GOVT. POLYTECHNIC, SIRSA (HARYANA)

ELECTRICAL ENGINEERING DEPARTMENT

ELECTRICAL POWER-I

5TH SEMESTER

Power Generation

ENERGY

The energy of a body is its capacity to do work. It is measured the total amount of work that the body can do.

Energy cannot be generated or cannot be destroyed but it can be converted into one form to another form.

According to the law of conservation of energy, the total energy of a system remains constant, though energy may transform into another form.

The S.I unit of energy is **Joule** or **KJ** or **Watt.h** or **Kwh**.

MAIN RESOURCES OF ENERGY

Conventional
(or Non-Renewable)
Energy Sources

Non-Conventional
(or Renewable)
Energy Sources

Conventional (or Non-Renewable) Energy Sources:

A **Non-Renewable Resource** is a Natural resource which cannot be produced, re-grown, regenerated, or reused on a scale which can sustain its consumption rate. These resources often exist in a fixed amount, or are consumed much faster than nature can recreate them. Non-Renewable energy sources come out of the **ground** as *liquids, gases, and solids*.

Liquids – Crude oil (Petroleum).
Gases – Natural gas, Propane etc.
Solids – Coal, Coke anthracite etc.

Non-Conventional (or Renewable) Resources of Energy:

The sources of energy which are being produced continuously in nature and are inexhaustible are called *Renewable Sources of Energy or Non-Conventional Energy Source.*

Some of these energy sources are:

1. Solar energy
2. Wind energy
3. Tide energy
4. Geothermal energy
5. Energy stored in water

TYPES O POWER STATIONS

- Thermal or Steam Power Station
- Hydro Electric Power Station
- Gas Turbine Power Station
- Diesel Electric Station
- Nuclear Power Station

Thermal Power Station

or

(Steam Power Station)

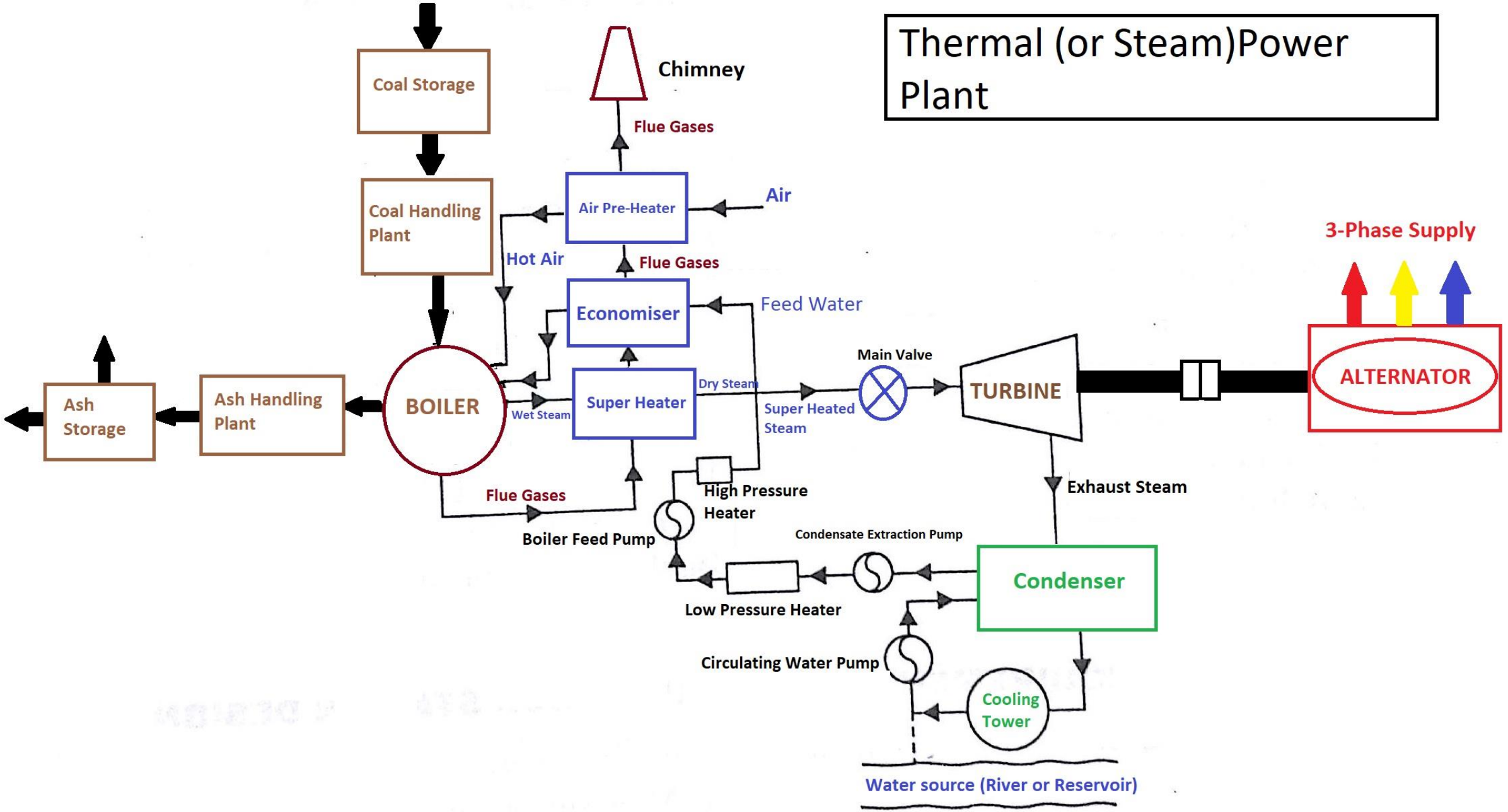
Thermal Power Plant

A thermal power plant converts the heat energy of the coal into electrical energy.

Coal is burnt in a boiler which converts water into steam. The expansion of steam in turbine produces mechanical power which derives the alternator.

To achieve efficient conversion of heat energy into electric energy, a variety of auxiliary equipment are needed.

Thermal (or Steam)Power Plant



WORKING

The coal handling supplies coal to the boiler. The ash formed in the boiler is disposed off by the ash handling plant. Air taken from the atmosphere by the action of forced or induced draft fan is heated in pre-heater (*by the heat of flue gases*) before being fed to the boiler. The flue gases passes through the **Super-Heater**, **Economizer** and **Pre-heater** before being discharged to the atmosphere through the chimney. The boiler vaporizes the water into steam, steam further heated in the super-heater and fed to the high pressure turbine. Then turbine drives the alternator which is coupled with turbine and alternator generates the electrical energy.

The **main and auxiliary** equipment in a thermal power plant are:

1. Coal Handling Plant
2. Pulverizing Plant
3. Boiler
4. Ash Handling Plant
5. Super-Heater
6. Economizer
7. Air Pre-Heater
8. Turbine
9. Alternator
10. Condenser
11. Cooling Tower

1. Coal Handling Plant:

The function of coal handling plant is automatic feeding of coal to the boiler.

2. Pulverizing Plant:

In this plant, the coal is reduced to a fine powder with the help of grinding mill and then feed to the combustion chamber.

3. Boiler

It is a closed vessel which converts water into steam by combustion of fuel. There are two types of boilers used in steam power plant

(a) Fire Tube Boiler

(b)Water Tube Boiler

In *Fire Tube Boilers*, the tube containing hot gases of combustion inside are surrounded with water while, in *Water Tube Boilers*, the water inside the tubes and hot gases outside the tubes.

4. Ash Handling Plant:

A huge quantity of ash is produced in central station, sometimes being as much as 10 to 20 % of the total quantity of coal burnt in a day.

Ash handling comprises following operations:

(a)Removal of ash from furnace.

(b)Transfer of this ash to a storage.

(c)Disposed off this stored ash.

5. Super-Heater:

The function of super-heater is ***to make the wet steam very dry by utilizing the flue gases***.

In other words, sure-heater removes the last traces of moisture from the saturated steam leaving the boiler tube and also increases the temperature above the saturation temperature.

6. Economizer:

Flue gases coming out of the boiler carry lot of heat. An economizer extracts a part of this heat from the flue gases and uses it for heating feed water.

The use of economizer *results in* **saving in coal consumption** and **higher boiler efficiency** but *needs* extra investment and increase in maintenance cost and floor area required for the plant.

7. Air Pre-Heater:

It is **used** to *recover the heat from the flue gases leaving the economizer and heat the incoming air required for combustion.*

This increases the temperature of the furnace gases, improves combustion rates and efficiency, thus improving the overall efficiency of the boiler.

8. Turbine:

It converts the *heat energy of steam* into *mechanical energy* and drives the generator.

Turbine works as prime mover for the generator.

9. Alternator:

The alternator is a device which converts the mechanical energy into electrical energy.

Alternator is coupled to the turbine (or prime mover)

10. Condenser:

A condenser that condenses low pressure steam into water.

Steam, after expansion through the prime mover, goes through the condenser which condenses the exhaust steam and also removes air and other non-condensable gases from steam while passing through them. It increases the efficiency of the plant.

11. Cooling Tower:

A cooling tower is a steel or concrete hyperbolic structure having a reservoir at the bottom for the storage of cooled water. Warm or hot water is led to the top. Air flows from the bottom to the top. The water drops falling from the top come in contact with air, lose heat to the air and get cooled.

Advantages
&
Disadvantages

of Steam (or Thermal) Power Plant

ADVANTAGES

1.Fuel used is cheaper in cost.

2.It requires less space in comparison of hydro-power plants.

3.Its production cost is less (or cheaper) than that of diesel power stations.

4.Its initial cost is less (or cheaper) than that of diesel power stations.

5.It can be located very conveniently near the load center.

6.As these plants can be set up near the industry, transmission costs are reduced.

7.It can respond to rapidly changing loads without difficulty.

8.A portion of the steam generated can be used as a process steam in different industries.

DISADVANTAGES

1.Maintenance and repairing costs are high.

2.Atmosphere gets polluted due to fumes and smoke.

3.It requires long time for erection and putting into the action.

4.It requires a huge quantity of water.

5. Handling of coal and disposal of ash is quite difficult.

6.The plant cost increases with the increase in the operating temperature and pressure.

7.Presences of trouble due to smoke and heat in the plant.

Selection of Site

for

Steam (or Thermal) Power Plant

Selection of Site for Steam (or Thermal) Power Plant

1.Availability of water

2.Availability of fuel (coal)

3. Nature of land

4.Cost of land

5.Transport facilities

6.Availability of labour (or labor)

7.Ash disposal facilities

8.Load center

9.Public problem

10. Future expansions

Hydro-Electric Power Plant

or

Hydro-Electric Power Station

In hydro-electric power plants, the energy of the water is utilized to move the turbines which in turn run the electric generators.

The energy of water, it may be K.E (Kinetic Energy) or P.E (Potential Energy), utilized for power generation.

The kinetic energy of water is its energy in motion and is a function of mass and velocity.

The **kinetic energy** of water is its energy in motion and is a function of mass and velocity.

The **potential energy** is the function of difference in head of water between two points *(up-stream and down-stream sides).*

In both cases, continuous availability of water is a basic necessity; to ensure this, water collected in natural lakes and reservoir at high height may be utilize or water may be artificially stored by constructing dams across flowing stream.

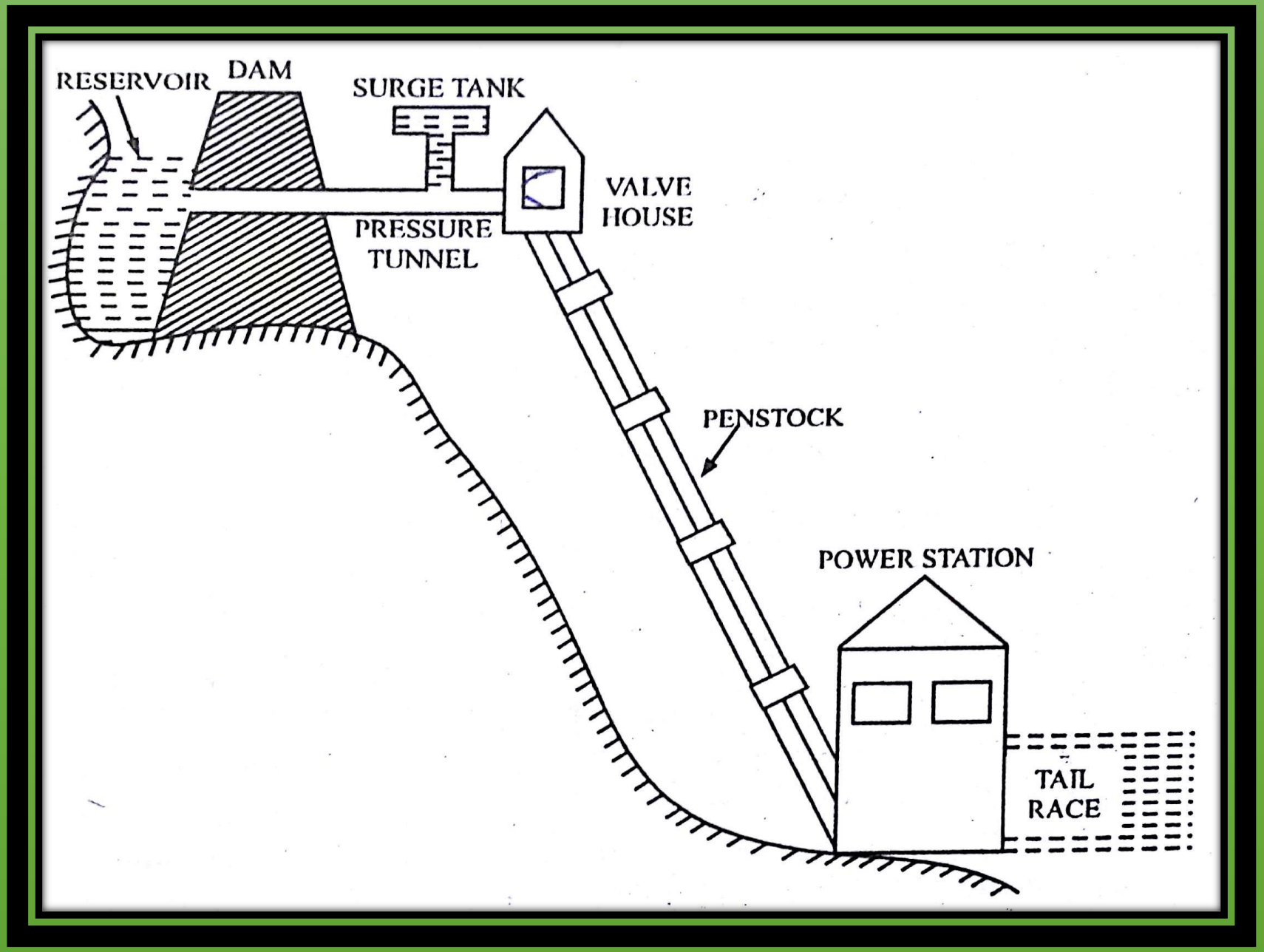
Hydro (water) power is a conventional renewable source of energy which is clean, free from pollution and generally a good environmental effect.

Most of the hydro-electric plants are located at sites which are usually quite far away from load center. Main reason behind this is impounding of water in huge quantities by dams is not possible in thickly populated and industrial areas.

Hydro-electric power plants capture the energy released by water falling through a vertical distance, and transform this energy into useful electricity.

In general, falling water is channeled through a turbine which converts the water's energy into mechanical power.

The rotation of the water turbines is transferred to a generator which produces electricity.


RESERVOIR
DAM
SURGE TANK
VALVE HOUSE
PRESSURE TUNNEL
PENSTOCK
POWER STATION
TAIL RACE

The amount of electricity which can be generated at a hydro-electric plant is dependent upon **two factors**.

These factors are:

(1) **the vertical distance through which the water falls**, called the "head", and

(2) **the flow rate**, measured as *volume per unit time*.

The electricity produced is **proportional** to the product of the head and the rate of flow.

The following is an equation which may be used to roughly determine the amount of electricity which can be generated by a potential hydro-electric power site:

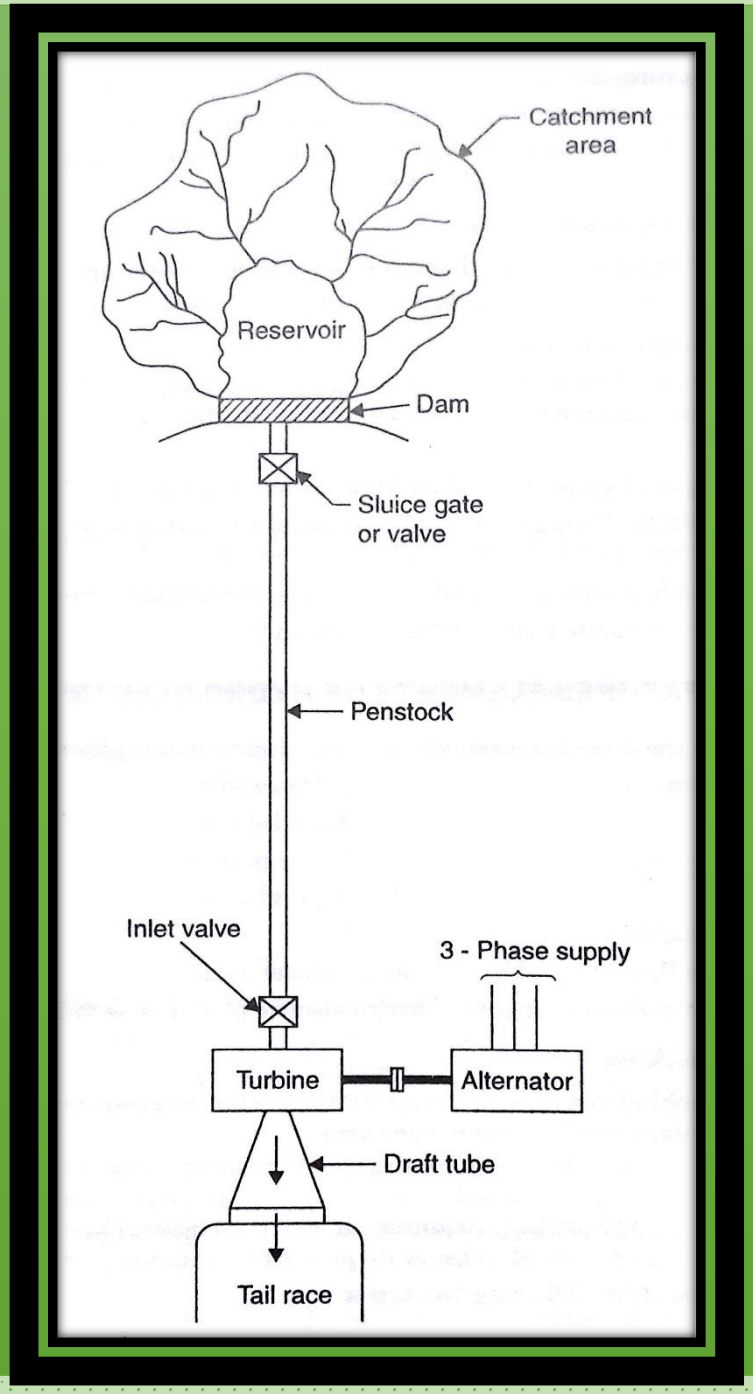
POWER (kW) = 5.9 x FLOW x HEAD

In this equation,
FLOW is measured in *cubic meters per second*
HEAD is measured in *meters*.

Essential Features (or Elements) of Hydro-Electric Power Plant:

The following are the essential elements of hydro-electric power plant:

1. Catchment area
2. Reservoir
3. Dam
4. Spillway
5. Penstock(or Conduit) and Tunnel
6. Surge Tank
7. Tail Race
8. Draft Tube
9. Prime Mover
10. Power House and Equipment


Catchment area
Reservoir
Dam
Sluice gate or valve
Penstock
Inlet valve
3 - Phase supply
Turbine
Alternator
Draft tube
Tail race

1. Catchment Area:

It is the area, bounded by water sheds, which drains into a stream or river across which the dam has been built at a suitable place.

2. Reservoir:

This is the basic requirement of a hydro-electric plant.

It is the **artificial storage of water.**

The **purpose** of reservoir is **to store the water during the rainy season and supply that stored water during the dry season** and thus it helps in supplying water to the turbines to the load on the power plant.

3. Dam:

Dams are structures built over rivers to stop the water flow and form a reservoir.

The reservoir stores the water flowing down the river. This water is diverted to turbines in power stations.

The dams collect water during the rainy season and store it, thus allowing for a steady flow through the turbines throughout the year.

Dams are also used for controlling floods and irrigation.

The dams should be water-tight and should be able to withstand the pressure exerted by the water on it.

There are *different types* of dams such as **arch dams, gravity dams and buttress dams**. The *height of water* in the dam is called ***head race***.

4. Spillway:

A spillway as the name suggests could be called as **a way for spilling of water from dams**. It is constructed to **act as safety valve**.

It is used to provide for the release of flood water (or overflow water) from a dam.

It is used to prevent over toping of the dams which could result in damage or failure of dams.

Spillways could be **controlled type** or **uncontrolled type**.

The uncontrolled types start releasing water upon water rising above a particular level. But in case of **the controlled type**, regulation of flow is possible.

5. Penstock (or Conduit) and Tunnel:

Penstocks are **pipes** which carry water from the reservoir to the turbines inside power station.

They are usually **made of steel** and are **equipped with gate systems** .

Water under high pressure flows through the penstock.

A tunnel serves the same purpose as a penstock.

It is used when an obstruction is present between the dam and power station such as a mountain.

6. Surge Tank:

The load on the generator keeps on **fluctuating**. Therefore, the water intake to the turbine has to be regulated according to the load.

A reduction in load on alternator causes the governor to close the turbine gate.

Sudden closure of turbine gate creates an increased pressure, known as ***water hammering***.

When governor opens the turbine gate suddenly to admit more water, there is a tendency to cause a vacuum in the penstock.

The *function* of surge tank is ***to absorb these sudden changes in the water requirements so as to prevent water hammering and vacuum*.**

7. Tail Race:

The water after having done its useful work in the turbine is discharged to the tail race which may lead it to the same stream or to any other.

The design and size of the tail race should be such that water has a free exit and the jet of water, after it leaves turbine, has unimpeded (or unobstructed) passage.

8. Draft Tubes:

An air tight pipe of suitable diameter attached to the runner outlet and conducting water down from the wheel and discharging it under the surface of the water in the tail race is known as draft tube.

The draft tubes serve the following **two purposes**:

(a) It allows the turbine to be set above tail water level, without loss of head, to facilitate inspection and maintenance.

(b) It regains, by diffuser action, the major portion of the kinetic energy delivered to it from the runner.

9. Prime Mover:

In hydro-electric power plants, water turbines are **used as prime mover**.

The **function** of the prime mover is **to convert the water energy (*i.e.* K.E) in to the mechanical energy** which further utilized to drive the generator (or alternator).

10. Power House & Equipment:

The power house is positioned at **the toe of the dam**.

The power house separated from the dam expansion joints.

Power house comprises with **turbine, generator, protection and control equipment, dewatering, drainage system, auxiliary, power system, grounding, emergency and standby power system, lighting and ventilation, and Tail race channel.**

(a)Generator (or Alternator): It is coupled with the prime mover and converts the mechanical energy of the prime mover into electrical energy.

(b)Transformer: The function of the transformer is to step-up the generated voltage level.

(c)Power Lines: Out of every power plant come four wires: the three phases of power being produced simultaneously plus a neutral or ground common to all three.

Advantages
&
Disadvantages

of Hydro-Electric Power Plant:

Advantages:

1. It is renewable - rainfall renews the water in the reservoir, so the fuel is almost always there.
2. Water to run the power plant is provided free by nature.
3. No fuel charges.
4. No fuel transportation problem.
5. Fuel is not burned so there is minimal pollution and hence environment friendly.
6. Low operation and maintenance cost.
7. A hydro-electric plant is highly reliable.
8. Low generation cost compared with other energy sources.

9. Higher efficiency, 95% to 98%.

10. In addition to power generation these plants are also used for flood control and irrigation purpose.

11. Less supervising staff is required.

12. Such a plant has a long life.

13. The number of operations required is considerably less as compared to thermal power plants.

14. Running cost of the plant is low.

15. The plant has no stand by losses.

Disadvantages:

1.The initial coat of the plant is very high.

2.It takes long period for erection.

3.Loss of large land.

4.Such plants are usually located in hilly area far away from the load center and as such they require long transmission lines to deliver the power, subsequently the cost of transmission lines and losses in them will be more.

Selection of Site
for
Hydro Power Plants

Selection of Site for Hydro Power Plants

1. Large quantity of water at a reasonable head should be available.

2. The rainfall should be sufficient to maintain desired water level in the reservoir throughout the year.

3. The catchments area for the reservoir to collect rainwater should be large.

4. The land should be cheap in cost and rocky.

5.Adequate transportation facilities.

6.It should be near to the load center so that transmission cost of the power can be reduced.

It should be easily accessible.

Gas Turbine Power Plants

Gas Turbine Power Plants

Gas turbine power plant is a plant in which **a gas turbine is used as the prime mover for the generation of electricity (or electrical energy).**

The Principle of Operation of Gas Turbine Plants

A gas turbine plant consists of

1. A compressor
2. Combustion chamber
3. Gas turbine, and
4. A alternator.

The compressor takes in atmospheric air, compresses it and supplies the pressurized air to the combustion chamber.

Fuel is injected to the combustion chamber and burnt in the stream of air supplied by the compressor.

The combustion raises the temperature of the air and increases its volume under constant pressure.

The hot pressurized gas expends in the turbine, produces mechanical power and turns the rotor of the turbine. **Both the compressor and the alternator are coupled to the turbine shaft.**

Due to the high temperature of the products of combustion, the turbine output exceeds the input to the compressor.

The turbine, therefore, drives the compressor and the surplus power drives the alternator.

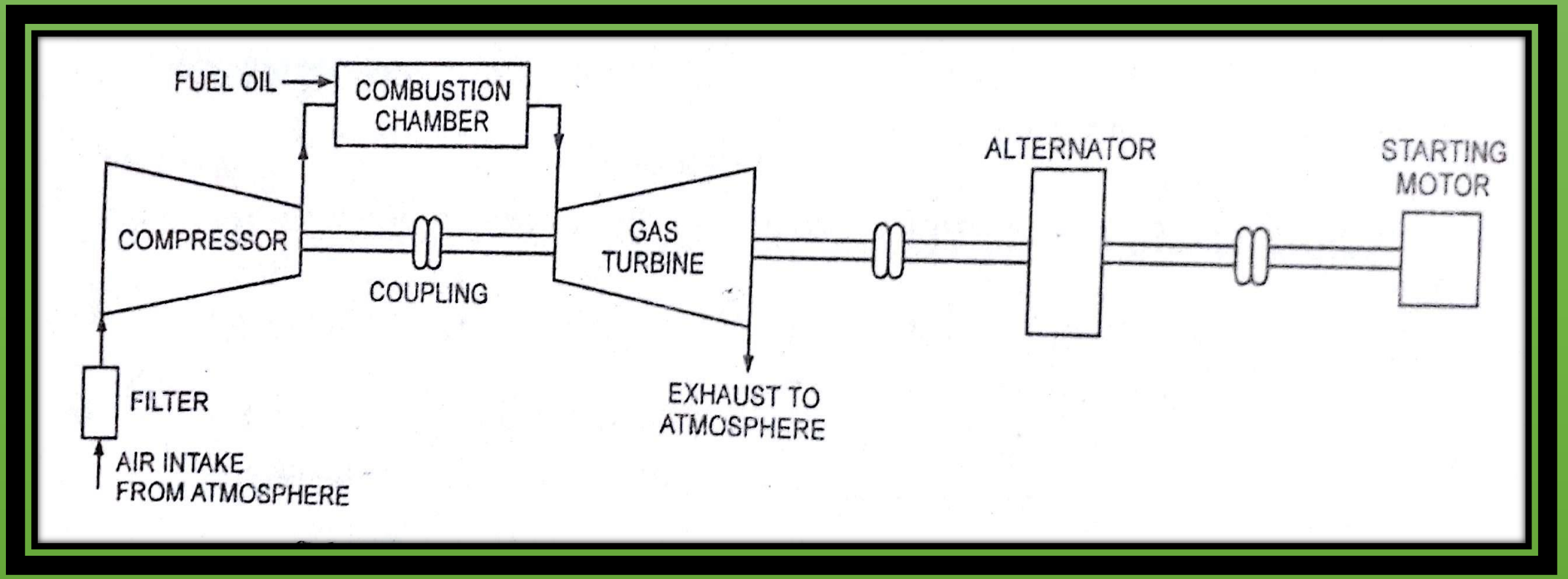
The productions of combustion, after expansion through the turbine, are finally exhausted to the atmosphere. **Such plants are known as Open Cycle Gas Turbine Plants.**

Elements
of
Gas Turbine Power Plant

Elements of Gas Turbine Power Plant

A gas turbine power plant consists of:

1. Compressor
2. Combustion Chamber
3. Gas Turbine
4. Generator (or Alternator)


FUEL OIL
COMBUSTION CHAMBER
COMPRESSOR
COUPLING
GAS TURBINE
ALTERNATOR
STARTING MOTOR
FILTER
AIR INTAKE FROM ATMOSPHERE
EXHAUST TO ATMOSPHERE

1. Compressor:

It sucks the air from the atmosphere through the filter, which removes the dust from the air. The rotary blades push the air between the stationary blades to raise its pressure to 4-5 atmospheres. Thus, air is available at high pressure at the output of the compressor.

It is used in gas turbine power plant is usually **of axial flow (or rotary) type.**

2. Combustion Chamber:

The main function of the combustion chamber is to provide for the chemical reaction of fuel (oil) and air being supplied by the compressor. It must fulfill the following conditions:

(a)Combustion must occur at high efficiency.

(b)The pressure losses must be low.

(c)Ignition must be reliable.

(d)Thorough mixing of fuel and air.

(e)Carbon deposition must not be formed under any conditions.

Advantages
&
Disadvantages
of
Gas Turbine Power Plant

Advantages:

1. Simple in construction because there is no need of boiler and their auxiliaries.
2. It has no standby losses.
3. Low initial cost.
4. It requires less space.
5. It is more reliable.
6. It can be located very near the load even in the cities and towns.
7. Low maintenance cost.

Disadvantages:

1. Low overall efficiency.
2. Noisy operation.
3. Short life.
4. Special metals and alloys are required for different components of the plant.
5. High specific fuel consumption and limited unit capacity.

Selection of Site

for

Gas Turbine Power Plant

Selection of Site for Gas Turbine Power Plant

While selecting the site for gas turbine plant, following points must be considered in mind:

1. The plant should be near the load to avoid the transmission cost and losses.

2. Cheap and good quality fuel should be easily available.

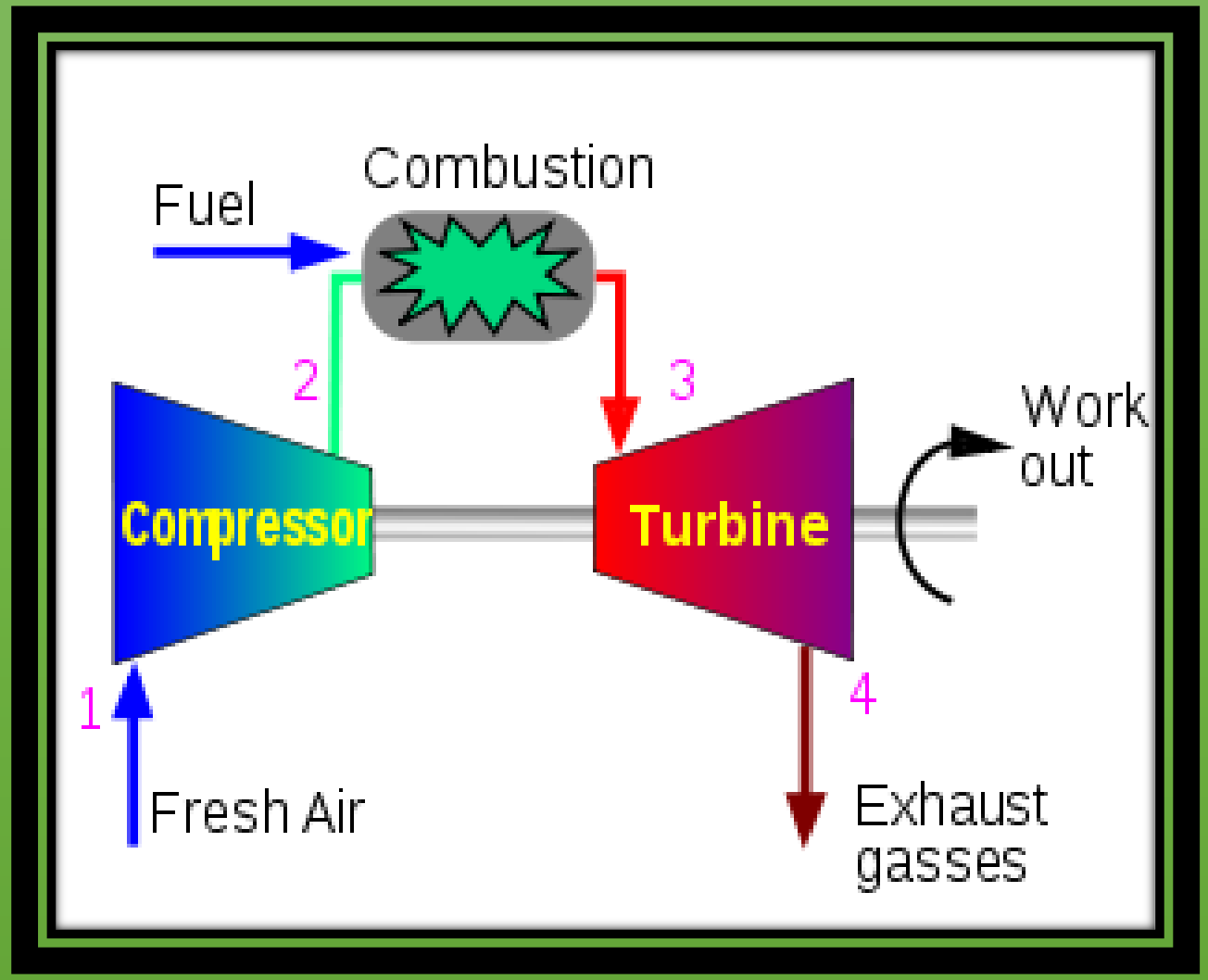
3. The plant should be away from the business and hospital centers due to its noisy operation.

4. The transportation facilities should be easily available.

5. Availability of labor should be easy and should be cheap in cost.

6. The land should be available at a cheap price.

7. The bearing capacity of the land should be high.


Fuel
Combustion
2
3
Work
out
Compressor
Turbine
1
4
Fresh Air
Exhaust
gasses

Diesel Electric Power Plants

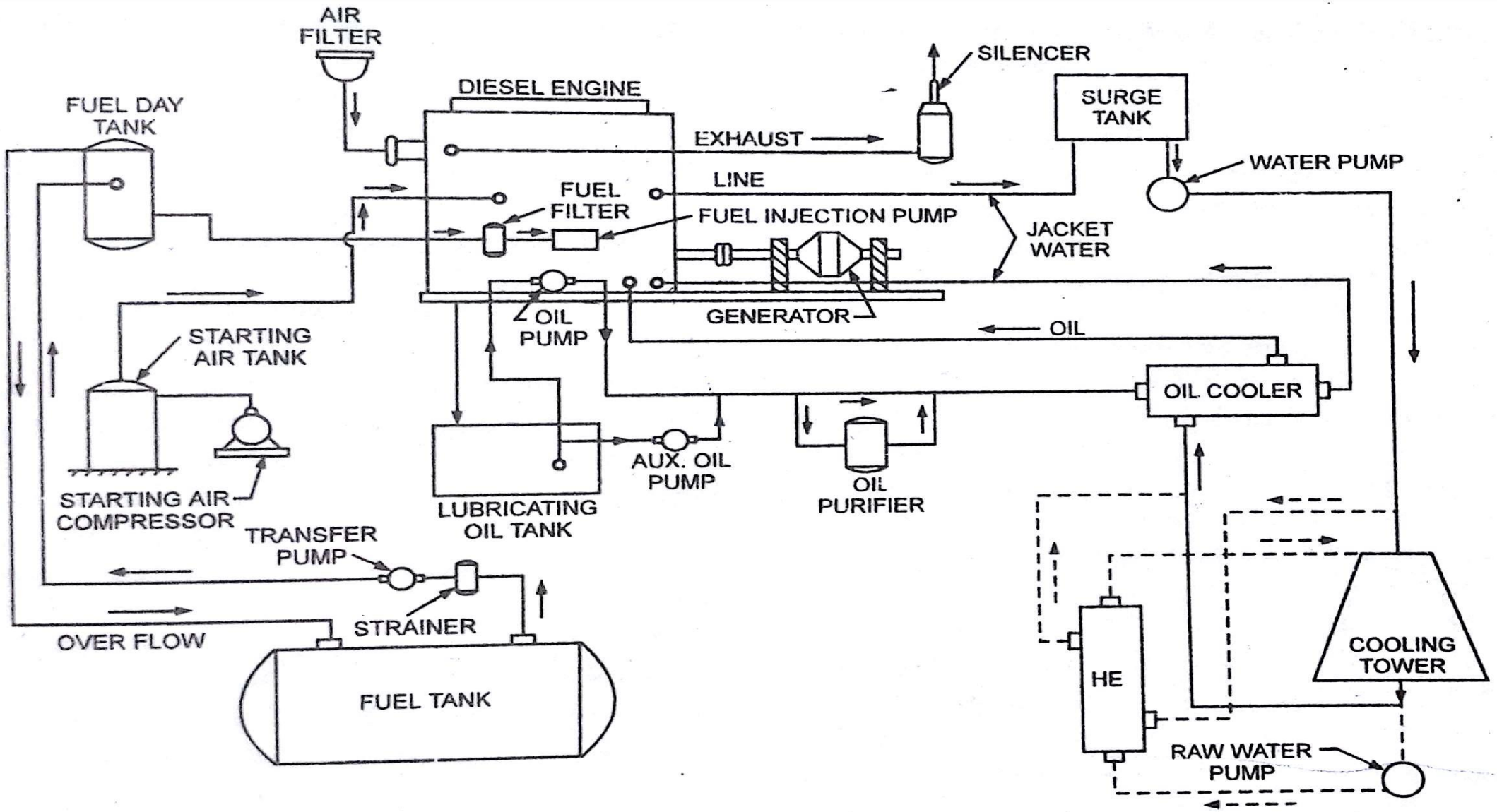
Diesel electric power plant is a power plant in which **a diesel engine** is used as **the prime mover** for **the generation of electric energy**.

These plants are installed *where supply of coal and water is not available in sufficient quantity or where power is to be generated in small quantity or where standby sets are required for continuity of supply* **such as in hospitals, telephone exchanges, radio stations and cinemas.**

Diesel engine obtains energy from a liquid fuel (diesel oil) and converts it into mechanical energy.

An alternator mechanically coupled to the diesel engine converts the **mechanical energy (ME)** into **electrical energy (EE)**.

Elements
of
Diesel Electric Power Plants


AIR FILTER
SILENCER
DIESEL ENGINE
FUEL DAY TANK
SURGE TANK
EXHAUST
LINE
WATER PUMP
FUEL FILTER
FUEL INJECTION PUMP
JACKET WATER
OIL PUMP
GENERATOR
OIL
STARTING AIR TANK
OIL COOLER
AUX. OIL PUMP
OIL PURIFIER
STARTING AIR COMPRESSOR
LUBRICATING OIL TANK
TRANSFER PUMP
STRAINER
OVER FLOW
HE
COOLING TOWER
FUEL TANK
RAW WATER PUMP

A diesel electric power plant comprises of engine and the auxiliary equipment as detailed below.

1. Air intake system.
2. Exhaust system.
3. Fuel system.
4. Cooling system.
5. Lubrication system.
6. Engine starting system.
7. Diesel engine alternator.

1. Diesel Engine:

This is the main component of the plant which develops the required power. The diesel engine used for diesel electric power plants may be 4 or 2 stroke engine.

2. Air Intake System:

Air intake system is provided to supply the necessary air to engine for fuel combustion. It includes **Air Filter** and **Supercharger.**

The *air filters*, are provided to removes the dust and other suspended impurities from the air to be supplied to the engine. The filters are to be cleaned periodically.

The *supercharger* is usually used to increase the pressure of the intake air above the atmospheric one in order to develop an increased power output. Superchargers are usually driven by the engine.

3. Exhaust System:

The purpose of this system is **to discharge the engine exhaust to the atmosphere outside the building.**

As the temperature of the exhaust gases is sufficiently high, therefore, the heat of these gases is **utilized in heating oil or air supplied to the engine.**

A **silencer** is usually incorporated in the system *to reduce the noise level*.

4. Fuel System:

This is consists of *Fuel Storage Tank, Fuel Transfer Pump, Strainers, Heaters,* and *Connection Pipe Work.*

Fuel Storage Tank: it is used to store the fuel which is usually situated outdoor for safety.

Fuel Transfer Pump: it is used to transfer the fuel from storage tank to daily consumption tank and then to engine.

Strainers: these are used remove suspended impurities and thus ensure clean fuel supply to engine.

Heaters: these are required to heat the oil especially during winter season.

5. Cooling System:

The extra heat, not used for doing useful work, has to be removed from the engine. Otherwise, this extra heat may disintegrate the lubricating oil film on the cylinder walls, piston and rings.

Small engines may be **air-cooled** but

large engines mostly **employed forced water cooling**.

6. Lubrication System:

High pressures and small clearance necessitate a good lubrication system for a diesel engine. The life of the engine and efficiency depend largely on the lubrication system. In addition to lubricating the moving parts, the lubricating oil removes heat from cylinder and bearings.

7. Engine Starting System:

Because of high compression pressures, even a small diesel engine in a power plant cannot be started by hand cranking. Compressed air system is mostly used for starting diesel engines in power plants.

8. Diesel Engine Alternator:

The alternator used in diesel electric power plants are of rotating field, salient pole construction, the number of poles varying from 6 to 28 , and capacities from 25 to 5000 kVA at 0.8 lagging. Generally they are rated at 440 V though larger machines may have a voltage rating of 2.2 kV. The alternator is directly coupled to engine.

Advantages & Disadvantages of Diesel Electric Power Plant

Advantages:

1. Very simple in operation.
2. Requires less space.
3. Simple in Design.
4. Installation is very simple.
5. Less standby losses .
6. It can be located at any place.
7. Quick in start.
8. Requires less quantity of water for cooling purpose.
9. Overall capital cost is lesser.
10. The cost of building and civil engineering works is low.
11. No problem of ash handling.
12. Less fire hazard.

Disadvantages:

1. Operating cost is high.
2. The operating cost is depending upon the cost of diesel cost.
3. Repair and maintenance costs are high.
4. Overload capacity is small.
5. They are more polluting.
6. Useful life is very short, only about 5 years.

Applications of Diesel Electric Power Plant

The applications of diesel power plants in the following fields:

1. Mobile plants.
2. Starting stations.
3. Emergency plants.
4. Nursery stations.
5. Peak load plants.
6. Central stations.
7. Standby units.

Selection of Site

for

Diesel Electric Power Plants

1. The site should be as near to the load center as possible in order to avoid the transmission costs and losses.
2. The land should be available at cheaper rate to keep the capital cost of plant to reasonable one.
3. The availability of the fuel should be easy and at cheap rate.
4. The availability of the water easy and in sufficient quantity for cooling purpose.
5. The site should be located away from the populated area because of noise and pollution.

NUCLEAR POWER PLANT

The power plant in *which nuclear energy is converted into electric energy* is called Nuclear Power Plant. **Nuclear power** is the fourth-largest source of electricity in India after thermal, hydro and renewable sources of electricity.

Nuclear Fuels:

The fuels mainly used are ;

1. Natural uranium (U-235)
2. Uranium (U-233)
3. Plutonium (Pu-239) and
4. Thorium-232 (Th-232)

Pu-239 & U-233 are not found in **nature** but **U-238 & Th-232** can be produce them by **nuclear reaction**.

The main atomic fuel used are uranium $_{92}U^{235}$ and $_{92}U^{238}$.

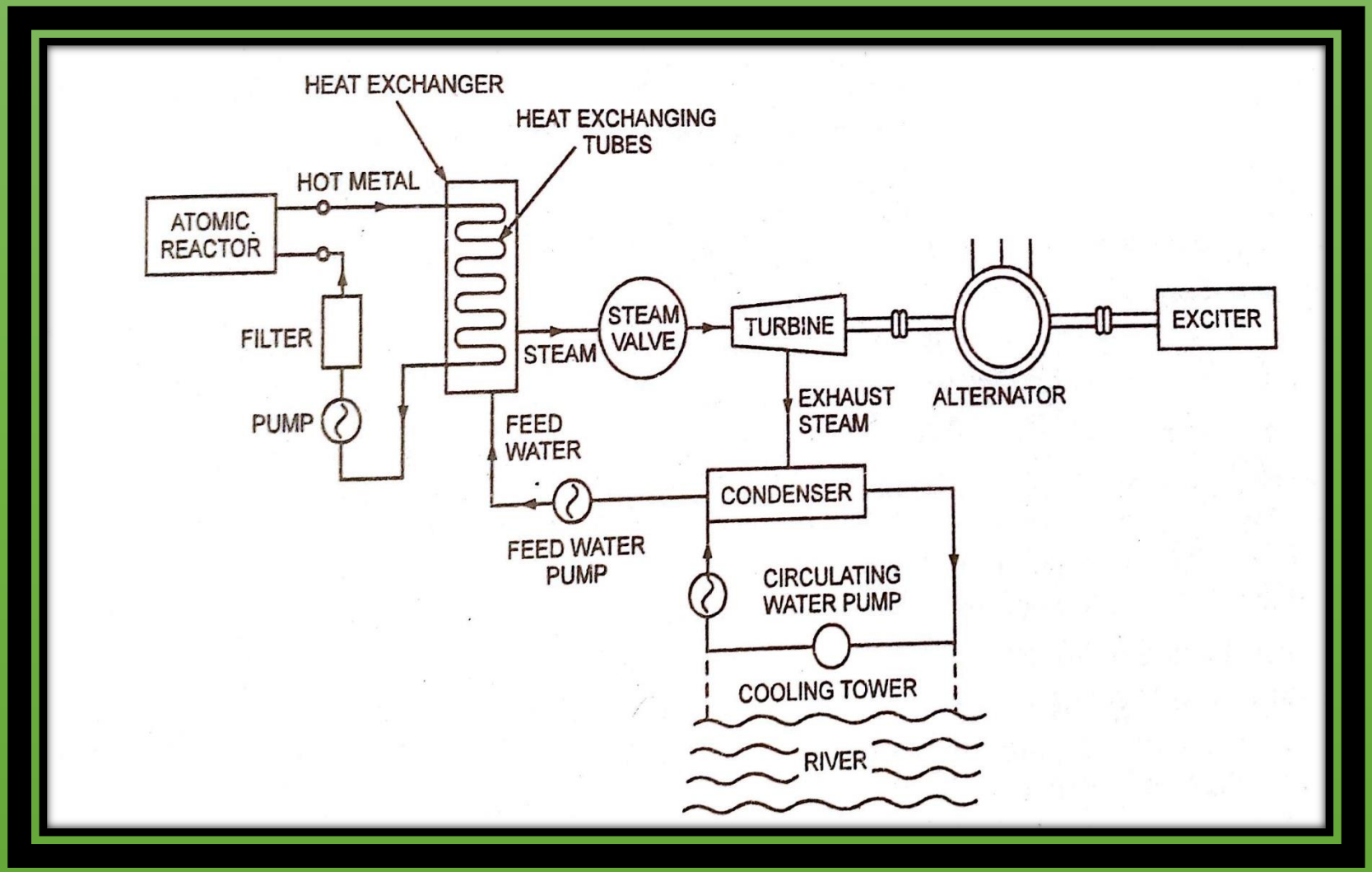
The natural uranium contains 99.23 % $_{92}U^{238}$ and less than 1% $_{92}U^{235}$. But, uranium $_{92}U^{235}$ mostly used, reason is being, when $_{92}U^{238}$ is struck by a loose neutron, it absorbs the neutron into **its nucleus** and **does not fission**. Thus, by absorbing loose neutrons, $_{92}U^{238}$can prevent a nuclear chain reaction from occurring.

Working of Nuclear Power Plant:

The concept of nuclear power plant generation are much similar to that of conventional steam power generation. The difference lies only in the steam generation part i.e coal or oil burning furnace and the boiler are replaced by nuclear reactor and heat exchanger.

Thus, it (nuclear power plant) consists of;

1. Nuclear Reactor
2. Heat Exchange
3. Steam Turbine
4. Alternator
5. Condenser


HEAT EXCHANGER
HEAT EXCHANGING TUBES
HOT METAL
ATOMIC REACTOR
FILTER
PUMP
STEAM
STEAM VALVE
TURBINE
EXCITER
ALTERNATOR
EXHAUST STEAM
FEED WATER
CONDENSER
FEED WATER PUMP
CIRCULATING WATER PUMP
COOLING TOWER
RIVER

The huge amount of heat energy produced in breaking of uranium by fission process in an atomic reactor is extracted by pumping fluid or molten metal like liquid sodium through the pipe.

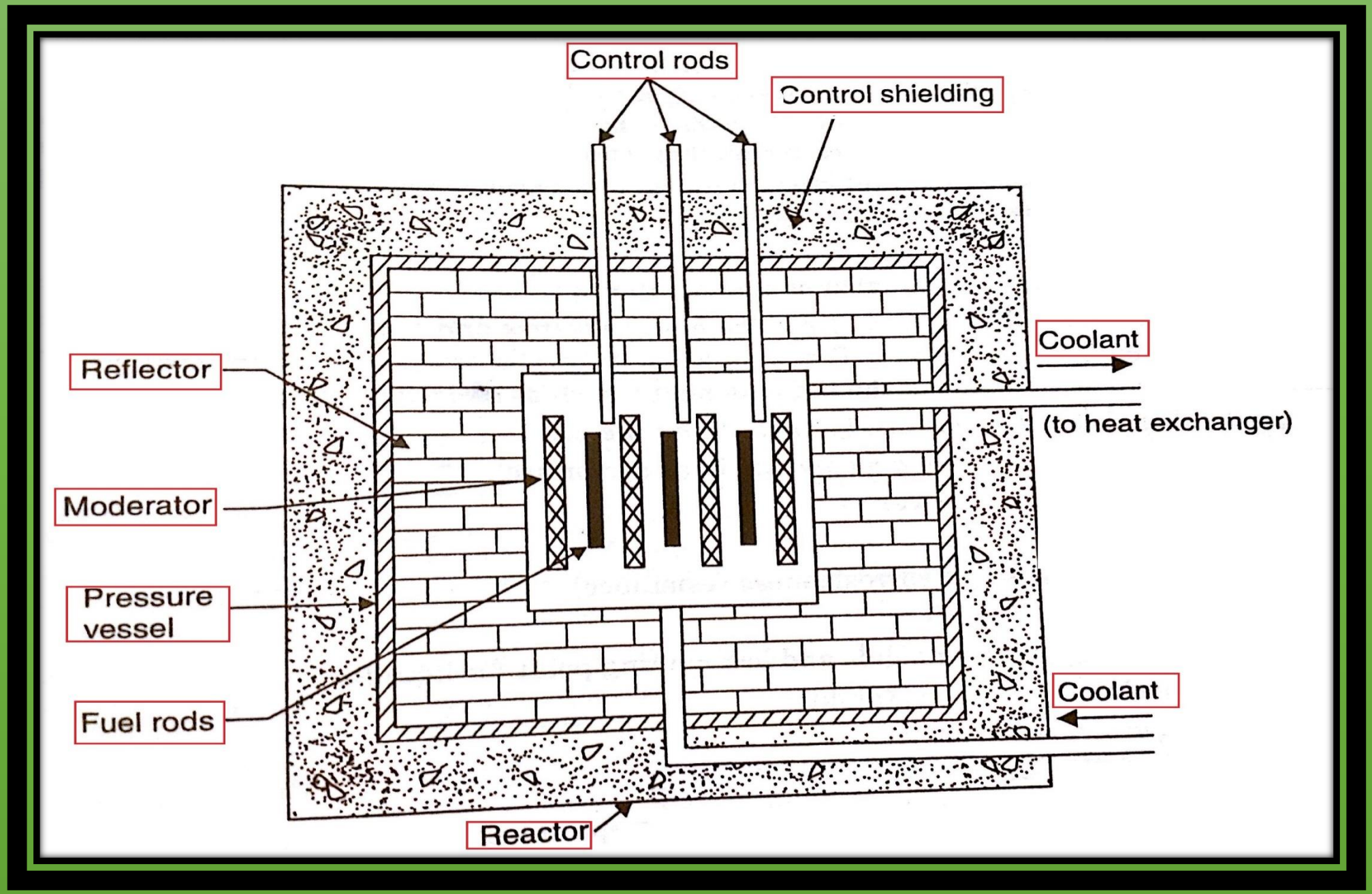
The heated metal is then allowed to exchange its heat to the heat exchanger by circulation.

In heat exchanger, the gas is heated or steam is generated which are utilized to drive the turbine which is coupled to an alternator, thereby, **electricity generated**.

Essential Components of a Nuclear Reactor

The essential components are as follows:

1. Reactor core
2. Reflector
3. Fuel rods
4. Control rods
5. Moderator
6. Coolant
7. Shielding.


Control rods
Control shielding
Coolant
(to heat exchanger)
Reflector
Moderator
Pressure vessel
Fuel rods
Coolant
Reactor

1. **Reactor Core:**

The reactor core is that part of a nuclear power plant where fission chain reaction is made to occur and where fission energy is liberated in the form of the heat for operating power conversion equipment.

It contains a number of fuel rods made of fissile material.

2. **Reflector:**

This is completely surround the reactor core to reflect back most of the neutrons that leak out from the surface of the core. It is generally made of the same material as the moderator. The reflector should have good neutron scattering property.

3. Fuel Rods:

The fissionable material used in the reactor called *fuel.* The fuel used is enriched uranium 235 (U235).

4. Control Rods:

To control the fission process, rods made of *Cadmium* or *Boron* are placed between the fuel rods (as show in fig.). Control rods absorb some of the slowed neutrons. These are inserted into the reactor core from the top of the reactor vessel.

These rods can be raised or lowered and control the fission process by absorbing neutrons. That is why they are called **control rods**.

If the rate of the chain reaction is to be increased, the control rods are moved out slightly so that they absorb less number of neutrons and vice-versa.

5. Moderator:

The functions of a moderator are:

- To reduce the neutron speeds to a value that increases the probability of fission occurrence.
- To slow down the neutrons but not absorb the.

The commonly used materials are:

1. H_2O
2. Heavy water (D_2O),
3. Helium Gas (He) and
4. Graphite.

As a moderator *Heavy Water* (D_2O) is the best material.

The good characteristics of a *moderator* are:

(a) It should be Non-corrosiveness.

(b) Slowing down power should be high.

(c) High thermal conductivity.

(d) Low parasite capture.

(e) Melting point for solids should be high.

(f) Melting point for liquid should be low.

(g) Stability to chemical and radiation should be high.

(h) Abundance in pure form.

6. Coolant:

The function of coolant is **to remove the intense heat produced in reactor and to bring out for being utilized.**

The liquid (coolant) cools down and is recycled again. This liquid is called **the coolant**.

The materials used as coolant are;

(1) Carbon dioxide (CO_2) (2) Liquid metal (3) Water and heavy water.

Usually **Heavy Water** is used as coolant so that it may also act as moderator.

The desirable characteristics for a Coolant are:

(a) It should be non-toxic.

(b) It should be non-corrosive and non-oxidizing.

(c) It should not absorb neutrons.

(d) It should have high chemical and radiation stability.

(e) It should have high boiling point.

(f) It should have low melting point.

(g) It should have low viscosity.

7. Shielding:

Shielding is necessary in order to:

(a) Protect the walls of the reactor vessel from radiation damage, and

(b) Protect operating personnel from exposure to radiation.

The entire reactor core is enclosed in heavy steel or concrete some called the *Shield*.

ECONOMICS

OF

GENERATION

The art of determining the per unit (i.e., one kWh) cost of production of electrical energy is known as **economics of power generation.**

Fixed cost. It is the cost which is independent of maximum demand and units generated. The fixed cost is due to the annual cost of central organization, interest on capital cost of land and salaries of high officials.

Running cost. It is the cost which depends only upon the number of units generated. The running cost is on account of annual cost of fuel, lubricating oil, maintenance, repairs and salaries of operating staff.

Demand factor:

It is the ratio of the sum of the maximum demand of a system (or part of a system) to the total connected load on the system (or part of the system) under consideration. Demand factor is always less than one.

Diversity factor:

It is the ratio of the sum of the individual maximum demands of the various subdivisions of a system (or part of a system) to the maximum demand of the whole system (or part of the system) under consideration. Diversity is usually more than one.

Load Factor: It is defined as the ratio of the average load over a given period to the maximum demand (peak load) occurring in that period. In other words, the load factor is the ratio of energy consumed in a given period of the times of hours to the peak load which has occurred during that particular period.

Load Curve: It is the graphical representation of load (in kW or MW) in proper time sequence and the time in hours. It shows the variation of load on the power station.

Power Factor :

The **Power Factor** is the ratio of the **active power** (kW) to the **apparent power** (kVA).

Causes Low Power Factor:

Low power factor usually is caused by inductive loads, such as:

1. Electric motors
2. Transformers
3. Arc welders
4. HVAC systems
5. Molding equipment
6. Presses
7. High-intensity discharge lighting

Base Load:

It is the level that it typically does not go below, that is, the basic amount of electricity that is always required.

Peak Load:

It is the daily fluctuation of electricity use. It is usually lowest in the wee hours of the morning and highest in the early evening. It also varies seasonally.

INTER-CONNECTION OF POWER STATION:

The interconnected grid increases the reliability of power system significantly. In case of failure of any generating station, the network (grid) will share the load of that generating plant. Increased reliability is the most significant advantage of a grid system.

The arrangement can exchange the peak load of a plant.

ADVANTAGES OF INTERCONNECTED POWER SYSTEM

1) Use of older plants

2) Economical operation

3) Increase reliability of power supply

4) Exchange of peak load

5) Increase diversity factor

6) Reduce plant reserve capacity

7) Reduce capital and operating cost:

CONCEPT 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**.

Regional Grid – The Regional grid is formed by interconnecting the different transmission system of a particular area through the transmission line.

National Grid – It is formed by interconnecting the different regional grid.

TRANSMISSION SYSTEMS

The purpose of the electric transmission system is the interconnection of the electric energy producing power plants or generating stations with the loads. A three-phase AC system is used for most transmission lines.

DEFINITION OF TRANSMISSION SYSTEM:

The transmission system is defined as the system that delivers bulk power from power stations to the load center and large industrial consumers.

LAYOUT OF ELECTRIC POWER SYSTEM

An electric power system having **three** essential components:

1.Power station (or Generating Station)

2.Transmission system.

(i) Primary transmission.

(ii) Secondary transmission.

3. Distribution system.

(a) Primary distribution.

(b) Secondary distribution.

ADVANTAGES & DISADVANTAGES OF HIGH VOLTAGE (H.V) FOR TRANSMISSION

ADVANTAGES

1. Lesser conductor material required.
2. Transmission efficiency is increased.
3. The voltage drop in the lines is low. This leads to better voltage regulation

DISADVANTAGES

1. The cost of insulating the conductor increases.
2. High towers.
3. Longer cross arm.
4. The cost of transformers, switchgears, and terminal apparatus increases.

COMPARISON

OF

BETWEEN DC & AC SYSTEMS

OF

TRANSMISSION

D.C. TRANSMISSION SYSTEM

The transmission of electric power by High Voltage D.C. system claim the following advantages over High Voltage A.C system.

Advantages:

1. It requires only two conductors for transmission purpose as compared to three conductors in a.c. system. Hence, much copper is saved.
2. There is no skin effect in d.c. system. Therefore, entire cross-section of the conductor is utilized.
3. There is no inductance, capacitance, phase displacement and surge problem in d.c. system.
4. Less corona losses.
5. Reduced interference with communication lines.
6. No stability problems and synchronizing difficulties.
7. Better voltage regulation.
8. No stabilizer is required for long distance.
9. Free from the dielectric losses.

Disadvantage:

1. The system is costly.
2. Converters require considerable reactive power.
3. Converters do not have overload capability.
4. Harmonics are generated which require filters.
5. The d.c. voltage cannot be generated at high d.c. voltage due to commutator problem.

A.C. TRANSMISSION SYSTEM

Now-a-day, high voltage a.c. transmission system (3-phase, 3-wire) is extensively used. A.C. high voltage transmission has the following advantages and disadvantages;

Advantages:

1. The power can be generated at high voltage.
2. The maintenance of the equipment is easy and cheaper.
3. The a.c. power can be stepped up and stepped down by means of transformer easily and efficiently as per requirement.

Disadvantages:

1. The construction of transmission lines is comparatively difficult.
2. The quantity of copper required is more.
3. Skin effect is more.
4. More corona losses.
5. The alternators need to be synchronized before they are put in parallel.

SELECTION OF CONDUCTORS (KELVIN`S LAW)

There are several factors in designing a line. Economy is also one of the considerations which are taken into account to select a conductor for a line. The cost of conductor material is substantial part of the total line cost. It is, therefore, necessary to choose economic size of conductor. A design is considered to be the most efficient if the total annual cost is a minimum.

KELVIN'S LAW

The cross section of a conductor is selected according to heating limits rather than voltage, as voltage drop in a feeder can be compensated using devices like shunt capacitors or boosters.

Kelvin's law gives the cross section of a feeder conductor,

Based on an economic balance between expenditure on structure (capital cost) and expenditure on operation (running cost).

The cost of the conductor and therefore, the standing charges, namely, the interest and depreciation on initial investment will be directly proportional to the area of cross-section of the conductor. The cost of energy loss will be inversely proportional to the conductor section.

LIMITATION OF KELVIN`S LAW

Followings are the limitation of Kelvin`s law:

1. Interest and depreciation of on the capital outlay cannot be calculated correctly.
2. The law does not take into account other important factors like current density, corona, losses etc.
3. The calculation from this formula gives such a small cross section of the cable that it may cause too much voltage drop and corona losses.
4. It is difficult to calculate energy losses in the line, without the load curve which is not available.
5. The Kelvin’s law gives high current density, which cause excess heating.

LINE SUPPORTS

The line supports (i.e. poles and tower) used for transmission and distribution of electric power should have the following **characteristics**:

- Cheaper in cost.
- High mechanical strength.
- Light in weight.
- Longer life.
- Good looking.
- Low maintenance cost.
- Easily accessible for erection of line conductors, painting etc.

The line supports may be:

1. Wooden Poles
2. Steel Poles
3. R.C.C. poles
4. Steel Towers

LINE INSULATORS

- These insulators provide insulation of high voltage wire with the metal structure and also provide support to the conductor.

The line insulators should posses the following properties:

a) High mechanical strength
b) High insulation resistance
c) High relative permittivity
d) High ratio of rupture strength to flash-over voltage.
e) The insulating material used should not be porous

TYPES OF INSULATORS

Various types of insulators used in for transmission and distribution lines are described below:

1. Pin type insulators.
2. Suspension type insulators.
3. Strain type insulators.
4. Shackle insulators.
5. Stay or Egg insulators.

CAUSES OF FAILURE OF INSULATORS

The following are the causes of failure of insulators:

1. Mechanical stresses
2. Porosity of material
3. Cracking of insulator
4. Improper verification
5. Short circuits
6. Flash-over
7. Dust deposition

POWER FACTOR: The **Power Factor** is the ratio of the active power P (kW) to the apparent power S (kVA)

Disadvantages of Low Power Factor

These are the main disadvantages of Low Power Factor in our electrical system.

1. Large kVA rating and size of Electrical equipment
2. Greater conductor size and cost of transmission line
3. High Transmission loss hence poor efficiency
4. Poor Voltage regulation
5. Penalty from power supply company

CAUSES OF LOW POWER FACTOR

The main causes for the low power factor are because of the inductive load. In the case of inductive load, the current lag behind the voltage. Therefore power factor becomes lagging nature.

1. INDUCTIVE LOAD

Low power factor usually is caused by inductive loads, such as:

(a) Electric motors (b) Transformers (c) Arc welders (d) HVAC systems (e) Moulding equipment (f) Presses (g) High-intensity discharge lighting

2. VARIATIONS IN POWER SYSTEM LOADING

3. HARMONIC CURRENT