Probable question paper with solution for PGE(18EE42)

1.Explain the factors to be considered for the selection of site for a hydroelectric power plant.

1. **Availability of Water:**
Since in such power stations potential energy of waterfall or kinetic energy of flowing stream is utilized for generation of electric power, therefore such stations should be built where there is adequate water available at good head or huge quantity of water is flowing across a given point.
2. **Water Storage:**
Since storage of water in a suitable reservoir at a height or building of dam across the river is essential in order to have continuous and perennial supply during the dry season, therefore, convenient accommodation for the erection of a dam or reservoir must be available.
3. **Water Head:**
The available water head depends upon the topography of the area. Availability of head of water has considerable effect on the cost and economy of power generation. An increase in effective head reduces the quantity of water to be stored and handled by penstocks, screens and turbines and, therefore, capital cost of the plant is reduced.
4. **Distance from Load Centre:**
Hydroelectric power plant is usually located far away from the load centre. Hence for economical transmission of electric power, the routes and the distances need active considerations.
5. **Accessibility of the Site:**
Adequate transportation facilities must be available or there should be possibility of providing the same so that the necessary equipment and machinery could be easily transported.
6. **Water Pollution:**
Polluted water may cause excessive corrosion and damage to the metallic structures. Hence availability of good quality water is essential.
7. **Sedimentation:**
Gradual deposition of silt may reduce the capacity of the storage reservoir and may also cause damage to the turbine blades. Silting from forest areas is negligible but the regions subject to violent storms and not protected by vegetation contribute lot of silt to the run-off.
8. **Large Catchment Area:**
The reservoir must have a large catchment area so that level of water in the reservoir may not fall below the minimum required in dry season.
9. **Availability of Land:**
The land available should be cheap in cost and rocky in order to withstand the weight of the large building and heavy machinery.
10. There should be possibility of stream diversion during period of construction.

2.Explain how the hydroelectric plants are classified.

According to Head of water,
a) Low head plant
b) Medium head plant
c) High head plant
According to Nature of load,
a) Base load plant
b) Peak load plant
According to Capacity of plant,
a) Low capacity plant (100-999 kW)
b) Medium capacity plant (1 MW-10 MW)
c) High capacity plant (above 10 MW)
According to Quantity of water available,
a) Run-off river plants without pondage
b) Run-off river plants with pondage
c) Pumped storage plant

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3. Describe merits and demerits of hydroelectric power plants?

Hydroelectric power plants offer many distinct advantages over other power plants.

These advantages can be summarised as under:

(i) No fuel is required by such plants as water is the source of energy. Hence operating costs are low and there are no problems of handling and storage of fuel and disposal of ash.

(ii) The plant is highly reliable and it is cheapest in operation and maintenance.

(iii) The plant can be run up and synchronized in a few minutes.

(iv) The load can be varied quickly and the rapidly chang-ing load demands can be met without any difficulty.

(v) Very accurate governing is possible with water tur-bines so such power plants have constant speed and hence constant frequency.

(vi) There are no standby losses in such plants.

(vi) Such plants are robust and have got longer life (around 50 years).

(viii) The efficiency of such plants does not fall with the age.

(ix) It is very neat and clean plant because no smoke or ash is produced.

(x) Highly skilled engineers are required only at the time of construction but later on only a few experi-enced persons will be required.

(xi) Such plants, in addition to generation of electric power, also serve other purposes such as irrigation, flood control and navigation.

(xii) Hydroelectric plants are usually located in remote areas where land is available at cheaper rates.

However, **the hydroelectric power plants have the fol-lowing disadvantages also:**

(i) It requires large area.

(ii) Its construction cost is enormously high and takes a long time for erection (owing to involvement of huge civil engineering works).

(iii) Long transmission lines are required as the plants are located in hilly areas which are quite away from the load centre.

(iv) The output of such plants is never constant owing to vagaries of monsoons and their dependence on the rate of water flow in a river. Long dry season may affect the power supply.

(v) The firm capacity of hydroelectric plants is low and so backup by steam plants is essential.

(vi) Hydroelectric power plant reservoir submerges huge areas, uproots large population and creates social and other problems.

4.Explain the characteristics of water turbines.

Characteristics of Water Turbines:

1. Head:

Reaction turbines of various types can be used for operating heads up to 500 m and Peltonturbines are used for operating heads above 500 m.

2. Specific Speed.

3. Turbine Setting:

A Pelton wheel is always set at a higher level than the highest tailrace level (usually 2 m above) while a Francis turbine runner is placed at a level very near or below the lowest tailrace level.

4. Runaway Speed:

This is the maximum speed at which a turbine wheel would run under the worst operating conditions with all gates open so as to allow all possible water inflow under maximum head. The generator coupled to the turbine must be capable of withstanding the full runaway speed of turbine under permissible head.

5. Constant Speed Curves:

In hydroelectric power plants, the turbines operate at constant speed and, therefore, variables are operating head H and discharge Q. As the discharge and head vary so as to keep the speed constant, the turbine output P_t is measured by brake arrangement. The turbine efficiency η is then calculated for various values of Q and H. Now the output discharge (P_t– Q), efficiency- discharge (η – Q) curves, as shown in Fig. 2.19 and efficiency-percentage full load curves are drawn as shown in Figs. 2 20 and 2.21. From the curves drawn, it can be concluded that the Kaplan and Pelton turbines perform well at part loads but Francis and Propeller turbines do not.

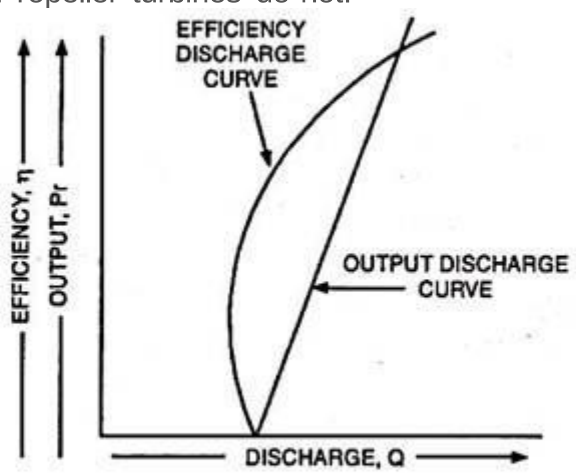


Fig. 2.19. ***Efficiency-Discharge Curve***

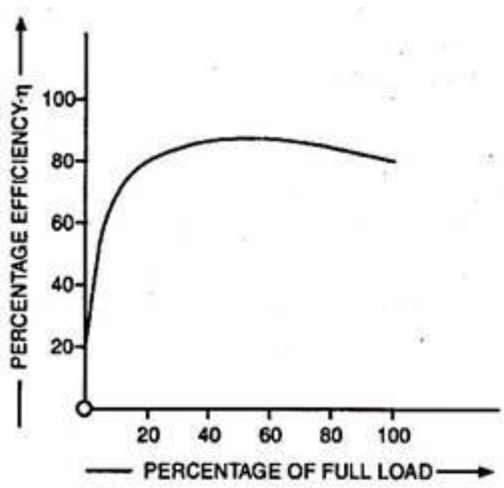


Fig. 2.20. ***Efficiency Curve of Impulse Turbine***

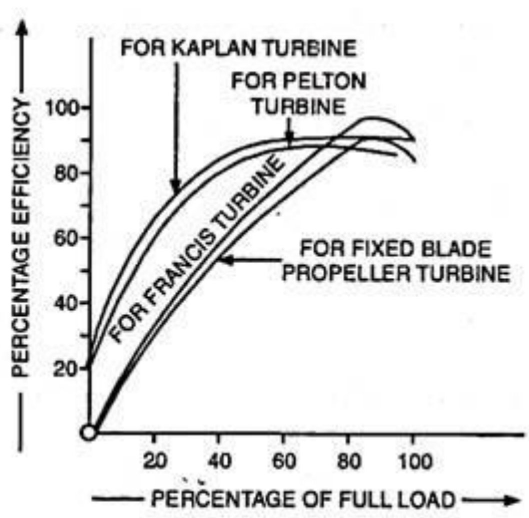
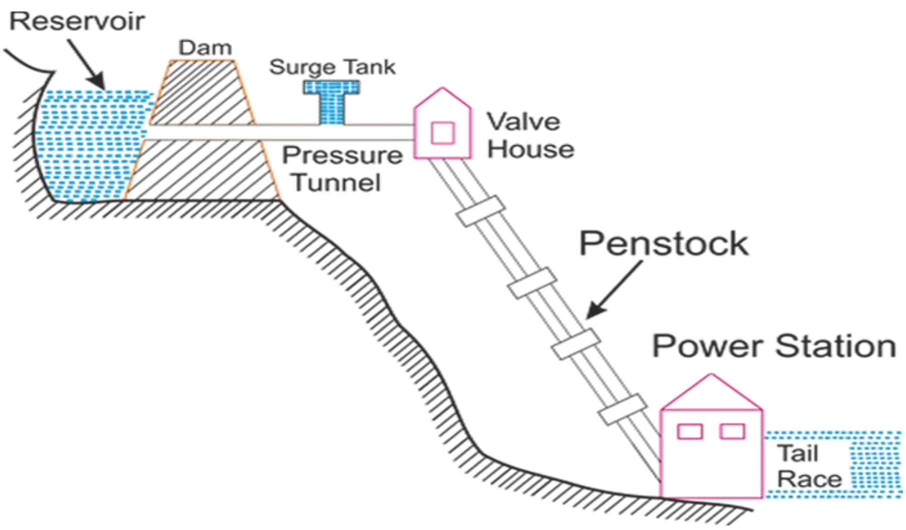


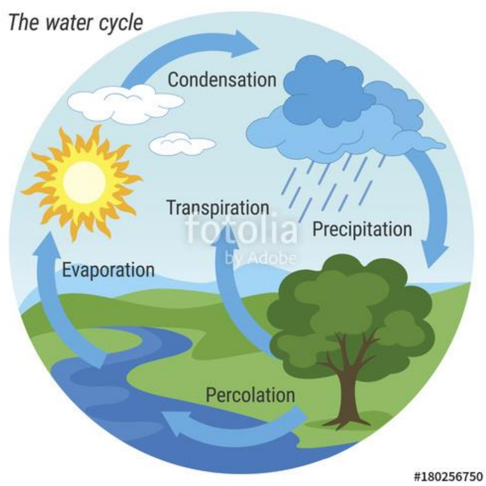
Fig. 2.21. ***Efficiency Curve of Reaction Turbines***

5. With a neat schematic diagram, explain the essential elements of hydroelectric power plant.

Working principle of hydroelectric power plant depends on the conversion of hydraulic energy into electrical energy. To get this hydroelectricity,hydroelectric power plant needs some arrangements for proper working and efficiency. The block diagram of hydroelectric power plant is shown below:
Hydroelectric power station needs huge amount of water at sufficient head all the time. So a hydroelectric dam is constructed across the river or lake.an artificial storage reservoir where water is stored, is placed back side of the dam. This reservoir creates sufficient water head. A pressure tunnel is placed in between the reservoir to valve house and water is coming from reservoir to penstock via this tunnel. An automatic controlling sluice valve is placed in valve house and it controls water flow to the power station and the letter cuts off supply of water in case the penstock bursts. Penstock is a huge steel pipe in which water is taken from valve house to turbine. A surge tank is also provided just before the valve house for better regulation of water pressure in the system. Now water turbine converts hydraulic energy into mechanical energy and an alternator which is couple to the water turbine converts this mechanical energy into electrical energy.



3.b) Define Hydrological cycle with neat figure.
The Hydrologic Cycle (also called the Water Cycle) is the continuous movement of water in the air, on the surface of and below the Earth. This cycle is the exchange of energy which influences climate. When water condenses, it releases energy and warms the environment. When water evaporates it takes energy from the surrounding environment, dropping temperatures.



6.Neatly draw the plan layout for hydel power plants with impulse turbine and reaction turbine.

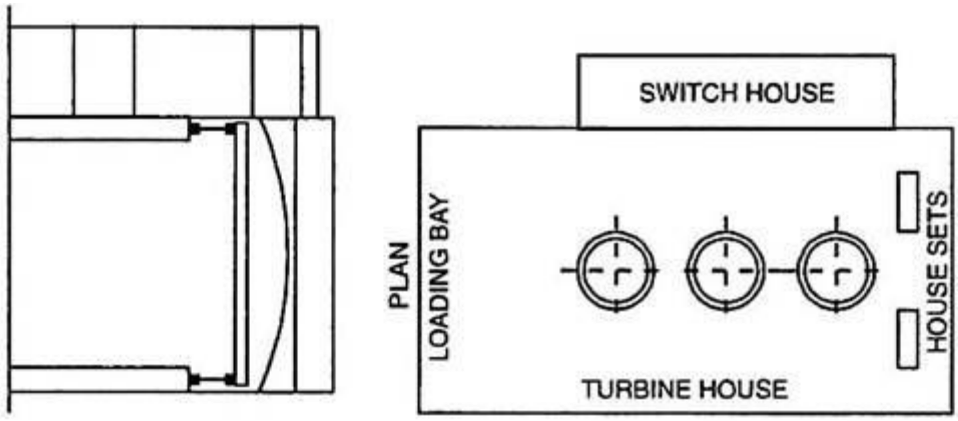


Fig. 2.26. ***Typical Plan Layout of Hydro Power Plant with Vertical Reaction Turbines***

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7. With a neat diagram explain the working of turbine governing.

In order to have electrical output of constant frequency it is necessary to maintain speed of the alternator driven by the turbine constant. This is achieved by controlling the flow of water entering the turbine by the automatic adjustment of guide vanes in case of reaction turbines and of the nozzle needle in the case of impulse turbines. Such an operation of speed regulation is called the governing, and it is attained automatically by means of a governor. In case of impulse turbine the governor also operates the auxiliary relief valves or jet deflectors.

For the regulation of water below the penstock connection, at the time of decrease in load on the impulse turbines, the governor reduces the water flow from the power nozzle and the surplus water is diverted with the help of auxiliary relief nozzles. In the case of multi-nozzle turbines, a deflector plate deflects some water from the runner buckets by swinging into the water jet from each nozzle. With the movement of deflector plate out of the path of water jets, the needles slowly reduces the flow of water so as to keep the output of the turbine constant at the level of new load.

In the case of Francis turbine, there are pressure regulators for discharging the water from the casing to the tailrace at the time of drop in load. The regulators close as fast as the guide vanes open and vice versa.

The governor should be quite sensitive to variations in the shaft speed and should be rapid in action but not so rapid as to cause water hammer in the penstock. The governing systems for the modern hydraulic turbines have a regulating time of 3-5 seconds.

Simplified arrangement of a water turbine governor is illustrated in Fig. 2.22. The principal elements of the governor are:

1. The speed-responsive element—usually flyball mechanism or speed (centrifugal) governor.

2. Control valve or relay valve to supply fluid under pressure to the power cylinder (servomotor) in order to actuate the turbine control mechanism. The use of control valve and servomotor is to amplify the small force created by the flyballs.

3. The restoring mechanism or follow-up linkage to hold the servomotor in required fixed position when the turbine output and load demand are equalised.

4. The fluid pressure supply required for the action of servomotor.

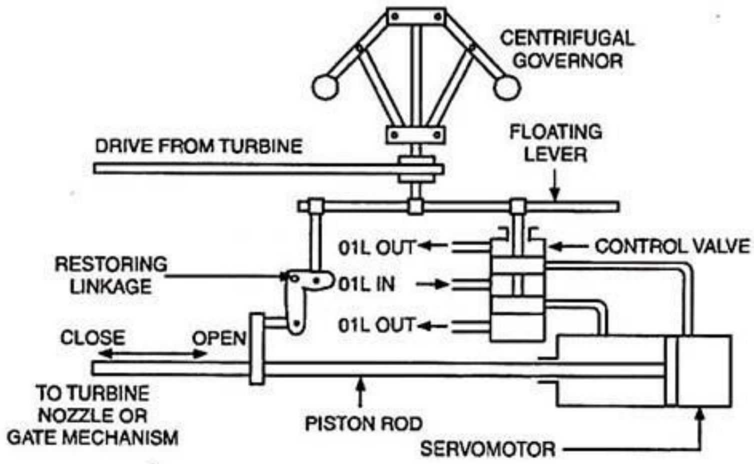

Fig. 2.22. ***Governing of Water Turbines***

The flyballs may be belt driven, as shown in Fig. 2.22 or driven by a small electric motor fed from a separate generator operated in synchronism with the turbine. When the load on the turbine decreases, the speed of the turbine increases, consequently, the flyballs also rotate at high speed and move outwards. The floating lever gets lifted up, control valve is displaced upwards from its central or dead beat position, the upper port is uncovered and the oil flows from a pressure tank through the port into the right hand end of the servomotor cylinder.

The piston moves to the left and closes the nozzle with the help of a spear in the case of Pelton wheels and adjusts the guide vanes in the case of reaction turbines. In case of increase of load on the generator, the speed of the turbine will decrease and the reverse action would take place. The restoring or follow up linkage resets the relay; pilot or control valve after the servomotor piston has adjusted the water control mechanism.

In case of Pelton wheel a combined spear and deflector regulation is employed in order to avoid water hammer in the penstock. In case of decrease of load on turbine, the deflector, which is usually a plate connected to the servomotor by means of levers, is brought in between the nozzle and buckets, thereby, diverting water away from the runner and directing into the tailrace. In the mean time, the spear has been adjusted to the new position of equilibrium and the deflector plate is moved out of the path of water nozzle.

8. Prepare a short note on surge tank.

A surge tank, in its simplest design, is a supplementary reservoir within a pipe system subject to variable flow rates. Surge tanks are used to protect piping and turbines from pressure waves that occur when the flow rate quickly decreases. Most commonly surge tanks are used within hydroelectric power plants where large size piping is used at relatively high flow rates, however they can be applied to many other piping systems such as waste water management, water supplied for manufacturing, and even the automotive industry. Surge tanks for handling water flow come in a variety of styles ranging from 40 gallon pressurized units to thousands of gallon reservoirs open to the atmosphere. Surge tanks have been used for many years however it is still a topic that sees active research and improvements are frequently proposed. Figure 3 below shows The Elwha dam which was once located on the Elwha river in Olympic National Park. In the center of the picture a surge tank can be seen rising to the height of the dam before it.

9. Define the phenomenon “Water hammer”? Explain how surge tanks help to reduce water hammer effect.

Water Hammer is a pressure surge or wave that occurs when there is a sudden momentum change of a fluid (the motion of a fluid is abruptly forced to stop or change direction) within an enclosed space (Water Hammer). This commonly occurs in pipelines when a valve is closed suddenly at the end of a pipeline where the velocity of the fluid is high. The pressure wave created will propagate within the pipeline. Cause and Effect Water hammer is caused by a change in fluid momentum. The most common cause of this change in momentum is sudden closure of a valve on a pipeline. When this occurs, a loud hammer noise can be produced and vibrations can be sent through the pipe (Water Hammer). The pressure wave produced from this event can cause significant damage to pipe systems. The large increase in pressure can cause pipes to crack and in some cases burst. It also causes cavitation within pipe lines and if is severe enough can cause the pipe line to implode (Water Hammer)

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10. With a neat layout describe diesel power plant.

The layout of the diesel power station illustrates the main and auxiliary components of the plant and the importance of each component as:

Diesel engine:

Also known as compression ignition engine consists of a cylinder, cylinder head, piston, inlet valve, an inlet port, exhaust valve, valve spring, cooling fins, wrist fines, wrist pin, connecting rod, crankcase, crank pin, crank, and crankshaft.

And it's classified into a two-stroke engine and four-stroke engines.

Engine starting system:

It's an arrangement to initially rotating the engine, we used a compressed air for starting the engine until it runs with its own power.

Fuel handling system:

We use trucks, railway wagons (barges) or oil tankers to deliver the fuel oil to the plant site, and we deliver the oil to the main tanks from engine day tanks which capable to store oil equivalent to 8-hour consumption through strainers.

And we heat the oil by hot water or steam to reduce viscosity and in order reduce the pumping power input

Fuel injection system:

We can say that this system is the heart of the diesel engine as it can uses as:

- Filter the ensuring oil from dirt.
- Meters the correct quantity of fuel to be injected into the cylinder.
- Also, regulates the fuel supply.
- Atomize the fuel oil for better mixing with the hot oil.
- And finally distribute the atomized fuel properly in the combustion chamber.

Air intake system:

It's used to transfer fresh air through louvers and air filter to the cylinder by an intake manifold, and we can fit a supercharger driven by the engine between the filter and the engine to augment the power.

Exhaust system:

- It's used to discharge the engine exhaust to the atmosphere with minimum noise.
- We use an exhaust manifold to connect the engine cylinder exhaust to the exhaust pipe to demand the fluctuating pressure of the exhaust line with a muffler or silencer to in turn reduces most the noise resulted when gases discharged directly to the atmosphere.
- There is also a flexible tubing system to take up the facts of expansion and isolate the exhaust system from the engine vibration. And we may also use a heat recovery steam generator to generate low-pressure steam for process work.

Engine lubrication system:

It's used to provide sufficient quantity of cool filtered oil to give adequate lubrication to the moving parts of the engine, it consists of lubricating oil tank, pump, filter, and oil cooler. and it's classified into:

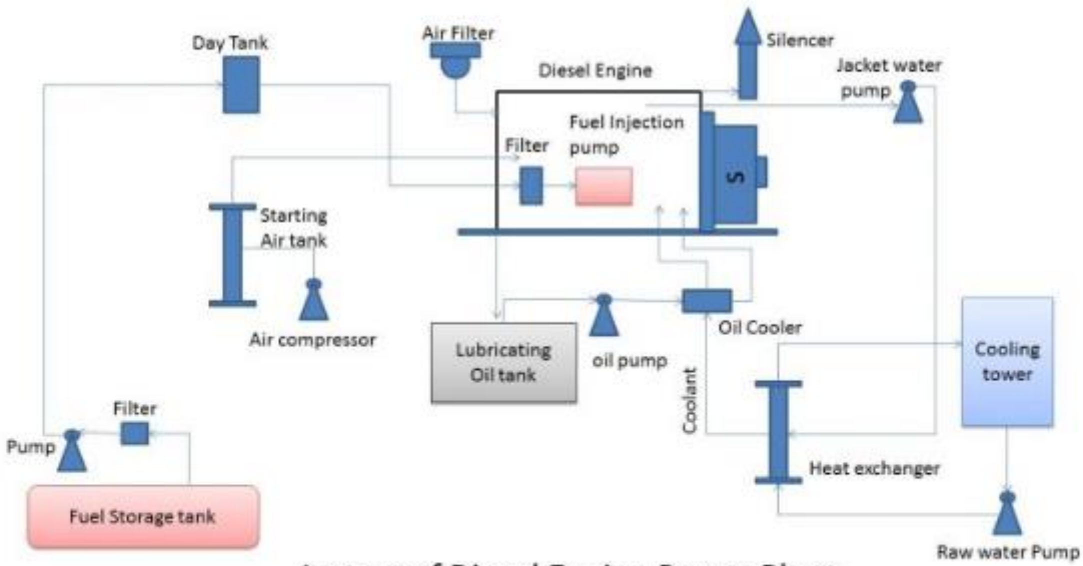
Mixed lubrication system: it's usually used in the two-stroke engine where we mix a small quantity of lubricating oil in the fuel tank.

Wet sump lubrication system: which may be splash system, pressure fed system or splash or pressure feed system.

Dry sump lubrication system: it's usually used in a large stationary marine engine where we carry the supply of oil in an external tank with some help of scavenging pump through a strainer and filter.

Cooling system:

It consists of a water source; a pump which circulates water through a cylinder and head jacket; and cooling tower in which it can cool the hot water from the engine.



Layout of Diesel Engine Power Plant

11.Discuss the advantages and disadvantages diesel power plant.

Advantages of diesel power plant:

- The low initial cost which makes it easy to quickly install and commission it.
- The design is very simple and requires small space.
- It can start and stop with quick facilities; as small generators can start and stop in few seconds without any standby loss in the system.
- The thermal efficiency is quite higher than other types.
- We can build it near the load center and doesn't cause a problem of ash disposal exists.
- The size of the plant is quite smaller than steam plants also they have the same capacity.
- It's easy to design it for portable use.
- The cooling is easy and requires a small quantity of water.
- There isn't any difficulty with varying loads.
- Also, the fuel cost required for operation is low.
- Replacement losses are smaller
- And it also requires fewer members of engineers.

Disadvantages of diesel power station:

- The higher running costs due to the high cost of the diesel.
- The general use of this plant is to produce small power requirement.
- It can't stand up for a long period of overload conditions.
- The lubricants cost is high.
- Complex and high-cost maintenance; which makes the life of the plant small from 7 to 10 years.
- Its capacity is only about 50 MW.
- It's difficult to construct it for large scale.
- Also, the noise produced by the plant is high.

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12. Mention the applications of diesel –electric power plants.

- A central station for medium or small power supplies.
- And for emergency services as a stand by plant to hydroelectric power plants and steam power plants.
- We can Use with thermal or hydro power plants as a peak load plant in combinations.
- For mobile power generation, transportation systems like automobiles, railways, airplanes, and ships.
- A nursery station to transport the power from stations to small power plants, or supply power to small towns.
- It's economical for industries where they require a small power in the order of 500 KW as it offers high overall efficiency.

- And also used for electrical power generation in capacities 100 to 500 H.P.

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13. Define supercharging? Give its advantages and disadvantages.

- Increased amount of air at pressure greater than atmosphere is supplied to the cylinder to increase the output of the cylinder
- It simply makes available a greater weight of air to effect combustion with the result that greater quantity of fuel can be burned in each power stroke without change in engine's :
  - ✓ Efficiency
  - ✓ Capacity
  - ✓ Speed
  - ✓ temperature
- Used at high altitudes to get sea level output
- Requires power
- **Advantages :**
- ❖ 30 – 50 % increased output
- ❖ Fuel economy
- ❖ Better mechanical efficiency
- ❖ Reduced knocking
- ❖ Better scavenging
- **Methods of supercharging :**
- ❖ Positive displacement type super charger
- ❖ Centrifugal supercharger

  Exhaust turbo charger

14. Discuss in detail the factors to be considered for selection of the site for a thermal power plant.

- ***Supply of fuel-*** Thermal power station as close as possible to the coal mine, economy consideration , considering transmission & transportation charges.
- ***Ash disposal facility-*** Ash content of the coal should be as low as possible, Indian coal has ash content 20-40% & sufficient space is required for storing ash.
- ***Availability of water-*** Feed water for the boiler, Huge quantity of water is required for condenser & disposal of ash.
- ***Land requirement-*** Average land requirement is 3 to 4 acres per MW capacity. Land should be available cheap rate & good bearing capacity.
- ***Transportation facility-*** Huge quantity of coal is required, rail & road facility should be available very near.
- ***Distance from the populated area-***As huge amount of coal is burnt in steam power station, therefore smoke & fumes pollute the surrounding area. This necessitates that the plant should be located at a considerable distance from the populated area.
- ***Labour supplies-*** Skilled labours should be available at reasonable rates near the site of the plant.

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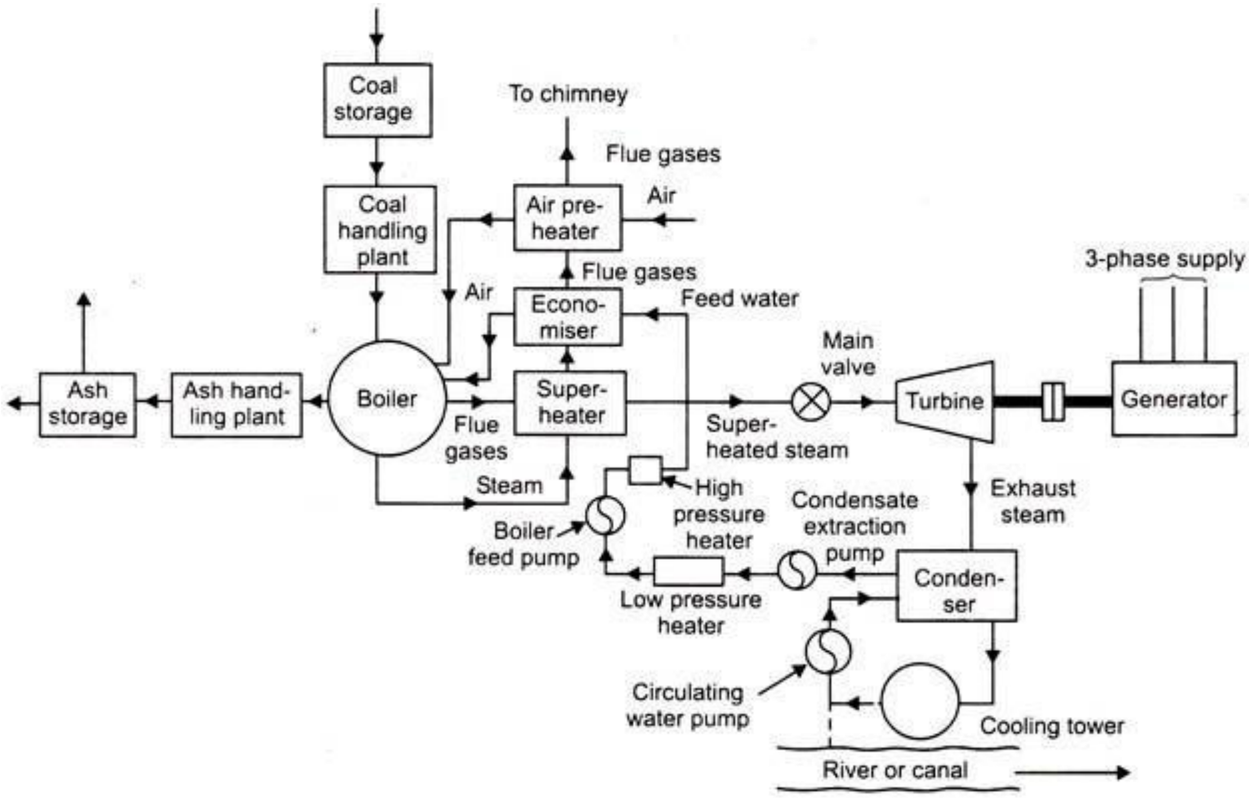
15. Discuss the advantages of gas-turbine power plant over steam power plant.

- Compact – same capacity
- Fewer auxillaries – lesser personnels;
- Installation takes less time
- No condensor maintainance – almost no water requirement
- Simple lubrication systems
- Light foundation
- Easily controlled
- Can be started quickly
- Fuel consumption during starting and shutting low
- Clean exhaust – no stack required
- Low weight power ratio
- Less capital cost

2.a) Explain the working of steam power plant with neat schematic diagram.



The schematic arrangement of a modern steam power station can be divided into the following stages:

- *Coal and ash handling plant*
- *Steam generating plant*
- *Steam turbine*
- *Alternator*
- *Feed water*
- *Cooling arrangement*

COAL AND ASH HANDLING PLANT

- Coal is transported to power station by rail or road and stored in coal storage plant and then pulverised
- Pulverised coal is fed to fed to the boiler by belt conveyers
- Coal gets burned in the boiler and ash produced is removed to the ash handling plant and then delivered to ash storage plant for disposal
- A 100MW station operating at 50% LF may burn about 20000 tons of coal per month and produce 3000 tons of ash

The Ash from the boiler is collected in two forms:

1. **Bottom Ash(Slurry):It's a waste which is dumped into a Ash Pond**
2. **Fly ash: Fly ash is separated from Flue Gases in ESP(Electro static Precipitator).**

STEAM GENERATING PLANT

The steam generating plant consists of a boiler for the production of steam and other auxiliary equipment for the utilization of flue gases

1) ***Boiler:*** The heat of combustion in the boiler is utilized to convert water into steam at high temperature and pressure
2) ***Superheater:*** The steam produced in boiler is wet and is passed through a superheater where it is dried and superheated. Increases efficiency
3) ***Economiser:*** It's essentially a feed water heater and derives heat from the flue gases
4) ***Air Preheater:*** Increases the temperature of the air supplied for coal burning by deriving heat from flue gases. Air is drawn from the atmosphere by a forced drought fan and is passed through air preheater before supplying to the boiler furnace.

STEAM TURBINE

- Dry and superheated steam from superheater is fed to the steam turbine.
- The heat energy of steam when passing over the blades of turbine is converted into mechanical energy.
- After giving energy to the turbine, the steam is exhausted to the condenser which condenses the exhausted steam by means of cold water circulation

ALTERNATOR
- Steam turbine is coupled to an alternator which converts the mechanical energy to electrical energy
- The electrical output of the alternator is delivered to the bus bars through transformer, circuit breakers and isolators.

FEED WATER
- The condensate from the condenser is used as feed water to the boiler.
- The water that may be lost in the cycle is made up from the external source
- The feed water on its way to boiler gets heated up by water heaters and economiser.
- This helps to improve the overall efficiency of the plant

COOLING ARRANGEMENT
- Condenser condenses the steam exhausted from the turbine
- Water is drawn from natural sources like river, lake, canals…
- Circulating water takes up the heat and itself gets heated up
- This hot water can be discharged away or used again by using a cooling tower

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16. Discuss the general merits of gas-turbine power plant
- Storage of fuel require less area & handling is easy.
- Maintenance cost is less.
- Simple in construction. There is no need for boiler, condenser etc.
- Cheaper fuels such as kerosene, paraffin, benzene & powered coal can be used which are cheaper than petrol & diesel.
- Suitable in water scarcity area.
- More reliable.
- Less pollution and water requirement.

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17. Explain any three methods used for disposal of ash in steam power plant.

❖ **Belt Conveyer System.**
- In this system ash is carried with the belt conveyor with a water bed carrier, through a channel and finally dumped in the sump.
- This is continuous handling & the power consumption is low.

❖ **Pneumatic System**
- Air is employed as the medium for driving the ash through a pipe over long distance.
- The ash is passed from boilers & then into conveying pipe.
- Air is sucked through the delivery end which makes the ash to flow into separators where ash is collected in hoppers.
- The dusty air is filtered & exhausted to atmosphere through the exhaust fan.

Advantage
- Can carry ash through long distance.

Disadvantage
- High maintenance charges & noisy operation.

❖ **Hydraulic System**
- In this system a stream of water carriers ash along with it in a closed channel & disposes it off to the proper site.
- This system can be used for large capacity power plants where the ash is to be disposed off over long distances.
- This is a healthy, clean dustless & completely enclosed system.
- Hydraulic system are
- **High pressure system.**
- **Low pressure system.**

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18. Compare of hydro power plant and steam power plant.

Steam Power Plant:

a. It should be set up a place where available for water, coal transportation.
b. Initial cost is low compare to hydraulic power plant.
c. Its running cost is higher than nuclear power plant running cost.

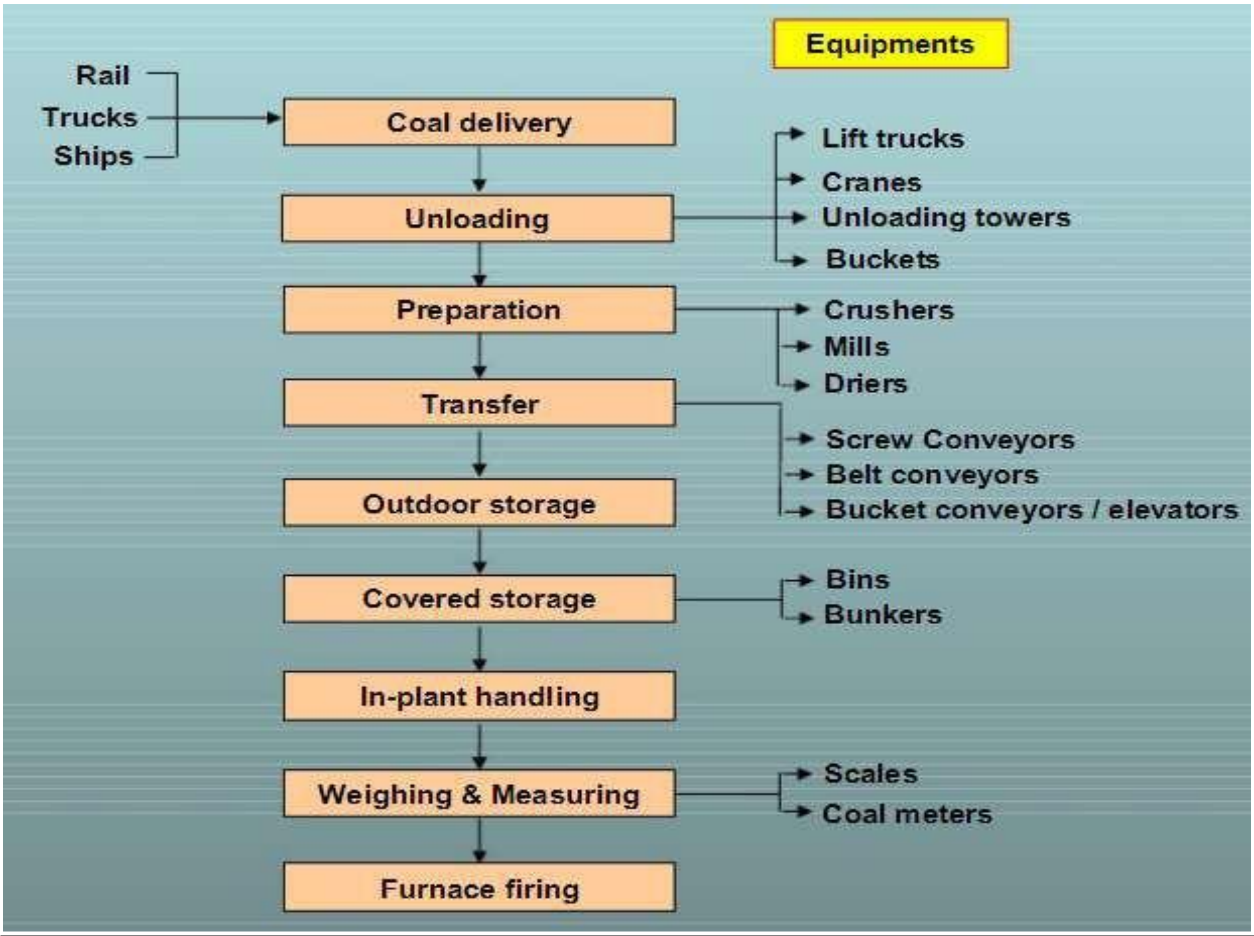
d. Its source of power is coal.
e. Its fuel transportation cost is high.
f. Lowest environment friendly.
g. Its efficiency is 25 %
h. Its maintenance cost is very high.

Hydro-electric Power Plant:

a. It is set up a place where available is water resource.
b. It's initial cost is higher than Steam power plant.
c. It has no running cost.
d. Its source of power is water.
e. It's transportation cost is very low.
f. It is most environment friendly.
g. Its efficiency is about 85 %
h. It's maintenance cost is quite low.

19.Explain with a line-diagram, fuel handling system of a thermal power plant.

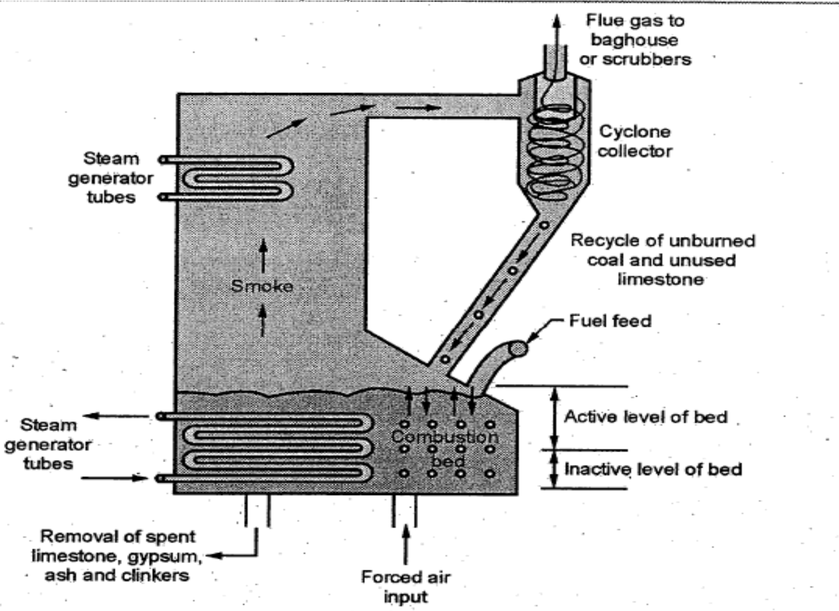
- Coal can be handled manually or mechanically
- Mechanical handling is usually adopted as it is reliable and economical.
- Large quantity of coal is required to be handled everyday, mechanical handling has become necessary.
- The main requirement of a coal handling plants are reliability, soundness & simplicity requiring a minimum of operatives & minimum of maintenance.



20.With a neat sketch explain fluidized bed combustion.

- A fluidized bed may be defined as the bed of solid particles behaving as a fluid.
- When an evenly distributed air is passed upward through a finely divided bed of solid particles at low velocity, the particles remain undisturbed

- But if the velocity is steadily increased, a stage is reached when individual particles are suspended in the air stream.
- If air velocity is further increased , the bed becomes highly turbulent (moving unsteadily) & rapids mixing of particles occur.
- This appear like formation of bubbles in a boiling liquid & a bed is said to be fluidized.



- There are two basic systems in FBC namely
  - **Atmospheric FBC**
  - **Pressurized FBC**

Advantages of FBC

- High thermal Efficiency
- Easy ash Removal system
- Short Erection and Commissioning period.
- Fully Automatic & Safe operation
- Reduced maintenance & Uniformity of temperature.

21. Discuss the methods of increase the thermal efficiency in gas turbine plant

- The efficiency of a simple gas turbine power plant can be improved by employing regenerator, intercooler and reheater.
- **Regenerator** is usually of shell and tube construction. The exhaust gases are made to flow inside the nest of tubes while air flows outside the tubes in the shell in the counter flow and heated up by the heat given out by the exhaust gases. Thus the regenerator utilizes the heat of exhaust gases to heat the compressed air before it is sent to the combustion chamber, reduces the fuel consumption of the plant and improves the cycle thermal efficiency. It is noteworthy that addition of the regeneration in the circuit makes no change in the duties/work of the compressor and turbine but the quantity of fuel supplied is substantially reduced as the temperature of the air entering the combustion chamber is raised. The other noteworthy point is that the gain in efficiency is greater at lower pressure ratios.
- The heat transfer from the regenerator can be improved either by increasing the surface area or by increasing the flow turbulence. Increasing of surface area regenerator involves higher initial cost, while the increasing of flow turbulence involves increased pressure drop. Thus the design of a regenerator is a compromise between the gain in heat recovery on the one hand and higher initial cost and operating cost on the other.
- However, for short time operation such as peak loads, the cost of regenerator may not justify its use in gas cycle.

- Also, a greater part (about two – third) of power developed by the turbine is used in driving the compressor. This requirement of power, however, can be reduced if the compression of air could be done in two or more stages and an **intercooler** is introduced between the two. This is because of reduction in volume of air due to cooling in the intercooler.
- The cooling of air between two stages of compression is known as **intercooling**. This reduces the work of compression and increases the specific output of the plant with a decrease in the thermal efficiency. In intercooling, a heat exchanger is used to cool the compressor gases at the time of compression process. When the compressor involves the high and low pressure unit in it, the intercooler could be installed between them to cool down the flow. This cooling process decreases the work needed for the compression in the high pressure unit thus improves the thermal efficiency, air rate and work ratio.

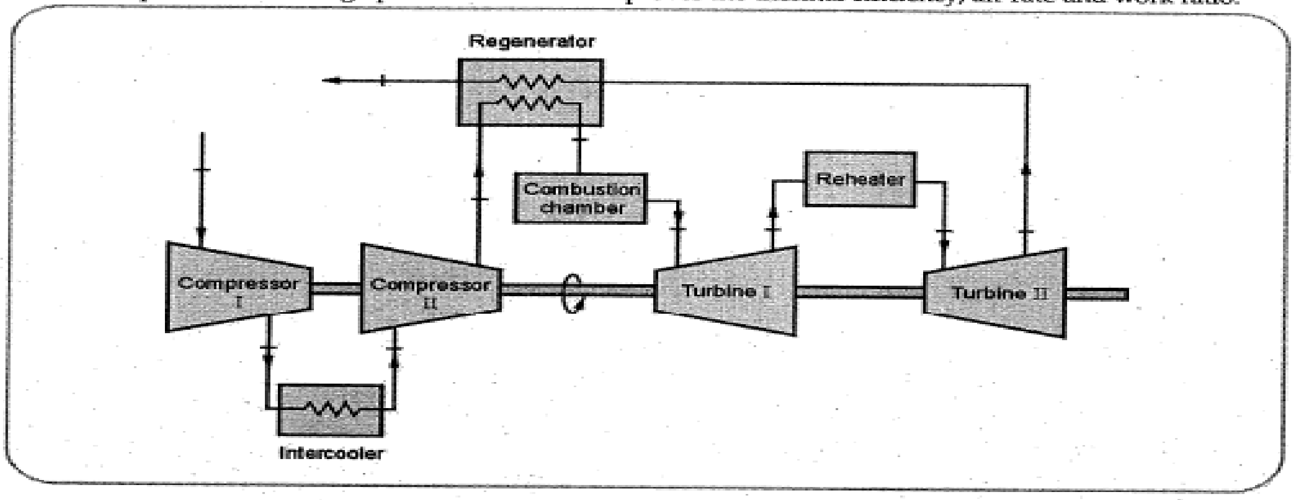


Fig. 4.6.1 A Gas-Turbine Engine with two - stage compression with Intercooling, two – stage expansion with Reheating, and Regeneration.

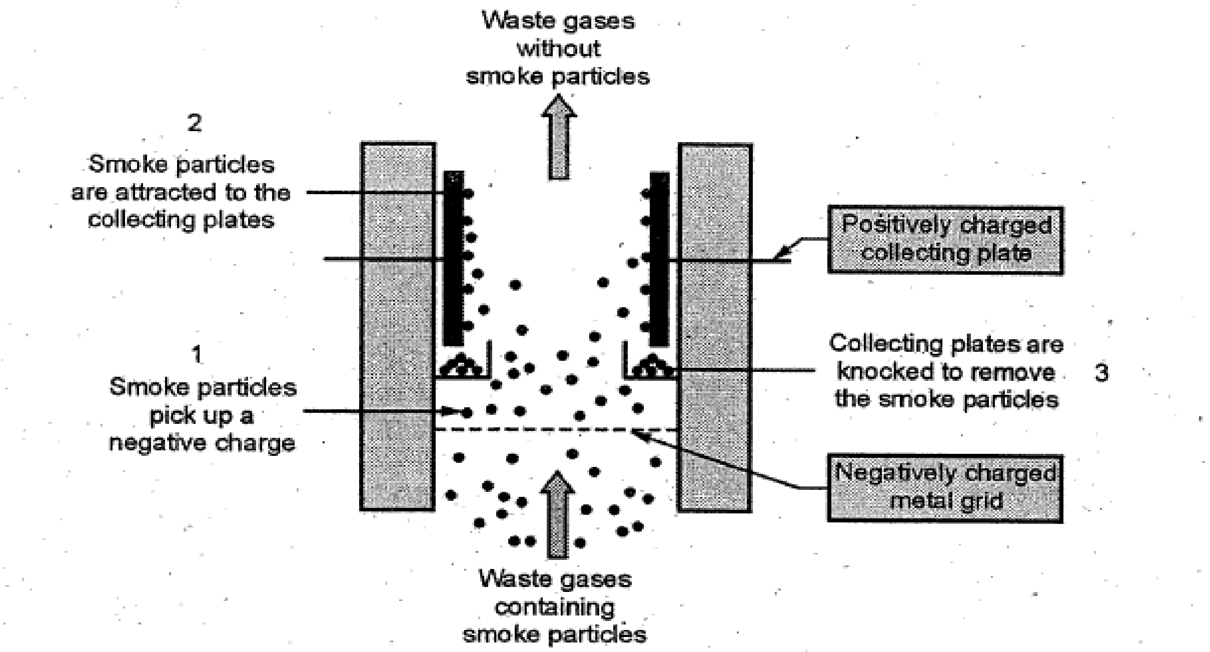
- Some large compressors have several stages of compression with intercooling between stages. The determination of the number of stages and the conditions at which to operate the various intercoolers is a problem in optimization. The use of multistage compression with intercooling in a gas turbine power plant increases the net work developed by reducing the compression work. A lower temperature at the combustor inlet would require additional heat transfer to achieve the desired turbine inlet temperature. The lower temperature at the compressor exit enhances the potential for regeneration, however, so when intercooling is used in conjunction with regeneration, an appreciable increase in thermal efficiency can result.
- In **reheating** the combustion gases are not expanded in one turbine only but in two turbines. The exhaust of the high pressure turbine is reheated in reheater and then expanded in a low pressure turbine. Reheating improves the output from the turbine due to multiple heating in the same way as intercooling improves the performance of the compressor.

22.Explain the techniques of dust collection in thermal power station

- The exhaust gases leaving the boiler contain particles of dust, fly ash or carbon as a material called Cinder.
- The quantity of solid particles depends upon the method of fuel firing.
- In pulverised fuel firing 60 to 80 % of the total ash produced in the furnace, escapes through the chimney as flue dust.
- Removal of dust from exhaust gases is very important because the environment gets polluted.
- Dust collectors are classified into **Mechanical & Electrical ones (Electrostatic Precipitator).**
- Mechanical dust collectors can be further classified as Wet & Dry dust collectors.
- **Electrostatic Precipitator**
- It is a device that removes dust particles from a flowing gas using the force of an induced **electrostatic** attraction.
- It consists of two electrodes which are completely insulated from each other.
- One set is called **emitting or discharge electrode.**
- Other set is called **Collecting electrode.**
- The emitting or Discharge plates are connected to **negative polarity** of hvdc source.
- While the Collecting electrodes are connected to **positive polarity.**
- High electrostatic field is set up between two sets of electrodes creates corona discharge & ionizes the gas molecules as flue gases flow in between the plates.
- The dust particles acquire negative charge & are attracted to positive polarity & gets deposited there.

Types of Electrostatic precipitator

- ❖ **Plate or Tubular type.**
- ❖ **Horizontal & Vertical flow type.**
- ❖ **Dry or Wet type**



7. a) Discuss the working principles of stokers used in steam power plants.

- ➢ Stoker gives mechanical feeding of a coal
- ➢ Mechanical Stokers receive fuel by gravity, carry it to the furnace for combustion & after combustion discharge of ash at appropriate point.

❖ **Advantages**

- ➢ Uniform feeding of fuel into furnace.
- ➢ Greater combustion facility.
- ➢ Saving labour cost.
- ➢ Fluctuations of load demand can be met because of control of combustion.
- ➢ Very reliable & maintenance charges are reasonably low.

Disadvantages

- ➢ Complicated construction.
- ➢ Loss of fuel in the form of riddling's (remove ashes) through the gates.
- ➢ Standby losses are always present.
- ➢ With very large units the initial cost may be rather high than with pulverized fuel.

❖ **Mechanical Stokers are of two types.**

- ➢ **Underfeed Stokers.**
- ➢ **Overfeed Stokers.**

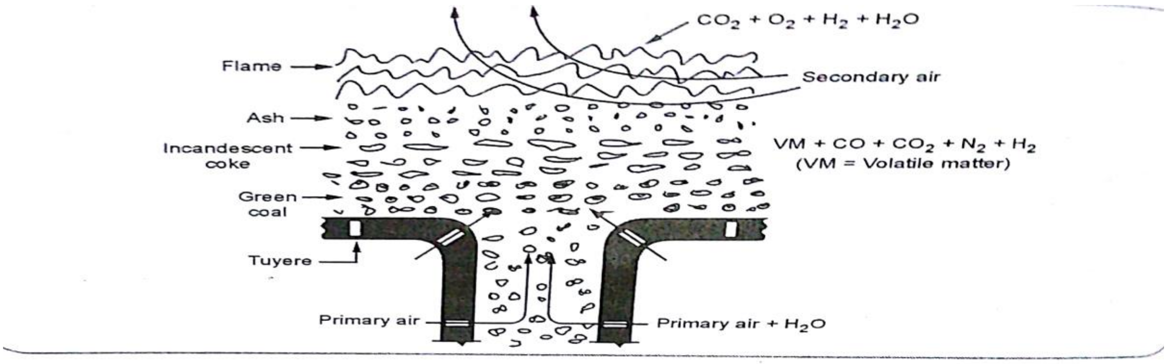


Fig. 2.10.1 Underfeed Stoker

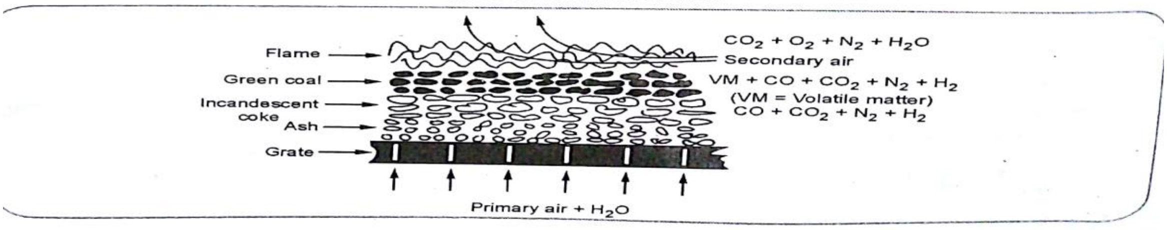


Fig. 2.10.2 Overfeed Stoker

Underfeed Stokers

- The coal is fed into the furnace below the point of admission of air.
- Coal from the container discharges into furnace.
- When coal gets heated up all volatiles in it are distilled & when coal reaches active combustion it is in the form of coke & ash.
- The ash discharge plates are at back of furnace & by time coal is washed down on the plates, all combustion has been complete.
- Here air is admitted through holes in furnace sides.

Overfeed Stokers

- Overfeed stokers are used for large capacity boilers where coal is burnt as lumps (i.e., without pulverization).
- In this type of stoker, the fuel bed receives fresh coal on top surface.
- In the first layer (top layer), fresh coal is added
- Second layer is the drying zone, where coal losses moisture
- Third layer is distillation zone, where coal loses volatile matter
- Fourth layer is the combustion zone, where the fixed carbon in coal is consumed.
- Fifth layer is the ash cooling zone

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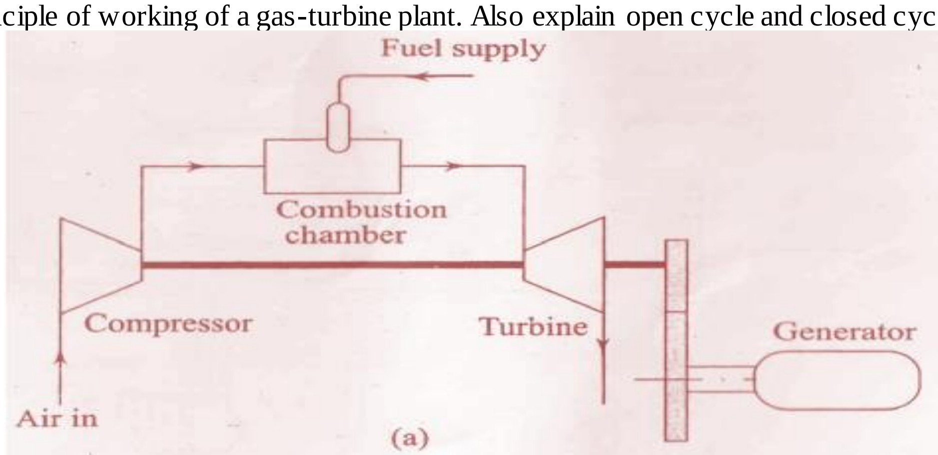
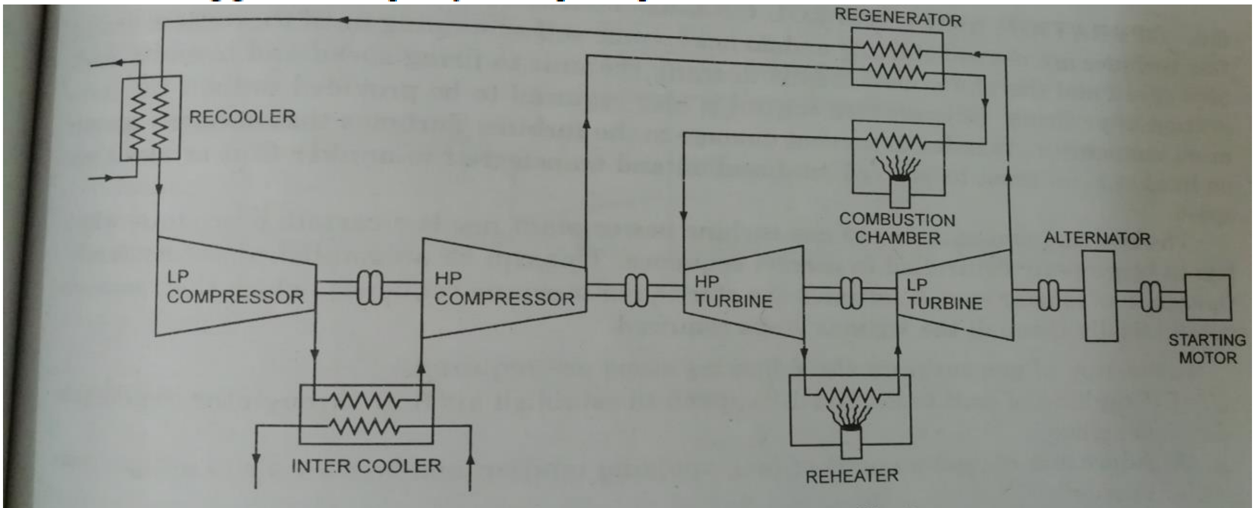
23. Explain the principle of working of a gas-turbine plant. Also explain open cycle and closed cycle gas turbines.



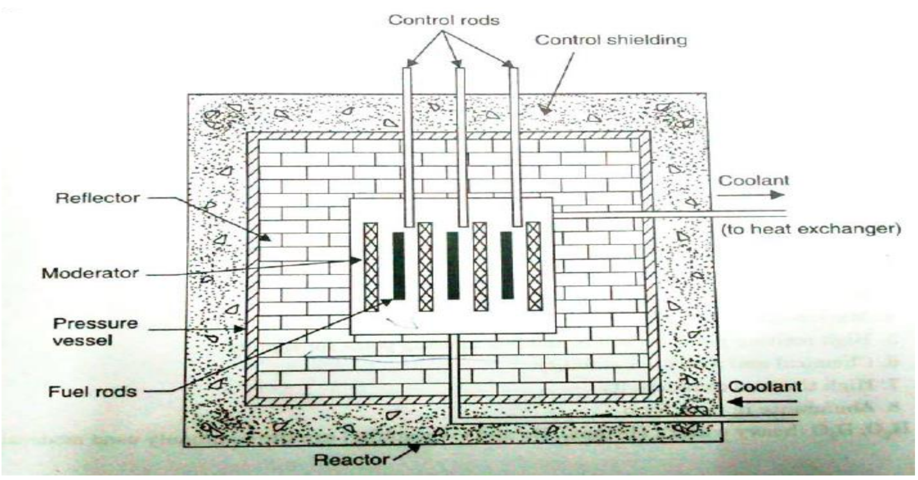
- The open cycle power plants (as shown in fig.) are most widely used in majority of GT power plants.
- In open cycle GT power plants, atmospheric air is continuously drawn into the compressor and compressed to high pressure.
- The compressed air then enters the combustion chamber, where it is mixed with fuel and combustion occurs at constant pressure.
- The heated gases coming out of combustion chamber are then expanded in the gas turbine to produce mechanical work.
- The part of the mechanical work produced by the turbine is utilized to drive the compressor and other accessories and remaining is used for power generation.
- The gases leaving turbine are exhaust to surroundings.
- The working gas is air in open cycle GT power plant.



Closed Cycle Gas Turbine Power Plant

- In a closed cycle GT power plants (as shown in fig.), the working gas coming out of compressor is indirectly heated at constant pressure in heat exchanger by an external heat source.
- The external heat source may be gas cooled nuclear reactor or flue gases resulting from the combustion chamber or furnace.
- The high pressure high temperature working gas coming from heat exchanger is expanded through the gas turbine.
- The working gas leaving the turbine after expansion is cooled in heat exchanger with help of surrounding and supplied to the compressor to repeat cycle of operation.
- The working gas may be air, helium, argon, carbon di oxide and so on.

24.



- Reactor is the part of nuclear power plant where nuclear fuel is subjected to nuclear fission and the energy released in the process is utilised to heat the coolant which may in turn generate steam.
- The main function of the reactor is to control the emission and absorption of neutrons.

The main parts of reactor are

- **Reactor core, Moderator, Control rods, Coolant, Reflector, Thermal Shielding, Reactor vessel, Biological shield.**

Reactor core

- The reactor core mainly comprises of a number of rods made of fissile materials.
- In a view to have better control of the fission reaction, it is usually to clad the fuel with aluminium or zirconium or stainless steel.
- The fuel is finely powdered and shaped into a form which facilitates uniform production of heat.
- It is then enclosed inside the cladding material, and the cladded fuel is suitably placed inside the reactor.

Moderator

- The purpose of moderator is to **slow down the fast moving secondary neutrons, so that chain reaction is sustained.**
- The moderator surrounds the fuel rods.
- As soon as fast moving neutrons are given out, as a result of chain reaction they collide against the moderator and slow down.
- They are now capable of causing further fission, and thus the chain reaction continues.
- Materials used as moderators are ordinary **water, heavy water, beryllium and graphite.**
- **Moderator should have high scattering cross section and low neutron absorption cross section**

Control rods

- Control rods are meant for **controlling the rate of fission of U 235.**
- Control rods are rods, plates, or tubes containing a **neutron absorbing material** which are made of boron, cadmium etc, that absorb some of the slowed neutrons.
- **Chain reaction is controlled either by removing the control rods(to increase reaction) or by inserting it to decrease the reaction**.
- The materials used for control rods must have **very high absorption capacity for neutrons.**
- If the fissioning rate of the chain reaction is to be increased, the control rods are moved out slightly so that they absorb less number of neutrons & vice versa.

Coolant

- It is a **medium through which the heat generated in the reactor is transferred to the heat generator for further utilization of power generation**.
- If water is used as coolant it takes up heat & gets converted into steam in the reactor which is directly used for driving the turbine.
- A good coolant should not absorb neutrons, should be non oxidising, non toxic & non corrosive and have high chemical and radiation stability and good heat transfer ability.
- **Gases : Air, helium, hydrogen & CO2**
- **Liquids : Light & heavy water.**
- **Metals : Molten sodium & Lithium are used as coolants.**
- **Ordinary water is** used both as coolant & moderator in Boiling water reactors.
- **Pressurized water** is used as coolant & moderator in Pressurized water reactors.
- Water has good **thermal capacity and good heat transport medium.**
- **Liquid metals are used as coolant in fast reactors which have large heat release from, a small core.**
- They have **high heat transfer capability & low vapour pressure.**
- **CO_2 is colourless & odourless & has low neutron absorption cross section.**
- When dry, it doesn't react with mild steel of the pressure vessel.
- It reacts with graphite so special steps to be taken in the design of reactor so as to inhibit the reaction between CO_2 and graphite.

Reflector

- A neutron reflector is placed around the core and used to avoid the leakage of neutrons from the core.

- Reflector **sends back any slow moving secondary neutron which tries to escape out of th reactor core .**
- The reflector surrounds the reactor core completely.
- It is made of the same material as the moderator, and possesses the same characteristic feature as the moderator.
- The reflector helps to conserve the nuclear fuel by preventing the escape of the neutrons.

Thermal shielding

- The shielding is usually **constructed from iron and help in giving protection from the deadly ά and β particle radiations and ϒ rays as well as neutrons given off by the process of fission with the reactor.**
- In this manner it gets heated and prevents the reactor wall from getting heated and coolant which flows over it takes away this heat.

Reactor vessel

- The reactor core, **reflector and thermal shielding are all enclosed in the main body of the reactor and is called the reactor vessel.**
- It is strong walled container and provides the entrance and exit for the coolant and also passages for its flow through and around the reactor core.
- The reactor core is usually placed at the bottom of the vessel.

Biological shield

- The whole of the reactor is enclosed in a biological shield to prevent the escape or leak away of the fast neutrons, slow neutrons, β particles and ϒ rays as theses radiations are very harmful for living organisms.
- Lead iron or dense concrete shields are used for this purpose.

25. Merits

- The amount of fuel required is quite small, therefore there is no problem of transportation, storage etc
- These plants need less area as compared to any other plant of the same size. A 2000 MW nuclear power plant needs about 80 acres whereas the coal fired steam power plant of same capacity needs about 250 acres of land.
- Man power required for the operation of nuclear power plant is less. Therefore the cost of operation is reduced.
- In these plants transportation is not required so it can be located near to the load centres,
- These plants are most economical in large capacity. The output control is extremely flexible i.e, the output can be instantaneously adjusted from zero to upper limit.
- There are large deposits of nuclear fuel available all over the world. Therefore such plants can ensure continued supply of electrical energy for long years.

- **Demerits**

- The initial cost of the power plants will be high as compared to the other types of power plants
- The erection & commissioning of the plant requires greater technical skills.
- The fission by products are generally radio active & may cause a dangerous amount of radioactive pollution
- The fuel used is expensive & difficult to recover.
- The disposal of the products, which are radioactive is a big problem. They have either to be deposed off in a deep trench or in a sea away from sea shore.
- Maintenance charges are high.
- The cooling water requirements of a nuclear power plants are very heavy. Hence cooling towers required for nuclear power plants are larger & costlier than those for conventional steam power plants.

1. According to the application
   - Research and Development Reactors: These reactors are used for testing new reactor designs and research.
   - Production: For converting fertile materials into fissile materials.
   - Power: These reactors are used for generation of electrical energy.

   According to type of fission

- **Slow reactors**
  - Neutron kinetic energy is less than 0.1 eV
- **Intermediate reactors**
  - Neutron kinetic energy is between 0.1 eV and 0.1 MeV
- **Fast neutron**
  - Neutron kinetic energy 1 MeV or more.

According to type of fuel used

- Natural uranium
- Enriched uranium
- Plutonium

According to state of fuel

- Solid
- Liquid

According to fuel cycle

- **Burner reactor**
  - Designed for producing heat only without any recovery of converted fertile material.
- **Converter reactor**
  - Such reactors convert fertile material into fissile material different from the one initially fed into the reactor core.
- **Breeder reactor**
  - Such reactors convert fertile material into fissile material, which is similar to one initially supplied to the reactor core.
  - A breeder reactor is also which convert fertile material into fissile material at a higher value than at which the fissile material is consumed.

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Arrangement of fissile and fertile material

- **One region**
  - Fissile and fertile material mixed
- **Two region**
  - Fissile and fertile material separated

Arrangement of fuel and moderator

- **Homogeneous reactor**
  - Nuclear fuel and moderator represent uniform mixture in the fluid form, including gases, liquids and slurries (mixture of an insoluble substance, as cement, clay with liquid)
- **Heterogeneous reactor**
  - Separate fuel rods are inserted in the moderator in some sort of regular arrangement forming a so called lattice.

Moderator material

- **Heavy water**
- **Graphite**
- **Ordinary water**
- **Beryllium**
- **Organic reactors**

On basis of coolant used

- **Gas**
- **Water**
- **Heavy water**
- **Liquid metal reactors**

On basis of cooling system

- **Direct**
  - The liquid fuel circulated from the reactor to heat exchanger where steam is generated.
- **Indirect**
  - Coolant passed through the reactor and then through the heat exchanger for steam generation

Power reactors in common use

- **Boiling Water Reactor**
- **Pressurized Water Reactor**
- **Gas Cooled Reactor**
- **Heavy Water Cooled and Moderated (CANDU TYPE) Reactor**
- **Liquid Metal Cooled Reactors**
- **Fast Breeder Reactor**

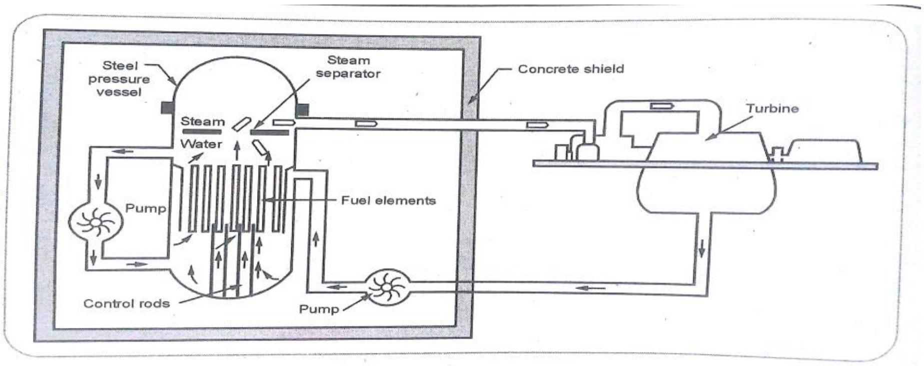


Fig. 5.16.1 Boiling water reactor

- It has a steel pressure vessel surrounded by a concrete shield.
- Fuel used is **enriched uranium oxide**.
- **Ordinary water is used both as moderator and coolant**.
- The steam is generated in reactor itself.
- Feed water enters the reactor vessel at the bottom and takes the heat produced due to fission of fuel and gets converted into steam
- This steam leaves the reactor at the top and after passing through turbine and condenser returns to the reactor.
- Uranium fuel elements are arranged in a **particular lattice form** inside the pressure vessel containing water.
- A BWR assembly comprises 90-100 fuel rods and there are up to 750 assemblies in a core holding up to 140 tonnes of uranium.

Advantages

- This includes small size pressure vessel, high steam pressure, simple construction & elimination of heat exchanger resulting in reduction in cost & gain in thermal efficiency.

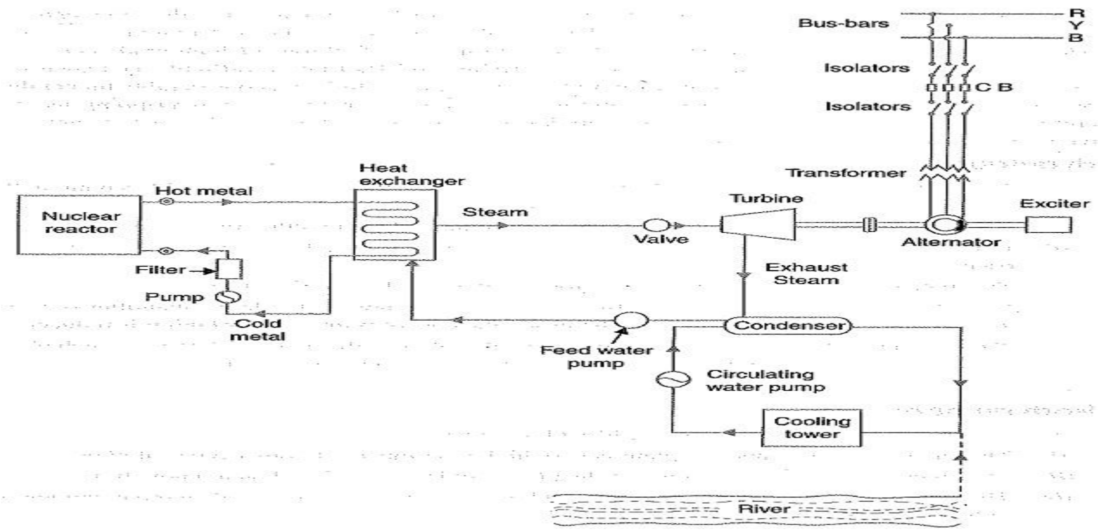
Disadvantages

- In view of direct cycle there is a danger of radioactive contamination of steam, therefore more safety measures are provided for piping and turbine.
- It cannot meet sudden increase in load.
- Because of the danger of small amounts of fissile materials passing through along with the steam/water more biological protection is needed.

26.

- Fast reactors get more neutrons out of their primary fuel than thermal reactors, so many can be used to breed new fuel, vastly enhancing the sustainability of nuclear power.
- Fast reactors are capable of destroying the longest-lived nuclear waste, transforming it to waste that decays to harmlessness in centuries rather than hundreds of millennia.
- Fast reactors typically use liquid metal coolants rather than water.
- These have superior heat-transfer properties and allow natural circulation to remove the heat in even severe accident scenarios.

27.



- The concepts of Nuclear power generation are much similar to that of conventional steam generation.
- The difference lies only in the steam generation part i.e coal furnace & Boiler are been replaced by the Nuclear reactor and Heat exchanger.

The nuclear power plant consists of a

- **Nuclear reactor : For heat generation**
- **Heat exchanger : For converting water into steam by using the heat generated in Nuclear reactor.**
- Followed by steam turbine, alternator, condenser etc.
- The reactor and the cooling circuit have to be shielded to eliminate radiation hazards.
- The tremendous amount of heat energy produced in breaking of atoms uranium or other similar metals by fission process in an atom reactor is extracted by pumping fluid or molten metal like liquid sodium or gas through the pile.
- The heated metal or gas is then allowed to exchange its heat to the heat exchanger by circulation.
- In steam generator steam is generator which are utilised to drive the turbine coupled to alternator thereby generating electrical energy.
- While deciding the layout of a nuclear power plant due consideration should be given to safety, operation convenience & capital economy.
- One of the important operational areas in a reactor building is the charge hall which is used for refueling operation.
- The main parts of nuclear power plant are Nuclear reactor, turbine, alternator, hence the layout is simple.
- A main control room is provided in a central location & consists of all necessary equipment's for the operation.
- All other auxiliary rooms such as charge room maintenance room, store, machine shop, switchyard, railway siding etc are suitably located for convenient operation.

28. **Selection of site**

- **Availability of Water Supply**
  - Sufficient water is required for cooling etc, therefore the site selected should be nearer to river , lake etc
- **Distance from populated area**
  - The nuclear plant should be located away from populated area because of the presence of radio activity in the atmosphere near the plant. However as precautionary a dome is used in the plant which does not allow the radio activity to spread.
- **Transportation Facilities**
  - A nuclear plant requires very little fuel, hence it does not require direct rail facilities for fuel transport. However, transportation to be needed during construction stage.
- **Nearness to Load centre**
  - Plants should be nearer to load centre as possible, in order to reduce transmission costs.
- **Availability of Space for Disposal of Waste**
  - The site selected for such power plants should have adequate space & arrangement for the disposal of radio active waste
- **Type of Land**
  - The foundation must be strong enough to support the heavy reactors which may weigh as high as 1,00,000 tonnes & impose bearing pressure around 50 tonnes/m^2 .

29. **Disposal of nuclear waste and effluent**

- Solid radioactive wastes arise from used filters, sludge from the cooling ponds, pieces of discarded fuel element cans, splitters etc.
- These discarded items of plants such as control rods have to be stored on site in **shielded concrete vaults.**
- The storing in shielded storage vaults consists of fixing the solid waste in **borosilicate glass and then storage of this glass in leak tight capsules.**
- These capsules or vaults cab then be stored in deep salt mines or in deep wells drilled in the stable ocean floor.
- Sometimes, **suitable containers are filled with radioactive waste and sunk to the bottom of seas and oceans.**
- Another way of disposal is the **separation and transmutation of the long lived isotopes to short-lived or stable products following neutron absorption in a breeder or fusion reactor.**
- It is safe enough to store radioactive waste underground in liquid form in suitable tanks or in reduction to clinker (Stony residue)
- Clinkering serves a two fold purpose of improving the protection and reducing the volume of waste.
- One more method is "**solidifying**" the liquid radioactive waste through heat up and evaporation.
- Gaseous effluents are filtered before discharging into atmosphere. Moreover, the filtered gas is discharged at high levels so that it is dispersed properly.
- The probability of fire in the reactor fuel channel is extremely low. However, if fire breaks out, large volumes of gaseous fission products may be released.
- So it is necessary to have a **clean up plant through which theses products can be passed for removal of radioactive iodine which is the main hazard.**

Shielding

- Adequate shielding is necessary to guard personnel and delicate instruments.
- The various materials used for shielding are **lead, concrete, steel and cadmium.**
- **Lead** is a common shielding material and is invariably employed due to its low cost.
- **Concrete** is another shielding material having efficiency lesser than that of lead.
- **Steel** is not an efficient shielding material but has good structural properties and is sometimes employed as an attenuating shield.
- **Cadmium** is capable of absorbing slow neutrons by a nuclear reaction.
- A material containing hydrogen e.g water or polythene is used to slow down fast neutrons.
- Boron or steel is employed for absorption of thermal neutrons.
- A heavy material like lead is required to act as a thermal shield and absorb gamma rays.
- In nuclear power reactors a thermal shield of thickness of several cms of steel surrounded by about 3 m thick concrete is used.

30. a **nuclear reaction** is semantically considered to be the process in which two nuclei, or else a nucleus of an atom and a subatomic particle (such as a proton, neutron, or high energy electron) from outside the atom, collide to produce one or more nuclides that are different from the nuclide(s) that began the process. Thus, a nuclear reaction must cause a transformation of at least one nuclide to another. If a nucleus interacts with another nucleus or particle and they then separate without changing the nature of any nuclide, the process is simply referred to as a type of nuclear scattering, rather than a nuclear reaction.

In principle, a reaction can involve more than two particles colliding, but because the probability of three or more nuclei to meet at the same time at the same place is much less than for two nuclei, such an event is exceptionally rare. "Nuclear reaction" is a term implying an **induced** changing in a nuclide, and thus it does not apply to any type of radioactive decay.

Natural nuclear reactions occur in the interaction between cosmic rays and matter, and nuclear reactions can be employed artificially to obtain nuclear energy, at an adjustable rate, on demand. Perhaps the most notable nuclear reactions are the nuclear chain reactions in fissionable materials that produce induced nuclear fission, and the various nuclear fusion reactions of light elements that power the energy production of the Sun and stars.

5.8 Nuclear Fission Process

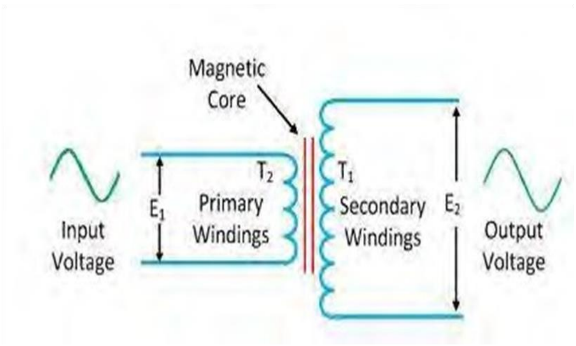
- Nuclear fission is the process of splitting apart nuclei (usually large nuclei). In other words, *nuclear fission is a nuclear reaction in which the nucleus of an atom splits into smaller parts (lighter nuclei). This nuclear reaction is triggered by the neutron.* When large nuclei, such as uranium-235, fissions, energy is released. The amount of energy released is so large that there corresponds a measurable decrease in mass, from the mass-energy equivalence. This means that some of the mass is converted to energy. The amount of mass lost in the fission process is equal to about 3.20×10^{-11} J of energy. This fission process generally occurs when a large nucleus that is relatively unstable (meaning that there is some level of imbalance in the nucleus between the Coulomb force and the strong nuclear force) is struck by a low energy thermal neutron. In addition to smaller nuclei being created when fission occurs, fission also releases neutrons.
- The fission of U-235 in reactors is triggered by the absorption of a low energy neutron, often termed a "slow neutron" or a "thermal neutron". Other fissionable isotopes which can be induced to fission by slow neutrons are plutonium-239, uranium-233, and thorium-232.

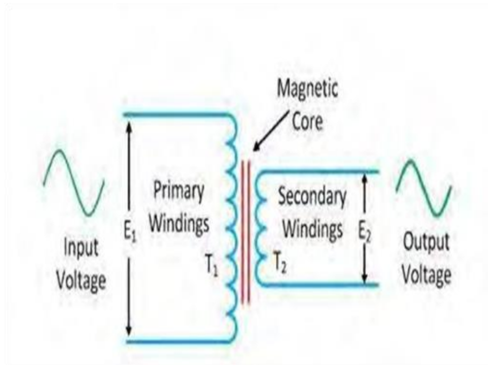
31. A **substation** is a part of an **electrical generation, transmission, and distribution system.**

- Substations transform voltage from high to low, or the reverse, or perform any of several other important functions.
- Between the generating station and consumer, electric power may flow through several substations at different voltage levels.
- A substation may **include transformers to change voltage levels between high transmission voltages and lower distribution voltages, or at the interconnection of two different transmission voltages.**
- Some substations are simply **switching stations** where different connections between various transmission lines are made.
- The other stations are **converting stations** which either convert ac into dc or vice versa or convert frequency from higher to lower or vice versa.
- Substations include safety devices to disconnect the equipment or circuit in the event of fault.
- Voltage on the outgoing distribution feeders can be regulated at substation.

Transformers

- A transformer is a static device which transforms electric power from one circuit to another circuit without the change in frequency. It depends on Faraday's Law of Electromagnetic Induction.
- Step up transformer : A transformer in which the output (secondary) voltage is greater than its input (primary) voltage is called a step-up transformer.





- **Step down transformer** : A transformer in which the output (secondary) voltage is less than its input (primary) voltage is called a step-down transformer.

Isolator

- Circuit Breaker always trip the circuit but open contacts of breaker cannot be visible physically from outside of the breaker.
- So for better safety there must be some arrangement so that one can see open condition of the section of the circuit before touching it.
- Isolator is a mechanical switch which isolates a part of circuit from system as when required.
- Electrical isolators separate a part of the system from rest for safe maintenance works.
- **Isolator is a manually operated mechanical switch which separates a part of the electrical power.**

Protective Relaying

- A protective relay is a **device that detects the fault and initiates the operation of the circuit breaker to isolate the defective element from the rest of the system.**
- The relays detect the abnormal conditions in the electrical circuits by **constantly measuring the electrical quantities** which are different under normal & fault conditions.
- Electrical quantities which may change in fault conditions are V, I, frequency & phase angle.
- Having fault detected the fault, the relay operates to close the trip circuit of the breaker.
- This results in the opening of the breaker & disconnection of the faulty circuit.

32. **Classification of Substation**

- **Indoor type substation**
- **Outdoor type substation**
- **Indoor type substation**
- In these substations the apparatus is installed within the substation building.
- Such substation are usually for a **voltage up to 11KV but can be erected for 33KV and 66KV volts** when surrounding atmosphere is contaminated with impurities such as metal corroding gases and fumes, conductive dust etc.
- The several compartments in which the indoor station is divided are
- **Control compartment**
- **Indicating and metering instruments**
- **Protective device compartment**
- **Circuit breaker and operating mechanism compartment**
- **Main bus compartment**
- **Current transformer and cable sealing box compartment**
- **Indoor distribution & transformer substations as well as high switchboards** consist of a series of open and enclosed chambers or compartments.

According to construction indoor distribution substations & high voltage switchboards are further divided into following categories.

- **Substations of the integrally built type**
- The apparatus is installed on site. In such substations the cell structure are constructed of concrete.
- **Substations of the Composite build up type**

- The compartments of such substations take form of metal cabinets or enclosures, each of which contains the equipment of one main connection cell.
- **Unit type factory fabricated substations and metal clad switchboards**
- This will be designed with the metal clad cubicles
- **Outdoor Substations**
- **Pole Mounted Substations**
- **Foundation Mounted Substations**

Pole Mounted Substations

- These substations are erected for mounting distribution transformers of capacity up to 250 KVA.
- They are cheapest, simple & smallest of substations.
- All the equipment is mounted on the supporting structure of **HT distribution line**.
- Triple pole mechanical operated switch is used for switching on & off of ht transmission line.
- HT fuse is installed for protection of HT side.
- Lightning arrestors are installed over the ht line to protect the transformers from surges.
- Transformers of capacity up to 1**25KVA** are mounted on double pole structure.
- Transformers of capacity above **125 KVA & below 250 KVA** are mounted on 4 pole structure.
- The maintenance cost of theses substations is low.

Foundation Mounted Substations

- Theses substations are entirely in the open and in such substations all the equipment is assembled into one unit usually enclosed by a fence from the point of view of safety.
- The **primary and secondary transmission and for secondary distribution (above 250 KVA) are foundation mounted outdoor type.**
- The equipment's are heavy for such substations, therefore site selected for theses substations must have good access for heavy transport.
- They may be of two types low type and high type.

33. **Advantages and Disadvantages of outdoor substations Over Indoor substations**
    - **Advantages**
    - All the equipment is within view and therefore fault location is easier.
    - The extension of the installation is easier
    - The small amount of building materials
    - The construction work required is comparatively smaller and cost of the switchgear installation is low.
    - Repairing work is easy.
    - Sufficient space between equipments
    - **Disadvantages**
    - More space is required for the substation
    - Protection devices are required to be installed for protection against lightning surges.
    - The length of control cable required is more.
    - Since the equipment's are exposed to the atmosphere, there would be accumulation of dust and dirt on them.
    - During the rainy season, switching operations may be difficult.
34. **Advantages of neutral earthing**
    - Earth fault protection can be used easily
    - The high voltages due to transient line to ground fault are eliminated
    - Neutral earthing reduces the impact of lightning by discharging the stroke to earth
    - Greater safety to the personnel
    - It provides stable neutral point
    - It improves reliability, economy and performance of the system

35.

(iii) Sinking fund method: In this method, a fixed depreciation charge is made every yea and interest compounded on it annually.The constant **depreciation charge** is such that total c annual instalments plus the interest accumulations equal to the cost of replacement c equipment after its useful life.

Must Read:

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Let P = Initial value of equipment

n = Useful life of equipment in years

S = Scrap value after useful life

r = Annual rate of interest expressed as a decimal

Let us suppose that an amount of q is set aside as depreciation charge every year and interest compounded on it so that an amount of $P - S$ is available after n years. An amount q at annual interest rate of r will become *$q(1 + r)^n$ at the end of n years.

Now, the amount q deposited at the end of first year will earn compound interest for $n - 1$ years and shall become $q(1 + r)^{n-1}$ *i.e.*,

Amount q deposited at the end of first year becomes

$$= q\,(1 + r)^{n-1}$$

Amount q deposited at the end of 2nd year becomes

$$= q\,(1 + r)^{n-2}$$

Amount q deposited at the end of 3rd year becomes

$$= q\,(1 + r)^{n-3}$$

Similarly amount q deposited at the end of $n - 1$ year becomes

$$= q\,(1 + r)^{n-(n-1)}$$
$$= q\,(1 + r)$$

$$\therefore \quad \text{Total fund after } n \text{ years} = q\,(1 + r)^{n-1} + q\,(1 + r)^{n-2} + ... + q\,(1 + r)$$
$$= q\,[(1 + r)^{n-1} + (1 + r)^{n-2} + ... + (1 + r)]$$

This is a G.P. series and its sum is given by :

$$\text{Total fund} = \frac{q(1 + r)^n - 1}{r}$$

This total fund must be equal to the cost of replacement of equipment P − S.

$$\therefore \quad P - S = q\frac{(1 + r)^n - 1}{r}$$

$$\text{or} \quad \text{Sinking fund, } q = (P - S)\left[\frac{r}{(1 + r)^n - 1}\right]$$

The value of 'q' gives the uniform annual **depreciation charge**.The parenthetical term in eq (i) is frequently referred to as the "sinking fund factor".

$$\therefore \quad \text{Sinking fund factor} = \frac{r}{(1+r)^n - 1}$$

Though this method does not find very frequent application in practical depreciation accounting it is the fundamental method in making economy studies and most effective **method of determining depreciation**.

36.

Ex. 8.9.3 : The equipment in a power station costs ₹ 15, 60,000 and has a salvage value of ₹ 60,000 at the end of 25 years. Determine the depreciated value of the equipment at the end of 20 years on the following methods :

1. Straight line method ;

2. Diminishing value method ;

3. Sinking fund method at 5 % compound interest annually.

Sol. : Initial cost of equipment, P = ₹ 15, 60,000

Salvage value of equipment, S = ₹ 60,000

Useful life, n = 25 years

Straight line method

$$\text{Annual Depreciation} = \frac{P-S}{n} = ₹\frac{1560000-60000}{25} = ₹\,60000$$

$$\text{Value of equipment after 20 years} = P - \text{Annual depreciation} \times 20$$

$$= 15,60,000 - 60,000 \times 20$$

$$= ₹\,3,60,000$$

Diminishing value method

$$\text{Annual Unit Depreciation } x = 1 - \left(\frac{S}{P}\right)^{\frac{1}{n}}$$

$$= 1 - \left(\frac{60000}{1560000}\right)^{\frac{1}{25}}$$

$$= 1 - 0.878 = 0.122$$

Value of equipment after 20 years

$$= P(1-x)^{20}$$

$$= 15,60,000\,(1-0.122)^{20}$$

$$= ₹\,1,15,615$$

3. Sinking fund method

Rate of interest, $r = 5\,\% = 0.05$

$$\text{Annual deposit in the sinking fund is } q = (P-s)\left[\frac{r}{(1+r)^n - 1}\right]$$

$$= (15,60,000 - 60,000)\left[\frac{0.05}{(1+0.05)^{25} - 1}\right]$$

$$= ₹\,31,433$$

So, sinking fund at the end of 20 years

$$= q\,\frac{(1+r)^{20} - 1}{r}$$

$$= 31,433\,\frac{(1+0.05)^{20} - 1}{0.05}$$

$$= ₹\,10,39,362$$

Value of plant after 20 years = ₹ (15, 60, 000 – 10, 39, 362)

$$= ₹\,5,20,638$$