UNIT-I Generation of electric power

Non-Conventional Sources:- The sources of energy that are been used for the new. which can be renewable.

Ex:- Solar energy, wind energy, tidal energy.

Conventional sources:- The source of energy which cannot be renewable.

Ex:- Coal, petroleum.

Difference b/w Convential and non-convential sources.

Convential energy sources	Non-convential energy sources
The source of energy that are being used for the many years and are easily available in nature.	Non-conventional energy sources are the source of energy which are new. and used as an alternative of conventional energy.
Conventional sources are non renewable sources.	They are renewable sources.
These sources causes pollution.	These sources are pollution free.
They present in limited quantity in nature.	They are present ~~in absence~~ in nature & being regenera[ted in] short time.

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Generation of Electric Power :- 20-04-23

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They present in limited quantity in nature.	They are present in absence in nature & being regenerated in short time.

They are expensive.	They are relatively less expensive.
Ex:- coal, petroleum, gas, fire & other fossil fuels etc.	Ex:- sun, wind, biogas, biomass etc.

Solar Energy:-

* The heat energy received by earth in the form of radiation is known as solar energy.
* It can be collected by using solar devices such as solar collectors.
* The solar energy is used to generate the electricity with the help of solar panels.

Advantages:-

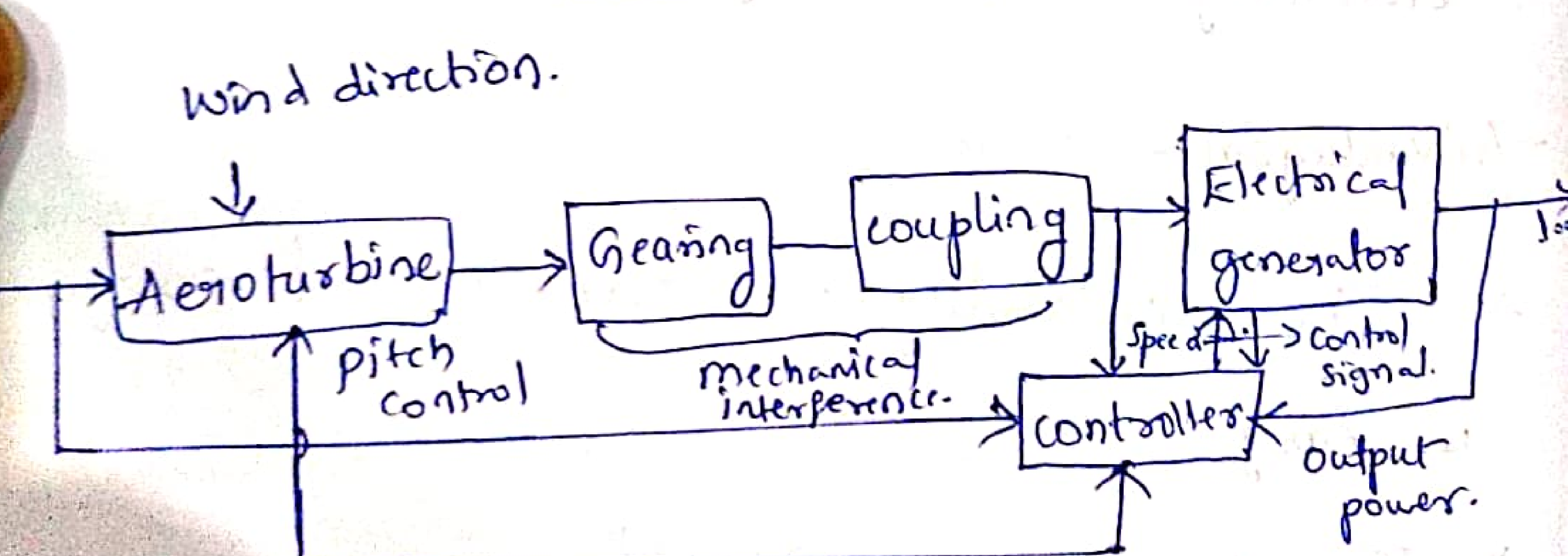
* The availability of solar thermal energy is easy.
* The solar energy can reused.
* This solar energy doesn't cause pollution and it is eco-friendly.

- The installation of (energy) solar panels is easy.

Disadvantages -

- They require more space & large area.
- The solar thermal energy is completly dependent on climate.
- The time taken for the process may be more compared to other forms of energy.
- The solar panel are used in the solar thermal plant should be cleaned at regular intervals.

Wind energy :-



Energy Generation from wind power.

* The energy generated from high velocity winds is known as wind energy.
* And it is renewable source of energy.
* The main function of Aeroturbine is used to convert wind energy to mechanical energy.
* The rotary mechanical energy generated by Aeroturbine is transmitted to an electrical generator with the help of gearing and coupling.
* The output of generator is connected to load or power grid as per our requirements.
* The location where wind is in one direction of turbine and is designed in such a way that orientation of rotor is fixed and the area is perpendicular to predominat wind direction.
* The function of controller is to sense wind speed & wind direction. It also detects output & the temperature of generator.

Advantages:-

1. Wind Power plants consumes less time for its construction.

2. It is non-polluting power station. Thereby no adverse effect on environment.

3. There is no requirement of fuel.

Disadvantages:-

1. This system is noisy in operation.

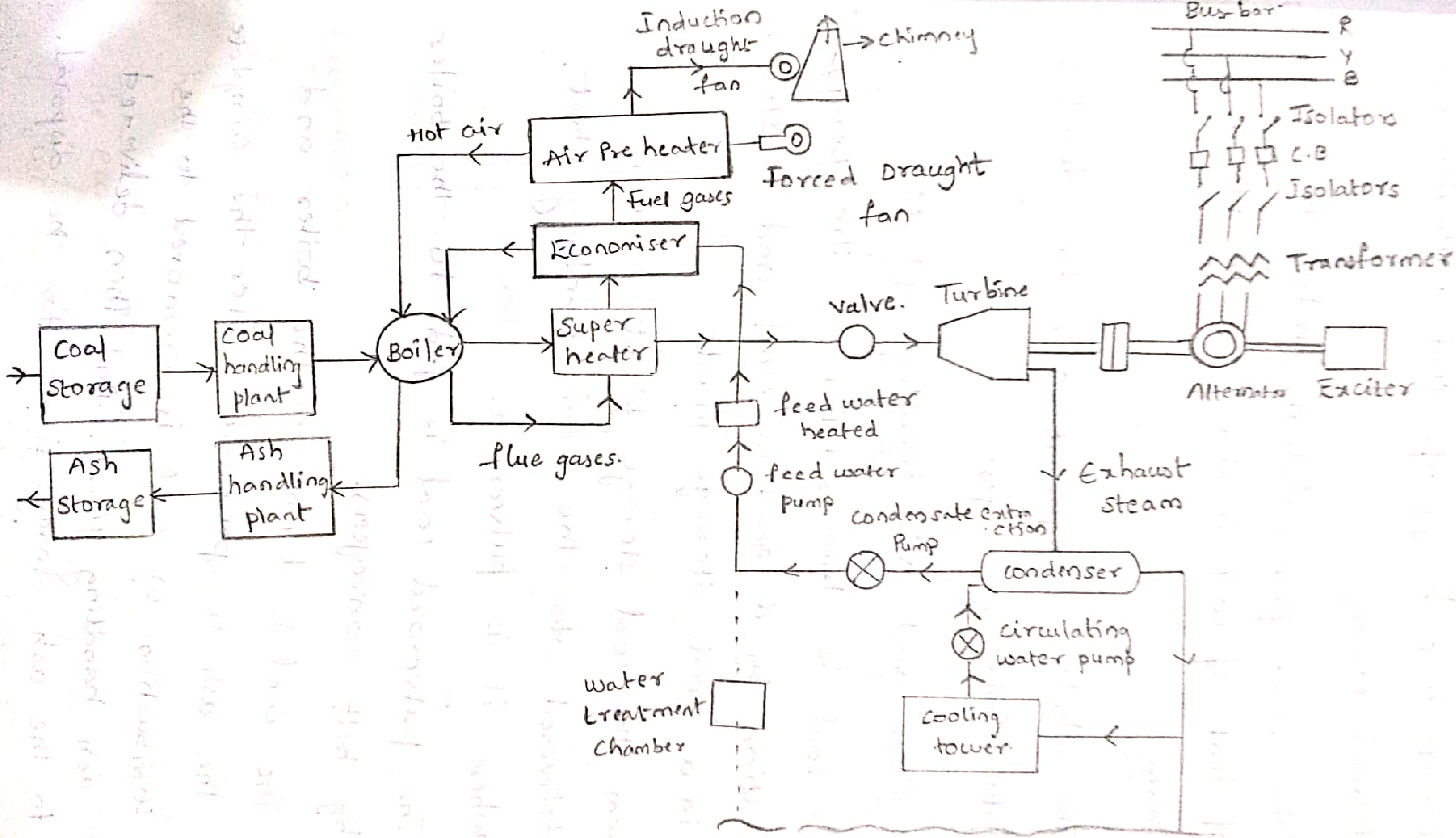
2. It involves very high initial cost.

3. This system produces limited amount of power.

2. And it

Conventional Energy Sources

1. Steam Power station.



Schematic Arrangement of Steam Power Plant.

* The generating power station which converts heat energy of coal combustion into electrical energy.

* The steam power station involves the conversion of heat of coal combustion into electrical energy.

* The whole arrangement can be divided into following stages:-

1- Coal and Ash handling plant:-

* The coal is transportated to the power station by a road or rail and is stored in a coal storage plant.

* From the coal storage plant coal is delivered to the coal handling plant, where it is pulverised.

* The pulverized coal is fed to the boiler by belt conveyers.

* The coal is burnt in the boiler and the ash is produced after the complete combustion of coal is removed to the ash handling plant. And Then delivered to the ash storage plant for the disposal.

2. Steam generating plant:-

* The steam generating plant consists of boiler for the production of steam & other auxiliary equipment for the utilizatio of flue gases.

Boiler:-

The heat of combution of coal in the boiler is utilized to convert the water into steam at high temperature & pressure.

Super heater:-

* The steam produced in the boiler is wet and is passed through a superheater where it is dried & superheated.

* The superheated steam is fed to steam turbine through the valve.

Economiser:-

* An economiser is essentially feed water heater and drives heat from flue gases.

* The economiser extracted a part of heat of flue gases to increase the temperature of

feed water.

Air pre-heater-

An air pre-heater increases the temperature of air supplied for coal burning by driving heat from flue gases. (And also) This increases the thermal efficiency & also increases steam capacity.

Steam Turbine:-

The dry and super heated steam from the superheater is fed to the steam turbine, when passing through the turbine gets converted into mechanical energy.

Alternator-

The steam turbine is coupled to an alternator. The alternator then converts mechanical energy of turbine into electrical energy. And then the output from the alternator is delivered to bus-bars through T/F, C.B and Isolators.

Feed water:-

The water from the condenser is used as feed water to the boiler.

The feed water on its way to the boiler is heated by water heaters & economiser.

Cooling arrangement:-

Water is drawn from natural source of supply such as rivers, canals. & is circulated through condenser.

The circulating water takes up the heat of exhausted steam and itself becomes hot.

This hot water coming out from the condenser is discharged down to the river.

In case the availability of water from the source of supply is not assured through out the heat, cooling tower are used.

The cold water from the cooling tower is reused in the condenser

Advantages:-

- The fuel used is quite cheap.
- Less initial cost compared to other generating stations.
- It can be installed at any place irrespective of existence of coal.
- The coal can be transported to the site (of) by rail or road.
- It requires less space

Disadvantages-

1. It pollutes the atmosphere due to the production of large amount of smoke & fumes.
2. It is costlier in the running cost as compared to hydro electric plant.

Efficiencies of Steam Power Station :-

Thermal efficiency :- (η_{ther}) :- The ratio of heat equivalent of mechanical energy transmitted to the turbine shaft to the heat of combustion of coal. is known as thermal efficiency of steam power station.

Thermal efficiency (η_{ther}) =

$$100 \times \frac{\text{Heat equivalent to mechanical energy transmitted to turbine}}{\text{Heat of coal combustion}}$$

$= 30\%$.

The thermal efficiency of steam power station is about 30%.

Overall Efficiency :- ($\eta_{overall}$) :-

The ratio of heat equivalent of electrical output to the heat of combustion of coal is known as overall efficiency of steam power station.

$$\eta_{overall} = \frac{\text{heat equivalent of electrical o/p}}{\text{Heat of combustion of coal}} \times 100$$

$= 29\%$

The overall efficiency of steam power station is about 29%.

Overall efficiency is equal to thermal efficiency x (into) electrical efficiency.

In order to achieve overall economy, the following points should be considered while selecting a site for a steam power station.

(i) Supply of fuel :- The steam power station should be located near the coal mines so that transportation cost of fuel is minimum. However, if such a plant is to be installed at a place where coal is not available, then care should be taken that adequate facilities exist for the transportation of coal.

(ii) Availability of water :- As huge amount of water is required for the condenser, therefore, such a plant should be located at the bank of a river or near a canal to ensure the continuous supply of water.

(iii) Transportation facilities :- A modern steam power station often requires the transportation of material & machinery. Therefore, adequate transportation facilities must exist i.e., the plant should be well connected to other parts of the country by rail, road etc.

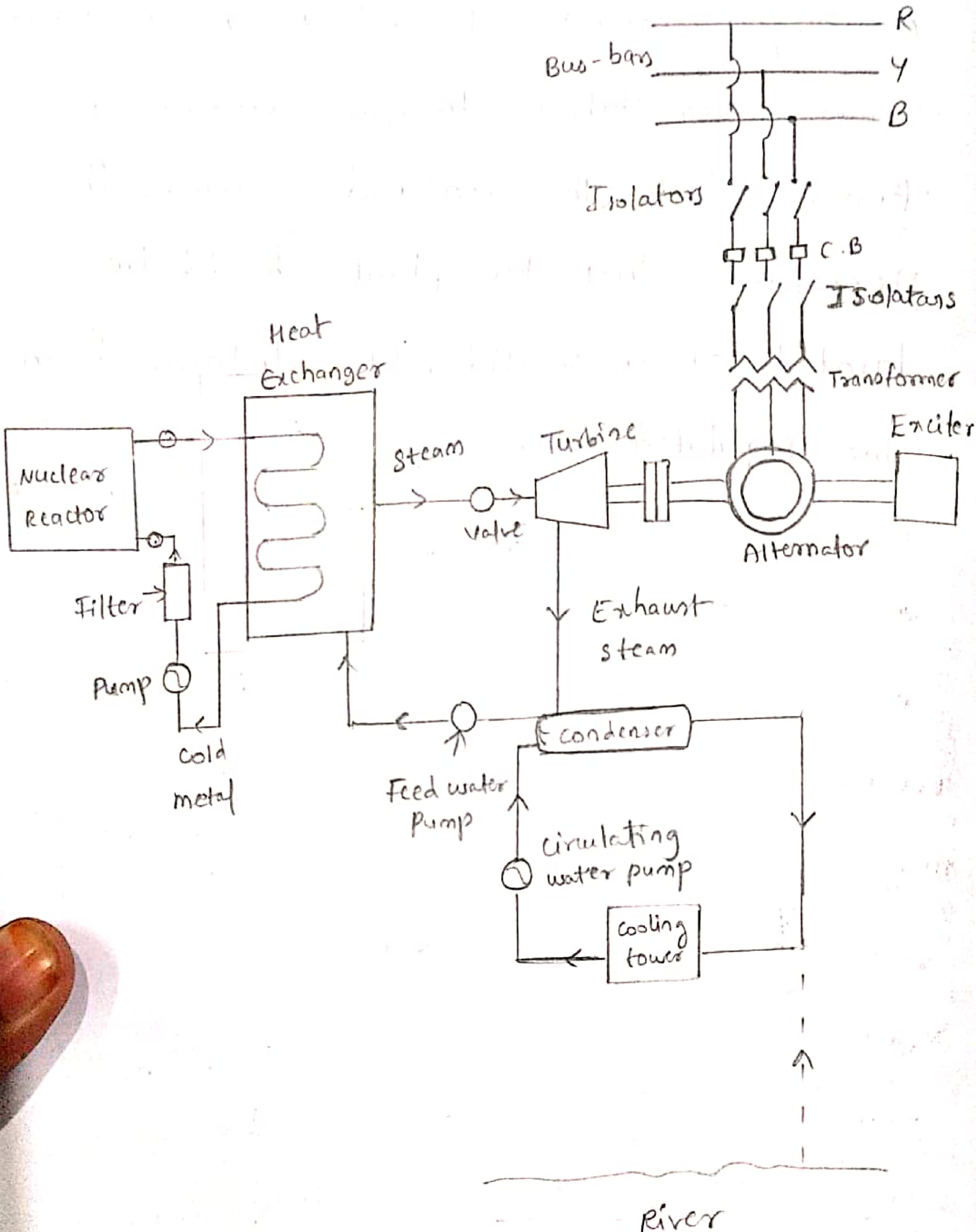
(iv) Cost & type of land :- The steam power station should be located at a place where land is cheap & further extension, if neccessary, is possible. Moreover, the bearing capacity of the ground should be adequate so that heavy equipment could be installed.

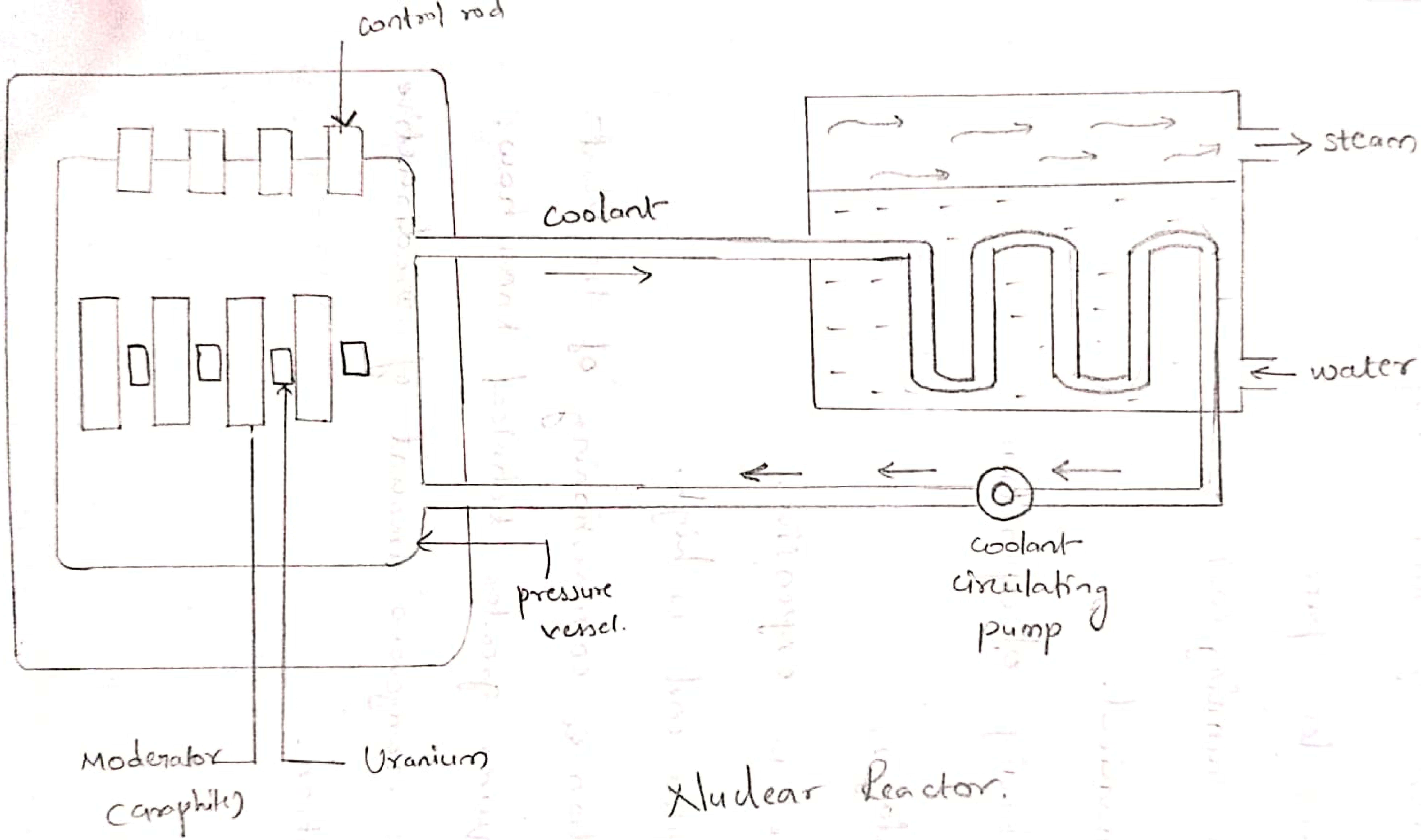
(v) Nearness to load centres :- In order to reduce the transmission cost, the plant should be located near the centre of the load. This is particularly important if d.c. supply system is adopted. However, if a.c. supply system is adopted, this factor becomes relatively less important. It is because a.c. power can be transmitted at high voltages with consequent reduced transmission cost. Therefore, it is possible to install the plant away from the load centres, provided other conditions are favourable.

(vi) Distance from populated area:-

As huge amount of coal is burnt in a 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 areas.

Schematic Arrangement of Nuclear Power station:-





Nuclear Reactor.

Advantages:-

1. Amount of fuel required is quite small. Therefore, there is a considerable saving in the cost of fuel transportation.

2. Requires less space.

3. low running cost.

4. Economical.

5. Reliability of operation.

Disadvantages:-

1. fuel is expensive.

2. Capital cost is high.

3. erection & commissioning of the plant requires greater technical know-how.

4. Causes dangerous amount of radioactive pollution.

Nuclear power Station :-

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

In nuclear power station heavy elements such as (U^{235}, Uranium or thorium (Th_{232}) are subjected to nuclear fission in a special apparatus is known as reactor.

The schematic arrangement of nuclear power station is shown in figure 1.

The whole arrangement can be divided into following stages

1. **Nuclear reactor :-**

The nuclear reactor is a cylindrical pressure vessel and houses fuel rods, moderator and control rods.

The fuel rod constitute fission material and release huge amount of energy when bombarded with slow moving neutrons.

The moderator consists of graphite rods which enclose fuel rods and control rods which is strong absorber and regulates the supply of neutrons for fission.

Most of these fission neutrons causes fission and few are available for chain reaction.

[Nuclear fission is done by Bombarding uranium nuclie with slow moving neutrons.] (will increases) Hence intensity of chain reaction.

By pulling out the control rods the power of nuclear reactor is increased. whereas by pushing them in it is reduced.

The heat produced in reactor is removed by coolant.

The coolant carries the heat to heat exchanger.

2. 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 reactor.

3. Steam turbine :-

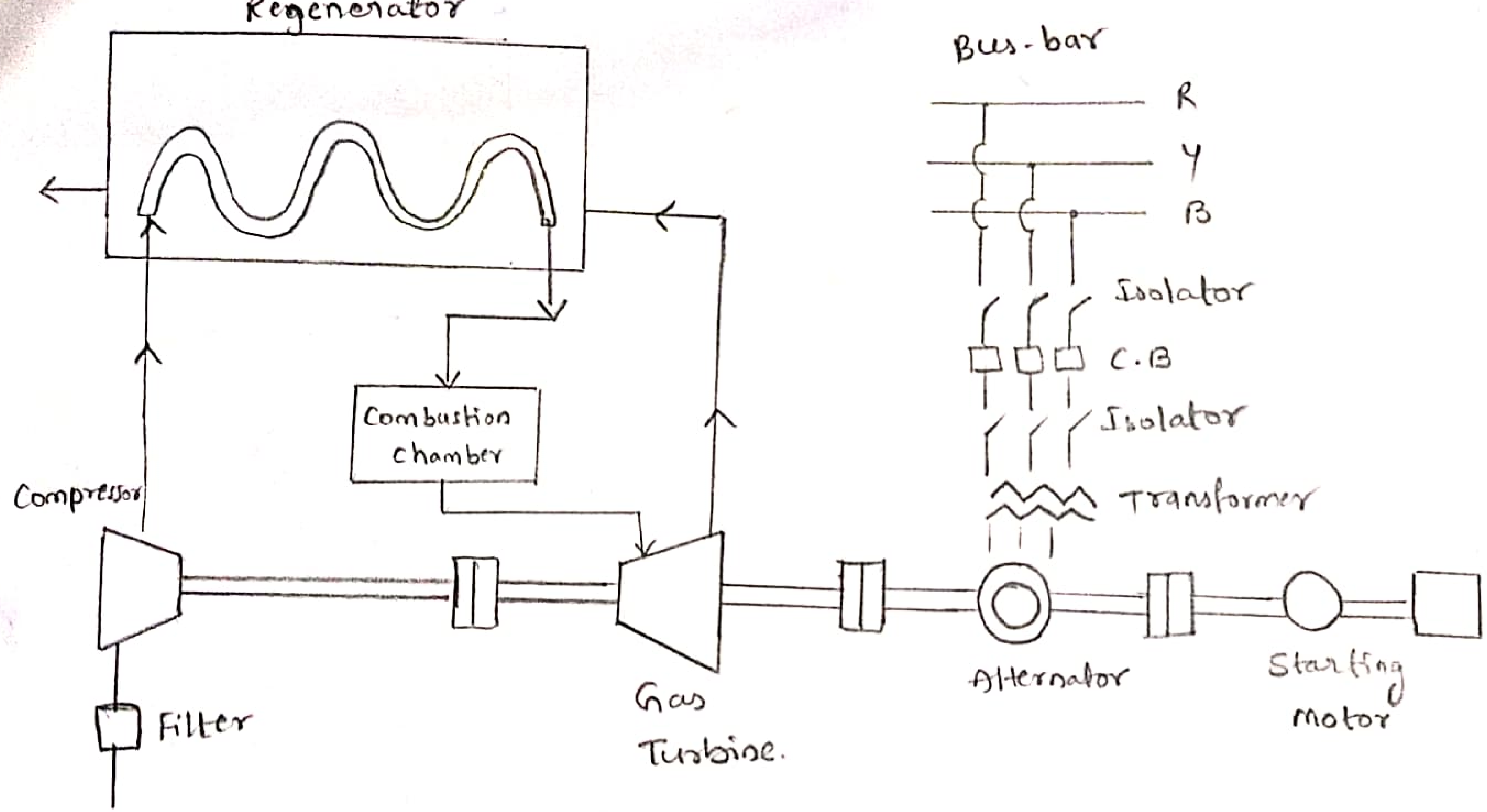
The steam produced in the heat exchanger is fed to steam turbine through a valve.

After doing a useful work in the turbine the steam is exhausted to condenser.

4. Alternator:-

The steam turbine drives the alternator which converts mechanical energy into electrical energy. The output from the alternator is delivered to bus-bars through transformer, Isolator & circuit Breaker.

Gas Turbine Power plant



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

In a gas turbine power plant air is used as working fluid, where it is compressed by compressor and is led to the (compressed air) combustion chamber, where heat is added to air by raising its temperature.

Heat is added to compressed air either by burning fuel in the chamber or by the use of air-heaters.

And the high pressure air is passed to the gas turbine where it expands and does mechanical work.

The gas turbine drives the alternator which converts mechanical energy to electrical energy.

The main components of the gas turbine power plant are :-

1. Compressor
2. Regenerator
3. Combustion chamber
4. Gas turbine
5. Alternator
6. Starting motor

1. Compressor-

The compressor used in the plant is rotatary type, the air at atmospheric pressure is drawn by the compressor via filter which removes the dust from the air. The rotatary blades of the compressor push the air between stationary blades to raise its pressure. Thus the pressure of the air increased.

2. **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 nest of tubes in a shell. The compressed air from the compressor passes through the tubes on its way to combustion chamber.

In this way, compressed air is heated by the hot exhaust gases.

3. **Combustion Chamber:-**

The air at high pressure from the compressor is led to the combustion chamber via regenerator. In this chamber heat is added to the air by burning oil. The result is that the chamber attains a very high temperature about 3000°F.

4. Gas turbine :-

The products of combustion consisting of a mixture of gases at high temperature & pressure are passed to gas turbine. These gases in passing over the turbine blades expands and thus do mechanical work. The temperature of the exhaust gases from the turbine is 900°F.

5. Alternator :-

The gas turbine is coupled to the alternator which converts mechanical energy of the turbine into electrical energy. The output of the alternator is given to bus-bars through Transformers, C.B, Isolators

6. Starting Motor -

Before starting the turbine compressor has to started. For this purpose an electric motor is mounted on the same shaft as that of turbine.

The motor is energized by the batteries. Ones the unit starts a part of mechanical power of the turbine drives the compressor & there is no need of motor now.

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Advantages –

- It is simple in design as compared to steam power station since no boilers are required.
- It requires comparatively less water as no condenser is used.
- The maintains charges are quite small.
- The initial & operating costs are much lower than that of steam power station.
- Gas turbines are much simpler in construction and operation than steam turbines.

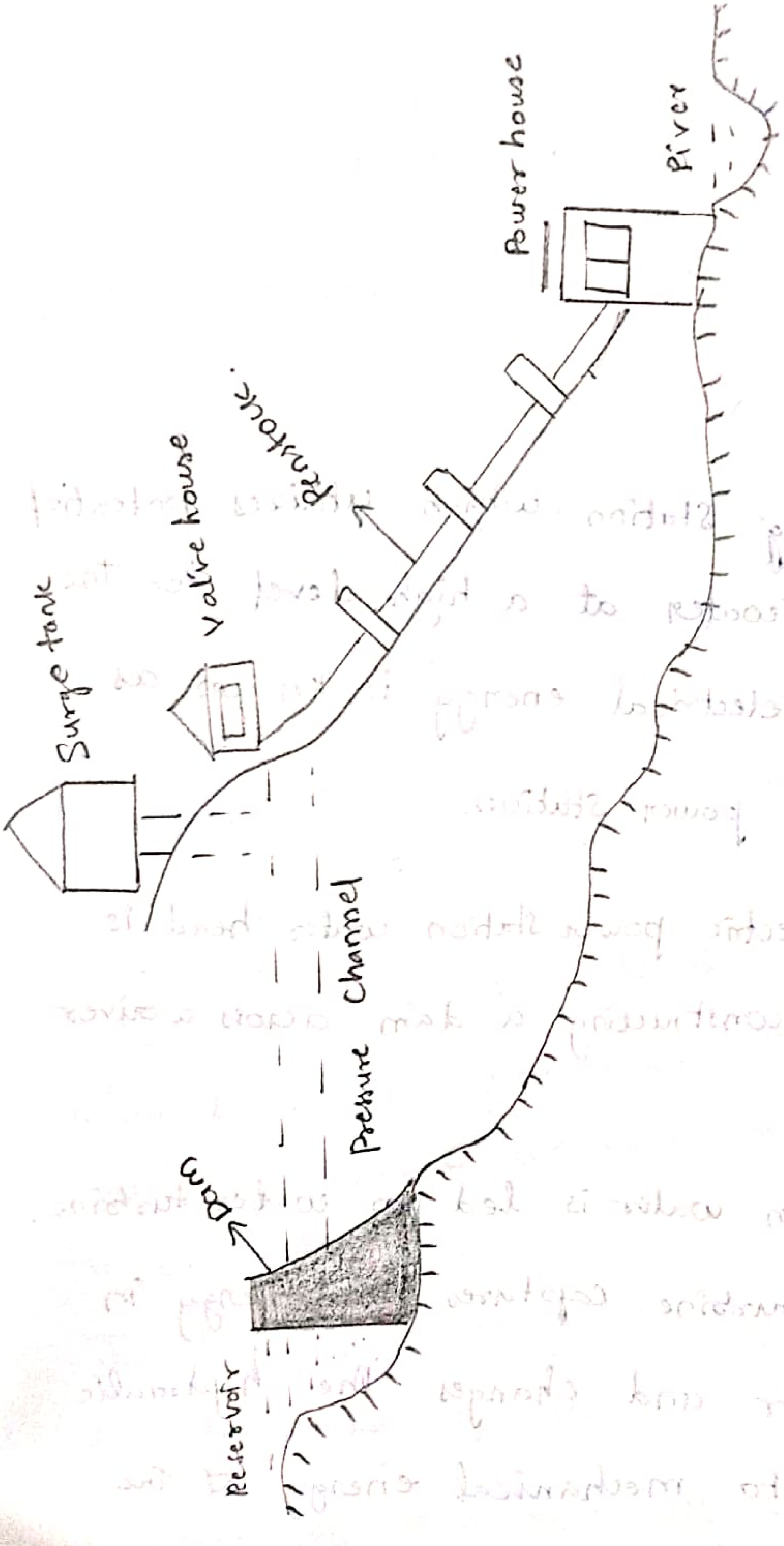
Disadvantages –

- The overall efficiency of such plants is low (about 20%) because the exhaust gases from the turbine contain sufficient heat.
- The temperature of combustion chamber is quite high so that its life is comparetively reduced.

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

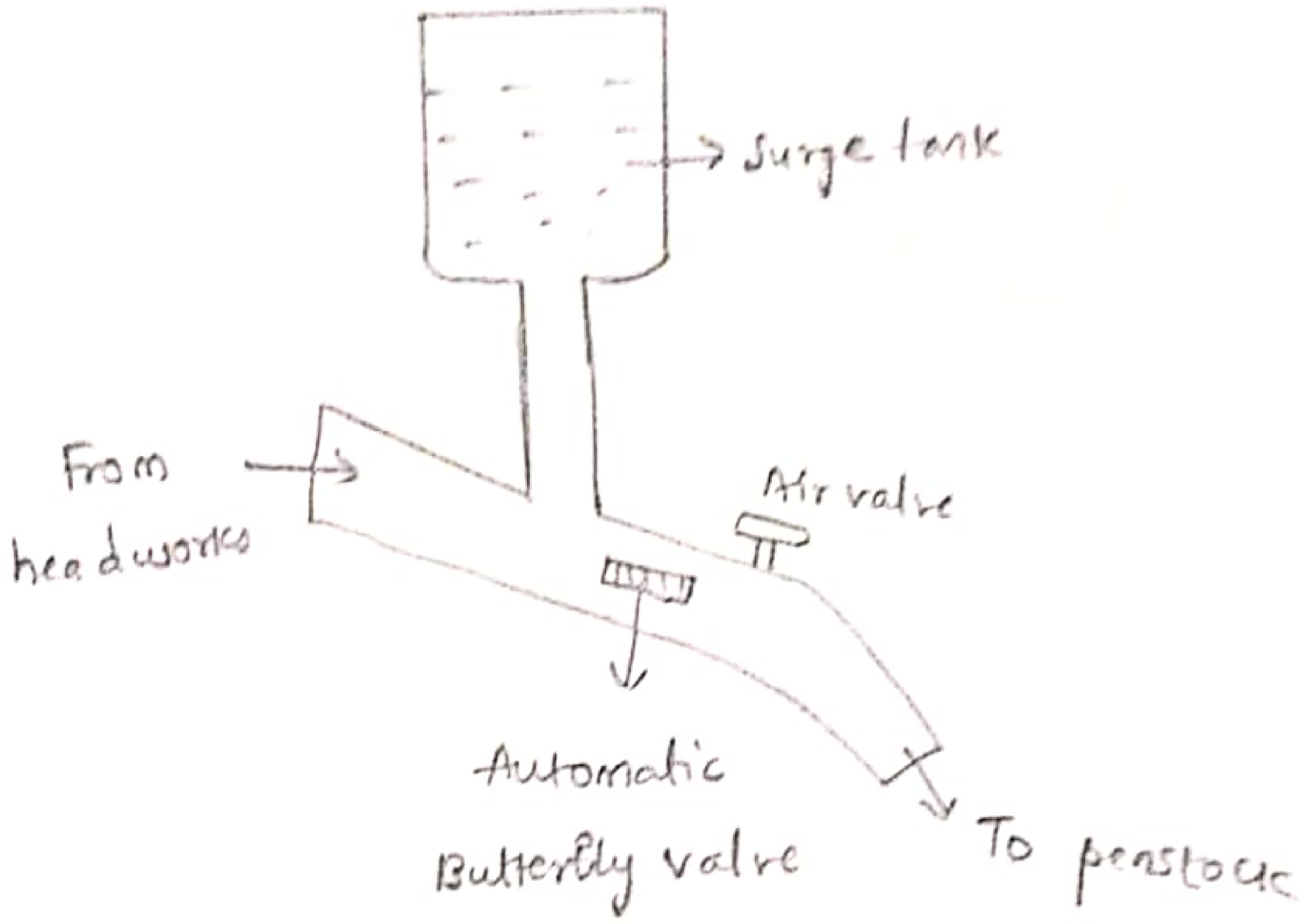
* There is no problem for starting the unit it is because before starting the turbine, the compressor has to be operated for which power is required from some external source.

Hydro Electric Power Plant:-



Hydro Electric Power Plant :-

Various penstock protective devices



A generating station which utilizes potential energy of water at a high level for the generation of electrical energy is known as hydro electric power station.

In hydro electric power station water head is created by constructing a dam across a river or lake.

From the dam water is led to water turbine.

The water turbine captures the energy in falling water and changes the hydraulic energy into mechanical energy at the turbine shaft.

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

Constituents of hydro electric plant :-

The constituents of hydro electric power plant are

1. Hydraulic structures 2. water turbines

& 3. electrical equipments

1. Hydraulic structures :- (in hydro)

Hydraulic structures in hydro electric plant (in an hydro) includes dam, spill ways, headworks, surge tank, penstock and other accessory works.

1- **Dam** :- A dam is a barrier which stores water & creates water head. The dams are built of concrete or stone masonary, earth & rock fill.

The type and arrangment depends upon the topography of site.

A masonary may be built in narrow canyon and earth dam is suited for wide valley.

The type of dam depends upon foundation conditions, local material & transportation available & other hazards.

At most of sites more than one type of dam may be suitable and the one which is most economical is choosen.

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2. <u>Spill ways</u>:-

There are times where river flow water exceeds the storage capacity of the reservoir such a situation arises during heavy rainfall in the catchment area.

In order to discharge the water from the storage reserviour into the river on the downstream side of the dam, spill ways are used.

3. <u>Head works</u>:-

The head work consists of the divertion structures at the head of an intake, they generally include booms ands racks for diverting floating debries, sluices for bypassing debris & sediments & valves for controlling the flow of water to the turbine.

The flow of water into an through head works should be as smooth as possible to avoid head loss.

4. Surge tank:-

A surge tank is a small reservoir (or) tank in which water level rises (or) falls to reduce the pressure swings in the conduit.

It is located near the begging of the conduit. When the turbine is running at a steady load, there are no surges in the flow of water through the conduit i.e. the quantity of water flowing in the conduit is just sufficient to meet the turbine requirements.

However when the load on the turbine decreases, the governer closes the gates of turbine, reducing water supply to the turbine.

The excess water at the lower end of the conduit rushes back to the Surge tank and increases its water level. Thus, the conduit is prevented from bursting On the other hand when the load on the turbine increases additional water is drawn from the surge tank to increase load requirement. Hence a surge tank overcomes the abnormal pressure in the conduit when the load on the turbine falls & acts as reservoir during increase of load on the turbine.

5- <u>Penstock</u> :-

Penstocks are open or closed conduits which carry water to the turbine. They are generally made of reinforced concrete or steel, The concrete penstocks are suitable for low heads as greater pressure causes rapid deterioration of concrete. The steel penstock can be designed for

The force of water jet strikes the buckets on the wheel drives the turbine.

The quantity of water falling on the turbine is controlled by needle placed in the tip of nozzle.

The movement of needle is controlled by governor. If the load on the turbine decreases the governor pushes the needle into nozzle. Thereby reducing the quantity of water.

2 <u>Reaction Turbine</u> :- Reaction turbines are used for low and medium heads. In a reaction turbine, water enters the runner partly with pressure energy & partly with velocity head. The important types of reaction turbines are francis turbine & kaplan turbines.

Francis turbine is used for low to medium heads. It consists of outer ring of stationary guide blades fixed to the turbine casing & inner ring of rotating blades.

any head, the thickness of the penstock increases with head or running pressure.

when the water runs out of penstock faster than it enters, a vaccum is created which may cause the penstock to collapse. Under such situation air valve opens and admits air in the penstock to maintain inside air pressure equal to the outside air pressure.

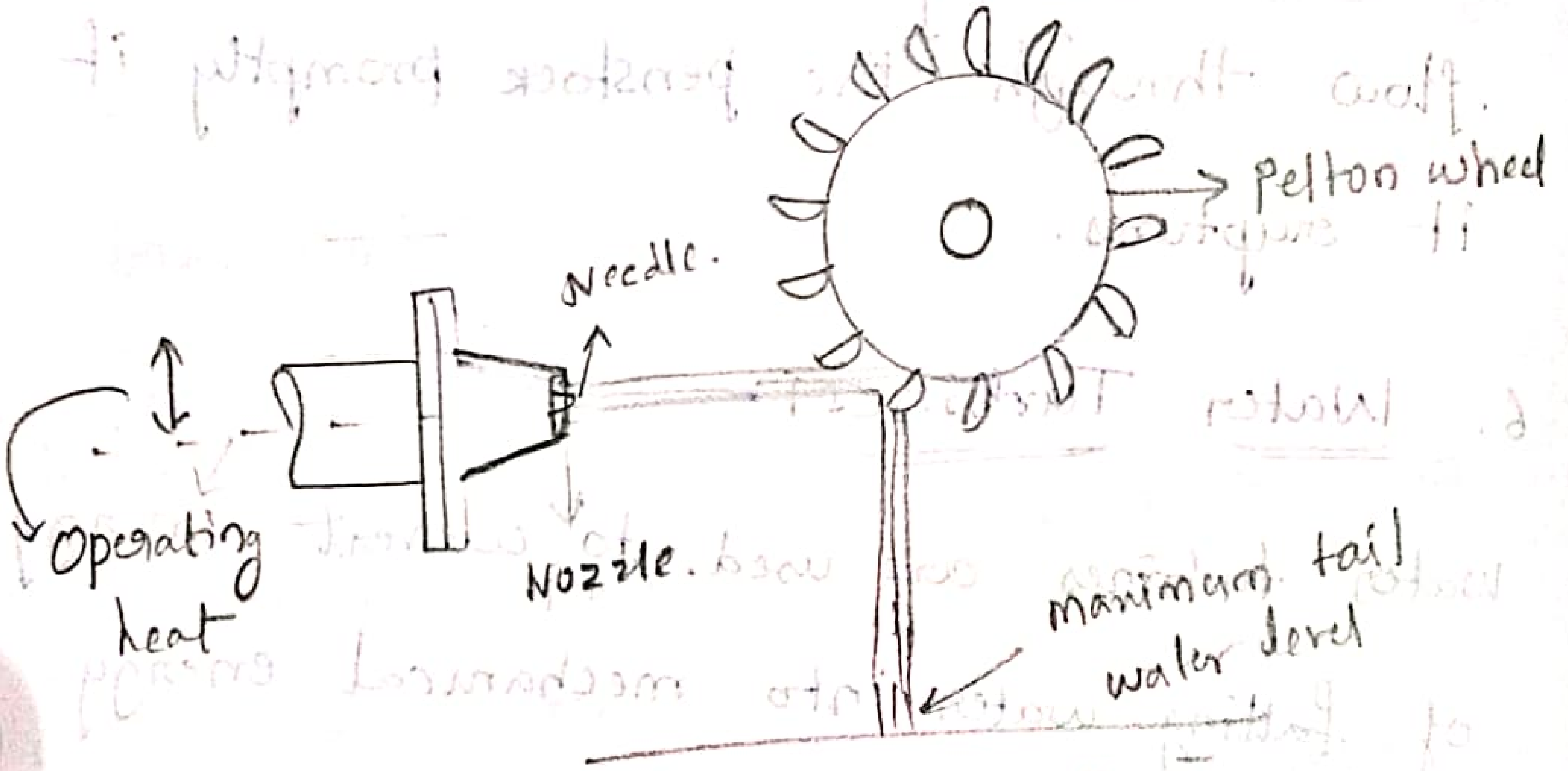
Automatic air valve shuts off water
& Butterfly
flow through the penstock promptly if it ruptures.

6. <u>Water Turbines</u>:-

Water turbines are used to convert energy of falling water into mechanical energy. The principle types of water turbines are
1. Impulse turbine 2. Reaction turbine

1. Impulse turbine :- Such turbines are used for high heads in an impulse turbine the entire pressure of water is converted into kinetic energy in a nozzle and the velocity of the jet drives the wheel.

The example of this type of turbine is pelton wheel.



Pelton wheel :-

It consists of a wheel fitted with elliptical buckets along its peripheary.

The guide blades controlls the flow of water to the turbine. Water flows radially inwards & changes to downward direction while passing. As the water passes over the rotating blades both velocity & pressure are reduced this causes reaction force which drives the turbine.

- A Kaplan turbine is used for low heads and large quantities of water it is similar to francis turbine except the runner of kaplan turbine receives water axially. Water flows radially inwards by changing the direction this cause reaction force which drives the turbine.

3. Electrical Equipment :-

The electrical equipment of hydro electric power station includes alternators, transformers circuit breakers & other switching & (protecting) protective devices.

Choice of Site for Hydro-electric Power stations

(1) **Availability of water** :- Since the primary requirement of a hydro-electric power station is the availability of huge quantity of water, such plants should be built at place where adequate water is available at a good head.

(2) **Storage of water** :- There are wide variations in water supply from a river or canal during the year. This makes it necessary to store water by constructing a dam in order to ensure the generation of power throughout the year.

(3) **Cost & type of land** :- The land for the construction of the plant should be available at a reasonable price. Further, the bearing capacity of the ground should be adequate to withstand the weight of heavy equipment to be installed.

(4) Transportation facilities:- The site selected for a hydro-electric plant should be accesible by rail and road so that necessary equipment and machinery could be easily transported.

Advantages:-

1. Requires no fuel
2. Quite neat & clean and no smoke or ash.
3. very small running charge.
4. Simple in construction.
5. Less maintenance.
6. Doesn't require a long starting time
7. Robust & has a longer life.
8. Help in irrigation & controlling floods.

Disadvantages:-

1. High capital cost.
2. Uncertanity about the water availability.
3. Requires skilled & experienced hands to build the plant
4. High cost for transmission lines.

Co-generation :-

It is defined as sequential generation of two different forms of useful energy from a single energy source, typically mechanical energy and thermal energy.

Mechanical energy may be used either to drive an alternator for producing electricity or rotating equipment such as motor, pump for delivering various services.

Thermal energy can be used either for direct process application or for producing steam.

Cogeneration provides wide range of technologies for the applications in various domains.

Overall efficiency of energy used in cogeneration mode can be upto 85%.

Energy Conservation :-

The reduction or elimination of unneccessary or unwanted energy use is reffered as energy conservation.

(or)

It is an effort to reduce wasteful energy consumption by using fuel energy services.

This can be acheived through the efficient energy use which has no. of advantages including reduction in green house gas emission as well as cost, water and energy savings.

Energy Storage :-

It is the capture of energy produced at one time for use at later time to reduce imbalance between the energy.

A device that stores energy is generally called an "Accumulator" or "Battery".

Energy storage involves converting energy from forms that are difficult to store more convenitially or economically storable forms.

Common examples of energy storage are rechargable battery, which chemical energy readily convertable electricity to operate mobile phone.

The hydro electric dam, which stores energy in a resorvour as gravitational potential energy.

Problems on steam power station:-

① A steam power station which has an overall efficiency of 20% and 0.6kg coal is burnt per kwh of electrical energy generated. Calculate the calorific value of fuel.

let, x kcal/kg be the calorific value of fuel.

Heat produced by 0.6 kg of coal

$= 0.6x$

Heat equivalent of 1 kwh = 860 kcal

$$\eta_{overall} = \frac{\text{Electrical o/p in heat equivalent}}{\text{Heat of combustion of coal}}$$

$$0.2 = \frac{860}{0.6x}$$

$$x = \frac{860}{0.2 \times 0.6}$$

$$x = 7166.67 \text{ kcal/kg}$$

$\therefore$ The calorific value of fuel is

7166.67 kcal/kg.

(5) A 100 MW steam station uses coal of calorific value 6400 Kcal/kg. Thermal efficiency of the station is 30%. And electrical efficiency is 92%. Calculate the coal consumption per hour when the station is delivering its full rated output.

Sol:- Given,

Calorific value of coal = 6400 kcal/kg.

$\eta_{thermal} = 30\% = 0.3$

$\eta_{electrical} = 92\% = 0.92$

$\eta_{overall} = \eta_{thermal} \times \eta_{electrical}$

$\eta_{overall} = 0.3 \times 0.92$

$\eta_{overall} = 0.276$

$\eta_{overall} = 27.6\%$

Unit generated/hr = 100 MW

$= 100 \times 10^3$ kW

$= 10^5$ kWh

$$\eta_{overall} = \frac{\text{Electrical o/p in heat equivalent}}{\text{Heat of coal combustion}}$$

Heat of coal combustion = $\dfrac{\text{Electrical o/p in heat}}{\eta_{overall}}$

$= \dfrac{10^5 \times 860}{0.276}$

$= 311594200.9$

$\dfrac{\text{Heat produced}}{\text{hour}} = 311.6 \times 10^6 \text{ K cal}$

Coal consumption / hr = $\dfrac{\text{Heat produced / hr}}{\text{calorific value}}$

$= \dfrac{311.6 \times 10^6}{6400}$

$= 48687.5 \text{ kg}$

Problems on : Hydro electric plant

(8)

(1) It has been estimated that a minimum run off approximately 94 m^3/sec will be available at a hydraulic project with a head of 39 m. Determine firm capacity yearly gross o/p assume the efficiency of the plant to be 80%.

sol) Given,

minimum run off = 94 m³/sec

Head = 39 m

$\eta\%$ = 80% = 0.8

Gross o/p = ?

weight of water = run off = 94 m³/sec

= 94×1000 kg/sec

= 94000 kg/sec

[mass of 1 m³ of water = 1000 kg]

work done = weight × head

= 94000 × 39 × 9.81 N

= 35963460 wh

= 35,963 kwh

= 35963.460 kwh

Gross plant capacity

firm capacity = plant efficiency × gross plant capacity

= 0.8 × 35963.460

= 28770.768 kw.

Yearly gross o/p = firm capacity × hrs in year

= 28770.768 × (365×24)

= 252031927.7 kwh

252.0319277×10⁶ kwh

(2) A run-off river hydro electric plant with pondage has the following data

1. Install capacity = 10 MW

2. Water head = 20 m

3. $\eta_{overall}$ = 80 %

4. Load factor = 40 %

(i) Determine the river discharge in m^3/sec required for the plant.

(ii) If on a particular day the river flows is $20 m^3/sec$. what load factor can be the plant supply.

Sol

Given,

~~ma~~ Install capacity = 10 MW = 10×10^3 kW.

water head = 20 m.

$\eta_{overall}$ = 80 % = 0.8

load factor = 40 % = 0.4

Units generated / week = Max demand × hrs in week

$= (10 \times 10^3 \times 0.4) \times (24 \times 7)$

$= 672000$

$= 672 \times 10^3$ kwh — (1)

(7) A run-off river hydro electric plant with pondage has the following data

1. Install capacity = 10 MW
2. Water head = 20m
3. $\eta_{overall}$ = 80%
4. load factor = 40%

(i) Determine the river discharge in m^3/sec required for the plant.

(ii) If on a particular day the river flow is $20 m^3/sec$. what load factor can be the plant supply.

soln Given,

~~Max demand~~ Install capacity = 10 MW = 10×10^3 kW.

water head = 20m.

$\eta_{overall}$ = 80% = 0.8

load factor = 40% = 0.4

Units generated / week = Max demand × hrs in week

$= (10 \times 10^3 \times 0.4) \times (24 \times 7)$

= 672000

$= 672 \times 10^3$ kWh — (1)

load factor]

weight of water/sec = $Q \times 9.81 \times 1000 = 9810Q$ newton

[Q = Discharge]

Average power = $W \times H \times \eta_{overall}$

$= 9810Q \times 20 \times 0.8$

$= 156960\,Q$ W

$= 156.96\,Q$ KW — ②

(Equating ① = ②)

Units generated / week = $156.96Q \times 168$ kwh

$= 26369.28\,Q$ kwh.

Equating ① = ②

$672 \times 10^3 = 26369.28\,Q$

$$Q = \frac{672 \times 10^3}{26369.28} = 25.48 \text{ m}^3/\text{sec}.$$

Discharge of water (Q) = 25.48 m^3/sec

Average Power = $156.96 \times Q = 156.96 \times 25.48$

$= 4002.48$

(ii) $Q = 20\ m^3/sec$

Average power $= \cancel{Q \times 9.81 \times 1000}$

$= W \times H \times \eta_{overall}$

$= 9810\ Q \times 20 \times 0.8$

$= 9810 \times 20 \times 20 \times 0.8$

$= 3139200\ W$

$= 3139.2\ KW.$

Units generated on a particular day $= 3139.2 \times 24$

$= 75340.8\ KWh$

Load factor $= \dfrac{\text{Units generated / Day}}{10^4 \times 24} \times 100$

Load factor for $Q = 20$ $= 31.392\ \%.$

Mass of Uranium fission per hour

$$= \frac{235}{6.023 \times 10^{23}} \times 3.3 \times 10^{22}$$

$$= 1.31 \times 10^{-1}$$

$$= 131 \text{ grams.}$$

(2) What is the power output of U^{235}_{92} reactor if it takes 30 days to use upto 2kg of fuel. Given that energy released per fission and Avagadro number = 6.023×10^{26} per kilomile

Sol:- No. of atoms in 2kg fuel is

$$= \frac{2}{235} \times 6.023 \times 10^{26}$$

$$= 25.12 \times 10^{24}$$

atom in 30 days.

fission rate (fission / hour) $= \frac{5.12 \times 10^{24}}{30 \times 24 \times 60 \times 60}$

$$= 1.975 \times 10^{18}.$$

Energy released / fission $= 200 \text{ Mev} + 200 \times 10^{6} \times 1.6 \times 10^{-9}$

$$= 3.2 \times 10^{-4} g.$$

Problems on Nuclear Power station :-

1. An atomic Power reactor can deliver 300 MW. If due to fission of each atom of $_{92}U^{235}$ the energy released is 200 Mev calculate the mass of Uranium Fission / hour.

Sol:- Energy received from vector = 300 MW

$= 300 \times 10^6 W.$

$= 3 \times 10^8 W$

Energy received per hour $= (3 \times 10^8) \times 3600$

$= 108 \times 10^{10} J.$

Energy released / fission = 200 Mev.

$= 200 \times 10^6 \times 1.6 \times 10^{-19}$

$= 3.2 \times 10^{-11} J.$

Charge of electron
$1.6 \times 10^{-19} J$

No. of atom fission / hour = $\frac{\text{Energy received}}{\text{Energy released.}}$

$= \frac{108 \times 10^{10}}{3.2 \times 10^{-11}} = 3.375 \times 10^{2}$

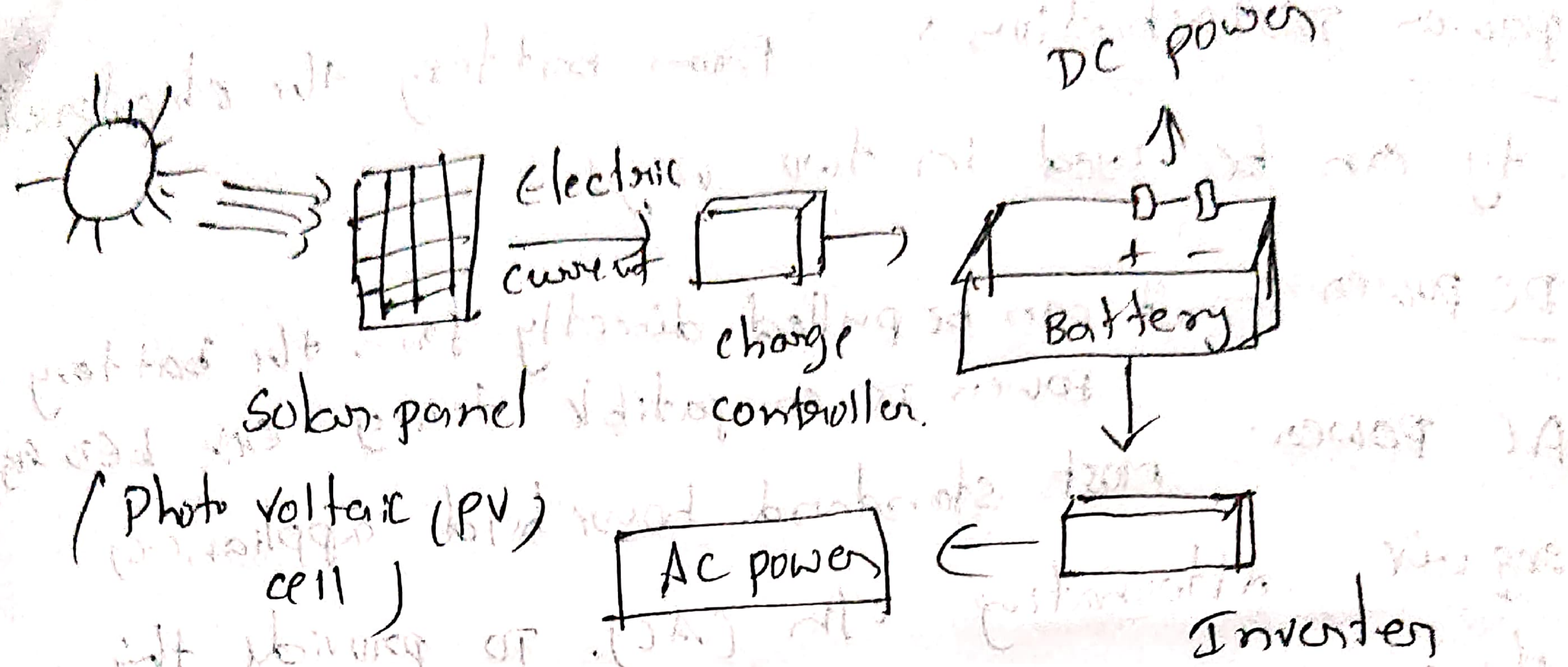
Value of one gram of atom

6.023×10^{23} atoms.

Power o/p = (Energy released per fission) × fission rate.

$= 63.2 \times 10^6 \Rightarrow 63.2$ MW

Solar power Generation



solar Energy collection:- The process begins with the solar panel, which captures photons from sunlight. Through the photovoltaic effect, the panel converts this light energy into Direct current (DC) electricity.

charge controller:- The electric cln flows into a charge controller. This component acts as a regulator to ensure the battery is charged at the correct voltage & protected from over charging, which extends battery lifespan.

Energy storage (Battery):- the regulated power is sent to battery. This allows the system to store energy for later use, such as at night following points

③

on during cloudy weather.

Power Distribution :- From battery the elec-
-ty can be used in two ways.

DC power :- It can be pulled directly from the batt. Ex:- LED
power DC-compatible devices

AC power :- Most standard household appliances
require Alternating c/n (AC). To provide this
the energy flow into an Inverter; which convert
the DC into AC power.

* Photovoltaic effect is a physical process
where a material generate vtg or electric
c/n when exposed to light.

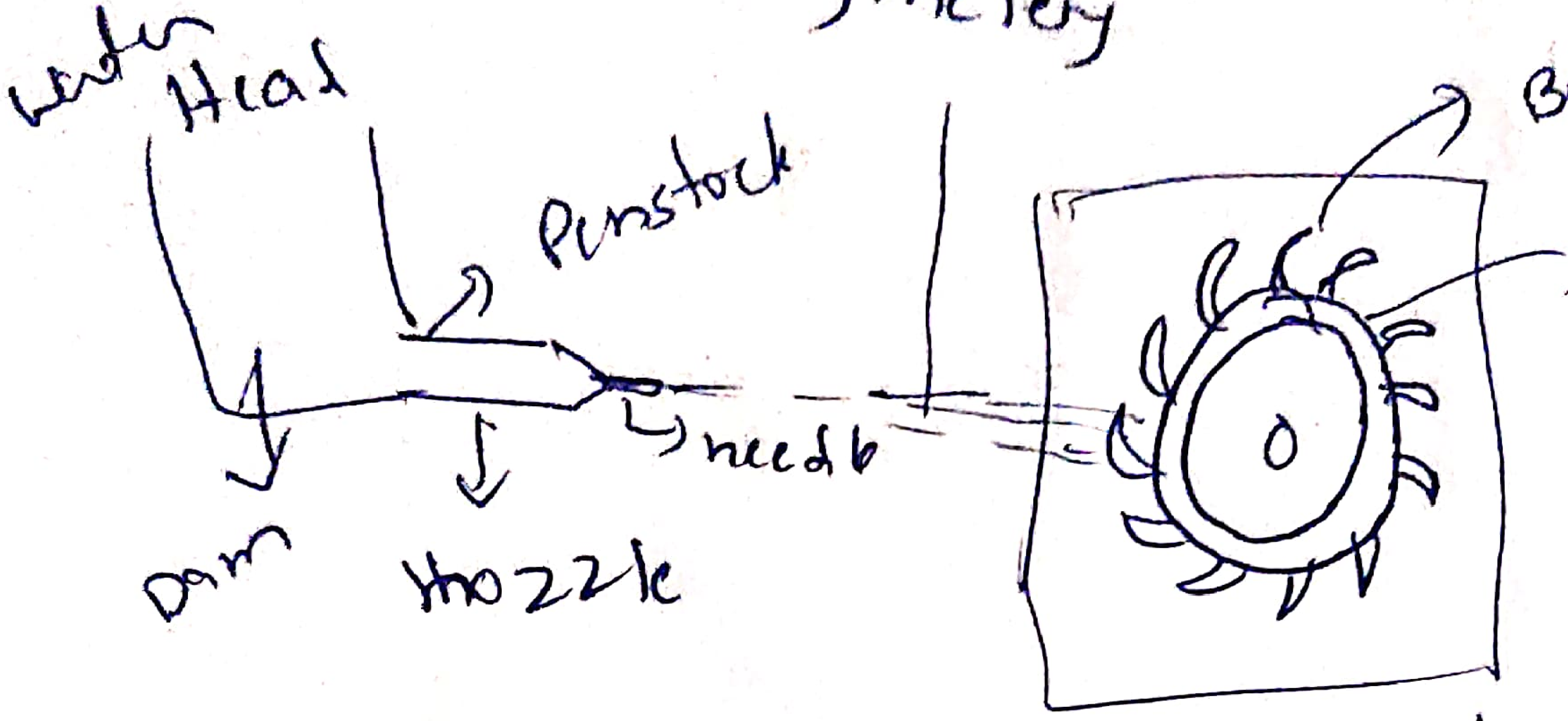
photon :- The fundamental particle of light
that carry energy.

Types of water turbines

1) Impulse Turbines (Tangential flow) (best suited for high heads)

(i) Pelton Turbine (Ideal for high head)

(80 - 1600) meters



Tangential flow B'

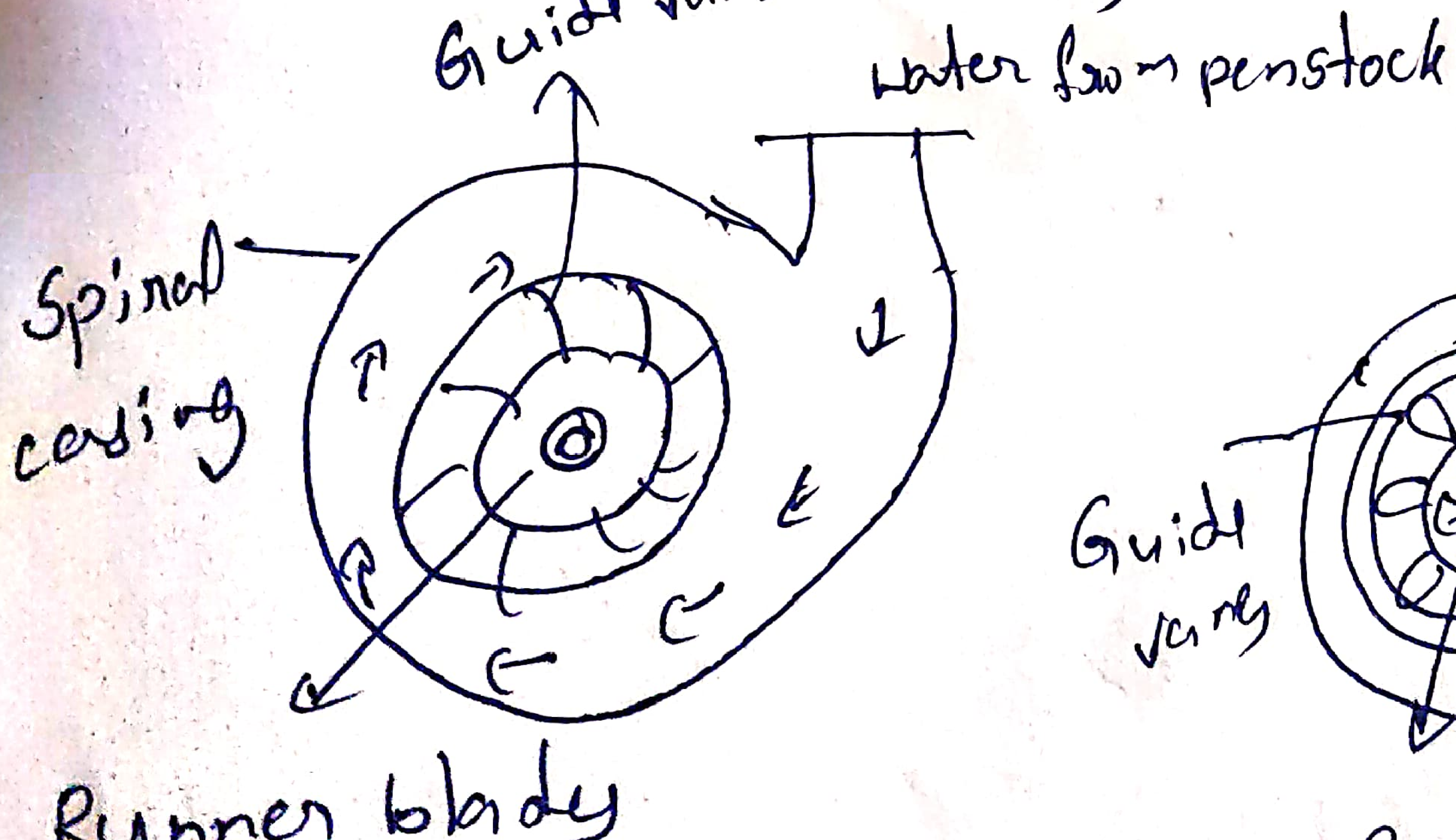
2) Reaction Turbines → Best suited for medium to low heads with high flow rates. (Axial flow)

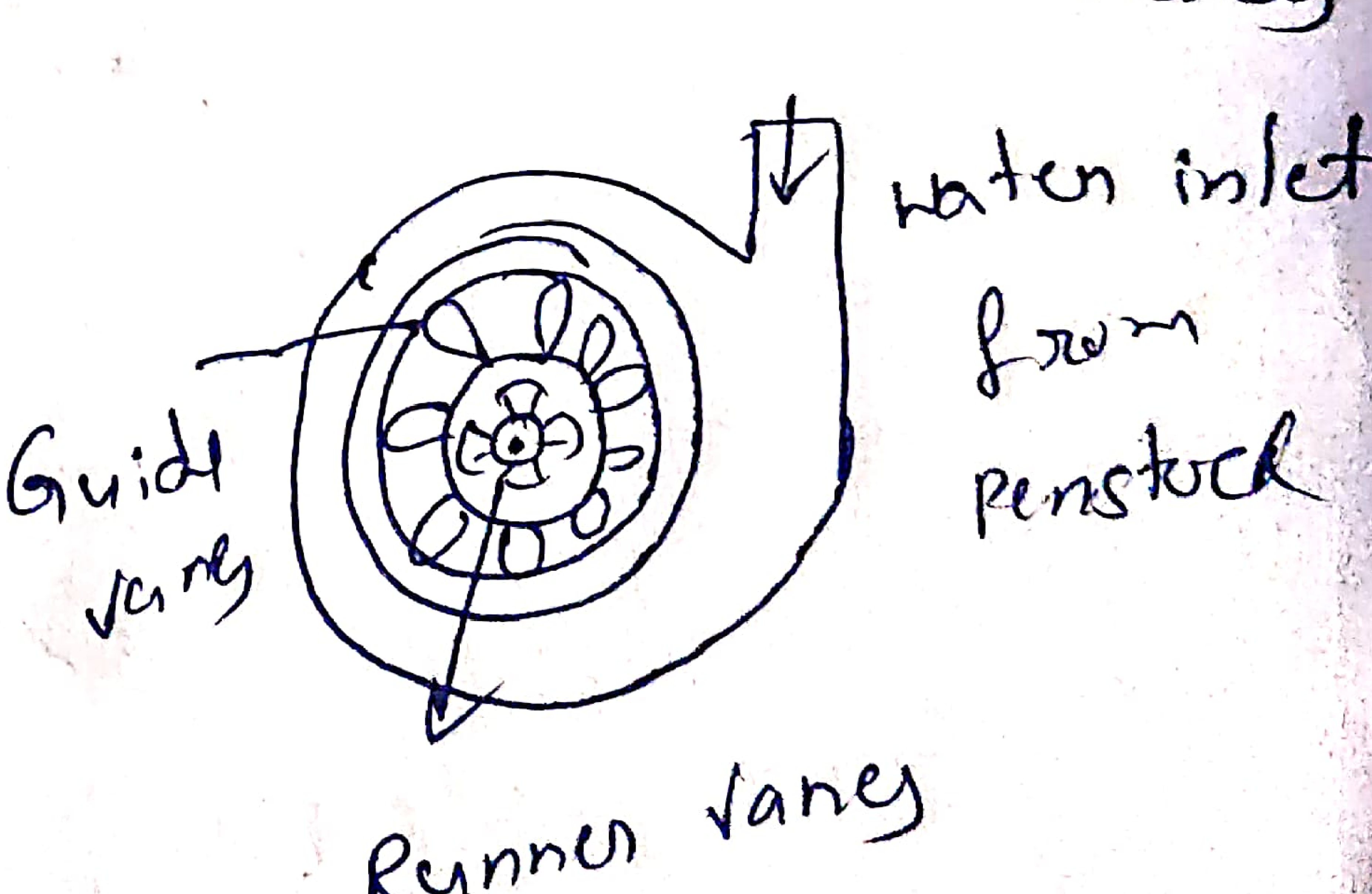
(i) Francis Turbine

10 – 300 meters (medium) heads

(ii) Kaplan Turbine

(2-70) m ideal for low heads





→ water flow is parallel to turbine

on the downstream side of the dam, spill ways are used.

3. <u>Head works</u>:- → Head works are the primary structures built at the start of a hydroelectric plant's waterway. they divert river waters, control flow volume & filter out harmful debris & sediment.

Broken stones

stones, rocks sand etc

~~The head work consists of the diversion structures at the head of an intake, they generally include booms and racks for diverting floating debries, sluices for bypassing debris & sediments & valves~~

Acting as the initial intake zone they protect downstream machinary (like turbines) from damage

UNIT – II

ECONOMICS OF GENERATION :-

→ Introduction.

→ Definitions of connected load, maximum demand, demand factor.

→ Load factor, diversity factor.

→ Load duration curve, number and size of generator units

→ Base load & peak load plants.

→ Cost of electrical energy – fixed cost, running cost. Tariff on charge to customer.

04/05/2023

The art of determining the per unit (1 KWh) cost of production of electrical energy is known as economics of power generation.

Connected load :

It is the sum of continuous ratings of all the equipments connected to the supply system is known as connected load.

The sum of continuous ratings of all the equipments in consumer premises is called connected load of consumer.

Maximum Demand :-

It is the greatest demand of the load on the power station during a given period. load on the power station varies from time to time, the maximum of all the demands that have occurred during a given period (a day) is known as maximum demand.

Demand factor :-

It is the ratio of maximum demand on the power station to its connected load is known as demand factor.

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

The value of demand factor is usually less than '1'

→ Average load (or) Average demand :-

The Average of loads occuring on the power-station in a given period [Day / month / year / week) is known as average load (or) average demand.

→ Daily Average load = $\dfrac{\text{No. of units (KWh) generated in a day}}{24 \text{ hours}}$

→ Monthly Average load =

$$\frac{\text{No. of units (KWh) generated in a month}}{\text{No. of hours in a month}}$$

→ Yearly Average load =

$$\frac{\text{No. of units (KWh) generated in a year}}{8760 \text{ hours}}$$

→ Load Factor :-

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

$$\text{Load factor} = \frac{\text{Average load}}{\text{Maximum demand}}$$

If the plant is in operation for 'T' hours.

$$\text{Then load factor} = \frac{\text{Average load} \times T}{\text{Maximum demand} \times T}$$

$$= \frac{\text{Units generated in T hours}}{\text{maximum demand} \times \text{T hours}}$$

The load factor is always less than 1. Because, average load is smaller than the maximum demand.

Higher the load factor of the power station lesser will be the cost per unit generated.

load factor plays key role in determining Overall cost per unit generated.

Diversity factor :-

The ratio of sum of individual maximum demand to the maximum demand on power station is known as diversity factor.

$$\text{Diversity factor} = \frac{\text{Sum of individual max. demand}}{\text{maximum demand on power station}}$$

The max. demand on the power station is always less than sum of individual maximum demands of the consumer.

Obviously, diversity factor is greater than 1.

The greater the diversity factor the lesser is the cost of generation of power.

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

Sol: Given,

maximum demand on power station = 100 MW

Annual load factor = 40% = 0.4

Energy generated /year = Max. demand × L.F × hours

$= 100 \times 0.4 \times 8760$

$= 350400$ MW.

$= 350400 \times 10^3$ KW.

2) A Generating station has a connected load of 43 MW and a max. demand of 20 MW. The units generated being 61.5×10^6 per annum. Calculate the demand factor & load factor.

Sol: Given,

Connected load = 43 MW

Maximum demand = 20 MW

Units generated /year = 61.5×10^6 W

(i) Demand factor = $\dfrac{\text{max demand}}{\text{Connected load}}$

$= \dfrac{20 \text{ MW}}{43 \text{ MW}} = 0.465$

(ii) Load factor = $\dfrac{\text{Average load}}{\text{max demand}}$

$$\text{Average load} = \frac{\text{No. of units generated}}{(24 \times 365)\ \text{year}}$$

$$= \frac{61.5 \times 10^6}{24 \times 365}$$

$$= 7020.54\ \text{KW}$$

$$\text{Load factor} = \frac{7020.54 \times 10^3}{20 \times 10^6} = 0.351$$

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

Sol:- Given,

A power station delivers.

100 MW for 2 hours

50 MW for 6 hours

And shut down for rest of each day.

and also for maintainance for 45 days/year

Energy supplied for each working day.

$= 100 \times 2 + 50 \times 6 = 200 + 300 = 500$ MWh.

$= 500$ MWh.

Station operates for $= 365 - 45 = 320$ days in a yr.

Energy supplied for year $= 320 \times 500$

$= 160000$ MWh

$$\text{Load factor} = \frac{\text{Avg load}}{\text{max. demand}}$$

$$\text{Annual load factor} = \frac{\text{load supplied per annum}}{\text{max. demand in MW} \times 24 \times 320} \times 100$$

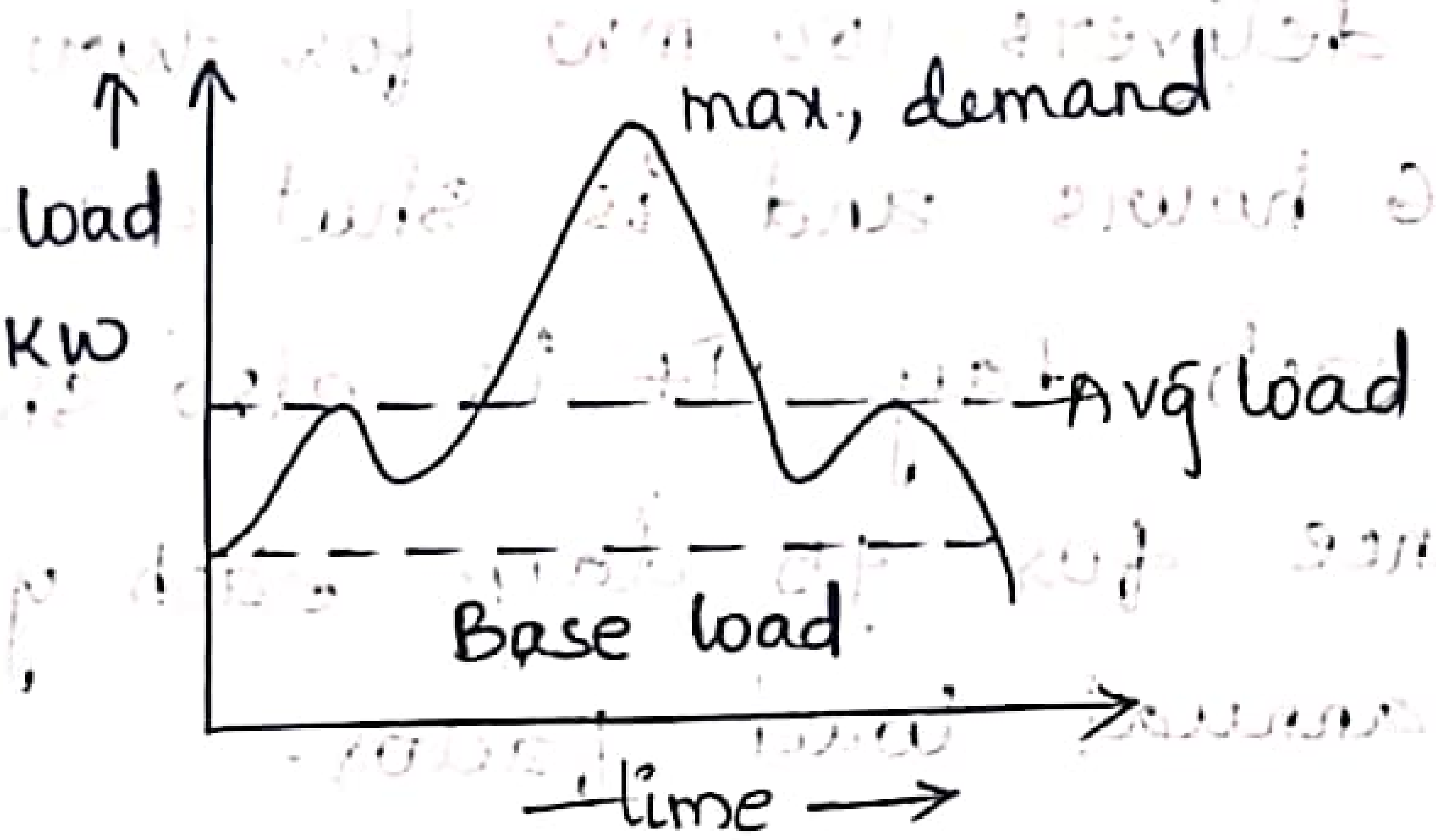
$$= \frac{160000 \times 10^6}{100 \times 10^6 \times 24 \times 300} \times 100$$

$$= 20.833$$

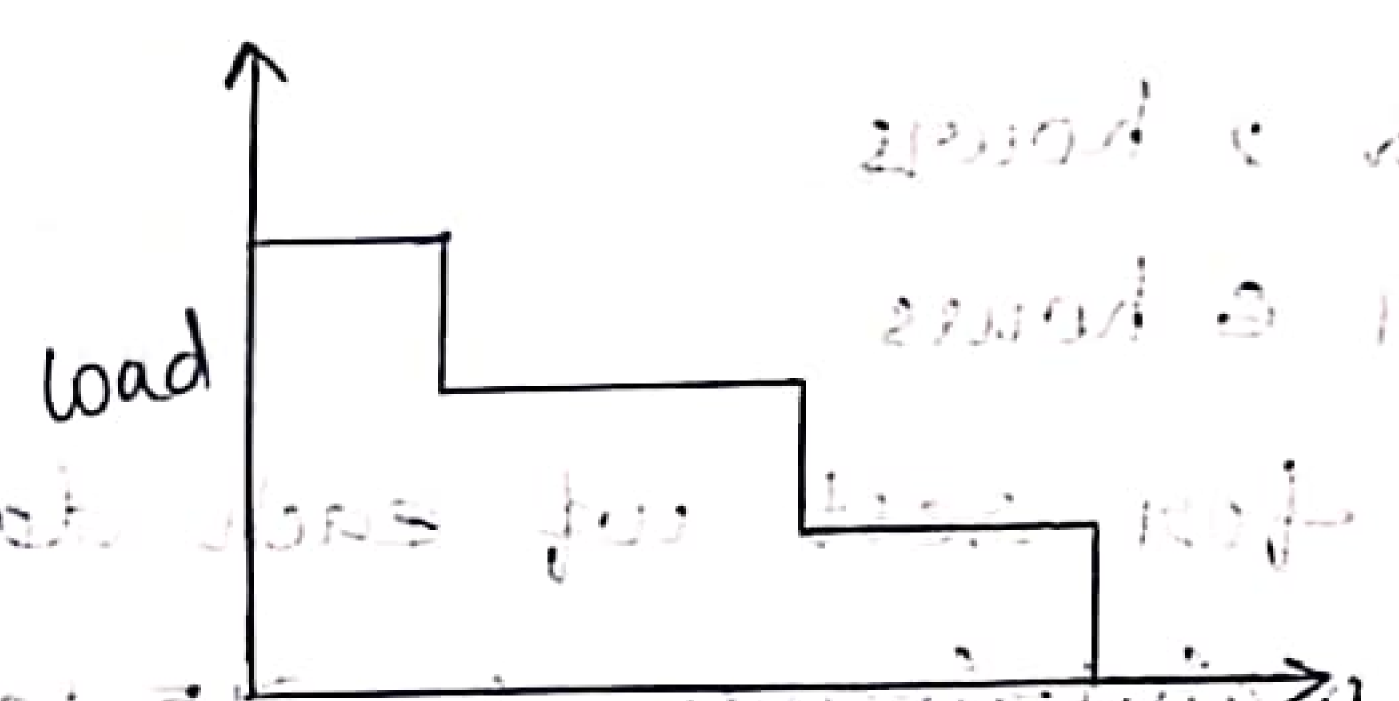
$$A.L.F = 20.833\%$$

08/06/2023

Load duration Curves :-



Load Curve



Load elements of load curve are arranged in decreasing magnitude

Load Duration Curve

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

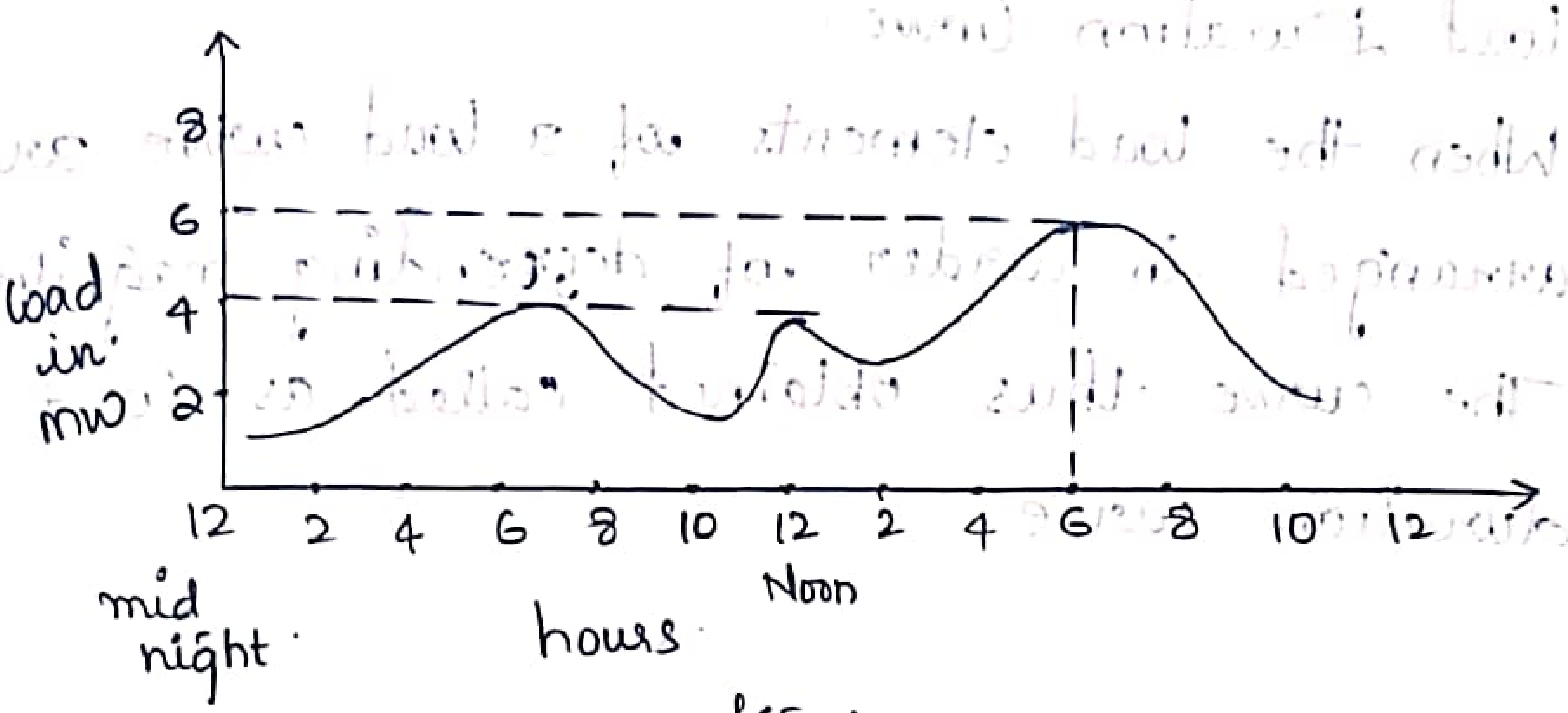


fig-1.

The load on the P.S is never constant. It varies from time to time.

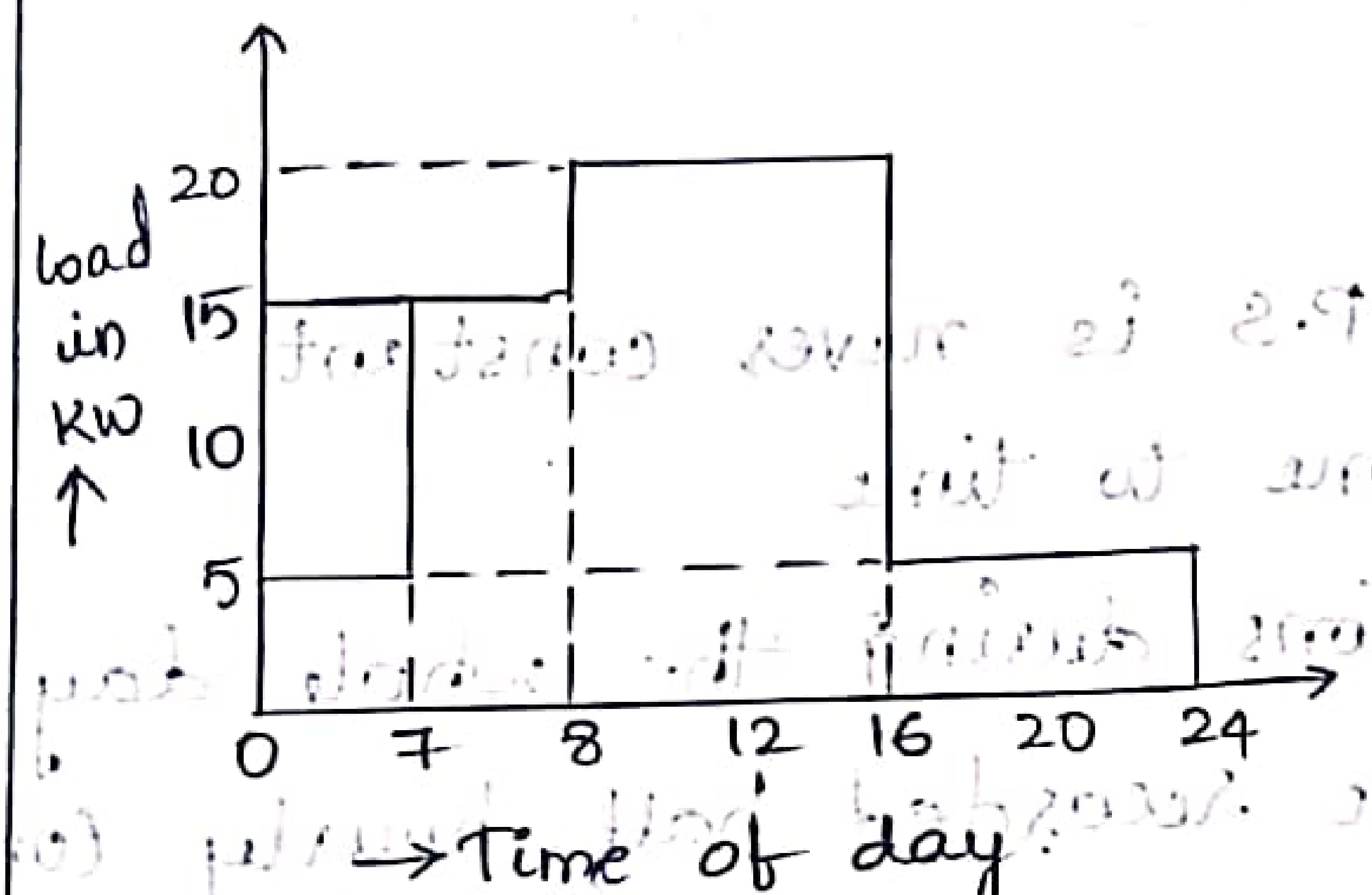
These load variations during the whole day (i.e., 24 hours) are recorded half hourly (or) hourly. And are plotted against time on the graph. The curve thus obtained is known as daily load curve. Fig-1 shows typical daily load curve of a P.S. it is clear that load on P.S is varying being maximum at 6 P.m.

The monthly load curve can be obtained from daily load curves of that month.

The yearly load curve is obtained by considering monthly load curves of that particular year, which is used to determine annual load factor

Load Duration Curve :-

When the load elements of a load curve are arranged in order of descending magnitude The curve thus obtained called as load duration curve.



load curve

The load duration curve is obtained from the same data as the load curve but the ordinates are arranged in order of descending magnitudes.

In the other words the maximum load is represented to the left and the decreasing loads are represented to the right in the descending order. Hence, the area under load duration curve & area under the load curve are equal.

The load duration curve can be extended to include any period of time. By laying out the time form 'o' hour to '8760' hours, the variation and distribution of demand for entire year can be summarized in one curve. The curve thus obtained is called annual load duration curve.

Number and size of generator units :-

→ While making selection of numbers & sizes of generator units the following points should be kept in view.

1) The no. & size of the units should be so selected that the approximately fit the annual load curve of the station.

2) The units should be preferably of different capacities to meet the load requirements.

3) The capacity of the plant should be made is 20% more than the max demand to meet the future load requirements.

4) There should be a spare generating unit so that repairs and over hauling of the working units can be carried out.

5) The tendency to select large no. of units of smaller capacity in order to fit the load curve vary accurately should be avoided.

Base load and peak load of the P.S:-

→ The change in load of P.S makes it load curve of variable nature.

→ It is clear that load on P.S varies from time to time and there can be consider into 2 parts namely

1, Base load:

The unvarying load which occurs almost whole the day on the station is known as base load.

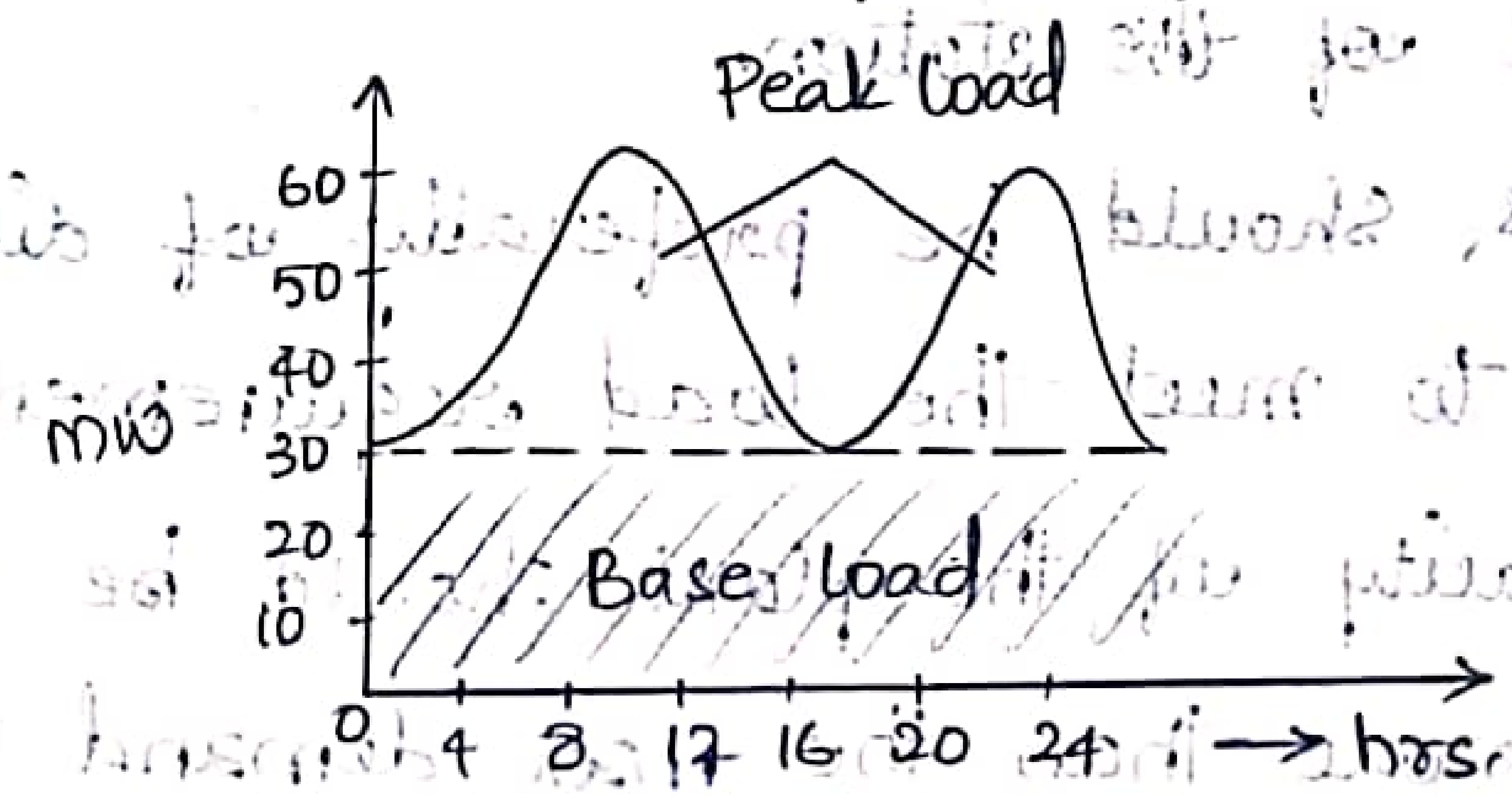


fig (1)

It is clear that fig (1) shows 30 MW of load has to be supplied by the station at all times of day and night (i.e, through 24 hrs)

∴ 30 MW is the base load of the station

Hence, base load on the station is almost of constant nature.

Peak load :-

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

Cost of electrical energy :-

The total cost of electrical energy generated can be divided into 3-parts namely

1) Fixed cost

2) Semi fixed cost

3) Running / Operating cost

1) Fixed cost:

It is the cost which is independent of max. demand and units generated.

→ The fixed cost is due to annual cost of organisation & salaries of high officials, interest on capital, cost of sand.

→ The annual expenditure on central orgn. & salaries of high officials is fixed. Since it has to meet weather the plant has high (or) low max demand are of generates less (or) more units.

2) Semi fixed cost:

It is the cost which depends upon max demand on P.S But is independent of units generated.

→ The semi fixed cost is directly proportional to the max demand on P.S & is on account of annual income and deposition on capital investment of building and equipment, taxes and staff.

Running cost :-

It is the cost which depends on fixed cost and the no. of units generated.

→ The running cost is an account of annual cost of fuel, maintenance, Repairs and salaries of operating staff.

→ Since, these charges depends upon the energy output, running cost is directly proportional to the no. of units generated by the station.

Tariff on charge to customer :-

The rate at which electrical energy is supplied to a customer is known as tariff.

Types of tariff :-

These are several types of tariff the commonly used types of tariff are :

1) Simple tariff
2) Flat rate tariff
3) Block rate tariff
4) 2- part tariff
5) Max demand tariff
6) Power factor tariff
7) 3- part tariff

1, Simple tariff:

When there is a fixed rate per unit of energy consumed it is called simple tariff this can also be known as uniform rate tariff.

2, Flat rate tariff:

When different types of consumers are charged at different uniforms per unit rate. It is called flat rate tariff.

Ex :- lighting loads ⟶ 60 P / KWh.

power load → slightly less which is 55 P.

Advantages :-

→ It is quite simple in calculations.

→ It is more fair to different types of consumers.

Disadvantages :-

→ Seperate meters are requiries for lighting, power load, etc.

→ This makes the application of such tarrif expensive and complicated.

Advantages of Simple tariff :-

→ The price charged per unit is constant

→ It doesn't change with the increase (or) decrease in no. of units consumed.

→ It is the simplest of all the tariff.

Disadvantages :-

→ The cost per unit delivered is high.

→ There is no discrimination b/w different type of consumer.

→ Every consumer has to pay equal.

3) Block rate tariff :-

→ When a given block of energy is charged at specified rate and the succeeding blocks of energy are charged at progressively reduced rates.

Ex: 1st 30 units is charged at 60 p/unit & then next 25 units is charged at 55 p/unit and the remaining units may be charged at the rate of 30 paise per unit.

Advantages :-

In this tariff the consumer gets an incentive to consume more electrical energy. This increase the load factor of system & hence cost of generation is reduced.

→ This type of tariff is being used for majority of residential and small commercial consumers.

4) Two - Pa

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4) Two - Part Tariff :-

When the rate of electrical energy is charged on the basis of maximum demand of the consumer and the units consumed it is called as Two-part tariff.

In the two-part tariff the total charge to be made for the consumer is split into two components.

i.e., Fixed charges & running charges

The fixed charges depends upon the maximum demand of the consumer while the running charges depends upon no. of units consumed by the consumer.

Total charges = Rs $(b \times KW + c \times KWh)$

where, b = maximum demand charge / KW of maximum demand.

c = Charge / KWh of energy consumed

Advantages :-

- It is easily understood by the consumers.
- This type of tariff is mostly applicable to industrial consumers who have appreciable maximum demand.

Disadvantages :-

→ The consumer has to pay fixed charges irrespective of fact whether he has consumed (or) not consumed electrical energy.

→ There is always error in assessing maximum demand.

→ 5) Maximum demand Tariff :-

It is similar to two-part tariff with the only difference that maximum demand is measured by installing max. demand meter.

This type of tariff is applied to big consumers.

→ 6) Power Factor Tariff :-

The tariff in which power factor of consumers load is taken into consideration.

→ 7) Three-part tariff :-

When the total charge to be made from the consumer is split into three parts i.e., Fixed charge,

Semi fixed charge and

Running charge.

It is known as Three (3) part Tariff

Total charge = Rs $(a + b \times kW + c + kWh)$

where; a = fixed charge made during each billing period

b = Charge / kW of max., demand

c = Charge / kWh of energy consumed

This type of tariff is applied to big - consumers.

UNIT – III
AIR INSULATED SUBSTATIONS

SUBSTATION:

The assembly of apparatus used to change some characteristic (e.g. voltage, ac. to dc. frequency, p.f. etc.) of electric supply is called a Substation. Sub-stations are important part of power system. The continuity of supply depends to a considerable extent upon the successful operation of sub-stations. It is, therefore, essential to exercise utmost care while designing and building a sub-station. The following are the important points which must be kept in view while laying out a sub-station :

- It should be located at a proper site. As far as possible, it should be located at the centre of gravity of load. It should provide safe and reliable arrangement.
- For safety, consideration must be given to the maintenance of regulation clearances, facilities for carrying out repairs and maintenance, abnormal occurrences such as possibility of explosion or fire etc.
- For reliability, consideration must be given for good design and construction, the provision of suitable protective gear It should be easily operated and maintained.
- It should involve minimum capital cost.

CLASSIFICATION OF SUBSTATION:

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

- **Service requirement and**
- **Constructional features.**

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

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

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

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

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

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

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

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

- Indoor sub-station
- Outdoor sub-station
- Underground sub-station
- Pole-mounted sub-station

1. Indoor sub-stations:

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

2. Outdoor sub-stations:

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

3. Underground sub-stations:

In thickly populated areas, the space available for equipment and building is limited and the cost of land is high. Under such situations, the sub-station is created The reader may find further discussion on underground sub-stations.

4. **Pole-mounted sub-stations:**

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

Comparison between Outdoor and Indoor SubStation:

The comparison between outdoor and indoor sub-stations is given below in the tabular form:

S.No.	Particular	Outdoor Sub-station	Indoor Sub-station
1	Space required	More	Less
2	Time required for erection	Less	More
3	Future extension	Easy	Difficult
4	Fault location	Easier beacuse the equipment is in full view	Difficult because the equipment is enclosed
5	Capital cost	Low	High
6	Operation	Difficult	Easier
7	Possibility of fault escalation	Less because greater clearances can be provided	More

From the above comparison, it is clear that each type has its own advantages and disadvantages. However, comparative economics (i.e. annual cost of operation) is the most powerful factor influencing the choice between indoor and outdoor sub-stations. The greater cost of indoor sub-station prohibits its use. But sometimes non-economic factors (e.g. public safety) exert considerable influence in choosing indoor sub-station. In general, most of the sub-stations are of outdoor type and the indoor sub-stations are erected only where outdoor construction is impracticable or prohibited by the local laws.

Air Insulated Substation (AIS)

The AIS uses air as the primary dielectric from phase to phase, and phase to ground insulation. They have been in use for years before the introduction of GIS.

Actually, most substations across all regions are AIS. They are in extensive use in areas where space, weather conditions, seismic occurrences, and environmental concerns are not an issue such as rural areas, and favourable offsite terrain.
The indoor AIS version is only used in highly polluted areas, and saline conditions, as the air quality is compromised.

Advantages

1. The primary choice for areas with extensive space
2. With quality design, the system is viable due to the low construction costs and cost of switchgear
3. Less construction time, thereby more suited for expedited installations
4. Easy maintenance as all the equipment is within view. It is easy to notice and attend to faults.

Disadvantages

1. More space is required compared to GIS
2. Vulnerable to faults since the equipment are exposed to the external elements such as human intrusion, pollution, deposition of saline particles, lightning strikes and extreme weather conditions
3. More maintenance requirements, thus leading to high costs
4. The poor dielectric properties of air, as well as secondary factors such as humidity, pollutants, moisture means that more space is required for efficiency.

SUBSTATION LAYOUT

- **Substation Layout AIS**

AIS Substation Description

An Air Insulated Switchgear substation (AIS substation) uses atmospheric air as the phase to ground insulation for the switchgear of an electrical substation. The main advantage of the AIS substation is the scope of the substation for future offloading, for this reason AIS substations tend to be the most popular 400kV substation type. The equipment of an AIS substation is easily sourced and has a short lead-time; this means that the required future offloading does not need to be built immediately, unlike GIS where it must be considered. The main disadvantage to the AIS substation is its overall size. At 400kV level these substations can have a significant footprint and require sensitive locating in any rural environment. AIS are usually installed outdoor.

AIS Substation Size

Based on the single line diagrams given in Appendix B the minimum size of an AIS substation for this project would be as follows:

1. Overall substation Compound Size 46,864.5m2(235.5m x 199m or approximately 11.6 acres)
2. Height of highest element of substation ~ 28m (lightning protection structures situated in the substation compound)

Note: The switchgear in an AIS substation is outdoors therefore no building sizes are considered.

AIS Maintenance Requirements

1. Ongoing maintenance requirements, all equipment exposed to weather conditions
2. Disconnect contacts must be cleaned regularly, operating mechanisms must be checked and maintained

INDOOR AND OUTDOOR SUBSTATIONS

INDOOR SUBSTATIONS:

In these substations, the apparatus is installed within the substation building. Such substations are usually for a voltage up to 11,000 V but can be erected for 33,000 V and 66,000 volts when the surrounding atmosphere is contaminated with impurities such as metal corroding gases and fumes, conductive dust etc. The switchgear on supply or primary side will consist of oil circuit breakers only.

The high voltage supply is given to the primary of the transformer through circuit breaker. From the bus-bar various feeders emerge out. The panel for each feeder consists of an isolator switch and circuit breaker. In addition to isolator and circuit breaker, the panel is provided with the measuring instruments. As regards protection of feeders usually reverse power relay is employed. For the protection of oil filled transformers with conservator tanks Buchholz's relay is most common.

The auxiliaries of the indoor type of substations are:

(i) Storage batteries,

(ii) Fire-fighting equipment such as water buckets, fire extinguishers, etc.

The batteries are used for the:

(i) Operation of the protective gear and switch operating solenoids, and

(ii) Emergency lighting in substations in case of failure of supply.

The several compartments in which the indoor substation is divided are control compartment, indicating and metering instruments and protective device compartment, circuit breaker and operating mechanism compartment, main bus-bar compartment and current transformer and cable sealing box compartment.

Indoor distribution and transformer substations as well as high voltage switchboards consist of a series of open and enclosed chambers or compartments. The main equipment of the given installation is arranged in these compartments. The chamber space, within which the equipment of any one main bus-bar connection is mounted, as a whole, is called as a cell, cubicle or compartment.

According to construction indoor distribution transformer substations and high voltage switchboards are further subdivided into the following categories:

1. Substations of the Integrally Built Type:

It is that in which the apparatus is installed on site. In such substations the cell structures are constructed of concrete or bricks.

2. Substations of the Composite Built-Up Type:

It is that type in which the assemblies and parts are factory or workshop prefabricated, but is assembled on site within a substation switchgear room. The compartments of such substations take form of metal cabinets or enclosures, each of which contains the equipment of one main connection cell. Within such cabinets or enclosures an oil minimum circuit breaker, a load-interrupter switch and one or more voltage transformers may be mounted.

3. Unit Type Factory Fabricated Substations and Metal Clad Switchboards:

These are built in electrical workshops and are shipped to the site of installations fully pre-assembled. After installations of substations and switchboards only connection to the incoming and outgoing power circuits are required to be made. Cubicles for unit type switchboards or substations take the form of fully enclosed metal clad cabinets.

Metal clad cubicles designed with withdrawable trucks and divided into several compartments are usually employed. The several compartments in which the cubicle is divided are control compartment, indicating and metering instrument and protective device compartment, circuit breaker and operating mechanism compartment, main bus-bar compartment and current transformers and cable sealing box compartment.

By partitioning of the cubicle space into compartments safe access to the apparatus is provided. The circuit breaker and its operating mechanism are mounted on the truck, which can be withdrawn from the cubicle. In withdrawable-truck unit-type cubicles the isolating device is of the plug-in-type.

When the truck is rolled out from the cubicle the holes in which the isolating devices enter for making contacts are automatically closed by metal shutters serving to isolate the live parts from possible casual contact. When the truck is rolled back into the cubicle, the shutters open automatically.

To prevent any possible opening or closing of the disconnecting devices when the circuit breaker is closed, these cubicles are designed with interlocks which prevent the truck from being rolled in or withdrawn when the circuit breaker is closed.

OUTDOOR SUBSTATIONS:

Outdoor substations are of two types namely:

1. Pole-mounted substations, and

2. Foundation-mounted substations.

1. Pole-Mounted Substations:

Such substations are erected for mounting distribution transformers of capacity up to 250 kVA. Such substations are cheapest, simple and smallest of substations. All the equipment is of outdoor type and mounted on the supporting structure of ht distribution line. Triple Pole Mechanically Operated (TPMO) switch is used for switching "on" and "off' of ht transmission line. HT fuse unit is installed for protection of ht side.

To control ht side iron clad low tension switch of suitable capacity with fuses is installed. Lightning arresters are installed over the ht line to protect the transformer from the surges. Substation is earthed at two or more places.

Generally a transformer of capacity up to 125 kVA are mounted on double pole structure and for transformers of capacity above 125 kVA but not exceeding 250 kVA 4-pole structures with suitable platform is used. This type of pole-mounted substation is erected in very thickly populated location.

The maintenance cost of such substations is low and by using a large number of such substations in a town it is possible to lay the distributors, at a lower cost. But owing to increase in number of transformers, total kVA is increased, no load losses increase and the cost per kVA is thus more. Economy is the main consideration when a choice is made for such substations.

2. Foundation Mounted Substations:

These substations are built 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. Substations for primary and secondary transmission and for secondary distribution, (above 250 kVA) are foundation mounted outdoor type. Since equipment required for such substations is heavy, therefore, site selected for these substations must have a good access for heavy transport.

Again, owing to exposed bus-bars and other associated equipment the clearances and spacings are not only to be governed by the operating voltage but also from the considerations of the encroachment from outside. Low level types of substations are designed except when the space available is limited as these provide facility of easy inspection, cleaning and maintenance.

The switchgear consists of circuit breakers of suitable type on both the sides but with the increased reliability of the modern transformers, the practice is to dispense with the circuit breaker on the incoming side form the economic consideration. The isolating switches thus serve the purpose.

Advantages and Disadvantages of Outdoor Substations over Indoor Substations:

The outdoor substations have the following main advantages over indoor substations:

(i) All the equipment is within view and therefore fault location is easier.

(ii) The extension of the installation is easier, if required.

(iii) The time required in erection of such substations is lesser.

(iv) The smaller amount of building materials (steel-concrete) is required.

(v) The construction work required is comparatively smaller and cost of the switchgear installation is low.

(vi) There is practically no danger of a fault which appears at one point being carried over to another point in the installation because the apparatus of the adjoining connections can be spaced liberally, without any appreciable increase in costs.

(vii) Repairing work is easy.

The disadvantages of outdoor installations in comparison of indoor installations are:

(i) The various switching operations with the isolators, as well as supervision and maintenance of the apparatus are to be performed in the open air during all kinds of weather.

(ii) More space is required for the substation.

(iii) Protection devices are required to be installed for protection against lightning surges.

(iv) The length of control cables required is more.

(v) The influence of rapid fluctuation in ambient temperature and dust and dirt deposits upon the outdoor substation equipment makes it necessary to install apparatus specially designed for outdoor service and, therefore, more costly.

Notwithstanding the disadvantages, outdoor substations are very widely used in power systems.

COMPONENTS OF SUB-STATIONS:

Besides the transformers, the several other equipment include

- Bus bars
- Circuit Breakers
- Isolators
- Surge Arresters
- Substation Earthing system
- Current Transformers
- Voltage Transformers
- Shunt Reactors
- Shunt Capacitors etc.

Each equipment has certain functional requirement.

BUSBARS

Bus bars are conducting bars to which number of circuit connections is connected. Bus-bars are copper or aluminum bars (generally of rectangular *x*-section) and operate at constant voltage. The incoming and outgoing lines in a sub-station are connected to the bus-bars. The most commonly used bus-bar arrangements in sub-stations are :

(i) Single bus-bar arrangement

(ii) Single bus-bar system with sectionalisation

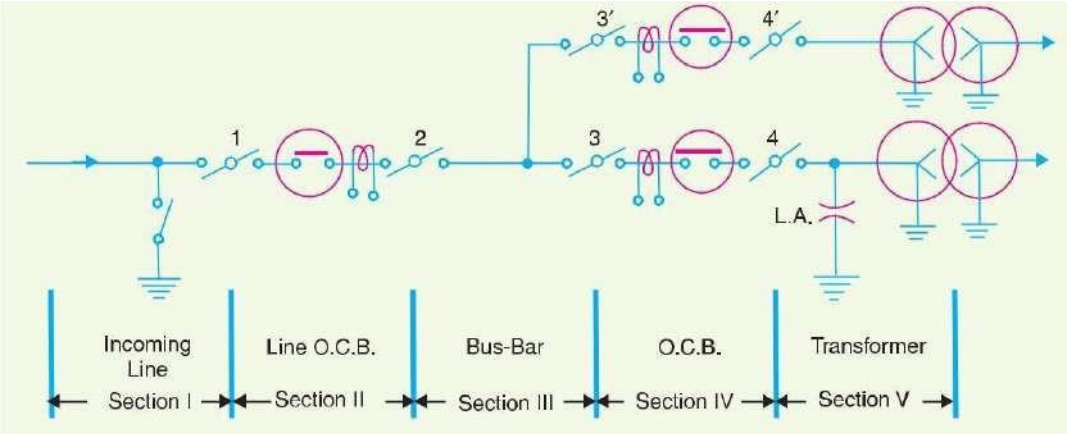
(iii) Double bus-bar arrangement

INSULATORS:

The insulators serve two purposes. They support the conductors (or bus-bars) and confine the current to the conductors. The most commonly used material for the manufacture of insulators is porcelain. There are several types of insulators (*e.g.* pin type, suspension type, post insulator etc.) and their use in the sub-station will depend upon the service requirement. For example, post insulator is used for bus-bars. A post insulator consists of a porcelain body, cast iron cap and flanged cast iron base. The hole in the cap is threaded so that bus-bars can be directly bolted to the cap.

ISOLATING SWITCHES:

In sub-stations, it is often desired to disconnect a part of the system for general maintenance and repairs. This is accomplished by an isolating switch or isolator. An isolator is essentially a knife switch and is designed to open a circuit under *no load*. In other words, isolator switches are operated only when the lines in which they are connected carry *no current.



The entire sub-station has been divided into V sections. Each section can be disconnected with the help of isolators for repair and maintenance. For instance, if it is desired to repair section No. II, the procedure of disconnecting this section will be as follows. First of all, open the circuit breaker in this section and then open the isolators 1 and 2. This procedure will disconnect section II for repairs. After the repair has been done, close the isolators 1 and 2 first and then the circuit breaker.

CIRCUIT BREAKER:

A circuit breaker is equipment which can open or close a circuit under normal as well as fault conditions. It is so designed that it can be operated manually (or by remote control) under normal conditions and automatically under fault conditions. For the latter operation, a relay circuit is used with a circuit breaker. Generally, bulk oil circuit breakers are used for voltages upto 66kV while for high (>66 kV) voltages, low oil circuit breakers are used. For still higher

POWER TRANSFORMERS:

A power transformer is used in sub-station to step-up or step-down the voltage. Except at the power station, all the subsequent sub-stations use step-down transformers to gradually reduce the voltage of electric supply and finally deliver it at utilisation voltage. The modern practice is to use 3-phase transformers in sub-stations ; although 3 single phase bank of transformers can also be used. The use of 3-phase transformer (instead of 3 single phase bank of transformers) permits two advantages. Firstly, only one 3-phase load-tap changing mechanismcan be used. Secondly, its installation is much simpler than the three single phase transformers. The power transformer is generally installed upon lengths of rails fixed on concrete slabs having foundations 1 to 1·5 m deep. For ratings upto 10 MVA, naturally cooled, oil immersed transformers are used. For higher ratings, the transformers are generally air blast cooled.

INSTRUMENT TRANSFORMERS:

The lines in sub-stations operate at high voltages and carry current of thousands of amperes. The measuring instruments and protective devices are designed for low voltages (generally 110 V) and currents (about 5 A). Therefore, they will not work satisfactorily if mounted directly on the power lines. This difficulty is overcome by installing *instrument trans-formers* on the power lines. The function of these instrument transformers is to transfer voltages or currents in the power lines to values which are convenient for the operation of measuring instruments and relays.

There are two types of instrument transformers *viz.*

(i) Current transformer (C.T.)

(ii) Potential transformer (P.T.)

(i) Current transformer (C.T.):

A current transformer in essentially a step-up transformer which steps down the current to a known ratio. The primary of this transformer consists of one or more turns of thick wire connected in series with the line. The secondary consists of a large number of turns of fine wire and provides for the measuring instruments and relays a current which is a constant fraction of the current in the line. Suppose a current transformer rated at 100/5 A is con-nected in the line to measure current. If the current in the line is 100 A, then current in the secondary will be 5A. Similarly, if current in the line is 50A, then secondary of C.T. will have a current of 2·5 A. Thus the C.T. under consideration will step down the line current by a factor of 20.

(ii) Voltage transformer:

It is essentially a step down transformer and steps down the voltage to a known ratio. The primary of this transformer consists of a large number of turns of fine wire connected across the line. The secondary winding consists of a few turns and provides for measuring instruments and relays a voltage which is a known fraction of the line voltage. Suppose a potential transformer rated at 66kV/110V is connected to a power line. If line voltage is 66kV, then voltage across the secondary will be 110 V.

Metering and Indicating Instruments:

There are several metering and indicating instruments (*e.g.* ammeters, voltmeters, energy meters etc.) installed in a sub-station to maintain watch over the circuit quantities. The instrument transformers are invariably used with them for satisfactory operation.

Miscellaneous equipment.

In addition to above, there may be following equipment in a substation:

- Fuses
- carrier-current equipment
- sub-station auxiliary supplies

BUSBAR ARRANGEMENTS IN SUBSTATIONS:

Busbar are the important components in a sub-station. There are several Busbar Arrangements in Substations that can be used in a sub-station. The choice of a particular arrangement depends upon various factors such as system voltage, position of sub-station, degree of reliability, cost etc.

The following are the important bus-bar arrangements used in sub-stations:

(i) Single bus-bar system:

As the name suggests, it consists of a single bus-bar and all the incoming and outgoing lines are connected to it. The chief advantages of this type of arrangement are low initial cost, less maintenance and simple operation. However, the principal disadvantage of single bus-bar system is that if repair is to be done on the bus-bar or a fault occurs on the bus, there is a complete interruption of the supply. This arrangement is not used for voltages exceeding 33kV. The indoor 11kV sub-stations often use single Busbar Arrangements in Substations.

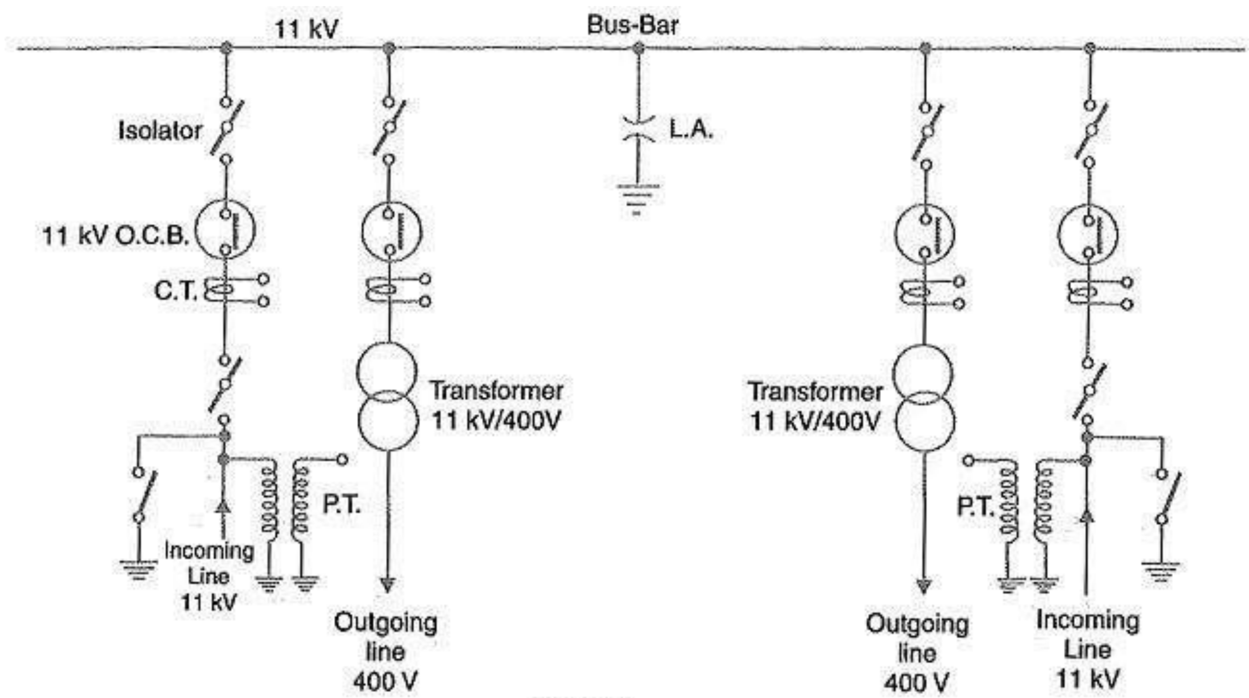


Fig. 25.5

Fig. 25.5 shows single Busbar Arrangements in Substations. There are two 11 kV incoming lines connected to the bus-bar through circuit breakers and isolators. The two 400V outgoing lines are connected to the bus bars through transformers (11kV/400 V) and circuit breakers.

(ii) Single bus-bar system with sectionalisation:

In this arrangement, the single bus-bar is divided into sections and load is equally distributed on all the sections. Any two sections of the bus-bar are connected by a circuit breaker and isolators. Two principal advantages are claimed for this arrangement. Firstly, if a fault occurs on any section of the bus, that section can be isolated without affecting the supply from other sections. Secondly, repairs and maintenance of any section of the bus-bar can be carried out by de-energising that section only, eliminating the possibility of complete shut down. This arrangement is used for voltages upto 33 kV.

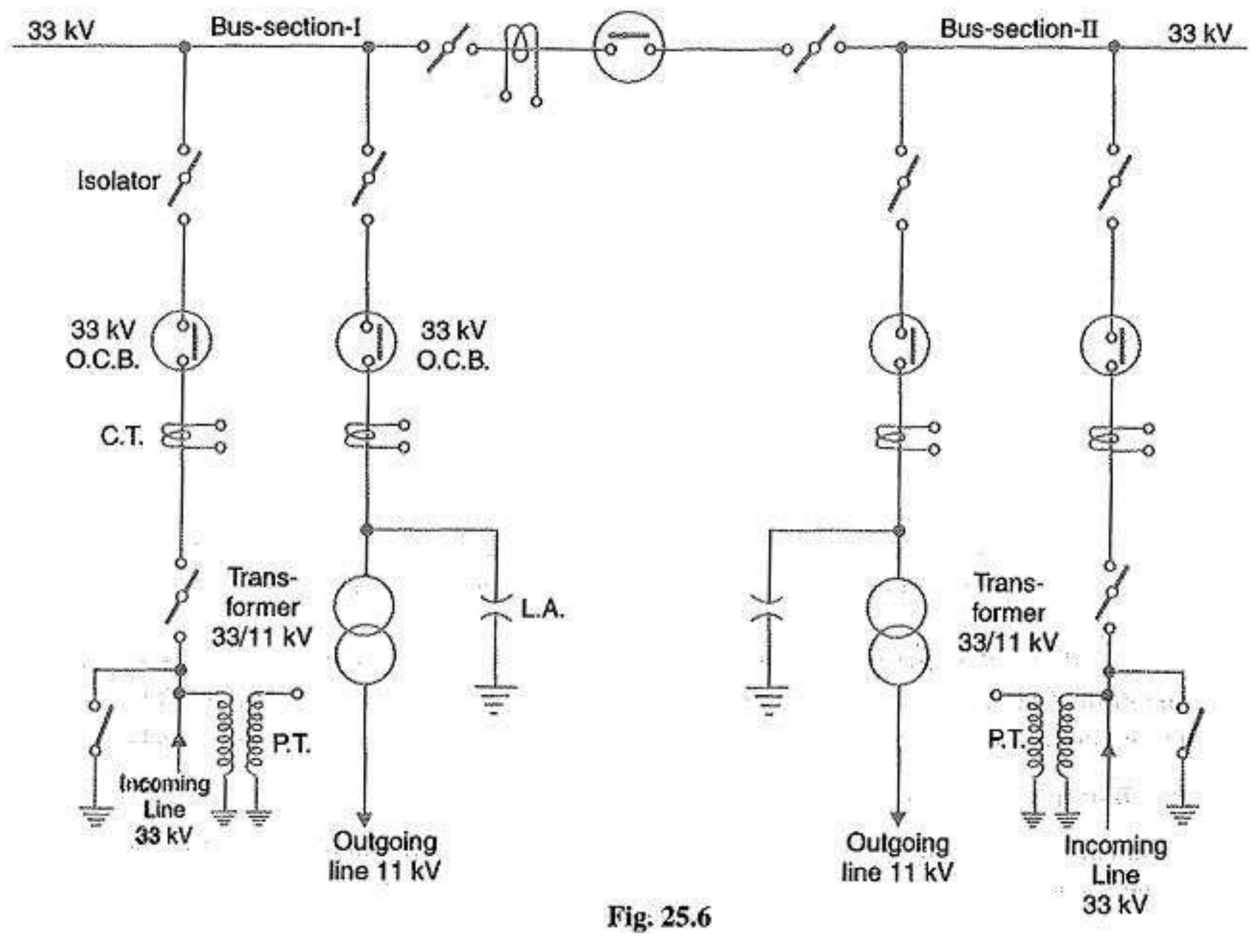


Fig. 25.6

Fig. 25.6 shows bus-bar with sectionalisation where the bus has been divided into two sections. There are two 33 kV incoming lines connected to sections I and II as shown through circuit breaker and isolators. Each 11 kV outgoing line is connected to one section through transformer (33/11 kV) and circuit breaker. It is easy to see that each bus-section behaves as a separate bus-bar.

(iii) Duplicate bus-bar system:

This system consists of two bus-bars, a "main" bus-bar and a "spare" bus-bar. Each bus-bar has the capacity to take up the entire sub-station load. The incoming and outgoing lines can be connected to either bus-bar with the help of a bus-bar coupler which consists of a circuit breaker and isolators. Ordinarily, the incoming and outgoing lines remain connected to the main bus-bar. However, in case of repair of main bus-bar or fault occurring on it, the continuity of supply to the circuit can be maintained by transferring it to the spare bus-bar. For voltages exceeding 33kV, duplicate bus-bar system is frequently used.

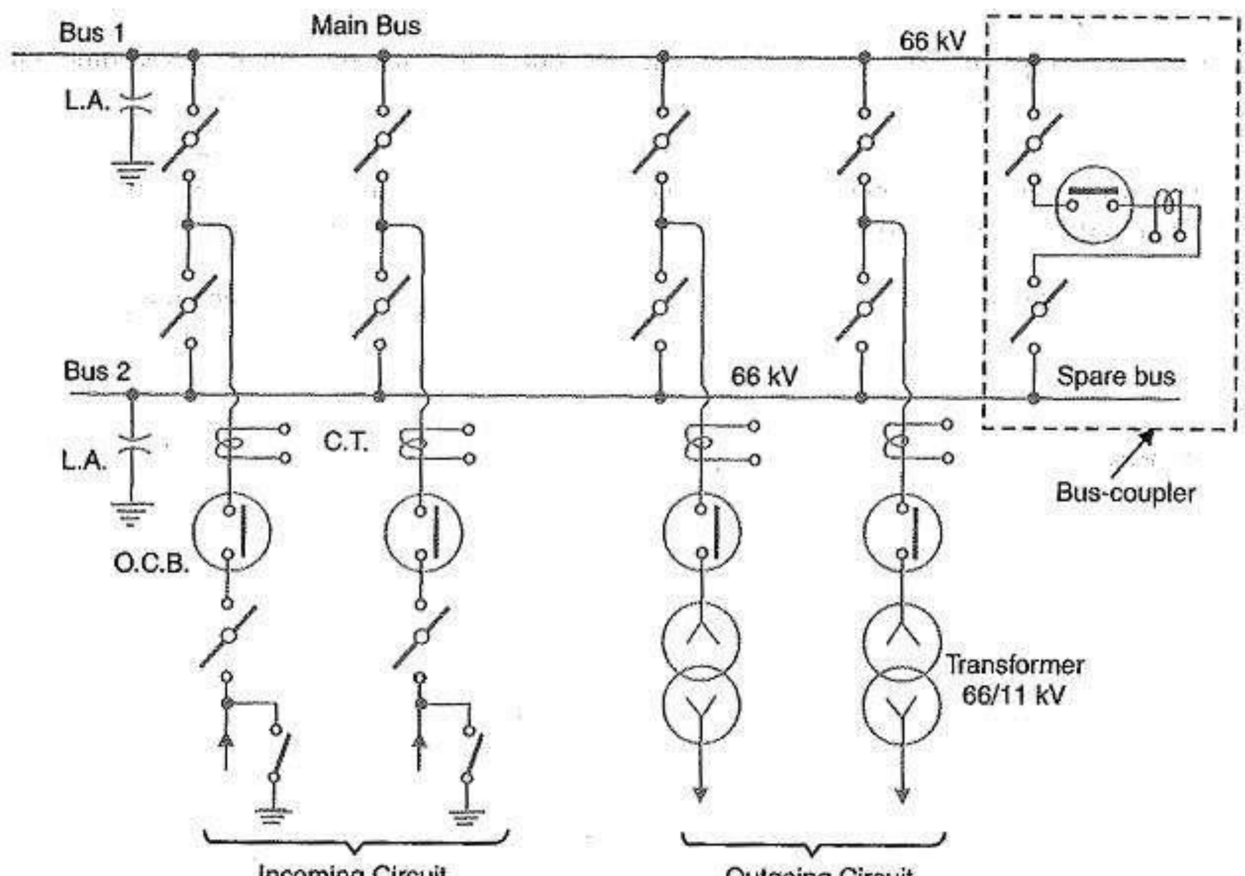


Fig. 25.7

Fig. 25.7 shows the arrangement of duplicate bus-bar system in a typical sub-station. The two 66kV incoming lines can be connected to either bus-bar by a bus-bar coupler. The two 11 kV outgoing lines are connected to the bus-bars through transformers (66/11 kV) and circuit breakers.

TERMINAL AND THROUGH SUBSTATIONS:

All the transformer sub-stations in the line of power system handle incoming and outgoing lines. Depending upon the manner of incoming lines, the sub-stations are classified as :

- **Terminal sub-station**
- **Through sub-station**

TERMINAL SUB-STATION:

A terminal sub-station is one in which the line supplying to the substation terminates or ends. It may be located at the end of the main line or it may be situated at a point away from main line route. In the latter case, a tapping is taken from the main line to supply to the sub-station. Fig. 25.8 shows the schematic connections of a terminal sub-station. It is clear that incoming 11 kV main line terminates at the sub-station. Most of the distribution sub-stations are of this type.

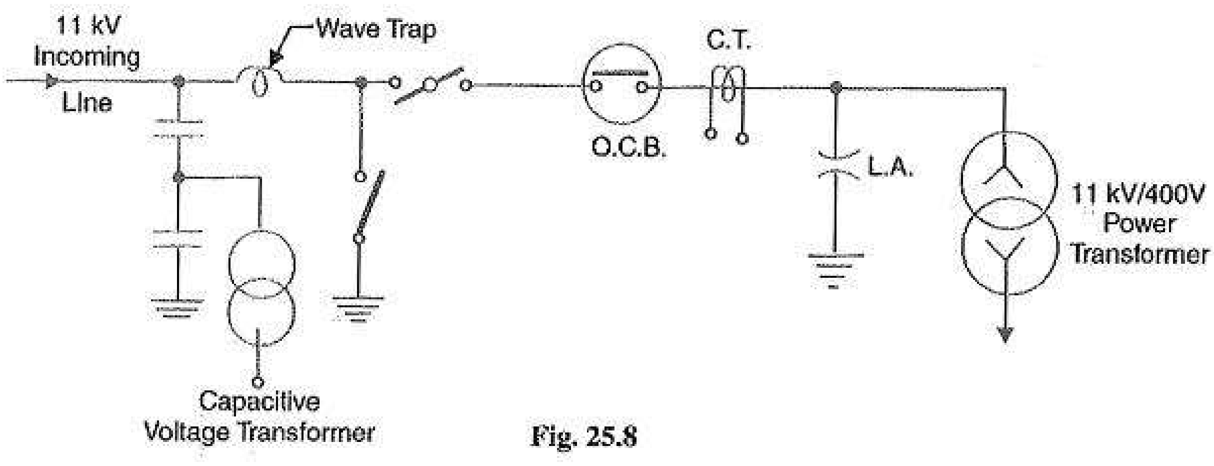
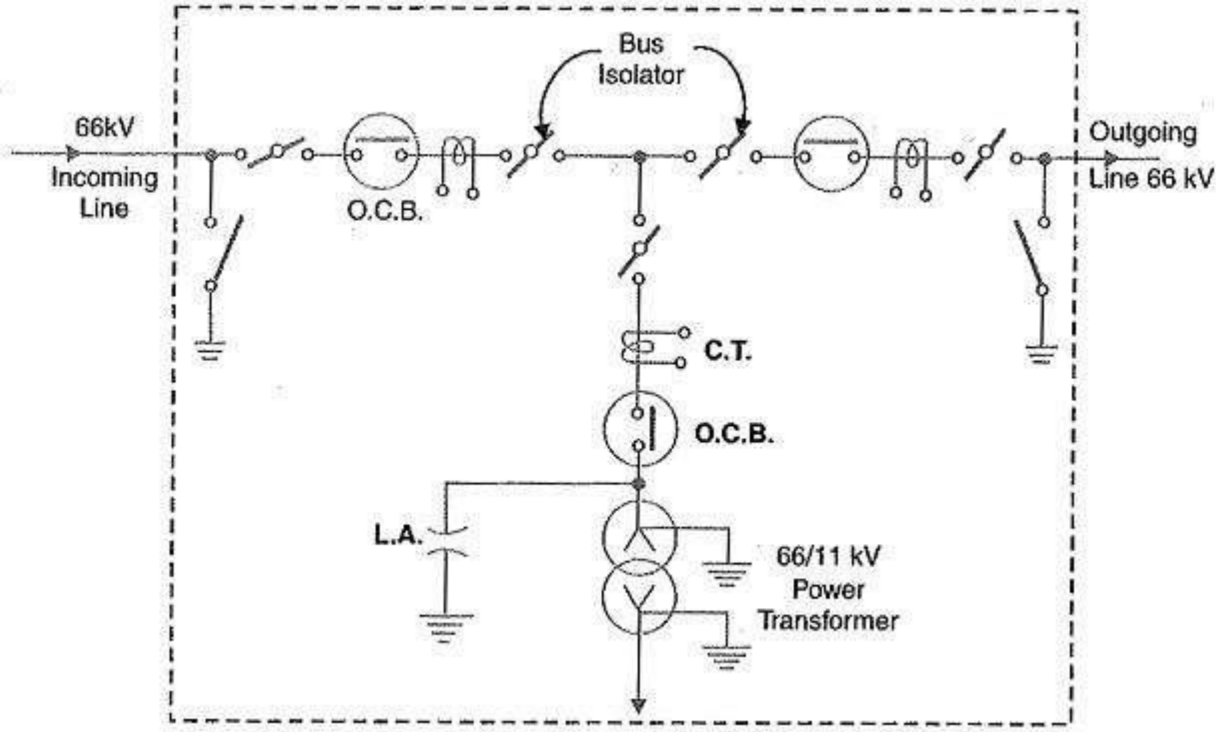


Fig. 25.8

THROUGH SUB-STATION:

A through sub-station is one in which the incoming line passes `through' at the same voltage. A tapping is generally taken from the line to feed to the transformer to reduce the voltage to the desired level. Fig. 25.9 shows the schematic connections of a through substation. The incoming 66 kV line passes through the sub-station as 66kV outgoing line. At the same time, the incoming line is tapped in the sub-station to reduce the voltage to 11 kV for secondary distribution.



Bus
Isolator
66kV
Incoming
Line
O.C.B.
Outgoing
Line 66 kV
C.T.
O.C.B.
L.A.
66/11 kV
Power
Transformer

Fig. 25.9

BUS-BAR ARRANGEMENT: (VERSION 2.0)

Different bus-bar arrangements in an electric circuit will be discussed here. All the diagrams refer to 3-phase arrangement but are shown in single phase for simplicity.

Type # 1. Single Bus-Bar Arrangement:

This is the simplest arrangement consisting of a single set of bus-bars for the full length of the switchboard and to this set of bus-bars are connected all the generators, transformers and feeders, as illustrated by single line diagram in Fig. 1.10. Each generator and feeder is controlled by a circuit breaker. The isolators permit isolation of generators, feeders and circuit breakers from the bus-bars for maintenance. The chief advantages of such a bus-bar arrangement are low initial cost, less maintenance and simple operation.

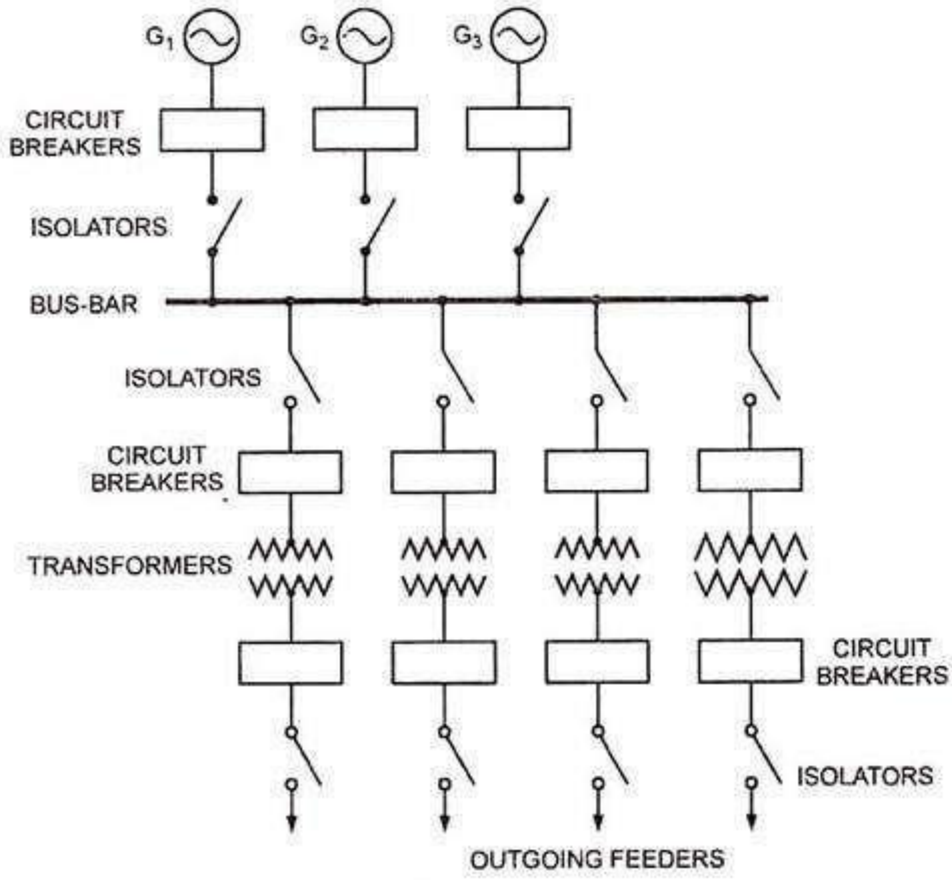


Fig. 1.10. ***Single Bus-Bar Arrangement***

The glaring drawback of this system is that in case of fault on the bus-bars, whole of the supply is affected and all the healthy feeders are disconnected. Moreover, when maintenance is to be carried out on any of the feeder sections or on a part of bus-bar the whole supply is to be disrupted. Thus such an arrangement provides least flexibility and immunity from total shutdown.

Such bus-bar arrangement is employed for switchboards, small and medium sized substations, small power stations and dc stations.

Type # 2. Single Bus-Bar Arrangement with Bus Sectionalization:

The bus-bar may be sectionalized by a circuit breaker and isolating switches so that a fault on one part does not cause a complete shutdown. In large generating stations, where several units are installed, it is a common practice to sectionalize the bus as illustrated in Fig. 1.11.

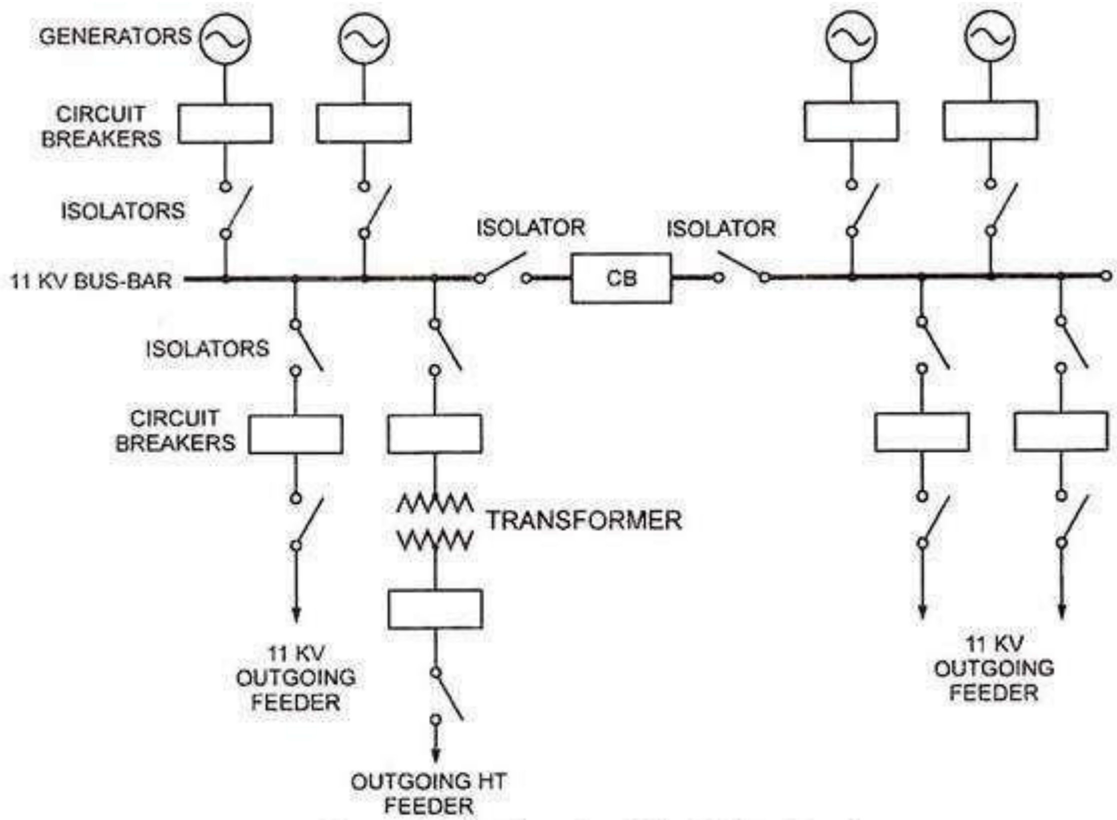


Fig. 1.11. ***Sectionalized Single Bus-Bar System***

Normally the number of sections of a bus-bar are 2 to 3 in a substation, but actually it is limited by the short-circuit current to be handled. In a sectionalized bus-bar arrangement only one additional circuit breaker is required which does not cost much in comparison to the total cost of the bus-bar system.

Such an arrangement provides three main advantages over simple single bus-bar arrangement. Firstly, in the event of occurrence of fault on any section of the bus-bar, the faulty section can be isolated without affecting the supply of other section or sections.

Secondly, one section can be completely shut-down for maintenance and repairs without affecting the supply of the other section (s). Thirdly, by adding a current limiting reactor between the sections the fault level (MVA) can be reduced thereby circuit breakers of lower capacity can be used.

At times air-break isolators were used in place of circuit breakers as bus-sectionalizer due to economy, but it must be remembered that any isolation affected by them must be affected under off-load conditions otherwise it may cause spark. It will be preferable to provide circuit breaker as a sectionalizing switch so that uncoupling of bus-bar may be carried out safely during load transfer.
A double isolation is however necessary when the circuit breaker is employed as sectionalizing switch so that the maintenance work can be carried out on circuit breaker while the bus-bars are alive.

Type # 3. Main and Transfer Bus Arrangement:

This arrangement has been quite frequently adopted whore the loads and continuity of supply justify additional costs. This arrangement provides additional flexibility, continuity of supply and allows periodic maintenance without total shutdown. Such an arrangement is suitable for highly interconnected power network in which flexibility is very important.

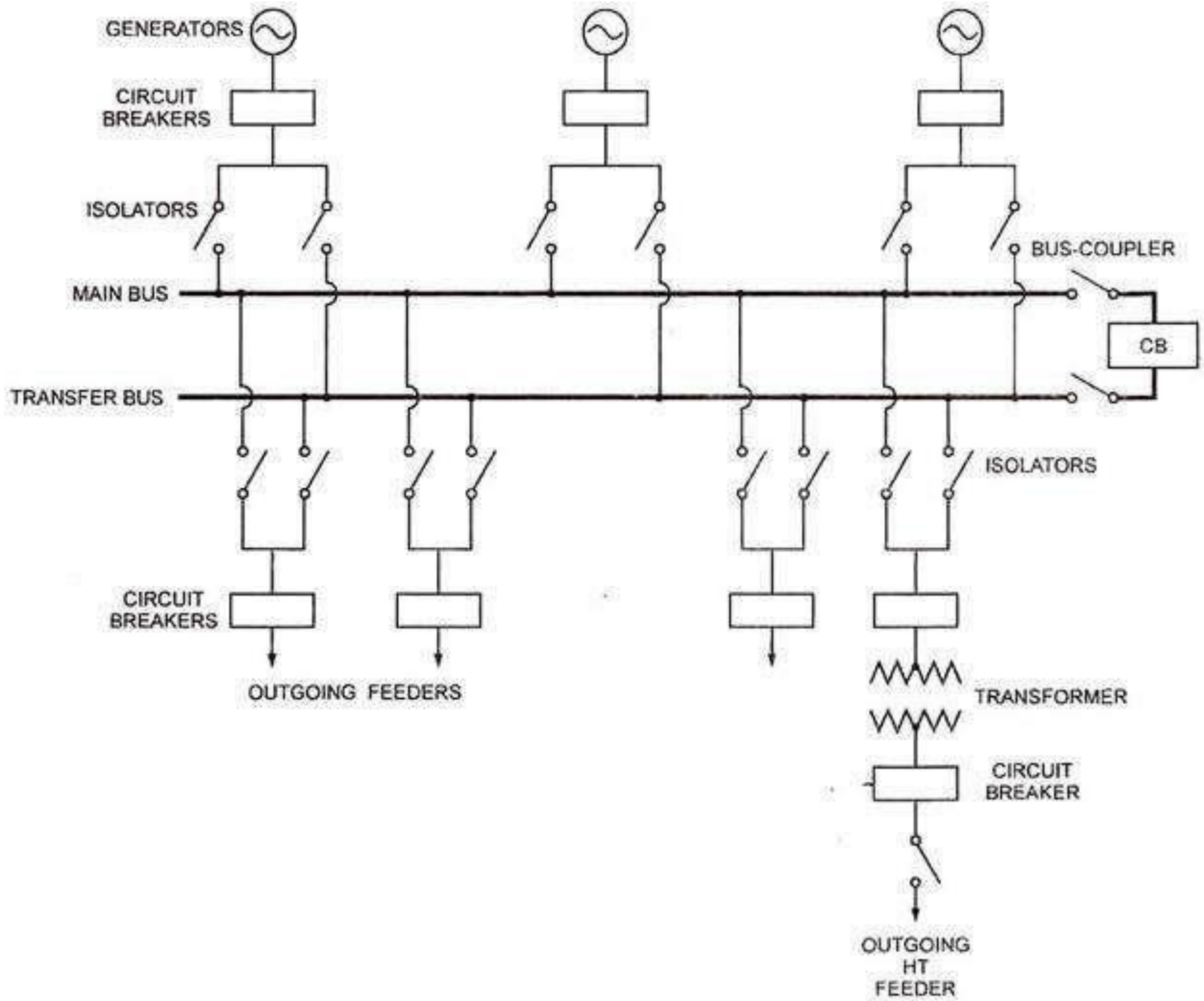


Fig. 1.12. ***Main and Transfer Bus Arrangement***

Figure 1.12 illustrates the main and transfer bus arrangement in a generating station. Such an arrangement consists of two bus-bars, known as main bus-bar and transfer bus-bar used as an auxiliary bus-bar. Each generator and feeder may be connected to either bus-bar with the help of bus coupler which consists of a circuit breaker and isolating switches. In this arrangement a bus coupler is usually used so that change-over from one bus-bar to the other can be carried out under load conditions.

While transferring the load to the reserve bus, the following steps may be taken:

1. Close the bus-coupler (circuit breaker) so as to make the two buses at the same potential.
2. Close isolators on the reserve bus.
3. Open isolators on the main bus.

The load is now transferred to the reserve or auxiliary bus and main bus is disconnected.

The advantages and disadvantages of the arrangement are gives below:

Advantages:

1. It ensures continuity of supply in case of bus fault. In the event of occurrence of fault on one of the bus, the entire load can be transferred to the other bus.
2. Repair and maintenance can be carried out on the main bus without interrupting the supply as the entire load can be transferred to the auxiliary bus.
3. Each load can be supplied from either bus.
4. The infeed and load circuit may be divided into two separate groups if required from operational considerations.
5. The testing and maintenance of feeder circuit breakers can be done by putting them on spare bus, thus keeping the main bus undisturbed.
6. The maintenance cost of substation is lowered.
7. The bus potential can be used for relays.

Disadvantages:

1. Additional costs.
2. The bus is maintained or expanded by transferring all of the circuits to the auxiliary bus depending upon the remote backup relays and breakers for removing faults of the circuits. During this condition a line fault on any of the circuits of the bus would shut-down the entire station.

Type # 4. Double Bus Double Breaker Arrangement:

In very important power stations two circuit breakers are employed for each circuit, as illustrated in Fig. 1.13. Such a bus-bar arrangement does not require any bus-coupler and permits switchover from one bus to the other whenever desired, without interruption. This bus arrangement is very costly and its maintenance cost is also high.

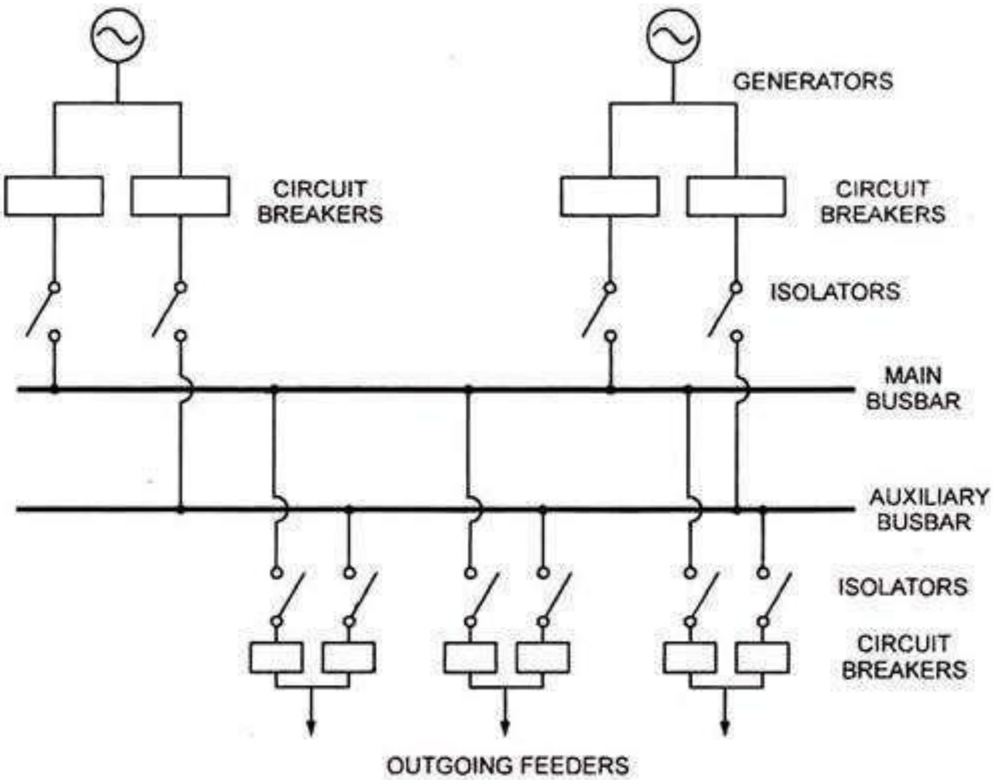


Fig. 1.13. ***Double Bus Double Breaker Arrangement***

This arrangement provides maximum flexibility and reliability as the faults and maintenance interrupt the supply to the minimum. A circuit breaker can be opened for repairs and usual checks and the load can be shifted on the other circuit breaker easily. But because of its higher cost, this arrangement is- seldom used at the substations.

For 400 kV switchyards two main buses plus one transfer bus scheme is preferred. The transfer bus is used for transferring power from main bus 1 to main bus 2 and vice-versa.

Type # 5. Sectionalized Double Bus Arrangement:

In this arrangement duplicate bus-bars are used with the main bus-bar in sections connected through a bus-coupler, as illustrated in Fig. 1.14. In this arrangement, any section of bus-bar can be isolated for maintenance, while any section may be synchronised with any other through the auxiliary bus-bar. Sectionalization of auxiliary bus-bar is not required and would increase the cost if done.

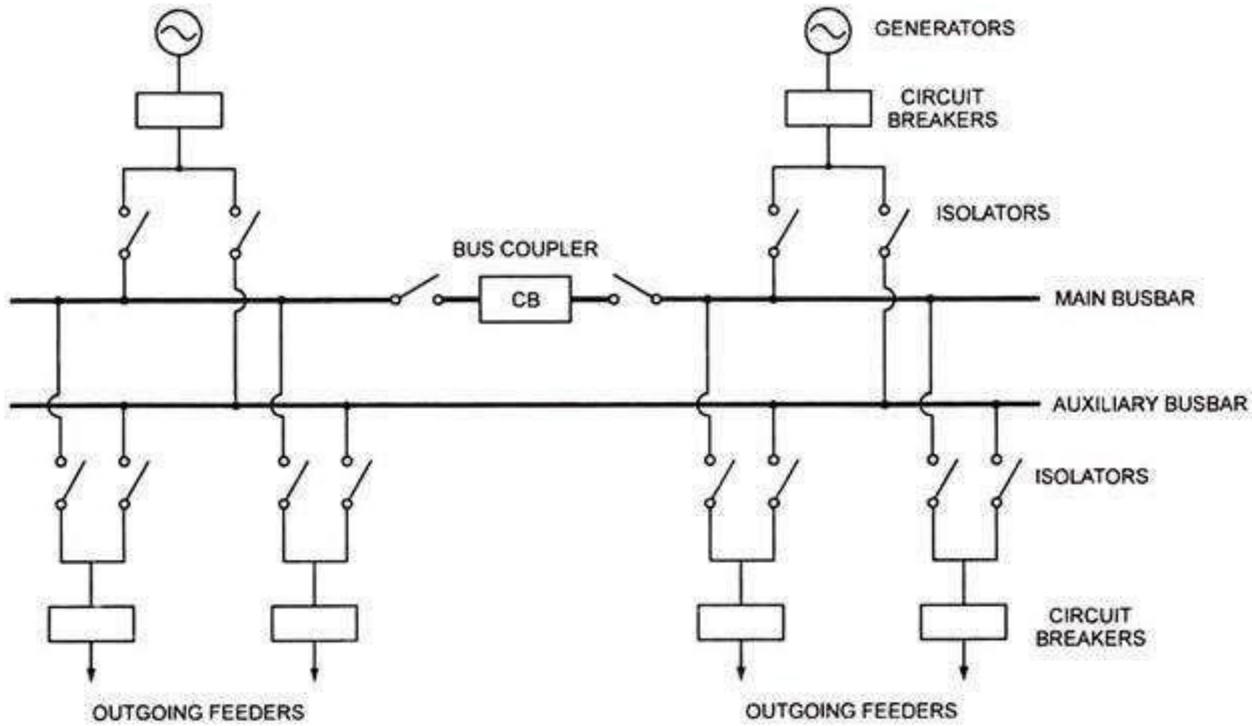


Fig. 1.14. ***Sectionalized Double Bus Arrangement***

Type # 6. One-and a Half Breaker Arrangement:

This is an improvement over double bus double breaker arrangement and it affects saving in the number of circuit breakers. This arrangement needs three circuit breakers for two circuits. The number of circuit breakers per circuit comes out to be 1½ hence the name. This arrangement is preferred in important large stations where power handled per circuit is large.

This arrangement is shown in Fig. 1.15. This arrangement provides high security against loss of supply as a fault in a bus or in a breaker will not interrupt the supply. Possibility of addition of circuits to the system is another advantage. The bus potential can be used as supply to relays, however, at the time of bus fault such potential to the relay should be thrown off.

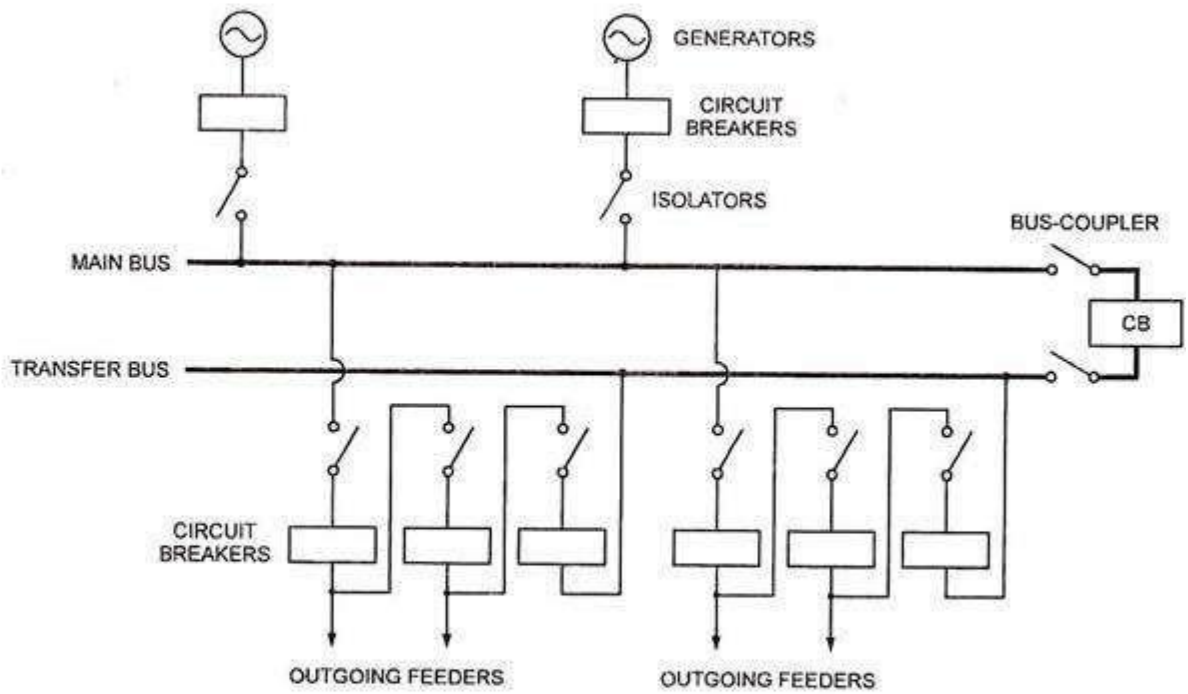


Fig. 1.15. *One-and-a-Half Circuit Breaker Arrangement*

The main drawback of this arrangement is complications in relaying system because at the time of fault two breakers are to be opened. The other drawback is that for maintenance of circuit breakers if the load shedding is not used, two breakers are to be opened in which case the other circuit in the line-up will be operating with one breaker from one bus only. At the time of fault in that bus supply to the other circuit is also interrupted. The maintenance cost is higher.
The above arrangement has been used in important 400 kV and 750 kV substations.

Type # 7. Ring Main Arrangement:

This is an extension of the sectionalized bus-bar arrangement where the ends of the bus-bars are returned upon themselves to form a ring, as illustrated in Fig. 1.16. This arrangement provides greater flexibility as each feeder is supplied by two paths, so that the failure of a section does not cause any interruption of the supply.

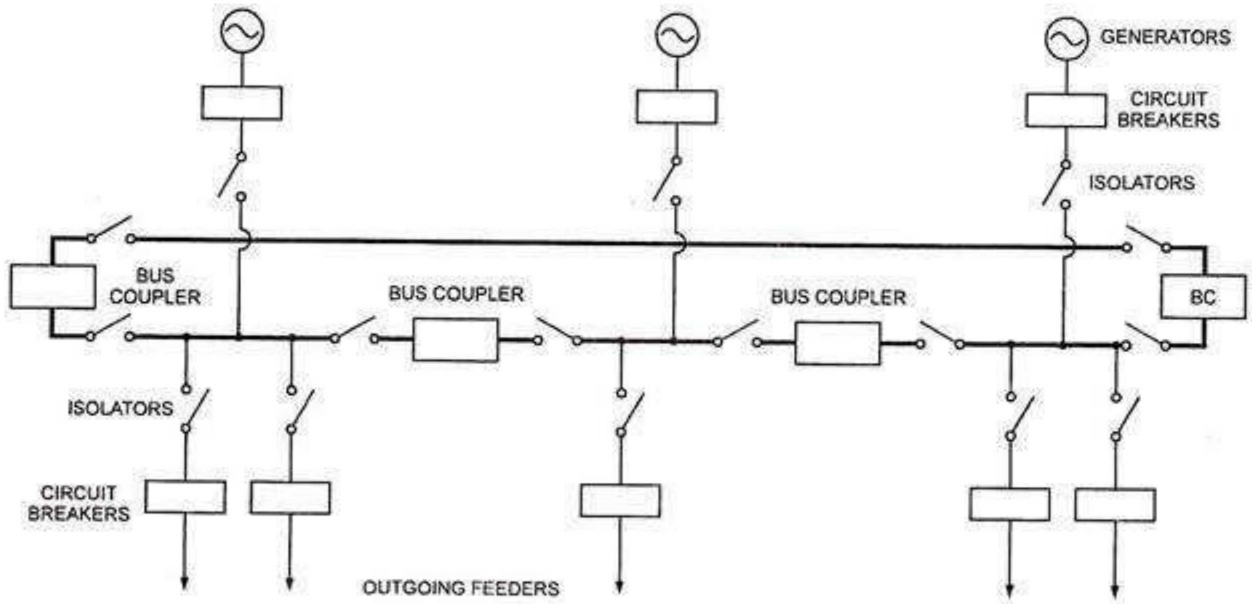


Fig. 1.16. ***Ring Main Arrangement***

The effect of fault in one section is localised to that section alone. The rest of the sections continue to operate. Circuit breakers can be maintained without interrupting the supply. The cost is also not much as the numbers of breakers used are nearly the same as that of a single bus-bar system.

The drawbacks of the system are:

(i) Difficulties in addition of any new circuit in the ring,

(ii) Possibility of overloading of the circuits on opening of any section of the breaker and

(iii) Necessity of supplying potential to relays separately to each of the circuit.

Type # 8. Mesh Arrangement:

This is another arrangement making economical use of circuit breakers in a substation. In this bus-bar arrangement, the circuit breakers are installed in the mesh formed by the buses, as illustrated in Fig. 1.17. The circuits are tapped from the node points of the mesh. In Fig. 1.17 eight circuits are controlled by four circuit breakers.

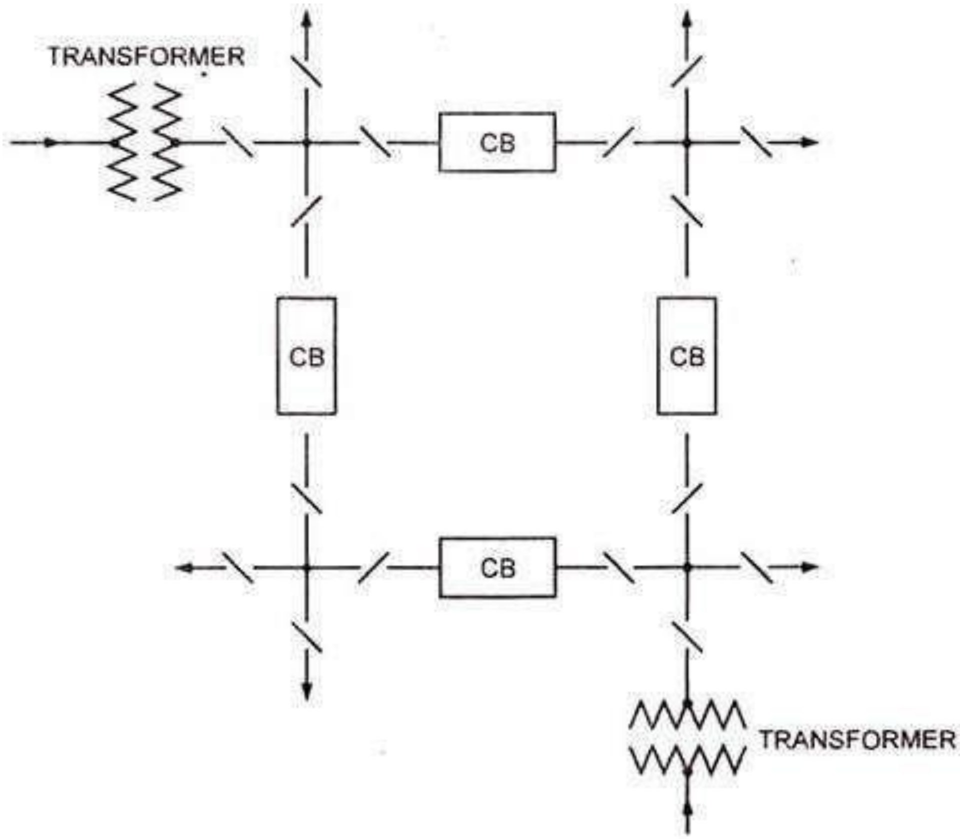


Fig. 1.17. *Mesh Arrangement*

When fault occurs on any section, two circuit breakers have to open, resulting in opening of the mesh. This arrangement provides security against bus-bar faults but lacks switching facility. It needs fewer circuit breakers than that required by one-and a half breaker arrangement. It is preferred for substations having large number of circuits.

UNIT IV
GAS INSULATED SUBSTATIONS

INTRODUCTION ABOUT GIS

A Gas Insulated Substation (GIS) is a high-voltage substation in which the major electrical equipment is enclosed in grounded metal enclosures filled with SF6 gas. GIS technology is widely used in transmission and distribution systems because of its compact size, reliability, and suitability for polluted and urban environments.

A gas insulated substation (GIS) is a HIGH VOLTAGE SUBSTATION in which the major structures are contained in a sealed environment with sulfur hexafluoride gas as the insulating medium.

OR

Gas-insulated high-voltage switchgear (GIS) is a compact metal encapsulated switchgear consisting of high-voltage components such as circuit-breakers and disconnectors, which can be safely operated in confined spaces.

NEED FOR GIS

• Rapid urbanization and scarcity of land.
• Requirement of high reliability.
• Reduction in maintenance requirements.
• Operation in polluted and coastal areas.
• Improved safety and environmental performance.

ADVANTAGES OF GIS

• Requires only 10–20% of the land needed for AIS.
• High dielectric strength due to SF6 gas.
• Compact and modular construction.
• High reliability and availability.
• Minimal maintenance requirements.
• Suitable for polluted and coastal regions.
• Improved personnel safety.
• Low electromagnetic interference.
• Better aesthetics for urban installations.

DISADVANTAGES OF GIS

• High initial cost.
• Specialized maintenance personnel required.
• Gas leakage monitoring is necessary.
• SF6 gas has high global warming potential.
• Expansion may be difficult compared to AIS.

TYPES OF GIS

1 Indoor GIS
Installed inside buildings and widely used in urban areas.

2 Outdoor GIS

Installed in open environments with weatherproof enclosures.

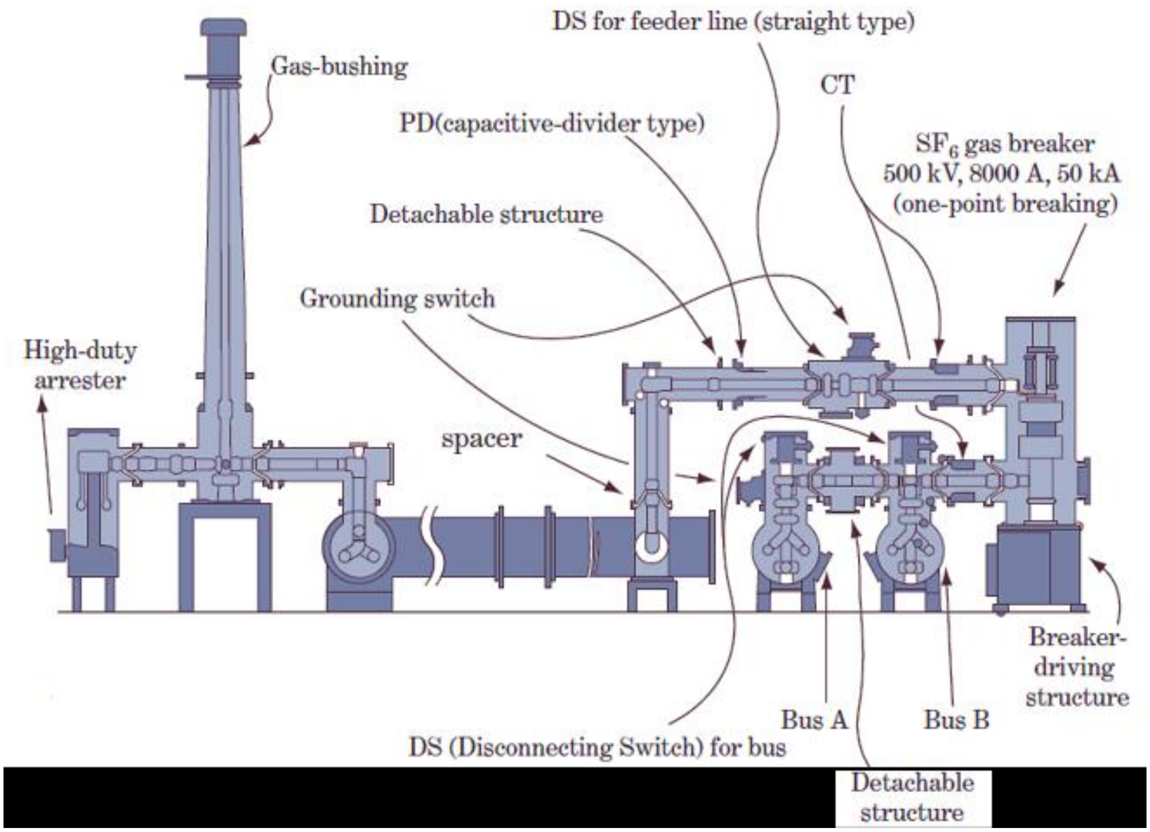
3 Hybrid GIS
Combination of AIS and GIS equipment.

4 Underground GIS
Installed below ground where land availability is limited.

5 Compact GIS
Highly integrated modules with minimum footprint.

MAIN COMPONENTS OF GIS

• Circuit Breakers
• Disconnectors
• Earthing Switches
• Bus Bars
• Current Transformers (CT)
• Voltage Transformers (VT)
• Surge Arresters
• Cable Terminations
• SF6 Gas Monitoring System



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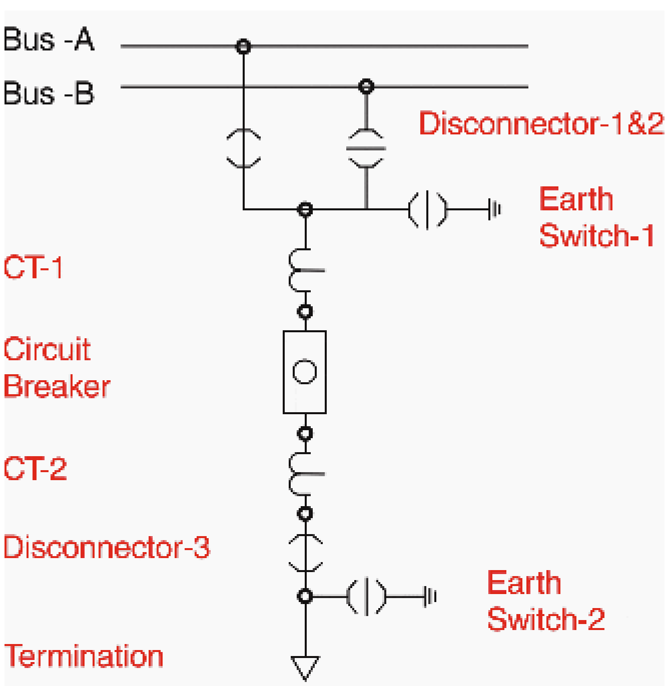
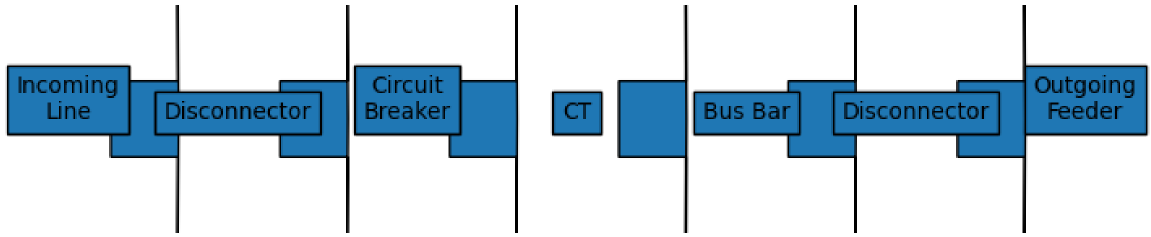
SINGLE LINE DIAGRAM OF GIS





WORKING:

Power enters through incoming lines, passes through switching and protection devices, is connected to the bus bar, and then distributed to outgoing feeders.

BUS BAR ARRANGEMENTS IN GIS

1 Single Bus Bar
Simple and economical arrangement.

2 Double Bus Bar
Provides higher reliability and operational flexibility.

3 Ring Bus Scheme
Improved reliability with alternate power paths.

4 Breaker-and-a-Half Scheme
Used in EHV and UHV substations for maximum reliability.

CONSTRUCTION ASPECTS OF GIS

• Metallic grounded enclosure.
• Aluminum conductors.
• Epoxy resin spacers and insulators.
• SF6 gas-filled compartments.
• Gas-tight sealing arrangement.
• Modular construction.
• Monitoring and control systems.

SF6 GAS PROPERTIES

Heavy, chemically inert, non toxic
• No poisonous effect on the human body but decomposition products are poisonous.
• Color less and odor less
• It is gaseous at normal room temperature and pressure
• Density is about 6.6g/l at 20oC (5 times denser than air)
• Critical temperature is at 45.6oC and can be liquefied by compression
• Very good insulant with high dielectric strength

• SF6 gas is electronegative (tends to attract the free electrons and has the arc quenching property). Because of this main reason SF6 gas is used for arc quenching and insulation medium in circuit breakers.
• Decomposition occurs on the exposure to the electric arc. (Disassociation products will be SF2 and SF4 lower order fluorides)
• Excellent dielectric strength.
• High arc-quenching capability.
• Chemically stable.
• Non-flammable.
• Electronegative gas.
• Thermal conductivity aids cooling.

INSTALLATION OF GIS

Step 1: Site preparation.
Step 2: Foundation construction.
Step 3: Transportation of modules.
Step 4: Mechanical assembly.
Step 5: Electrical interconnections.
Step 6: Vacuum treatment.
Step 7: SF6 gas filling.
Step 8: Testing and commissioning.

TESTING OF GIS

• Insulation Resistance Test.
• High Voltage Test.
• Gas Leakage Test.
• Contact Resistance Test.
• Functional Testing.
• Partial Discharge Test.

MAINTENANCE OF GIS

Routine Maintenance:
• Gas pressure monitoring.
• Visual inspections.
• Leak detection.
• Functional checks.
• Protection relay testing.
• Partial discharge monitoring.

Preventive Maintenance:
• Scheduled inspections.
• Replacement of worn components.
• Calibration of instruments.

COMPARISON OF AIS AND GIS

Sr. No.	Point	Indoor	Outdoor substation
1.	Fault location	Difficult	Easy as all equipments are within view
2.	Time required for erection	More	Less
3.	Future expansion	Difficult	Easy
4.	Amount building material required	Large	Small
5.	Capital cost and cost of switchgear installation	More	Less
6.	Construction work required to be done	More	Less
7.	Operation	Easy	Difficult
8.	Performance of all the operations, maintenance and supervision	In closed atmosphere	In open air in all kinds of weather
9.	Space required	Less	More

APPLICATIONS OF GIS

- Urban substations.
- Underground substations.
- Industrial plants.
- Power stations.
- Offshore platforms.
- Metro rail systems.
- Airports and commercial complexes.

Applications of GIS-72.5 - 1200 kV

- Power transmission
- Integration of renewable power generation units to the grid
- Railways

DESIGN CONSIDERATIONS

- Voltage level.
- Short-circuit rating.
- Bus bar configuration.
- Future expansion.
- Environmental conditions.
- Reliability requirements.
- Economic analysis.

RECENT TRENDS

- Eco-friendly insulating gases.
- Digital GIS monitoring.
- Online condition monitoring.
- Smart substations.
- Integration with renewable energy systems.

UNIT V
AC Distribution Systems

SPESIFICATION OF DISTRIBUTION SYSTEMS:

A distribution system may be classified according to ;

(i) ***Nature of current.*** According to nature of current, distribution system may be classified as **(a) D.C distribution system (*b*) A.C distribution system**.

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

(ii) ***Type of construction.*** According to type of construction, distribution system may be classified as **(*a*) overhead system (*b*) underground system**.

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

(iii) ***Scheme of connection***. According to scheme of connection, the distribution system may be classified as **(*a*) Radial system (*b*) Ring main system (*c*) Inter-connected system.** Each scheme has its own advantages and disadvantages

A.C. Distribution

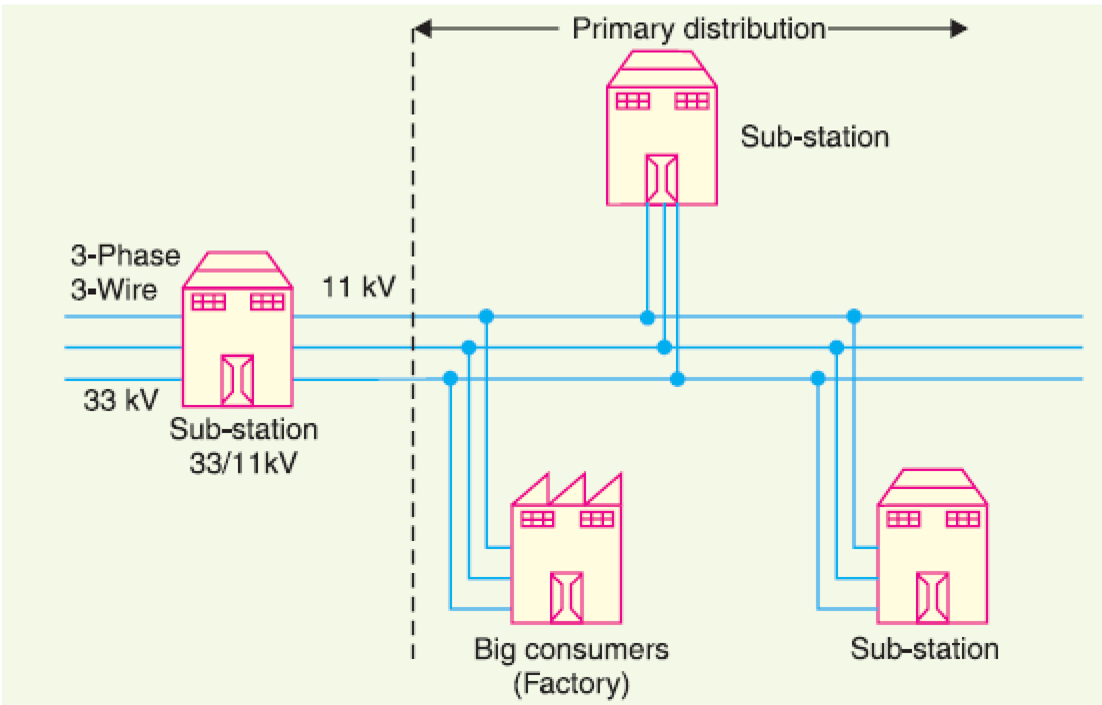
- Now-a-days electrical energy is generated, transmitted and distributed in the form of alternating current.
- Alternating current is preferred to direct current is the fact that alternating voltage can be conveniently changed by current means of a transformer.
- High distribution and distribution voltages have greatly reduced the current in the conductors and the resulting line losses.

  The A.C distribution system is the electrical system between the step down substation fed by the distribution system and the consumers' meters.

The **A.C**. distribution system is classified into

- Primary Distribution System and Secondary Distribution System.

PRIMARY DISTRIBUTION SYSTEM



It is that part of A.C. distribution system which operates at voltages somewhat higher than general utilisation than the average low-voltage consumer uses

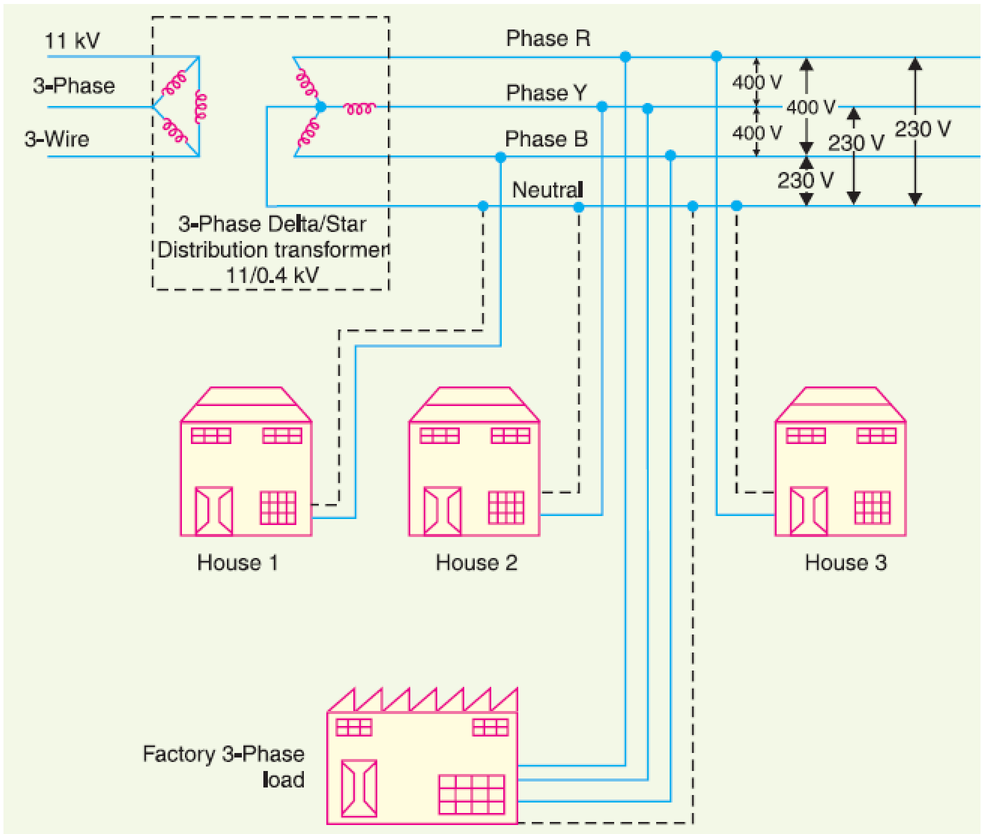
 The most commonly used primary distribution voltages are 11 kV, 6·6kV and 3·3 kV

Primary distribution is carried out by 3-phase, 3-wire system.

 Fig. shows a typical primary distribution system.

Electric power from the generating station is transmitted at high voltage to the substation located in or near the city. At this substation, voltage is stepped down to 11 kV with the help of step-down transformer. Power is supplied to various substations for distribution or to big consumers at this voltage. This forms the high voltage distribution or primary distribution

SECONDARY DISTRIBUTION SYSTEM.



It is that part of A.C. distribution system employs 400/230 V, 3-phase, 4-wire system.

 shows a typical secondary distribution system.

 The primary distribution circuit delivers power to various substations, called distribution substations. The substations are situated near the consumers' localities and contain step down transformers.

 At each distribution substation, the voltage is stepped down to 400 V and power is delivered by 3-phase,4-wire a.c. system.

 The voltage between any two phases is 400 V and between any phase and neutral is 230 V.

The single phase domestic loads are connected between any one phase and the neutral,.

 Motor loads are connected across 3-phase lines directly.

A.C DISTRIBUTION

Advantages

- The power can be generated at high voltages.
- The maintenance of A.C. sub-stations is easy and cheaper.
- The A.C. voltage can be stepped up or stepped down by transformers with ease and efficiency. This permits to transmit power at high voltages and distribute it at safe potentials.

Disadvantages

- The construction of A.C distribution line is more complicated than a D.C distribution line.
- Due to skin effect in the A.C. system, the effective resistance of the line is increased.
- An A.C. line has capacitance. Therefore, there is a continuous loss of power due to charging current even when the line is open.
- An A.C. line requires more copper than a D.C. line.

OVERHEAD VERSUS UNDERGROUND SYSTEM

The distribution system can be overhead or underground.

- Overhead lines are generally mounted on wooden concrete or steel poles which are arranged to carry distribution transformers in addition to the conductors
- The underground system uses conduits and cables and manholes under the surface of streets and sidewalks.

The choice between overhead and underground system depends upon a number of widely differing factors.

(i) Public safety. The underground system is safer than overhead system because all distribution wiring is placed underground and there are little chances of any hazard.

(ii)Initial cost. The underground system is more expensive due to the high cost of trenching, conduits, cables, manholes and other special equipment. The initial cost of an underground system may be five to ten times than that of an overhead system.

(iii) Flexibility. The overhead system is much more flexible than the underground system. In the latter case, manholes, duct lines etc., are permanently placed once installed and the load expansion can only be met by laying new lines. However, on an overhead system, poles, wires, transformers etc., can be easily shifted to meet the changes in load conditions.

(iv) ***Faults.*** The chances of faults in underground system are very rare as the cables are laid underground and are generally provided with better insulation.

(v) ***Appearance.*** The general appearance of an underground system is better as all the distribution lines are invisible. This factor is exerting considerable public pressure on electric supply companies to switch over to underground system.

(vi) ***Fault location and repairs.*** In general, there are little chances of faults in an underground system. However, if a fault does occur, it is difficult to locate and repair on this system. On an overhead system, the conductors are visible and easily accessible so that fault locations and repairs can be easily made.

(vii) ***Current carrying capacity and voltage drop.*** An overhead distribution conductor has a considerably higher current carrying capacity than an underground cable conductor of the same material and cross-section. On the other hand, underground cable conductor has much lower inductive reactance than that of an overhead conductor because of closer spacing of conductors.

(viii) ***Useful life.*** The useful life of underground system is much longer than that of an over head system. An overhead system may have a useful life of 25 years, whereas an underground system may have a useful life of more than 50 years.

(ix) ***Maintenance cost.*** The maintenance cost of underground system is very low as compared with that of overhead system because of fewer chances of faults and service interruptions from wind, ice, and lightning as well as from traffic hazards.

(x) ***Interference with communication circuits.*** An overhead system causes electromagnetic interference with the telephone lines. The power line currents are superimposed on speech currents, resulting in the potential of the communication channel being raised to an undesirable level. However, there is no such interference with the underground system.

REQUIREMENTS OF A DISTRIBUTION SYSTEM

Requirements of a good distribution system are: proper voltage, availability of power on demand and reliability.

(i) **Proper voltage.** One important requirement of a distribution system is that voltage variations at consumer's terminals should be as low as possible. The changes in voltage are generally caused due to the variation of load on the system. Low voltage causes loss of revenue, inefficient lighting and possible burning out of motors. High voltage causes lamps to burn out permanently and may cause failure of other appliances. Therefore, a good distribution system should ensure that the voltage variations at consumer's terminals are within permissible limits. The statutory limit of voltage variations is ± 6% of the rated value at the consumer's terminals. Thus, if the declared voltage is 230 V, then the highest voltage of the consumer should not exceed 244 V while the lowest voltage of the consumer should not be less than 216 V.

(ii) **Availability of power on demand.** Power must be available to the consumers in any amount that they may require from time to time. For example, motors may be started or shut down, lights may be turned on or off, without advance warning to the electric supply company. As electrical energy cannot be stored, therefore, the distribution system must be capable of supplying load demands of the consumers. This necessitates that operating staff must continuously study load patterns to predict in advance those major load changes that follow the known schedules.

(iii) **Reliability.** Modern industry is almost dependent on electric power for its operation. Homes and office buildings are lighted, heated, cooled and ventilated by electric power. This calls for reliable service. Unfortunately, electric power, like everything else that is man-made, can never be absolutely reliable. However, the reliability can be improved to a considerable extent by

AC Distribution Calculations:

AC Distribution Calculations differ from those of D.C. distribution in the following respects:

- In case of D.C. system, the voltage drop is due to resistance alone. However, in A.C. system, the voltage drops are due to the combined effects of resistance, inductance and capacitance.
- In a D.C. system, additions and subtractions of currents or voltages are done arithmetically but in case of A.C. system, these operations are done vectorially.
- In an A.C. system, power factor (p.f.) has to be taken into account. Loads tapped off form the distributor are generally at different power factors.
- There are two ways of referring power factor viz
- It may be referred to supply or receiving end voltage which is regarded as the reference
- It may be referred to the voltage at the load point itself.

There are several ways of solving AC Distribution Calculations. However, symbolic notation method has been found to be most convenient for this purpose. In this method, voltages, currents and impedances are expressed in complex notation and the calculations are made exactly as in D.C. distribution.

Methods of Solving AC Distribution Problems:

In AC Distribution Calculations, power factors of various load currents have to be considered since currents in different sections of the distributor will be the vector sum of load currents and not the arithmetic sum. The power factors of load currents may be given

(i) w.r t. receiving or sending end voltage or
(ii) w.r.t. to load voltage itself. Each case shall be discussed separately.

(i) **Power Factors Referred To Receiving End Voltage:** Consider an a.c. distributor AB with concentrated loads of I1 and I2 tapped off at points C and B as shown in Fig. 14.1. Taking the receiving end voltage VB as the reference vector, let lagging power factors at C and B be cos Φ1 and cos Φ2 w.r.t. VB. Let R1,X1 and R2,X2 be the resistance and reactance of sections AC and CB of the distributor.

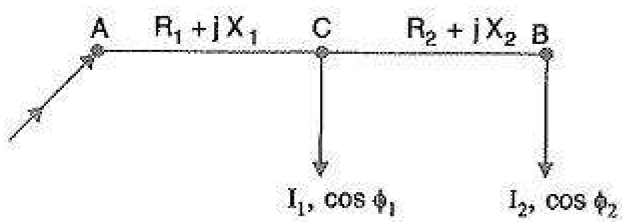


Fig. 14.1

Impedance of section AC, $\overrightarrow{Z_{AC}} = R_1 + jX_1$

Impedance of section CB, $\overrightarrow{Z_{CB}} = R_2 + jX_2$

Load current at point C, $\overrightarrow{I_1} = I_1(\cos\phi_1 - j\sin\phi_1)$

Load current at point B, $\overrightarrow{I_2} = I_2(\cos\phi_2 - j\sin\phi_2)$

Current in section CB, $\overrightarrow{I_{CB}} = \overrightarrow{I_2} = I_2(\cos\phi_2 - j\sin\phi_2)$

Current in section AC, $\overrightarrow{I_{AC}} = \overrightarrow{I_1} + \overrightarrow{I_2}$

$$= I_1(\cos\phi_1 - j\sin\phi_1) + I_2(\cos\phi_2 - j\sin\phi_2)$$

Voltage drop in section CB, $\overrightarrow{V_{CB}} = \overrightarrow{I_{CB}}\,\overrightarrow{Z_{CB}} = I_2(\cos\phi_2 - j\sin\phi_2)(R_2 + jX_2)$

Voltage drop in section AC, $\overrightarrow{V_{AC}} = \overrightarrow{I_{AC}}\,\overrightarrow{Z_{AC}} = \left(\overrightarrow{I_1} + \overrightarrow{I_2}\right) Z_{AC}$

$$= [I_1(\cos\phi_1 - j\sin\phi_1) + I_2(\cos\phi_2 - j\sin\phi_2)]\,[R_1 + jX_1]$$

Sending end voltage, $\overrightarrow{V_A} = \overrightarrow{V_B} + \overrightarrow{V_{CB}} + \overrightarrow{V_{AC}}$

Sending end current, $\overrightarrow{I_A} = \overrightarrow{I_1} + \overrightarrow{I_2}$

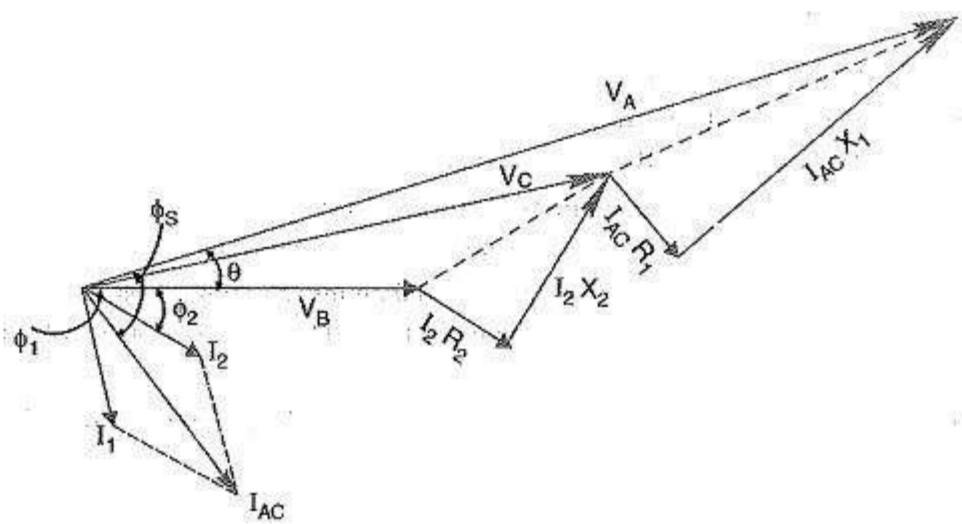


Fig. 14.2

The vector diagram of the AC Distribution Calculations under these conditions is shown in Fig. 14.2. Here, the receiving end voltage VB is taken as the reference vector. As power factors of loads are given w.r.t. VB, therefore, I1 and I2 lag behind VB by Φ1 and Φ2 respectively.

(ii) **Power Factors Referred To Respective Load Voltages**: Suppose the power factors of loads in the previous Fig. 14.1 are referred to their respective load voltages. Then Φ1 is the phase angle between VC and I1 and Φ2 is the phase angle between VB and I2. The vector diagram under these conditions is shown in Fig. 14.3.

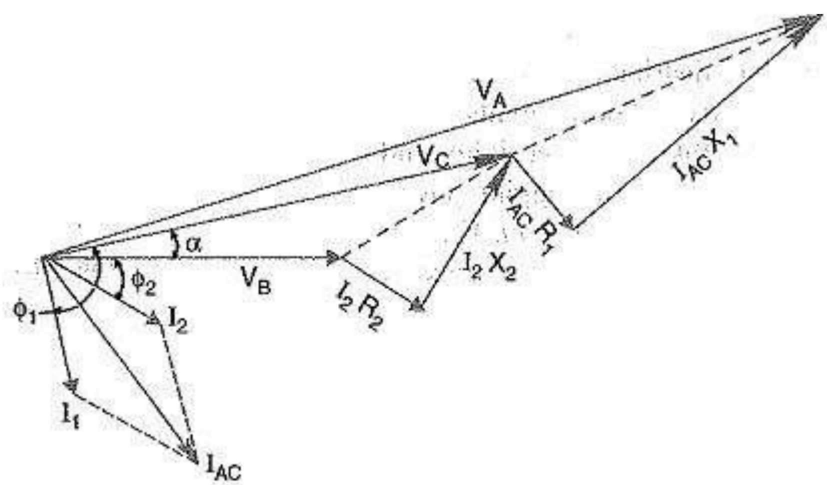


Fig. 14.3

$$\text{Voltage drop in section } CB = \vec{I_2}\,\vec{Z_{CB}} = I_2 (\cos \phi_2 - j \sin \phi_2)(R_2 + jX_2)$$

$$\text{Voltage at point } C = \vec{V_B} + \text{Drop in section } CB = V_C \angle \alpha \text{ (say)}$$

$$\vec{I_1} = I_1 \angle -\phi_1 \quad \textit{w.r.t.} \text{ voltage } V_C$$

$$\vec{I_1} = I_1 \angle -(\phi_1 - \alpha) \quad \textit{w.r.t.} \text{ voltage } V_B$$

$$\vec{I_1} = I_1 [\cos(\phi_1 - \alpha) - j \sin(\phi_1 - \alpha)]$$

$$\vec{I_{AC}} = \vec{I_1} + \vec{I_2}$$

Introduction

Power generated in power stations pass through large and complex networks like transformers, overhead lines, cables and other equipment and reaches at the end users.

It is fact that the unit of electric energy generated by Power Station does not match with the units distributed to the consumers. Some percentage of the units is lost in the distribution network.

This difference in the generated and distributed units is known as Transmission and Distribution loss. Transmission and Distribution loss are the amounts that are not paid for by users.

T&D Losses = (Energy Input to feeder(Kwh) – Billed Energy to Consumer(Kwh)) / Energy Input kwh x 100

There are two types of Transmission and Distribution Losses:

1. **Technical Losses**
2. **Non Technical Losses** (Commercial Losses)

1. Technical Losses

The technical losses are due to energy dissipated in the conductors, equipment used for transmission line, transformer, sub transmission line and distribution line and magnetic losses in transformers. Technical losses are normally **22.5%**, and directly depend on the network characteristics and the mode of operation.

The major amount of losses in a power system is in primary and secondary distribution lines. While transmission and sub-transmission lines account for only about 30% of the total losses. Therefore the primary and secondary distribution systems must be properly planned to ensure within limits.

- The unexpected load increase was reflected in the increase of technical losses above the normal level
- Losses are inherent to the distribution of electricity and cannot be eliminated.

There are two Type of Technical Losses.

1. Permanent / Fixed Technical losses

- Fixed losses do not vary according to current. These losses take the form of heat and noise and occur as long as a transformer is energized
- Between 1/4 and 1/3 of technical losses on distribution networks are fixed losses. Fixed losses on a network can be influenced in the ways set out below
- Corona Losses
- Leakage Current Losses
- Dielectric Losses
- Open-circuit Losses
- Losses caused by continuous load of measuring elements
- Losses caused by continuous load of control elements

2. Variable Technical losses

Variable losses vary with the amount of electricity distributed and are, more precisely, proportional to the square of the current. Consequently, a 1% increase in current leads to an increase in losses of more than 1%.

- Between 2/3 and 3/4 of technical (or physical) losses on distribution networks are variable Losses.
- By increasing the cross sectional area of lines and cables for a given load, losses will fall. This leads to a direct trade-off between cost of losses and cost of capital expenditure. It has been suggested that optimal average utilization rate on a distribution network that considers the cost of losses in its design could be as low as 30 per cent.
- Joule losses in lines in each voltage level
- Impedance losses
- Losses caused by contact resistance.

Main Reasons for Technical Losses

1. Lengthy Distribution lines

In practically **11 KV** and **415 volts lines**, in rural areas are extended over long distances to feed loads scattered over large areas. Thus the primary and secondary distributions lines in rural areas are largely radial laid usually extend over long distances.

This results in high line resistance and therefore high I^2R losses in the line.

- Haphazard growths of sub-transmission and distribution system in to new areas.
- Large scale rural electrification through long 11kV and LT lines.

2. Inadequate Size of Conductors of Distribution lines

The size of the conductors **should be selected on the basis of KVA x KM capacity of standard conductor for a required voltage regulation**, but rural loads are usually scattered and generally fed by radial feeders. The conductor size of these feeders should be adequate.

3. Installation of Distribution transformers away from load centers

Distribution Transformers are not located at Load center on the Secondary Distribution System.

In most of case Distribution Transformers are not located centrally with respect to consumers. Consequently, the farthest consumers obtain an extremity low voltage even though a good voltage levels maintained at the transformers secondary.

This again leads to higher line losses. (The reason for the line losses increasing as a result of decreased voltage at the consumers end therefore in order to reduce the voltage drop in the line to the farthest consumers, the distribution transformer should be located at the load center to keep voltage drop within permissible limits.)

4. Low Power Factor of Primary and secondary distribution system

In most LT distribution circuits normally the Power Factor ranges from 0.65 to 0.75. A low Power Factor contributes towards high distribution losses.

For a given load, if the Power Factor is low, the current drawn in high And the losses proportional to square of the current will be more. Thus, line losses owing to the poor PF can be reduced by improving the Power Factor.

This can be done by application of shunt capacitors.

- Shunt capacitors can be connected either in secondary side (11 KV side) of the 33/11 KV power transformers or at various point of Distribution Line.

- The optimum rating of capacitor banks for a distribution system is 2/3rd of the average KVAR requirement of that distribution system.
- The vantage point is at 2/3rd the length of the main distributor from the transformer.
- A more appropriate manner of improving this PF of the distribution system and thereby reduce the line losses is to connect capacitors across the terminals of the consumers having inductive loads.
- By connecting the capacitors across individual loads, the line loss is reduced from 4 to 9% depending upon the extent of PF improvement.

5. Bad Workmanship

Bad Workmanship contributes significantly role towards increasing distribution losses.

Joints are a source of power loss. Therefore the number of joints should be kept to a minimum. Proper jointing techniques should be used to ensure firm connections. Replacement of deteriorated wires and services should also be made timely to avoid any cause of leaking and loss of power.

6. Feeder Phase Current and Load Balancing>

One of the easiest loss savings of the distribution system is balancing current along three-phase circuits.

Feeder phase balancing also tends to balance voltage drop among phases giving three-phase customers less voltage unbalance. Amperage magnitude at the substation doesn't guarantee load is balanced throughout the feeder length.

Feeder phase unbalance may vary during the day and with different seasons. Feeders are usually considered "balanced" when phase current magnitudes are within 10.Similarly, balancing load among distribution feeders will also lower losses assuming similar conductor resistance. This may require installing additional switches between feeders to allow for appropriate load transfer.

Bifurcation of feeders according to Voltage regulation and Load.

7. Load Factor Effect on Losses

Power consumption of customer varies throughout the day and over seasons.

Residential customers generally draw their highest power demand in the evening hours. Same commercial customer load generally peak in the early afternoon. Because current level (hence, load) is the primary driver in distribution power losses, keeping power consumption more level throughout the day will lower peak power loss and overall energy losses.

Load variation is Called load factor and It varies from 0 to 1.

Load Factor = Average load in a specified time period / peak load during that time period.

For example, for 30 days month (720 hours) peak Load of the feeder is 10 MW. If the feeder supplied a total energy of 5,000 MWH, the load factor for that month is (5,000 MWh)/ (10MW x 720) =0.69.

Lower power and energy losses are reduced by raising the load factor, which, evens out feeder demand variation throughout the feeder.

The load factor has been increase by offering customers "time-of-use" rates. Companies use pricing power to influence consumers to shift electric-intensive activities during off-peak times (such as, electric water and space heating, air conditioning, irrigating, and pool filter pumping).

With financial incentives, some electric customers are also allowing utilities to interrupt large electric loads remotely through radio frequency or power line carrier during periods of peak use. Utilities can try to design in higher load factors by running the same feeders through residential and commercial areas.

8. Transformer Sizing and Selection

Distribution transformers use **copper conductor windings** to induce a magnetic field into a grain-oriented silicon steel core. **Therefore, transformers have both load losses and no-load core losses.**

Transformer copper losses vary with load based on the resistive power loss equation (P loss = I^2R). For some utilities, economic transformer loading means loading distribution transformers to capacity-or slightly above capacity for a short time-in an effort to minimize capital costs and still maintain long transformer life.

However, since peak generation is usually the most expensive, **total cost of ownership (TCO)** studies should take into account the cost of peak transformer losses. Increasing distribution transformer capacity during peak by one size will often result in lower total peak power dissipation-more so if it is overloaded.

Transformer no-load excitation loss (iron loss) occurs from a changing magnetic field in the transformer core whenever it is energized. Core loss varies slightly with voltage but is essentially considered constant. Fixed iron loss depends on transformer core design and steel lamination molecular structure. Improved manufacturing of steel cores and introducing amorphous metals (such as metallic glass) have reduced core losses.

9. Balancing 3 phase loads

Balancing 3-phase loads periodically throughout a network can reduce losses significantly. It can be done relatively easily on overhead networks and consequently offers considerable scope for cost effective loss reduction, given suitable incentives.

10. Switching off transformers

One method of **reducing fixed losses** is to switch off transformers in periods of low demand. If two transformers of a certain size are required at a substation during peak periods, only one might be required during times of low demand so that the other transformer might be switched off in order to reduce fixed losses.

This will produce some **offsetting increase in variable losses** and might affect security and quality of supply as well as the operational condition of the transformer itself. However, these trade-offs will not be explored and optimized unless the cost of losses are taken into account.

11. Other Reasons for Technical Losses

- Unequal load distribution among three phases in L.T system causing high neutral currents.
- leaking and loss of power
- Over loading of lines.
- Abnormal operating conditions at which power and distribution transformers are operated
- Low voltages at consumer terminals causing higher drawl of currents by inductive loads.
- Poor quality of equipment used in agricultural pumping in rural areas, cooler air-conditioners and industrial loads in urban areas.

SYSTEM GROUNDING

The process of connecting some electrical part of the power system (e.g. neutral point of a star-connected system, one conductor of the secondary of a transformer etc.) to earth (i.e. soil) is called System Grounding. The system grounding has assumed considerable importance in the fast expanding power system. By adopting proper schemes of system grounding, we can achieve many advantages including protection, reliability and safety to the power system network. But before discussing the various aspects of neutral grounding, it is desirable to give two examples to appreciate the need of system grounding. (i) Fig. 26.5 (i) shows the primary winding of a distribution transformer connected between the line and neutral of a 11 kV line. If the secondary conductors are ungrounded, it would appear that a person could touch either secondary conductor without harm because there is no ground return. However, this is not true. Referring to Fig. 26.5, there is capacitance C1 between primary and secondary and capacitance C2 between secondary and ground. This capacitance coupling can produce a high voltage between the secondary lines and the ground.

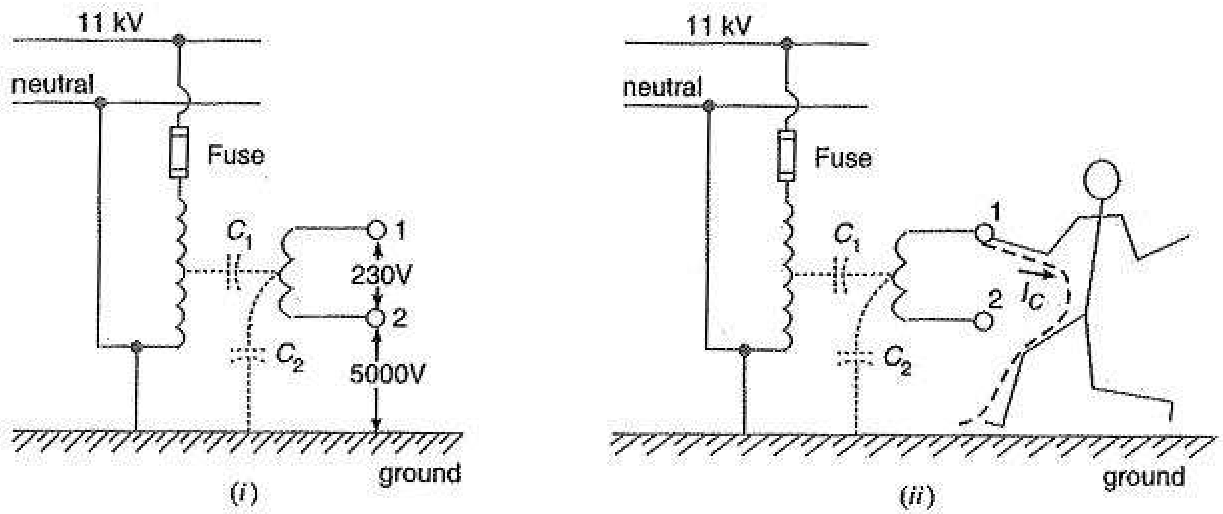


Fig. 26.5

Depending upon the relative magnitudes of C1 and C2, it may be as high as 20% to 40% of the primary voltage. If a person touches either one of the secondary wires, the resulting capacitive current IC flowing through the body could be dangerous even in case of small transformers [See Fig. 26.5(U)]. For example, if IC is only 20 mA, the person may get a fatal electric shock. If one of the secondary conductors is grounded, the capacitive coupling almost reduces to zero and so is the capacitive current IC As a result, the person will experience no electric shock. This explains the importance of system grounding.

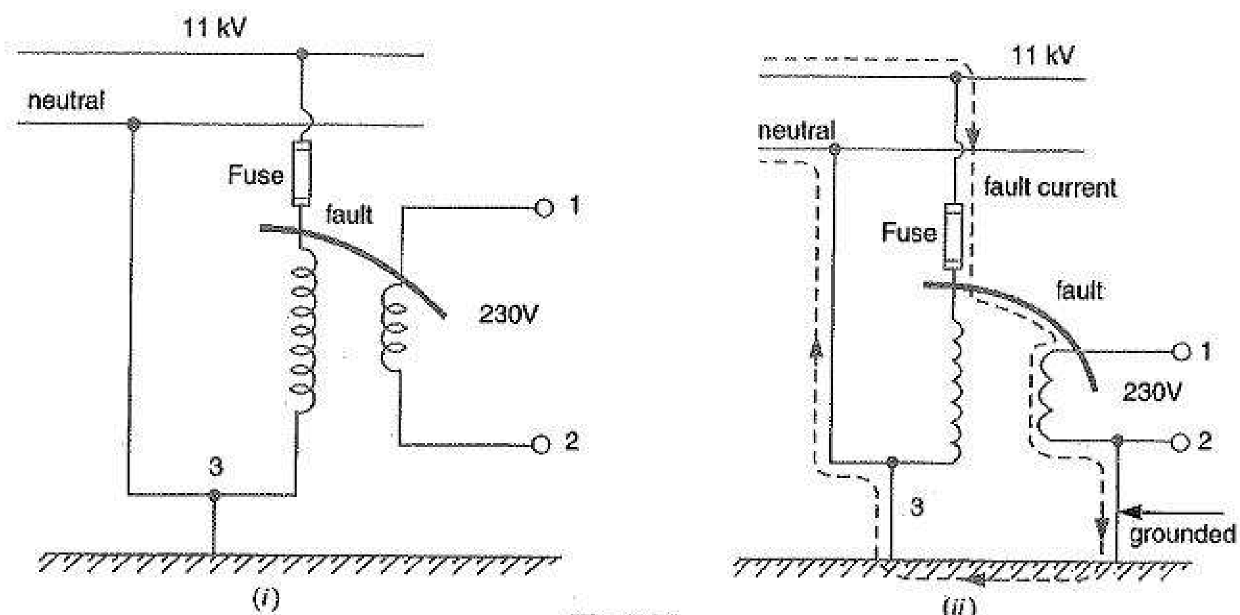


Fig. 26.6

(ii) Let us now turn to a more serious situation. Fig. 26.6 (i) shows the primary winding of a distribution transformer connected between the line and neutral of a 11 kV line. The secondary conductors are ungrounded. Suppose that the high voltage line (11 kV in this case) touches the 230 V conductor as shown in Fig. 26.6 (i). This could be caused by an internal fault in the transformer or by a branch or tree falling across the 11 kV and 230 V lines. Under these circumstances, a very high voltage is imposed between the secondary conductors and ground. This would immediately puncture the 230 V insulation, causing a Massive flashover. This flashover could occur anywhere on the secondary network, possibly inside a home or factory. Therefore, ungrounded secondary in this case is a potential fire hazard and may produce grave accidents under abnormal conditions. If one of the secondary lines is grounded as shown in Fig. 26.6(ii), the accidental contact between a 11 kV conductor and a 230 V conductor produces a dead short. The short-circuit current (Le. fault current) follows the dotted path shown in Fig. 26.6 (ii). This large current will blow the fuse on the 11 kV side, thus disconnecting the transformer and secondary distribution system from the 11 kV line. This explains the importance of system grounding in the line of the power system.