Chapter - 1

General transmission & Distribution

Generation of electricity

STEAM / THERMAL POWER STATION :-

CHOICE OF SITE :-

1. SUPPLY OF FUEL :-
The steam power station should be located near coal mines so that transportation cost of fuel is minimum.

2. Availability of water :-
A huge amount of water is required for the condenser for which it is essential that the plant should be located at the bank of a river or near a canal to ensure continuous supply of water.

3. Transportation of facilities :-
A modern steam power station often requires the transportation of material and machinery. Therefore adequate transportation facilities by rail or road should exist.

4. Cost and type of land :-
The steam power station should be located at a place where land is cheap and further extension if necessary is possible.

5. Nearness to load centres :-
In order to reduce transmission cost the plant should be located near the center of load.

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6. Distance from populated area:-
As huge amount of coal is burnt in a steam power plant due to which smoke and fumes pollutes the surrounding area this necessitates that plant should be located at a considerable distance from the populated areas.

Main units of plant:-

1. Coal storage plant:-
Coal is transported to the power station by road or rail and is stored in coal storage plant.

2. Coal handling plant:-
From the coal plant coal is delivered to the coal handling plant where it is pulverised for rapid combustion with out using excess amount of air.

3. Ash storage plant:-
The coal is burnt in the boiler and the ash produced after the complete combustion of coal is removed to the ash handling plant.

4. Ash handling plant:-
The ash from ash handling plant is then delivered to the ash storage plant for subsequent use as fertilizer etc.

5. Boiler:-
The heat of combustion of coal in the boiler is utilized to convert water into steam at very high temperature and pressure. The flue gases from the boiler makes their journey through superheater, economizer, air pre-heater & are finally exhausted to the atmosphere through the

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chimney.

6. Superheater:-
The steam produced in the boiler is wet and is passed through super heater where it is dried and super heated.

7. Economiser:-
An economizer is essentially a feed water heater and derives heat from the flue gases for the purpose.

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

9. Forced Draught fan:-
It draws air from atmosphere which is supplied to the boiler for effective combustion.

10. Induced Draught Fan:-
It draws the flue gas and sends to chimney.

11. Chimney:-
The hot flue gases go to the atmosphere through chimney.

12. Steam Turbine:-
The dry and super heated steam from the super heater is fed to the steam turbine which converts the heat energy of steam to mechanical energy.

13. Alternator:-
The alternator converts the mechanical energy to steam turbine to electrical energy.

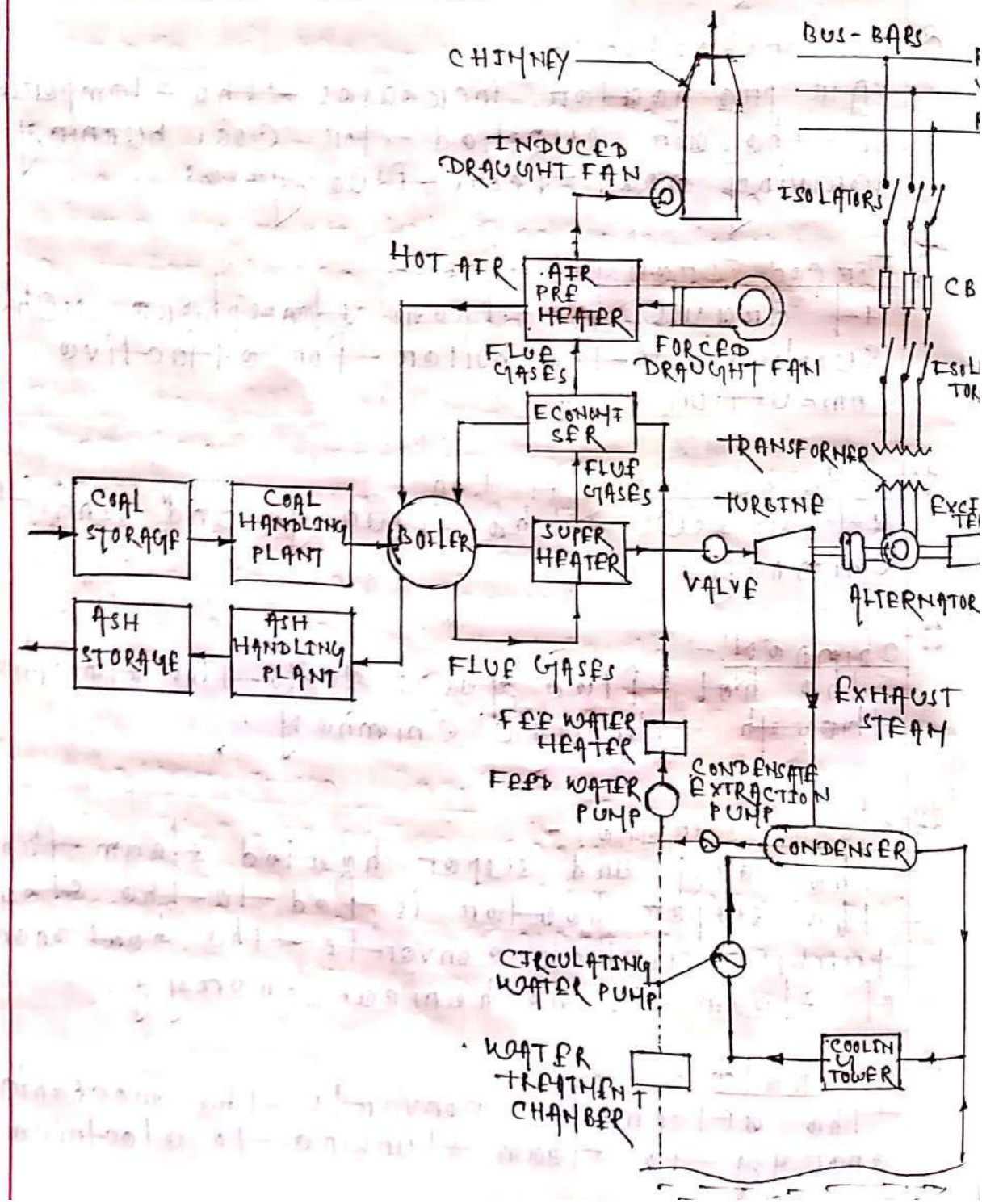
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14 Condenser:-

In order to improve the efficiency of the plant the steam exhausted from the turbine is condensed by means of a condenser. The condensate from the condenser is used as feed water to the boiler.

15 Cooling tower:-

The cooling tower provides a cooling arrangement for the feed water to be reused in boiler.



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Working of thermal power plant :-

When the water from condenser is fed to the boiler through economiser it remains a little hot. The boiler is a extremely heated chamber because of a continuous burning of coal in presence of air injected by F.D fan through pre-heater.

Advantages :-

→ The fuel (i.e. coal) used is quite cheap.
→ Less initial cost as compared to other generating stations.
→ It can be installed at any place and the coal can be transported by rail / Road.
→ It requires less space as compared to hydro-electric power station.

Disadvantages :-

→ It pollutes air / atmosphere due to smoke / fumes.
→ Running cost is higher than hydro power plant.

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Hydro-electric power station:-

Choice of site:-

1. **Availability of water:-**
Since the primary requirement of a hydro-electric power station is the availability of huge quantity of water at a good head this requirement is very essential.

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 through the year.

3. **Cost and type of Land:-**
The Land for the construction of 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 facility:-**
The site selected should be accessible by Rail and Road so that necessary equipment and machineries be easily transported.

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MAIN CONSTITUENTS OF PLANT :-

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

2- **spillways :-**
There are times when the river flow exceeds the storage capacity of the reservoir. In order to discharge the surplus water from the storage reservoir into the river on the down-stream side of the dam, spill ways are used.

3- **Head Works :-**
The head works consists of the diversion structures at the head of an intake. They generally include booms and racks for diverting floating debris, sluices for by-passing debris, sediments and valves for controlling the flow of water to the turbine.

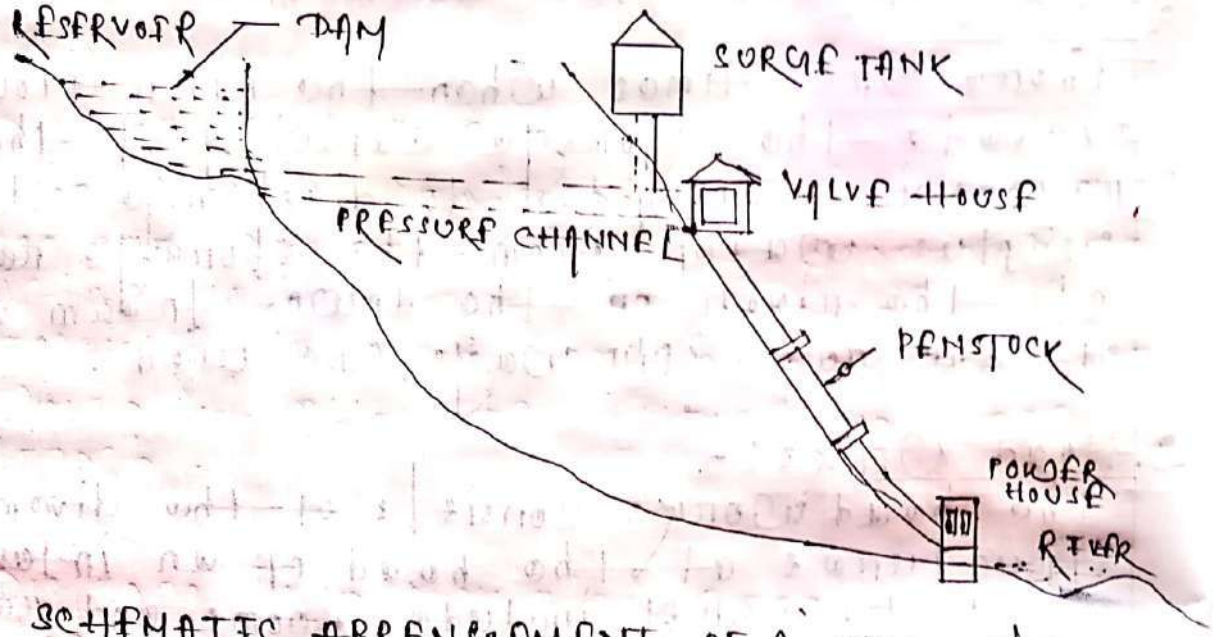
4. **Surge Tank :-**
For close conduits abnormal pressure may cause damage to the conduit leading from head works to penstock, surge tank acts as a protection for such situation.

5- **penstocks :-**
penstocks are open or close conduits which carry water to the turbines. They are generally made of reinforced concrete or steel.

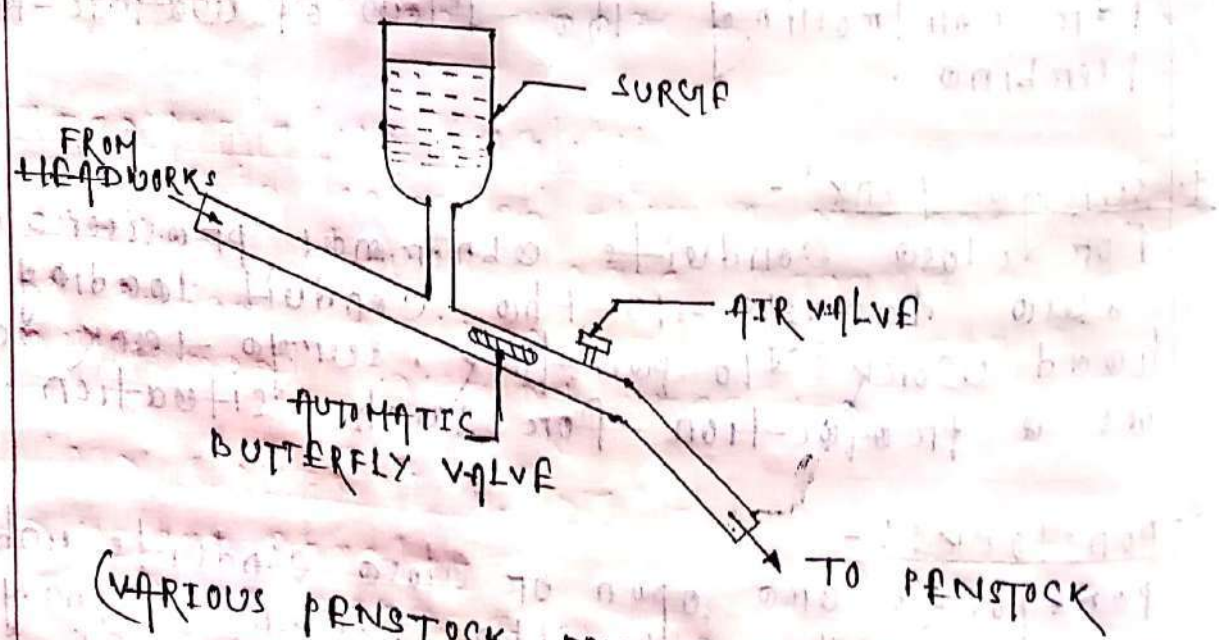
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6. Water turbines:-
Water turbines are used to convert the energy of falling water into mechanical energy.

7. Alternator:-
The alternator converts the mechanical energy of turbine to electrical energy.



SCHEMATIC ARRENGEMENT OF A HYDRO-ELECTRIC PLANT.



(VARIOUS PENSTOCK PROTECTION DEVICE)

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Working of Hydro-Electric power plant:-

When the water from reservoir is allowed to get released through pressure channel, it reaches the valve house. The surge tank is provided in order to safe guard the extra back-thrust of water causing heavy damage to penstock. The valve house controls the amount of water that will flow to the power house turbines through the large sized penstocks. Inside the power house the water turbine convert the potential energy of water with sufficient head to kinetic energy i.e. mechanical energy which in turn acts as a prime-mover for the alternator as before and generates electrical energy.

Advantages:-

- It requires no fuel as water is used for the generation of electrical energy.
- It is quite neat and clean as no smoke or ash is produced.
- Running cost is very less as water is used

Disadvantages:-

- It involves high capital lost due to construction of dams.
- Generation depends on average rainfall round the year.
- High cost of transmission as these plants are located in hilly areas quite far off from localities.

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NUCLEAR POWER STATION:-

CHOICE OF SITE:-

1- **Availability of water:-**
A huge amount of water is required for the condenser for which it is essential that the plant should be located at the bank of a river or near a canal to ensure continuous supply of water.

2- **Disposal of waste:-**
The waste produced by fission in a nuclear power station is generally radioactive which must be disposed off properly to avoid health hazards for which it must be buried in deep trench.

3- **Distance from populated area:-**
The site for setting up a nuclear power station should be quite away from populated areas.

4- **Transportation Facility:-**
The site selected for a nuclear power station should have adequate facilities in order to transport the heavy equipment during erection.

MAIN UNITS OF PLANT:-

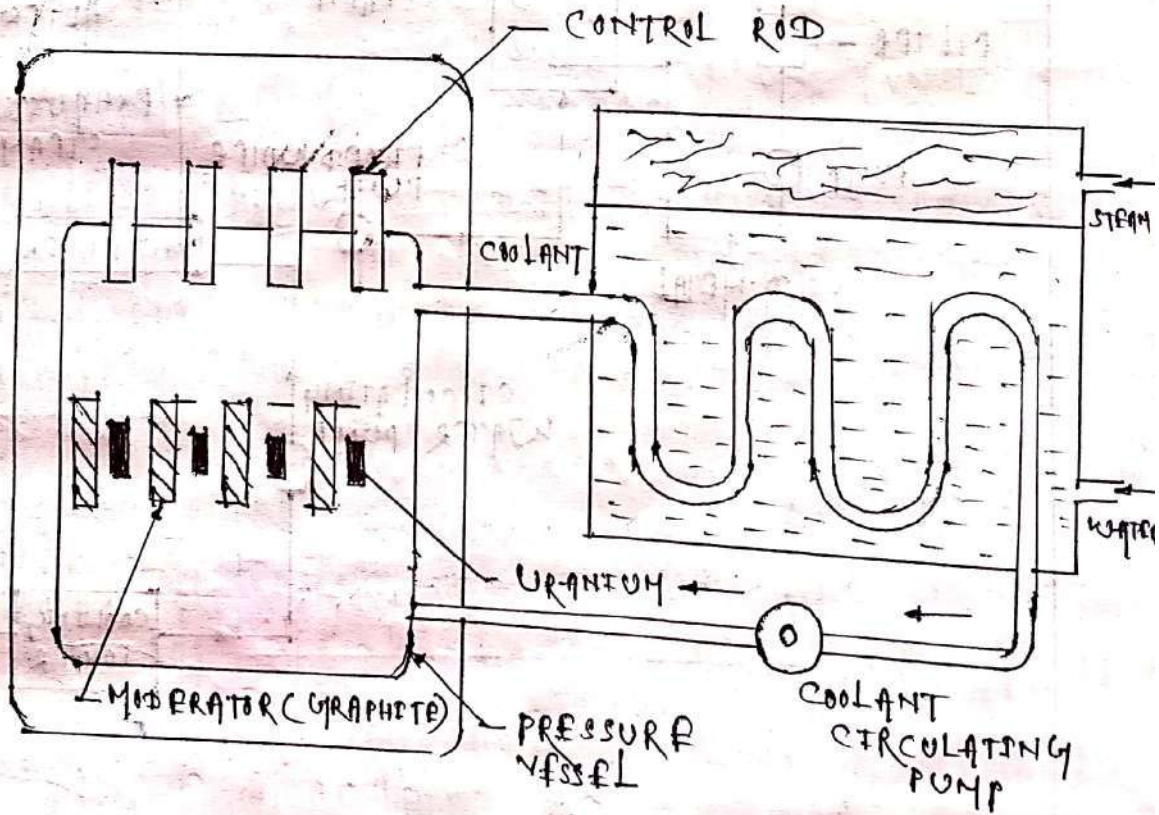
1- **Nuclear Reactor:-**
It is an apparatus in which the nuclear fuel (U^{235}) is subjected to nuclear fission.

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2- Heat Exchanger:-
The coolant gives up heat to the heat exchanger which is utilized in raising the the steam & after giving up heat the coolant is again fed to the reactor.

3- Steam Turbine:-
The dry & super heated steam from the super heater is fed to the steam turbine which converts the heat energy of steam to mechanical energy.

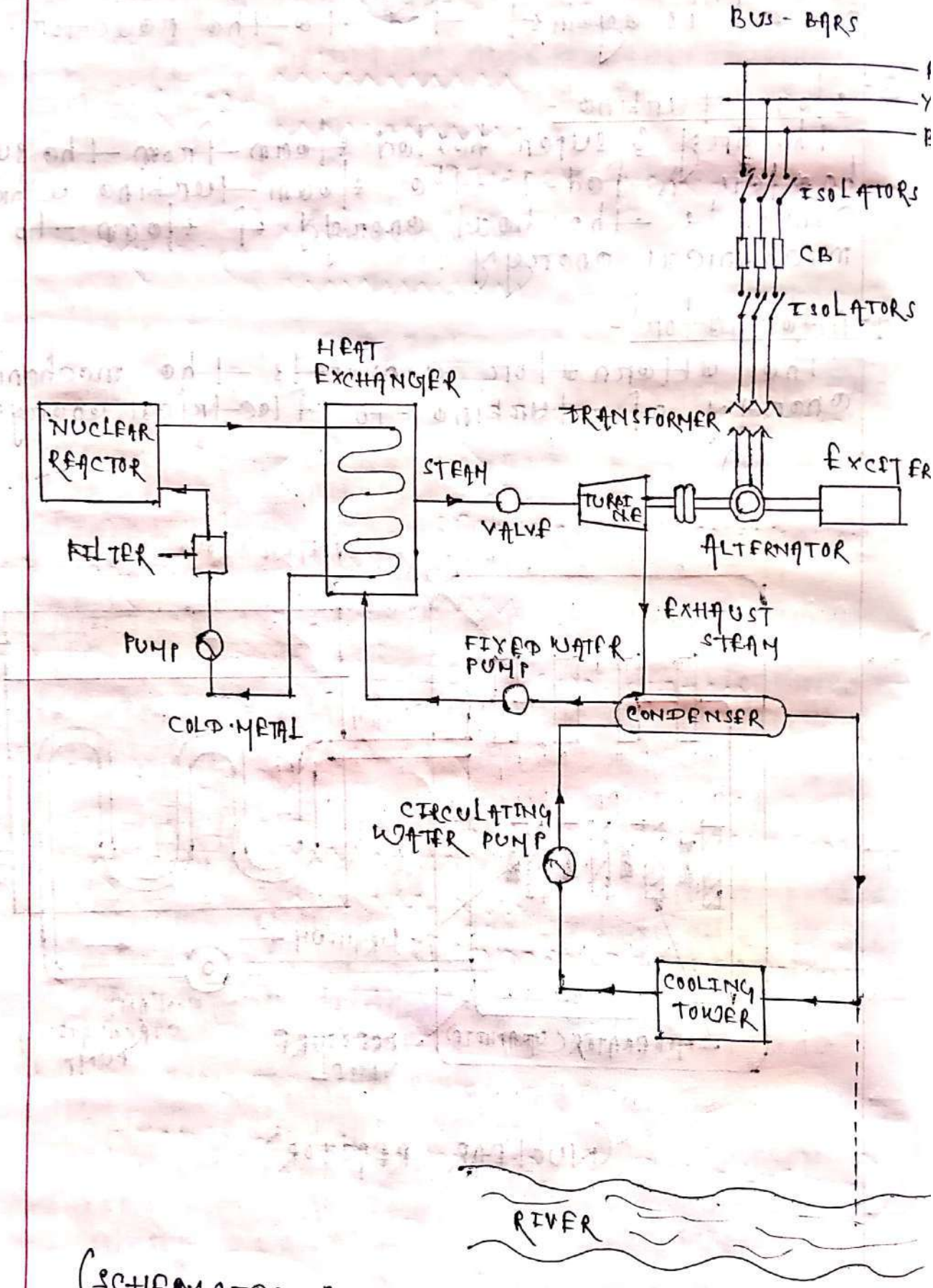
4- Alternator:-
The alternator converts the mechanical energy of turbine to electrical energy.



(NUCLEAR REACTOR)

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SH-1



SCHEMATIC ARRANGEMENT OF NUCLEAR POWER PLANT

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Working of Nuclear power plant:-

As discussed earlier, the chain reaction produces a huge amount of heat inside the nuclear reactor and requires a lot of care to control this reaction. The heat of the reactor is carried to heat-exchanger by molten sodium which also heats the water injected into this heat exchanger chamber. After the water gets converted to steam with very high temperature and high pressure, the turbine converts the internal energy of steam to mechanical energy and this is converted to electrical energy by alternator as before.

Advantages:-

- There is saving in fuel transportation as amount of fuel required is less.
- A nuclear power plant requires less space as compared to other plants.
- This type of plant is economical for producing bulk electrical energy.

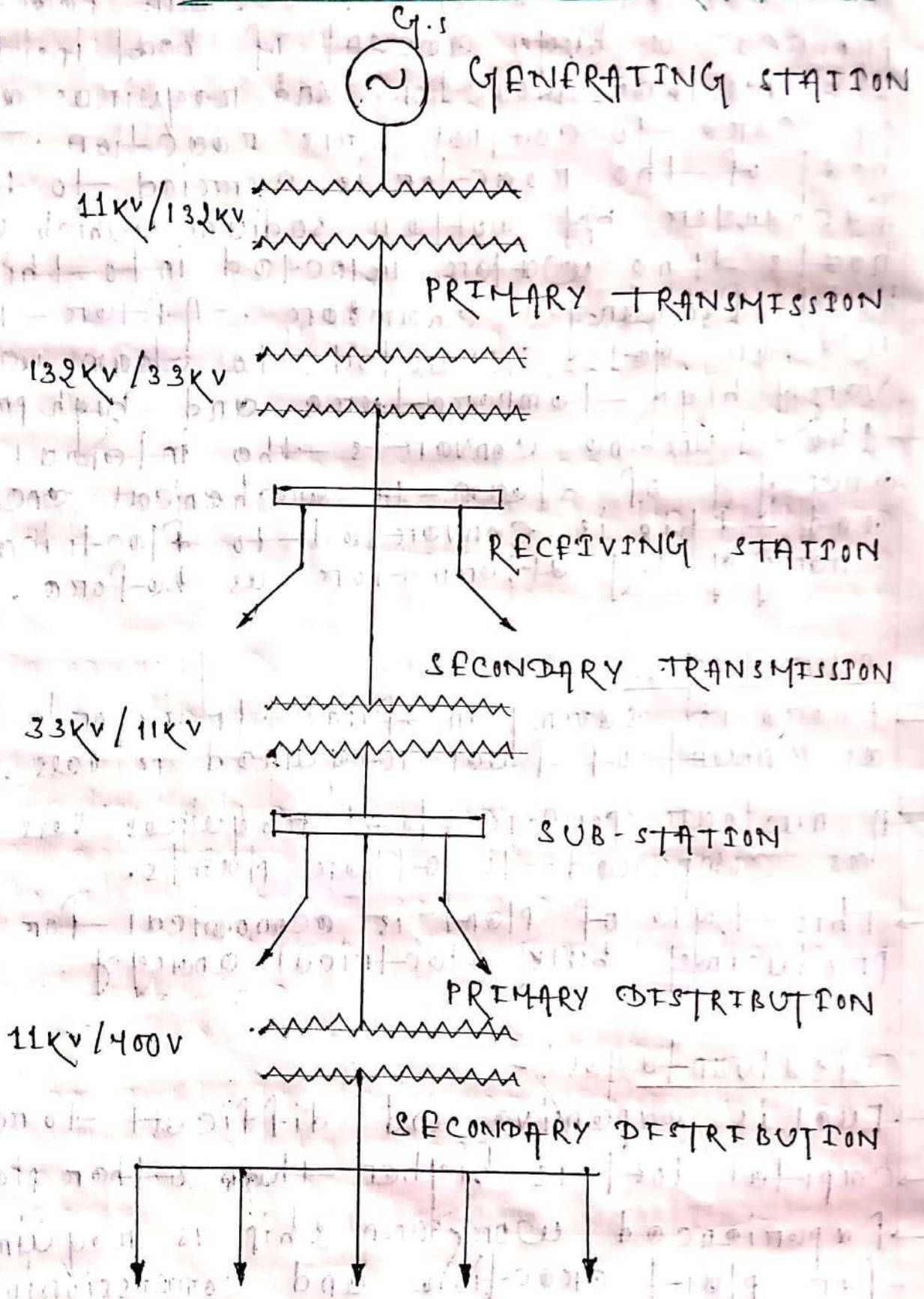
Disadvantages:-

- Fuel is expensive and difficult to recover.
- Capital cost is higher than other plants.
- Experienced workmanship is required for plant erection and commissioning.

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CHAPTER - 2

Transmission of ELECTRIC POWER



(Layout of transmission & Distribution)

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→ The large network of conductors between the power station and consumer can be divided into two parts. that is transmission and distribution system.

→ Each part can be subdivided into two parts i.e. primary and secondary transmission and primary and secondary distribution.

Generating station:-
In this above figure G.S represents generating station, where electric power is produced by 3-phase alternators operating in parallel. The usually generating voltage is 11kV for economic in transmission of electric power of the generating voltage 11kV is step up to 132kV of the generating station with the help of 3-phase transformer.

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

Secondary transmission:-
→ The primary transmission line terminates of the receiving station (R.S) which usually lies at the outskirt of the city.
→ At receiving station of voltage is reduced to 33kV by step down transformer.

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→ From this station electric power is transmitted at 33kV by 3-phase 3 wire overhead system to various substation located at different point of secondary transmission.

Primary Distribution:-
The secondary transmission line terminates at the substation where voltage is reduced from 33kV to 11kV, 3 phase 3 wire. The 11kV lines run along important road sides of the city and this forms a primary distribution.

Secondary Distribution:-
→ The electric power from primary distribution line (11kV) is delivered to distribution station these substations are located near the consumers locality and stepdown the voltage to 400V, 3-phase, 4 wire for secondary distribution.

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

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Voltage regulation (%):-

The difference in sending end voltage (V_S) and receiving end voltage (V_R) of transmission line w.r.t receiving end voltage is known as voltage regulation.

$$\% V.R = \frac{V_S - V_R}{V_R} \times 100$$

Transmission efficiency (η):-

The ratio of receiving end power to sending end power is known as transmission efficiency.

$$\% \eta = \frac{\text{o/p power}}{\text{i/p power}} = \frac{P_R}{P_S} \times 100$$

$$= \frac{V_R I_R \cos\phi_R}{V_S I_S \cos\phi_S} \times 100$$

State and explain Kelvin's Law for economical size of conductor:-

→ The most economical size of conductor is that for which total annual cost of transmission line is minimum this is known as Kelvin's law.

→ The annual cost of transmission line can be divided into 2 parts.

1- Annual charge on capital outlay
2- Annual cost of energy wasted.

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Annual charge on capital outlay:-

→ This is on account of interest and depreciation on the capital cost of complete installation of transmission line.

→ In case of overhead system it will be the annual interest & depriciation the capital cost of conductors, supports and insulators and the cost of their erection.

→ Now for an overhead line, insulator cost is constant, the conductor cost is proporsional to the area of cross-section and the cost of supports and their erection is partly constant and partly proporsional to area of cross-section of the conductor.

→ Therefore, annual charge on overhead transmission line can be express

Annual charge = $P_1 + P_2 a$ ---- eq^n (1)

where,

P_1 & P_2 are constant and 'a' is area of cross-section of conductor.

Annual cost of ENERGY WASTED:-

→ This is an account of energy lost mainly in the conductor due to I^2R losses.

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→ Assuming a constant current in the conductor throughout the year, the energy lossed in the conductor is proportional to resistance.

→ As resistance is inversly proportional to area of cross-section of conductor, their fore the energy lossed in the conductor is inversly proportional to area of cross-section.

→ Thus the annual cost of energy wasted in an overhead transmission line can be expressed as / Annual cost of energy wasted $= \frac{P_3}{a}$ ——— eqn (2)

where,

P_3 is constant

→ total annual cost (c) = eqn (1) + eqn (2)

$P_1 + P_2 a + \frac{P_3}{a}$ ——— eqn (3)

→ In eqn (3) only area of cross-section 'a' is variable, therefore the total annual cost of transmission line will be minimum if differentiation of 'c' w.r.t 'a' is equals to zero.

$$\frac{dc}{da} = 0$$

$$\frac{d}{da}\left(P_1 + P_2 a + \frac{P_3}{a}\right) = 0$$

$$= \frac{dP_1}{da} + \frac{d}{da}(P_2 a) + \frac{d}{da}\left(\frac{P_3}{a}\right) = 0$$

$$= 0 + P_2 - \frac{P_3}{a^2} = 0$$

$$= P_2 = \frac{P_3}{a^2}$$

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$= P_2 = \frac{P_3}{a^2}$

$= P_2 a = \frac{P_3}{a}$

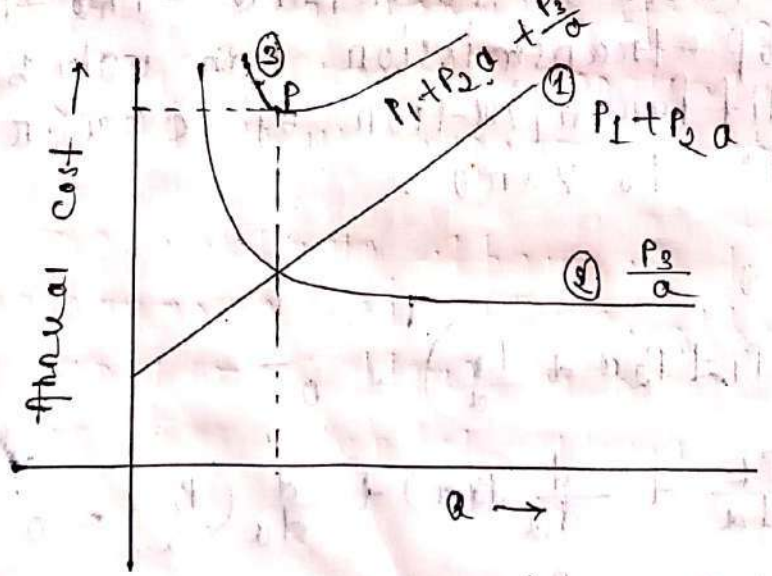
→ i.e. variable part of annual charge on capital outlay = Annual cost of energy wasted.

CONCLUSION:-

Therefore, Kelvin's law can be also be stated another way i.e., most economical area of conductor is that for which the variable part of annual charge is equal to the cost of energy losses per year.

GRAPHICAL REPRESENTATION OF KELVIN'S LAW:-

→ Kelvin's law can also be represented graphically by plotting annual cost against cross-sectional area ('a') of the conductor as shown in the below figure.



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→ In the diagram, the straight line (1) shows the relation between annual charge on capital outlay i.e. $(P_1 + P_2 a)$ & the area of cross-section 'a' of the conductor.

→ similarly the rectangular hyperbola (2) gives the relation between annual cost of energy wasted & area of cross-section.

→ By adding the ordinates of the curve (1) & (2), the curve (3) is obtained and this curve shows the relation between total annual cost $(P_1 + P_2 a + \frac{P_3}{a})$ of the transmission line of area of cross-section.

→ The lowest point on the curve (i.e point 'P') represents the most economical area of cross-section.

Limitations of Kelvin's Law:-

All the theoritically Kelvin's law holds good, there is often considerable difficulty in applying it to a proposed scheme of power transmission, the limitation of this law are as follows.

→ It is not easy to estimate, energy loss in the line without actual load curves, which are not available at the time of estimation.

→ The assumption that annual cost on account of interest and depriciation on the capital outlay is in the form $P_1 + P_2 a$ is strictly speaking it is not true.

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→ Here in cables neither the cost of di-electric material, sheathing materials nor the cost of laying is consider.

→ this law doesn't take into account several physical factors like current density, mechanical strength, corona loss etc.

→ the conductor size determine by this law may not always be practicable one become it may be too small for save carrying of necessary current.

→ Intrest & depriciation on the capital outlay can not be determine accurately.

CORONA Loss:-

The phenomenone of vilot glow, hissing noise and production of ozone gas in an overhead transmission line is known as corona.

→ In case of polished and smooth conductor the corona glow will be uniform throughout the length of conductor, otherwise in rough conductor the rough point will appear brighter.

→ With DC voltage their is difference in the appearance of wire, the +ve wires uniform glow, while the -ve conductor has spotty glow.

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Theory of corona formation :-

→ soft ionisation in always present in air due to cosmic rays, ultra violet radiation uv rays & radio-activity.

→ Therefore under normal condition the air around the conductor contains sum ionise particle (i.e free electrons and +ve ions) & neutral molecules.

→ When potential difference is applied between the conductors, potential gradient is setup in the air which will have maximum value at the conductor surface.

→ Under the influence of potential gradient the existing of free electrons a requires greater velocity. the greater the applied voltage, greater potential gradient and more is the velocity of free electrons.

→ When the potential gradient at the conductor surface the reaches about 30kv/cm (max value) the velocity a required by the free electrons is sufficient to strike neutral molecule with enough force to or discharge are or more electron from it.

→ this produces another ion and one or more free electrons, this process is continous and producing other ion.

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→ The process of ionisation is cumulative the result of these ionisations is that either corona is formed or spark takeplace between the conductor.

Methods of reducing corona effects:-

By increasing conductor size:-

By increasing conductor size the voltage at which corona occurs is raised and hence corona effects are considerable is reduced this is one of the reason that ACSR conductors, which have a large cross-section are used in transmission line.

By increasing conductor spacing:-

By this method the voltage at which corona occurs is raised and hence corona effects can be eliminated. However spacing can not be increased too much otherwise the cost of supporting structure may increase to considerable extend.

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CHAPTER-3
OVERHEAD LINES

Main components of overhead Line:-

1- Line supports
2- conductors
3- Insulators
4- Cross-arms
5- Miscellaneous items

Line supports:-
It may be poles or towers and keep the conductors and the suitable cable above the ground.

Conductors:-
Which carry electric power from sending end station to receiving end station.

Insulator:-
Which are attached to supports and insulate the conductor from ground.

Cross-arms:-
Which provides supports to insulator.

Miscellaneous Items:-
such as lightening arrester, anti climbing wires, phase plates etc.

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Different types of Line Supports:-

The line supports should have following properties:-

- High mechanical strength to withstand the weight of conductor & wind load etc.
- cheap in cost and economical to maintained.
- Light in weight without the loss of mechanical strength.
- Longer of life.
- Easy accessibility of conductors for maintainance.

Note:-

The line support are for transmission & distribution of electric power are of various types i.e.

1. Wooden poles
2. Still poles
3. RCC poles (Reinforced cement concrete)
4. Lattice still tower

Wooden poles:-

These are made of season wood (sal tree wood) and are suitable for lines of moderate cross-sectional area and of relatively shotter spans (upto 50 meters) such supports are cheap in cost, easily available and wide insulating properties.

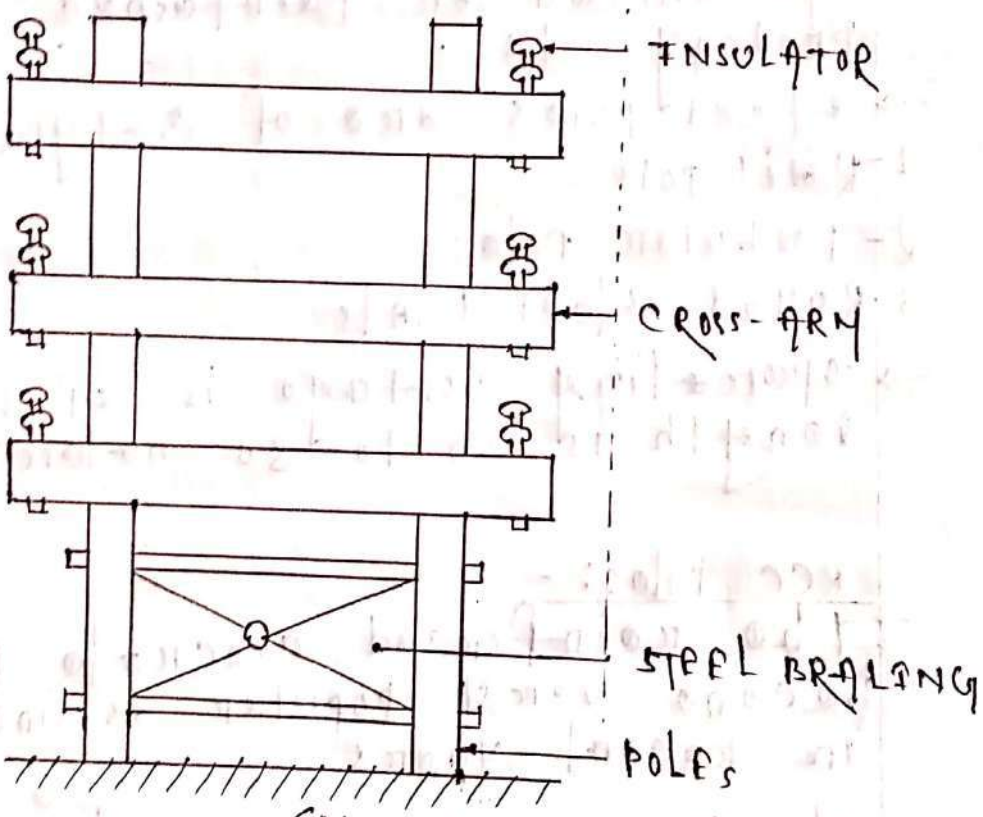
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→ Operating voltage is 20kV and lifespan in 20 to 25 years.

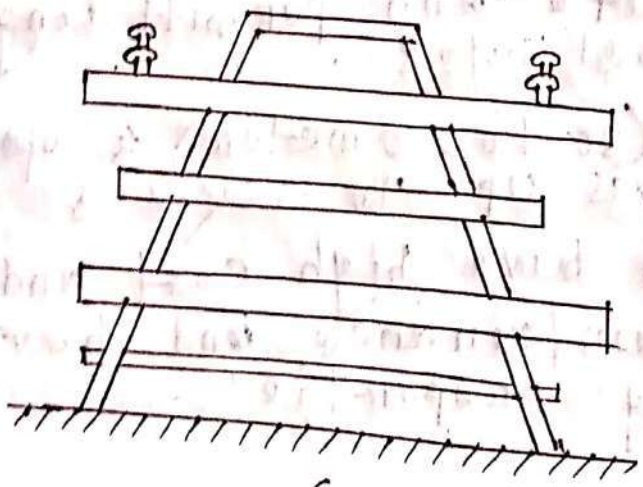
→ Less mechanical strength and required periodical instruction and used in rural area for distribution purpose.

- Those are of 2 types

1. A - type pole
2. H - type pole



(H-type pole)



(A-type)

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Steel poles:-

→ The steel poles are often used as a substitute for wooden pole.

→ They possess greater mechanical strength, longer life and permitt longer span to be used.

→ such poles are generally used for distribution purpose in cities.

→ This type of supports need to be galvanised or paintained in order to prolong its.

→ steel poles are of 3 types:-

1- Rail poles
2- Tubular poles
3- Rolled steel joints

→ operating voltage is of 33kV & span length is 50 to 80 meter.

RCC poles:-

→ The reinforced concrete poles have become very popular as line supports in recent years.

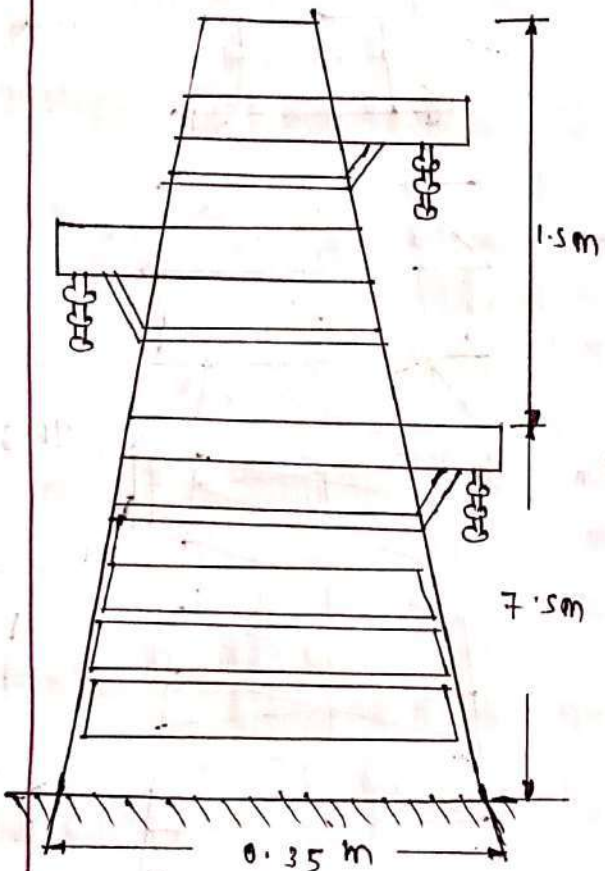
→ They have greater mechanical strength, longer life and permitt longer span then steel poles.

→ span is (80 to 200 meter) & operating voltage is up to 33kV & above.

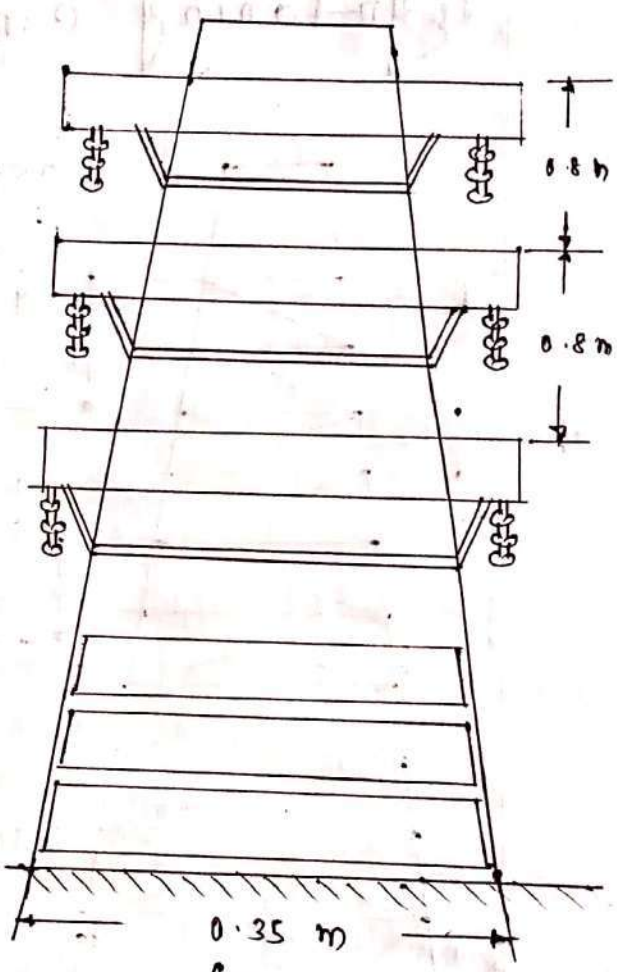
→ This pole have high cost and required little maintainance and have good insulating properties.

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→ The holes present in the poles facilitate the climbing of poles and at sum time reduce the weight of line supports.



(single ckt).



(Double ckt)

Steel towers:-

→ For long distance transmission at higher voltage steel towers are used.

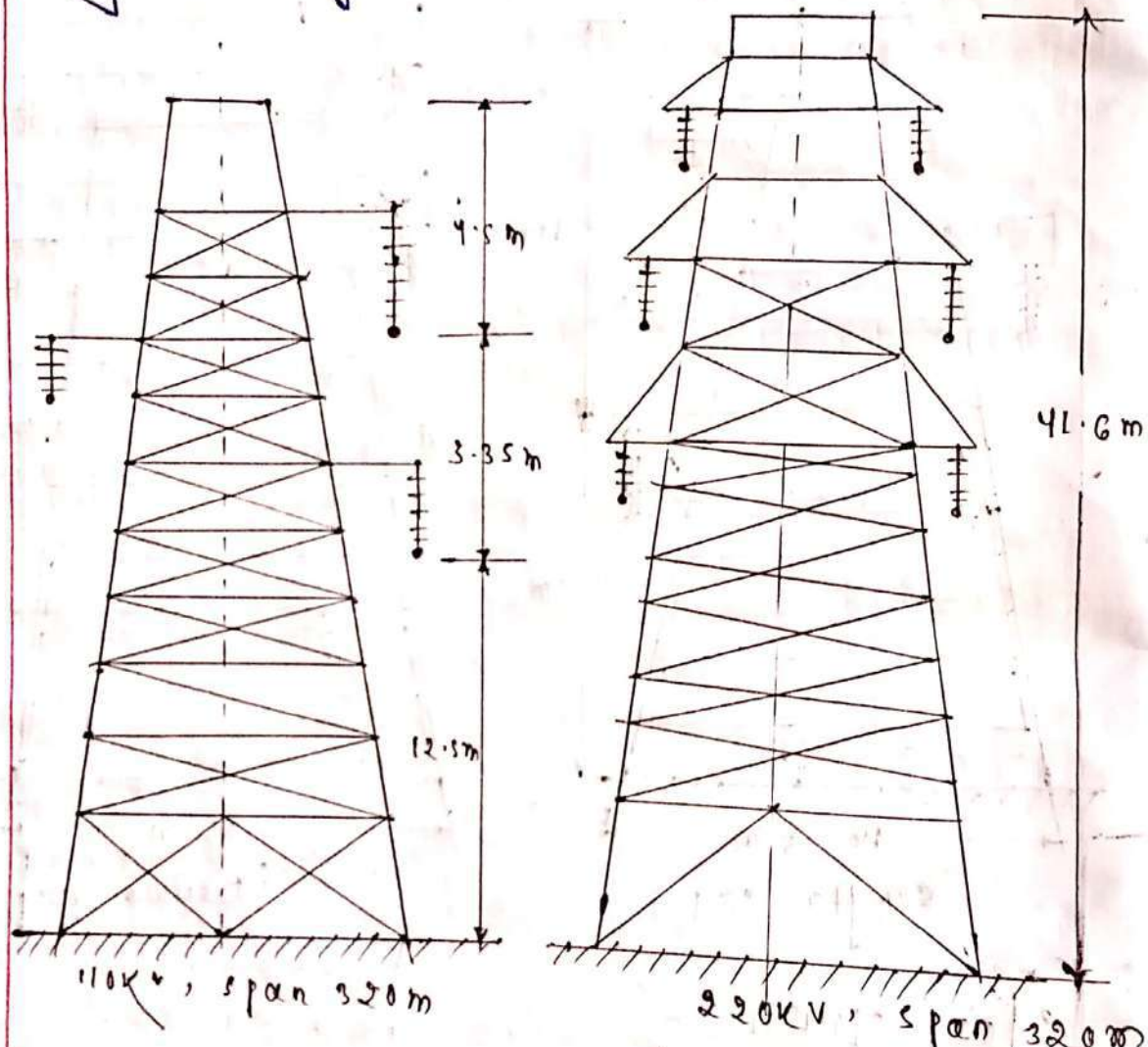
→ steel tower has greater mechanical strength.

→ Longer life and can withstand most severe climatic condition and permit the used of longer span.

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→ This tower of have spans of 300m at above used for operating voltage of 66kV, 132kV and above.

→ This tower minimize the lightening problems as ie tower acts as a lightening conductor.



Conductor Materials:-

The conductor material used for transmission & distribution of electric power should have flowing properties

→ High electrical conductivity, high tensile strength in order to withstand Mechanical stress.

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→ Low cost, so that it can be used for longer distance.

→ Low specific gravity, so that weight/unit volume is small.

→ commonly used for conducting are!-

1- Copper
2- Aluminium
3- Steel core aluminium
4- Galvanised steel
5- Cadmium copper.

Copper!-

→ Copper is an ideal material for overhead lines owing to its high electrical conductivity & greater tensile strength.

→ copper has high current density i.e. the current carrying capacity is per unit of cross-section area is wide Large.

→ Due to high cost and non availibility it is rarely used for this purpose.

→ specific gravity of copper is 8.9 gm/cc

Aluminium!-

→ It is cheap & light as compared to copper but it has much smaller conductivity & tensile strength.

→ the conductivity of aluminium is 60% that of copper. The smaller conductivity of aluminium means that for any particular transmission efficiency, the cross-sectional area of conductor must be Larger in aluminium than in copper.

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→ For same resistance, the diameter of aluminium conductor is about 1.26 times the diameter of copper conductor.

→ the specific gravity of aluminium is 2.7 gm/cc.

→ Aluminium conductor being light in weight, it is liable to greater swing and hence larger cross-arms are required.

→ Due to lower tensile strength and higher coefficient of linear expansion of aluminium, the sag is greater in aluminium conductor.

steel core aluminium:-

→ Due to low tensile strength, aluminium conductor produce greater sag. In order to increase the tensile strength of aluminium conductor is reinforced with a core of galvanised steel wire.

→ The composite conductor thus obtained is low, in steel core aluminium and is known as ACSR (Aluminium conductor steel Reinforced).

→ steel core aluminium conductor consists of central core of galvanised steel wire surrounded by number of aluminium strandes.

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Galvanised steel:-

→ This type of steel have high tensile strength.

→ Due to pure electrically conductivity and high resistance of steel, such conductors are not suitable for transmitting, large power, over long distance.

Cadmium copper:-

→ In addition of 1% or 2% of cadmium (Cd) to copper increase the tensile strength by about 50% and the conductivity is only reduced by 15% below that of pure copper, therefore cadmium copper conductor can be useful for excepting long span.

→ Due to high cost of cadmium such conductors will be economical for lines of small cross-section i.e. where the cost of conductor material is comparatively is small compare with the cost of supports.

Insulators:-

→ The overhead line conductor should be supported on the poles and towers in such a way that current from conductors do not flow to earth through support. i.e. line conductor must be properly insulated from supports.

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→ The insulator provide, necessary insulations between line conductors and supports and, thus prevent leakage current from conductors to earth.

Properties of Insulator:-

→ High mechanical strength in order to withstand conductor load, wind load etc.

→ High electrical resistance of insulator material in order to avoid leakage current to earth.

→ High relative permitivity of insulator material in order that di-electric strength is high.

→ The insulator material should non-porous, free from impurities and cracks otherwise the permitivity will be lower.

→ High ratio of puncture strength to flash over.

Types of insulator:-

1- Pin type insulator
2- suspension type insulator
3- Strain type insulator
4- Shackle type insulator.

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Pin type insulator:-

→ It has simple construction and cheap in cost.

→ As its name su., the pin type insulator is secured to the cross-arm on the poles.

→ pin type insulators are used for transmission and distribution of electric power and voltage of up to 33KV.

→ Beyond 33KV this insulator become to bulky and hence on economical.

→ Insulators are required to withstand both mechanical & electrical stresses.

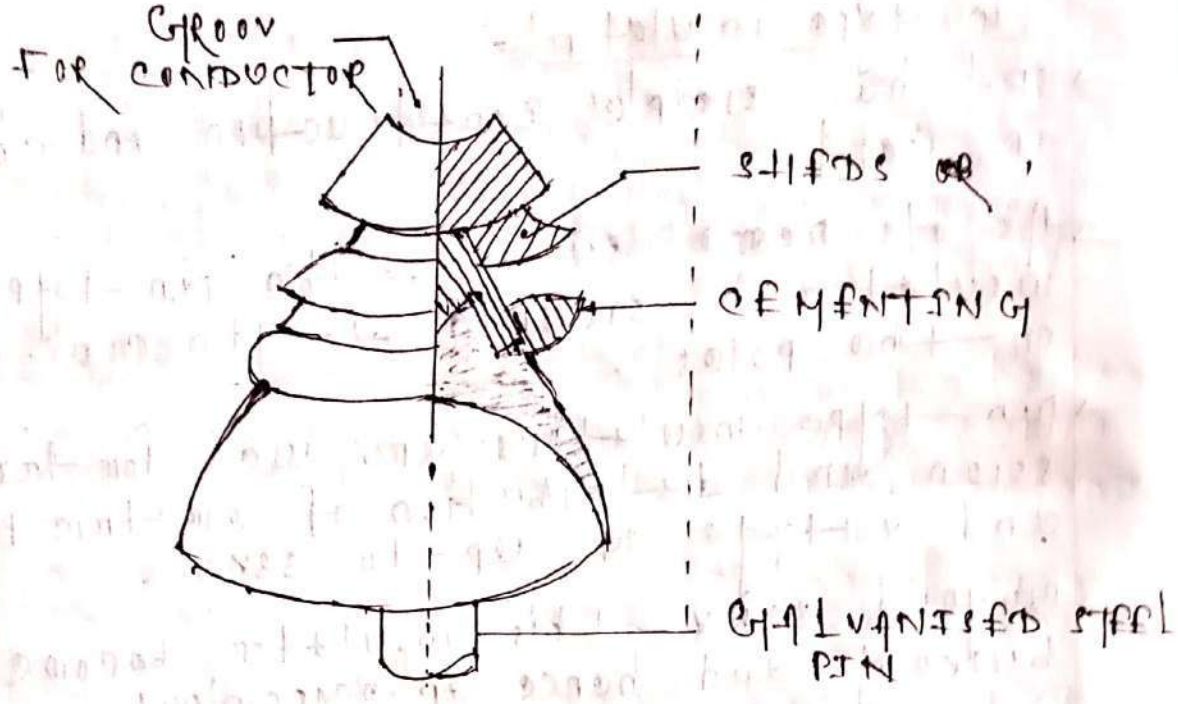
→ The electrical breakdown of insulator can occur either by flashover or puncture.

→ In case of flashover and, arc occurs between the line conductor and insulator pin & the discharge jump across air gap, flowing shortest distance when such breakdown involved the insulator is permanently destroyed due to excessive heat.

→ The ratio puncture strength to flashover voltage is known as safety factor.

→ For pin type insulator the value of safety factor is 10.

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Suspension type insulator :-

→ For high voltage is above 33KV, it is a usual practice to use suspension type insulator.

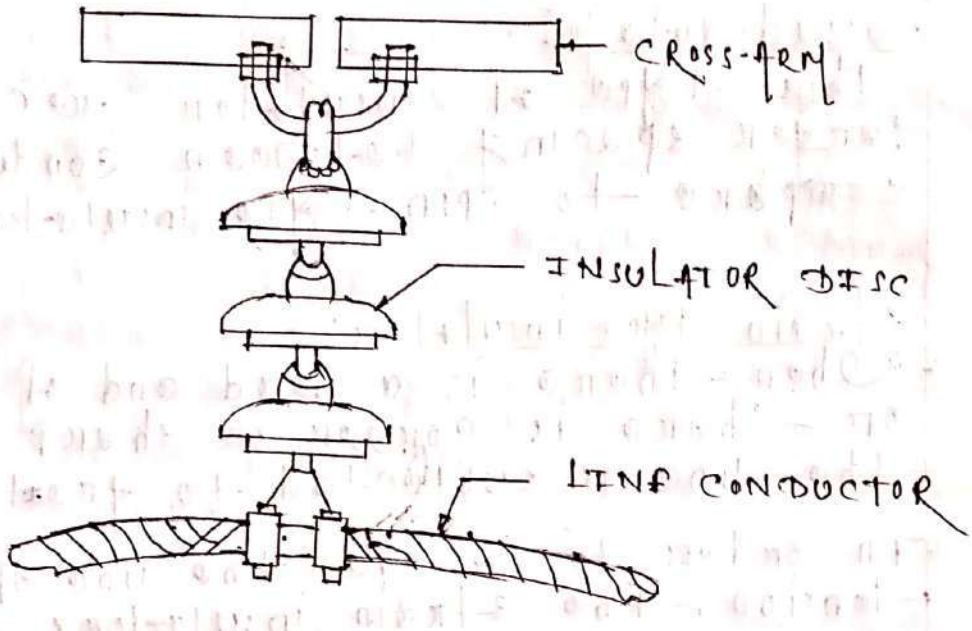
→ They consists of a number of porcelain discs connected in series by metal links in the form of a string.

→ The conductor is suspended at the bottom end of this string while the other end of the string is secured to the cross-arm of the tower.

→ Each unit or disc is designed for low voltage, say 11KV.

→ The number of discs in series would obviously depend upon the working voltage. For instance, if the working voltage is 66KV, then six discs in series will be provided on the string.

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Advantages:-

→ Suspension-type insulators are cheaper than pin-type insulators for voltage beyond 33kV.

→ Each unit or disc of suspension-type insulator is designed for low voltage, usually 11kV. Depending upon the working voltage, the desired number of discs can be connected in series.

→ If any one disc is damaged, the whole string does not become useless because the damaged disc can be replaced by the sound one.

→ The suspension arrangement provides greater flexibility to the line. The connection at the cross arm is such that insulator string is free to swing in any direction and can take up the position where mechanical stresses are minimum.

→ The suspension-type insulators are generally used with steel towers.

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Disadvantage:-

This type of insulator received larger spacing between conductors as compare to pin type insulator.

Strain type insulator:-

→ When there is a dead end of the line or there is corner or sharp curve, the line is subjected to greater tension.

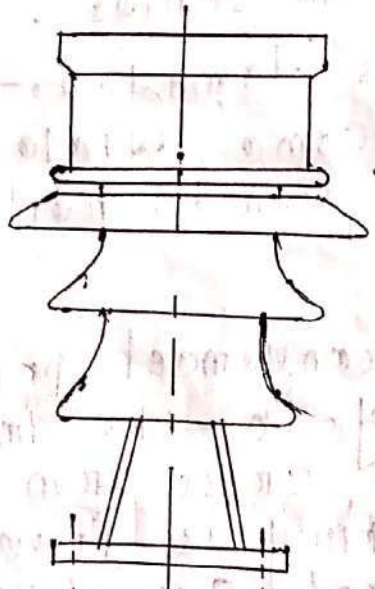
→ In order to relieve the line of excessive tension, the strain insulators are used.

→ For low voltage lines that is 11 KV.

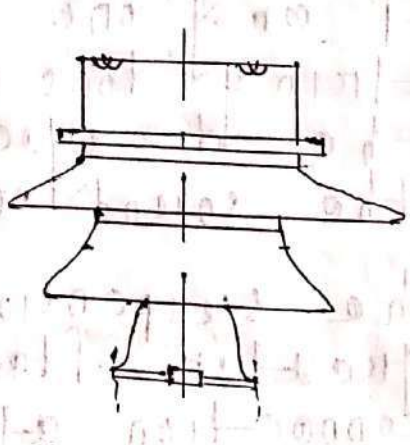
→ shackle insulators are used as strain insulators.

→ For high voltage transmission lines, strain insulator consists of an assembly of suspension insulators.

→ The discs of strain insulators are used in the vertical plane.



(a) CAP AND PIN INSULATOR FOR GOAB SWITCH



(b) ANOTHER DESIGN OF CAP & PIN INSULATOR FOR GOAB SWITCH

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shackle type insulator :-

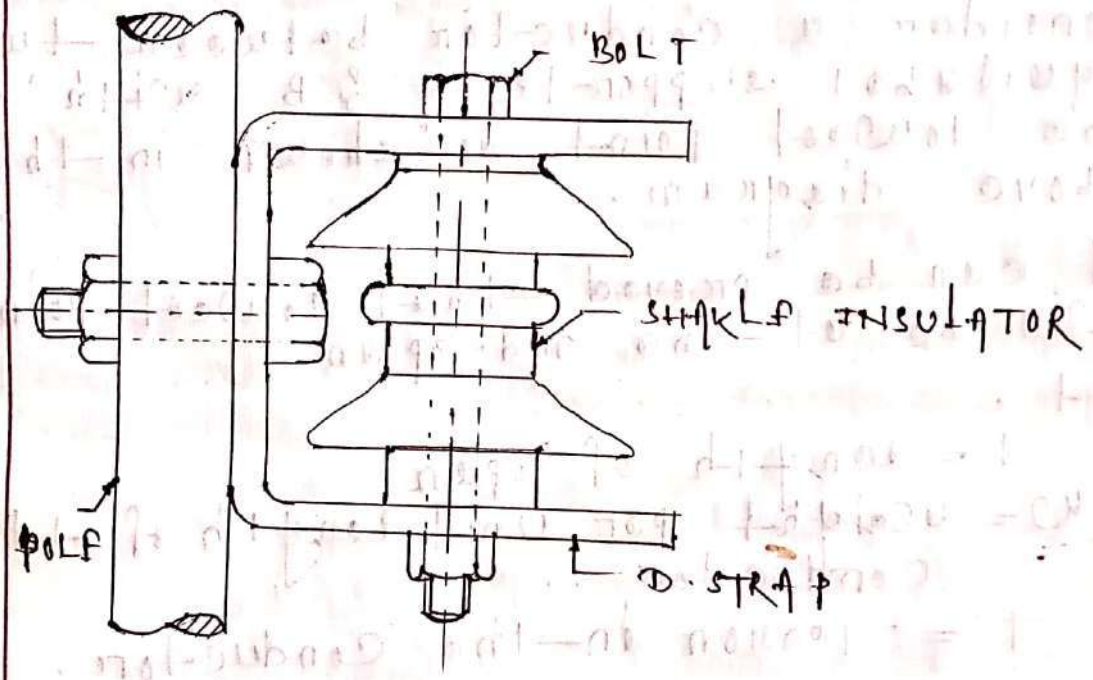
→ shackle insulators are generally used for terminating on corner poles.

→ these insulators are used for medium voltage line only.

→ they are frequency used for low voltage distribution line.

→ such insulators can be used either in horizontal position or in a vertical position.

→ they can be directly fix to the pole with a bolt or to the cross arm.



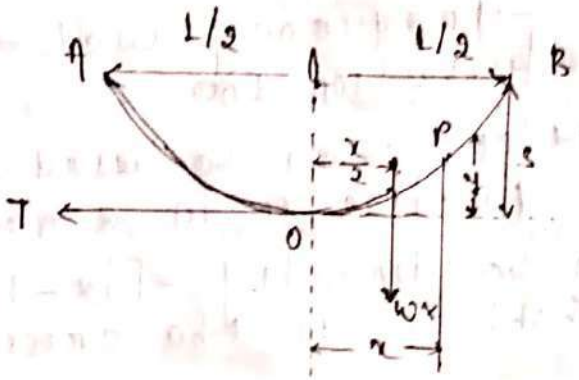
Sag :-

The difference in label between points of support and the lowest point of the conductor is called sag.

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Calculation of sag & derive expression for sag :-

Case-1
When supports are at equal level :-



→ Consider a conductor between two equilabel supports A & B with 'O' is the lowest point, as shown in the above diagram.

→ It can be proved that lowest point will be at the mid-span.

→ Let,

l = length of span

w = weight per unit length of the conductor.

T = tension in the conductor.

→ Consider a point 'P' on the conductor & taking a lowest point 'O' as the origin, let the co-ordinates of point 'P' be xy.

→ Assuming that the curve is show small that curve length is equal to the horizontal projection (i.e. OP = x) the two forces acting on the portion 'OP' of the conductor are :-

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(a) The weight (w_x) of conductor acting at a distance $\frac{x}{2}$ from point 'O'.

(b) The tension 'T' acting at a point 'O'.

→ Equating the moments of above two forces about point 'O' we get,

$$Ty = wx \cdot \frac{x}{2}$$

$$y = \frac{wx^2}{2T}$$

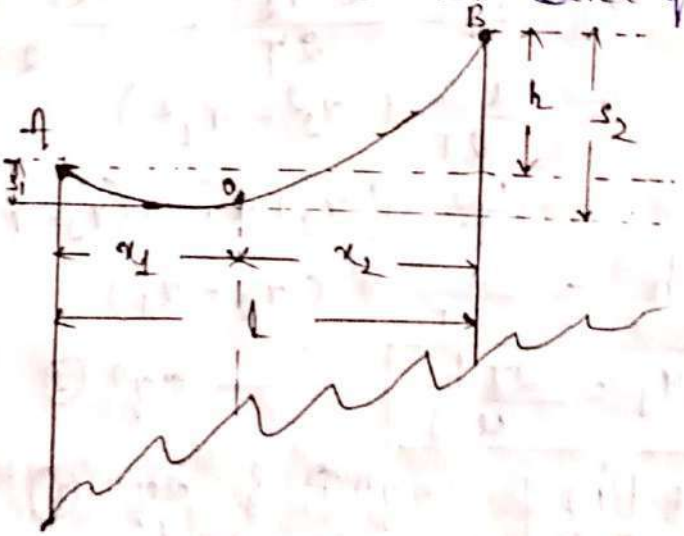
→ The maximum sag is represented by the value of 'y' at either of the support A & B.

→ At support 'A' $x = l/2$ & $y = s$

$$s = \frac{w \cdot (\frac{l}{2})^2}{2T} = \frac{wl^2}{8T}$$

Case-2

When supports are at unequal level:-



→ In hilly areas we generally come across conductor suspended between supports at unequal level.

→ In the above figure a conductor suspended between two support A & B which are at different levels.

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→ The lowest point on the conductor is 'O'.

→ Let, l = span length
h = difference in level between two support
x_1 = Distance of support at lower level (i.e. A) from 'O'.
x_2 = Distance of support at higher level (i.e. B) from 'O'.
T = tension in the conductor.

→ If 'w' is the weight per unit length of conductor then,

$s_1 = \frac{w \cdot x_1^2}{2T}$ & $s_2 = \frac{w \cdot (x_2)^2}{2T}$

→ Also $\boxed{x_1 + x_2 = l}$ — eqn (1)

→ Now,

$$s_2 - s_1 = \frac{w \cdot x_2^2}{2T} - \frac{w \cdot x_1^2}{2T}$$

$$= \frac{w}{2T}(x_2^2 - x_1^2)$$

$$= \frac{w}{2T}(x_2 + x_1) \cdot (x_2 - x_1)$$

$$h = \frac{w}{2T} l (x_2 - x_1)$$

$$\boxed{x_2 - x_1 = \frac{2Th}{wl}} \quad \text{— eqn (2)}$$

Equating eqn (1) & eqn (2) & solving eqn (1) & (2) we get.

$$\boxed{x_1 = \frac{l}{2} - \frac{Th}{wl}}$$

$$\boxed{x_2 = \frac{l}{2} + \frac{Th}{wl}}$$

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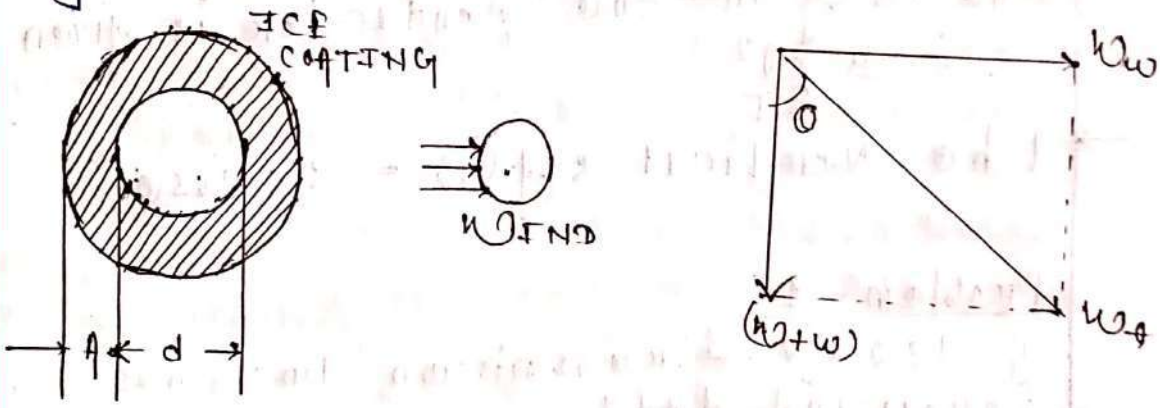
Effect of wind & ice loading :-

→ A conductor may have ice-loading & simultaneously subjected to wind pressure.

→ The weight of ice acts vertically downward i.e. in the same direction as the weight of conductor.

→ The force due to wind is assumed to act horizontally i.e. at right angle to the projected surface of the conductor.

→ Hence the total force of conductor is the vector sum of horizontal and vertical forces as shown in the below figure.



→ Total weight of conductor per unit length is $W_t = \sqrt{(W+w_i)^2 + W_w^2}$

→ Where,

W = weight of the conductor per unit length.

= conductor material density × volume per unit length.

w_i = weight of ice per unit length

= Density of ice × volume of ice per unit length

= Density of ice $\times \frac{\pi}{4}\left[(d+t)^2 - d^2\right] \times 1$

= Density of ice $\times \pi t(d+t)$

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W_w = weight of wind per unit length
= wind pressure per unit area × projected area per unit length
= wind pressure × $[(d+2t)\times 1]$

→ When the conductor has wind & ice-loading the following point may be noted.

→ The conductor seats itself in a plane at an angle 'θ' to the vertical.
where,
$$\tan\theta = \frac{W_w}{W+W_i}$$

→ The sag in the conductor is given by
$$s = \frac{w\times l^2}{8T}$$

→ The vertical sag (s) = $s \times \cos\theta$

Problem - 1

A 132 kV transmission line has a, the following data
weight of conductor 680 kg/km.
Length of span = 260 m
ultimate strength = 3100 kg
safety factor = 2
Calculate the height above ground at which the conductor should be supported ground clearance required is 10m.
Given data,
$w = 680 kg/km = 0.68 kg$
$L = 260 m$
$U = 3100 kg$
$s = 2$
w = weight of conductor per meter length $= \frac{680}{1000} = 0.68 kg$

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L = span length = 260m

tension $T = \frac{W.S}{S.F} = \frac{3100}{2} = 1550$

$S = \frac{wl^2}{8T} = \frac{0.68 \times (260)^2}{8 \times 1550} = 3.7070$

conductor should be supported at a height of $10 + 3.7 = 13.7$ m

Problem-2

A transmission line has a span of 150m between level supports, the conductor has a cross-sectional area of $2cm^2$. The tension in the conductor is 2000kg. If the specific gravity of the conductor material is 9.9gm/cm^3 & wind pressure in 1.5kg/m, calculate the sag & what is the vertical sag.

Given data,

L = 150m

cross-sectional area a = $2cm^2$

tension T = 2000kg

S.G = 9.9gm/cm^3

w_w = 1.5kg/m

S = ?

Vertical sag = ?

Weight of conductor per meter length

w = SG x volume of 1m conductor

= 9.9 x 2 x 100 cm

= 1980gm = 1.98kg

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$$w_t = \sqrt{(w + w_i)^2 + w_w^2} = \sqrt{w^2 + w_w^2}$$

$$= \sqrt{(1.98)^2 + (1.5)^2} = 2.48 \text{ kg}$$

$$s = \frac{w_t L^2}{8T} = \frac{2.48 \times (150)^2}{8 \times 2000} = 3.48 \text{ m}$$

$$w.s = s \cos\theta$$

$$\tan\theta = \frac{w_w}{w}$$

$$\theta = \tan^{-1}\left(\frac{w_w}{w}\right)$$

$$= \tan^{-1}\left(\frac{1.5}{1.98}\right)$$

$$= 37.14$$

$$\text{vertical sag} = s \times \cos\theta$$

$$= 3.48 \times \cos 37.14$$

$$= 2.77 \text{ m}$$

Problem-3

A transmission line has a span of 200m between level supports the conductor has a cross-sectional area of 1.29 cm^2, weight 1170 kg/km & has a breaking stress of 421.8 kg/cm^2, Calculate the sag for a safety factor is 5, height allowing wind pressure of 122 kg/m^2 of projected area. what is the vertical sag.

Given data,

$$L = 200 \text{ m}$$

$$a = 1.29 cm^2$$

$$w = 1170 \text{ kg/km} = 1.17 \text{ kg/m}$$

Breaking stress = 421.8 kg/cm^2

Wind pressure = 122 kg/m^2

$$= \frac{122 \times 1.29}{100} = 1.56 \text{ kg/m}$$

$$S.F = 5$$

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vertical sag = ?

$$T = \frac{B.S \times \text{area}}{S.F} = \frac{4218 \times 1.29}{5} = 1088.24 \text{ kg}$$

$w_{w/m}$ = wind pressure x projected area in m^2

$$= 122 \times (d \times 1)$$
$$= 122 \times (1.28 \times 10^{-2} \times 1)$$
$$= 1.56 \text{ kg}$$

$$w_t = \sqrt{w^2 + w_w^2} = \sqrt{(1.17)^2 + (1.56)^2}$$
$$= 1.95 \text{ kg}$$

$$s = \frac{w_t \cdot l^2}{8T} = \frac{1.95 \times (200)^2}{8 \times 1088.24} = 8.95 \text{ m}$$

$s \cos\theta$

$$\theta = \tan^{-1}\left(\frac{w_w}{w}\right)$$
$$= 53.13$$

$$v.s = s\cos\theta$$
$$= 8.95 \cos 53.13 = 5.3 \text{ m}$$

Problem-4

A transmission line has a span of 275 m between level support. The conductor has an effective diameter of 1.96 cm and weight 0.865 kg/m. Its ultimate stress is 8060 kg if the conductor has ice-coating of radial thickness 1.27 cm & is subjected to a wind pressure of 3.9 gm/cm² of projected area, calculate sag for safety factor of 2; weight of 1cc of ice is 0.91 gm.

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Given data,

$l = 275\ m$

Diameter $= 1.96\ cm$

$w = 0.865$

Ultimate strength $= 8060\ kg$

ice-coating thickness $t = 1.27\ cm$

$w_w = 3.9\ gm/cm^2$

safety factor $= 2$

$w_i = 1cc = 0.91\ gm$

$s = ?$

Volume of ice per meter (i.e. 100 cm) length of conductor $= \pi t(d+t) \times 100\ cm^3$

$= 1288.71\ cm^3$

$w_i = D \times v$

$= 0.91 \times 1288.71 = 1172.72\ gm$

$= 1.172\ kg$.

Wind force per meter length of conductor

$w_w = w.p \times (d+2t) \times 100\ gm$

$= 3.9\ gm (1.96 + 2 \times 1.27) \times 100$

$= 1755\ gm$

$= 1.755\ kg$

$w_0 = \sqrt{w + (w_i)^2 + w_w^2}$

$= \sqrt{(0.865 + 1.172)^2 + (1.755)^2}$

$= 2.688\ kg$

Tension $(T) = \frac{U.S}{SF} = \frac{8060}{2} = 4030$

$s = \frac{w_0 l^2}{8T} = \frac{2.688 \times 275^2}{8 \times 1.27} = 6.305\ m$

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chapter-4

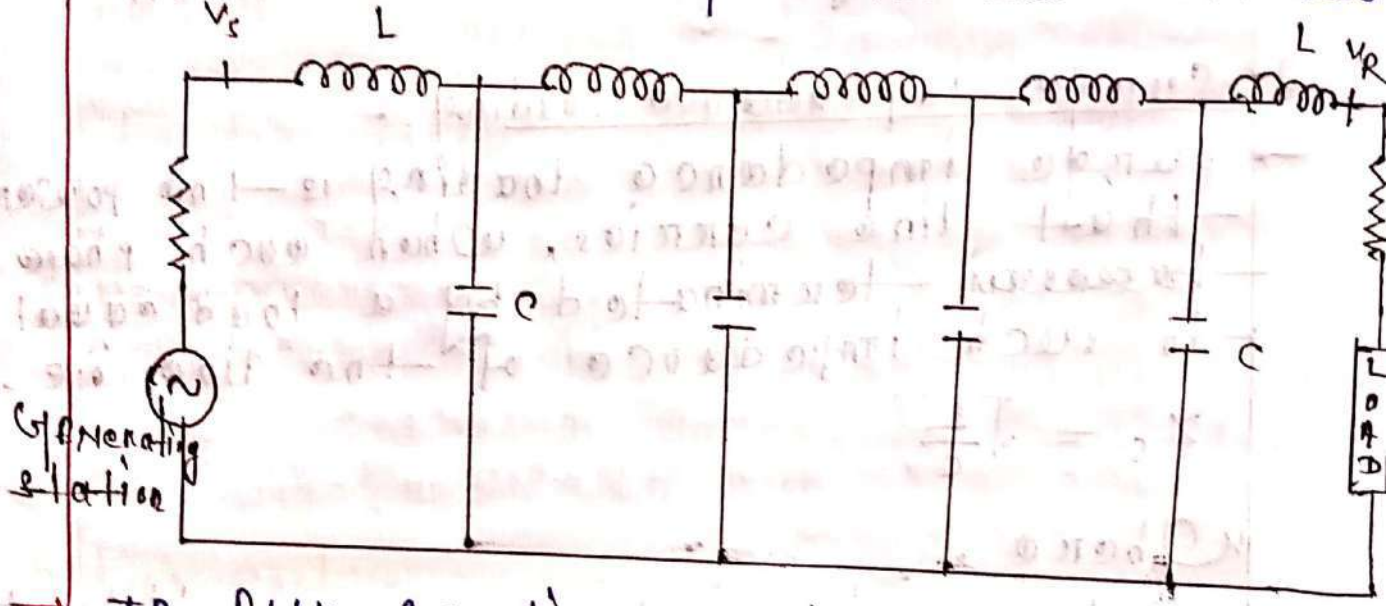
Extra high voltage (EHV) Transmission

Introduction:-

→ Generally the voltage of 300KV to 765KV are considered as extra high voltage.

→ Generally EHV-ac lines are selected for long distances 250 km & above & high power of 500 MW & above.

→ Electrical 3φ EHV-ac lines are as follows



→ In EHV ac lines series inductance (L) & shunt capacitance (C) influence the performance of line i.e. voltage regulation, power flow, stability, efficiency etc.

→ Here the surge impedance of the line is $Z_S = \sqrt{\frac{L}{C}}$.

→ For example 400 KV EHV line has been installed in India, in 1974 but recently 765 EHV-ac line installed in 1992.

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Reasons for adaption of HV transmission.

1- **Increase in size of generating units :-**

In order to reduce investment cost per kw, the size of generating unit has been constantly increasing, thus this ~~increasing~~ increases large amount of power over long distance can be transmitted technically & economically in HV transmission.

2- **Surge impedance loading :-**

→ Surge impedance loading is the power that line carries, when each phase ~~terminated~~ terminated by a load equal to such impedance of the line i.e.

$$Z_s = \sqrt{\frac{L}{C}}$$

where,

L = series inductance per unit length

C = shunt capacitance per unit length

$$SIL = \frac{3V^2}{Z_s}$$

→ Therefore voltage at higher value makes large power transmission economically.

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3- Pithead steam plants & Remote hydro plant:-

→ Generally steam & hydroplants are located according to their favourable characteristics like availability of water, coal, labour, transportation facilities etc.

→ Generally these power plants are very far from load centre, hence here transmission of large amount of power over large distance can only be technically and economically possible by EHV transmission.

4- Transmission:-

The no. of circuit and the land requirement for transmission decreases with adaption of EHV AC transmission.

5- Line Cost:-

→ The line installation cost per MW, per km decreases with the increase in voltage level.

→ Moreover the impact of the cost of losses on the overall transmission cost can be substantially different & different voltage level. The total line cost including the cost of losses per MW per km decreases considerable by use of EHV AC transmission.

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Problems involved in HV transmission:-

1- **Corona loss & Radio-interference:-**
Generally corona appearse in high voltage transmission line, which not only a source of power loss, but it is also a source of interferance with radio & television Communication line.

2- **Heavy supporting structure & erection difficulties:-**
Generally HV AC transmission use bundle conductor which results in large mechanical loading on tower similarly large air & ground clearance, dynamic forces due to broken conductor etc, makes large mechanical load, hence strength of tower should be heavy.

3. **Insulation required:-**
Generally HV AC transmission require high insulation to withstand of voltage surge due to internal source i.e. switching operation or due to external sources i.e. lightening etc. which Produces very high voltage generally 2 to 3 times of normal voltage. hence insulator level depends upon switching over voltages and atmospheric over voltage.

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HVDC transmission:-

→ Generally high voltage DC transmission require converter station at both end (i.e. sending end & receiving end).

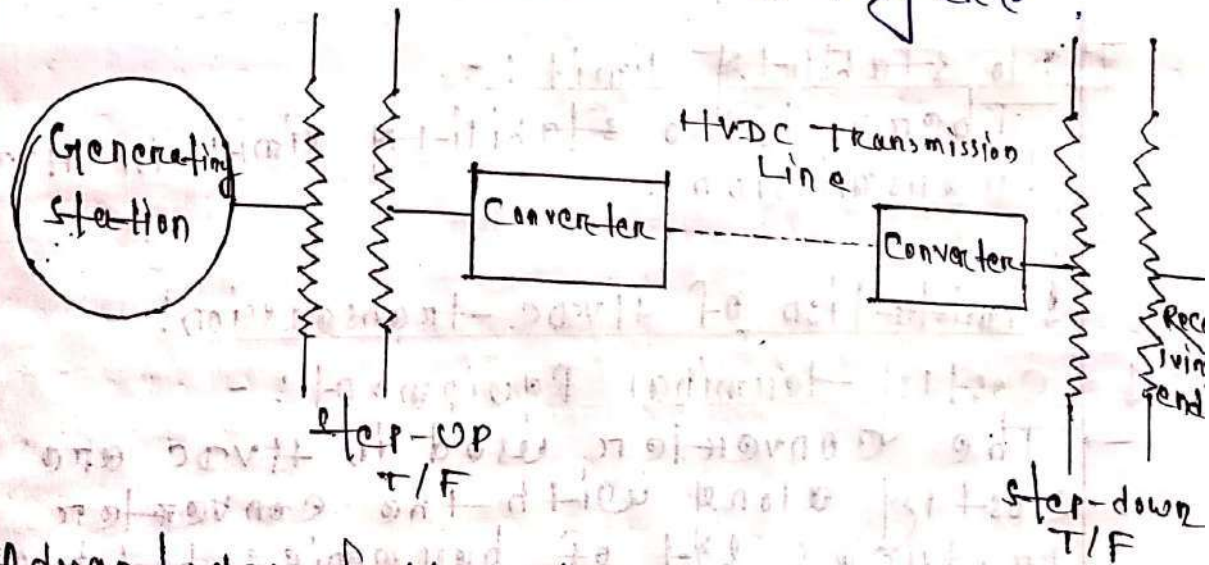
→ the converter station are transformer & thyristor valve.

→ At sending end thyristor valve act as a rectifier to convert AC into DC which is transmitted over line, where as the receiving end thyristor valve act as inverter to convert DC into AC which is utilise at receiving end.

→ Each converter can function as rectifier or inverter.

→ Thus power can be transmitted in either direction.

→ single line diagram of HVDC transmission as shown in the bellow figure



Advantages of HVDC:-

1- **Cheaper in Cost:-**

HVDC transmission line require two pole conductor which is very cheap.

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2- Lower transformer losses:-
HVDC transformer system leads only two conductor & therefore the power loss in DC line is less.

3- Voltage regulation:-
Due to absence of inductance it has better voltage regulation.

4- Low short circuit current:-
It has no short circuit current.

5- Lesser corona loss & radio-interference:-
It has less or corona loss due to zero frequency.

6- Higher spe. operating voltages & know rectifier compensation:-
Generally HVDC system has high operating voltage & with absence of reactive power compensation.

7- No stability limit:-
There is no stability limit in HVDC transmission.

Limitation of HVDC transmission:-

1- Costly terminal equipment:-
→ The converter used in HVDC are very costly along with the converter produces lot of harmonics both on DC & AC side, which requires filtering & smoothing equipment resulting extra cost.

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→ It also require complex cooling system & circuit breaker which again act extra cost.

2- More Maintainance & line insulation!-
It requires more maintainance for insulation.

3- voltage Transformer!-
voltage transformation is not easier incase of DC & hence it has to complete on the AC side of the system, DC system can't not be employed for distribution.

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chapter-5

Types of Tariff

The rate at which electrical energy is supply to the consumer is known as tariff.

Types of tariff:-

1. simple & uniform rate tariff
2. Flat rate tariff
3. Block rate tariff
4. two-part rate tariff
5. Maximum demand tariff
6. Power factor tariff
7. three-part tariff.

1. Flat rate tariff:-

When different types of consumer are charged at different uniform per unit rate it is called flat rate tariff.

Disadvantages:-

- since the flat rate tariff where is according to way the supply is use, separate meters or required for lighting load, power load etc.
- this makes the application of such a tariff expensive & complecated.
- A particular class of consumer is charged at the same rate irrespective of the magnitude of energy consume. However a big consumer should be charged at a lower rate as in is case the fixed charges per unit are reduced.

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2 Block rate tariff :-

When a given block of energy is charged at a specified rate & the succeeding blocks of energy are charged as progressively reduced rate it is called block rate tariff.

Advantages :-

The advantages of such tariff is that consumer gets incentive to consume more electrical energy. this increases the load factor of the system & hence the cost of generation of the reduce.

3 Two-part tariff :-

→ When the rate of electrical energy is charged on the basis of maximum demand of the consumer & the units consume it is called two-part tariff.

→ In two-part tariff the total charge to be made from the consumer is divided into two components i.e. fixed charges & runing charges.

→ The fixed charges depend upon the maximum demand of consumers, while the runing charges depend upon the no. of unit consumed by the consumer.

→ Hence the total charge is a shorten amount per kw of maximum demand plus a shorten amount per kwh of energy consume i.e.

total charge = Rs (b x kw + c x kwh)

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Where,

b = charge per kW of maximum demand

c = charge per kW hour of energy consumed

→ This type of tariff is mostly applicable to industrial consumers, who have maximum demand.

Advantages:-

→ It is easily understood by the consumer.

→ It recover by the fixed charges which depends upon the maximum demand of consumer but are independent of units consume.

Disadvantages:-

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

→ There is always error in assessing the maximum demand of consumer.

Maximum demand tariff:-

→ It is similar to two part tariff with difference that the maximum demand is actual measured by installing maximum demand meter in the premises of the consumer.

→ This removes the objection of two-part tariff, where the maximum demand accesid recently on the basis of units consume.

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→ This type of tariff is mostly applied to big consumers & it is not suitable for small consumers (Residential consumer) as a separate maximum demand meter is required.

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chapter - 6

Performance of transmission line

Overhead transmission line can be classified into 3 types!-

1. **Short transmission Line!-**
Length of overhead short transmission line is up to about 50 km & voltage is less than 20kv.

2. **Medium transmission Line!-**
Length of overhead medium transmission line is about, 50 to 150 km & voltage is moderately high i.e. greater than 20kv & less than 100kv.

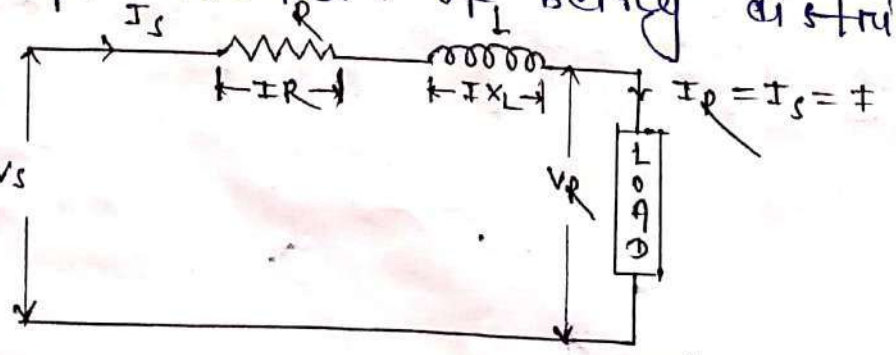
3. **Long transmission line!-**
Length of overhead long transmission line is more than 150 km & voltage is very high i.e. above 100kv.

Performance of single phase short transmission line:-

→ In short transmission line we considered two parameter i.e. resistance & inductance.

→ Capacitance is neglected, due to shorter length & less working voltage.

→ Here, the total line resistance & inductance are shown as concentrated or lumped instead of being distributed.



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Let,

V_S = sending end voltage

I_S = sending end current

V_R = receiving end voltage

I_R = receiving end current

I = Load current

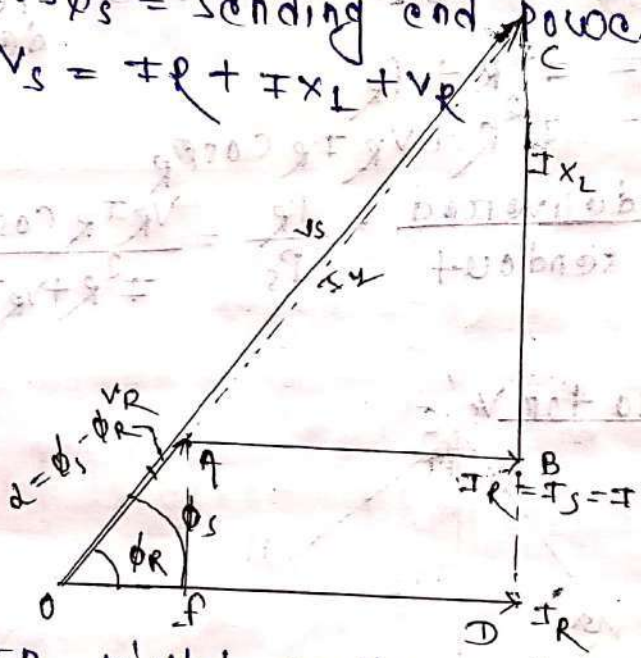
R = Loop resistance i.e. resistance of both conductors.

X_L = Loop reactance

$\cos\phi_R$ = receiving end power factor

$\cos\phi_S$ = sending end power factor

$V_S = IR + IX_L + V_R$



In right angle triangle ODC we get,

$OC^2 = OD^2 + CD^2$

$= (Of + fD)^2 + (BD + BC)^2$

$\Rightarrow V_S^2 = (V_R\cos\phi_R + IR)^2 + (V_R\sin\phi_R + IX_L)^2$

$\Rightarrow \boxed{V_S = \sqrt{(V_R\cos\phi_R + IR)^2 + (V_R\sin\phi_R + IX_L)^2}}$

Voltage regulation

$\%\ V.R = \frac{V_S - V_R}{V_R} \times 100$

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Sending end power factor

$$\cos\phi_S = \frac{OD}{OC} = \frac{Of + fD}{OC}$$

$$= \frac{V_R \cos\phi_R + IR}{V_S}$$

Power delivered (receiving end power)

$$\boxed{P_R = V_R I_R \cos\phi_R}$$

Line losses $= I^2 R$

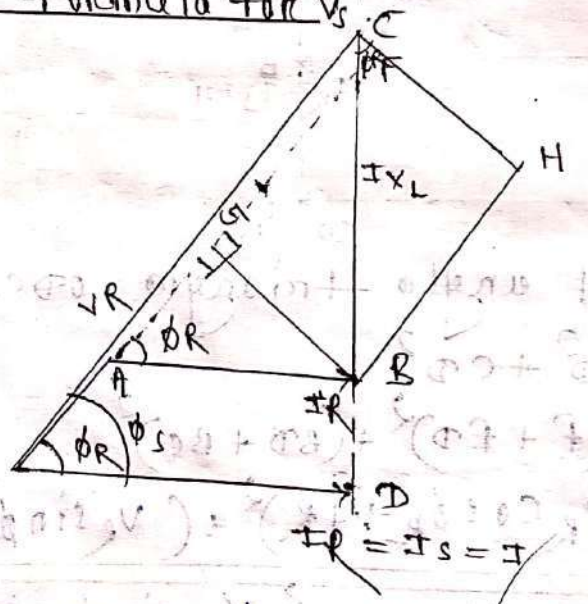
sending end power P_S = line losses + power delivered

$$= I^2 R + P_R$$

$$= I^2 R + V_R I_R \cos\phi_R$$

$$\% \eta = \frac{\text{power delivered}}{\text{power sendout}} = \frac{P_R}{P_S} = \frac{V_R I_R \cos\phi_R}{I^2 R + V_R I_R \cos\phi_R}$$

Another formula for V_S



→ Draw a perpendicular from B & C on OA produce as shown in the above figure.

→ Then OC is nearly equal to 'OF'

$OC \simeq OF$

$\triangle AGB$

$\angle ABG = 90 - \phi_R$

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ΔAFE

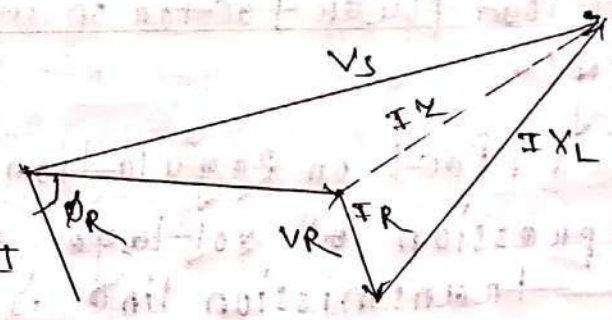
$\angle AEB = 90 - \phi_R$

ΔBHC

$V_S = OA + AG + BH$

$$\boxed{V_S = V_R + IR\cos\phi_R + IX_L \sin\phi_R}$$

Solution in complex plane or complex notation:-
taking $\vec{V_R}$ as reference draw the phasor diagram as shown in the below figure.



It is clear that $\vec{V_R}$ is the phasor sum of

$\vec{V_S} = \vec{V_R} + \vec{IZ}$

$\vec{V_R} = V_R + j0$

$\vec{I} = I \angle -\phi_R$

$= I(\cos\phi_R - j\sin\phi_R)$

$\vec{Z} = R + jX_L$

$\vec{V_S} = \vec{V_R} + \vec{IZ}$

$= (V_R + j0) + I(\cos\phi_R - j\sin\phi_R)(R + jX_L)$

$= V_R + IR\cos\phi_R + IjX_L - IRj\sin\phi_R - I$

$= V_R + (I\cos\phi_R - jI\sin\phi_R)(R + jX_L)$

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$= V_R + IR\cos\phi_R + jIX_L\cos\phi_R - jIR\sin\phi_R + IX_L\sin\phi_R$

$\vec{V_S} = \sqrt{(V_R + IR\cos\phi_R + IX_L\sin\phi_R)^2 + j(IX_L\cos\phi_R - IR\sin\phi_R)^2}$

$|\vec{V_S}| = \sqrt{(V_R + IR\cos\phi_R + IX_L\sin\phi_R)^2 + j(IX_L\cos\phi_R - IR\sin\phi_R)^2}$

→ The 2nd term under the root is quite small & can be neglected.

Hence $\boxed{V_S = V_R + IR\cos\phi_R + IX_L\sin\phi_R}$

Effect of load power factor on regulation or efficiency :-

Case-1 (Effect on regulation) :-

The expression of voltage regulation on a short transmission line is given by

$\%.V.R = \frac{V_S - V_R}{V_S} \times 100$

$= \frac{V_R + IR\cos\phi_R + IX_L\sin\phi_R - V_R}{V_R} \times 100$

$= \frac{IR\cos\phi_R + IX_L\sin\phi_R}{V_R} \times 100$ (Lagging P.f)

$\%.V.R = \frac{IR\cos\phi_R - IX_C\sin\phi_R}{V_R} \times 100$ (Leading P.f)

Following conclusions can be drawn from above expression :-

→ When the load power factor is lagging or unity than $IR\cos\phi_R$ is $> IX_L\sin\phi_R$, than voltage regulation in +ve i.e. receiving end voltage will be $<$ (V_S) sending end voltage.

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→ For a given V_R & I the voltage regulation of the line increases with the decrease in power factor for lagging loads.

→ When the load power factor is leading, $IX_c \sin\phi_R > IR\cos\phi_R$, then voltage regulation in -ve i.e. receiving end voltage is > sending end voltage.

→ For a given V_R & I the voltage regulation of the line decreases with the decreasing power factor for leading loads.

Case-2 (Effect on transmission efficiency)- the power delivered to the load depends on power factor.

$$P_R = V_R I R \cos\phi_R \quad (1-\phi)$$

$$= V_R I \cos\phi_R \quad (I_R = I_S = I)$$

$$\boxed{I = \frac{P_R}{V_R \cos\phi_R}}$$

$$P_R = 3 V_R I_R \cos\phi_R \quad (3-\phi)$$

$$\boxed{I = \frac{P_R}{3 V_R I_R \cos\phi_R}}$$

→ It is clear that in is case for a given amount of power to be transmitted (P_R) & receiving end voltage (V_R), the load current (I) is inversely proportional to load power factor ($\cos\phi_R$).

→ With the decrease in load power factor, Load current than the line losses are increased, this leads to the conclusion that transmission efficiency of a line decreases with the decrease in Load power factor & vice-versa.

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Problem:- 1

A single phase overhead transmission power delivered 1100 KW at 33 KV at 0.8 p.f. lagging. The total resistance & inductive reactance of the line are 10Ω & 15Ω respectively.

(a) Determine sending end voltage.
(b) sending end power factor
(c) transmission efficiency.

Given data,

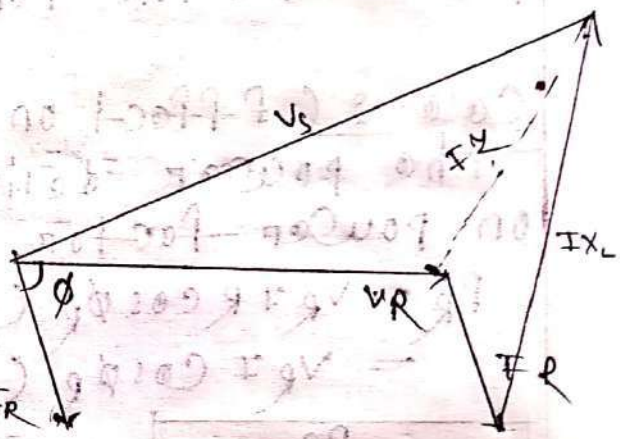
$P_R = 1100 KW$

$V_R = 33 KV$

$\cos\phi_R = 0.8$ lagging

$R = 10\Omega$

$X_L = 15\Omega$



$$I = \frac{P_R}{V_R \cos\phi_R}$$

$$= \frac{1100}{33 \times 0.8} = 41.66$$

$$\overrightarrow{V_R} = V_R + j0$$

$$= 33 \times 10^3 \text{ V}$$

$$\overrightarrow{I} = I(\cos\phi_R - j\sin\phi_R)$$

$$I = \frac{P_R}{V_R \cos\phi_R} = \frac{1100}{33 \times 0.8} = 41.67 \text{ amp}$$

$$\sin\phi_R = \sin(36.86)$$

$$= 0.59$$

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Problem - 2

An overhead 3-ϕ transmission line $V_L = 33$ kV delivered 5000 kW at 22 kV at $V_{ph} = \frac{V_L}{\sqrt{3}}$ 0.8 p.f. lagging. The resistance & reactance of each conductor in 4 Ω & 6 Ω respectively. Determine.

(a) sending end voltage (V_S)
(b) % V.R
(c) transmission efficiency.

Given data, 3-ϕ

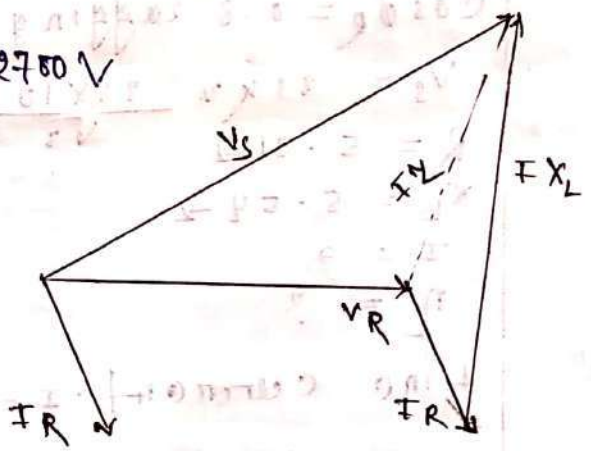
$P_R = 5000 \text{ kW} = 3 V_{Ph} I_{Ph} \cos\phi_R \times 10^3$

$V_R = 22 \text{ kV} = \frac{22 \times 10^3}{\sqrt{3}} = 12700 \text{ V}$

$\cos\phi_R = 0.8$ lagging

$R = 4\ \Omega$

$X_L = 6\ \Omega$



$\vec{V_S} = \vec{V_R} + \vec{I}\vec{Z}$

$V_R = V_R + j0$

$= 12700 \text{ V}$

$I = \frac{P_R}{3 V_R \cos\phi_R} = 164.4 \text{ amp}$

$\vec{I} = 164 (0.8 - j0.6)$

$\vec{V_S} = \vec{V_R} + \vec{I}\vec{Z}$

$= 12700 + 164(0.8 - j0.6) \times 4 + j6 = 13815.2 + j393.6$

$V_S = \sqrt{3} \times 13821.04$

$= 23938.74 \text{ V}$

$= 23.938 \text{ kV}$

$\% \text{ V.R} = \frac{V_S - V_R}{V_R} \times 100$

$= \frac{13821.04 - 12700}{12700} \times 100$

$= 8.827\%$

$\eta = \frac{P_R}{P_R + 3I^2R} = \frac{5000 \times 10^3}{5000 \times 10^3 + 3(164)^2 \times 4} \times 100$

$= 93.93$

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problem-3

A 3ϕ line deliverse 3600 kW at a p.f 0.8 lagging to a load, if the V_s is 33kV determine.

(i) V.R

(ii) Line current (I_L)

(iii) transmission efficiency the resistance & reactance of each conductor are 5.31Ω $X_L = 5.54\Omega$

Give data,

$P_R = 3600$ kW

$V_R = ?$

$\cos\phi_R = 0.8$ lagging

$V_S = 33kV \frac{33\times10^3}{\sqrt{3}} = 19052$ volt

$R = 5.31\Omega$

$X_L = 5.54\Omega$

$I = ?$

$\eta = ?$

Line current $I = \frac{P_R}{V_R \cos\phi_R} = \frac{3600\times10^3}{3\times V_R \times 0.8}$

$= \frac{1200\times10^3}{0.8 V_R}$

$\Rightarrow I = \frac{150\times10^4}{V_R}$

$V_S = V_R + IR\cos\phi_R + IX_L\sin\phi_R$

$19052 = V_R + \frac{150\times10^4}{V_R}\times 5.31\times0.8 + \frac{150\times10^4}{V_R}\times 5.54\times0.6$

$= \frac{6372\times10^3}{V_R} + \frac{4986\times10^3}{V_R}$

$19052 = \frac{V_R^2 + 6372\times10^3 + 4986\times10^3}{V_R}$

$\Rightarrow 19052 V_R = V_R^2 + 11358\times10^3$

$\Rightarrow V_R^2 - 19052 V_R + 11358\times10^3 = 0$

$\Rightarrow V_R = 18435.92$ V

$V_S =$

$I =$

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$$\eta = \frac{P_R}{P_R + 3I^2R} \times 100$$

$$= \frac{3600 \times 10^3}{3600 + 3 \times (81.36)^2 \times 5.31} \times 100$$

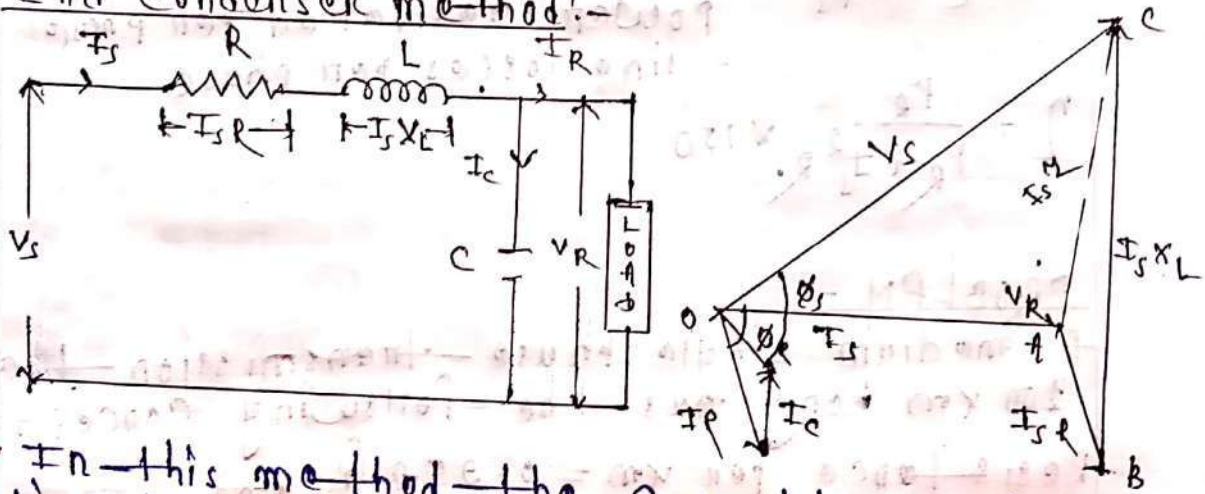
$$= 97.15$$

Medium transmission Line:-

The commonly used method for medium transmission line:

1. End condenser method
2. Nominal 'T' method
3. Nominal 'π' method.

End condenser method:-



→ In this method the capacitance of the line is lumped or concentrated at the recieving end as shown in the above figure.

→ Let,

I_R = Recieving end current per phase

R = Resistance per phase

X_L = inductive reactance per phase

C = capacitance per phase

$\cos\phi_R$ = Recieving end p.f (lagging)

V_S = sending end voltage per phase.

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1- $\overrightarrow{V_R} = V_R + j0$

2- $\overrightarrow{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

3- $\overrightarrow{I_C} = j \times 2\pi fc \cdot \overrightarrow{V_R} = JY\overrightarrow{V_R}$

4- $\overrightarrow{I_S} = \overrightarrow{I_R} + \overrightarrow{I_C}$

$= I_R(\cos\phi_R - j\sin\phi_R) + (J \times 2\pi fc \cdot \overrightarrow{V_R})$

$= I_R\cos\phi_R + j(-I_R\sin\phi_R + 2\pi fc\overrightarrow{V_R})$

5- voltage drop / phase $= \overrightarrow{I_S}\overrightarrow{Z} = \overrightarrow{I_S}(R + jX_L)$

6- $\overrightarrow{V_S} = \overrightarrow{V_R} + \overrightarrow{I_S} \cdot \overrightarrow{Z}$

7- $\%\ V.R = \frac{V_S - V_R}{V_R} \times 100$

8- $\%\ \eta = \frac{P_R}{P_S} = \frac{\text{power delivered per phase}}{\text{power delivered per phase} + \text{line losses per phase}} \times 100$

$\eta = \frac{P_R}{P_R + I_S^2 R} \times 100$

PROBLEM:-

A medium single phase transmission line 100 km long has the following constant

Resistance per km $= 0.25\Omega$ (Ω/km)

Resistance reactance per km $= 0.8$ (Ω/km)

Susceptance per km $= 14 \times 10^{-6}$ (Y/km)

Receiving end line voltage $= 66$ kV

Assuming that the total capacitance is localised at the receiving end along determined

(i) sending end current

(ii) sending end voltage

(iii) voltage regulation

(iv) supply power factor

(v) the line is delivering 45000 kW @ 0.8 power factor lagging.

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Given data,

$l = 100\ km$

$R/km = 0.25\ \Omega$

$x/km = 0.8\ \Omega$

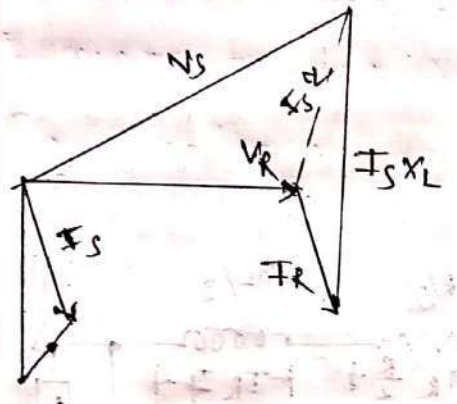
$Y/km = 14 \times 10^{-6}$

~~Admittance~~ (Y) ~~Impedance~~

$Y = G + jB$

$Z = R + jx$

$= \frac{1}{Z} = \frac{1}{R} + j\frac{1}{x}$



(1) ~~Total~~ resistance
$= 0.25 \times 100 = 25$

(2) ~~Total~~ reactance
$= 0.8 \times 100 = 80$

(3) susceptance
$= 14 \times 10^{-6} \times 100$
$= 1.4 \times 10^{-4}$

$V_R = 66,000$ volt

$P_R = 15000\ kW$

$\overrightarrow{I_S} = \overrightarrow{I_R} + \overrightarrow{I_C}$

$\overrightarrow{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

$I_R = \frac{P_R}{V_R \cos\phi_R} = \frac{15000}{66000 \times 0.8} = 0.284\ kW$
$= 284\ mP$

$\overrightarrow{I_R} = 284(0.8 - j0.6)$
$= 227 - j170$

$I_C = -j2\pi f_C \times V_R$
$= jYV_R$
$= 14 \times 10^{-6} \times 66000$
$= j92.4 \sin\phi_R$

$\overrightarrow{I_S} = \overrightarrow{I_R} + I_C$
$= 227 - j170 + (-j92.4)$
$= 227 - j78$

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$I_s = 240.02 \angle -18.95$

$\overrightarrow{V_S} = \overrightarrow{V_R} + \overrightarrow{I_S}\,\overrightarrow{Z}$

$= (66000 + 227 - j78)(25 + j80)$

$= 77915 + j16210$

$\overrightarrow{V_S} = 79583 \angle 11.75$

$V.R = \frac{V_S - V_R}{V_R} \times 100$

$= \frac{795.83 - 66,000}{66,000} \times 100$

$= 20.58$

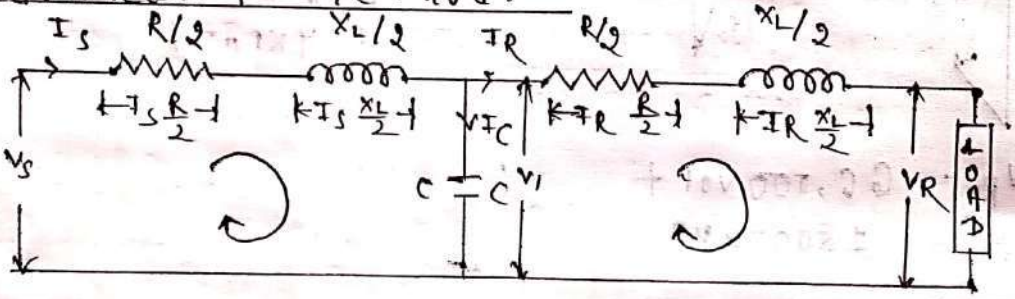
$\phi_S = 18.95 + 11.75$

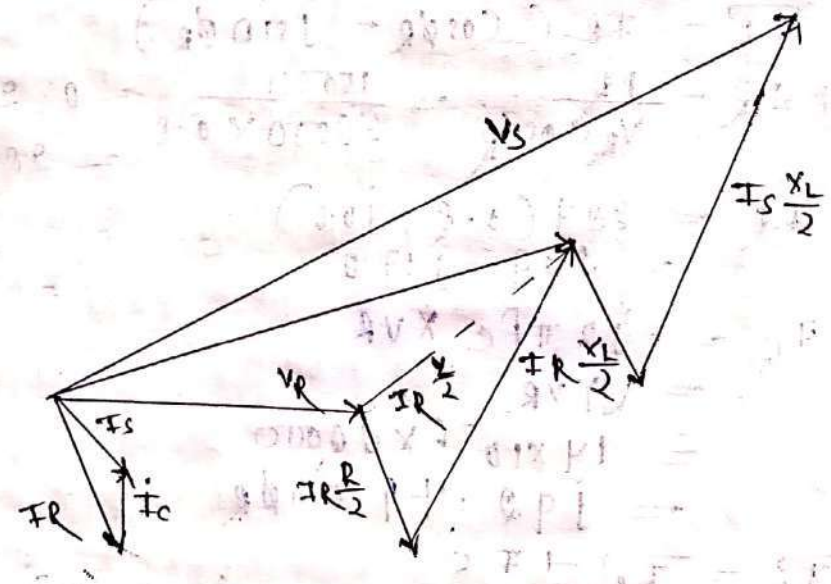
$= 30.7$

$\cos\phi_S = \cos(30.7)$

$= 0.85$

Nominal 'T' method:-





Let,

I_R = Receiving end current

R = Resistance per phase

X_L = Inductive reactance / phase

C = capacitance per phase

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$\cos\phi_R$ = Receiving end power factor
V_S = sending end power factor
V_L = voltage across capacitor

(i) $\overrightarrow{V_R} = V_R + j0$

(ii) $\overrightarrow{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

(iii) $\overrightarrow{I_C} = jY V_1$

(iv) $\overrightarrow{V_1} = \overrightarrow{V_R} + \overrightarrow{I_R}\frac{Z}{2}$

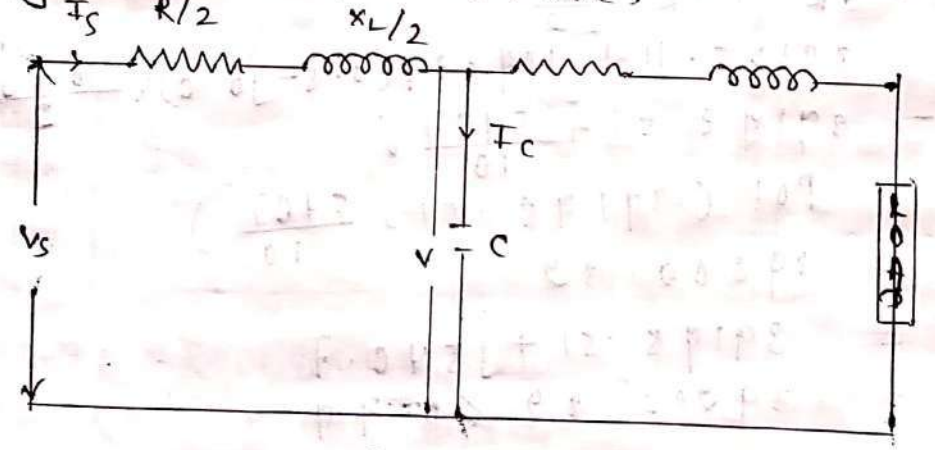
(v) $\overrightarrow{V_S} = \overrightarrow{V_1} + \overrightarrow{I_S}\frac{Z}{2}$

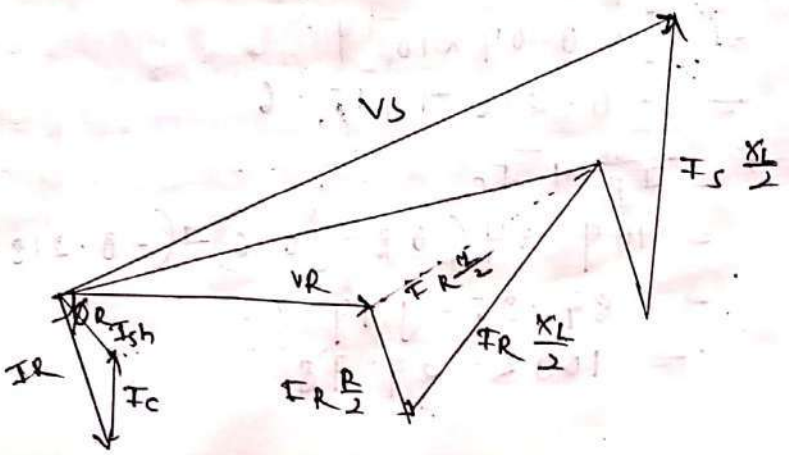
(vi) $\overrightarrow{I_S} = \overrightarrow{I_R} + \overrightarrow{I_C}$

(vii) $\% \eta = \frac{P_R}{P_R + 3I_S^2 R} \times 100$

problem:-

A 3-ϕ 50Hz overhead transmission line of 100 km long has the following data,
Resistance/km/phase = 0.1 Ω
X_L/km/phase = 0.2 Ω
Y/km/phase = 0.04×10^{-4} siemen
Determine (i) sending end voltage (ii) I_S (iii) $\cos\phi_S$ (iv) transmission efficiency (v) when supplying balance load of 1000 km at 66 kV, p.f is 0.8 lagging solve the problem by nominal 'T' method.





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Given data,

$P_R = 10,000$ kW
$V_R = 66$ kV
$\cos\phi_R = 0.8$

$l = 100$ km
$R/km/ph = 0.1\Omega$
$X_L/km/ph = 0.2\Omega$
$Y/km/ph = 0.04 \times 10^{-4}$ S

$\overrightarrow{I_s} = \overrightarrow{I_R} + \overrightarrow{I_C}$

$\overrightarrow{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

$I_R = \frac{P_R}{3V_R\cos\phi_R} = ?$

(i) $\overrightarrow{V_R} = V_R + j0$

$= \frac{66 \times 10^3}{\sqrt{3}} = 38105.11$ V

$\overrightarrow{V_1} = \overrightarrow{V_R} + \overrightarrow{I_R} \times \frac{Z}{2}$

$\overrightarrow{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

$I_R = \frac{P_R}{3 \times V_R \times \cos\phi_R} = \frac{10,000 \times 10^3}{3 \times 38105.11 \times 0.8}$

$= 109.34$

$\overrightarrow{I_R} = 109.34(0.8 - j0.6) = 2.068$

$\overrightarrow{V_1} = \overrightarrow{V_R} + \overrightarrow{I_R} \cdot \frac{\overrightarrow{Z}}{2}$

$= 38105.11 + 109.34(0.8 - j0.6) \times \frac{10 + j20}{2}$

$= 39198.51 + \frac{5467}{10}$

$= P01\left(39198.51, \frac{5467}{10}\right)$

$= 39202.32$

$= 39198.51 + j546.7$

$= 39202.32 \angle 0.79$

$\overrightarrow{I_C} = jYV_1$

$= j \times 0.04 \times 10^{-4}$

$= -0.218 + j15.6$

$\overrightarrow{I_S} = \overrightarrow{I_R} + \overrightarrow{I_C}$

$= 109.34(0.8 - j0.6) + (-0.218 + j15.6)$

$= 87.25 - j49.93$

$= 100 \angle -29.78$

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$$\overrightarrow{V_S} = \overrightarrow{V_1} + \overrightarrow{I_S}\,\frac{\overrightarrow{Z}}{2}$$

$$= 40128 + j1172$$

$$\text{POL}(40128, 1172)$$

$$\overrightarrow{V_S} = \text{POL}(40128 \cdot 0$$

$$\overrightarrow{V_S} = \text{POL}(40134 \cdot 06, 1172)$$

$$= 40151 \cdot 1688 < 1 \cdot 67$$

$$\cos\phi_S = \cos(31 \cdot 45)$$

$$= 0 \cdot 85$$

$$\phi_S = \phi_1 + \phi_2$$

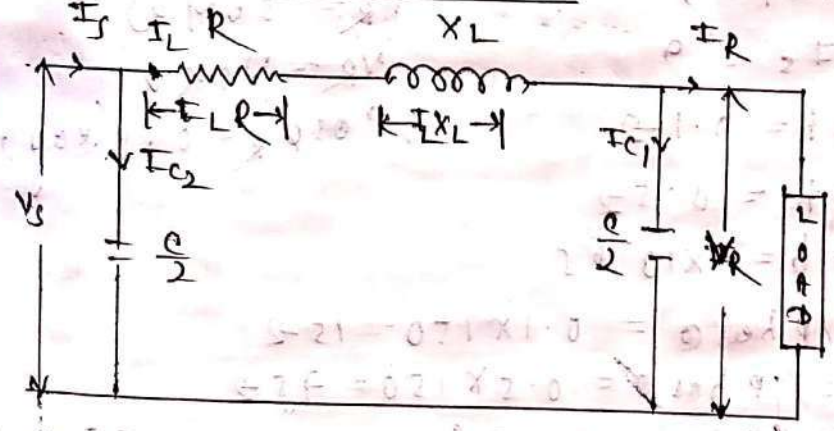
$$= 29 \cdot 78 + 1 \cdot 66 = 31 \cdot 45$$

$$\eta = \frac{P_R}{P_R + 3I_S^2 R}$$

$$= \frac{10 \cdot 000 \times 10^3}{10 \cdot 000 \times 10^3 + 3 \times (100)^2 \times 10} \times 100$$

$$= 97 \cdot 05\%$$

Nominal π method :-



Let, $\overrightarrow{I_R}$ = Receiving end current

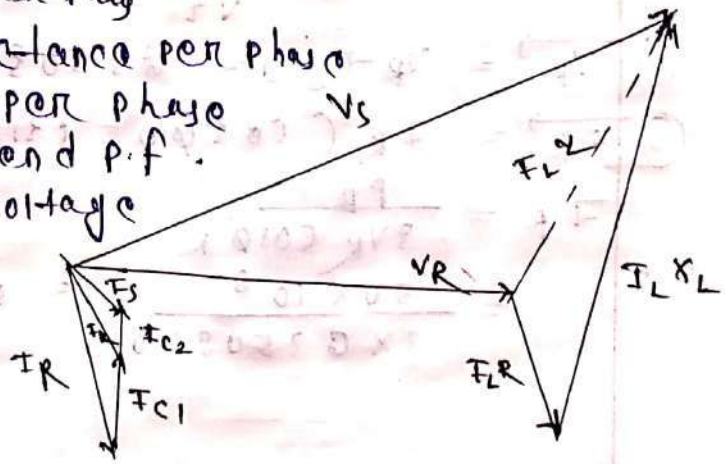
R = Resistance per phase

X_L = inductive reactance per phase

C = Capacitance per phase

$\cos\phi$ = Receiving end p.f.

V_S = sending end voltage



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(i) $\overrightarrow{V_R} = V_R + j0$

(ii) $\overrightarrow{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

(iii) $\overrightarrow{I_{C1}} = j2\pi f \frac{C}{2} \times \overrightarrow{V_R}$

$= j\frac{Y}{2}\overrightarrow{V_R}$

(iv) $\overrightarrow{I_L} = \overrightarrow{I_R} + \overrightarrow{I_{C1}}$

(v) $\overrightarrow{V_S} = \overrightarrow{V_R} + \overrightarrow{I_L}\overrightarrow{Z}$

(vi) $\overrightarrow{I_{C2}} = j2\pi f \frac{C}{2} \times \overrightarrow{V_S}$

$= j\frac{Y}{2}\overrightarrow{V_S}$

(vii) $\overrightarrow{I_S} = \overrightarrow{I_L} + \overrightarrow{I_{C2}}$

problem:-

1 3-ϕ, 50Hz, 150 km line has a resistance, inductive reactance & capacitive shunt admittance of 0.1Ω, 0.5Ω & 3×10^{-6} simen per/km/phase, If the line delivers 50MW at 110kV & 0.8 p.f. lagging, determine sending end voltage & sending end current.

Given data,

$V_S = ?$, $I_S = ?$

$R/km/ph = 0.1\Omega$

$X_L/km/ph = 0.5\Omega$

$Y/km/ph = 3\times10^{-6}$ S

$P_R = 50MW$

$V_R = 110kV$

$\cos\phi_R = 0.8$ (lag)

total R/phase $= 0.1\times150 = 15\Omega$

total X_L/phase $= 0.5\times150 = 75\Omega$

total Y/ph $= 3\times10^{-6}\times150 = 45\times10^{-5}$ S

$V_R/ph = \frac{110\times10^3}{\sqrt{3}} = 63508$ V

(i) $\overrightarrow{V_R} = V_R + j0 = 63508$ V

(ii) $\overrightarrow{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

$I_R = \frac{P_R}{3V_R\cos\phi_R}$

$= \frac{50\times10^6}{3\times63508\times0.8} = 328$ A

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(iii) $\overrightarrow{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

$= 3284(0.8 - j0.6)$

$= 2627.2 - 1970.4j$

OR $= 2624 - j196.8$

$\overrightarrow{I_{C1}} = j\frac{Y}{2}\overrightarrow{V_R}$

$= j\frac{45\times10^{-5}}{2} \times 63508$

$= j14.288$

$\overrightarrow{I_L} = \overrightarrow{I_R} + \overrightarrow{I_{C1}}$

$= 262.4 - j196.8 + j14.28$

$= 262.4 - j182.52$

$\overrightarrow{I_{C2}} = j\frac{Y}{2}\overrightarrow{V_S}$

$= \frac{45\times10^{-5}}{2} \times 81131.5 \times j16942.5$

$= -3.81 + j18.25$

$\overrightarrow{V_S} = \overrightarrow{V_R} + \overrightarrow{I_L}\,\overrightarrow{Z}$

$= 63508 + (262.4 - j182.52)(15 + j75)$

$= 81131.5 + j16942.5$

POI $(81131.5, 16942.5)$

$r = 82881.65 \angle 11.79$

$\overrightarrow{I_S} = \overrightarrow{I_L} + \overrightarrow{I_{C2}}$

$= 262.4 - j182.52 + -3.81 + j18.25$

$= 258.54 - j164.27$

$= 306.34 \angle -32.4$

$V_S = 82881.65 \times \sqrt{3}$

$= 143555.22$

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problem:-

A 100 km long 3-ϕ 50 Hz transmission line has following constants

$R/km/ph = 0.1\Omega$

$X_L/km/ph = 0.5\Omega$

$Y/km/ph = 10\times10^{-6}$

If the line supplies load of 20 MW at 0.9 p.f. lagging at 66 kV at the receiving end calculate the following data by nominal 'π' method.

(1) sending end p.f $\cos\phi_s$

(2) % V.R (3) transmission efficiency.

Given data,

$P_R = 20$ MW

$V_R = 66$ kV

$\cos\phi_R = 0.9$ lag

$R/km/ph = 0.1\Omega$

$X_L/km/ph = 0.5\Omega$

$Y/km/ph = 10\times10^{-6}$

total $R/ph = 0.1\times100 = 10$

total $X_L/ph = 0.5\times100 = 50$

total $Y/ph = 10\times10^{-6}\times100 = 1\times10^{-3}$ S

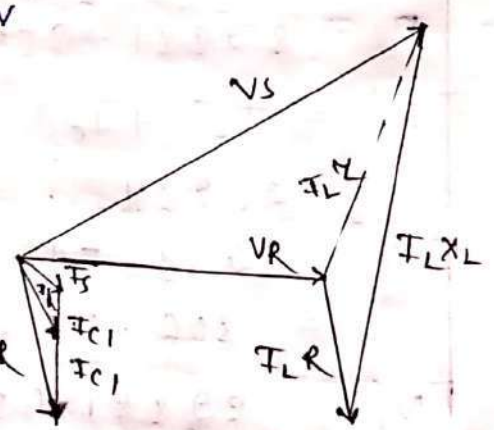
$V_R/ph = \frac{66\times10^3}{\sqrt{3}} = 38105$ V

(i) $\overrightarrow{V_R} = V_R = j0 = 38105$ V

(ii) $\overrightarrow{I_R} = I_R(\cos\phi_R - i\sin\phi_R)$

$I_R = \frac{P_R}{3V_R\cos\phi_R}$

$= \frac{20\times10^6}{3\times38105\times0.9} = 194.39$



(iii) $\overrightarrow{I_R} = I_R(\cos\phi_R - i\sin\phi_R)$

$= 194.39(0.9 - j0.435)\cdot25.84$

$= 174.906 - j84.5379$

$\overrightarrow{I_{C1}} = j\frac{Y}{2}\overrightarrow{V_R}$

$= j\frac{10\times10^{-6}}{2}\times38105$

$= j0.194$ A

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$$\overrightarrow{I_L} = \overrightarrow{I_R} + \overrightarrow{I_{C_1}}$$

$$= 174.906 - j84.5379 + j0.19$$

$$= 175.096 - j84.53$$

$$\overrightarrow{I_{C_2}} = j\frac{Y}{2}\overrightarrow{V_s}$$

$$= j\frac{10 \times 10^{-6}}{2}$$

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CHAPTER - 7

Underground cables

Introduction :-

→ Underground cables essentially consists of one or more conductor covered with suitable insulation & surrounded by protective coverse.

→ The underground cables have several advantage such as Less liable to damage due to lightening, low maintenance cost, less chances of fault, smaller voltage drop & better general appearance.

→ For this reason underground cables employed where it is impracticable to use overhead line.

→ The major disadvantage is that they have greater installation cost & introduce insulation problem at high voltage compared with overhead system.

Construction of underground cable :-

1. Conductor :-

→ A cable may have one or more than one core (conductor) depending upon the type of service for which it is use.

→ The conductors are made up of with copper or aluminium & are usually stranded in order to provide flexibility of the cable.

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2. Insulator:-

→ The conductor are insulated from each other by paper or, rubber, mineral compound or impregnated paper.

→ The insulation is provided with a suitable thickness of insulation & protect from moisture & from other damaging liquid in the soil or atmosphere.

3. Metalic sheath:-

→ In order to protect the cable from moisture, gases or other damaging acids in the soil & atmosphere.

→ A metalic sheath of lead or alluminium is provided over the insulation as shown in the below figure.

4. Bedding:-

→ Over the metalic sheath their is a layer of bedding which consist of fibrous material like jute or hessian-tape, the purpose of bedding is to protect the metal sheath against corosion & from mechanical injury due to armouring.

5. Armouring:-

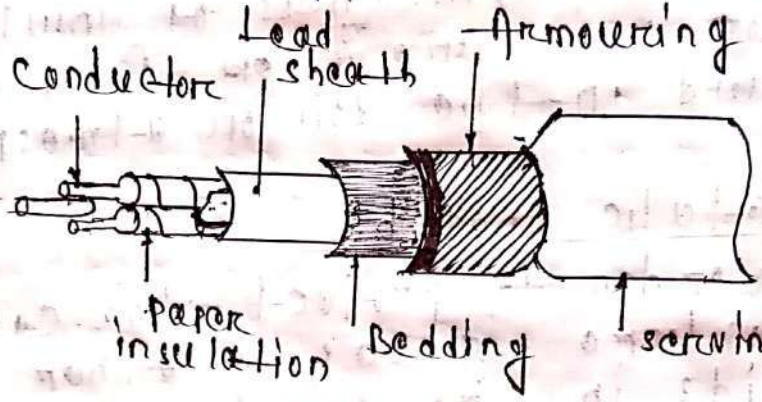
→ over the bedding armouring is provided which consists of one or two layers of galvanised steal wire or steel tap.

→ Its purpose protect the cable from mechanical injury while laying it.

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6- Serving!-

In over to protect armouring from atmospheric condition a layer of fibrous material (jute) similar to bedding is provided over the armouring, this is known as serving.



Classification of cables!-

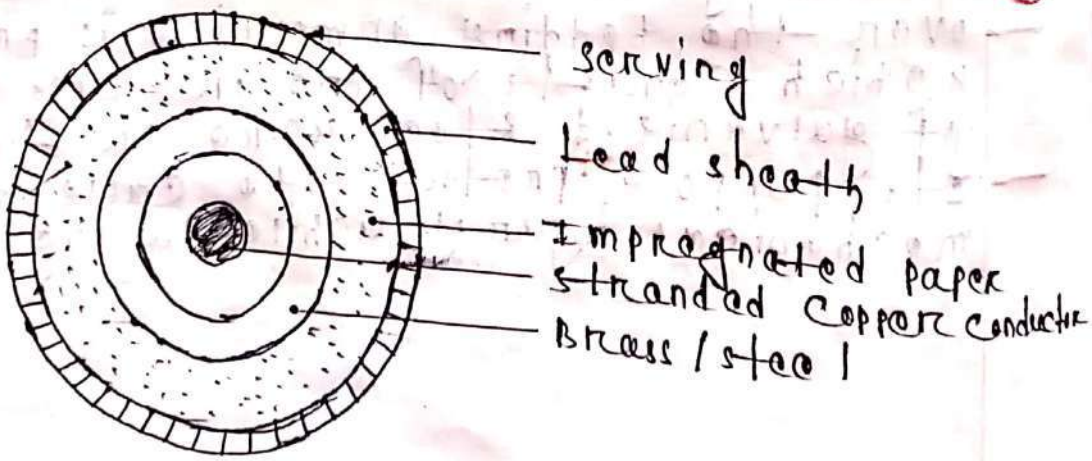
1. Low tension cable (LT)
2. High tension cable (HT)

Low tension cable!-

→ these are used for voltage cable up to 1000 volt.

→ paper is used as an insulation material in this cable, sum time resin is also used which increases the viscosity. Resin is a hydrocarbon liquid.

→ the below fig shows the constructional details of LT cable.



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→ It is consists of one circular core of stranded copper or aluminium insulated by layer of impregnated paper.

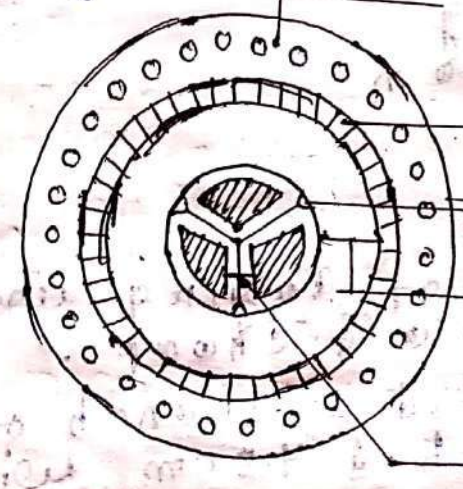
→ the insulation is surrounded by a lead sheath which prevents the entry of moisture into the inner parts.

→ In order to protect the lead sheath from corrosion & overall serving of compounded fibrous material (jute) is provided.

→ The main advantage of single core cable are simple construction & availibility of larger copper section.

High tension cable :-

→ These are a cable which are used for voltage up to 11kV, but in extra ordinary case is may be extended.



→ Above figure shows the constructional details of 3 core HT Cable.

→ the core are insulated from each other by layer of impregnated paper & another layer of impregnated paper tape called as paper belt is wound the grouped insulated core.

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→ The gap between insulated core is filled with fibrous insulating material (jut) so as to give circular cross-section to the cable.

→ The cores are generally stranded & may be of non-circular shape to make better use of available space.

→ The belt is covered with lead sheath to protect the cable from moisture & mechanical injury.

→ The lead sheat is covered with one or more layer of armouring with an outer serving.

Methods cable laying:-
There are 3 main method of laying underground cable:-

1. Direct laying
2. Draw in system
3. Solid system

Direct laying:-

→ This method of laying underground cable is simple & cheap.

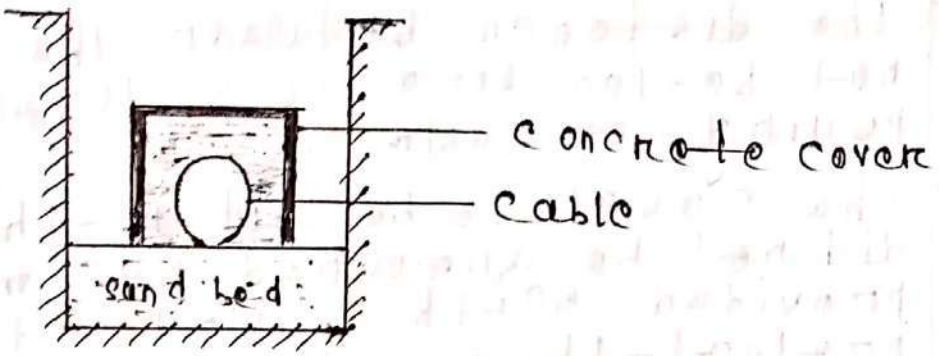
→ In this method a trench of about 1.5 m depth & 45 cm wide is dumbed.

→ The trench is covered with a layer of fine sand of about 10 cm thickness & the cable is laid over this sand belt.

→ The sand prevents the entry of moisture from the ground & thus protects the cable.

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→ After the cable has been laid in the trench it is covered with another layer of sand of about 10cm thickness.
→ The trench is then covered with bricks & other material in order to protect the cable from mechanical injury.



Advantage :-
→ It is a simple & less costly method.
→ It is a clean & save method as the cable is invisible & free from external disturbance.

Disadvantage :-
→ The maintainance cost is very high.
→ Localisation of fault is difficult.
→ The alternation in the cable network can not made easily.
→ It can not be use in conjusted area.

Draw-in system :-
→ In this method conduit or duct of glad stone or cast iron or concrete are laid in the ground with holes at suitable position along the cable root.
→ The cables are then pulled into position from the poles.

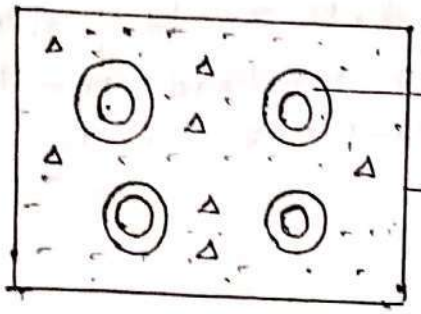
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→ The below figure shows section through four weight underground duct line.

→ 3 of the 4 ducts carry transmission cable & the 4 duct carries relay protection connection.

→ The distance between the hole should not be too long. so as to simplify the pulling of cables.

→ The cables to be laid in this weight did not be armoured but must be provided with serving (jut) in order to protect them, when being pulled into the ducts.



Advantages!-

→ Repairs, alternation or addition to the cable network can be made without opening the ground.

→ As the cables are not armoured joint become simpler & maintainance cost is reduced.

→ There are very less chances of fault occurance due to strong mechanical protection provided by the system.

Disadvantage!-

→ The initial cost is very high.

→ The current carrying capacity of the cable is produced, due to the close grouping of cables.

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Solid system:-

→ In this method of laying the cable is laid in open pipes or duct out in earth along the cable root.

→ The pipe is of cast iron, stone ware or treated wood.

→ After the cable is laid in position the surrounding area is filled with bituminus compound & covered over.

→ Cable laid in this manner area usually plane laid cover because it is gives good mechanical protection.

Disadvantages:-

→ It is more expensive than direct ~~laying~~ laying system.

→ It requires skilled labour & favourable weather condition.

Loop test for location of fault in underground cable:-

There are several methods for locating the faults in underground cables.

Two popular methods are as follows:-

1- Murray loop test

2- Varley loop test.

These simple test can be used locate earth fault & short circuited fault in underground cables. Both these test employed the principle of Wheatstone bridge for fault location.

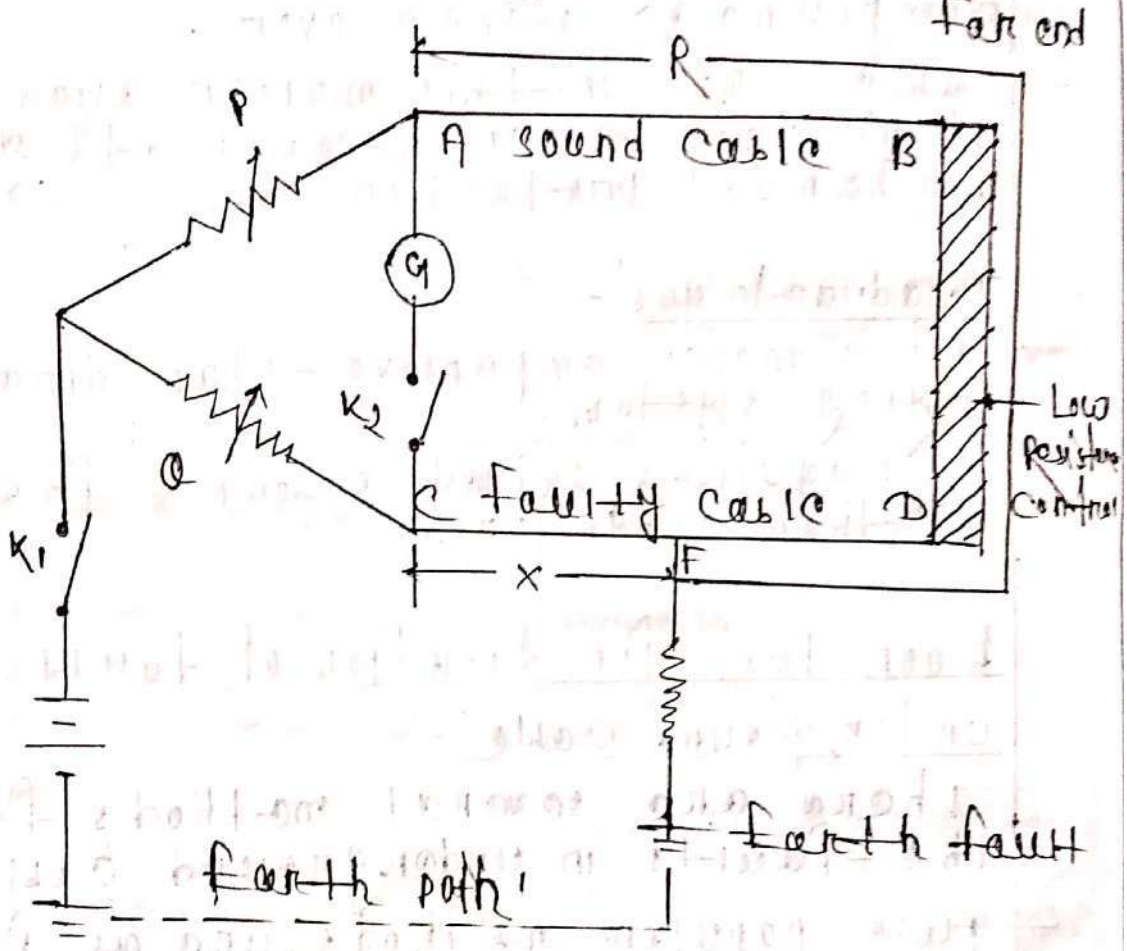
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1. Murray loop test :-

The murray loop test is the most common & accurate method for locating earth fault or short ckt fault in underground cables.

Case - 1

Earth fault :- Far end



→ The above fig shows the ckt diagram for locating the earth fault by murray loop test.

→ Here, AB is the sound cable & CD is the faulty cable, the earth fault occuring at point 'F'.

→ The far end 'D' of the faulty cable is joint to the far end 'B' of the sound cable through a low resistance connection.

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→ two variable resistance 'P' & 'Q' are joined to ends 'A' & 'C' respectively & serve as the ratio arms of the wheatstone bridge.

→ Let, R = Resistance of the conductor loop of, to the fault from the test end.

→ X = Resistance of the other length of the loop.

→ Note that P, Q, R and 'X' are the 4 arms of wheatstone bridge, the resistance P & Q are varied to till the galvanometer indicates '0' deflection.

→ In the balance position of the bridge behave $\frac{P}{Q} = \frac{R}{X}$

$= \frac{P}{Q} + 1 = \frac{R}{X} + 1$

$\Rightarrow \frac{P+Q}{Q} = \frac{R+X}{X}$

$\Rightarrow \frac{P+Q}{Q} = \frac{2r}{X} \Rightarrow X = \frac{Q}{P+Q} \cdot 2r$

→ If 'r' is the resistance of is cable than, $R + X = 2r$.

→ If 'l' is length of is cable in meters than resistance per meter length of cable is $= \frac{r}{l}$

→ Distance of fault point from test is

$d = \frac{X}{r/l}$

$= \frac{\frac{Q}{P+Q} \cdot 2r}{r/l} = \frac{Q}{P+Q} \times 2l$

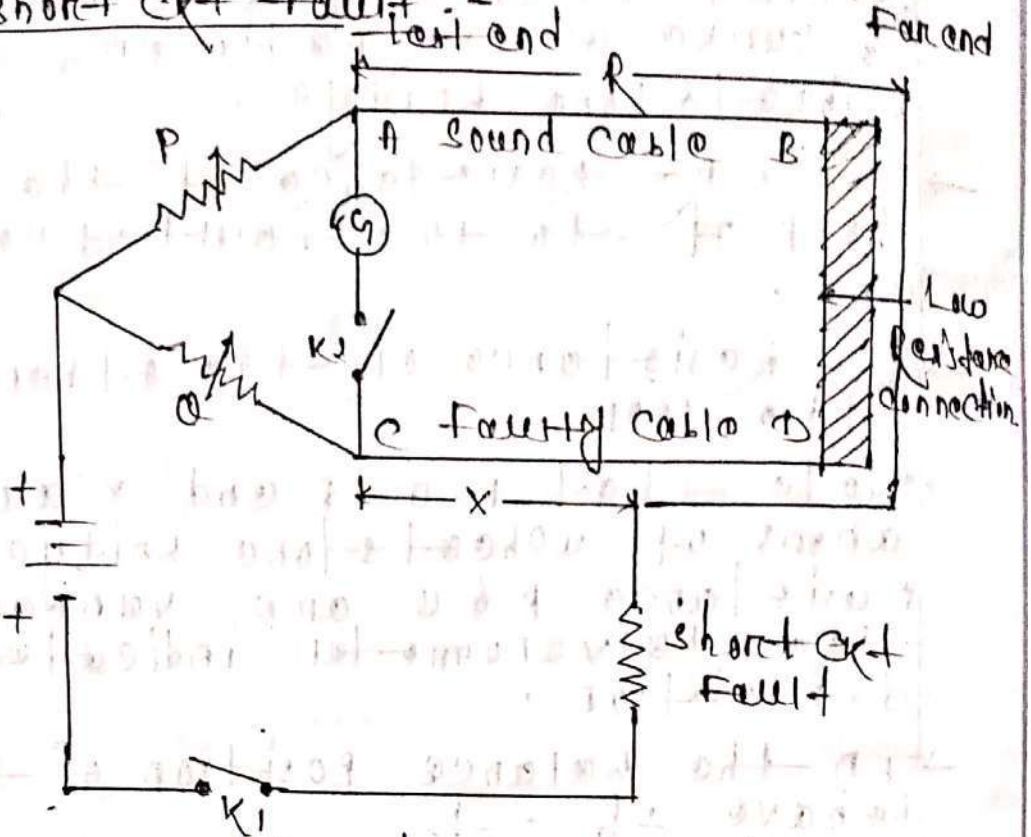
$= \frac{Q}{P+Q} \times (\text{loop length})$ km

→ Thus the fault is located.

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Case-2

For short ckt fault :-



→ The above fig shows the short ckt diagram from locating the short ckt fault by Murray loop test.

→ Again P, Q, R & X are the 4 arms of the wheatstone bridge.

→ Note that fault resistance is in the battery ckt and not in the bridge ckt.

→ The bridge is balanced by adjusting the resistance 'P' & 'Q'.

→ In the balance position of the bridge,

$$\frac{P}{Q} = \frac{R}{X} \Rightarrow \frac{P}{Q} + 1 = \frac{R}{X} + 1$$

$$\Rightarrow \frac{P+Q}{Q} = \frac{R+X}{X}$$

$$\Rightarrow \frac{P+Q}{Q} = 2R$$

$$\Rightarrow X = \frac{Q}{P+Q} \cdot 2R$$

→ If 'l' is the length of each cable in meters, then resistance per meter length of cable is R/l.

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Varley

2. Working loop test.

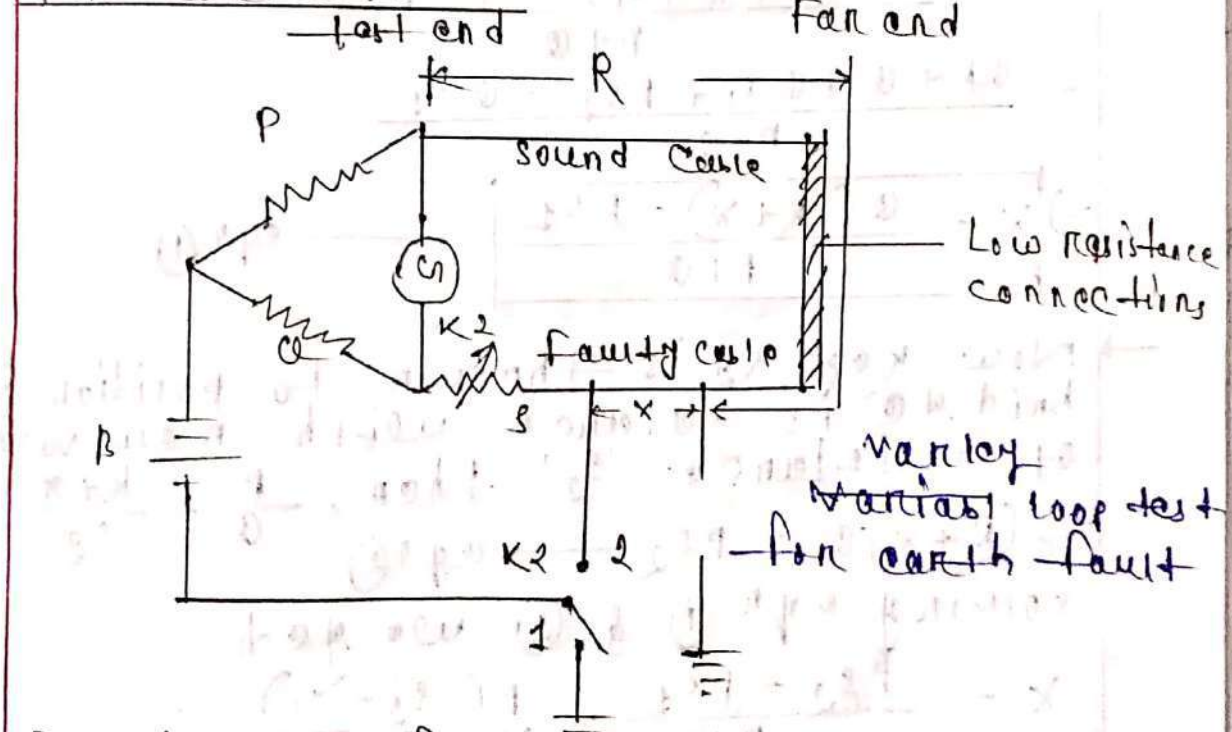
→ The working loop test is also used to locate earth fault or short circuit fault in under ground cables.

→ This test also employ wheatstone bridge principle it differs from Murray loop test in that means the ratio P & Q are fixed resistances.

→ Balance is obtained by adjusting the variable resistance 'S' connected with the faulty cable.

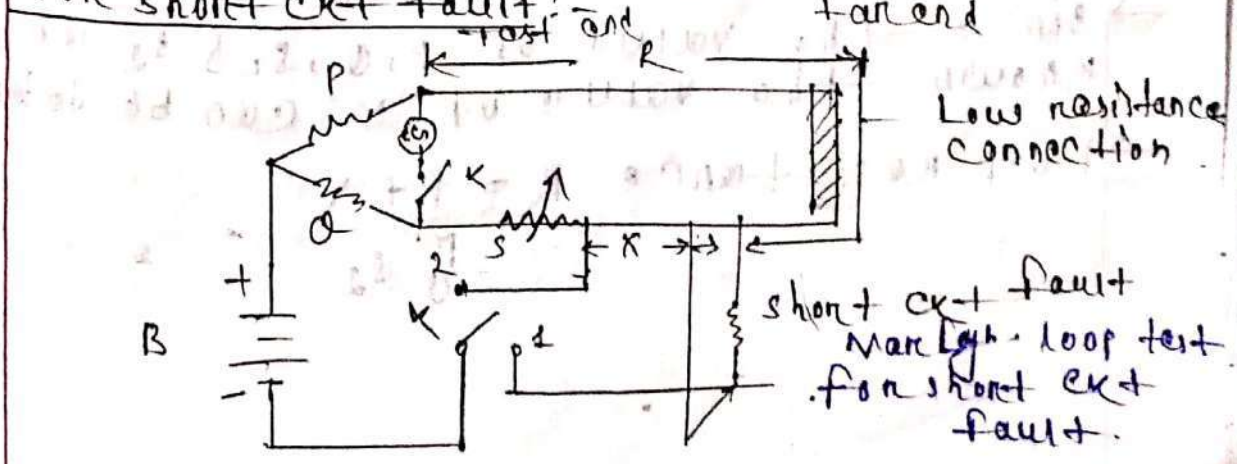
→ The connection diagram for locating the earth value or short ckted fault is as follows.

For earth fault



Varley loop test for earth fault

For short ckt fault



Varley loop test for short ckt fault.

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→ For earth fault or short ckt fault the key K_2 is first thrown to position 1.

→ The variable resistance is S_1 is varried till the bridge is balance for resistance value of S_1.

then, $\frac{P}{Q} = \frac{R}{X+S_1}$

$\Rightarrow \frac{P}{Q} + 1 = \frac{R}{X+S_1} + 1$

$\Rightarrow \frac{P+Q}{Q} = \frac{R+X+S_1}{X+S_1}$

$\Rightarrow (P+Q)(X+S_1) = (R+X+S_1)Q$

$\Rightarrow (X+S_1) = \frac{(R+X+S_1)Q}{P+Q}$

$X = \frac{Q(R+X+S_1)}{P+Q} - S_1$

$= \frac{Q(R+X+S_1) - S_1(P+Q)}{P+Q}$

$= \frac{QR+Q+QS_1+PS_1-QS_1}{P+Q}$

$\Rightarrow \boxed{X = \frac{Q(R+X)-PS_1}{P+Q}}$ ——— eqn (1)

→ Now key K_2 is thrown to position (2) & bridge is balance with new value of resistance 'S_2' then, $\frac{P}{Q} = \frac{R+X}{S_2}$

$\Rightarrow (R+X)\cdot Q = PS_2$ ——— eqn (2)

solving eqn (1) & (2) we get

$X = \frac{PS_2 - PS_1}{P+Q} = \frac{P(S_2-S_1)}{P+Q}$

→ since the value of P, Q, S_1 & S_2 are known the value of 'X' can be determine.

→ Loop resistance $R = R + X$

$= \frac{P}{Q} S_2$

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→ If 'r' is the resistance of the cable per meter length distance of fault for the test end is $d = \frac{x}{r}$ m.

Problem:-

Murray loop test is performed on a faulty cable 300 m long, it balanced the resistance connected to the faulty cable, said at 50 Ω & the resistance of the resistor connected to the sound core 45 Ω, calculate resistance of fault from test end.

Given data,

P = 45

Q = 15 Ω

l = 300 m

$d = \frac{Q}{P+Q} \times$ (Loop length)

$= \frac{15}{45+15} \times 300 \times 2$

$= 150$

CHAPTER - 8

Distribution system

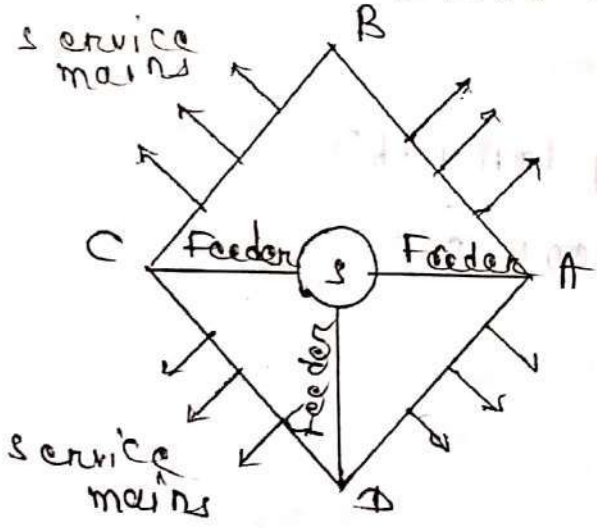
Introduction :-

→ It is that part of the power system which distribute electric power for local use is known as distribution system.

→ The distribution system is the electrical system between the substance fold by the transmission system & the consumers meters.

→ It generally consists of feeders, distributors & service mains.

→ The below fig shows the diagram of the distribution system.



Feeders :-

→ A feeder is a conductor which connects the substation to the area, where power is to be distributed.

→ Generally tappings are taken from feeders, so that current in it remains the same through out the feeder.

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→ the main consideration is design of feeder is the current carrying capacity.

Distributor :-

→ A distributor is a conductor from which tappings are taken for supply to the consumers.

→ In the above fig AB, DC, CD, DA are the distributors.

→ the current through a distributor is not constant because tappings are taken at various places along it length.

→ While designing a distributors voltage drop along the length is the main consideration, since the limit of voltage variation is ± 6 % of the rated value at consumer terminals.

Service Mains:-

A service mains is generally a small cable which connects the distribution distributor to the consumers.

Connection scheme of distribution system:-

→ All distribution of electrical energy is done by constant voltage system.

→ the following distribution system are generally use.

1. Radial system
2. Ring main system
3. Interconnected system.

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Radial system:-

→ In this system separate feeders radiate from a single sub-station & feed the distribution & one end only.

→ The below figure shows a single line diagram of a radial system for DC distribution, where a feeder OC supplies a distribution 'n' at point 'A' as shown in fig 1.

→ Fig 2 shows a single line diagram of radial system for AC distribution.

→ The radial system is employed only when power is generated at low voltages sub-station is located at the centre of load.

→ This is the simplest distribution circuit & helps lowest initial cost.

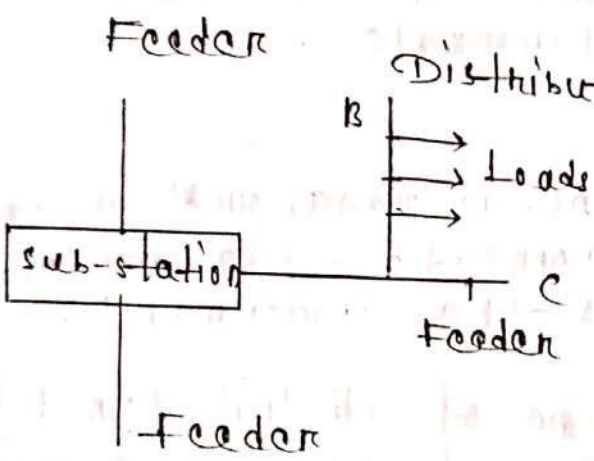


Fig (1)

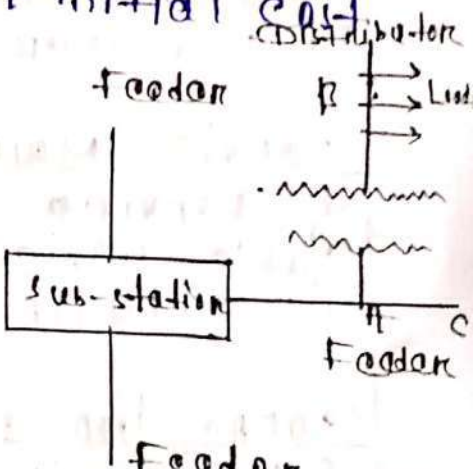


Fig (2)

Disadvantage:-

→ The end of the distributor nearest to the feeding point will be heavily loaded.

→ The consumers are dependent on single feeder & single distributor, therefore any fault of feeder or distributor cutoff supply to the consumer who are on the side of the fault away

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from the substation.

→ the consumers & the distance & of the distribution would be subjected to serious voltage fluctuation when the load on the distribution changes.

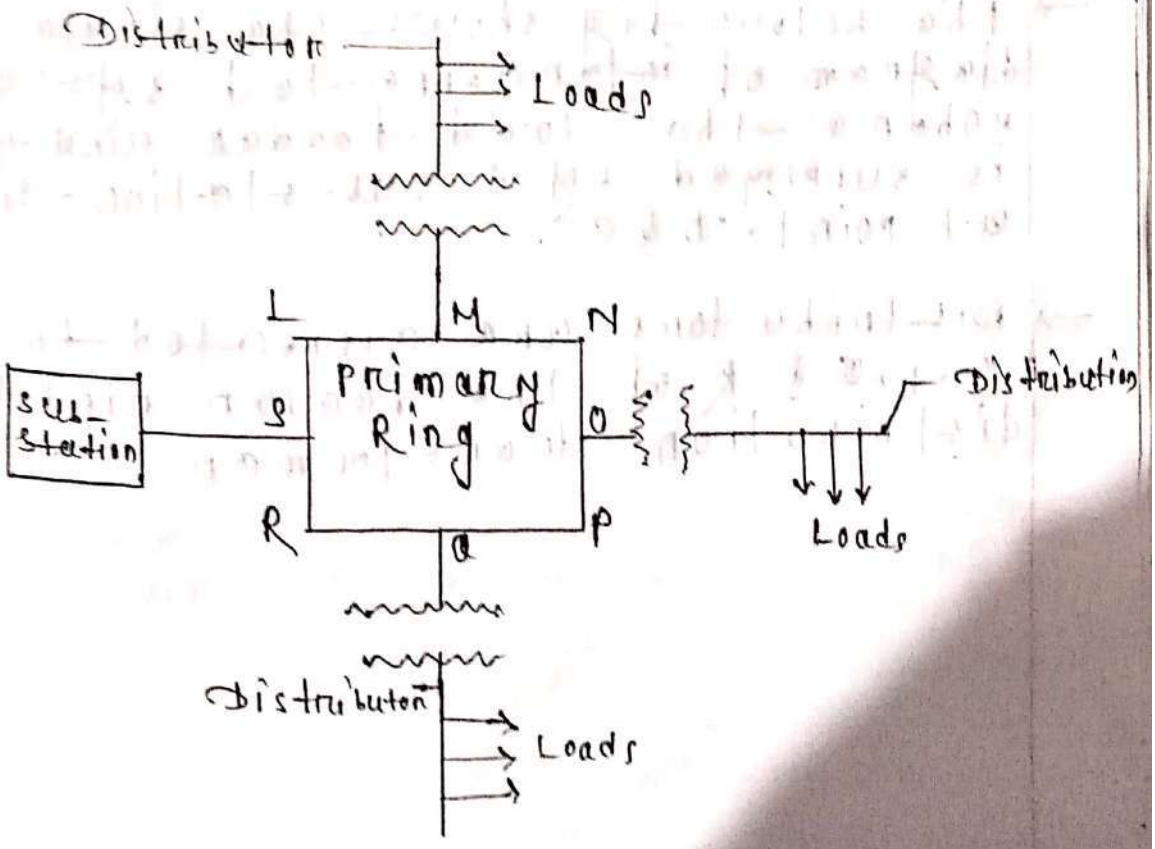
Ring main system:-

→ In this system the primary of distribution transformer from a loop.

→ the loop ckt starts from the substation bus-bar, makes a loop through the area of the served & returns to the sub-station.

→ the below fig shows the single line diagram, ring main system for dc distribution where sub-station supply to the closed feeder 4 MNOPQRS.

→ the distributors are tapped from different points M, O & Q of the feeder through distribution transformer.



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Advantages:-

→ There are less voltage fluctuation at consumers terminals.

→ The system is very reliable as it's distribution is fed by 2 feeder.

→ In the event of fault on any section of the feeder the continuity of the supply is maintained.

→ For example suppose the fault occurs at point F, of section S, 1 & M of the feeder, the S, 1 & M of the feeder can be isolated for repairing at the same time continuity of the supply maintain all the consumer by feeder S, R, Q, P, O, N, M.

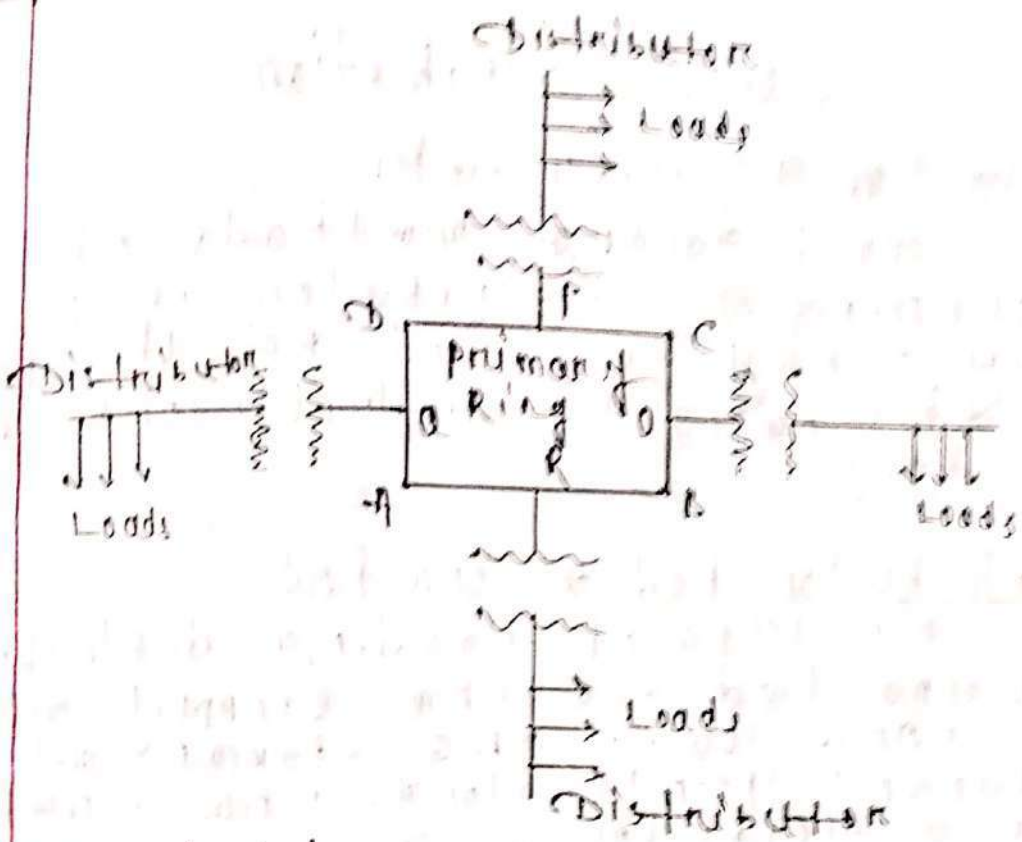
Interconnected system:-

→ When the feed ring is energised by 2 or more than 2 generating station or substation it is called interconnected system.

→ The below fig shows the single line diagram of interconnected system, where the closed feeder ring ABCD is supplied by 2 sub-station S, & S2 at point D & C.

→ Distributions are connected to point O, P, Q & R of the feeder ring through distribution transformer.

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Advantages:-

It increases the service reliability. Any area fed from one generating station during peak load hour can be fed from the other generating station, this increases the efficiency of the system.

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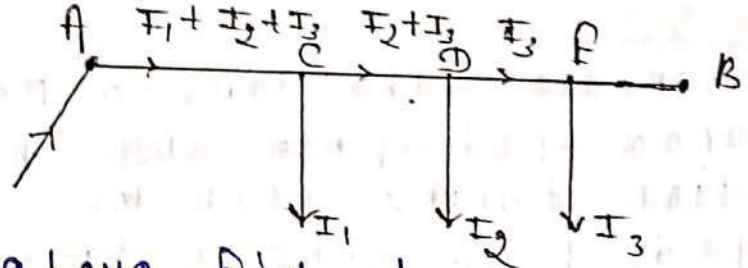
DC Distribution

Types of DC Distributor:-

The most general methods of classifying DC distributor is the way they are fed by the feeders on this basis DC distributors are as follows-

(i) Distributor fed at one end:-

→ In this type of feeding distributor is connected to the supply at one end and loads are taken at different points along the length of the distributor.



→ The above fig. shows the single line diagram of DC distributor AB fed at point A and loads I_1, I_2 & I_3 tapped off at point C, D & E. Hence this system is also known as single fed distributor.

→ Following points are observed in this distribution.

(a) The current in the various section of the distribution away from feeding point goes on decreasing. Thus current in section AC is more than the current in CD. & the current of section CD is more than the current of section DE.

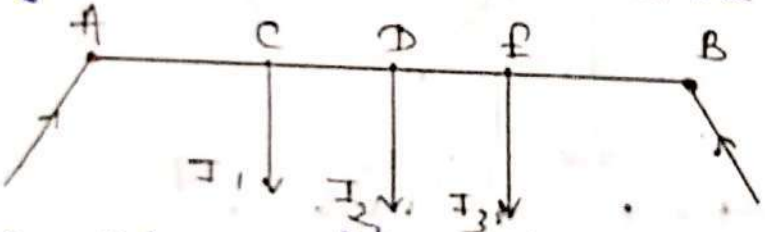
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(b) voltage across the load away from the feeding point goes on decreasing and the minimum voltage across at load point f.

(c) In case a fault occurs on any section of the distributor, the whole distributor will have to be disconnected from the supply. Therefore, continuity of supply is interrupted.

(ii) Distributor fed at both ends:-

→ In this type of feeding the distributor is connected to the supply mains at both ends & loads are tapped off at different points along the length of the distributor.



→ The above fig shows a distributor AB fed at the end A & B and loads of I_1, I_2 & I_3 tapped off at point C, D & E.

→ Here, the load voltage goes on decreasing as we move away from one feeding point till each point it reaches minimum value & then again starts rising & reaches maximum value when we reach the other feeding point B. The minimum voltage occurs at some load points & is never fixed.

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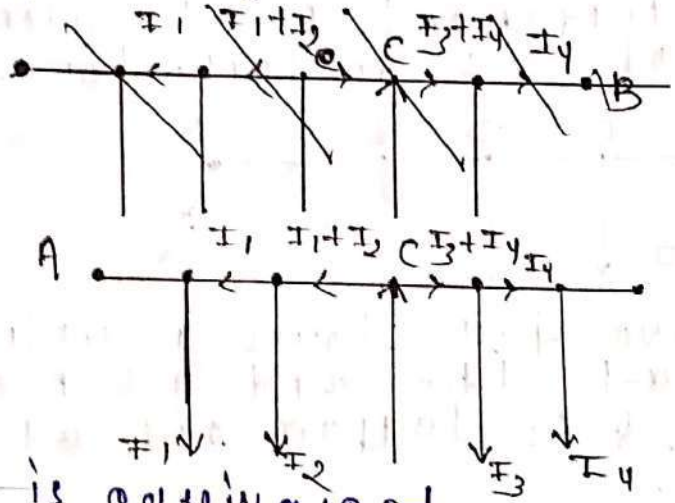
Advantages:-

→ If a fault occurs on any feeding point of the distributor, the continuity of supply is maintained from the other feeding point.

→ The area of x-section required for doubly fed distributor is much less than that of singly fed distributor.

(iii) Distributor fed at the centre:-

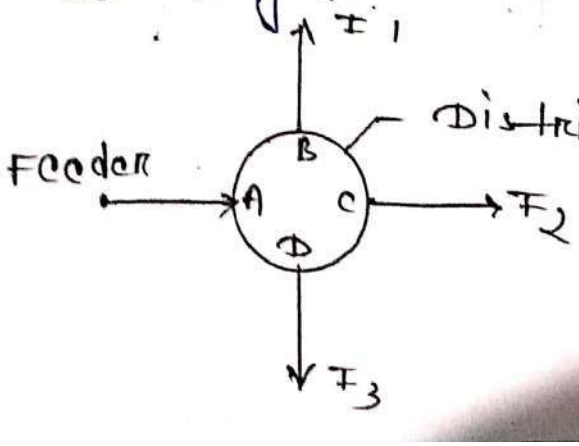
→ In this type of feeding, the centre of the distributor is connected to the supply mains as shown in below fig.



→ It is equivalent to two singly fed distributors, each having a common feeding point & length equal to the half of the total length.

(iv) Ring Mains:-

→ In this type, the distributor is in the form of a closed ring as shown in below fig.



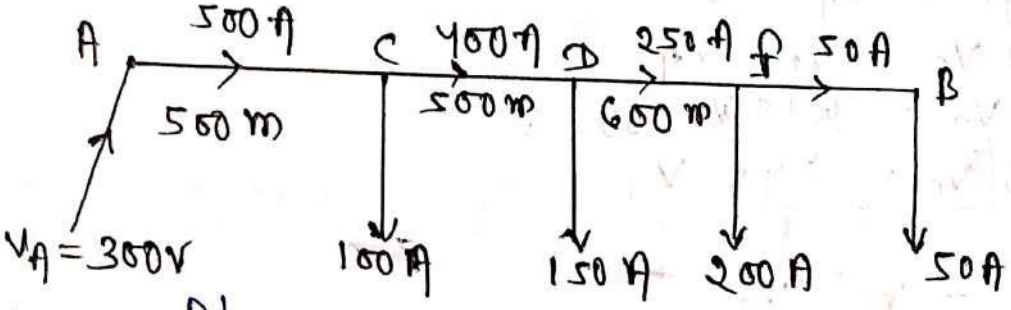
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→ It is equivalent to a straight distributor fed at both ends with equal voltages, the two ends being brought to form a closed ring.

→ The distributor ring may be fed at one or more than one point.

Problem:-

A 2-wire DC distributor cable AB is 2km long & supplies loads of 100A, 150A, 200A & 50A situated 500m, 1000m, 1600m & 2000m from the feeding point A. Each conductor has a resistance of 0.01Ω per 1000m. Calculate the p.d at each load point if a p.d of 300V is maintained at point A



above fig. shows the single line diagram of the distributor with its tapped currents.

→ Resistance per 1000m of distributor is
$= 2 \times 0.01\Omega = 0.02\Omega$

Resistance of section:-

$R_{AC} = 0.02 \times \frac{500}{1000} = 0.01\Omega$

$R_{CD} = 0.02 \times \frac{500}{1000} = 0.01\Omega$

$R_{DE} = 0.02 \times \frac{600}{1000} = 0.012\Omega$

$R_{EB} = 0.02 \times \frac{400}{1000} = 8 \times 10^{-3}\Omega$

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Current in various section of the distributor are :-

$I_{FB} = 50A$

$I_{DF} = 50 + 200 = 250A$

$I_{CD} = 250 + 150 = 400A$

$I_{AC} = 100 + 400 = 500A$

voltage drop in each section -

$V_{AC} = I_{AC} \times R_{AC} = 500 \times 0.01 = 5V$

$V_{CD} = I_{CD} \times R_{CD} = 400 \times 0.01 = 4V$

$V_{DF} = I_{DF} \times R_{DF} = 250 \times 0.012 = 3V$

$V_{FB} = I_{FB} \times R_{FB} = 50 \times 8 \times 10^{-3} = 0.4V$

Potential drop (P.d) at each load :-

(1) $V_{AC} = V_A - V_C$

$\Rightarrow V_C = V_A - V_{AC}$

$\Rightarrow V_C = 300 - 5$

$\Rightarrow \boxed{V_C = 295\ V}$

$V_{CD} = V_C - V_D$

$V_D = V_C - V_{CD}$

$\Rightarrow V_D = 295 - 4$

$\Rightarrow \boxed{V_D = 291\ V}$

$V_{DF} = V_D - V_F$

$\Rightarrow V_F = V_D - V_{DF}$

$\Rightarrow V_F = V_D - V_{DF}$

$\Rightarrow \boxed{V_F = 288V}$

$V_{FB} = V_F - V_B$

$\Rightarrow V_B = V_F - V_{FB}$

$= 288 - 0.4$

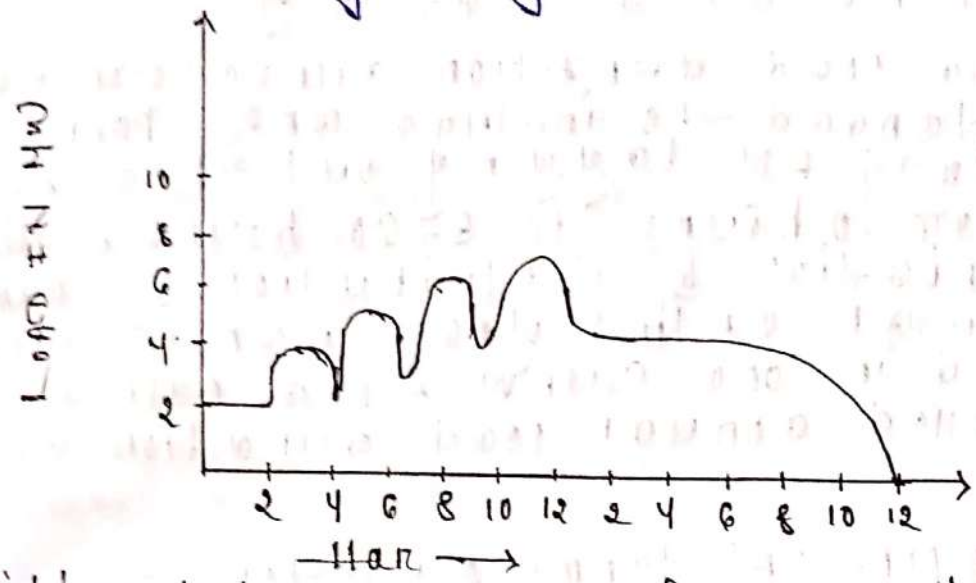
$\Rightarrow \boxed{V_B = 287.6\ V}$

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Economics Aspects

Load curve :-

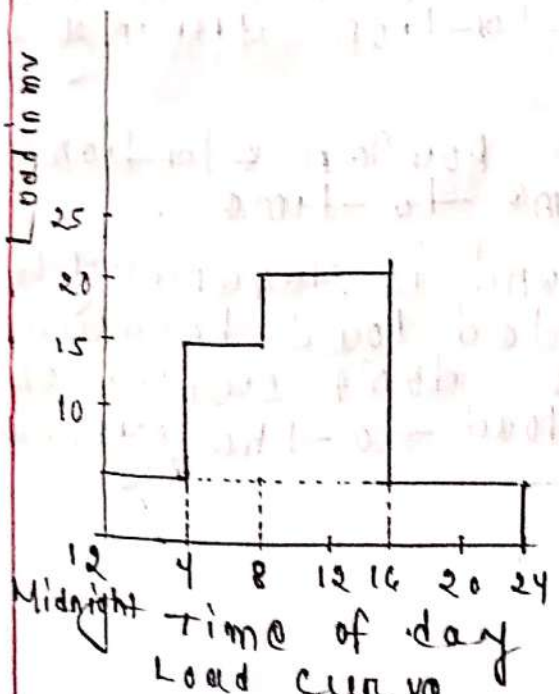
The curve showing the variation of load on the power station w.r.t time we can plot daily load curve monthly load curve yearly load curve.



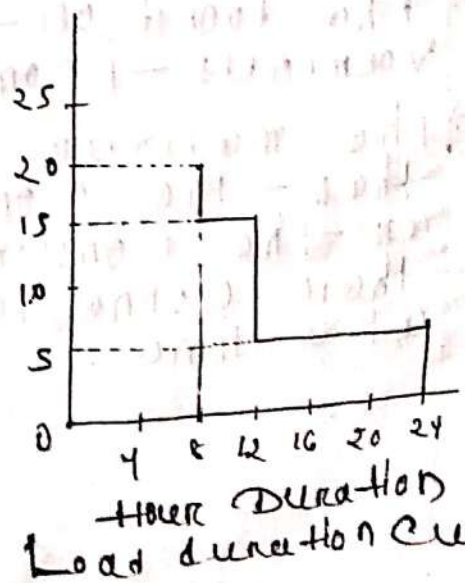
(Fig: Daily load curve of power station)

Load Duration curve :-

→ When the load elements of a load current are arrange the order of descending of magnitudes, the curve thus obtained is called a load duration curve.



Load curve



Load duration curve

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→ the load duration curve gives the data in a more presentable form.

→ the area under load duration curve is equal to that of the corresponding load curve. Area under daily load duration curve in (kwh) will gives the units generated on that day.

→ The load duration curve can be extended to include any period of time by laying out the abscissa from 0 hours to 8760 hours, the variation & distribution of demand for an entire year can be summarised in one curve. the curve is called annual load duration curve.

Important terms & Factors :-

1- Connected Load :-

It is the sum of continuous rating of all the equipments connected to supply system.

2- Maximum Demand :-

→ It is the greatest demand of load on the power station during a given period.

→ The load on the power station various from time to time.

→ The maximum demand is generally less than the connected load because all the consumers, don't switch on their connected load to the system at a time.

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3. **Demand Factor :-**

→ It is the ratio of maximum demand on the power station to its connected load i.e.

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

→ The value of the demand factor is less than 1.

4. **Average Load :-**

The average load occuring the power station in a given period (day / Month / year) is known as average load or average demand.

$$\text{Daily average load} = \frac{\text{No. of units (kwh) generated in a day}}{24 \text{ hours}}$$

$$\text{Monthly average load} = \frac{\text{No. of units (kwh) generated in a month}}{\text{No. of hours in a month}}$$

Yearly average load.

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

5. **Load Factor :-**

The ratio of average load to the maximum demand during a given period i.e.

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

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If the plant is operation of T hours

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

$$= \frac{\text{Units generated in } T \text{ hours}}{\text{Max}^m \text{ demand} \times T \text{ hours}}$$

→ Load factor is always less than 1, because average load is smaller than the maximum demand.

→ Load factor plays key role in determining the overall cost per unit generated higher the load factor of the power station. Lesser will be the cost per unit generated.

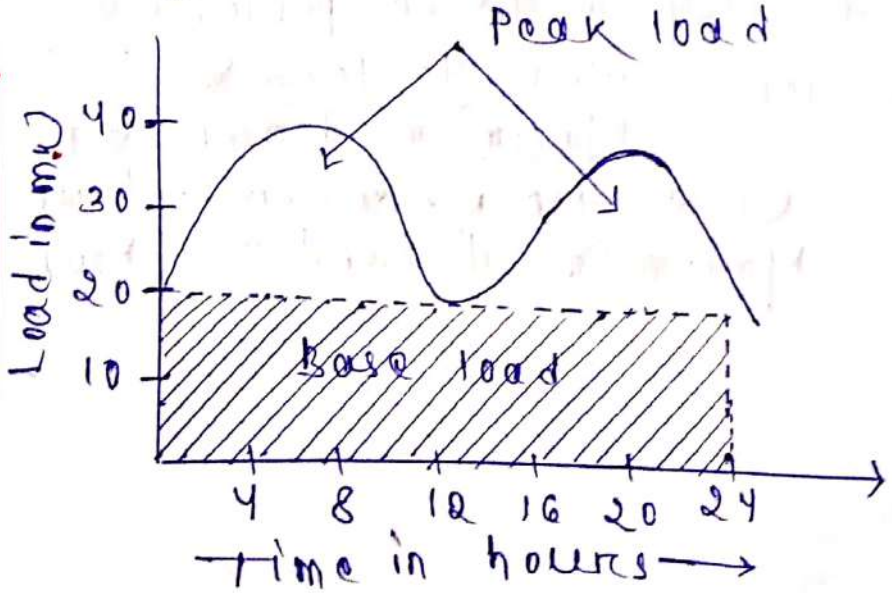
6 Diversity Factor :-

It is defind as the ratio between of individual maximum demands to the maximum demand on power station it is always grather than 2.

Base Load & peak load power station

1. Base Load :-

The ~~O~~ onvarying which occurs almost the whole day on the station as known as base load.



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From the above figure. It is clear that 20mw of load has to be supplied by the station at all time of a day and night i.e. throughout 24 hour. Therefore 20mw is the base load of station.

2- Peak Load!-

→ The various peak demand of load over & above the base load of the station is known as peak load.

→ From the above figure it is clear that their are peak demand of load excluding both load. These peak demands of station generally a small part of the total load may occure through the day.

Plant use Factor!-

It is the ratio of kwh generated to the product of plants capacity & no. of hours for which the plant was in operation.

$$\text{Plant use factor} = \frac{\text{station o/p in kwh}}{\text{plant capacity} \times \text{hour of use}}$$

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

∴ Energy generated / year = Maximum demand × load factor × hour in year.

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2. A generating station has a connected loads of 43MW & maximum demand of 20MW. The unit generated being @1.5 × 10^6 / annum
Calculate demand factor & load factor

∴ Energy generated / year = Maximum demand × load factor × hour in year

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

∴ Load Factor = $\frac{\text{Avg demand}}{\text{Max Demand}}$

Avg demand = $\frac{\text{Unit generated / Annum}}{\text{hours in a year.}}$

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