UNIT –II: NUCLEAR POWER PLANT, DIESEL POWER PLANT AND GAS TURBINE POWER PLANT

NUCLEAR POWER PLANT:

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

In nuclear power station, heavy elements such as Uranium (U^{235}) or Thorium (Th^{232}) are subjected to nuclear fission in a special apparatus known as a *reactor*. The heat energy thus released is utilized in raising steam at high temperature and pressure. The steam runs the steam turbine which converts steam energy into mechanical energy. The turbine drives the alternator which converts mechanical energy into electrical energy.

SELECTION OF SITE FOR NUCLEAR POWER STATION:

The following points should be kept in view while selecting the site for a nuclear power station:

(i) Availability of water: As sufficient water is required for cooling purposes, therefore, the plant site should be located where ample quantity of water is available, e.g., across a river or by sea-side.

(ii) Disposal of waste: The waste produced by fission in a nuclear power station is generally radioactive which must be disposed off properly to avoid health hazards. The waste should either be buried in a deep trench or disposed off in sea quite away from the sea shore. Therefore, the site selected for such a plant should have adequate arrangement for the disposal of radioactive waste.

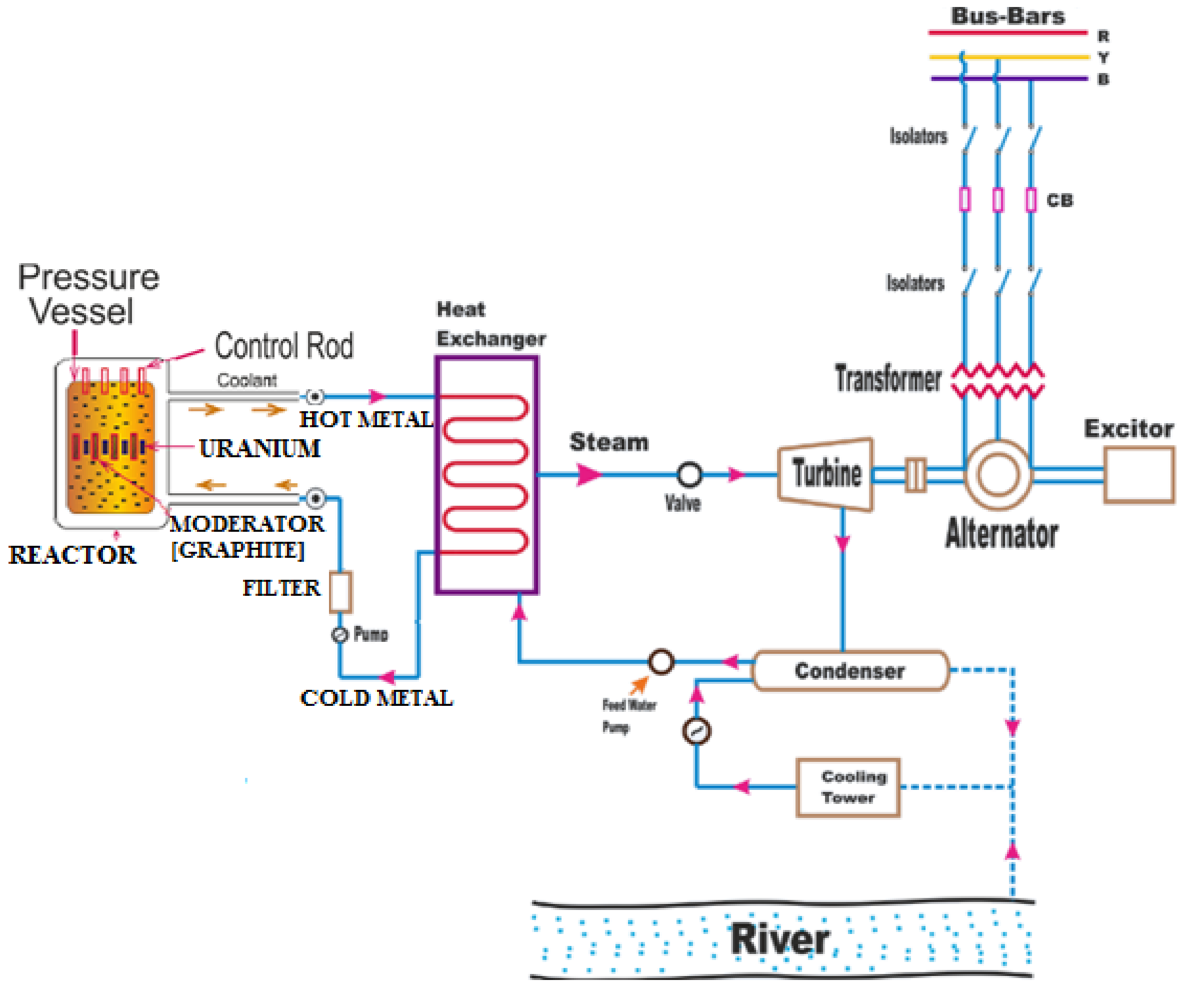
(iii) Distance from populated areas: The site selected for a nuclear power station should be quite away from the populated areas as there is a danger of presence of radioactivity in the atmosphere near the plant. However, as a precautionary measure, a dome is used in the plant which does not allow the radioactivity to spread by wind or underground waterways.

(iv) Transportation facilities: The site selected for a nuclear power station should have adequate facilities in order to transport the heavy equipment during erection and to facilitate the movement of the workers employed in the plant.

SCHEMATIC ARRANGEMENT OF NUCLEAR POWER STATION:

The schematic arrangement of a nuclear power station is shown in Figure. The whole arrangement can be divided into the following main stages:

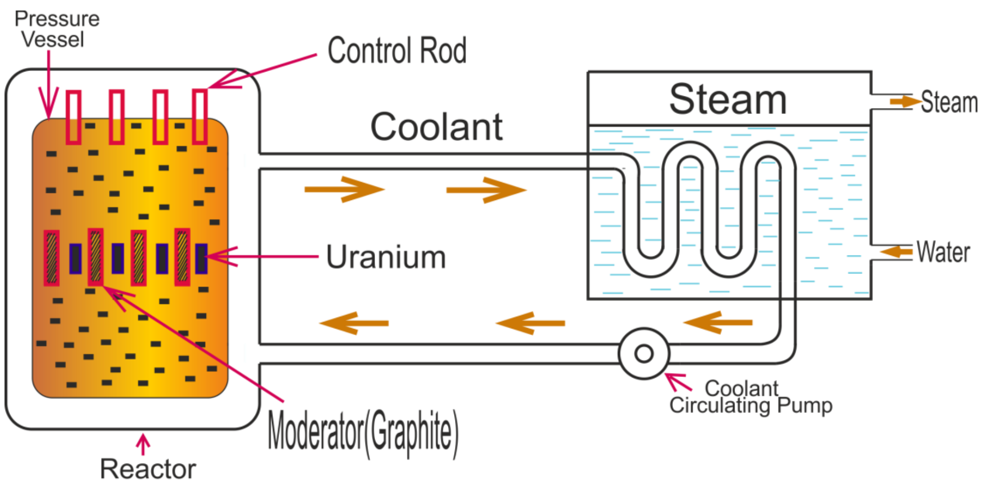
- ***(i)*** Nuclear reactor
- ***(ii)*** Heat exchanger
- ***(iii)*** Steam turbine
- ***(iv)*** Alternator.



(*i*) Nuclear reactor: It is an apparatus in which nuclear fuel (U^{235}) is subjected to nuclear fission. It controls the chain reaction that starts once the fission is done. If the chain reaction is not controlled, the result will be an explosion due to the fast increase in the energy released.

A nuclear reactor is a cylindrical stout pressure vessel and houses fuel rods of Uranium, moderator and control rods .The fuel rods constitute the fission material and release huge amount of energy when bombarded with slow moving neutrons. The moderator consists of graphite rods which enclose the fuel rods. The moderator slows down the neutrons before they bombard the fuel rods. The control rods are of cadmium and are inserted into the reactor. Cadmium is strong neutron absorber and thus regulates the supply of neutrons for fission. When the control rods are pushed in deep enough, they absorb most of fission neutrons and hence few are available for chain reaction which, therefore, stops. However, as they are being withdrawn, more and more of these fission neutrons cause fission and hence the intensity of chain reaction (or heat produced) is increased.

Therefore, by pulling out the control rods, power of the nuclear reactor is increased, whereas by pushing them in, it is reduced. In actual practice, the lowering or raising of control rods is accomplished automatically according to the requirement of load. The heat produced in the reactor is removed by the coolant, generally a sodium metal. The coolant carries the heat to the heat exchanger.



Nuclear Reactor

(*ii*) Heat exchanger: The coolant gives up heat to the heat exchanger which is utilized in raising the steam. After giving up heat, the coolant is again fed to the reactor.

(*iii*) Steam turbine: The steam produced in the heat exchanger is led to the steam turbine through a valve. After doing a useful work in the turbine, the steam is exhausted to condenser. The condenser condenses the steam which is fed to the heat exchanger through feed water pump.

(*iv*) Alternator: The steam turbine drives the alternator which converts mechanical energy into electrical energy. The output from the alternator is delivered to the bus-bars through transformer, circuit breakers and isolators.

ADVANTAGES:

(*i*) The amount of fuel required is quite small. Therefore, there is a considerable saving in the cost of fuel transportation.

(*ii*) A nuclear power plant requires less space as compared to any other type of the same size.

(*iii*) It has low running charges as a small amount of fuel is used for producing bulk electrical energy.

(*iv*) This type of plant is very economical for producing bulk electric power.

(*v*) It can be located near the load centers because it does not require large quantities of water and need not be near coal mines. Therefore, the cost of primary distribution is reduced.

(*vi*) There are large deposits of nuclear fuels available all over the world. Therefore, such plants can ensure continued supply of electrical energy for thousands of years.

(*vii*) It ensures reliability of operation.

DISADVANTAGES:

(*i*) The fuel used is expensive and is difficult to recover.

(*ii*) The capital cost on a nuclear plant is very high as compared to other types of plants.

(*iii*) The erection and commissioning of the plant requires greater technical know-how.

(*iv*) The fission by-products are generally radioactive and may cause a dangerous amount of radioactive pollution.

(*v*) Maintenance charges are high due to lack of standardization. Moreover, high salaries of specially trained personnel employed to handle the plant further raise the cost.

(*vi*) Nuclear power plants are not well suited for varying loads as the reactor does not respond to the load fluctuations efficiently.

(*vii*) The disposal of the by-products, which are radioactive, is a big problem. They have either to be disposed off in a deep trench or in a sea away from sea-shore.

APPLICATIONS OF NUCLEAR POWER PLANT:-

Following are the applications of nuclear power plant

1. For the production of electric energy.
2. Used in development and improvement of process for measurements, automation and quality control.
3. Used in process research, mixing, maintenance and study of wear and corrosion of plant and machinery.
4. Used in military applications i.e.in the nuclear weapons.
5. Used as nuclear medicine such as radiography.
6. Used in food perseveration.
7. Used in mining hydrology and space industries.
8. Used in agricultural production such as maximizing water resources, improving crop verities.

NUCLEAR POWER PLANT IMPACT:-

HEALTH PHYSICS:- Nuclear radiations can cause danger to living cells by ionization process. Radiations enter our body through breathing eating, drinking or by cuts. Some radiations are specially exerted while other remains in the form of sudden death or illness such as leukemia, anemia, cancer or congenital abnormalities. The work of health physics organization in a nuclear installation as under

i) Environmental control.
ii) Personnel monitoring.
iii) Biological monitoring.

NUCLEAR WASTES AND WASTE DISPOSAL:- The disposal of solids , liquid and gaseous waste and effluent from nuclear power plants needs special attention because of the danger of radiation. The emission intensity of the radioactive waste is very harmful to the living animals and organisms. Because of this dangerous gamma emission of the nuclear waste is a major problem.

The solids fission products are stored in shielded storage vaults where solid waste is fixed in borosilicate glass and then this glass is stored in leak proof tight capsules. These capsules are then stored in deep salt mines. Sometimes, large containers with the radioactive waste are placed at the bottom of oceans.

Another way of disposing radioactive waste is separating the long-lived isotopes from short-lived stable products following neutrons absorption in the fusion reactor.

The sludge from the cooling ponds are first heavily diluted and then discharged into the oceans. Sometimes, the liquid wastes are converted into clinkers of very small volume, then sealed in metal containers and then these metal containers are stored into deep salt mines.The gaseous effluents are filtered and then discharged into atmosphere where area is free from fire hazardous materials.

DIESEL POWER STATION

A generating station in which diesel engine is used as the prime mover for the generation of electrical energy is known as **diesel power station.**

ADVANTAGES:

(*i*) The design and layout of the plant are quite simple.

(*ii*) It occupies less space as the number and size of the auxiliaries is small.

(*iii*) It can be located at any place.

(*iv*) It can be started quickly and can pick up load in a short time.

(*v*) There are no standby losses.

(*vi*) It requires less quantity of water for cooling.

(*vii*) The overall cost is much less than that of steam power station of the same capacity.

(*viii*) The thermal efficiency of the plant is higher than that of a steam power station.

(*ix*) It requires less operating staff.

DISADVANTAGES:

(*i*) The plant has high running charges as the fuel (*i.e.*, diesel) used is costly.

(*ii*) The plant does not work satisfactorily under overload conditions for a longer period.

(*iii*) The plant can only generate small power.

(*iv*) The cost of lubrication is generally high.

(*v*) The maintenance charges are generally high.

SCHEMATIC ARRANGEMENT OF DIESEL POWER PLANT:

Figure shows the schematic arrangement of a typical diesel power station. Apart from the diesel generator set, the plant has the following auxiliaries:

(i) Fuel supply system: It consists of storage tank, strainers, fuel transfer pump and all day fuel tank. The fuel oil is supplied at the plant site by rail or road. This oil is stored in the storage tank. From the storage tank, oil is pumped to smaller all day tank at daily or short intervals. From this tank, fuel oil is passed through strainers to remove suspended impurities. The clean oil is injected into the engine by fuel injection pump.

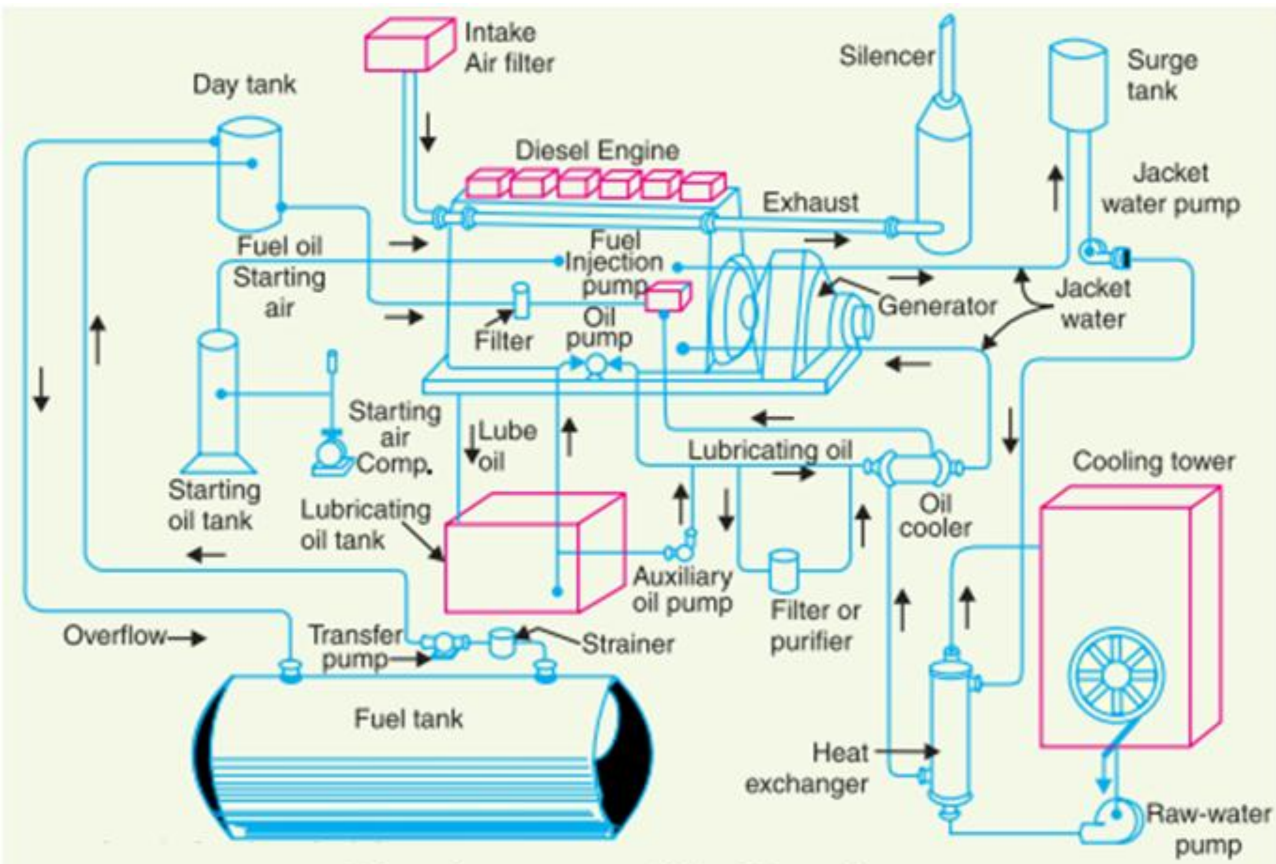
(ii) Air intake system: This system supplies necessary air to the engine for fuel combustion. It consists of pipes for the supply of fresh air to the engine manifold. Filters are provided to remove dust particles from air which may act as abrasive in the engine cylinder.

(iii) Exhaust system: This system leads the engine exhaust gas outside the building and discharges it into atmosphere. A silencer is usually incorporated in the system to reduce the noise level.

(iv) Cooling system: The heat released by the burning of fuel in the engine cylinder is partially converted into work. The remainder part of the heat passes through the cylinder walls, piston, rings etc. and may cause damage to the system. In order to keep the temperature of the engine parts within the safe operating limits, cooling is provided. The cooling system consists of a water source, pump and cooling towers. The pump circulates water through cylinder and head jacket. The water takes away heat form the engine and it becomes hot. The hot water is cooled by cooling towers and is recalculated for cooling.

(v) Lubricating system: This system minimizes the wear of rubbing surfaces of the engine. It comprises of lubricating oil tank, pump, filter and oil cooler. The lubricating oil is drawn from the lubricating oil tank by the pump and is passed through filters to remove impurities. The clean lubricating oil is delivered to the points which require lubrication. The oil coolers incorporated in the system keep the temperature of the oil low.

(vi) Engine starting system: This is an arrangement to rotate the engine initially, while starting, until firing starts and the unit runs with its own power. Small sets are started manually by handles but for larger units, compressed air is used for starting. In the latter case, air at high pressure is admitted to a few of the cylinders, making them to act as reciprocating air motors to turn over the engine shaft. The fuel is admitted to the remaining cylinders which makes the engine to start under its own power.



Schematic arrangement of Diesel Power Plant

GAS TURBINE POWER PLANT

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

ADVANTAGES:

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

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

(*iii*) The initial and operating costs are much lower than that of equivalent steam power station.

(*iv*) It requires comparatively less water as no condenser is used.

(*v*) The maintenance charges are quite small.

(*vi*) Gas turbines are much simpler in construction and operation than steam turbines.

(*vii*) It can be started quickly form cold conditions.

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

DISADVANTAGES:

(*i*) There is a problem for starting the unit. It is because before starting the turbine, the compressor has to be operated for which power is required from some external source. However, once the unit starts, the external power is not needed as the turbine itself supplies the necessary power to the compressor.

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

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

(***iv***) The temperature of combustion chamber is quite high (3000^{O}F) so that its life is comparatively reduced.

SCHEMATIC ARRANGEMENT OF GAS TURBINE POWER PLANT:

The schematic arrangement of a gas turbine power plant is shown in Figure. The main components of the plant are:

(***i***) Compressor

(***ii***) Regenerator

(***iii***) Combustion chamber

(***iv***) Gas turbine

(***v***) Alternator

(***vi***) Starting motor

(***i***) **Compressor.** The compressor used in the plant is generally of rotatory type. The air at atmospheric pressure is drawn by the compressor *via* the filter which removes the dust from air. The rotatory blades of the compressor push the air between stationary blades to raise its pressure. Thus air at high pressure is available at the output of the compressor.

(***ii***) **Regenerator.** A regenerator is a device which recovers heat from the exhaust gases of the turbine. The exhaust is passed through the regenerator before wasting to atmosphere. A regenerator consists of a nest of tubes contained in a shell. The compressed air from the compressor passes through the tubes on its way to the combustion chamber. In this way, compressed air is heated by the hot exhaust gases.

(***iii***) **Combustion chamber.** The air at high pressure from the compressor is led to the combustion chamber *via* the regenerator. In the combustion chamber, heat* is added to the air by burning oil. The oil is injected through the burner into the chamber at high pressure to ensure atomization of oil and its thorough mixing with air. The result is that the chamber attains a very high temperature (about 3000°F). The combustion gases are suitably cooled to 1300°F to 1500°F and then delivered to the gas turbine.

(*iv*) Gas turbine. The products of combustion consisting of a mixture of gases at high temperature and pressure are passed to the gas turbine. These gases in passing over the turbine blades expand and thus do the mechanical work. The temperature of the exhaust gases from the turbine is about 900°F.

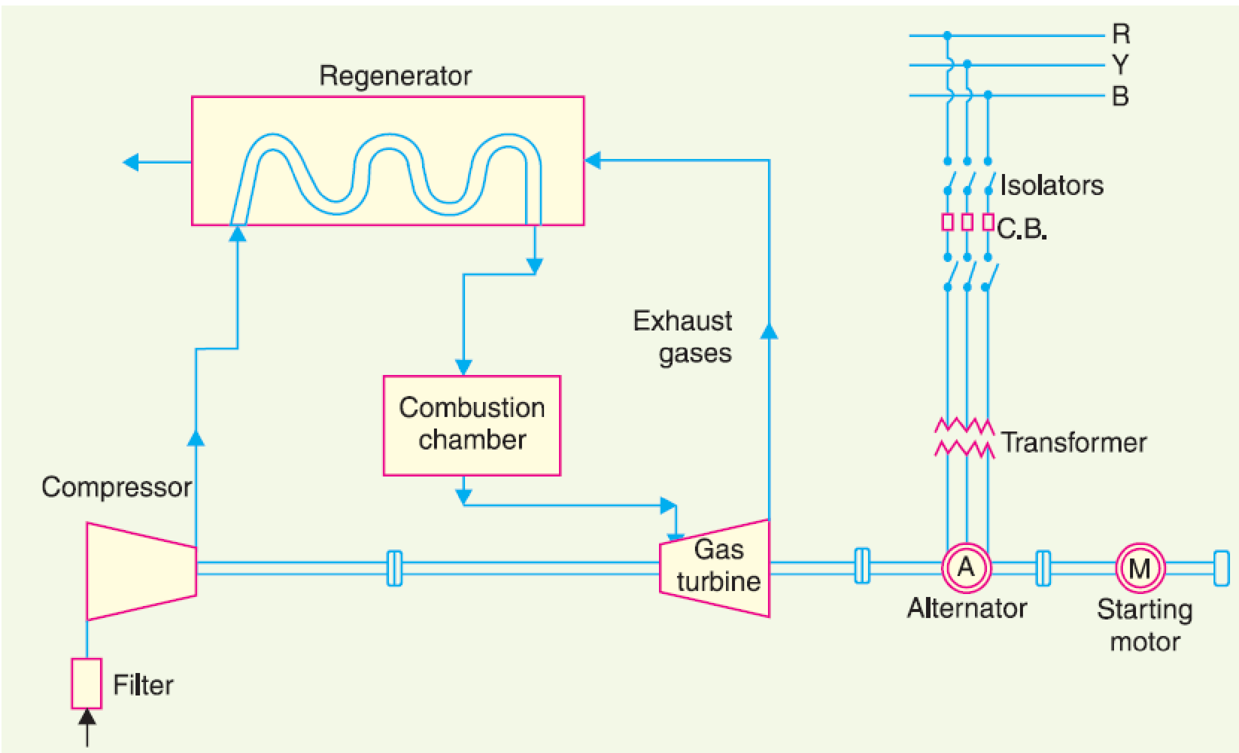


Fig: The schematic arrangement of a gas turbine power plant