U.G.M.I.T, Rayagada

DEPARTMENT OF ELECTRICAL ENGINEERING

LECTURE NOTES ON

Generation Transmission and Distribution

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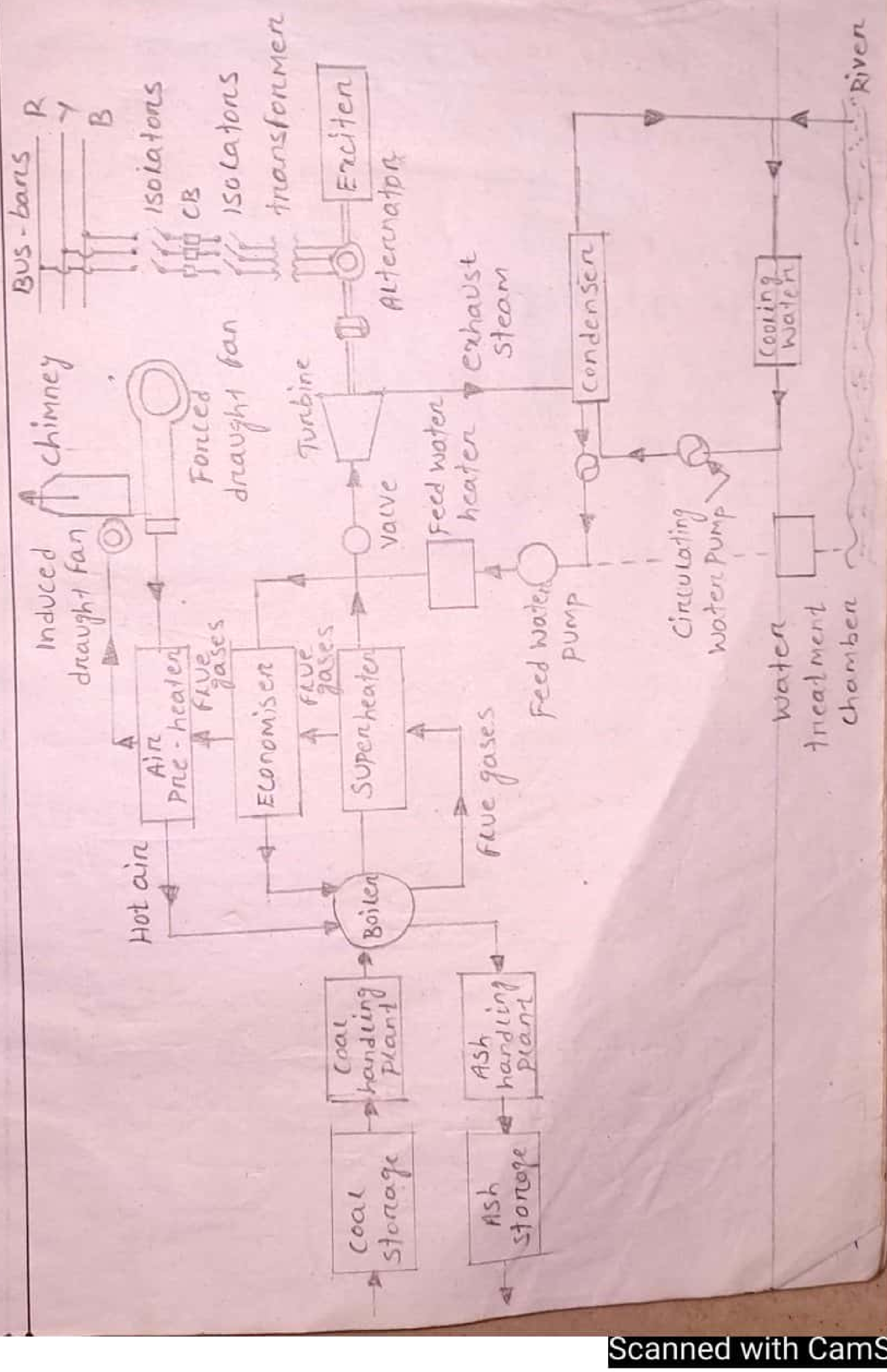
Steam power Plant

Chapter - 1

GENERATION OF ELECTRICITY

Defination:- the power plant which generates electrical energy from the combustion of coal called steam power plant.



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Selection of site for thermal power plant:-

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 to ensure continuous supply of water.

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

4) Transportation facilities:- A modern steam power station often requires the transportation of material & machinery.

5) Distance from populated area:- As huge amount of coal is burnt in a steam power plant due to which smoke & fumes pollutes the surrounding area. This necessitates that ~~power~~ should be locate at a considerable distance from the populated areas.

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Main units of plant :-

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

2) Coal handling plant :- From the coal storage plant coal is delivered to the coal handling plant where it is pulverized for rapid combustion without using excess amount of air.

3) Ash storage plant :- The coal is burnt in the boiler & 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 :- It is a major part of thermal power plant which convert water into steam. It is of two types fire tube boilers & water tube boilers.

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

7) Economiser :- An economiser is essentially a feed water heater & derives heat from

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The flue gases for this purpose the feed water is fed to the economiser beforeed supplying to the boiler.

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

9) Forced draught fan :- It draws air from atomosphere which is supplied to the boiler for effective combustion.

10) Induced draught fan :- It draws the flue gas & sends to chimney.

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

12) 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 mechnical work.

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

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 water :- The cooling tower provides

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a cooling arrangment for the feed water to be reused in boiler.

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.

So, the water gets converted to steam with very high temperature & pressure & reaches the steam turbine through super-heater. The internal energy of steam gets converted to mechanical energy by turbine & the Alternator converts the mechanical energy of turbine output to electrical energy. The electrical energy thus produced is supplied to the Bus-bar for power use.

Advantages :-

i) The fuel (i.e coal) used is quite cheap.

ii) Less initial cost as compared to another generating stations.

iii) It can be installed at any place & the coal can be transported by Rail/Road.

iv) It requires less space as compared to hydro-electric power station.

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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 neccessary to store water by constructing a Dam in order to ensure the generation of power throughout the year.

3) **Cost & type of land** :- The land for the construction of plant should be available at a resonable price.

4) **Transportation facility** :- The site selected should be accessible by rail/road so that necessary equipment & machineries be easily transported.

Main Constituents of plant :-

1) **Storage reservoir** :- It stores water during excess flow periods (Rainy seasons) & supplied the same during least flow of periods i.e (dry seasons). It can be either natural i.e lake or artificial made by construction dam across the river.

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2) Dam :- It is the most expensive & importan[t] part which is built up concrete or stone masonary earth or rock fill. A Dam is a barrier which stores water & creates water head.

3) Head works :- The head works consists of the diversion structures at the head of an intake. They generally include booms & racks for diverting floating debris, sediments & 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.

6) Water turbine :- 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.

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Working of Hydro-electric power plant :-

When the water from reservoir is allowed to get relased 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 pen-stocks. Inside the power house the water turbines 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 & generates electrical energy.

Advantages :-

i) It requires no fuel as water is used for the generation of electrical energy.

ii) Running cost is very less as water is used.

iii) It is simple in construction & requires less maintenance.

iv) It can be started quality as compared to thermal power station.

v) It is quite neat & clean as no smoke or

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

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

4) **Availability of space for dispol of water :-** Their should ~~be~~ have adequate space & arrangement for the disposal of radio activity waste.

5) **Types of land :-** The land should be strong enough to support the heavy reactor i.e 10,000 tones weight with imposed boarding pressure around 50 tones/m^2.

Nuclear fuel :-

1) Uranium (U^{235})
2) Plutonium (Pu^{239})
3) Thorium (Th^{232})

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Chain reaction:-

When a U-235 atom is struck by a slow neutron, it will spilt into two or more fragment. This is called a nuclear fission. This spitting is accompanied by release of thermal energy in large quantity & two or three fast neutrons. These fast moving neutrons are slowed down by moderators so that they have high probability to hit other U-235 atoms which is turn get fissioned & release heat & neutrons. This continuous self sustaining sequence of nuclear fissions is called chain reaction.

Main units of plant:-

1) Nuclear reactor:- It is the main part of nuclear power plant which is very similar to boiler of thermal power plant. In which the nuclear fuel (U^{235}) is subjected to nuclear fission.

2) Heat exchanger:- In heat exchanger the gas is heated or steam is generated by utilising heat from nuclear reactor, here heat is connected by heat exchanger tube by circulation.

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.

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4) Condenser :- The exhausted steam from steam turbine is condensed by condenser & again feed to heat exchanger by feed water pump.

5) Alternator :- It is coupled to steam turbine & it converts the mechanical energy of turbine to electrical energy.

Working of nuclear power plant :-

As ~~huge~~ discussed earlier, the chain reaction produces a huge amount of heat inside the nuclear reactor & 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 & high pressure, the turbine converts the internal energy of steam to mechanical energy & this is converted to electrical energy by Alternator as before.

Advantages :-

1) It requires less area as compared to in other plant.

2) It requires very small fuel.

3) It has most economical & flexible o/p.

4) The operating cost quite low after installation

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Disadvantages:-

i) The initial cost is very high as compared to any other plant.

ii) Fuel is expensive & difficult to recover.

iii) Heavy amount of water is needed.

iv) It bi-product is also radio activity causing dangereous pollution.

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ash is produced.

(vi) Disadvantages:-

i) It involves high capital cost due to construction of dams.

ii) Generation depends on average rainfall round the year.

iii) High cost of transmission as these plants are located in hilly areas quite far off from localities.

Nuclear power station:-

Defination:- The power plant which generates electricity by utilizing the vast energy relased from nuclear fission reaction is known as nuclear power plant.

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Disadvantages:-

i) It pollutes air/atmosphere due to smoke/ fumes.

ii) Running cost is higher than hydro power plant.

Hydro-electric power plant:-

Defination:- The power station which convert the kinetic energy of water in electrical energy are called hydro electric power station.

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Comparision of the various Power Plants

Sr no.	Item	Steam power plant	Hydro-electric power plant	Nuclear power plant
1.	Site	Such plants are located at a place where supply of water & coal is available, transportation facilities are adequate.	Such power plants are located where large reservoirs can be obtained by constructing a dam e.g in hilly areas.	These plants are located away from thickly populated area to avoid radio-active pollution.
2.	Initial Cost	Initial cost is lower than those of hydroelectric & nuclear power plants.	initial cost is very high because of dam construction & excavation work.	initial cost is highest because of huge investement on building a nuclear reactor.
3.	Running cost	Higher than hydroelectric & nuclear plant because of the requirement of huge amount of coal.	Pratically nil because no fuel is required.	Except the hydroelectric plant, it has the minium running cost because small amount of fuel can produce relatively large amount of power.
4.	Limit of source of power	coal is the source of power which has limited reserves all over the world.	water is the source of power which is not dependable because of wide variations in the rainfall every year.	The source of power is the nuclear fuel which is available in sufficient quantity. It is because small amount of fuel can produce huge power.
5.	Cost of fuel transportation	maxi^M because huge amount of coal is transported to the plant.	praticaly nil.	Minimum because small quantity of fuel is required.
6.	Cleanliness & simplicity	least clean as atmosphere is polluted due to smoke.	most simple & clean.	Less cleaner than hydro electric power plant.

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Chapter - 2 Supply System | Transmission of electric power

* Introduction :-

⇒ The conveyance of electric power from a power station to consumers premises is known as electric supply system.

⇒ The electric supply system brodly classified in to overhead system & under ground system.

⇒ Again depending on supply electric supply system classified in to two categories such as

① AC system ② DC system

* Types of transmission system :-

Transmission System

- DC system
  - DC - 2 wire
  - DC - 2 wire with centre earthed
  - DC - 3 wire system
- AC system
  - 1-ϕ
    - 2 wire system
    - AC 2 wire system with mid point earthed
    - AC 3 wire system
  - 2-ϕ
    - 2 phase 3 wire system
    - 2 phase 4 wire system
  - 3-ϕ
    - 3 phase 3 wire system
    - 3 phase 4 wire system

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* Comparison between AC system & DC system :-

AC system	DC system
1) The AC transmission line transmits the alternating current over a long distance.	1) The DC transmission line is used for transmitting the DC over the long distance.
2) The AC transmission line uses three conductors for long power transmission.	2) The DC transmission line uses two conductors for long power transmission.
3) The dielectric loss occurs in the ac transmission line.	3) The dielectric loss don't occurs in the DC transmission line.
4) It have inductance & surges.	4) It dont have inductance & surges.
5) Corona loss occurs in AC transmission.	5) Corona loss don't occurs in DC transmission.
6) Small length of conductors are used.	6) More length conductors are used.
7) More insulation is needed.	7) Less insulation is needed.
8) Frequency is 50 Hz or 60 Hz depending upon the country.	8) Frequency is zero.
9) High voltage drop.	9) Low voltage drop.
10) It is expensive	10) It is cheap.
11) Repairing & maintenance is easy & expensive	11) Repairing & maintenance is difficult & expensive.
12) Skin effect occurs in AC system.	12) Skin effect absent in DC system.

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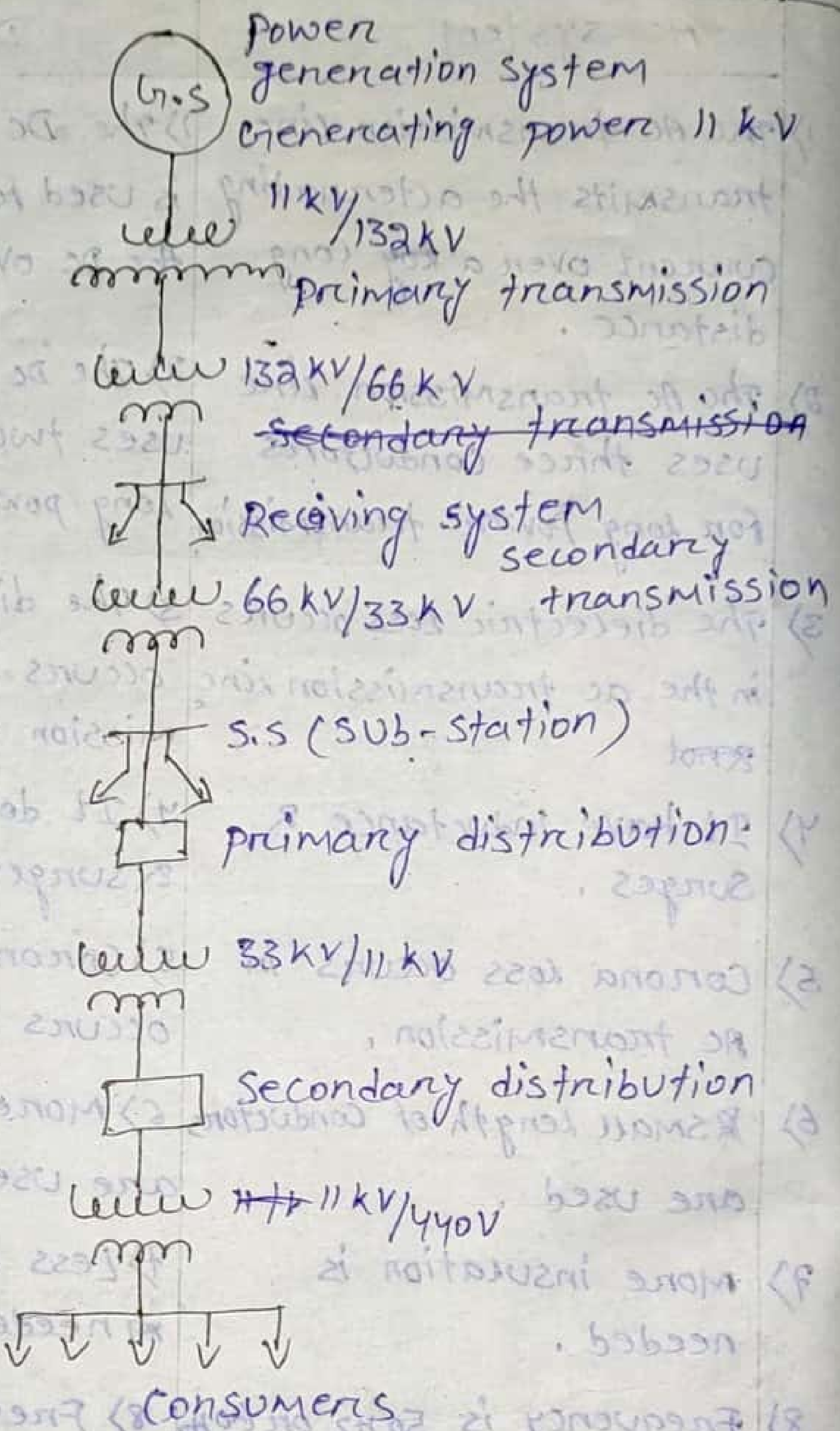
* Layout of transmission & distribution system



⇒ The large network of conductors between the power station & the consumers can be broadly divided into two parts

1) Transmission system
2) Distribution system

⇒ Transmission system can be sub divided into primary transmission & secondary transmission.

⇒ Distribution system can be sub divided in to primary distribution & secondary distribution.

* Generating Station :

-> The generating station where electric power is produced by 3-phase alternators operating in parallel.

-> The usual generation voltage is 11 kV.

-> For economy in the transmission of electric power, the generation voltage (i.e 11kV) is stepped upto 132 kV (or more) at the generating station with the help of 3-phase transformer.

-> The transmission of electric power at high voltage has several advantages including the saving of conductor material & high transmission efficiency.

-> Generally, the primary transmission is carried at 66 kV, 132 kV, 220 kV or 400 kV.

* Primary transmission :- The electric power at 132 kV is transmitted by 3-phase, 3-wire overhead system to the ~~outsp~~ outskirts of the city. This forms the primary transmission.

* Secondary transmission :-

-> The primary transmission line terminals at the receiving station (RS) which usually lies at the outskirts of the city.

-> At the receiving station, the voltage is reduced to 33 kV by stepdown transformer.

-> From this station, electric power is transmitted at 33 kV by 3-phase, 3-wire over-head system to

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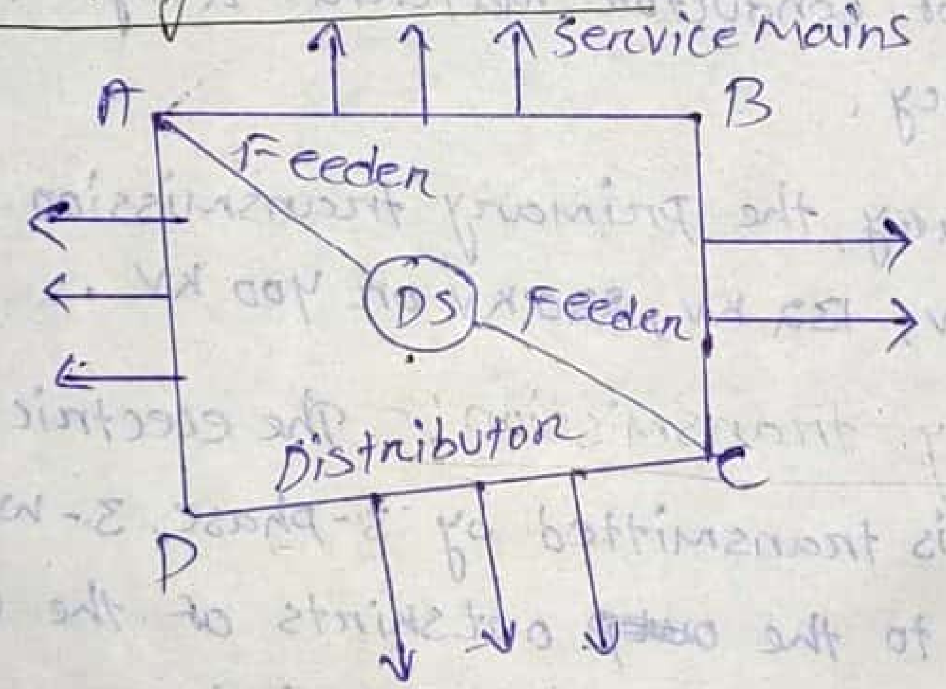
various sub-stations (ss) located at the strategic points in the city. This forms the secondary transmission.

* **Primary distribution:-**

-> The secondary transmission line terminals at the sub-station(ss) where voltage is reduced from 33 kV to 11 kV, 3-phase, 3-wire.

-> The 11kV lines run along the important road sides of the city. This forms the primary distribution.

* **Secondary distribution:-**



-> The electric power from primary distribution line (11 kV) is delivered to distribution sub-stations (DS).

-> The sub-stations are located near the consumers localities & step down the voltage 400V, 3-phase 4-wire for secondary distribution.

-> The voltage between any two phases is 400V & between any phase & neutral is 230V.

-> The single-phase residential lighting load is connected between any one phase & neutral,

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Whereas 3-phase, 400V Motor load is connected across 3-phase lines directly.

* Transmission efficiency:- Transmission efficiency is defined as the ratio of receiving end power to sending end power.

Mathematically,

$$\eta = \frac{P_R}{P_S} \times 100\%$$

$$= \frac{P_R}{P_S + \text{transmission loss}} \times 100\%$$

where,

P_R = Receiving end power

P_S = Sending end power

* Voltage regulation:- Voltage regulation is defined as the ~~ratio of~~ difference between sending end ~~power~~ voltage & receiving end ~~power~~ voltage of a transmission line from no load to full load.

→ Voltage regulation is expressed in terms of percentage of receiving end voltage.

$$\text{Voltage regulation} = \frac{V_S - V_R}{V_R} \times 100\%$$

where, V_S = supply end voltage, V_R = Receiving end voltage

* Elements of a transmission Line:-

~~For reasons associated with economy~~ the principle elements of a high-voltage transmission line are:-

(i) Conductors:- Usually three for a single-circuit line & six for a double-circuit line. The usual material is aluminium reinforced with steel.

(ii) step-up & step-down transformer:- At the sending & receiving ends respectively. The use of transformers permits power to be transmitted at high efficiency.

(iii) Line insulators:- which mechanically support the line conductors & isolate them electrically from the ground.

(iv) Support:- which are generally steel towers & provide support to the conductor.

(v) Protective devices:- such as ground wires, lightning arrestors, circuit breakers, relays etc. They ensure the satisfactory service of the transmission line.

* economical choice of conductor size by kelvin's law:-

→ kelvin's law states that "the ~~economical~~ most economical area of conductor is that for which the total annual cost of transmission line is minimum."

→ The total annual cost of transmission line can be divided in to two parts they are
① Annaual charge on capital
② Annaual cost of energy wasted.

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① Annual charge on capital :-

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

→ The annaual charge of an overhead line is ~~partially~~ partly constant & partly variable.

→ The cost of conductor is partly constant & partly variable and the cost of supports, insulators are constant.

→ The conductor cost is proportional to its cross-sectional area which is variable cost. therefore, the annual charge ~~is equa~~ on an overhead transmission line can be expressed as:

Annual charge = $P_1 + P_2 a$

where,

P_1 & P_2 are constant

a is the cross-sectional area of the conductor.

② Annual cost of energy wasted :-

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

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

→ As resistance is inversely proportional to the area of x-section of the conductor, therefore, the energy lost in conductor is inversely proportional to the area of x-section.

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→ Thus, the annual cost of energy wasted in an overhead transmission line can be expressed as :-

Annual cost of energy wasted = P_3/a

where, P_3 is a constant.

The total annual cost (C) = Annual charge + Annual cost of energy wasted

$$C = P_1 + P_2 a + \frac{P_3}{a}$$

According to kelvins law the size of conductor is economical when the total annual cost is minimum if differentiation of C w.r.t a is zero i.e

$$\frac{d}{da}(C) = 0$$

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

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

$$\Rightarrow P_2 = P_3/a^2 \Rightarrow \boxed{P_2 a = \frac{P_3}{a}}$$

so,

Variable part of annual charge = Annual cost of energy wasted

Therefore,

Kelvin's law can also be stated in an other way i.e the most economical area of conductor is that for which the variable part of annual charge is equals to annual cost of energy wasted.

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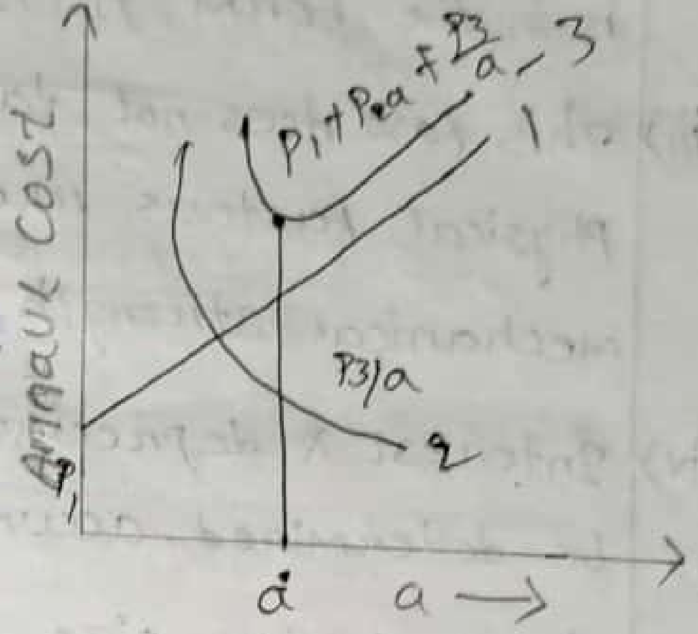
* Graphical representation of kelvin's law :-

-> Kelvin's law can be described graphically by plotting annual cost against x-sectional area 'a' of the conductor as shown in fig.



-> In the diagram, the straight line (1) shows the relation between the annual charge (i.e, P_1+P_2a) & the area of x-section 'a' of the conductor.

-> Similarly, the rectangular hyperbola (2) gives the relation between annual cost of energy wasted & x-sectional area 'a'.

-> By adding the ordinates of curves (1) & (2), the curve (3) is obtained. This latter curve shows the relation between total ~~cost~~ annual cost $(P_1+P_2a+\frac{P_3}{a})$ of transmission line & area of x-section 'a'.

-> The lowest point on the curve (i.e point P) represents the most economical area of x-section.

* Limitations of kelvin's law :-

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

ii) The assumption that annual cost on account of interest & depreciation on the capital cost is in the form $P_1 + P_2 a$ is not true.

iii) This law does not take into account several Physical factors like safe current density, mechanical strength, corona loss etc.

iv) Interest & depreciation on the capital cannot be determined accurately.

v) The conductor size determined by this law may not always be practicable one because it may be too small for the safe carrying of necessary current.

Q1) A 2-conductor cable 1 km long is required to supply a constant current of 200 A throughout the year. The cost of cable ~~makin~~ including installation is Rs (20a + 20) per metre where 'a' is the area of x-section of the conductor in cm^2. The cost of energy is 5p per kWh & interest & depreciation changes amount of 10%. Calculate the most economical conductor size. assume resistivity of conductor material to be 1.73 $\mu\Omega$ cm.

Sol^n

Given Data:-

No of conductor $n = 2$

$l = 1 km = 10^3 m = 10^5 cm$

$\rho = 1.73 \mu\Omega cm$

$I = 200 A$

$P_1 + P_2 a = 20 + 20A$ per m

Resistance of one conductor, $R = \rho \frac{l}{a}$

$$= \frac{1.73 \times 10^{-6} \times 10^5}{a} = \frac{0.173}{a} \Omega$$

Energy lost per annum $= \frac{2I^2Rt}{1000}$ kWh

$$= \frac{2(200)^2 \times \frac{0.173}{a} \times 365 \times 24}{1000 \times a}$$

$$= \frac{121238.4}{a} \text{ kWh}$$

Annual cost of energy lost = Cost per kWh × Annual energy loss

$$= Rs. \frac{15}{100} \times \frac{121238.4}{a}$$

$$= Rs. \frac{6061.92}{a}$$

~~Annual Variable Charge~~ =

The capital cost (variable) of the cable is given to be 20a per metre. Therefore, for 1 km length of the cable, the capital cost (variable) is Rs. 20 a × 1000 = Rs. 2000 a

Variable annual cost = Annual interest & depreciation on capital cost of cable

$$= Rs. 0.1 \times 2000 a$$

$$= Rs. 2000 a$$

According to kelvin's law the most economical X-section ~~size~~ of the conductor,

Variable annual charge = Annual cost of energy lost

$$2000a = \frac{6061.92}{a}$$

$$\Rightarrow a^2 = \frac{6061.92}{2000}$$

$$\Rightarrow a = \sqrt{\frac{6061.92}{2000}} = 1.74 \text{ cm}^2$$

(2) The cost of a 3-phase overhead transmission line is (25000a + 2500) per km where 'a' is the area of x-section of each conductor in cm^2. The line is supplying a load of 5MW at 33KV & 0.8 p.f lagging assumed to be constant throughout the year. Energy costs 4P per kwh & interest & depreciation total 10% per annually. Find the economical size of the conductor. Given that specific resistance of conductor material is 10^{-6} Ω cm.

Sol^n

Resistance of each conductor, $R = \frac{\rho l}{a}$

$$= \frac{10^{-6} \times 10^5}{a} = \frac{0.1}{a} \ \Omega$$

Line current, $I = \frac{P}{\sqrt{3} V \cos\phi}$

$$= \frac{5 \times 10^6}{\sqrt{3} \times 33 \times 10^3 \times 0.8} = 109.35 \text{ A}$$

Energy lost per annual $= \frac{3I^2Rt}{1000}$ kwh

$$= \frac{3(109.35)^2 \times 0.1 \times 8760}{1000 \times a}$$

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$= \frac{31424.10}{a}$ kWh

Annual cost of energy lost $= Rs\ 0.04 \times \frac{31424.10}{a}$

$= Rs.\ \frac{1256.96}{a}$

Variable annual charge = 10% of capital cost (variable) of line

$= Rs.\ 0.1 \times 25,000a$

$= Rs.\ 2500\,a$

According to Kelvin's law, for most economical X-section of the conductor,

Variable annual charge = Annual cost of energy lost

$2500a = \frac{1256.96}{a}$

$\Rightarrow a = \sqrt{\frac{1256.96}{2500}} = 0.071\ cm^2$

* Corona:- The phenomenon of violet glow, hissing noise & production of ozone gas in an overhead transmission line is known as corona.

* Theory of corona formation:-

-> Some ionisation is always present in air due to cosmic rays, ultraviolet radiations. Therefore, under normal condition the air around the conductors contains some ionised particles (i.e free electrons & +ve ions) & neutral molecules.

-> When potential difference is applied between the conductors, potential gradient is set up in the air which will have maximum value at the

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Conductor surfaces:

→ Under the influence of potential gradient, the existing free electrons acquire greater velocities.

→ The greater the applied voltage, the greater the potential gradient & more in the velocity of free electrons.

→ When the potential gradient at the conductor surface reaches about 30 kV per cm (max. value) the velocity acquired by the free electrons is sufficient to strike a neutral molecule with enough force to dislodge one or more electrons from it.

→ This produces another ion & one or more free electrons which are accelerated until they collide with other neutral molecules, thus producing other ions.

→ The commulative ionisation process results either formation of corona or spark takes place between the conductors.

* Factors affecting Corona:-

(i) Atmosphere:- As corona is formed due to ionisation of air surrounding the conductor, therefore, it is affected by the physical state of atmosphere.

→ In the stormy weather, the number of ions is more than normal & as such corona occurs at much less voltage as compared with

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fair weather.

(ii) Conductor size :- The Corona effect depends upon the shape & conditions of the conductors.

-> The rough & irregular surface will give rise to more Corona because unevenness of the surface decreases the value of breakdown voltage

-> Thus, a stranded Conductor has irregular surface & hence gives rise to more Corona that a solid Conductor.

(iii) Spacing between Conductors :- If the spacing between the Conductors is made very large as compared to their diameters, there may not be any Corona effect.

-> It is because the larger distance between Conductors reduces the electro-static stresses at the Conductor surface, thus avoiding corona formation.

(iv) Line Voltage :- The line voltage greatly affects Corona. If it is low, there is no change in the condition of air surrounding the conductors & hence no corona is formed.

-> However, if the line voltage has such a value that electrostatic stresses developed at the conductor surface make the air around the conductor conducting, then Corona is formed.

* Important terms related to corona :-

i) Critical disruptive voltage :- It is the minimum

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phase to neutral voltage at which corona occurs.

Critical disruptive voltage, $V_c = g_0 \delta r \log_e \frac{d}{r}$

where,

g_0 = breakdown strength of air at standard atmospheric condition (i.e 76 cm of mercury 25°C)

= 30 kV/cm (max) or 21.2 kV/cm (r.m.s)

d = space between the two conductors

r = radius of the conductor

m_0 = irregularity factor

or

$V_c = m_0 g_0 \delta r \log_e \frac{d}{r}$ kV/φ

where,

m_0 = 1 for polished conductor

= 0.98 to 0.93 for dirty conductors

= 0.87 to 0.8 for standed conductors

δ = Air density factor $= \frac{3.92 b}{273 + t}$

b = baro

t = temperature in °C.

$\delta = 1$ under standard atmospheric condition.

(ii) Visual critical voltage :- It is the minimum phase neutral voltage at which corona glow appears all along the line conductor.

$$V_v = m_v g_0 \delta r \left(1 + \frac{0.3}{\sqrt{\delta r}}\right) \log_e \frac{d}{r} \text{ kV/phase}$$

where,

m_v = irregularity factor = 1 for polished conductor

= 0.72 to 0.82 for rough conductors.

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(iii) Power loss due to Corona :- The power loss due to Corona is given by

$$P = 242.2\left(\frac{f+25}{\delta}\right)\sqrt{\frac{r}{d}}\,(V-V_c)^2 \times 10^{-5}\ kW/km/\phi$$

* Advantages of Corona :-

i) Due to Corona formation, the air surrounding the Conductor becomes Conducting & hence virtual diameter of the Conductor is increased. The increased diameter reduces the electrostatic streeses between the Conductors.

ii) Corona reduces the effects of transients produced by surges.

* Disadvantages :-

i) Corona is accompained by a loss of energy. This affects the transmission efficiency of the line.

ii) Ozone is produced by Corona & may Cause corossion of the Conductor due to chemical action.

iii) The current drawn by the line due to Corona is non-sinusoidal & hence non-sinusoidal voltage drop occurs in the line.

* Methods of reducing Corona effect :-

The Corona effects can be reduced by the following methods :

(i) By increasing Conductor size

(ii) By increasing Conductor spacing

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Chapter-4

Performance of short & medium lines

* Classification of overhead transmission lines:

A transmission line has three constants R, L & C distributed uniformly along the whole length of the line. The overhead transmission lines are classified as:

① Short transmission lines
② Medium transmission lines
③ Long transmission lines

① Short transmission Lines:-

-> When the length of an overhead transmission line is about 50 km & the line voltage is comparatively low (< 20 kV), it is usally considered as short transmission line.

-> Due to smaller length & lower voltage, the capacitance effects are small & hence can be neglected.

-> Therefore, while studying the performance of a short transmission line, only resistance & inductance of the line are taken in to account.

② Medium transmission Lines:-

-> When the length of an overhead transmission line is about 50 - 150 km & the line voltage is moderatly high (20 kV < L < 100 kV), it is considered as a medium transmission line.

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→ Due to sufficient length & voltage of the line, the capacitance effects are taken into account.

* Long transmission Lines :- When the length of over head transmission line is more than 150km & the line voltage is very high (>100kV), it is considered as a long transmission line.

* Important terms :-

(i) Voltage regulation :- When a transmission line is carrying current, there is a voltage drop in the line due to resistance & inductance of the line.

→ This voltage drop ($V_S - V_R$) in the line is expressed as a percentage of receiving end voltage V_R & is called voltage regulation.

Mathematically,

$$\% \text{ Voltage regulation} = \frac{V_S - V_R}{V_R} \times 100\%$$

(ii) Transmission efficiency :- The ratio of receiving end power in the sending end power of a transmission line is known as the transmission efficiency of the line.

$$\% \eta_T = \frac{\text{Receiving end power}}{\text{Sending end power}} \times 100$$

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

Where,

V_R, I_R & $\cos\phi_R$ are the receiving end voltage, current & power factor while V_S, I_S & $\cos\phi_S$ are the sending end voltage, current & power factor.

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* Performance of single phase ~~tran~~ short transmission lines :-

Let, I = Load current

R = Loop resistance i.e, resistance for both conductors

X_L = Loop reactance

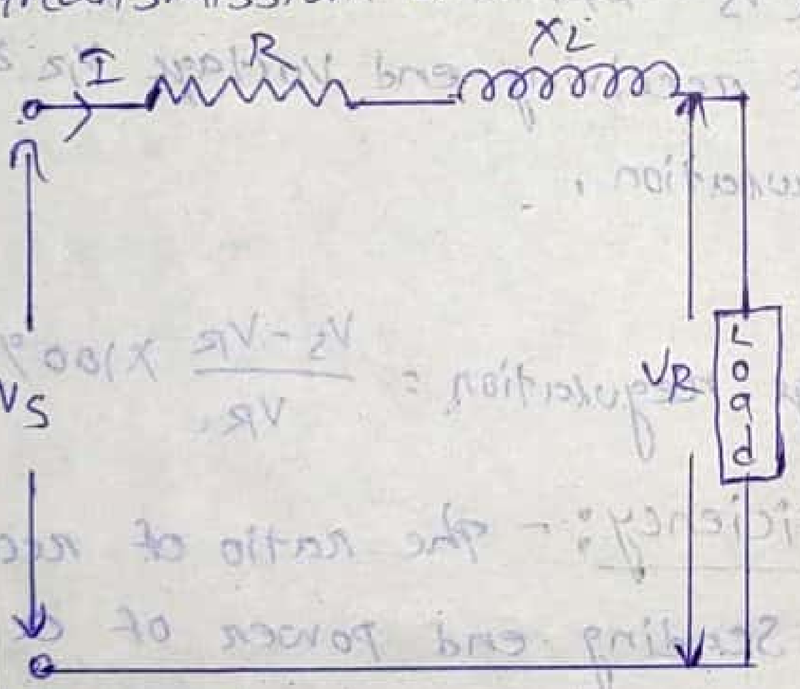
V_R = Receiving end voltage

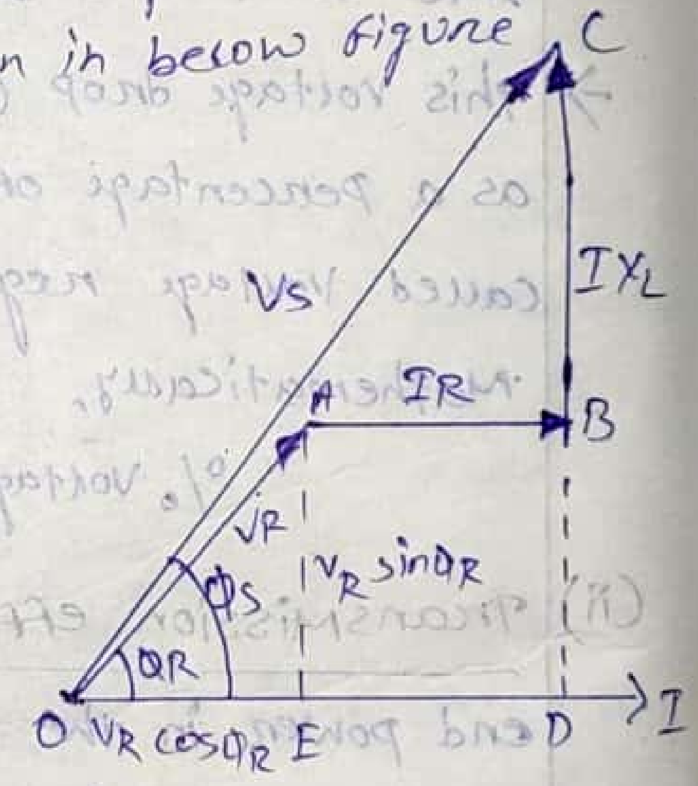
$\cos\phi_R$ = Receiving end power factor (lagging)

V_S = sending end voltage

$\cos\phi_S$ = sending end power factor

The equivalent circuit of a single phase short transmission line is shown in below figure





Phasor - diagram - Current I is taken as the reference phasor. OA represents the receiving end voltage V_R leading ~~to~~ I by ϕ_R, AB represents the voltage drop IR in phase with I. BC represents the inductive drop IX_L & leads I by $90°$. OC represents the sending end voltage V_S & leads I by ϕ_S.

Note :- Voltage drop in resistor $V_d \parallel I_L$

Voltage drop in inductor $V_d \perp I_L$

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From the right angled triangle ODC, we get.

$$(OC)^2 = (OD)^2 + (BC)^2$$

$$\Rightarrow V_S^2 = (OE+ED)^2 + (DB+BC)^2 \quad \left(\because \begin{matrix} AB = ED \\ AE = BD \end{matrix}\right)$$

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

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

(i) Power factor (sending end), $\cos\phi_S = \frac{OD}{OC}$

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

$$\Rightarrow \phi_S = \cos^{-1}\left(\frac{V_R \cos\phi_R + IR}{V_S}\right)$$

(ii) Sending end power (P.S) = Receiving end power + losses

= P_R + losses

Losses in transmission line $= I^2R$

$$\%\text{Efficiency} = \frac{\text{Power delivered}}{\text{Power sent out}} \times 100$$

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

$$= \frac{V_R I_R \cos\phi_R}{V_R I_R \cos\phi_R + I^2R} \times 100$$

(iii) % Voltage regulation $= \frac{V_S - V_R}{V_R} \times 100$

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$$= \frac{33.96 - 33}{33} \times 100$$

$$= 2.9\%$$

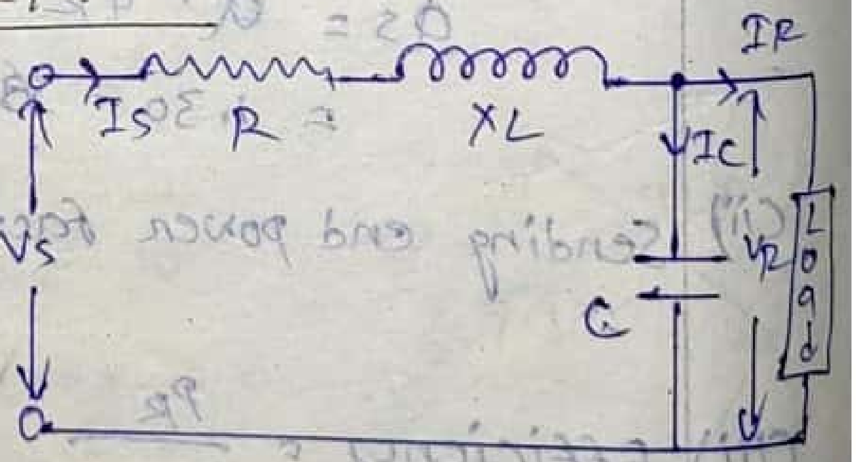
Performance of medium transmission line :-

~~Since~~ In medium transmission lines have sufficient length (   ) & usually operate at voltage greater than 20V, Hence the effects of capacitance cannot be neglected.

The capacitance is uniformly distributed over the entire length of the line. However, ~~the~~ in order to make the calculations simple, the line capacitance is assumed to be concentrated in the form of capacitors shunted across the line at one or more points.

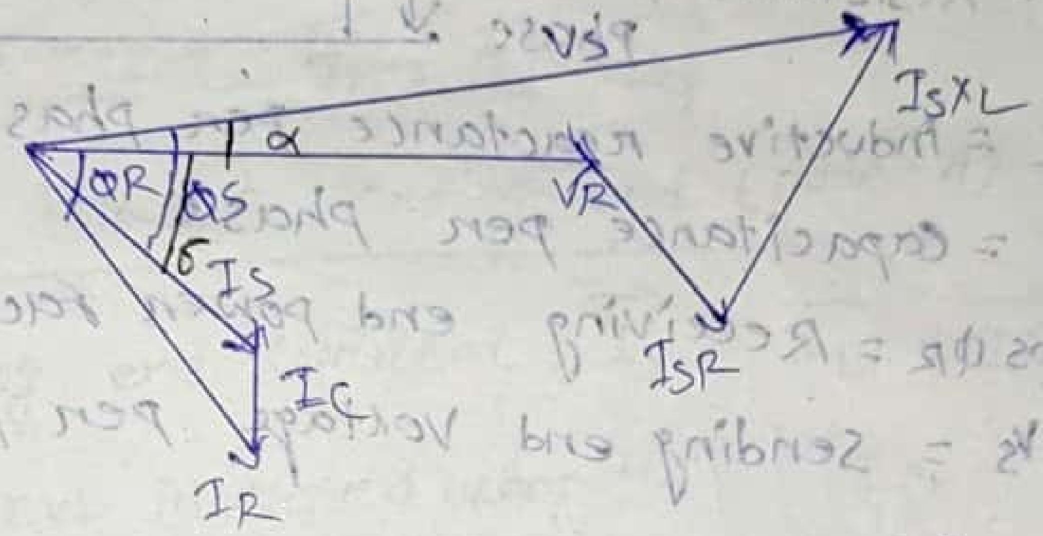
The most commonly used methods for the solution of medium transmission line are
(i) End condenser method (ii) Nominal T method
(iii) Nominal π method

* **End Condenser method :-**



Let,
I_R = Load current per phase
R = Resistance per phase.
X_L = Inductive reactance per phase
C = capacitance per phase
$\cos\phi_R$ = Receiving end power factor (lagging)
V_s = sending end voltage per phase

V_R = Receiving end voltage per phase



Taking the receiving end voltage $\vec{V_R}$ as the reference phasor, we have

$$\vec{V_R} = V_R + j0 = V_R \angle 0'$$

Load current, $\vec{I_R} = I_R(\cos\phi_R - \sin\phi_R)$

$$= I_R \angle -\phi_R$$

Capacitive current, $\vec{I_C} = j\,\vec{V_R}\,\omega C$

$$= j\,2\pi f C\,\vec{V_R}$$

Sending end current, $\vec{I_S} = \vec{I_R} + \vec{I_C}$

Voltage drop / phase, $\vec{I_S}\vec{Z} = \vec{I_S}(R + jX_L)$

Sending end voltage, $\vec{V_S} = \vec{V_R} + \vec{I_S}\vec{Z}$

$$= V_S \angle \alpha$$

% Voltage regulation $= \dfrac{V_S - V_R}{V_R} \times 100$

% Efficiency $= \dfrac{\text{Power delivered / phase}}{\text{power delivered/phase} + \text{losses/phase}} \times 100$

$$= \frac{V_R I_R \cos\phi_R}{V_R I_R \cos\phi_R + I_S^2 R} \times 100$$

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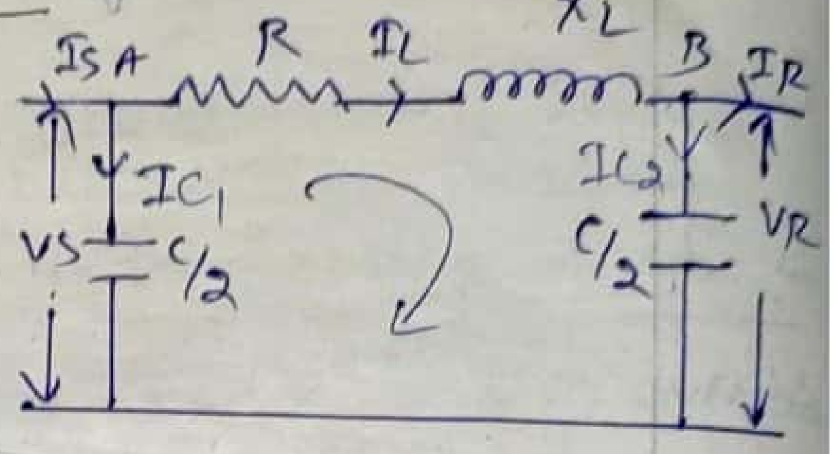
* Nomical π Method :-

Let,

I_R = Load current per phase

R = Resistance per phase

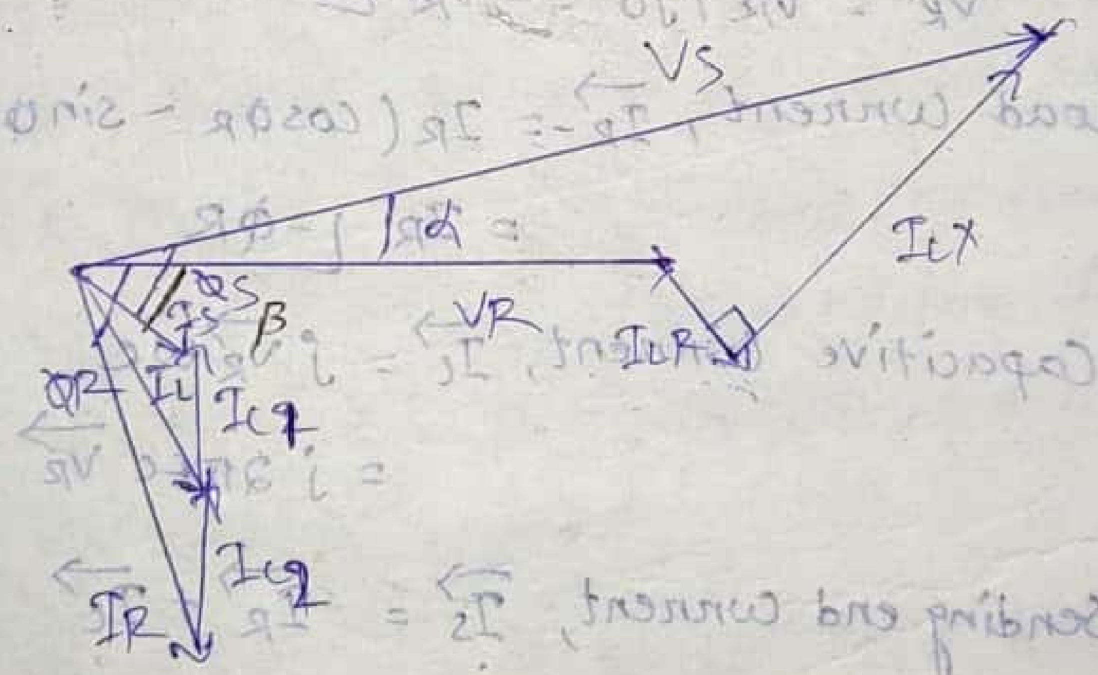


X_L = Inductive reactance per phase

C = Capacitance per phase

$\cos\phi_R$ = Receiving end power factor (lagging)

V_S = Sending end voltage per phase



Taking the receiving end voltage as the reference phasor, we have,

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

Load current, $\vec{I_R} = I_R \angle -\phi_R$

$= I_R(\cos\phi_R - \sin\phi_R)$

Charging current at load end is

$$\vec{I_{c2}} = j \vec{V_R}\,\omega C \quad j\vec{V_R}\frac{Y}{2} \qquad \because I = \frac{V}{X_C} = \frac{V}{1/\omega C} = \omega C V$$

Changing current at sending end is

$\vec{I}_{C1} = j \vec{V_S} \frac{Y}{2}$

Apply KCL at receiving end (node-B)

Line current, $\vec{I_L} = \vec{I_R} + \vec{I}_{C2}$

Apply KCL at sending end (node-A)

Sending end current, $\vec{I_S} = \vec{I_L} + \vec{I}_{C1}$

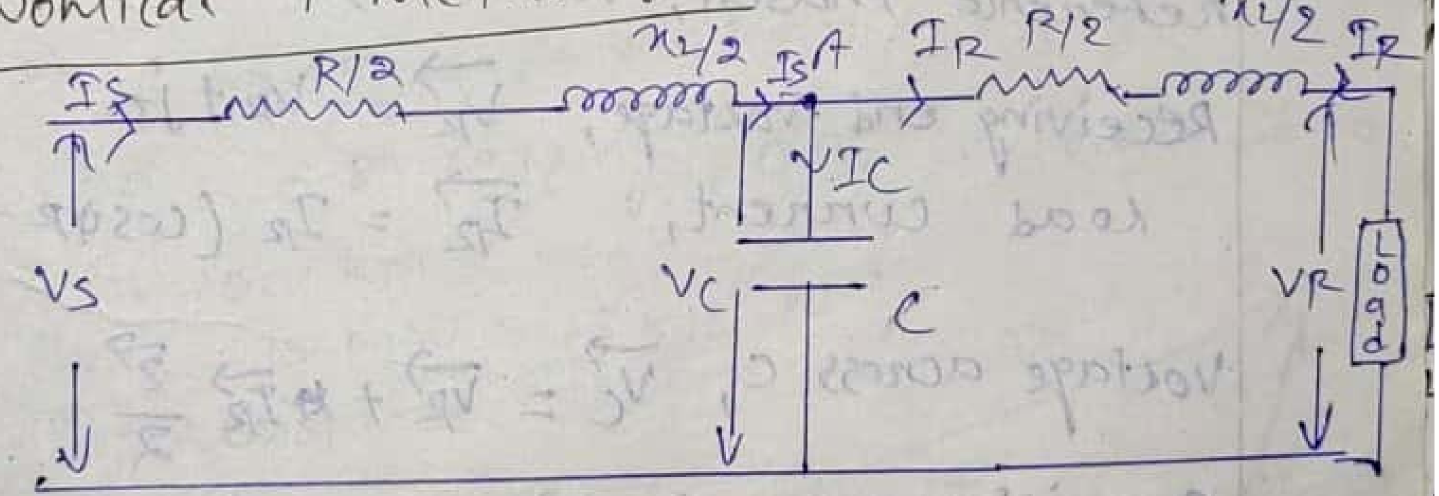
Apply KVL in closed loop :-

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

$= \vec{V_R} + I_L R + I_L X_L$

$= \vec{V_R} + \vec{I_L}(R + jX_L)$

* Nomical T method :-



I_R = Load current per phase,

X_L = inductive reactance per phase,

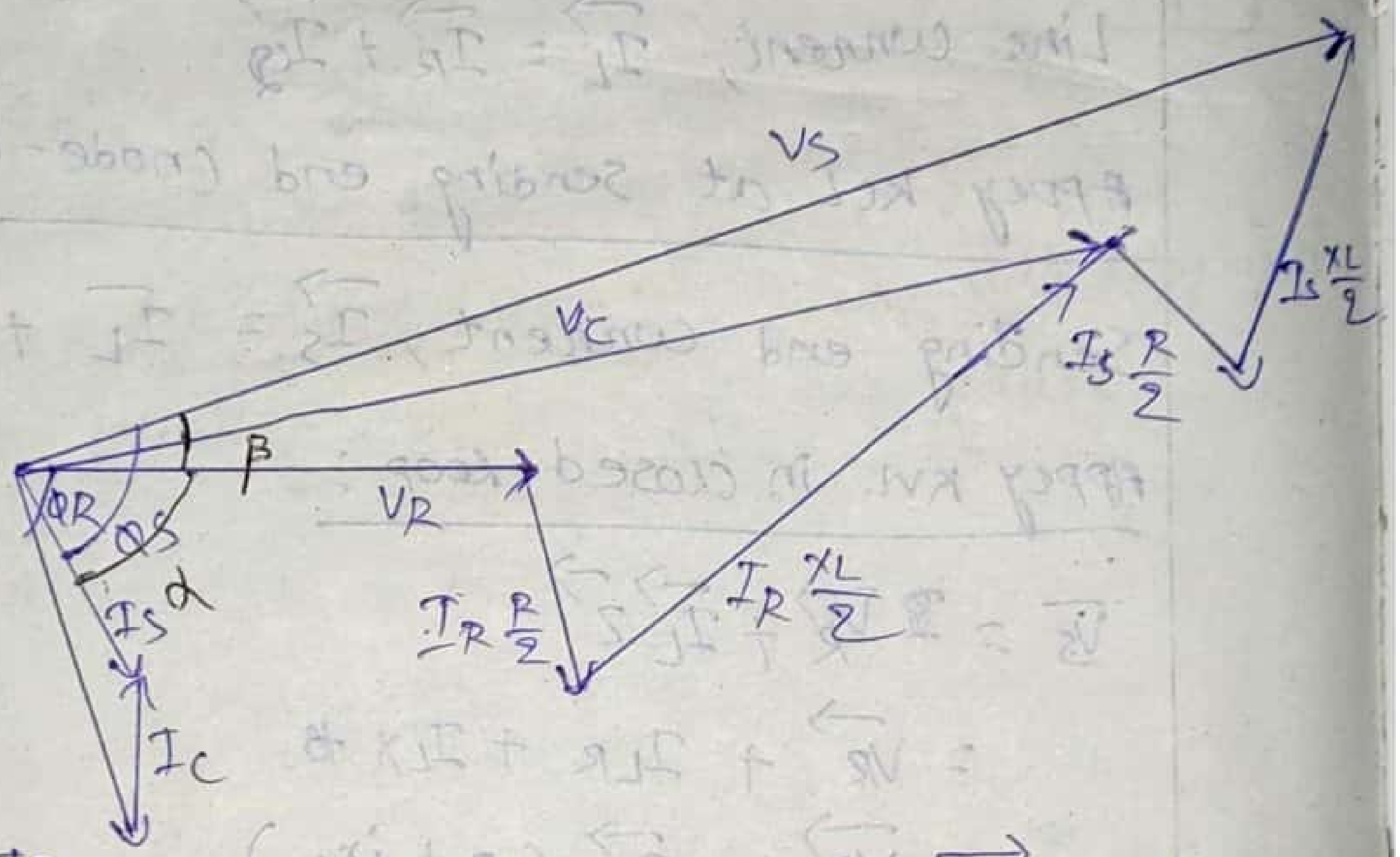
$\cos\phi_R$ = receiving end power factor

V_C = voltage across capacitor

R = Resistance per phase

C = capacitance per phase

V_S = sending end voltage /phase .



Taking the receiving end voltage $\vec{V_R}$ as the reference phasor, we have,

Receiving end voltage, $\vec{V_R} = V_R + j0$

Load current, $\vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

Voltage across C, $\vec{V_C} = \vec{V_R} + \vec{I_R}\frac{\vec{Z}}{2}$.

Capacitive current, $\vec{I_C} = j\omega C\vec{V_C}$

Sending end current, $\vec{I_S} = \vec{I_R} + \vec{I_C}$

Sending end voltage, $\vec{V_S} = \vec{V_C} + \vec{I_S}\frac{\vec{Z}}{2}$.

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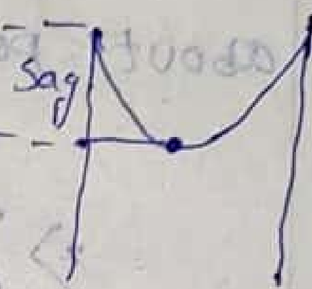
Over head lines

* Sag in over head lines :-

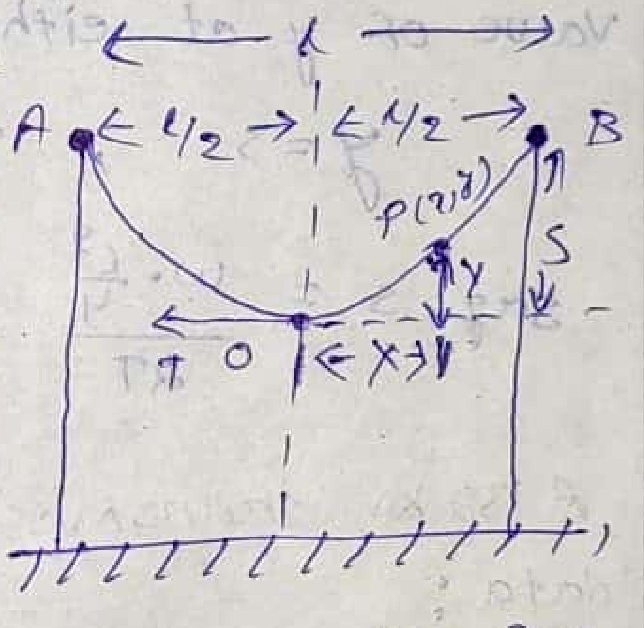
Sag :- The difference in level between points of supports & lowest point on the conductor is called sag.



Calculation of Sag :-

(i) When supports are at equal levels :-

Consider a conductor between two equal level supports A & B with O is the lowest point on the conductor.

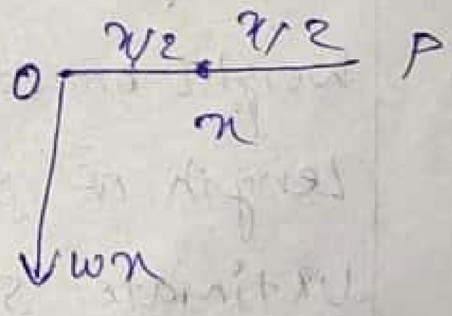


Let,

L = length of the span

W = weight of the conductor per unit length

T = tension in the conductor



Consider a point P on the conductor having co-ordinates (x, y).

Assume the curvature is so small the curved length is equal to its 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 wx of conductor acting at a distance $x/2$ from O. Force $= wx \times \frac{x}{2}$

(b) The ~~so~~ tension T acting at O, Force $= T \times y$

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

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

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

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

$$y = s, \quad x = \frac{l}{2}$$

$$\text{sag}, s = \frac{w \cdot \frac{l^2}{4}}{2T} \Rightarrow \boxed{s = \frac{w \cdot l^2}{8T}}$$

Q1) A 132 kV transmission line has the following data:

Weight of conductor (w) = 680 kg/km

Length of span (l) = 260 m

Ultimate strength = 3100 kg

Safety factor = 2

Ground clearance = 10 m

Calculate the height above ground at which the conductor should be supported.

$$\boxed{\text{Working strength} = T = \frac{\text{Ultimate factor}}{\text{Safety factor}}}$$

~~Sag, S =~~

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Weight of the conductor per meter (w)

$$= \frac{680}{1000} = 0.68\ kg$$

Working tension, $T = \frac{\text{Ultimate factor}}{\text{Safety factor}}$

$$= \frac{3100}{2} = 1550\ kg$$

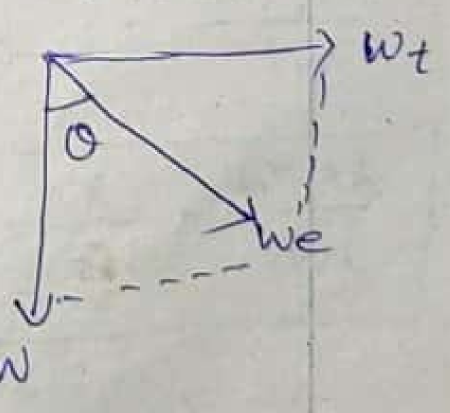
Span length, $l = 260\ M$

$$\text{Sag}, S = \frac{wl^2}{8T} = \frac{0.68 \times (260)^2}{8 \times 1550} = 3.70\ M$$

∴ Height of the pole = S + G.C

= 3.70 + 10 = 13.70 M

2) A transmission line has a span of 150 M between level supports. The conductor has a cross-sectional area of 2 cm². The tension in the conductor is 2000 kg. If the specific gravity of the conductor material is 9.9 gm/cc & wind pressure is 1.5 kg/m length, calculate the sag, what is the vertical sag?



Given Data:

Span length, l = 150 M

Working tension, T = 200 kg

Wind force 1m length of conductor, w_t = 1.5 kg

Cross-sectional area of conductor = 2 cm^2

Specific gravity = 9.9 gm/cm^3

~~we know th~~

Volume of 1m conductor = 2 cm^2 × 1M

= 2 cm^2 × 100 CM = 200 CM^3

we know that

$$\text{specific weight} = \frac{\text{weight}}{\text{volume}}$$

$$\Rightarrow 9.9\ gm/cm^3 = \frac{\text{weight}}{200\ cm^3}$$

$$\Rightarrow \text{weight} = 9.9\ \frac{gm}{cm^3} \times 200\ cm^3$$

$$= 1980\ gm = 1.98\ kg$$

Effective weight $W_e = \sqrt{w^2 + w_t^2}$

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

$$= 2.48\ kg$$

$$\text{Sag, } s = \frac{W_e l^2}{8T} = \frac{2.48 \times (150)^2}{8 \times 2000} = 3.48\ m$$

This is the value of slant sag.

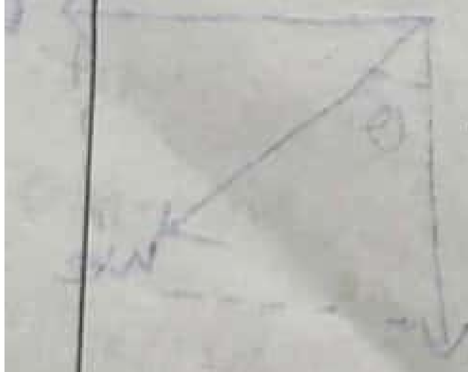
$$\cos\theta = \frac{w}{w_e} = \frac{w}{\sqrt{w^2 + w_t^2}}$$

$$= \frac{1.98}{\sqrt{(1.98)^2 + (1.5)^2}} = 0.797$$

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

$$= 3.48 \times 0.797$$

$$= 2.77\ m$$

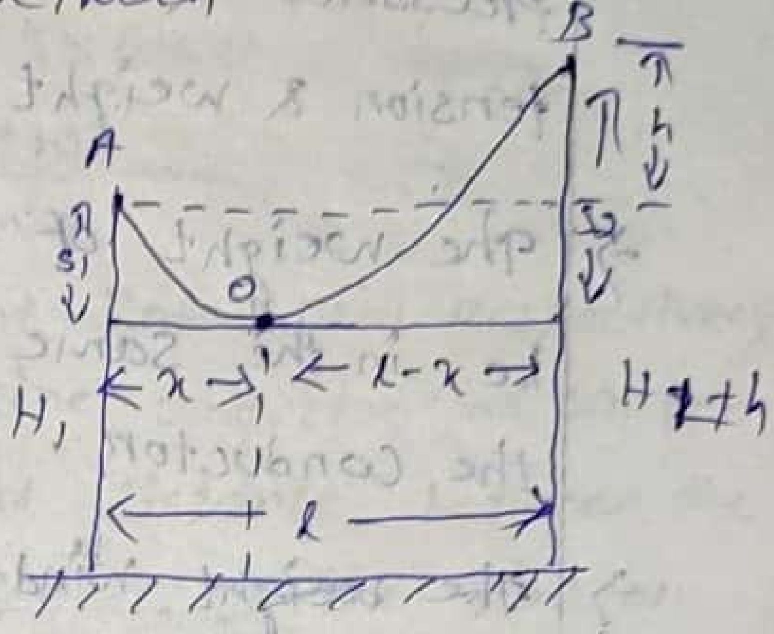


(ii) **When supports are at unequal levels :-**

l = span length

h = height difference between two supports A & B,

T = tension in the conductor



As we know that

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

So,

Sag $S_1 = \frac{wx^2}{2T}$ & $S_2 = \frac{w(l-x)^2}{2T}$

Now,

$$h = S_2 - S_1$$

$$\Rightarrow h = \frac{w(l-x)^2}{2T} - \frac{wx^2}{2T}$$

$$\Rightarrow h = \frac{wl^2 + wx^2 - 2wlx - wx^2}{2T}$$

$$\Rightarrow h = \frac{wl(l-2x)}{2T}$$

$$\Rightarrow \frac{2T \times h}{wl} = l - 2x \Rightarrow 2x = l - \frac{2T \times h}{wl}$$

$$\Rightarrow x = \left(l - \frac{2T \times h}{wl}\right)\frac{1}{2} \Rightarrow \boxed{x = \frac{l}{2} - \frac{T \times h}{wl}}$$

Similarly,

$$\boxed{l - x = \frac{l}{2} + \frac{T \times h}{wl}}$$

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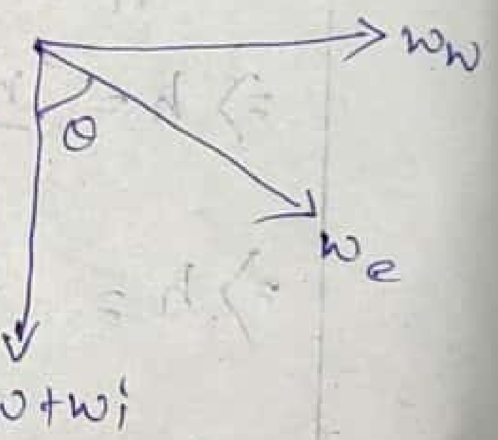
Effect of wind & ice loading :

- A conductor is also subjected to wind pressure & ice ~~loading~~ coating including the tension & weight of the conductor.
- The weight of ice acts vertically downward i.e in the same direction as the weight of the conductor.
- The ~~weight~~ wind pressure acts in horizontal direction i.e perpendicular to weight of the conductor.
- Hence, the total force on the conductor is the vector sum of horizontal & vertical forces.

So, the total weight of conductor per unit length is



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

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 × $\frac{\pi}{4}\left[(d+2t)^2 - d^2 \times h\right]$ at h = 1

w_w = wind force per unit length
= wind pressure per unit area × projected area per unit length

So, sag in the conductor is given by

$sag(s) = \frac{W_e l^2}{2T}$ This is called slant sag.

The vertical sag $= S \times \cos\theta$

Where, $\cos\theta = \frac{w + w_i}{W_e}$

Q ① The towers of height 30m & 90m respectively support a transmission line conductor at water crossing. The horizontal distance between the ~~conductor~~ towers is 500m. If the tension of the conductor is 1600 kg. Find the minimum clearance of the conductor & water and clearance midway between the supports. weight of the conductor is 1.5 kg/m.

Given Data :-

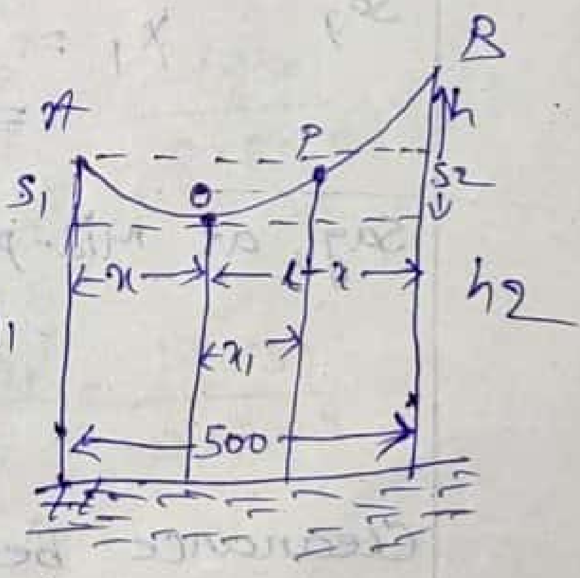
$w = 1.5$ kg/m

$h_1 = 30$ m

$h_2 = 90$ m

$L = 500$ m

$T = 1600$ kg



Difference between two supports, $h = h_2 - h_1 = 90 - 30 = 60$ m

Let, the lowest point O of the conductor be at a distance x from the support A & at a distance ~~l-x~~ from support at higher level i.e. support B.

So, $x = \frac{l}{2} - \frac{Th}{wl}$

$= \frac{500}{2} - \frac{1600 \times 60}{1.5 \times 500} = 122$ m

$l - x = \frac{l}{2} + \frac{Th}{wl}$

$= \frac{500}{2} + \frac{1600 \times 60}{1.5 \times 500} = ~~128~~.378 \text{ M}$

Now,

$S_1 = \frac{wx^2}{2T} = \frac{1.5(122)^2}{2 \times 1600}$

$= 7 \text{ M}$

Clearance between lowest point & water surface at pole - A

~~at pol~~ $= 30 - 7 = 23 \text{ M}$

~~at pole-B~~
~~90-~~

Let the mid-point P be at a distance 'x_1' from the lowest point O.

So, $x_1 = 250 - x$
$= 250 - 122 = 128 \text{ M}$

Sag, at mid-point P $= \frac{wx_1^2}{2T}$

$= \frac{1.5(128)^2}{2 \times 1600} = 7.68 \text{ M}$

Clearance between P & water level

$= 23 + 7.68 = 30.68 \text{ M}$

(2) An overhead transmission line at a river crossing is supported from two towers of heights of 40m & 90m above water level, the horizontal distance between the ~~conduc~~ towers being 400m. if the maximum allowable tension is 2000 kg. Find the clearance between the conductor & water at a point midway between the ~~to~~ towers. weight of conductor is 1 kg/m

Given data:-

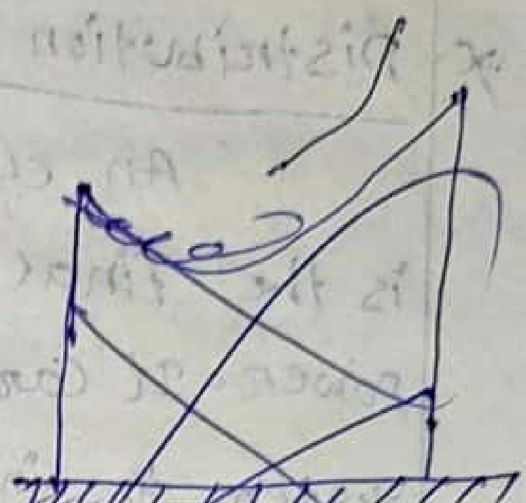
$w = 1\ kg/m$

$l = 400\ m$

$h_1 = 40\ m$

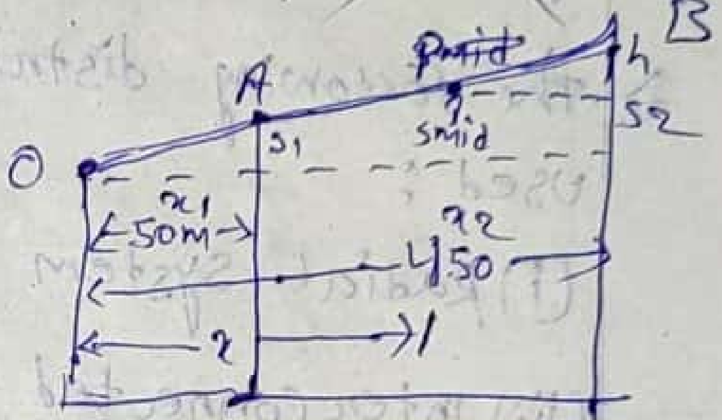
$h_2 = 90\ m$

$T = 2000\ kg$



$x_1 = \frac{400}{2} - \frac{2000 \times 50}{1 \times 400}$

$= -50\ m$



Distance of mid point P from lowest point O is

x = Distance A from O + $\frac{400}{2}$

$= 50 + 200 = 250\ m$

Sag, at point P, $S = \frac{wx^2}{2T} = \frac{1(250)^2}{2 \times 2000}$

$= 15.6\ m$

Sag, at point B, $S = \frac{wx_2^2}{2T} = \frac{1(450)^2}{2 \times 2000}$

$= 50.6\ m$

Height of point B above mid-point P

$= S_2 - S_{mid} = 50.6 - 15.6$

$= 35\ m$

Clearance of mid-point P above water level $= 90 - 35 = 55\ m$

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Chapter - 6
Distribution system

* **Distribution system :-**

An electric power distribution system is the final stage in the delivery of electric power. It carries electricity from transmission system to individual consumer.

→ The following distribution circuits are generally used :

(i) Radial system (ii) Ring main system

(iii) Inter connected system

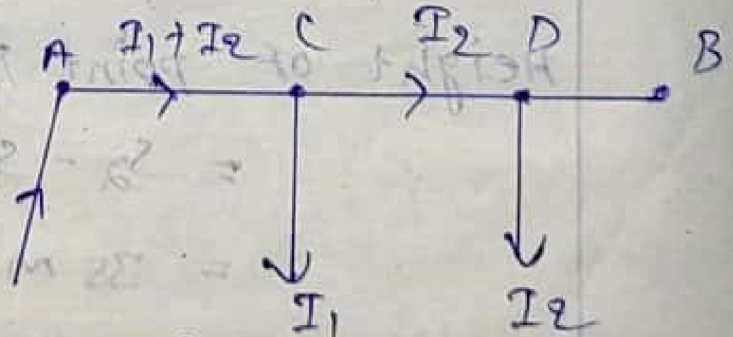
DC distribution system :-

* **Types of DC distributors :-**

1) Distributor fed at the one end
2) Distributor fed at both end
3) Distributor fed at the centre
4) Ring main

① Distributor fed at the one end :-

→ In this type of feeding, the distributor is connected to the supply



at one end & loads are taken at different points along the length of the distributor.

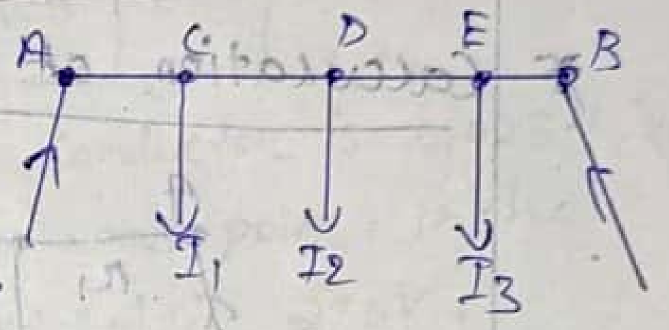
→ The current in the various sections of the distributor away from feeding point goes on decreasing.

-> The voltage across the loads away from the feeding point goes on decreasing. Thus, the minimum voltage occurs in section CD.

-> In case ~~of~~ a fault occurs on any section of the distributor, the whole distributor will ~~be~~ have to be disconnected from the supply mains.

(2) Distributor fed at both ends :-

-> In this ~~feeding~~ 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.



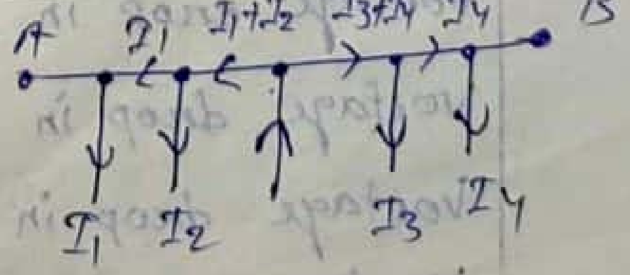
-> The voltage at the feeding points may or may not be equal.

-> The voltage goes on decreasing as we move away from one feeding point say A, reaches minimum value & then again starts rising & reaches maximum value when we reach the other feeding point B.

-> If a falut occurs on any feeding point of the distributor, the continuity of supply is maintained from the other feeding point.

(3) Distributor fed at the Centre :-

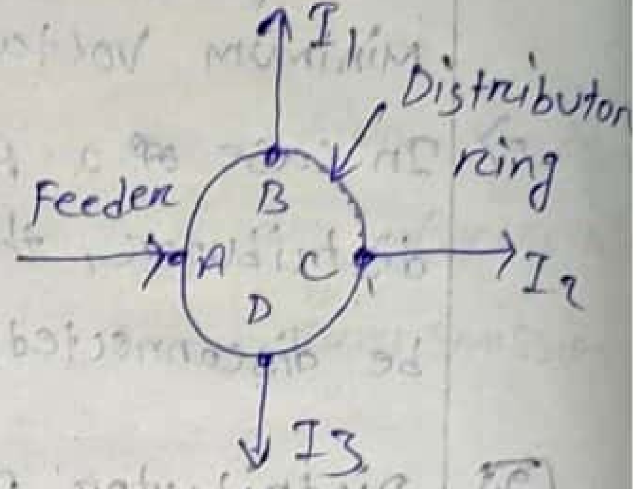
In this type of feeding, the cerre of the distribu..n is connected



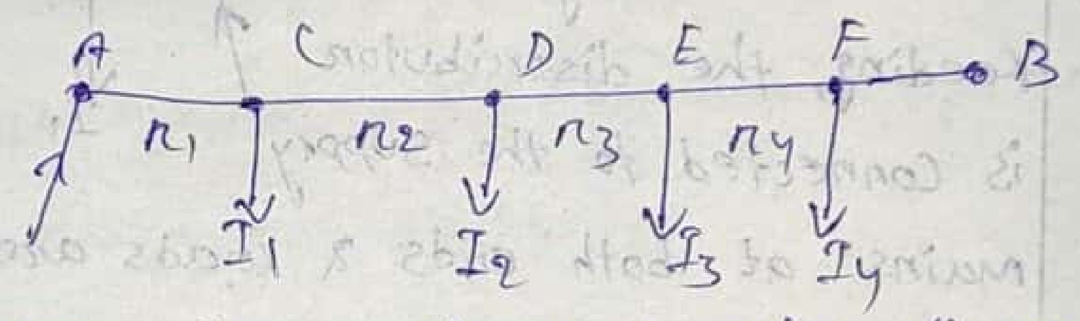
to the supply mains.

(4) Ring mains :-

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



* Calculation of Distributor fed at one end :-



The figure shows the single line diagram of a 2-wire d.c distributor AB fed at one end A & having concentrated loads I_1, I_2, I_3 & I_4 tapped off at points C, D, E & F respectively.

Let,
r_1, r_2, r_3 & r_4 be the resistances of the sections AC, CD, DE, & EF of the distributor respectively.

Current fed from point A = $I_1 + I_2 + I_3 + I_4$

Current in section AC = $I_1 + I_2 + I_3 + I_4$

Current in section CD = $I_2 + I_3 + I_4$

Current in section DE = $I_3 + I_4$

Current in Section EF = I_4

Voltage drop in section AC = $r_1 (I_1 \cdot I_2 + I_3 + I_4)$

Voltage drop in section CD = $r_2 \cdot I_2 + I_3 + I_4)$

Voltage drop in Section DE = $3 (I_3 + I_4)$

Voltage drop in Section EF = $r_4 I_4$

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Total Voltage drop in the distributor

$= r_1(I_1+I_2+I_3+I_4) + r_2(I_2+I_3+I_4) + r_3(I_3+I_4) + r_4 I_4$

Q ① A DC distributor cable 1000 M long & is ~~located~~ loaded

Distance from feeding point 'A' in M	250	750	1000
Load in Amp	100	200	500

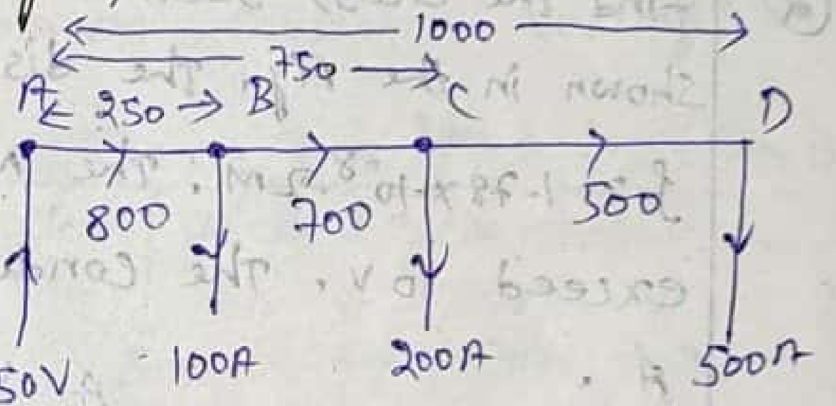
The resistance of each conductor is 0.025 Ω/km. Find the voltage at each load point. If the voltage at feeding point 'A' is 250V.

Given Data

$L = 1000$ M

$V_A = 250$ V

$R/km = 0.025\ \Omega$



Distance between AB = 250 m

Distance between BC = 750 - 250 = 500 M

Distance between CD = 1000 - (500 + 250) = 250 M

The resistance of each conductor per KM = 0.025 Ω

The resistance of section AB, $R_{AB} = \frac{0.025}{1000} \times 250 \times 2$

$= 0.0125\ \Omega$

The resistance of section BC, $R_{BC} = \frac{0.025}{1000} \times 500 \times 2$

$= 0.025\ \Omega$

The resistance of section CD, $R_{CD} = \frac{0.025}{1000} \times 250 \times 2$

$= 0.0125\ \Omega$

Voltage at first load point B, $V_B = V_A - V_{AB}$

$\Rightarrow V_B = 250 - I_{AB} \times R_{AB}$

$\Rightarrow I_B = 250 - (800 \times 0.012)$

$\Rightarrow I_B = 240 V$

Voltage at second load point C, $V_C = V_B - V_{BC}$

$\Rightarrow V_C = 240 - I_{BC} R_{BC}$

$\Rightarrow V_C = 240 - (700 \times 0.025) = 222.5 V$

Voltage at third load point D, $V_D = V_C - V_{CD}$

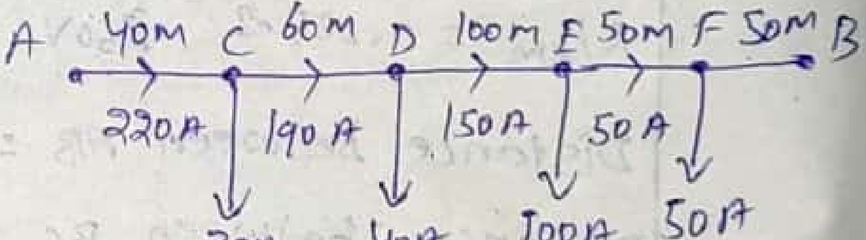
$\Rightarrow V_D = 222.5 - (I_{CD} \times R_{CD})$

$\Rightarrow V_D = 222.5 - (500 \times 0.012)$

$\Rightarrow V_D = 216.5 V$

(2) Find the cross-sectional area of the distributor shown in the fig. The distance is given in meters. $\rho = 1.78 \times 10^{-8} \Omega M$. The maximum voltage drop is not exceed 10 V. The conductor is fed from point A.

Soln



Let,

the two wire cable resistance per meter = R/M

According to the question

Voltage drop across AB = 10

$\Rightarrow (220 \times 40R) + (190 \times 60R) + (150 \times 100R) + (50R \times 50) + 0 = 10$

$\Rightarrow R(220 \times 40 + 190 \times 60 + 150 \times 100 + 50 \times 50) = 10$

$\Rightarrow R(37700) = 10 \Rightarrow R = \frac{10}{37700} = 2.65 \times 10^{-4} \Omega$

We know that

$R = \rho \frac{l}{a}$

$\Rightarrow 2.65 \times 10^{-4} = 1.78 \times 10^{-8} \times \frac{2 \times 1}{a}$

$\Rightarrow a = \dfrac{2.65 \times 10^{-4} \times 2}{1.75 \times 10^{-8}} = 1.34 \times 10^{-4} \, M^2$

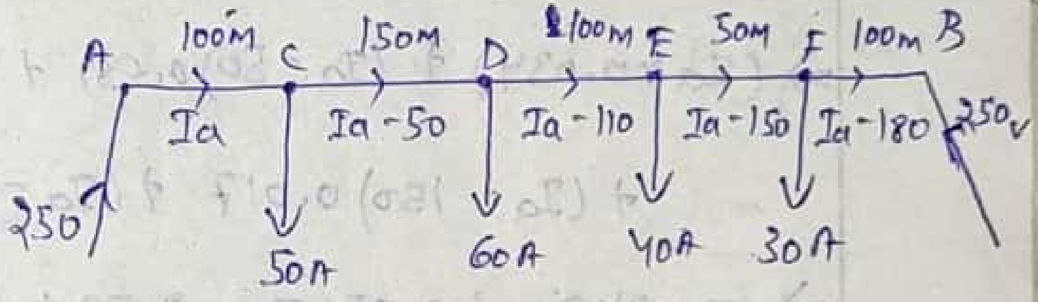
$a = 1.34 \times 10^{-4} \times 1000$

$= 0.134 \, MM^2$

1 M = 100 CM
1 CM = 10 MM
100 CM = 100 × 10
= 1000 MM

(3) A two conductor distributor AB, 500 M in length is fed at both ends at 250V load of 50A, 60A, 40A, 30A are tapped at distances of 100M, 250MM, 350MM, 400 M from A respectively. Cross-sectional area of the conductor is $1 \, cm^2$, resistivity is $1.7 \times 10^{-8} \, \Omega M$. Determine the voltage at each load point & minimum consumer voltage.

Sol^n



Distance between AC = 100M

Distance between CD = 250 - 100 = 150 M

Distance between DE = 350 - (100 + 150) = 100 M

Distance between EF = 400 - 350 = 50 M

Distance between FB = 500 - 400 = 100 M

We know that,

$\rho = 1.7 \times 10^{-8} \, \Omega M$

Area = $1 \, CM^2 = 10^{-4} \, M^2$

$l = 1 \, M$

Resistance per 2 wire cable

$R = 1.7 \times 10^{-8} \times \dfrac{1 \times 2}{10^{-4}} = 3.4 \times 10^{-4} \, \Omega$

The resistance of section AC, $R_{AC} = 3.4 \times 10^{-4} \times 100$

$= 0.034 \, \Omega$

The resistance of section CD, $R_{CD} = 3.4 \times 10^{-4} \times 150$

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$R_{CD} = 0.051\ \Omega$

The resistance of section DE, $R_{DE} = 3.4\times10^{-4}\times 100$
$= 0.034\ \Omega$

The resistance of section EF, $R_{EF} = 3.4\times10^{-4}\times 50$
$= 0.017$

The resistance of section FB, $R_{FB} = 3.4\times10^{-4}\times 100$
$= 0.034\ \Omega$

Voltage drop across AB $= V_A - V_B$

$\Rightarrow V_{AB} + V_{CD} + V_{DE} + V_{EF} + V_{FB} = 250 - 250$

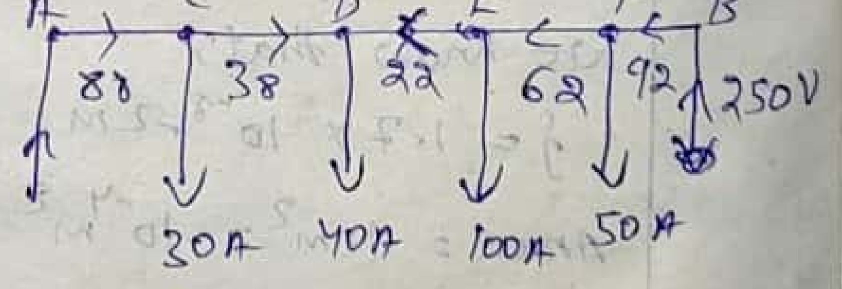
$\Rightarrow (I_a\times0.034) + (I_a-50)R_{CD} + (I_a-110)R_{DE} + (I_a-150)R_{EF} + (I_a-180)_{FB} = 0$

$\Rightarrow (I_a\times0.034) + (I_a-50)0.051 + (I_a-110)0.034 + (I_a-150)0.017 + (I_a-180)0.034 = 0$

$\Rightarrow 0.034I_a + 0.051I_a - 2.55 + 0.034I_a - 3.74 + 0.017I_a - 2.55 + 0.034I_a - 6.12 = 0$

$\Rightarrow I_a(0.034 + 0.051 + 0.034 + 0.017 + 0.034) = 14.96$

$\Rightarrow I_a = 88\,A$



$V_C = V_A - V_{AC}$
$= 250 - I_{AC}\times R_{AC}$
$= 250 - 88\times0.034$
$= 247\,V$

$V_D = V_C - V_{CD}$
$= 247 - 38\times0.051$
$= 245.06\,V$

$V_E = V_D - V_{DE}$
$= 245.06 - (-22\times0.034)$
$= 245.80\,V$

$V_F = V_E + V_{EF}$
$= 245.80 + 62\times0.017$
$= 246.85\,V$

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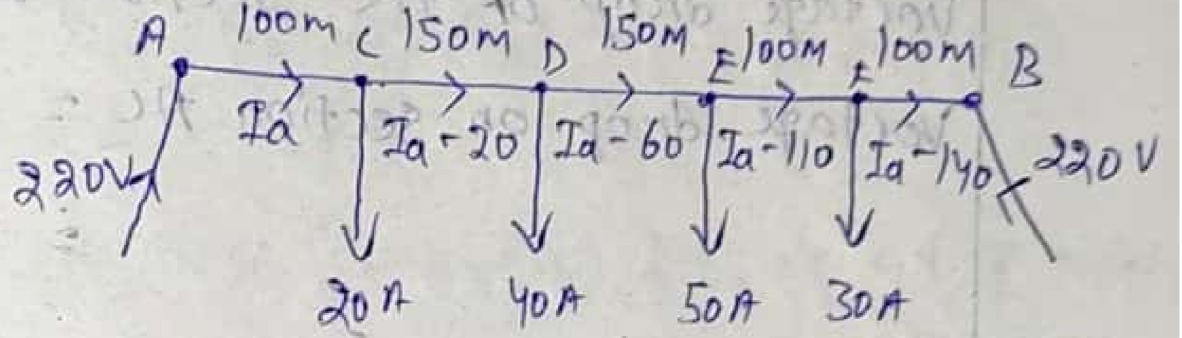
maintained at 235 V & at

(4) A 2-wire DC distributor AB 600 M long is fed from both end at 220V. loads of 20A, 40A, 50A & 30 A are tapped at distances of 100M, 250M 400 M & 500 M from the end A respectively. If the cross-sectional area of the distributor is 1 cm^2. Find the voltage at each load point $\rho = 1.7 \times 10^{-6}\ \Omega$ CM.

Solⁿ



$1 M = 100 CM$

$1 cm = \frac{1}{100} = 10^{-2}$

$1 cm^2 = 10^{-4}$

Area $= 1\ cm^2 = 1 \times 10^{-4}\ m^2$

$\rho = 1.7 \times 10^{-6}\ \Omega$ CM

$= 1.7 \times 10^{-8}\ \Omega$ M

we know that,

$R = \rho \frac{l}{a} = 1.7 \times 10^{-8} \times \frac{1}{10^{-4}}$

$= 1.7 \times 10^{-4}\ \Omega$ for 1 conductor & 1 meter

Resistance of section AC, $R_{AC} = 1.7 \times 10^{-4} \times 2 \times 100$
$= 0.034\ \Omega$

Resistance of section CD, $R_{CD} = 1.7 \times 10^{-4} \times 2 \times 150$
$= 0.051\ \Omega$

Resistance of section DE, $R_{DE} = 1.7 \times 10^{-4} \times 2 \times 150$
$= 0.051\ \Omega$

Resistance of section EF, $R_{EF} = 1.7 \times 10^{-4} \times 2 \times 100$
$= 0.034\ \Omega$

Resistance of section FB, $R_{FB} = 1.7 \times 10^{-4} \times 2 \times 100$
$= 0.034\ \Omega$

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Let,

Current supplied by source A = I_A

Current through AC = $I_{AC} = I_A$

Current through CD = $I_{CD} = (I_A - 20)$ A

Current through DE = $I_{DE} = (I_A - 60)$ A

Current through EF = $I_{EF} = (I_A - 110)$ A

Current through FB = $I_{FB} = (I_A - 140)$ A

Voltage drop of the section of distributor

Voltage drop on section AC = $V_{AC} = I_{AC} \times R_{AC}$

$= 0.034 I_A$

Voltage drop on section CD = $V_{CD} = I_{CD} \times R_{CD}$

$= (I_A - 20)\, 0.051 = 0.051 I_A - 1.02$V

Voltage drop on section DE = $V_{DE} = I_{DE} \times R_{DE}$

$= (I_A - 60)\, 0.051 = 0.051 I_A - 3.06$ V

Voltage drop on section EF = $V_{EF} = I_{EF} \times R_{EF}$

$= (I_A - 110)\, 0.034 = 0.034 I_A - 3.74$V

Voltage drop on section FB = $V_{FB} = I_{FB} \times R_{FB}$

$= (I_a - 140)\, 0.034 = 0.034 I_A - 4.76$ V

Voltage drop across AB = $V_1 - V_2$

$\Rightarrow V_{AC} + V_{CD} + V_{DE} + V_{EF} + V_{FB} = 220 - 220$

$\Rightarrow 0.034 I_a + 0.054 I_A - 1.02 + 0.051 I_A - 3.06 + 0.034 I_A$
$- 3.74 + 0.034 I_A - 4.76 = 0$

$\Rightarrow I_a (0.034 + 0.051 + 0.051 + 0.034 + 0.034) = 12.58$

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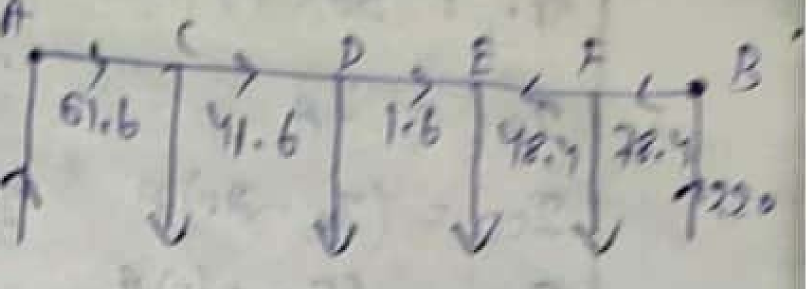
$\Rightarrow I_A = 61.6\ A$



$V_C = V_A - V_{AC}$

$= 220 - 61.6 \times 0.034$

$= 217.90\ V$

$V_D = V_C - V_{CD}$

$= 217.90 - 41.6 \times 0.051$

$= 215.77\ V$

$V_E = V_D - V_{DE}$

$= 215.77 - 1.6 \times 0.051$

$= 215.68\ V$

$V_F = V_E + V_{EF}$

$= 215.68 + 48.4 \times 0.034$

$= 217.32$

$\therefore$ minimum consumer voltage 215.68 at E point.

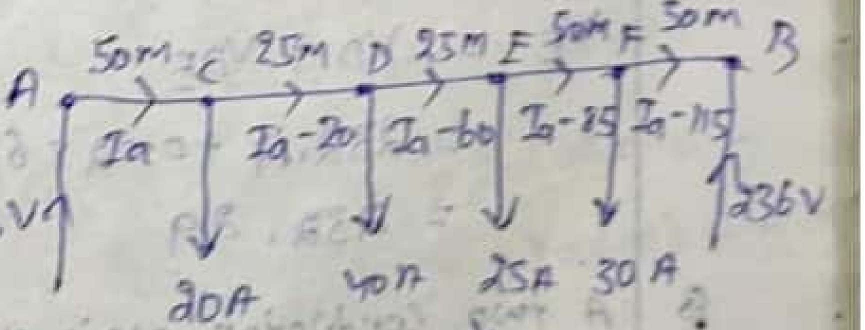
(5) A DC distributor is fed at both ends at feeding point A. The voltage is maintained at 235V & at point B at 236V. The total length of the distributor is 200 m & the loads are tapped of as

20A at 50 m from A — 25A at 100m from A

40A at 75 m from A — 30A at 150 m from A

The resistance per km of one conductor is 0.4 Ω. Calculate the minimum voltage & the point at which it occurs?

Soln



$R/km = 0.4\ \Omega$

Resistance per meter $= \frac{0.4}{1000} = 4 \times 10^{-4}\ \Omega$

$R_{AC} = 50 \times 4 \times 10^{-4} \times 2 = 0.04\ \Omega$

$R_{CD} = 25 \times 4 \times 10^{-4} \times 2 = 0.02\ \Omega$

$R_{DE} = 25 \times 4 \times 10^{-4} \times 2 = 0.02\ \Omega$

$R_{EF} = 50 \times 4 \times 10^{-4} \times 2$ $= 0.04\ \Omega$

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$R_{FB} = 50\times4\times10^{-4}\times2 = 0.04\,\Omega$

$I_{AC} = I_A$ $\qquad I_{EF} = (I_A - 85)\,A$

$I_{CD} = (I_A - 20)\,A$ $\qquad I_{FB} = (I_A - 115)\,A$

$I_{DE} = (I_A - 60)\,A$

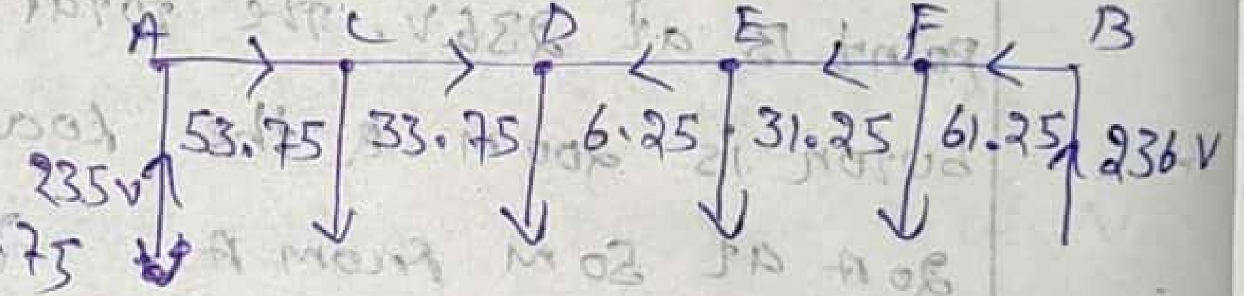
$V_{AC} + V_{CD} + V_{DE} + V_{EF} + V_{FB} = V_1 - V_2$

$\Rightarrow 0.04 I_A + (I_A - 20)0.02 + (I_A - 60)0.02 + (I_A - 85)0.04$
$\qquad + (I_A - 115)0.04 = 235 - 236$

$\Rightarrow 0.04 I_A + 0.02 I_A - 0.4 + 0.02 I_A - 1.2 + 0.04 I_A - 3.4$
$\qquad + 0.04 I_A - 4.6 = -1$

$\Rightarrow I_A(0.04 + 0.02 + 0.02 + 0.04 + 0.04) = -1 + 9.6$

$\Rightarrow I_A = \dfrac{8.6}{0.04+0.02+0.02+0.04+0.04} = 53.75\,A$



$V_C = V_A - V_{AC}$
$= 235 - 0.04\times53.75$
$= 232.85\,V$

$V_D = V_C - V_{CD}$
$= 232.85 - 0.02\times33.75$
$= 232.17\,V$

$V_E = V_D + V_{DE}$
$= 232.17 + 0.02\times6.25$
$= 232.29$

$V_F = V_E + V_{EF}$
$= 232.29 + 0.04\times31.25$
$= 233.54\,V$

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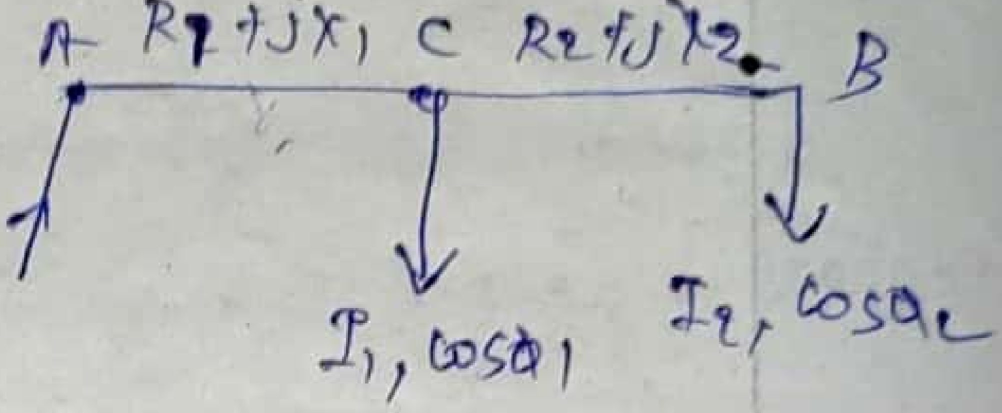
* Calculation of AC distribution problems:-

Power factors refered to receiving end voltage



impedance of section AC, $\vec{Z_{AC}} = R_1 + jX_1$

impedance of section CB, $\vec{Z_{CB}} = R_2 + jX_2$

Load current at point C, $\vec{I_1} = I_1 \angle -\phi_1$

or $I_1(\cos\phi_1 - j\sin\phi_1)$

Load current at point B, $\vec{I_2} = I_2 \angle -\phi_2$

or $\vec{I_2} = I_2(\cos\phi_2 - j\sin\phi_2)$

Current in section CB, $\vec{I_{CB}} = \vec{I_2} = I_2 \angle -\phi_2$

current in section AC, $\vec{I_{AC}} = \vec{I_1} + \vec{I_2}$

Voltage drop in section CB, $\vec{V_{CB}} = \vec{I_{CB}} \cdot \vec{Z_{CB}}$

Voltage drop in section AC, $\vec{V_{AC}} = \vec{I_{AC}} \cdot \vec{Z_{AC}}$

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

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

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Q(1) A single phase a.c distributor AB 300 meter long is fed from end A & is loaded as under:

(i) 100 A at 0.707 p.f lagging 200 M from point A

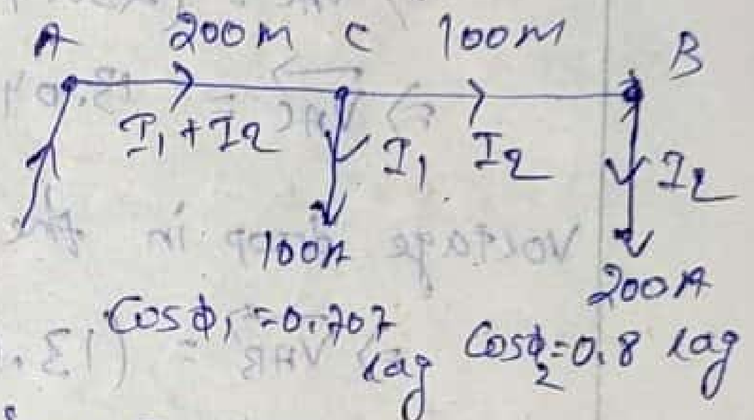
(ii) 200 A at 0.8 p.f lagging 300 M from point A

The load resistance & reactance of the distributor is 0.2 Ω & 0.1 Ω per kilometer. Calculate the total voltage drop in the distributor.

Soln

$R/km = 0.2\,\Omega$

$X/km = 0.1\,\Omega$



Total impedance of distributor / 1km $= 0.2 + j0.1\,\Omega$

Impedance of section AC, $\overrightarrow{Z_{AC}} = \frac{0.2 + j0.1}{1000} \times 200$

$= 0.04 + j0.02\,\Omega$

Impedance of section CB, $Z_{CB} = \frac{0.2 + j0.1}{1000} \times 100$

$= 0.02 + j0.01\,\Omega$

$\cos\phi_1 = 0.707$

$\phi_1 = \cos^{-1}(0.707) = 45$

$\cos\phi_2 = 0.8$

$\Rightarrow \phi_2 = \cos^{-1}0.8 = 36.86$

Load current at point C, $\overrightarrow{I_1} = I_1 \angle -\phi_1$

$\Rightarrow \overrightarrow{I_1} = 100\angle -45 = 70.7 - j70.7$ A

Load current at point B, $\overrightarrow{I_2} = I_2 \angle -\phi_2$

$\Rightarrow \overrightarrow{I_2} = 200\angle -36.86$

$\Rightarrow \overrightarrow{I_2} = 160.02 - j120$ A

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

$\Rightarrow \overrightarrow{I_{AC}} = (70.7 - j70.7) + (160.02 - j120)$

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$\Rightarrow \overrightarrow{I_{AC}} = 230.7 - j190.7$ A

Voltage drop in section CB, $\overrightarrow{V_{CB}} = \overrightarrow{I_{CB}}\ \overrightarrow{Z_{CB}}$

$\Rightarrow \overrightarrow{V_{CB}} = (160.02 - j\,190.7)(0.02 + j0.01)$

$\Rightarrow \overrightarrow{V_{CB}} = 4.4 - j0.8$ V

Voltage drop in section AC, $\overrightarrow{V_{AC}} = \overrightarrow{I_{AC}}\ \overrightarrow{Z_{AC}}$

$\Rightarrow \overrightarrow{V_{AC}} = (230.7 - j190.7)(0.047 + j0.02)$

$\Rightarrow \overrightarrow{V_{AC}} = 13.04 - j\,3.01$ V

Voltage drop in the distributor $\overrightarrow{V_{AB}} = \overrightarrow{V_{AC}} + \overrightarrow{V_{CB}}$

$\Rightarrow \overrightarrow{V_{AB}} = (13.04 - j3.01) + (4.4 - j0.8)$

$\Rightarrow \overrightarrow{V_{AB}} = 17.44 - j\,3.81 = 17.85 \angle -12.31^\circ$

Magnitude of drop $= \sqrt{(17.44)^2 + (3.81)^2}$

$= 17.85$ V

(2) A single phase distributor one km long has resistance & reactance per conductor of 0.1Ω & 0.15Ω respectively. At the far end, the voltage $V_B = 200$V & the current is 100 A at a p.f of 0.8 lagging. At the mid point M of the distributor, a current of 100A is tapped at p.f of 0.6 lagging with reference to the voltage V_m to the mid point. Calculate:

(i) Voltage at mid-point

(ii) Sending end voltage

(iii) Phase angle between V_A & V_B

(Draw the phasor diagram)

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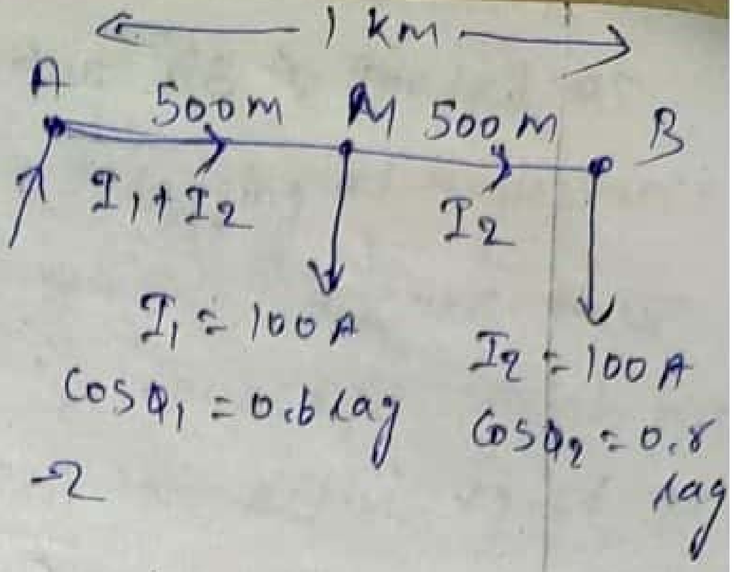
Soln



Total Resistance of distributor $= 2\times0.1 = 0.2\,\Omega$

Total Reactance of distributor $= 2\times0.15 = 0.3\,\Omega$

Total impedance of the distributor $= 0.2+j0.3\,\Omega$

impedance of Section MB, $\vec{Z_{MB}} = \frac{0.2+j0.3}{1000}\times500$

$= 0.1+j0.15\,\Omega$

impedance of Section AM, $\vec{Z_{AM}} = \frac{0.2+j0.3\times500}{1000}$

$= 0.1+j0.15\,\Omega$

$\cos\phi_1 = 0.6$

$\Rightarrow \phi_1 = \cos^{-1}0.6$

$\Rightarrow \phi_1 = 53.13$

$\cos\phi_2 = 0.8$

$\Rightarrow \phi_2 = 36.86$

Load current at point B, $\vec{I_2} = I_2\angle-\phi_2$

$\Rightarrow \vec{I_2} = 100\angle-36.86 = 80.01-j60$

current in section MB, $\vec{I_{MB}} = \vec{I_2}$

Voltage drop in section MB, $\vec{V_{MB}} = \vec{I_{MB}}\,\vec{Z_{MB}}$

$\Rightarrow \vec{V_{MB}} = (80.01-j60)(0.1+j0.15)$

$\Rightarrow \vec{V_{MB}} = 17+j6\ V = 18\angle19.44$

(i) Voltage at point M, $\vec{V_M} = \vec{V_B} + \vec{V_{MB}}$

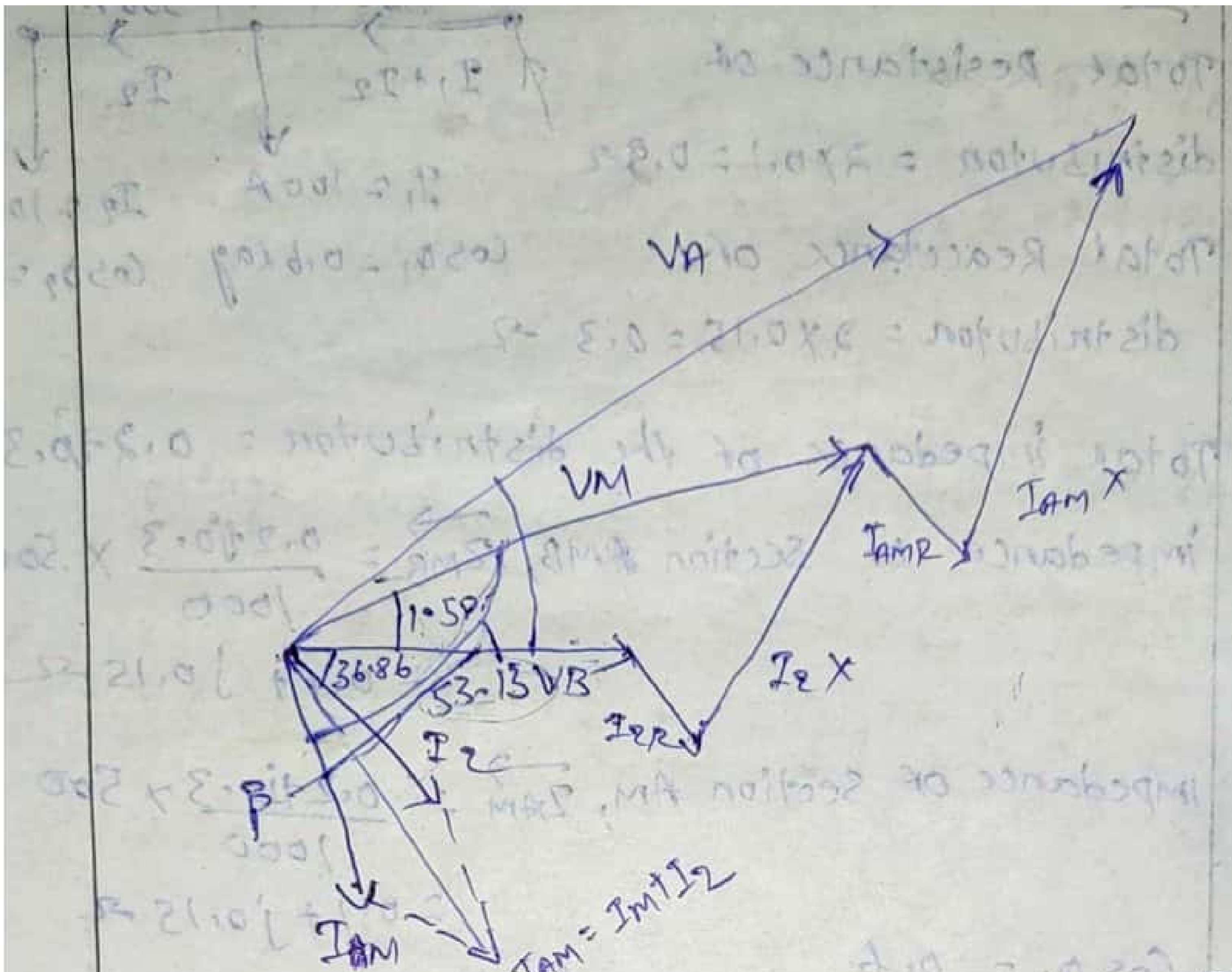
$\Rightarrow \vec{V_M} = (200+j0)+(17+j6)$ $\quad (\because \vec{V_B} = \vec{V_M} - \vec{V_{MB}})$

$\Rightarrow \vec{V_M} = 217+j6\ V = 217.08\angle1.58$

phase angle between V_M & V_B is 1.58,

phase angle between I_{AM} & $V_B = \beta = 53.13-1.58$

$\Rightarrow \beta = 51.55^\circ$



Load current at point M, $\vec{I_1} = I_1 \angle -\beta$

$\Rightarrow \vec{I_1} = 100\angle -51.55 = 62.18 - j78.31$ A

Current in section AM, $\vec{I_{AM}} = \vec{I_1} + \vec{I_2}$

$\Rightarrow \vec{I_{AM}} = (62.18 - j78.31) + (80.01 - j60)$

$\Rightarrow \vec{I_{AM}} = 142.19 - j138.31$

Voltage drop in section AM, $\vec{V_{AM}} = \vec{I_{AM}}\,\vec{Z_{AM}}$

$\Rightarrow \vec{V_{AM}} = (142.99 - j138.31)(0.1 + j0.15)$

$\Rightarrow \vec{V_{AM}} = 34.96 + j7.49$

(ii) Sending end voltage, $\vec{V_A} = \vec{V_M} + \vec{V_{AM}}$

$\Rightarrow \vec{V_A} = (217 + j6) + (34.96 + j7.49)$

$\Rightarrow \vec{V_A} = 251.96 + j13.49$

$= 252.32\angle 3.06$

(iii) Phase angle between VA & VB is 3.06.

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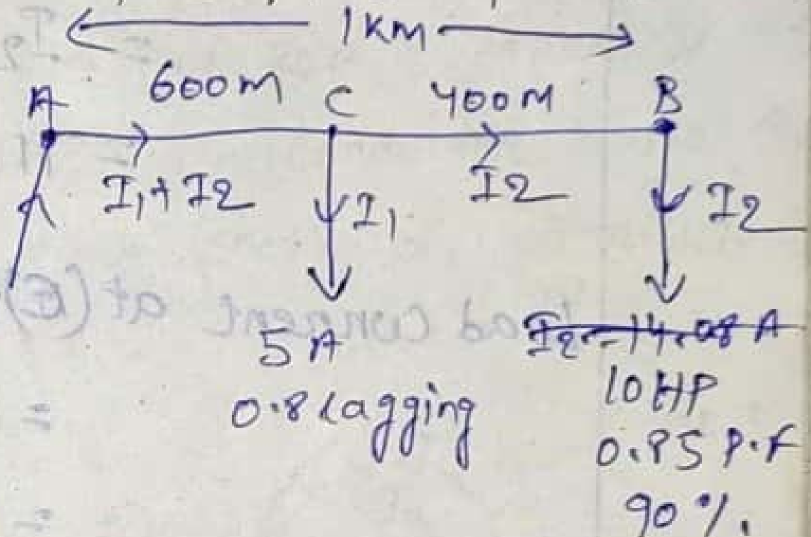
3) A 3-phase, 400V distributon AB is loaded as 5A per phase at a p.f 0.8 lagging at a distance 600m from point 'A'. At point 'B' a three-phase 400V induction motor is connected which has an output of 10 Hp with an efficiency of 90% & 0.85 p.f lagging. If voltage at point B is maintained at 400V what should be voltage at point A. The resistance & reactance of the line are 1Ω & 0.5Ω per phase per kilometer respectively.



Soln

Given Data

$R/km = 1\Omega$

$X/km = 0.5\Omega$

Line voltage = 400V

$P_o = 10\ HP = 10 \times 746\ W$

Efficiency $\eta = 90\%$.

$V_B = 400V$

Total impedance of the distributon per phase $\vec{Z} = (1+j0.5)\Omega$

Impedance of section AC, $\vec{Z_{AC}} = \frac{1+j0.5}{1000} \times 600$

$= 0.6 + j0.3\Omega$

Impedance of section CB, $\vec{Z_{CB}} = \frac{0.1+j0.5}{1000} \times 400$

$= 0.4 + j0.2\Omega$

phase voltage at point B, $V_B = \frac{400}{\sqrt{3}} = 230.94\angle 0°$

$= 230.94 + j0\ V$

we know that $\eta = \frac{\text{output}}{\text{Input}}$

$\Rightarrow \frac{90}{100} = \frac{10 \times 746}{\sqrt{3} VI \cos\phi}$

$\Rightarrow \frac{90}{100} = \frac{10 \times 746}{\sqrt{3} \times 400 \times I \times 0.85}$

$\Rightarrow I = \frac{10 \times 746 \times 100}{90 \times \sqrt{3} \times 400 \times 0.85}$

$\Rightarrow I = 14.07 A = I_2$

Load current at (B) $\vec{I_2} = I_2 \angle -\phi$ $\cos\phi = 0.85$

$= I_2 \angle -31.78 A$ $\phi = 31.78$

$= 11.96 - j7.41$

Load current at (C) $\vec{I_1} = I_1 \angle -\phi$ $\cos\phi = 0.8$

$= 5 \angle -36.86$ $\phi = 36.86$

$= 4 - j3 A$

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

$\Rightarrow \vec{I_{AC}} = (11.96 - j7.41) + (4 - j3)$

$\Rightarrow \vec{I_{AC}} = 15.96 - j10.41 A$

Voltage drop in section CB, $\vec{V_{CB}} = \vec{I_{CB}} \vec{Z_{CB}}$

$\Rightarrow \vec{V_{CB}} = (11.96 - j7.41)(0.4 + j0.2)$

$\Rightarrow \vec{V_{CB}} =$ ~~12.69 - j1.45~~ $6.26 - j0.57$

Voltage drop in section AC, $\vec{V_{AC}} = \vec{I_{AC}} \vec{Z_{AC}}$

$\Rightarrow \vec{V_{AC}} = (15.96 - j10.41)(0.6 + j0.3)$

$\Rightarrow \vec{V_{AC}} = 12.69 - j1.45$

~~Voltage drop in section AB, V~~

Voltage at point A/ϕ = $\vec{V_{AC}} + \vec{V_{CB}} + \vec{V_B}$

$= (12.69 - j1.45) + (6.26 - j0.57) + (230.94 + j0)$

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f) $\vec{V_A} = 249.89 - j2.02$

$= 249.89 \angle -0.46$

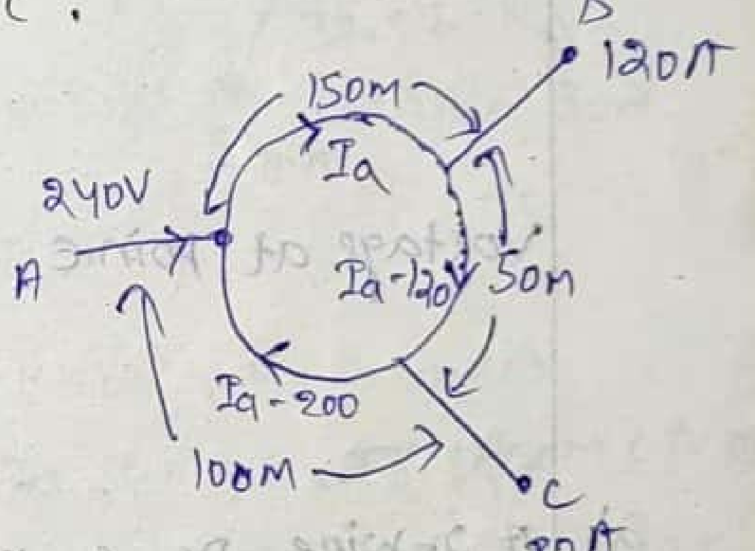
v) The line voltage at point A $= \sqrt{3} \times 249.89$

$= 432.82$ V

Ring main distributor :- (DC)

1) A 2-wire DC ring distributor is 300 m long & is fed at 240V at point A. At point B, 150m from A, a load of 120 A is taken & at C, 100m in the opposite direction, a load of 80A is taken. If the resistance per 100 m of single conductor is 0.03 Ω. Calculate current in each section of distributor & voltage at points B & C.

Sol^n



Resistance per 100 m of the distributor

$= 2 \times 0.03 = 0.06\ \Omega$

Resistance of section AB, $R_{AB} = \frac{0.06 \times 150}{100} = 0.09\ \Omega$

Resistance of section BC, $R_{BC} = \frac{0.06}{100} \times 50 = 0.03\ \Omega$

Resistance of section AC, $R_{AC} = \frac{0.06}{100} \times 100 = 0.06\ \Omega$

$V_{AB} + V_{BC} + V_{CA} = 0$

$\Rightarrow I_{AB} R_{AB} + I_{BC} R_{BC} + I_{CA} R_{CA} = 0$

$\Rightarrow I_a \times 0.09 + (I_a - 120)\, 0.03 + (I_a - 200)\, 0.06 = 0$

$\Rightarrow I_a (0.09 + 0.03 + 0.06) = 3.6 + 12$

$\Rightarrow I_a = \frac{15.6}{0.18} = 86.67$ A

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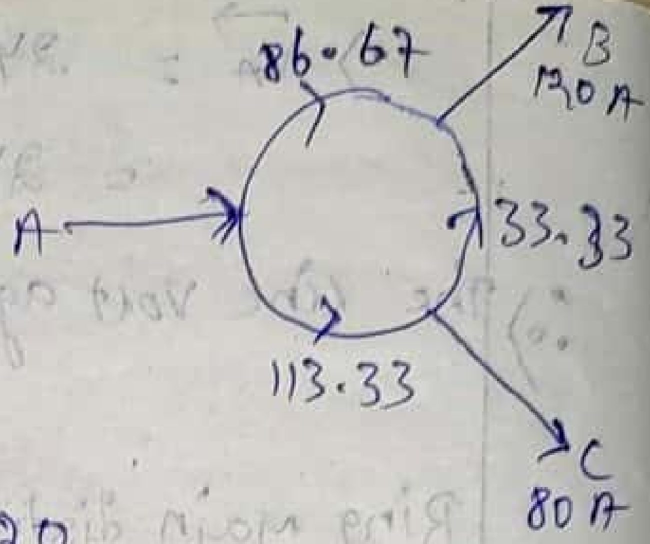
Current in section AB



$I_{AB} = I_A = 86.67\ A$

from A to B

Current in section BC,

$I_{BC} = I_A - 120 = 86.67 - 120$

$= -33.33\ A$ (from B to C)

$= 33.33\ A$ (from C to B)

Current in section AC, $I_{AC} = I_A - 200 = 86.67 - 200$

$= -113.33\ A$ (from C to A)

$= 113.33\ A$ (from A to C)

Voltage at point B, $V_B = V_A - V_{AB}$

$= 240 - 86.67 \times 0.09$

$= 232.19\ V$

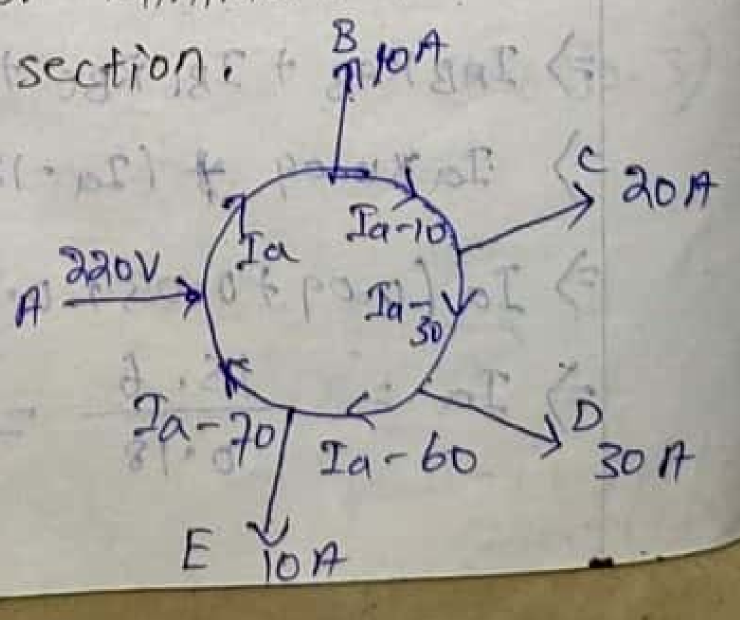
Voltage at poin C, $V_C = V_B + V_{BC}$

$= 232.19 + 33.33 \times 0.03$

$= 233.18\ V$

2) A 2-wire DC conditributor ABCDEA in the form a ringmain is fed at point A at 220V. & is loaded as 10A at B, 20A at C, 30A at D, 10A at E. The resistance of various sections are AB = 0.1 Ω, BC = 0.05 Ω, CD = 0.01 Ω, DE = 0.025 Ω, EA = 0.075 Ω. Calculate the point of minimum potential & current in each section.

Solⁿ



$I_{AB} = I_a\ A$

$I_{BC} = I_a - 10\ A$

$I_{CD} = I_a - 30\ A$

$I_{DE} = I_a - 60\ A$

$I_{EA} = I_a - 70$ A

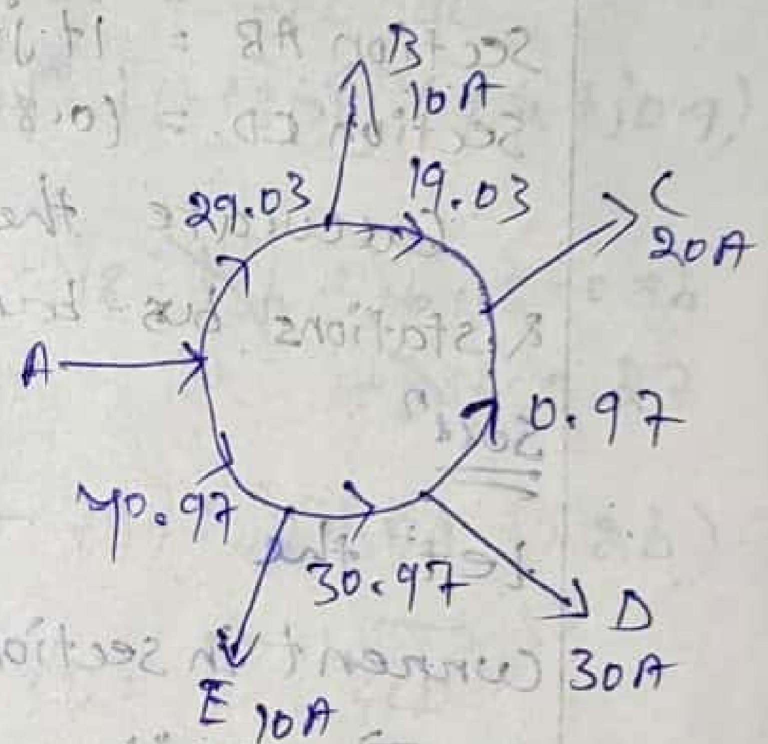
$V_{AB} + V_{BC} + V_{CD} + V_{DE} + V_{EA} = 0$

$\Rightarrow I_a \times 0.1 + (I_a - 10)\,0.05 + (I_a - 30)\,0.01 + (I_a - 60)\,0.025 + (I_a - 70)\,0.075 = 0$

$\Rightarrow I_a(0.1 + 0.05 + 0.01 + 0.025 + 0.075) - 0.5 - 0.3 - 1.5 - 5.25 = 0$

$\Rightarrow I_a(0.26) = 7.55$

$\Rightarrow I_a = 29.03$ A



Current in section

$I_{AB} = I_a = 29.03$ A (from A to B)

Current in section

$I_{BC} = I_a - 10 = 29.03 - 10$

$= 19.03$ A (from B to C)

Current in section CD

$I_{CD} = I_a - 30 = 29.03 - 30 = -0.97$ (from C to D)

$= 0.97$ (from D to C)

Current in section ED

$I_{ED} = I_a - 60 = 29.03 - 60 = -30.97$ (from D to E)

$= 30.97$ (from E to D)

Current in section AE

$I_{AE} = I_a - 70 = 29.03 - 70 = -40.97$ (from E to A)

$= 40.97$ (from A to E)

$\therefore$ Point C is the point of minimum potential.

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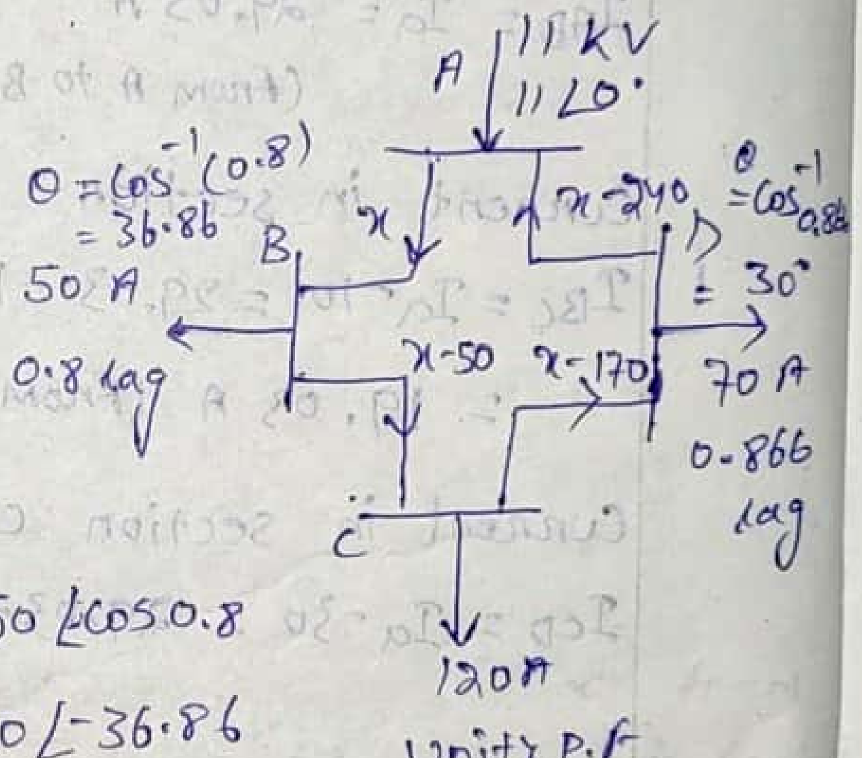
AC

1) A 3-phase Ringmain ABCD fed at A at 11kV supplies a balanced load of 50A at 0.8 p.f lagging at B, 120A at unity power factor at C & 70A at 0.866 lagging at D, the load currents having referred to the supply voltage at A, The impedances of the various are :
Section AB = 1+ j0.6 Ω ; Section BC = (1.2 + j0.9) Ω
Section CD = (0.8 + j0.5 Ω); Section DA = (3 + j2) Ω
Calculate the current in various sections & stations bus-bar voltages at B, C & D.

Soln



let the current in section AB, $\vec{x} = a + jb$

Current in section BC, $\vec{BC} = a + jb - 50\angle\cos 0.8$

$\Rightarrow \vec{BC} = a + jb - 50\angle -36.86$

$\Rightarrow \vec{BC} = a + jb - (40 - j30)$

$\Rightarrow \vec{BC} = (a - 40) + j(b + 30)$

Current in section CD, $\vec{CD} = [(a-40) + j(b+30)] - [120 + j0]$

$\Rightarrow \vec{CD} = (a-40) + j(b+30) - 120$

$\Rightarrow \vec{CD} = (a-160) + j(b+30)$

Current in section DA, $\vec{DA} = [(a-160) + j(b+30)] - 70\angle\cos 0.866$

$\Rightarrow \vec{DA} = (a-160) + j(b+30) - (60.62 - j35)$

$\Rightarrow \vec{DA} = (a - 160 - 60.62) + j(b + 30 + 35)$

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$\Rightarrow \overrightarrow{DA} = (a - 220.62) + j(b + 65)$

Voltage drop in section AB $= \overrightarrow{I_{AB}}\ \overrightarrow{Z_{AB}}$

$= (a + jb)(1 + j0.6)$

$= (a + j0.6a + jb + j^2 0.6b)$

$= (a + j0.6a + jb - 0.6b)$

Voltage drop in section BC $= \overrightarrow{I_{BC}}\ \overrightarrow{Z_{BC}}$

$= [(a - 40) + j(b + 30)](1.2 + j0.9)$

$= 1.2a + j0.9a - 48 - j36 + jb1.2 - 0.9b + j36 - 27$

$= (1.2a - 0.9b - 75) + j(0.9a + 1.2b)$

Voltage drop in section CD $= \overrightarrow{I_{CD}}\ \overrightarrow{Z_{CD}}$

$= [(a - 160) + j(b + 30)](0.8 + j0.5)$

$= 0.8a + j0.5a - 128 - j80 + j0.8b - 0.5b + 24j - 15$

$= (0.8a - 0.5b - 143) + j(0.5a + 0.8b - 56)$

Voltage drop in section DA $= \overrightarrow{I_{DA}}\ \overrightarrow{Z_{DA}}$

$= [(a - 220.62) + j(b + 65)](3 + j2)$

$= 3a + j2a - 661.86 - j441.24 + j3b - 2b + j195 - 130$

$\Rightarrow [3a - 2b - 791.8) + j(2a + 3b - 246.2)$

$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$

$[(a - 0.6b) + j(0.6a + b)] + [(1.2a - 0.9b - 75) + j(0.9a + 1.2b]$

$+[(0.8a - 0.5b - 143) + j(0.5a + 0.8b - 56)]$

$+[3a - 2b - 791.8) + j(2a + 3b - 246.2)] = 0$

$\Rightarrow (a - 0.6b + 1.2a - 48 - 0.9b - 27 + 0.8a - 128$
$- 0.5b - 15 + 3a - 661.86 - 2b - 130) +$
$j(0.6a + b + 0.9a - 36 + 1.2b + 36 + 0.5a - 80$
$+ 0.8b + 24 + 2a - 441.24 + 3b + 195) = 0$

$\Rightarrow (6a - 4b - 1009.86) + j(4a + 6b - 302.24) = 0 + j0$

$\Rightarrow 6a - 4b - 1009.86 = 0$ — (1)

$j(4a + 6b - 302.24) = j0$ — (2)

By solving eq^n (1) & (2) we get

$a = 139.7, \quad b = -42.8$

$I_{AB} = 139.7 + j(-42.8) = 139.7 - j42.8$

$I_{BC} = 99.7 - j12.8 \qquad I_{DA} = -80.92 + j22.2$

$I_{CD} = -20.3 - j12.8$

Voltage per Phase $= \frac{11 \times 10^3}{\sqrt{3}} = 6350.85$ V/ph.

Voltage at point B, $\vec{V_B} = \vec{V_A} - \vec{V_{AB}}$

$\Rightarrow \vec{V_B} = (6350.85 + j0) - (139.7 - j42.8)(1 + j0.6)$

$\Rightarrow \vec{V_B} = 6185.47 - j41.02$

$= 6185.6 \angle -0.37$ V/phase

Voltage at point C, $\vec{V_C} = \vec{V_B} - \vec{V_{BC}}$

$\Rightarrow \vec{V_C} = (6185.47 - j41.02) - (99.7 - j12.8)(1.2 + j0.9)$

$\Rightarrow \vec{V_C} = 6054.31 - j115.39 = 6055.4 \angle -1.09$ V/ph

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voltage at point D, $\vec{V_D} = \vec{V_C} - \vec{V_{CD}}$

$\Rightarrow \vec{V_D} = (6054.31 - j115.39) - (-20.3 - j12.8)(0.8 + j0.5)$

$\Rightarrow \vec{V_D} = 6064.15 - j95$

$= 6064.89 \angle -0.8$ V/phase

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Chapter - 5

EHV TRANSMISSION

The basic function of a transmission line systems is to transfer electrical power from one place to another place on one network to another network. The present trend is to use transmission voltage from high voltages (up to 300 kV)

Generally the voltages of 300 kV to 765 kV are considered as extra high voltage (EHV) transmission line. The voltages above 765 kV is considered as ultra high voltage (UHV) transmission line. Generally EHV AC lines are selected for long distances 250 km & above & high power 500 MW & above.

* Reasons for Adoption of EHV AC transmission or Necessity of EHV transmission :-

i) Line losses are reduced since line losses are inversely proportional to the trans-mission voltage.

ii) Transmission efficiency increases because of line losses are reduced.

iii) Voltage regulation is improved because of reduction of percentage of line drop.

iv) Lessen conductor material is required because conductor material inversely proportional to the squre of transsmission voltage.

i.e conductor material $\alpha \frac{1}{V^2}$

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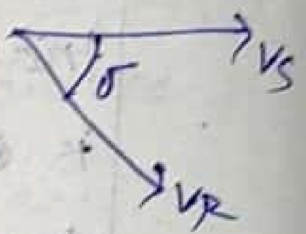
v) Transmission of bulk power from generating stations to the load centres is technically & economically feasible only at voltages in the EHV/UHV range.
(Economical & feasible)

vi) Flexibility for future system growth.

vii) Increase in transmission capacity of the line. The power transferred is expressed as

$$P = \frac{V_S \cdot V_R}{X} \cdot \sin\delta$$



where,
V_S & V_R two terminal voltages
δ is the load angle
X is the line reactance.

viii) Increase of surge impedance loading (SIL)
Load carrying capability of a line is expressed in terms of SIL.
The surge impedance $Z_S = \sqrt{\frac{L}{C}}$
where, L & C are respectively the series inductance & shunt capacitance per unit length.
The surge impedance loading $= \frac{V^2}{Z_S}$ or $\frac{3V_1^2}{Z_S}$
where, V = line voltage
V_1 = line to neutral voltage

ix) Reduction in right of way (ROW).

* Problems associated with EHV transmission:-

i) Corona & radio interference:-
As we know that corona is not only a source of power loss but it is also a

Source of interference with Radio & television. The Corona Loss is depends on various factors such as air density, air conductivity, size of the conductor, line voltage, atmospheric conditions etc.

When the electric field at the surface of an energized conductor exceeds 2-3 kV/mm, audible & some times visible corona discharge takes place, causing a loss of power & radiation of electrical noise.

For limiting the corona loss, radio interference it is necessary to limit electric stress at the surface of the conductor to 1.8 kV/mm preferably to 1.5 kV/mm.

Corona loss varies through the year depending upon weather conditions. The corona loss under bad weather conditions may be as high as 100 times of the fair wather condition loss.

Corona loss can be reduced ~~by~~ either by increasing the space between conductors or the diameters of conductor. Large diameter conductors (ACSR conductors) has been used to bring down corona loss & radio ~~interence~~ interference but the cost of manufacture of such conductors is high & their handling is both difficult & expensive.

2) Heavy supporting structure & Erection difficulties

EHV- AC transmission lines have large

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Mechanical loading on towers because of use of bundled conductors. Similarly large air & ground clearances Considerable dynamic forces due to broken conductors etc. Hence strength of towers should be heavy.

~~the transm~~ the

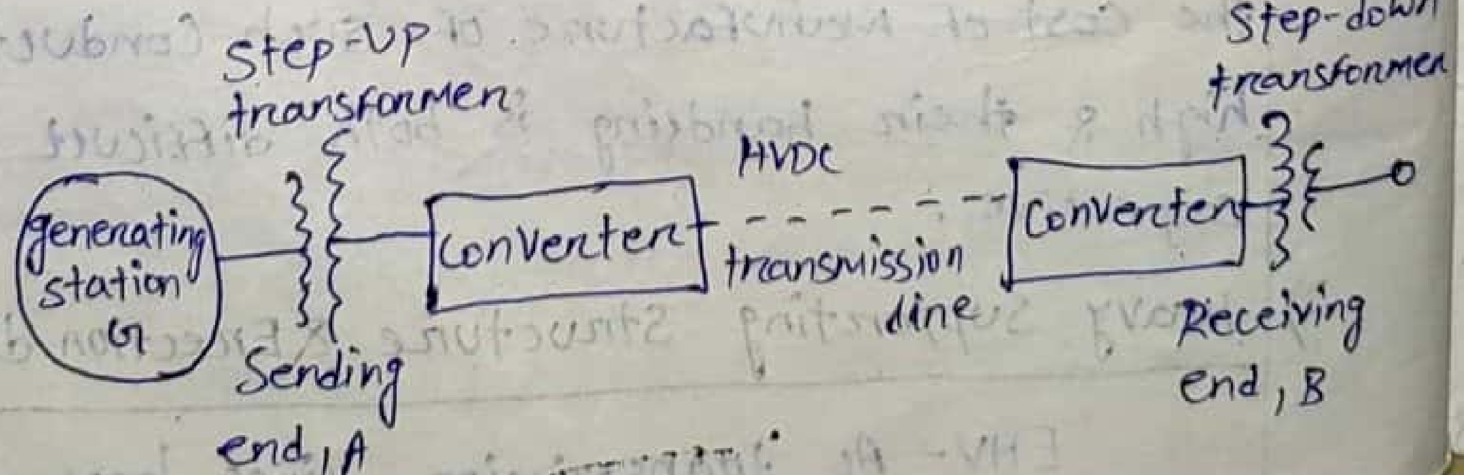
Problems of transportation & erection arise as the ~~po~~ suporting structures are to be tranported over long distances & high standard workshanship is required for erection of EHV transmission lines.

3) Insulation Requirements :-

Generally EHV-AC transmission requires high insulation to withstand the Voltage surges due to internal sources i.e switching operation or due to external sources i.e lighting etc. which produces very high Voltage generally 2-3 times of normal Voltage. Hence insulation level depends upon switching over-voltages, temporary over voltages & atmospheric over voltages.

* HVDC transmission :-

Line diagram of HVDC transmission system



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~~when using direct~~ In HVDC transmission system it is necessary to have two convertors stations one at each end of the transmission line. The main equipments in a convertor station are transformers & thyristors valves. At the sending end the thyristor valves act as rectifiers to convert ac into dc which is transmitted over the line. At the receiving end the thyristor valves act as inverters to convert dc into ac which is utilized at the receiving ~~sta~~ end.

In the above figure, A & B are the two converter stations. Converter station A is supplied from the generating station G. ~~In conver~~ The sending end voltage is step-up by the transformer & then converted into direct current by the thyristor valves. This rectified direct current flows through the transmission line to the receiving end where it converted into 3-phase ac current by the thyristor valves & then stopped down by the step-down transformer.

The power dispatched from the generating station Ps less the power received at the receiving end Rs i.e (Ps - PR) represents the power losses due to conversion & transmission.

The converter at the sending end acts as a rectifier & is suitable for power frequency (i.e frequency of generator). While the converter at the receiving end acts as an inverter & its frequency is determined by the frequency of the load system.

* AC & DC interconnection :-

The points to be considered while selecting the type of interconnection are :

i) Economy of power transmission

ii) Techanical ability iii) Reliability

(i) Economy of power transmission :-

This depends on the total cost involved for the system.

Total cost = investment cost + operational cost

-> The investment cost includes cost of conductors, transmission towers, insulators, ROW & terminal equipment cost. So, the investment cost of DC is greater than AC..

-> As the maximum voltage of a conductor being subjected to AC is $\sqrt{2}$ times more than DC so the insulation cost of DC is less than AC.

$\left(V_{rms} = \frac{V_M}{\sqrt{2}} \Rightarrow V_M = \sqrt{2}\, V_{rms} \right)$

-> Since the number of conductors required in dc is less than that of in ac so, the cost of conductors is also less in dc system.

-> The tower structures are simpler in dc as compared to AC, the cost of ROW is also less in DC as compared to AC.

-> The transmission loss (I^2R) is also less in dc as compared to AC.

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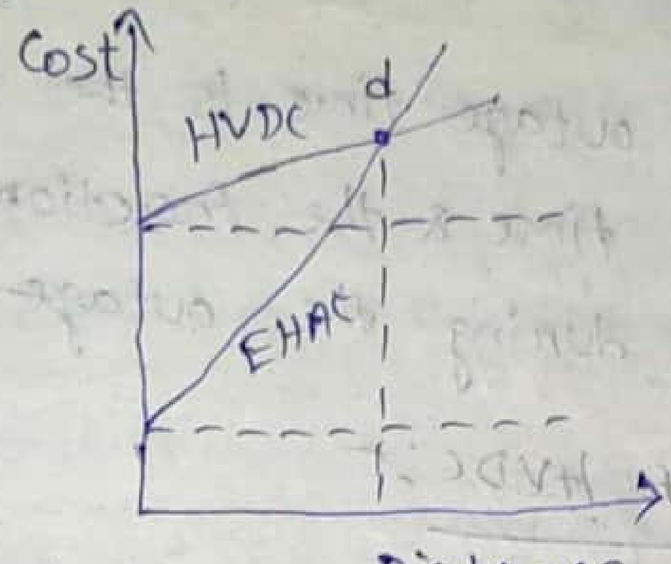
→ Hence the transmission cost in DC in less than AC.

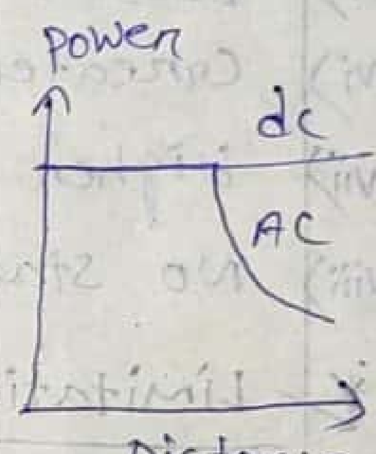


where,

d = break even ~~volta~~ distance

d varies 500 to 800 km for overhead lines & around 50 km for Underground & sub - c transmission.

* Techanical ability :-



→ DC power constant throught the t/x line since no capacitive & inductive effect. but in AC power ~~power~~ is constant that small distance but in long distance it varies because capatitance & inductance takes place.

→ Power transmission depends on the angle between sending end voltage & receiving end voltage. which further depends on distance.

→ But in DC transmission the power transfer depends on the current carrying capacity of the conductor & independent of distance.

* Reliability :-

The reliability of a system is expressed in terms of energy availability.

Energy availability = $\left(1 - \frac{\text{equivalent outage time}}{\text{total time}}\right) \times 100$

where,

equivalent outage time is the product of actual outage time & the fraction of system capacity loss during the outage.

* Advantages of HVDC :-

i) Economical for long transmission line
ii) No skin effect
iii) Lower transmission loss
iv) improve voltage regulation
v) Lessen corona loss
vi) Greater reliability.
vii) Higher surge impedance loading (SIL),
viii) No stability limit
ix) No reactive power loss
x) Fast fault clearing time
xi) Lo short circuit current.

* Limitations of HVDC :-

i) Costly terminal ~~voltages~~ equipment :- The converters are used in HVDC are very costly along with the converters produces lot of harmonics on both AC & DC sides, which requires filtering & smoothing equipment resulting extra additional cost. It also require complex cooling system & circuit breaker, which again adds cost.

ii) More maintenance of line insulators.

iii) Circuit breaking in multi terminal dc system is difficult & costlier.

iv) Voltage transformation :- Voltage transformation is not easier in case of dc & hence it has to be accomplished on the ac side of the system. DC system can not be employed for distribution, sub-transmission.

* Comparison between EHV-AC & HVDC transmission

SNo.	Characteristics	EHV-AC system	HVDC system
1.	Capital cost		
	Line cost	Higher	Lower
	Substation cost	Lower	higher
	Number of circuits	More	one
	Intermediate substations	required	Not required
2.	Skin effect	Present	absent
3.	Ground return	Not possible	possible
4.	Line losses	High	Low
5.	Corona & Radio interference	More	Less
6.	Reliability	Lesser	more
7.	Short-circuit currents	Large	Small
8.	Control system	Simpler, cheaper & limitations of control	Difficult, costlier but fast & accurate control
9.	Voltage control	Difficult for long lines	Easier

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Tariff chapter -

* **Tariff :-** The rate at which the electrical energy is supplied to a consumer is known as tariff.

* **objectives of tariff :-**

i) Recovery of cost of producing electrical energy at ~~generatin~~ power station.

ii) Recovery of cost of capital investment in transmission & distribution system.

iii) Recovery of cost of operation & maintenance of supply of electrical energy.

iv) A suitable profit on the investment.

* **characteristics of tariff :-**

i) **proper return :-** ~~The tot~~ It means the total receipts from the consumers must be equal to the cost of producing & supplying electrical energy plus reasonable profit.

ii) **Fairness :-** The tariff must be fair so that different types of consumers are ~~sta~~ satisfied with the rate of charge of electrical energy.

iii) **Simplicity :-** The tariff should be so simple so that an ordinary consumer can easily understand it.

iv) **Reasonable profit :-** The profit element of the tariff should be resonable.

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v) Attractive :- The tariff should be attractive so that a large number of consumers are encourged to use electrical energy.

* Types of tariff :-

1) Simple tariff :- When there is a fixed rate per unit of energy consumed, it is called a simple tariff or uniform rate tariff.

In this type of tariff, the price charged per unit is constant i.e, it does not vary with increase & decrease in number of units consumed. It is the simplest of all tariffs & is readily understood by the consumers.

2) Flat rate tariff :- When different types of consumers are charged at different uniform per unit rates, is called a flat rate tariff.

In this type of tariff, The consumers are grouped into different classes & each class of consumers is charged at a different uniform rate.

3) Block rate tariff :- When a given block of energy is charged at a specified & the succeeding blocks of energy are charged at progressively reduced rates, is called a block rate tariff.

In block rate tariff, the energy consumption is divided into blocks & the price per unit is fixed in each block. For example, the first

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30 units may be charged at the rate of 60 paise per unit; the next 25 units may be charged at the rate 55 paise per units & the remaining additional units may be charged at the rate of 30 paise per unit.

4) Two-part tariff :- When the rate of electrical energy is charge on the basis of maximum demand of the consumers & the units consumed, it is called a two-part tariff.

In two-part tariff, the total charge to be made from the consumers is spilt into two components such as fixed charges & running charges. The fixed charges depend upon the ~~number of units consumed by the~~ maximum demand of the consumers while the running ~~cost~~ charges depends upon the number of units consumed by the consumer.

Total charge = Rs (P × kW + Q × kWh)

P = Cost of maximum demand per kW

Q = Cost of energy consumed per kWh

5) Three-part tariff :- When the total charge to be made from the consumer is split into three parts such as fixed charge, semi-fixed charge & running charge, it is known as a three-part tariff.

Total charge = Rs (a + b × kW + c × kWh)

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Where,

a = Fixed charge made during each billing period.

b = ~~charge per~~ Cost of max^m demand per kW

c = Cost of energy consumed per kWh

Q1) A Consumer has a maximum demand of 200 kW at 40% load factor. If the ~~tar~~ tariff is Rs. 100 per kW of maximum demand plus 10 paise per kWh. Find the overall cost per kWh.

Soln

$$\text{Load factor} = \frac{\text{Total energy consumed}}{\text{Maximum demand}}$$

Total unit consumed/year = Maxi. demand × load factor × hour in a year

$= 200 \times 0.4 \times 365 \times 24$

$= 700800$ kWh

Total annual charge = Annual M.D charges + Annual energy charges

$= \text{Rs}(100 \times 200 + 0.1 \times 700800)$

$= \text{Rs. } 90080$

$\therefore$ overall cost per kWh $= \frac{90080}{700800} = \text{Rs } 0.128$

$= 12.8$ paise

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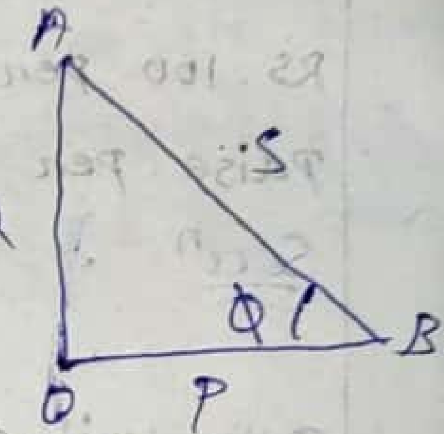
Chapter -

Power factor improvement

Power factor :- The Cosine angle between voltage & current in an a.c circuit is known as power factor.

Power triangle :



$P = VI\cos\phi$ & represents the active power in watt or kW

$Q = VI\sin\phi$ & represents the reactive power in VAR or kVAR

$S = VI$ & represents apparent power in VA or kVA

→ in Δ AOB $S^2 = Q^2 + P^2$

⇒ $(\text{apparent power})^2 = (\text{reactive power})^2 + (\text{Active power})^2$

→ power factor $\cos\phi = \frac{P}{S}$

⇒ $\cos\phi = \frac{\text{Active power}}{\text{apparent power}}$

⇒ apparent power $= \frac{\text{Active power}}{\cos\phi}$

* **Disadvantages of low power factor :-**

$P = V_L I_L \cos\phi$

$I_L = \frac{P}{V_L \cos\phi}$

$I_L \propto \frac{1}{\cos\phi}$

for single phase supply

$P = \sqrt{3} V_L I_L \cos\phi$

$I_L = \frac{P}{\sqrt{3} V_L \cos\phi}$

$I_L \propto \frac{1}{\cos\phi}$

for three phase supply

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i) Large kVA rating of equipment :-

As, Apparent power = $\frac{\text{Active power}}{\cos\phi}$

$\Rightarrow \quad kVA = \frac{kW}{\cos\phi}$

It is clear that kVA rating is inversely proportional to power factor. The smaller the power factor, the larger in the kVA rating. Therefore, at low power factor, the kVA rating of the equipment has to be made more, making the equipment larger & expensive.

ii) Greater Conductor Size :- To transmit or distribute fixed amount of power at constant voltage, the conductor will have carry more current at low power factor. This necessitates large conductor size. ($\because I \propto \frac{1}{\cos\phi}$)

iii) Large copper loss :- The large current at low power factor causes more I^2R losses in the supply system.

iv) Poor voltage regulation :- The large current at low power factor causes more I^2R losses hence voltage regulation is decreased.

v) Reducing handling capacity of the system :- The lagging power factor reduces the handling capacity of all the elements of the system.

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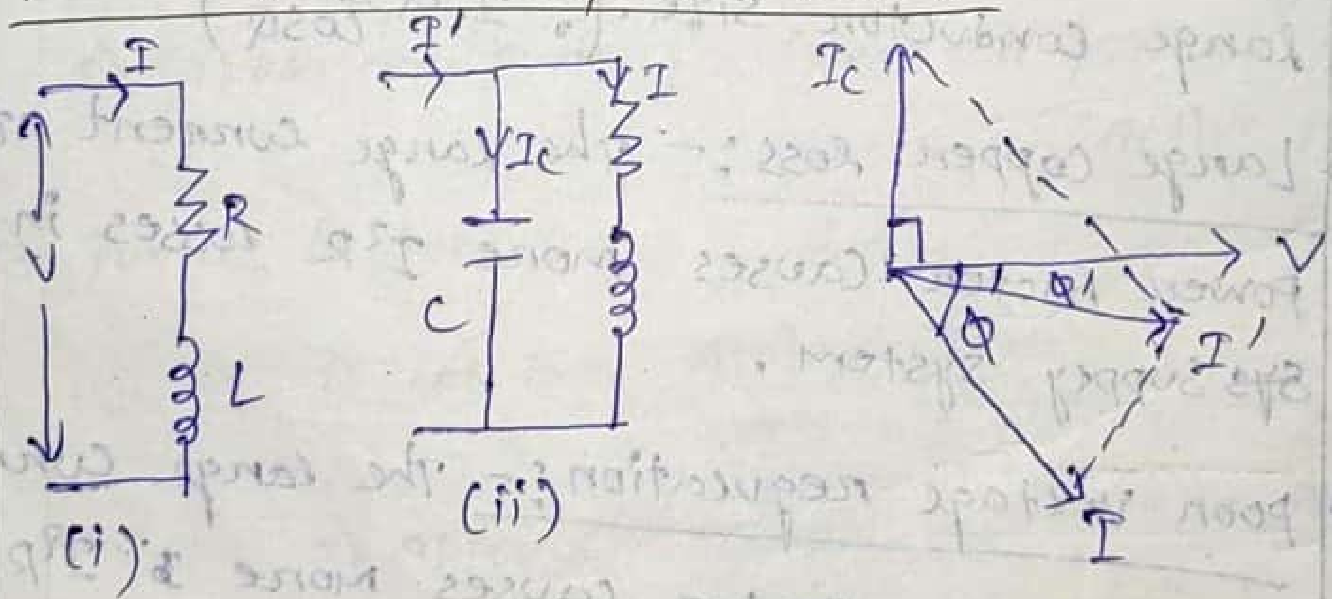
* Causes of Low power Factor :-

i) Arc lamps, electric discharge lamps & industrial heating furnace operate at low lagging power factor.

ii) Most of a.c motors are of induction type (1ϕ & 3ϕ induction motors) which have low lagging power factor.

iii) The load on the power system is varying; being high during moring & evening & low at night. During low load period, supply voltage is increased which increases the magnetisation current. This causes the decreased power factor.

* Power factor improvement :-



~~For power~~ In order to improve power factor, some device taking leading power should be ~~on~~ connected in parallel with the load.

The best of such a ~~cap~~ device is a capacitor. The capacitor draws a leading current & partly or completely neutralises the lagging reactive component of load current hence improves the power factor.

Explanation :-

→ Before powerfactor correction I is the lagging current drawn by the load & $\cos\phi$ is its powerfactor.

→ For improvement of power factor a capacitor is connected in parallel with the load & the capacitor ~~current~~ draws a current I_c which leads the voltage by an angle 90°.

→ So, the resulting line current I' is the phasor sum of I & I_c ($I' = I + I_c$) & the power factor is $\cos\phi'$.

→ From the phasor diagram, it is clear that ϕ_2 is less than ϕ so that $\cos\phi'$ is greater than $\cos\phi$. Hence the power factor is improved.

The following points are noting :-

i) The circuit current I' after p.f correction is less than the original circuit current I.

ii) The active component of current

$$I'\cos\phi' = I\cos\phi$$

iii) The reactive component of current

$$I'\sin\phi' = I\sin\phi - I_c$$

As $I\cos\phi = I'\cos\phi'$

$VI\cos\phi = VI'\cos\phi'$ (multiplying by V)

Therefore, Active power remains unchanged due to powerfactor improvement.

As $I'\sin\phi' = I\sin\phi - I_c$

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$VI' \sin\phi' = VI \sin\phi - VI_c$ (multiplying by V)

i.e

Net VAR after p.f correction	=	Net VAR before p.f correction	−	VAR of the capacitor

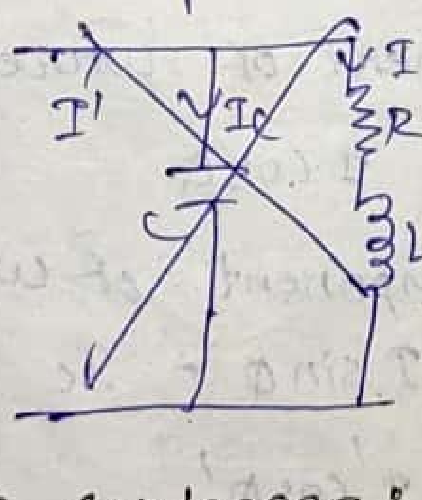
* Powerfactor improvement equipments :-

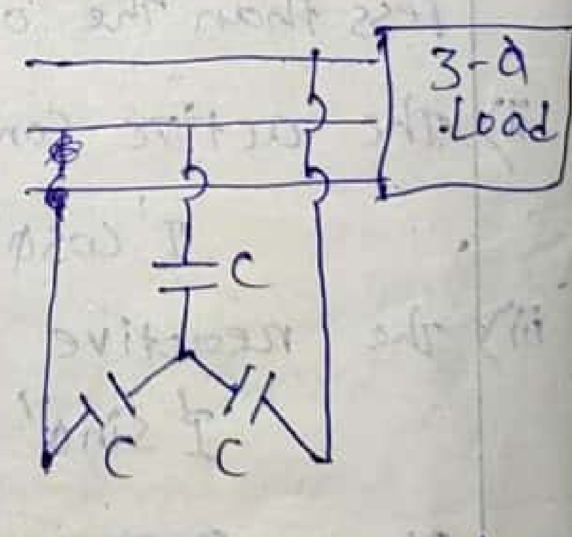
This can be achieved by the following equipment

1) Static capacitor
2) Synchronous Condenser
3) Phase advancers

1) Static capacitor :- The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor draws a leading current & partly or completely neutralises the lagging reactive component of load current. This raises the power factor of the load.

Advantages :- i) They have low losses.
ii) They require little maintenance as there are no rotating parts.





2) Synchronous condenser :- A synchronous motor takes a leading current when over-excited & therefore act as a capacitor. An over-excited synchronous motor running on no-load is known as synchronous condenser.

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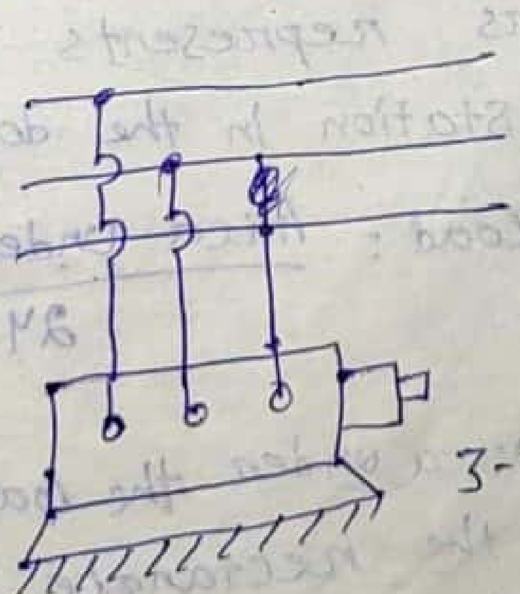
It may be connected in parallel with the supply & it takes a leading current which partly neutralises the lagging reactive component of the load. Thus PF is improved.

Advantages :- i) The faults can be removed easily.
ii) The motor windindings have high thermal stability to short circuit currents.

Dis :- i) It produces noise.
ii) The maintenance cost is high.

3) phase advanser :- These are used to improve the PF of induction motors. The low pf of an induction motor is due to fact that the stator winding draws exciting current which lags behiend the suppty voltage by an angle 90°.

If the exciting ampere turns can be ~~impro~~ provided from some other ac source than the stator winding will be relived of exciting current & the p.f of the motor can be improved. This job is performed by phase advancer which is simply an ac exciter.



3-ф synchronous condenser

* **Load Curve:-**

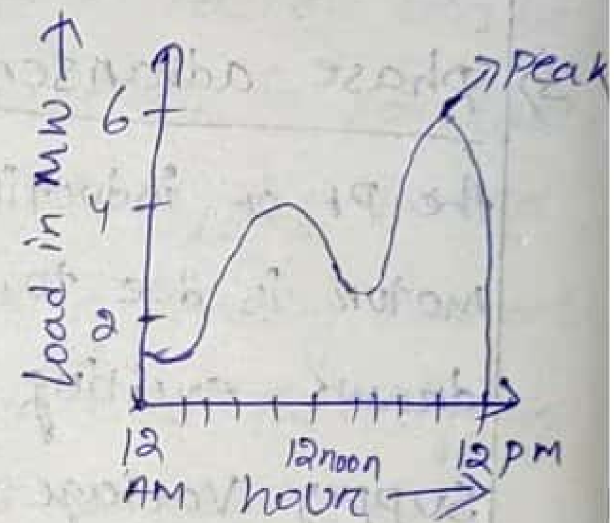
→ The curve showing the variation of load on the power station with respect to time is ~~take~~ known as load curve.

or

The curve plotted by taking load demand on ~~the~~ y-axis & time on x-axis is called as load curve.

→ The load curve supplies following information about the system:

i) The Cure shows the variations of load on the power station during different hours of a day.



ii) The area under the curve represents the total number of units generated in the day.

iii) The peak point on the load curve represents the maximum demand on the station on that day.

iv) The area under the load curve divided by the no of hours represents average load on the power station in the day.

Average load = $\frac{\text{Area under daily load curve}}{\text{24 hours}}$

v) The ratio of area under the load curve to the total area of the rectangle in which it contain, gives the load factor.

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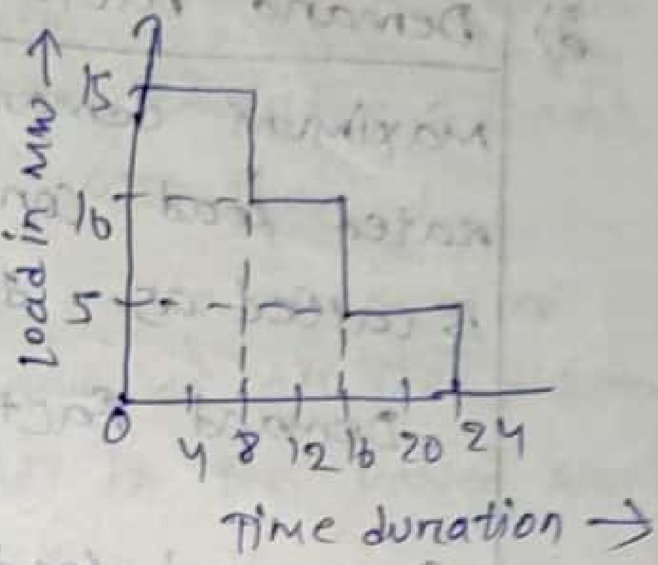
Load Factor = $\frac{\text{Average Load}}{\text{Maximum demand}} = \frac{\text{Average load} \times 24}{\text{Max. Demand} \times 24}$

* Load duration Curve :-

→ Load duration curve indicates the variation of load that are arranged in descending order of magnetude of time.



→ This curve gives the no of hours for which a particular load during the day.

* Types of Load curve :-

i) Daily Load curve :- Daily load variation in load from time to time is plotted on a graph taking load on y-axis or time on x-axis.

ii) Weekely Load Curve :- In this curve seven days of week on x-axis & load on y-axis.

iii) Monthey load curve :- The curve in which weeks of a month is taken on x-axis & load on y-axis.

iv) Yearly load curve :- The curve in which months are taken in x-axis & average load of a month are taken on y-axis.

* Important terms & factors :-

i) Maximum Demand :- The greatest demand of load on the power station during a given period is know as maximum demand.

→ The size & installed capacity of a power station is determined by the maximum demand.

2) Demand factor :- The ratio of actual maximum demand on the Station to the total rated load connected to the system /station is called as demand factor.

$$\text{Demand factor} = \frac{\text{Maxm. Demand}}{\text{Connected Load}}$$

(Connected load is the sum of all the continuous rating of Electrical equipments connected to the system)

→ Demand factor is always less than 1.

3) Average Load :- The average of loads occuring on the power station in a given period (day or moth or year) is known as Average Load.

→ It is also defined as the energy delivered in a ~~day~~ given period divided by the no of hours in that period.

$$\text{Daily avenge load} = \frac{\text{kwh suppiled in a day}}{24 \text{ hours}}$$

$$\text{Monthly avenge load} = \frac{\text{kwh sppiled in a month}}{24 \times 30}$$

$$\text{yearly average load} = \frac{\text{kwh suppiled in a year}}{24 \times 365}$$

4) Load factor :- The ratio of avg load to the maximum demand during a certain period of time is ~~know~~ Called as load factor.

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Load factor (L.F) = $\frac{\text{Avg. load}}{\text{Max. demand}}$

Load factor (L.F) = $\frac{\text{Unit generated in T hours}}{\text{Max. demand} \times T \text{ hours}}$

→ Load factor is always less than 1.

5) Diversity factor :- The ratio of sum of indivisual maximum demand of all the consumers to the maximum demand on the power station is called diversity factor.

$$D.F = \frac{\text{Sum of indivisual max demands}}{\text{Maxm. demand on power station}}$$

→ The value of diversity factor is always less than 1.

6) Plant capacity factor :- It is the ratio of actual energy produced to the maximum possible energy that could have been produced during the given period.

$$P.C.F = \frac{\text{Actual enenergy produced}}{\text{Max. energy that could have produced}}$$

$$= \frac{\text{Average demand} \times \text{Time}}{\text{Plant capacity} \times \text{Time}}$$

$$= \frac{\text{Average demand}}{\text{Plant capacity}} = \frac{\text{L.F} \times \text{Max. demand}}{\text{Plant capacity}}$$

7) Plant use factor :- It is the ratio of kwh generated to the product of plant capacity & the number of hours for which the plant was in operation i.e

$$\text{Plant use factor} = \frac{\text{Station output in kwh}}{\text{Plant capacity} \times \text{hours of use}}$$

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* Base Load & peak load on the power Station :-

Base Load :- The unvarying load which occurs almost the whole day (for a given time period) on the power station is known as base load.

Peak Load :- The various peak demand of load over & above the base load of the station is known as peak load.

* Need of Interconnected grid system :-

The connection of multiple generating stations in parallel is known as interconnecte grid system.

* Advantages of interconnected grid system :-

i) Exchange of peak load
ii) Use of older plants
iii) Ensure economical operation
iv) increase diversity factor.
v) Reduces plant reserve capacity.
vi) Increase Reliability.

Q1) A generating system has a connecting load of 43 MW & the max^{M} demand is 20 MW. The total units generated is 61.5×10^{6} /annum. Calculate demand factor & load factor?

Soln

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

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

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$$\text{Average demand} = \frac{\text{Unit generated/annum}}{\text{Hours in a year}}$$

$$= \frac{61.5 \times 10^6}{365 \times 24} = 7020.5\ kw$$

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

$$= \frac{7020.5\ kw}{20\ MW} = \frac{7020.5\ kw}{20 \times 10^6 \times 10^{-3}\ kw}$$

$$= 0.35$$

2) A diesel station supplies the following loads to various consumers:

Industrial Consumer = 1500 kw; Domestic power = 100 kw

Commercial consumer = 750 kw; Domestic load = 450 kw

If the maximum demand on the station is 2500 kw & the number of kwh generated per year is 45×10^5. Determine diversity factor annual load factor.

Soln

$$\text{Diversity factor} = \frac{1500 + 100 + 750 + 450}{2500} = 1.12\ kw$$

$$\text{Average demand} = \frac{\text{kwh generated/annum}}{\text{Hours in a year}}$$

$$= \frac{45 \times 10^5}{365 \times 24} = 513.7\ kw$$

$$\text{Load factor} = \frac{\text{Average demand}}{\text{Max. demand}}$$

$$= \frac{513.7}{2500} = 0.205 \doteq 20.5\%$$

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