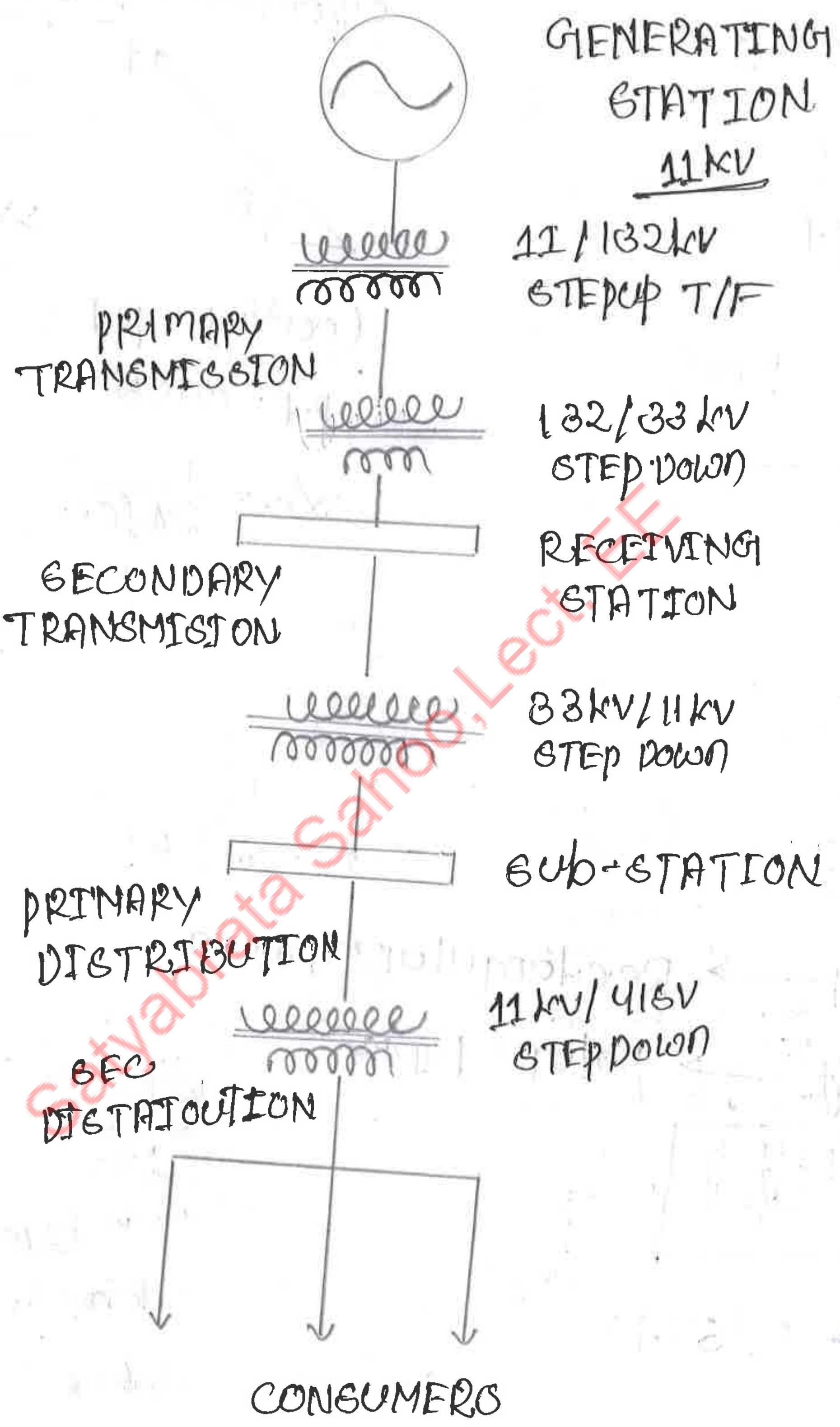

GENERATING STATION
11kV
11/132kV STEPUP T/F
PRIMARY TRANSMISSION
132/33kV STEP DOWN
RECEIVING STATION
SECONDARY TRANSMISSION
33kV/11kV STEP DOWN
SUB-STATION
PRIMARY DISTRIBUTION
11kV/415V STEP DOWN
SEC DISTRIBUTION
CONSUMERS

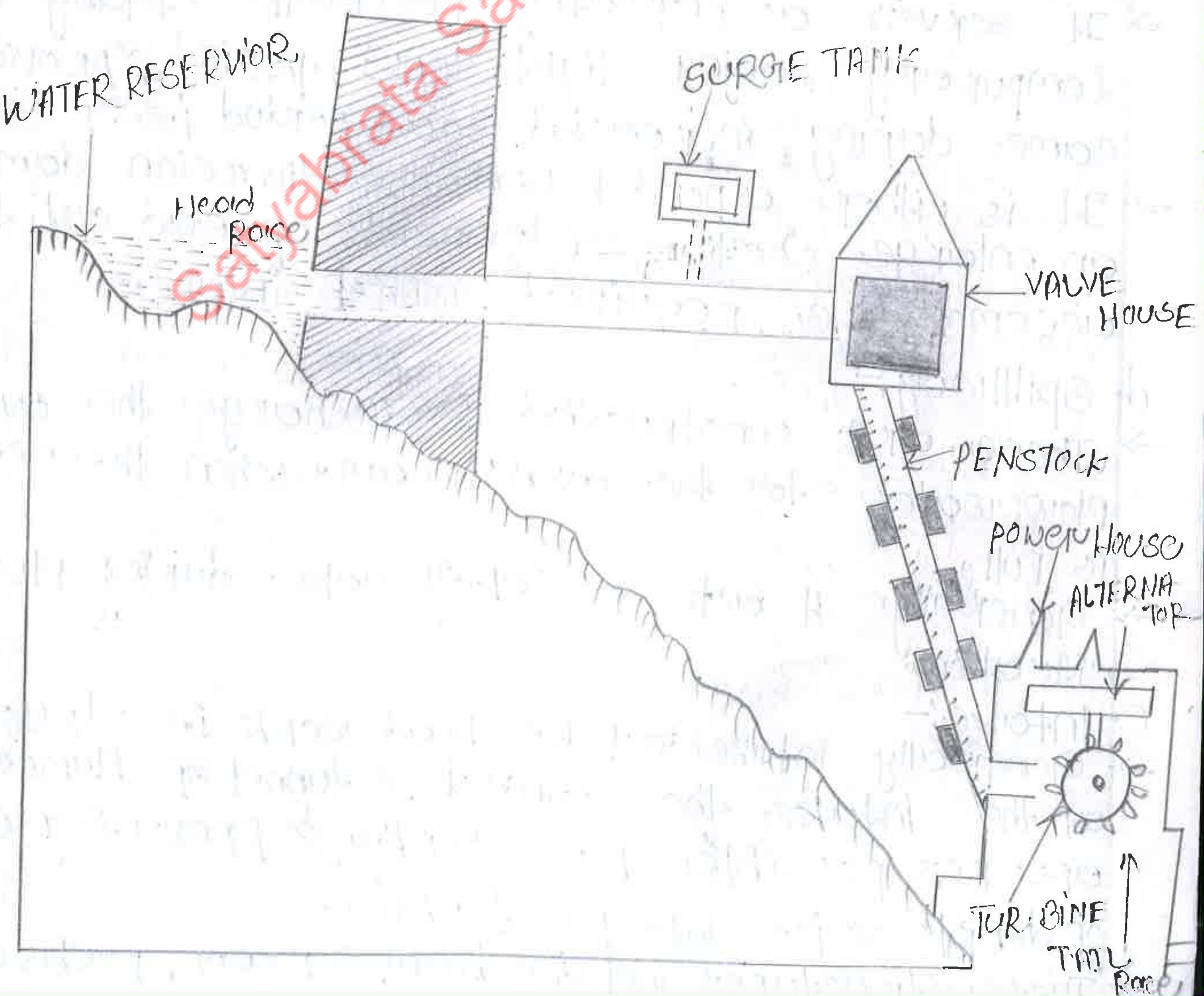
CHAPTER-1 GENERATION OF ELECTRICITY. Date-25.03.2

HYDRO ELECTRIC POWER PLANT –

Hydro Electric power – The power obtained from Energy of falling water is known as hydro Electric power.

HYDRO ELECTRIC POWER PLANT:-

→ The power plant which generates Electrical Energy by utilizing the potential energy ~~stored stored in water~~ is of water at high level called hydro electric power plant i.e. the potential energy stored in water is converted to kinetic energy again that kinetic energy is converted to mechanical energy by allowing water through hydrolic turbine runner & finally mechanical energy is used to run generators or alternator.



ELEMENTS OF HYDRO ELECTRIC POWER PLANT-

a. Storage reservoir-

→ It stores water during excess flow periods (Rai seasons) & supplied the same during least flow periods i.e (dry seasons)

→ It can be either natural i.e lake or artificial by construction dam across the river.

b. Dam:-

→ It is the most expensive & important part which built up concrete or stone masonry earth or rock fill.

→ It is not only raise the water surface b creating artificial head but provide pondo or storage.

c. Fore bay:-

→ It serves as regulating reservoir storing w temporary during light load period & provid same during increased load period i.e.

→ It is either a pond behind the diversion dam on enlarge section of cancal spread out to accommodate required with of intake.

d. Spillway:-

→ These are constructed to discharge the ove flow water to the downstream. when the res is full.

→ Generally it acts as safety valve during floo situation.

e. Intake:-

→ Generally intake includes head work i.e struct at the intake the conduits & tunnel or flumes are res possible for diverting & preventing e of debris & ice into the turbine.

... structures includes boom, scream, rocks o

SURGE TANK:-

→ Surge tank regulates & maintains required pressure in the penstock.

→ Because during light load pressure in the penstock becomes more even if which can burst the penstock b surge tank reduces the pressure by raising water level inside it.

→ Similarly during the low pressure additional wate flows provided by it. So search tank stabilize the velocity & pressure in the penstock.

VALVE & GATES-

→ Generally these are fitted at Entrance to the turb during in section & repairing these are shut off.

TAIL RACE-

→ The water from turbine is discharged to the tail ra generally tail race may be same stream or anoth one but design & size of tail race should be search t water are free exist.

PRIME MOVERS / WATER TURBINES-

→ In hydro power plant water turbinines are used as prime movers which convert kinetic energy of wa into mechanical energy which is further utilized to drive the alternators generating electric al energy

SELECTION OF SIDE FOR HYDROELECTRIC POWER PLA

→ These are some factors which are taken in to consideration for the selection of site for hydro electric power plant i.e.

1. Availability of water-

→ Hydro electric power plant should be built wher there adequate water available at goop head or huge quantity of water is flowing across a given point.

WATER STORAGE:-

→ For continuous supply of water. The water store in suitable reservoir at height or building of across the river is essential so convient accomm dation for the erection of a dam per reservoi must be avaible.

WATER HEAD-

→ It has a considerable effect on the cost & econ of power generation i.e an increasing effecti head reduces the quantity of storage water handle by pen stock screen & turbine result reduction in cost.

DISTANCE FROM LOAD CENTRE:-

→ Generally these plant locate far away from center so ~~rotor~~ roads & distances affects economical transmission.

ACCESSIBILITY OF SIZE:-

→ It requires adequate transportation facil for easy transportation required equipment & mechine.

→ AVAILABILITY OF LAND-

→ The land available must be cheap & rocky with stand large building & machinery.

merits-

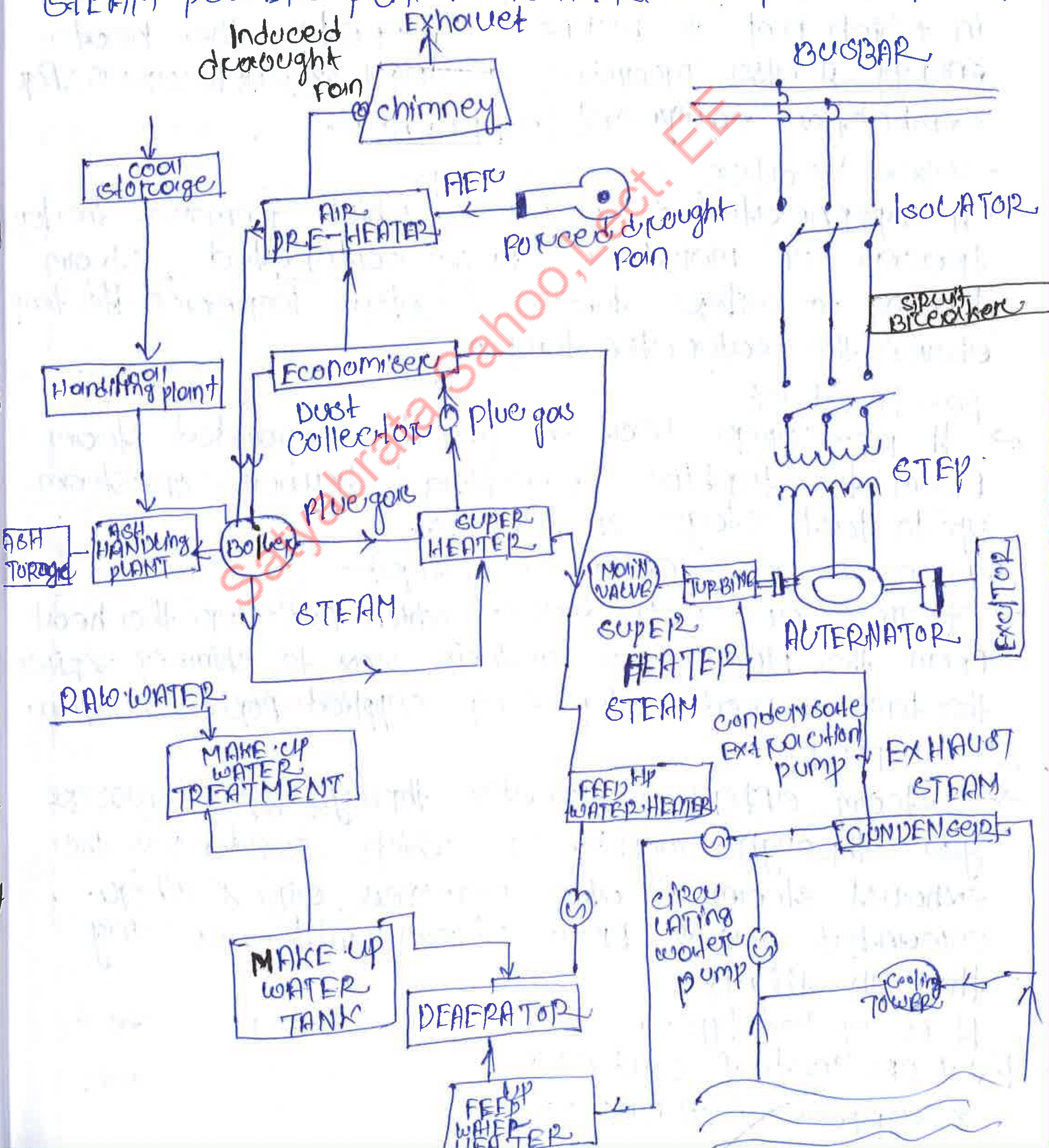
1. No fuel is required by such plant because wat is the source of energy.
2. It is highly reliable & cheapest & operation & main nance.
3. No stand by loss & variable load demand can easily.
4. Good longer life & robust.
5. Efficiency does not fall with age & It has neat clean environment due to absence of smoke

6. In addition to generation of provides irrigation flood control on navigation.

Demerits:-

1. It covers large area.
2. constructional cost is very high along with it require long transmission line as it far away from load centre.
3. Its o/p in uncertain.

STEAM POWER PLANT OR THERMAL POWER PLANT



ELEMENTS OF THERMAL POWER PLANT-

1. STEAM GENERATING EQUIPMENT-

a. Boiler- It is a major part of thermal powerpl
which convert water into steam.
→ It is of two types fire tube boiler & water tube bo
in fire tube boiler the tubes containing hot gasse
of combustion surrounded with water while in w
tubes water inside the tube while hot gases out

b. Boiler furnace- Boiler furnace is a chambe
in which fuel is burnt to liberate the heat
energy it also provides support & enclosures f
combustion equipment i.e burner.

c. super heater & re-heater-
→ A superheated is a device which removes the
traces of moisture from saturated steam
leaving a boiler tubes & also increase its t
above the saturation temp.

Re-heater-
→ It re-super heat the partly expanded steam
from the turbine resulting dryness of steam
up to last stage of turbine.

d. Economizer & Airpre-heater:-
→ To Those are such devices which recover the hea
from the flue gases on their way to chimney & r
the temp. of feed water & air supplied for combustio

2. CONDENSER-

→ steam after explanation through prime mover
goes through condenser which condenses the
exhaust steam & also removes air & other
unwanted gases from steam while passing
through them.

It is of two type.
1. Jet or contact condenser
2. surface condenser

3. EVAPORATOR:-
→ These are employed for feeding pure water to steam power plant by evaporating raw water.

4. FEED WATER HEATER:-
→ These heat the feed water by means of bled steam before supply to the boiler which dissolves improve efficiency.

PRIME MOVER:-
→ It converts the stored energy in steam into rotational mechanical energy.
→ It is either reciprocating or turbines. Now raises only steam turbine are use as prime movers.

WORKING PRINCIPLE OF STEAM POWER PLANT:-
→ The working of thermal power plant can be summarized as be follows.

FUEL & ASH CKT:-
→ Generally heavy amount of fuel i.e. coal is stored in coal storage his again transfer to boiler furnace through coal handling plant.
→ where gates pulverization. After combustion the resulting ash get transfer to ash storage to ash handling plant.

AIR & FLUE GAS CKT:-
→ Here, atmosphere air is drawn by forced draught fan or induced draught fan through air preheated in which air is heated by heat of flue gases passing to chimney & finally air is passed to furnace.
→ similarly flue gas after passing through boiler & super heater drawn by induced draught fan via dust collector (precipitator). Economizer & Air preheater finally Exhausted to the atmosphere to the chimney.

FEED WATER & STEAM CKT—

→ Generally steam coming from boiler is wet & having high pressure, which again dried & further super heated ~~by &~~ by super heater & supply to steam turbine through main valve where it give heat energy & passes through condenser.

Now, the condensate steam is extracted fr the condenser to the low pressure feed water by condensate extraction pump.

→ where is gets heats up at low pressure & pump to high pressure water heater through deaerat & finally to boiler through economizer where it g again heat up by heats of flue gas passing it on t way of chimney.

Here the function deaerator reduces dissolved oxygen in the condensate steam.

Generally a small part of steam & water is pa through different components are lossed. so w is added to feed water as make up water by makeup water treatment.

COOLING WATER CKT—

→ The cooling water is supply from the natural source of supply i.e river, lake canal etc. through screen to remove the matter that migh choke condenser tube. circulation of cooling wate maintenance low pressure in condenser.

SELECTION OF SITE FOR THERMAL POWER PLANT—

There are different factors which govern the site selection.

1. Near to the load center:—

→ It locates near the load center resulting low transmission cost & loss.

2. Supply of water –

Large quantity of water is required.

1. To raise steam in boilers.
2. For cooling.
3. For carrying disposal of Ash.
4. For drinking.

3. Availability of coal –

→ It required huge amount of coal so plants are located near the coal mines to avoid the transport of coal & ash.

4. Land requirement –

→ Land is requires not only for setting of plant but also other purpose for staff colony, coal storage ash disposal etc.

TRANSPORTATION FACILITIES :-

→ These facilities must be available for transportation of heavy equipment & fuels i.e near railway station.

merits –

1. The fuel (i.e coal) used is quite cheap.
2. cheaper in initial cost in comparison to the other plant.
3. Less space is required in comparison to hydropower plant.
4. such plant can be installed at any place where as hydro electric plants can only be developed at source of water.
5. A portion of steam raised can be used as process steam in various industries like paper mill, sugar mill, chemical or etc.

Demerits :-

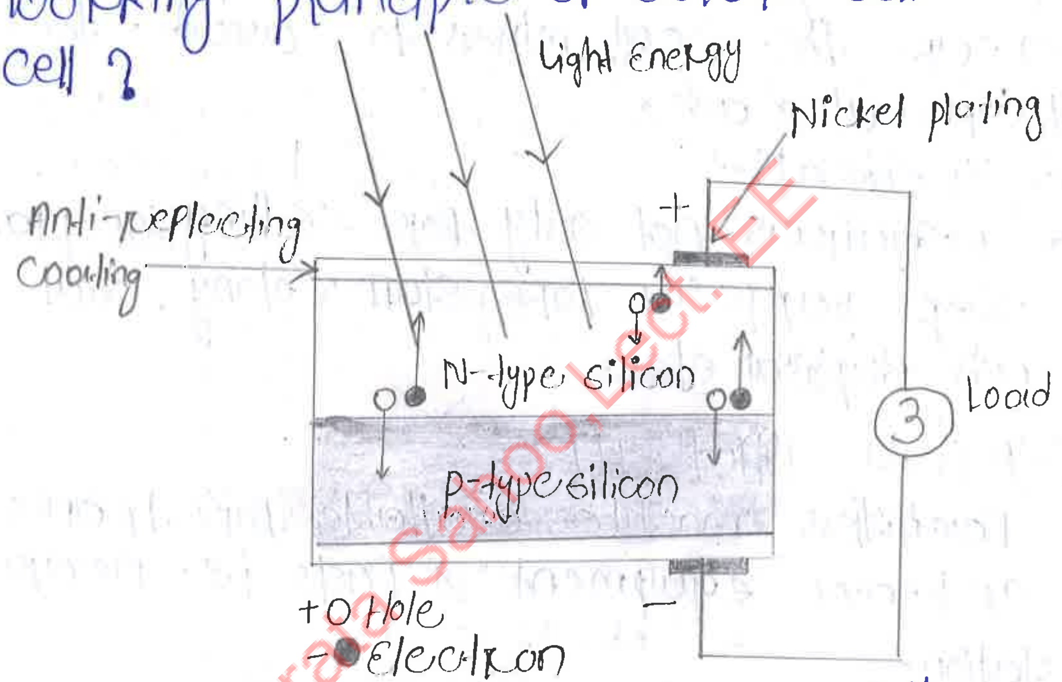
1. High maintenance & operating cost.
2. pollution of atmosphere due to fumes & feed residues

3. consumption of huge amout of water.
4. Handling of coal & disposal of ash in quite difficult.
5. Troubles from smoke & heat from the plan

Solar power plant –

Solar PV cell –

→ Working principle of solar cell and photovo cell ?



Construction of solar cell

→ conversion of light energy in electrical ene is based on a phenomenon called photovoltaic e

→ when semiconductor materials are exposed to the some of the photons of light ray are ab bed by the semiconductor crystal which co a significant number of free electrons in crystal.

→ This is the basic reason for producing electric to photovoltaic effect.

→ photovoltaic cell is the basic unit of the system e the photovoltaic effect is utilised of produce el from light eny. energy. Silicon is the most wid used semiconductor material for constructing photovoltaic cell.

→ when light falls on a silicon crystal if the intensity high enough, sufficient numbers of photons are absorbed by the crystal and these photons, in turn excite some of the electrons of covalent bonds.

→ These excited electrons then get sufficient energy to migrate from valence band to conduction band and leave a hole have vital hole in creating electricity in PV cell.

→ These electrons and holes are hence called light-generated electrons and holes respectively.

→ These light generated electrons and holes cannot produce electricity in the silicon crystal alone.

voltage regulation :-

→ voltage regulation is defined as the ratio between voltage drop from No load to full load to no load voltage.

$$V.R = \frac{\text{No load voltage} - \text{Full load voltage}}{\text{No load voltage}} \times 100$$

* corona :-

→ when an alternating potential difference is applied to the two conductor whose spacing large compare to diameter there no aparente change in condition of atmosphere. air surrounding in if the applied voltage is low when applied voltage exceeds certain value called critical. discreating voltage.

→ The conductor are surrounded by front by front violet glow called corona.

→ V > Vc

→ The phenomenon of corona is hising sound production of ozone power loss & radio interface.

→ The phenomenon of violet glow and hising noise and is known as corona.

→ Theory of corona formation:-

→ some ionisation is alway present in air in to conm there fore Normal condision the air sorrounding the the conductor have some ionised particles. when th potencial difference applied between the conductor a potential gradiant is set up in the air due to which exciting free electron applied. higher velocity great the applied voltage greater will be velocity of par when potencial gradient reach. as about 30kV/cm the velocity accowr by free electron is suffien to strike a neutral molecule to dislose an electron from it.

→ This produces another iron ~~&~~ the process of ionaization is gumility. The result of this ionisation is formation o sparne between the conductor.

Factors affecting corona:-

→ The phenomenon if corona is affected by the physi state of atmospheric as well as the condition of the line.

→ following are the factor open which corona depecte

I) Atmosphere -

→ At corona is formed due to tensal of air so which their fore there are affect the atmospheric condition.

II) → conductor size -

→ The corona effect desends upon the shape and condition of the surface Rough ~~& es~~ erregular surface will give rise to more cor

→ sparing between conducter-

→ If spacing between conducter is spred very large as compair to thm. thire diameter con may not happen.

line voltage –

→ If the voltage ~~teable is lowe~~ levele is low then be No change surrounding air. If voltage level exeess critical disrupthtive voltag . corona occur arround the conductor.

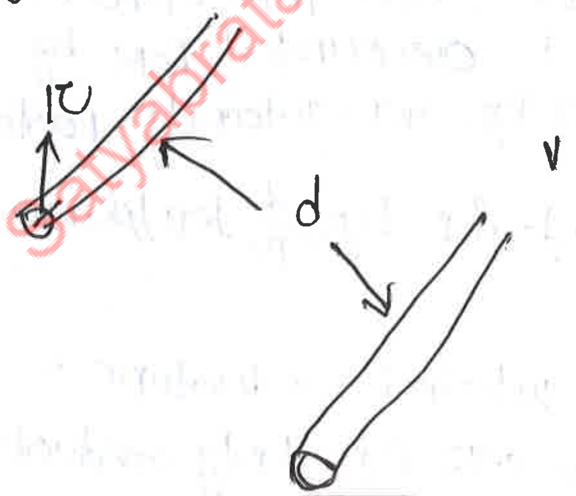
Date – 02.04.2022

Important terms:–

→ critical disruptive voltage:–

→ It is the minimum phase – neutral voltage at which corona occurs.

→ consider two conductors of radii 'r' cm and spaced 'd' cm apart. If 'V' is the phase – neutral potential then potential gradient at the conductor surface is given by



$$g = \frac{V}{r \ln \frac{d}{r}} \text{ volts/cm}$$

→ The value of 'g' must be made equal to be break down strength of air.

$$g_0 = 30 \text{ kV/cm (max)}$$

$$= (21.2 \text{ kV/cm}) \text{ rms}$$

rms = root mean square

→ If 'V_c' is the phase – neutral potential under atmospheric conditions at 76 cm pressure & 25 temp.

$$g_0 = \frac{V_c}{r \ln \frac{d}{r}}$$

⇒ $V_c = g_0 \, r \ln \frac{d}{r}$ ← critical voltage.

→ The above expression for disruptive voltage is under standard conditions. If it is vary air density changes altering the value of 'g_0' so the critical disruptive voltage given by.

$$V_c = g_0 \, \delta \, r \, \ln \frac{d}{r}$$

→ where, δ is called air density factors.

$$\delta = \frac{3.92 b}{t + 273}$$

b = air pressure.
t = atm temp

→ Correction must also made for surface condition of the conductor. This is accounted for by multiplying the above expression by irregularity factor 'm_0'.

$$V_c = m_0 g_0 \, \delta \, r \log_e \frac{d}{r} \text{ kV/phase}.$$

where,

m_0 = 1 for polished conductors.
= 0.98 to 0.92 for dirty conductors.
= 0.87 to 0.8 for stranded conductors.

→ Visual critical or disruptive voltage:-

→ It is the minimum phase-neutral voltage at which corona glow appears all along the line conductor.

$$V_v = m_0 g_0 r \delta \left(1 + \frac{0.3}{\sqrt{\delta r}}\right) \ln \frac{d}{r} \text{ kV/phase}$$

Power loss due to corona:-

Formula, $$P = 242.5\left(\frac{f+25}{\delta}\right)\sqrt{\frac{r}{d}}\,(V-V_c)^2 \times 10^{-5}\ \text{kW/km/phase}$$

where, f = supply frequency in Hz

V = phase-neutral voltage (r.m.s)

V_c = disruptive voltage (r.m.s) per phase.

Advantages of corona:-

→ Due to corona formation the air surrounding the conductor becomes conducting and hence virtual diameter of the conductor is increased.

→ The increased diameter reduces the electrostatic stresses between the conductors.

→ Corona reduces the effects of transients produced by surges.

Disadvantages of corona:-

→ Corona is accompanied by a loss of energy. This affects the transmission efficiency of the line.

→ Ozone is produced by corona and may cause corrosion of the conductor due to chemical action.

→ It cause communication lines.

Methods of Reducing corona Effect-

→ By increasing conductor size.

→ The increasing conductor spacing.

NUCLEAR POWER PLANT:-

→ The power plant which generates electricity by utilizing the vast energy released from nuclear fission reaction is known as nuclear power plant.

NUCLEAR FISSION :-

→ The nuclear reaction in which a heavy nucleus is splited in to small nucleus in splited in to small nuclei with liberation of vast energy by bombardment of neutron is known as Nuclear fission Reaction.

Eg - chemical reaction

$$_{92}U^{235} + {_0n^1} \rightarrow {_{56}Ba^{139}} + {_{36}Kr^{94}} + 3{_0n^1} + \text{Energy}.$$

$$_{92}U^{235} + {_0n^1} \rightarrow {_{92}Mo^{106}} + {_{50}Sn^{128}} + {_{20}n^1} + \text{Energy}.$$

Note:-

1 kg of natural uranium give enery equivalent to combustion of 10.500kg of coal i.e. $0.7/100 \times 3 \times 10^6 \times$ Joule.

NUCLEAR CHAIN REACTION:-

→ It may be defined as a fission reaction where the neutron from a previous step continuity propagate & repeat the reaction i.e.

components of the nuclear power plant:-

a. Nuclear Reactor-

→ It is the main part of nuclear power plant which is very similar to boiler of thermal power plant it has following component.

1. Reactor core -

→ It contains a number of fuel rods made of U^{234}, U^{233}, etc. as uranium gets oxidised rapidly so fuel rods clad with aluminum stainless steel or zirconium.

2. Moderator -

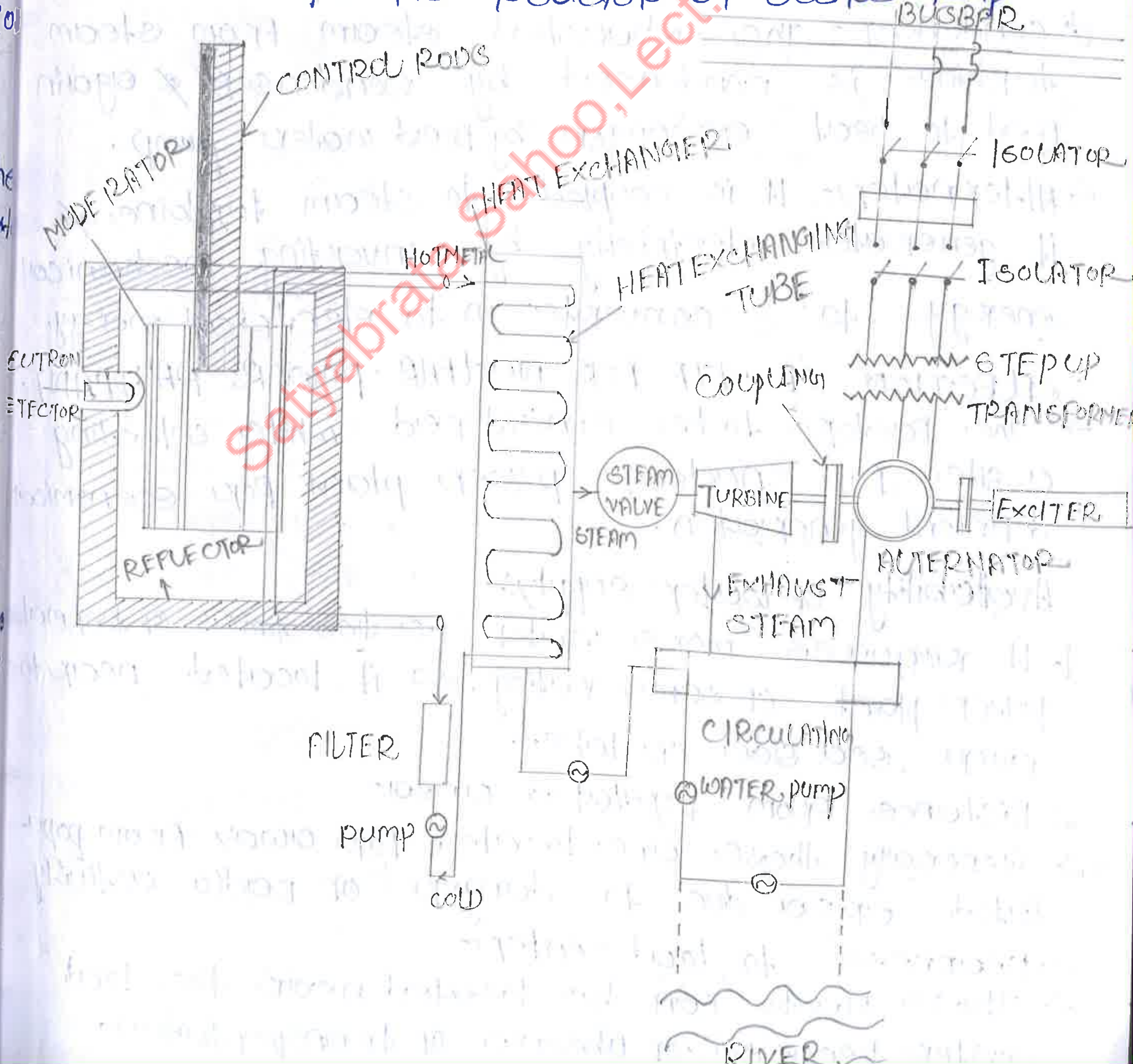
→ The moderator or reduces the neurons speed to a value that increase the probability of fission reactor. The elements which are used as moderator in nuclear reactor are hydrogen deuterium He, Li. or Graphite, heavy water, etc.

3. Control Rods -

→ The control rods which are made of Boron, cadium or Hafnium are inserted in to nuclear reactor from the top of reactor vessels. The control rods control rate of the nuclear fission reaction by absorbing neutrons. It can be inserted or taken out as according to requirement i.e if we need increased rate of reaction we have to taken out & vice verse.

4. coolant.

→ It is the medium through which heat generated in the reactor in transferred to the heat exchanger & it also keeps the reactor at desire temp.



a. The material like air He, H & CO_2 amongst
gases light or heavy water amongst the liq
molten sodium or lithium amongst the metal
as coolant.

b. Heat Exchanger- In heat Exchanger the gasic
or steam is generated by utilizing heat pr
nuclear reactor, here heat is connected b
exchanger tube by circulation.

c steam turbine - The steam produce in heat
exchanger is transferred to steam turbine
through steam valve where heat energy is
converted in to mechanical energy.

d condenser- The exhausted steam from ste
turbine is condensed by condenser & ag
feed to heat exchanger by feed water pump.

e Alternator- It is coupled to steam turbine
it generate electricity by converting mechan
energy to converte in to electrical ener

SELECTION OF SITE FOR NUCLEAR POWER PLANT

→ The factor to be considered while selecti
a site for nuclear power plant for econ
deficient generation.

Availability of water supply:-

1. It requires more water i.e two times of the
power plant of same rating. so it located nea
river, sea side or lake.

2. Distance from populated area-
→ Generally these are located far away from
lated area due to danger of radio acti

3. Nearness to load center-
→ Those plants can be located near the loa
center because of absence of transportation.

4. Availability of space for disposal of water -
→ There should 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 bearing pressure around 50 tones / m^2.

merits -
1. It requires very small fuel.
2. It requires less area as compared to in other plant.
3. In addition to generating power it powder variable fissel material.
4. It can be located at load center resulting reduction in primary distribution cost.
5. It has most economical & flexible o/p.
6. The operating cost quite low after installation.

Disadvantages -
1. The initial cost is very high as compared to any other plant.
2. It required greater technical known - how for its irrection & commissioning of the plant.
3. It bi-product is also radio activity causing dangerous pollution.
4. The fuel is used is very expensive & difficult to recover.
5. High maintenance charges.
6. Heavy amount of water is needed.

conductor materials :-
→ The conductor is one of the important items as most of the capital outlay is invested for it. There fore proper choice of material and size of the conductor is of considerable importance.

→ The conductor materials used for transformission & distribution of electric power should have the following properties.

(i) high electrical conductivity.

(ii) high tensile strength in order to withstand mechanic stresses.

(iii) low cost so that it can be used for long distances

(iv) low specific gravity so that weight per unit volume is small.

→ All above requirement are not that found in a single material.

* Commonly used conductor materials:-

→ The most commonly used conductor materials for over-head lines are copper, aluminium, steel cored aluminium, galvanised steel and cadmium copper.

→ The choice of a particular material will depend upon cost, the required electrical and mechanical pro and the local conditions.

① copper:-

→ copper is an ideal material for overhead lines o to its high electrical conductivity and greater te strength.

→ It is always used in the hard drawn form as st conductor ~~Altoy~~ Although hard drawing decrease the electrical conductivity slightly yet it increase the tensile strength considerably.

2. Aluminium:-

→ Aluminium is cheap and light as compared to co but it has much smaller conductivity and tensile

→ The conductivity of aluminium is 60% that of copper.

→ The smaller conductivity of aluminium ~~for~~ means that for any particular transmission efficiency, the x-sectional area of conductor must be larger in aluminium than in copper.

→ Aluminium conductor, being light, is liable to greater swings and hence larger cross-arms are required.

→ Due to lower tensile strength and higher co-efficient of linear expansion of aluminium the sag is greater in aluminium conductor.

③ Steel cored aluminium (ACSR) (Aluminium conductor, steel reinforced)

→ ~~The~~ It is order to increases the tensile strength, the aluminium conductor is reinforced with a core of galvanised steel wires.

→ The steel-cored aluminium conductor consists of central core of galvanised steel wire surrounded by a number of aluminium strands.

→ The reinforcement with steel increases the tensile strength but at the ~~and~~ same time keeps the composite conductor light.

→ Due to smaller sag with steel cored aluminium conductors, towers of smaller heights can be used.

* Galvanised steel :-

→ Steel has very high tensile strength. Therefore galvanised steel conductor can be used for extermely long spans or for short line section exposed to abnormally high stresses due to climatic condition.

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

* <u>cadmium copper:-</u>

→ The conductor material now being employed in certa[in] case is copper alloyed with cadmium. An addition of or 2% cadmium to copper increases the tensile st[rength] by about 50% and the conductivity is only reduced b[y] 15% below that of pure copper.

* Insulator:-

→ The overhead line conductors should be supported [on] the poles or towers in such a way that currents [from] conductors do not flow to earth through suppor[ts] i.e. line conductors must be properly insulate[d] from supports.

→ This is achieved by securing line conductors to supports to supports with the help of insulators.

→ The insulator should have following properties:

(i) High mechanical strength in order to withstand conductor load, wind load etc.

(ii) High electrical resistance of insulator material in order to avoid leakage currents to earth.

(iii) High relative permittivity of insulator material in order that dielectric strength is high.

(iv) The insulator material should be non-porous, free from impurities and cracks otherwise the permittivity will be lowered.

(v) High ratio of puncture strength to flashover.

<u>Types of Insulators:-</u>

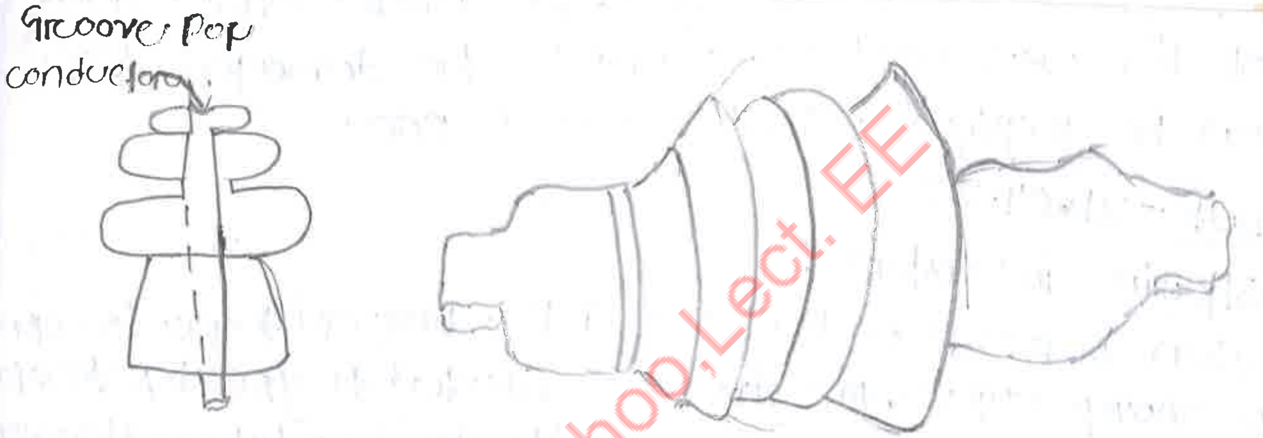
A. pin type Insulators:-

→ The pin type insulator is ~~do~~ secured to the cr[oss] arm on the pole.

→ There is a groove on the upper end of the insulator for housing the conductor.

→ The conductor passes through this groove and is bound by the annealed wire of the same material as the conductor.

→ pin type insulators are used for transmission and distribution of electric power at voltage upto 33kV. By Beyond operating voltage of 33kV.



(Pin-type insulator) (Suspension insulator)

b. Suspension type insulators:-

→ The cost of pin type insulator increase rapidly as the working voltage is increased. Therefor, this type of insulator is not economical beyond 33kV.

→ For high voltage, it is a usual practice to use suspension type insulator. They consist of a number of porcelain disc connected in series by metal in the links in the form of a string.

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

→ Each unit or disc is designed for low voltage say, 11kV. The number of disc in series would obviously depend

Advantages :-

i → suspension type insulators are cheaper than pin type insulators for voltages beyond 33kv.

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

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

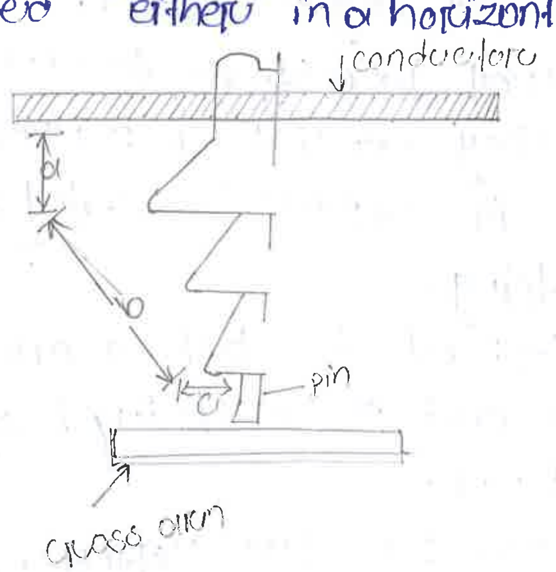
Date - 21.04.22

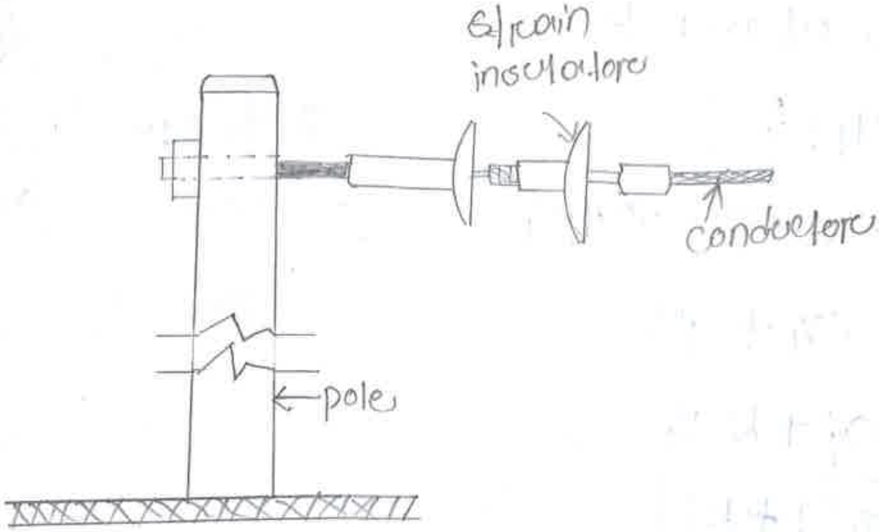
c) Strain insulators :-

→ when there is a dead end of the line or there is corner or sharp curve, the line is subjected to greater tension the insulators are used as strain insulator. However for high voltage transmission lines, strain insulator consists of an assembly of suspension insulators.

d. shackle insulators :-

→ In early days, the shackle insulators were used as strain insulators. But now a days, they are frequency used for low voltage distribution lines. such insulators can be used either in a horizontal position or in a vertical position.





(Strain insulator)

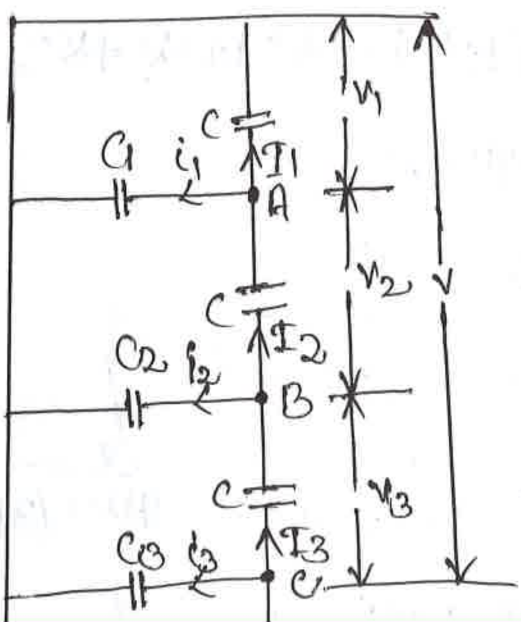
Imp

* String efficiency:-

→ String efficiency the ratio of voltage across the whole string to the product of number of discs and the voltage across the disc nearest to the conductor is known as String efficiency.

$$\text{String efficiency} = \frac{\text{voltage across the string}}{n \times \text{voltage across disc nearest to conductor}}$$

n = number of discs in the string.



Applying KCL at node "B"

$$I_2 = I_1 + i_1$$

$$\Rightarrow \omega C v_2 = \omega C v_1 + \omega C_1 v_1$$

$$\Rightarrow C v_2 = C v_1 + C_1 v_1$$

$$\Rightarrow C v_2 = C v_1 + kC v_1$$

$$\Rightarrow \boxed{v_2 = v_1(1+k)}$$

Applying KCL at node "A"

$$I_3 = I_2 + i_2$$

$$\Rightarrow \omega C v_3 = \omega C v_2 + \omega C_2 (v_1 + v_2)$$

$$\Rightarrow \omega C v_3 = \omega C v_2 + \omega k C_2 (v_1 + v_2)$$

$$\Rightarrow v_3 = v_2 + k(v_1 + v_2)$$

$$\Rightarrow v_3 = (1+k)v_1 + k v_1 + k(1+k)v_1$$

$$\Rightarrow v_3 = v_1 + k v_1 + k v_1 + k v_1 + k^2 v_1$$

$$\Rightarrow \boxed{v_3 = (k^2 + 3k + 1) v_1}$$

voltage between conductor and earth

$$v = v_1 + v_2 + v_3$$

$$= v_1 + v_1(1+k) + v_1(1 + 3k + k^2)$$

$$= v_1(3 + 4k + k^2)$$

$$\boxed{v = v_1(1+k)(3+k)}$$

From expression (i) (ii) (iii)

$$\frac{v_1}{1} = \frac{v_2}{1+k} = \frac{v_3}{1+3k+k^2} = \frac{v}{(1+k)(3+k)}$$

voltage across top unit $v_1 = \frac{v}{(1+k)(3+k)}$

voltage across second unit form top.

$V_2 = V_1(1+k)$

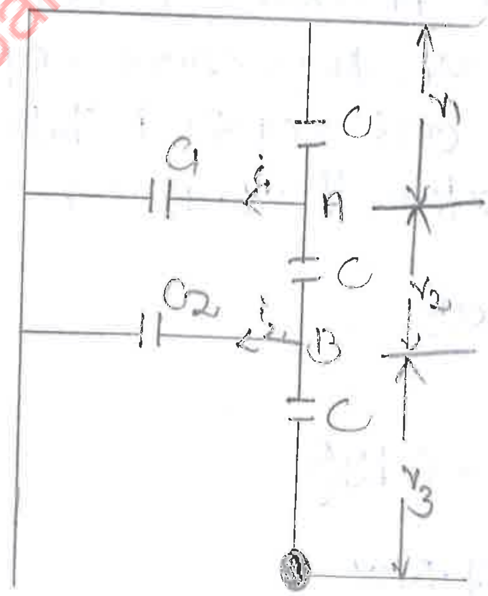
voltage across third unit form top $V_3 = V_1(1+3k+k^2)$

% age string efficiency = $\frac{\text{voltage across string}}{n \times \text{voltage across disc nearest to conductor}} \times 100$

$= \frac{V}{3 \times V_3} \times 100$

problem-1 Date-23.04.22

* In a 33kV overhead line, there are three units in the string of insulators. If the capacitance between each insulator pin and earth is 11% of self-capacitance of each insulator, find (i) the distribution of voltage over 3 insulators and (ii) string efficiency.



→ Given data:

$V = 33\,kV$

$n = 3$

$k = 0.11$

$V_{ph} = \frac{V_1}{\sqrt{3}} = \frac{33}{\sqrt{3}} = 19.05\,V$

$V_2 = (1+k)V_1$

$= (1+0.11)V_1$

$= 1.11\,V_1$

$V = V_1 + V_2 + V_3$

$= V_1 + 1.11V_1 + 1.342V_1$

$\Rightarrow V = 3.452V_1 = 19.05$

$\Rightarrow V_1 = 5.518\,V$

$V_3 = 1.342 \times 5.518 = 7.405\,V.$

$V_2 = 1.11 \times 5.518 = 6.124\,V.$

$$\eta = \frac{V}{n \times V_i} = \frac{19.05}{3 \times 7.405} \times 100 = 85\,\%$$

* Each line of a 3-phase system is suspended by a string of 3 similar insulators. If the voltage across the line unit is 17.5 kV, calculate the line to voltage. Assume that the shunt capacitance between each insulator and earth is 1/8th of the capacitance of the insulator itself. Also find the string efficiency.

<u>Given data:-</u>

$n = 3$

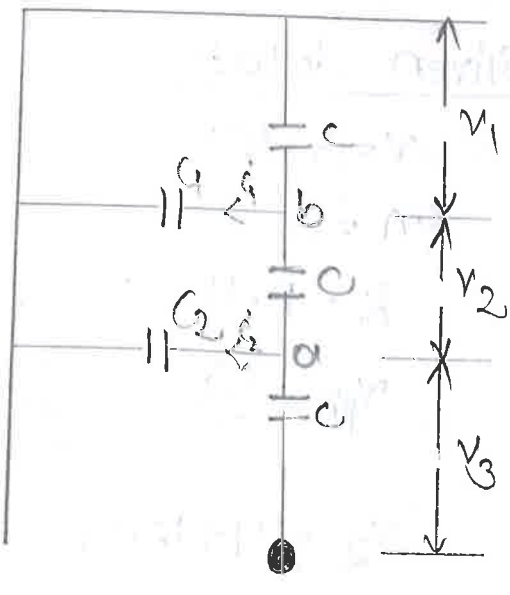
$k = \frac{1}{8} = 0.125$

$V_3 = 17.5\,kV$

$= (k^2 + 3k + 1)V_1 = 17.5$

$\Rightarrow (0.125)^2 + 3 \times 0.125 + 1 = 17.5$

$\Rightarrow V_1 = \frac{17.5}{1.390} = 12.589.$



$V_2 = (1 + k)V_1$

$= (1 + 0.125)V_1$

$$V = V_1 + V_2 + V_3$$

$$= 12.589 + 14.162 + 17.5$$

$$= 44.251 \text{ kV}$$

$$\eta = \frac{V}{n \times V_3} = \frac{44.251}{3 \times 17.5} \times 100$$

$$= 84.287\%$$

→ **methods of Improving string efficiency:-**

→ To improve the string efficiency. The various methods for this purpose are:

1) **By using longer cross-arms:-**

→ The value of string efficiency depends upon the value of 'k' i.e ratio of shunt capacitance to mutual capacitance.

→ The lesser the value of k, the greater is the string efficiency and more uniform is the voltage distribution.

→ The value of 'k' can be decreased by reducing the shunt capacitance; the distance of conductor from tower must be increased i.e, longer cross-arms should be used.

2) **By grading the insulator:-**

→ In this method insulator of different dimensions are so chosen that each has a different capacitance.

→ The insulators are capacitance graded i.e they are assembled in the string in such a way that the top unit has the minimum capacitance, increasing progressively as the bottom unit is reached. Since voltage is inversely proportional to capacitance, this method tends to equalise the potential distribution across the units in the string.

③ By using a guard ring:-

→ The potential across each unit in a string can be equalised by using a guard ring which is a metal ring electrically connected to the conductor and surrounding the bottom insulator.

→ The guard ring introduces capacitance between metal fittings and the line conductor.

Example:-

→ A 3-phase transmission line is being supported by three disc insulators. The potentials across top unit (i.e, near to the tower) and middle unit are 8 and 11kv respectively calculate (i) the ratio of the capacitance between pin and earth to the self-capacitance of each unit. (ii) the line voltage and (iii) string efficiency.

Given data:-

$v_1 = 8 kv$

$v_2 = 11 kv$

$v_2 = (1+k) v_1$

$\Rightarrow 1+k = \frac{v_2}{v_1}$

$\Rightarrow k = \frac{v_2}{v_1} - 1$

$\Rightarrow \frac{11}{8} - 1$

$\Rightarrow$ ~~0.9~~ $\Rightarrow 0.375$

$v_3 = (1+3k+k^2) v_1$

$= \left(1 + 3 \times \frac{3}{8} + \left(\frac{3}{8}\right)^2\right) 8$

$= 18.125$

$$r = r_1 + r_2 + r_3$$

$$= 8 + 11 + 18.125$$

$$= \frac{37.125}{3 \times 18.125} \times 100$$

$$= 68.28\%$$

Ans

→ performance of overhead Transmission lines:-

→ Depending upon the length of the line and voltage levels their are 3 times of transmission of lines are classified as.

① short transmission lines:-

→ when the length of an overhead transmission line is upto about 50km and the line voltage is comparatively low (< 20kV), it is usually considered as a short transmission line.

② medium transmission lines:-

→ when the length of an overhead transmission level is 20 to 100kV it is considered as a medium transmission line.

③ long transmission lines:-

→ when the length of an overhead transmission line is more than 150km and line voltage is very high (>100kV). It is considered as a long transmission line.

Voltage Regulation:-

→ The difference in voltage at the receiving end of a transmission line between conditions of no load and full load is called voltage regulation.

→ and is expressed as a percentage of the receiving end voltage.

$$VR = \frac{V_S - V_R}{V_R} \times 100$$

$$\frac{N_L - F_L}{N_L} \times 100$$

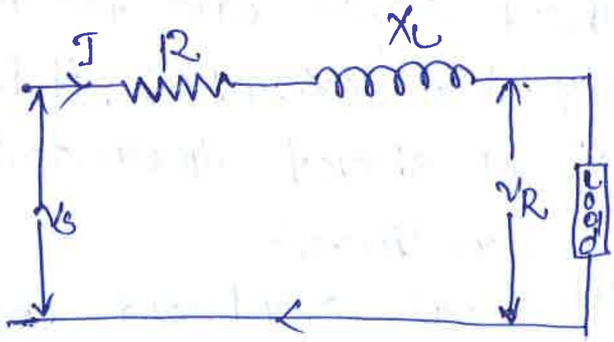
Transmission efficiency:-

→ The ratio of receiving end power to the sending end power of a transmission line is known as the transmission efficiency of the line.

$$\text{Transmission efficiency}, \eta_T = \frac{\text{Receiving end power}}{\text{Sending end power}} \times 100$$

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

→ performance of single phase short transmission lines.



→ The effect of capacitance is neglected.

I = load current.

R = loop resistance i.e. resistance of both conductor.

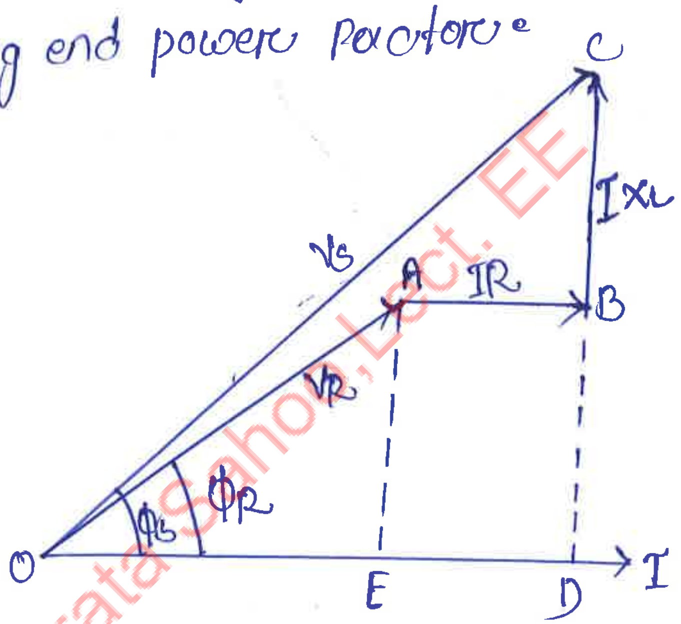
X_L = loop ~~resistance~~ reactance

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.



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

$$V_S^2 = (OE + ED)^2 + (DB + BC)^2$$

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

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

voltage regulation $\boxed{V_R = \frac{V_S - V_R}{V_R} \times 100}$

sending end p.f. $\cos\phi_S = \frac{V_R\cos\phi_R + IR}{V_S}$

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

* A single phase overhead transmission line delivers 1lkw at 33kV 0.8 power factor lagging the resistance and Inductance & reluctance the line are 10Ω & 15Ω resptively. Determine sending voltage, sending power and transmission efficiency?

→ Given data:

$P = 500$

Date 06.05.22

* An overhead 3-phase transmission line delivers 5000kw at 22kv at 0.8 p.f lagging. The resistance & reactance of each conductor is 4Ω & 6Ω respectively. Determine.
  - (i) sending end voltage.
  - (ii) percentage regulation
  - (iii) transmission efficiency

→ Given data:

$P = 5000\,kW$

$V = 22\,kV$

$p.f = 0.8$ log.

$I =$

$V_{ph} = \frac{V_c}{\sqrt{3}} = \frac{22}{\sqrt{3}} = 12.701$

$P = VI\cos\phi$

$I = \frac{P}{V \times \cos\phi} = \frac{5000}{3 \times 12.70} = 164.02\,Amp.$

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

$= \sqrt{(12.709 \times 100 \times 0.8 + 164.02 \times 4)^2 + (12.709 \times 1000 \times 0.6 + 164.02 \times 6)^2}$

$= 13829.93\,V$

$\sin\phi_R = \sqrt{1-0.8} =$

$\cos\phi_S = \frac{V_R\cos\phi_R + I_R R}{V_S}$

$= \frac{12709 \times 0.8 + 164.02 \times 4}{13829.93} = 0.78$

i) voltage regulation $= \frac{V_S - V_R}{V_R} \times 100$

$= \frac{13829.93 - 12709}{12709} \times 100 = 8.81$

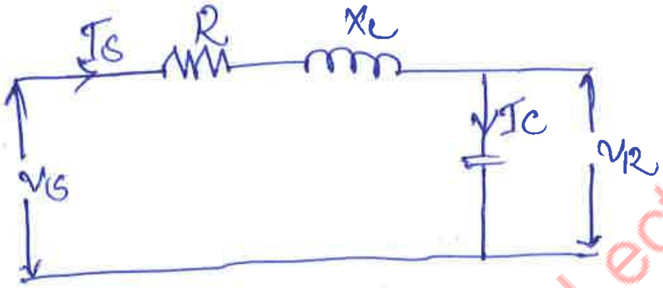
(ii) transmission efficiency $= \frac{V_R I_R \cos\phi_R}{V_S I_S \cos\phi_S} \times 100$

$= \frac{12.701 \times 164.02 \times 0.8}{13829.93 \times 164.02 \times 0.78} \times 100$

$= 94.1\%$

* medium transmission line :-

(i) End condenser model :-



→ In this method the capacitance of the line is the condenser at the receiving end.

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.

$\vec{I_R} = I_R(\cos\phi_R + j\sin\phi_R)$

$I_C = j\omega C V$

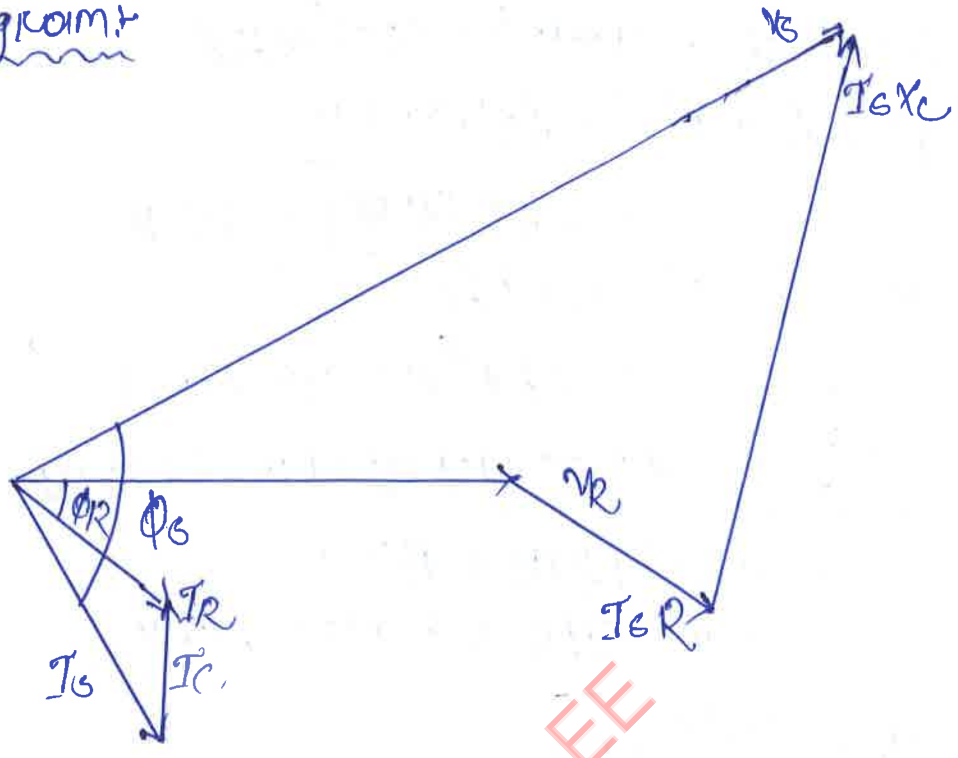
$\vec{I_S} = \vec{I_R} + \vec{I_C}$

$= I_R(\cos\phi_R - j\sin\phi_R) + j2\pi f C V_R$

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

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

→ phasor Diagram:-



Q. A single medium transmission line 100 km long has the following constants:-

Resistance/km = 0.25 Ω   Reactance/km = 0.8 Ω

Susceptance/km = 14×10^{-6} siemen. Receiving end line voltage = 66,000 V

Assuming that the total capacitance of the line is the localised at the receiving end alone, determine (i) the sending end current (ii) the sending end voltage (iii) regulation and (iv) supply power factor. The line is delivering 15,000 kW at 0.8 power factor lagging. Draw the phasor diagram to illustrate your calculations.

Ans→

Total resistance = 0.25 × 100 = 25 Ω

Total Inductive reluctance (X_L) = 0.8 × 100 = 80 Ω

Total suceptence (Y) = $14 \times 10^{-6} \times 100 = 14 \times 10^{-4}$ S

$$I = \frac{15000 \times 10^3}{66000 \times 0.8} = 284$$

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

$$= 284 (0.8 - j0.6)$$

$\vec{I_C} = j2\pi fC = j14\times10^{-6}\times66000 = 92j$

$\vec{I_S} = \vec{I_R} + \vec{I_C} = 227 - 170j + 92j$

$= 227 + j78 \text{ Amp} = 240\angle -18$

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

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

$= 66000 + 5675 + 18160j + 1950j + 6240j^2.$

$= 71675 + 11915 + j16210$

$= 77915 + j16210 = 79583\angle 11.75$

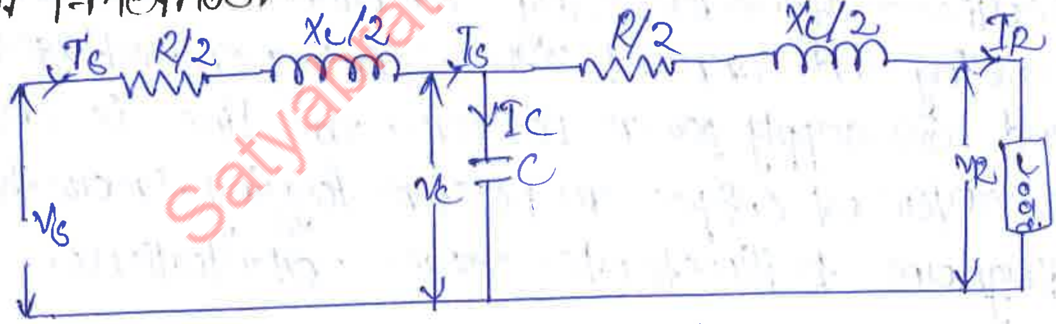
$V.R = \dfrac{V_S - V_R}{V_S} \times 100$

$= \dfrac{79583 - 66000}{66000} \times 100 = 20.58\,\%$

$\phi_S = 18.98 + 11.75 = 30.73$

$\cos\phi_S = \dfrac{V_R \cos\phi_R + I_R R}{V_S} = 0.86.$

i) Nominal T-method:



→ In this model the whole line capacitance is assumed to be concentrated at the middle point of the line. half of the impendance are placed either site of capacitance. In this model charging current flow through half of the transmission line.

I_R = load current per phase.

X_L = inductive reactance per phase.

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

V_C = voltage across capacitor C.

X_C = capacitance per phase.
R = Resistance per phase
V_C = sending end voltage/phase
I_C = sending end current.
C = capacitance per phase.

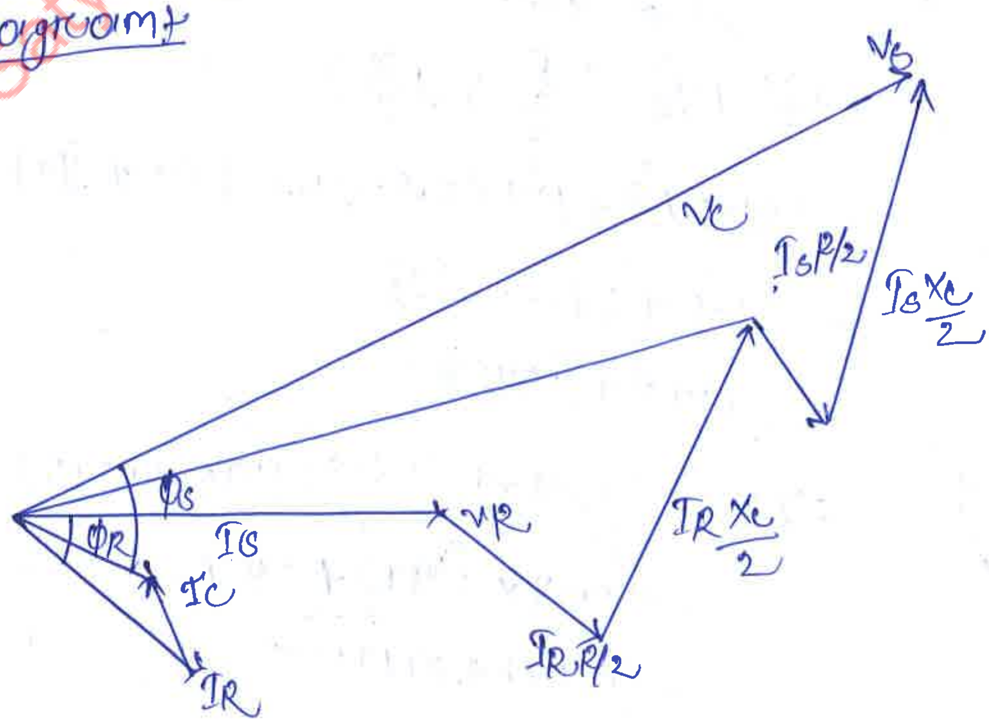
$$\vec{V} = \vec{V_R} + \vec{I_R}\, Z/2$$
$$= \vec{V_R} + \vec{I_R}\,(\cos\phi_R - j\sin\phi_R)\, Z/2$$
$$= \vec{V_R} + \vec{I_R}\,(\cos\phi_R - j\sin\phi_R)\left(\frac{R}{2} + j\frac{X}{2}\right) \quad \text{—(1)}$$

$$\vec{I_C} = j2\pi f C\, V_C \quad \text{—(2)}$$
$$\vec{I_S} = \vec{I_R} + \vec{I_C} \quad \text{—(3)}$$
$$\vec{V_S} = \vec{V_C} + \vec{I_S}\,(Z/2)$$
$$= \vec{V_C} + \vec{I_S}\,(R/2 + jX/2) \quad \text{—(4)}$$

$$V_R = \frac{V_S - V_R}{V_S} \times 100$$

$$\cos\phi_S = \frac{V_R\cos\phi_R + I_R\, R/2}{V_S}$$

phasor diagram:



* A 3 phase, 50Hz overload transmission line 100km long has the following constants:-

Resistance/km/phase = 0.1Ω

Inductive reactance/km/phase = 0.2Ω

capacitive susceptance/km/phase = 0.04×10^{-4} siemen.

Determine (i) the sending end current & voltage (ii) sending end power factor & (iv) transmission efficiency when suppling a balanced load of 10,000 kw at 66kv, p.f 0.8 lagging. Use nominal T method.

→ Total resistance/phase = $0.1\times100 = 10\Omega$

Total inductance/phase = $0.2\times100 = 20\Omega$

capacitive susceptance, $Y = 0.04\times10^{-4}\times100 = 4\times10^{-4}$ S

Reciving end voltage/phase = 66,000.

$V_R = 66000$

$V_{ph} = \frac{66000}{\sqrt{3}} = 38105\ V$

$\vec{I_R} = \frac{10000\times10^3}{\sqrt{3}\times66000\times0.8} = 109\ A$

$V_C = \vec{V_R} + \vec{I_R}\left(\frac{R}{2} + j\frac{X}{2}\right)$

$= 38105\angle0 + 109(0.8 - j0.6)\cdot(5 + j10)$

$= 38105 + 872 - 327j$

$= 39198 + j545\ V$

$I_C = jYV_C = j0.04\times10^{-2}\times(39195 \times j545)$

$= j0.04\times39195 + 545i$

$= 549i + 39198\ V$

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

$$= 109\,(0.8 + j0.6) + -0.218 + 15.6j$$

$$= 87 - 49.8j = 100\angle -29.47.$$

$$\vec{V_S} = \vec{V_C} + \vec{I_S}\left(\frac{R}{2} + j\frac{X}{2}\right)$$

$$= 39198 + j548 + (87 - 49.8j)\,(5 + j10)$$

$$= 40128 + 1166 i\ V = 40144\angle 1.66^\circ$$

$$\phi_S = 29.47 + 1.66 = 31.13$$

$$\cos\phi_S = 0.85$$

sending end power factor $= 3 V_S I_S \cos\phi_S$

$$= 3 \times 40145 \times 100 \times 0.853$$

$$= 10273\ kW$$

$$\eta_T = \frac{10,000}{10,273.105} \times 100 = 97.34\%.$$

Nominal π method :-

→ In this method, capacitance of each conductor is divided into two halves one half being lumped at the sending end and the other half at the receiving end.

→ Its charging current must be added to line current in order to obtain the total sending end current.

I_R = load current per phase.

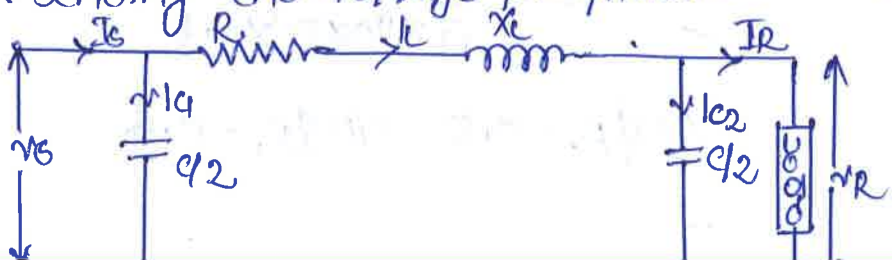
R = resistance per phase.

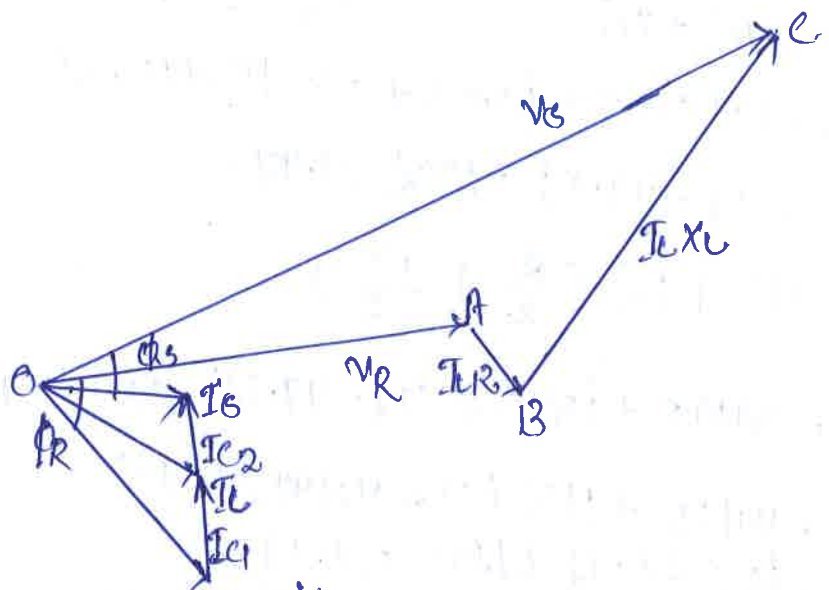
X_L = inductive reactance per phase.

C = capacitance per phase.

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

V_S = sending end voltage per phase.





Line current $\vec{I_L} = \vec{I_R} + \vec{I_{C_1}}$

sending end voltage $\vec{V_S} = \vec{V_R} + \vec{I_L}\vec{Z} = \vec{V_R} + \vec{I_L}(R + jX_L)$

charging current at the sending end is

$$\vec{I_{C_2}} = j\omega(C/2)\vec{V_S} = j\pi f C \vec{V_S}$$

∴ sending end current, $\vec{I_S} = \vec{I_L} + \vec{I_{C_2}}$

Example :1

→ A 3-phase, 50Hz, 150km line has a resistance, inductive reactance and capacitive admittance of 0.1Ω, 0.5Ω and 3×10^{-6} S per km per phase. If the line delivers 50MW at 110kV and 0.8pf. lagging, determine the sending end voltage and current. Assume a nominal π circuit for the line.

Total resistance/phase $R = 0.1 \times 150 = 15\,\Omega$

Total reactance/phase $X_L = 0.5 \times 150 = 75\,\Omega$

capacitive admittance/phase $Y = 3\times10^{-6}\times150 = 45\times10^{-5}$ S

Receiving end voltage/phase $V_R = 110\times10^3/\sqrt{3} = 63{,}508$ V

Load current $I_R = \dfrac{50\times10^6}{\sqrt{3}\times110\times10^3\times0.8} = 328$ A.

$\cos\phi_R = 0.8 \quad \sin\phi_R = 0.6$

$I_{C1} = jV_R \frac{Y}{2} = j \times 63.5 \times 10^3 \times \frac{45}{2} \times 10^{-5}$

$= 114.3 A$

$I_L + I_R + I_{C1} = 328.03 (\cos\phi_R - j \sin\phi_R) + j14.33$ (0.8 − j14.3)

$= 262.42 - 19081j + 14.33$

$= 262.42 - 182.52j$

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

$= 63500 \times (262.42 - j182.52)(15 + j75)$

$= 81125.3 + j16943.7 = 82875.83 \angle 11.75$

$I_{C2} = j \frac{Y}{2} V_S = j \times \frac{45}{2} \times 10^{-5} \times (81125.3 + j16443.7)$

$= -3.81 + j18.25$

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

$= 262.42 - j182.52 + (-3.81 + j18.25)$

$= 306.37 \angle -32.42$

V_S line $= \sqrt{3} \times 82875.83$

$= 143.53 kV$

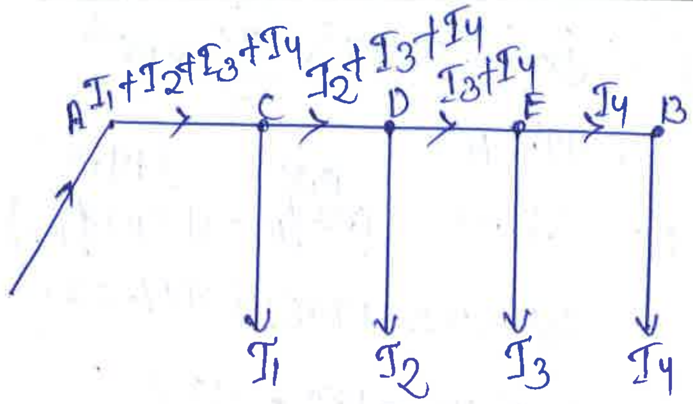
Date - 12.05.22

Distribution system:-

→ Types of D.C Distribution system.

→ The most general method classifying d.c distributions is the way they are fed by the feeders. On this basis, d.c distribution are classified as distribute phase & lm.

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

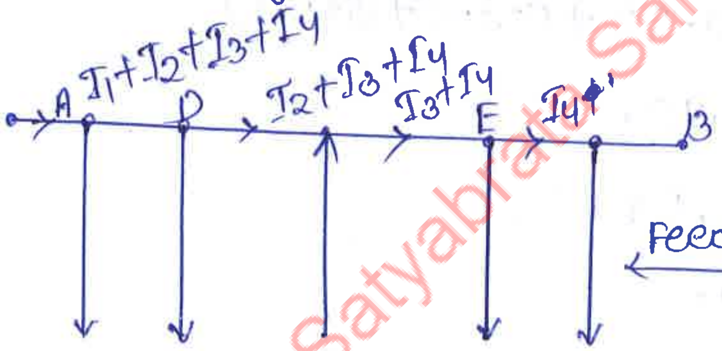


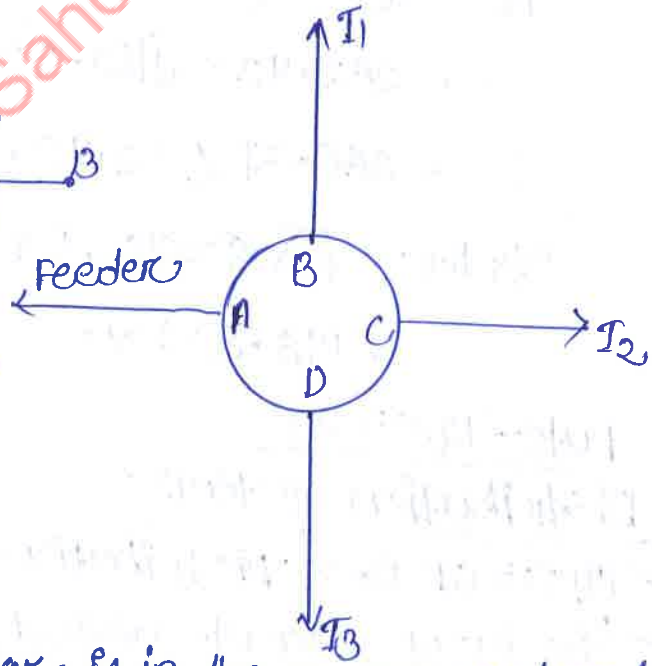
(ii) → Distributor fed at both ends:-

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

→ In case of fault on any section of of the distributor, the continuity of supply is maintained from the other feeding point.

(iii) Distributor fed at the centre:- In this type of feeding, the centre of the distributor is connected to the main supply.

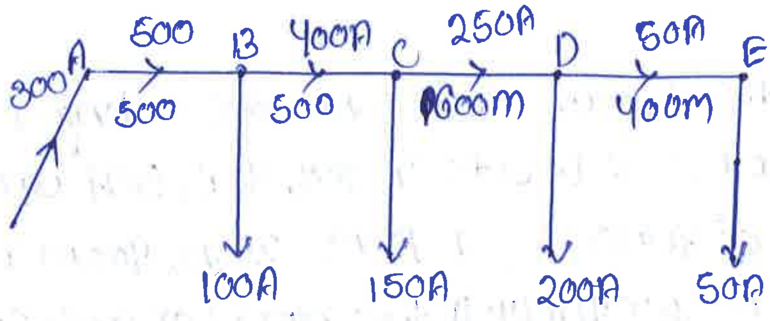




→ In this type, the distributor is in the form of a closed ring

→ when the distributer ~~phe~~ fed at 1 or more than one point.

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



→ Total Resistance of distribution perform $= 0.01 \times 2$
$= 0.02\ \Omega$

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

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

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

$R_{DE} = \frac{0.02}{1000} \times 400 = 0.008\Omega$

$V_B = V_A - I_{AB} R_{AB} = 300 - 500 \times 0.01$
$= 295V$

$V_C = V_B - I_{BC} R_{BC} = 295 - 400 \times 0.01$
$= 291V$

$V_D = V_C - I_{CD} R_{CD} = 291 - 0.012 \times 250$
$= 288V$

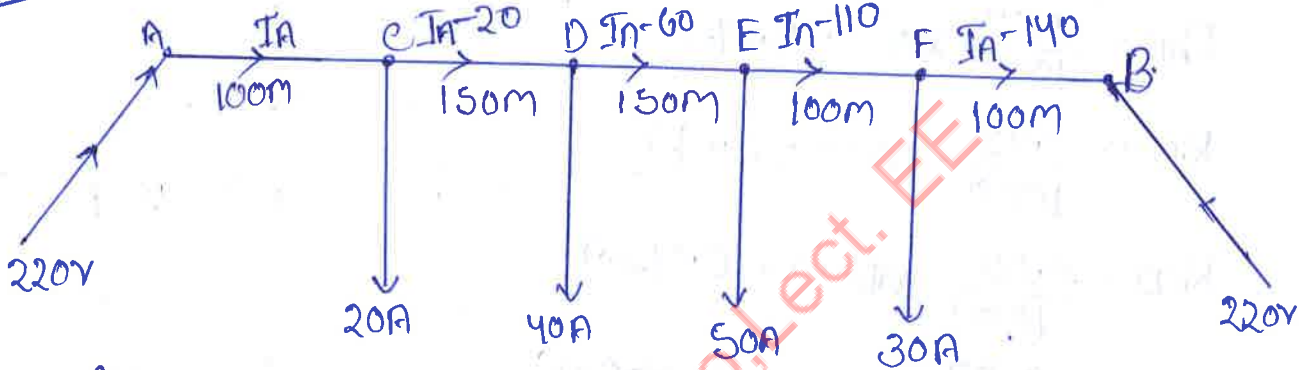
$V_E = V_D - I_{DE} R_{DE} = 288 - 50 \times 0.008 = 287.6V$

Distributor fed at both ends:-

Example:-

→ A 2wire d.c street mains AB, 600m long is fed from both ends at 220V Loads of 20A, 40A, 50A and 30A are tapped at distances of 100m, 250m, 400m and 500m from the end A respectively. If the area of x-section of distributor conductor is 1cm², find the minimum consumer voltage. Take $\rho = 1.7\times10^{-6}\,\Omega\cdot cm$.

Ans



Resistance of 1m length of distribution

$$= 2\times\frac{1.7\times10^{-6}\times100}{1} = 3.4\times10^{-4}\,\Omega$$

Resistance of section AC, $R_{AC} = (3.4\times10^{-4})\times100 = 0.034\,\Omega$

Resistance of section CD, $R_{CD} = (3.4\times10^{-4})\times150 = 0.051\,\Omega$

Resistance of section DE, $R_{DE} = (3.4\times10^{-4})\times150 = 0.051\,\Omega$

Resistance of section EF, $R_{EF} = (3.4\times10^{-4})\times100 = 0.034\,\Omega$

Resistance of section FB, $R_{FB} = (3.4\times10^{-4})\times100 = 0.034\,\Omega$

voltage at B = voltage at A − Drop over length AB.

$$V_B = V_A - [I_A R_{AC} + (I_A-20)R_{CD} + (I_A-60)R_{DE} + (I_A-110)R_{EF} + (I_A-140)R_{FB}]$$

$$220 = 220 - [0.034 I_A + 0.051(I_A-20) + 0.051(I_A-60) + 0.034(I_A-110) + 0.034(I_A-140)]$$

$$= 220 - [0.204 I_A - 12.58]$$

$$0.204 I_A = 12.58$$

$I_A = 12.58/0.204 = 61.7A$

→ The current are coming to load point 'E' from both side i.e from point 'D' and point 'F'. Hence 'E' is the point of minimum potential.

$$V_E = V_A - [I_{AC}R_{AC} + I_{CD}R_{CD} + I_{DE}R_{DE}]$$

$$= 220 - [61.7 \times 0.034 + 41.7 \times 0.051 + 1.7 \times 0.051]$$

$$= 220 - 4.34 = 215.69V.$$

Ring Distributor:-

Example:-

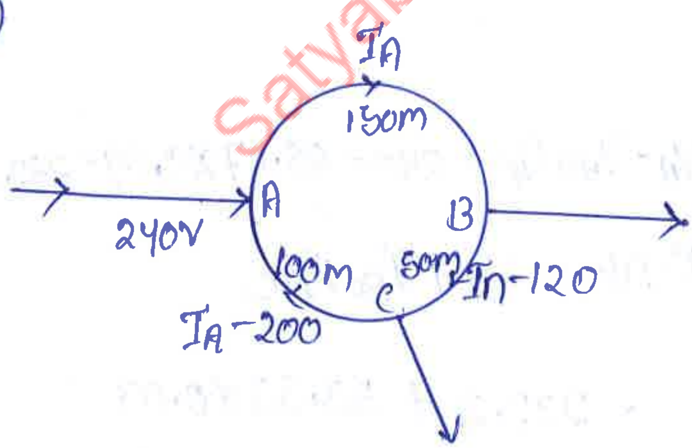
→ A 2-wire d.c ring distributor is 300m long and is fed at 240V at point A. At point B, 150m from A, a load of 120A is taken and at C, 100m in the opposite direction, a load of 80A is taken. If the resistance per 100m of single conductor is 0.03Ω find.

(i) current in each section of distributor.

(ii) voltage at point B and C.

Soln

(i)



Resistance per 100m of distributor.

$= 2 \times 0.03 = 0.06\Omega$

Resistance of section AB, $R_{AB} = \frac{0.03}{100} \times 150 \times 2 = 0.09\Omega$

$$R_{BC} = \frac{0.03}{100} \times 50 \times 2 = 0.03\Omega$$

$$R_{CA} = \frac{0.03}{100} \times 100 \times 2 = 0.06\Omega$$

(i) According to Kirchhoff's voltage law,

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

$\Rightarrow 0.09 I_A + 0.03(I_A - 120) + 0.06(I_A - 200) = 0$

$\Rightarrow 0.18 I_A = 15.6$

$\Rightarrow I_A = 15.6/0.18 = 86.67A$

current in section AB, $I_{AB} = I_A = 86.67$ from A to B

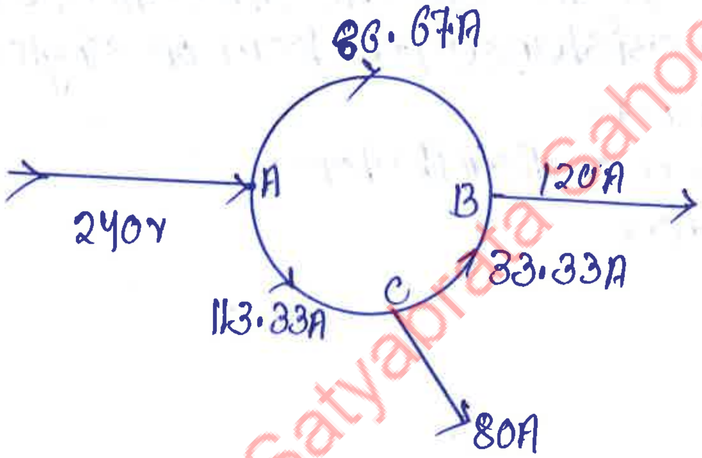
BC, $I_{BC} = I_A - 120 = 86.67 - 120 = -33.33A$

$= 33.33A$

CA, $I_{CA} = I_A - 200 = 86.67 - 200 = -113.33A$

$= 113.33A$

(ii)



(iii) voltage at point B, $V_B = V_A - I_{AB}R_{AB} = 240 - 86.67 \times 0.09 = 232.2V$

voltage at point C, $V_C = V_B + I_{BC}R_{BC}$

$= 232.2 + 33.33 \times 0.03$

$= 233.2V$

Ex-2

→ A 2-wire d.c distributor ABCDEA in the form of a ring main is fed at point A at 220 V and is loaded as under:-

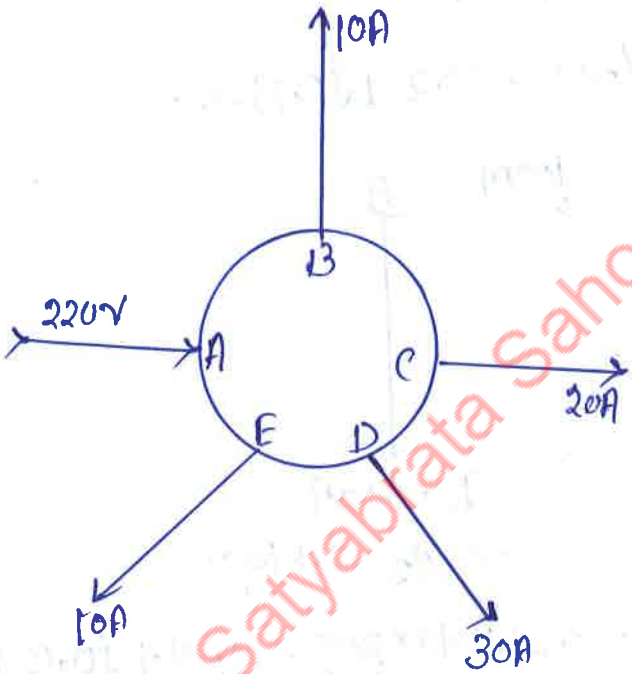
10A at B; 20A at C; 30A at D and 10A at E.

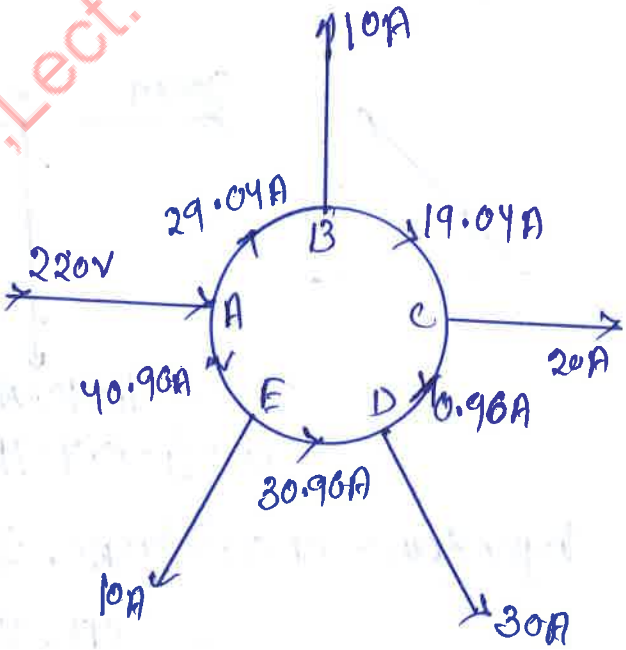
→ The resistance of various section are $AB = 0.1\Omega$, $BC = 0.05\Omega$, $CD = 0.01\Omega$, $DE = 0.025\Omega$ and $EA = 0.075\Omega$

Determine;

(i) the point of minimum potential.

(ii) current is each section of distributor.





(i) $I_{AB} R_{AB} + I_{BC} R_{BC} + I_{CD} R_{CD} + I_{DE} R_{DE} + I_{EA} R_{EA} = 0$

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

$\Rightarrow 0.26\,I = 7.55$

$\Rightarrow I = 7.55/0.26 = 29.04A$.

(ii) c is the point of minimum potential

current in section $AB = I = 29.04$ from A to B

$BC = I - 10 = 29.04 - 10 =$ ~~0.96A~~ $= 19.04A$

$CD = I - 30 = 29.04 - 30 = 0.96A$ ~~=0.96A~~

$EA = I - 70 = 29.04 - 70 = 40.96A.$

A.C Distribution:-

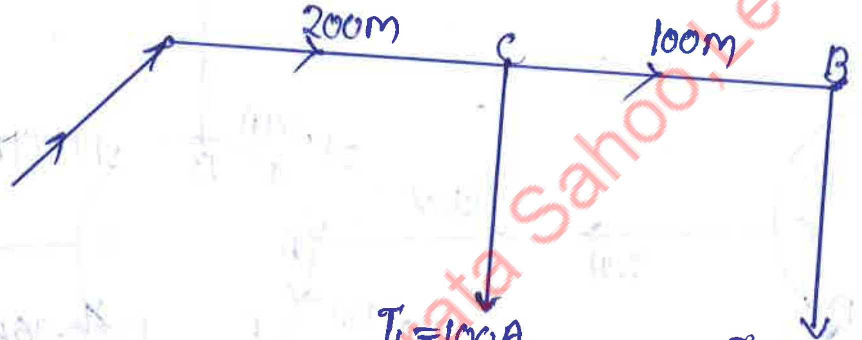
→ A single phase a.c distributor AB 300metres long is fed from end A and is loaded as under:-

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

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

→ The load resistance and reactance of the distributor is 0.2Ω and 0.1Ω per kilometer. Calculate the total voltage drop in the distributor. The load power factor refer to the voltage at the far end.

Soln Impendance of distributor/km $= (0.2 + j0.1)\,\Omega$



Impendance of section AC, $\vec{Z}_{AC} = (0.2 + j0.1) \times \frac{200}{1000} = (0.04 + j0.02)\,\Omega$

CB, $Z_{CB} = (0.2 + j0.1) \times \frac{100}{1000} = (0.02 + j0.01)\,\Omega$

Taking voltage at the far end B as the reference vector we have.

Load current at point B, $\vec{I}_2 = I_2(\cos\phi_2 - j\sin\phi_2) = 200(0.8 - j0.6)$

$= (160 - j120)A$

$\vec{I}_1 = I_1(\cos\phi_1 - j\sin\phi_1) = 100(0.707 - j0.707)$

$= (70.7 - j70.7)A$

current in section CB, $\vec{I_{CB}} = \vec{I_2} = (160 - j120)$ A

AC, $\vec{I_{AC}} = \vec{I_1} + \vec{I_2} = (70.7 - j70.7) + (160 - j120)$

$= (230.7 - j190.7)$ A

voltage drop in section CB, $\vec{V_{CB}} = \vec{I_{CB}}\,\vec{Z_{CB}} = (160 - j120)(0.02 + j0.01)$

$= (4.4 - j0.8)$ volts.

AC, $\vec{V_{AC}} = \vec{I_{AC}}\,\vec{Z_{AC}} = (230.7 - j190.7)(0.04 + j0.02)$

$= (13.04 - j3.04)$ volts.

voltage drop in the distributor =

$= \vec{V_{AC}} + \vec{V_{CB}} = (13.04 - j3.01) + (4.4 - j0.8)$

$= (17.44 - j3.81)$ volts.

Magnitude of drop $= \sqrt{(17.44)^2 + (3.81)^2} = 17.85$ V

underground cables:-

→ An underground cable essentially consists of one or more conductors covered with suitable insulation and surrounded by a protecting covers.

→ Although several types of cables are available, the type of cable to be used will depend upon the working voltage & service requirements.

construction of cables:-

① cores or conductors:-

→ A cable may be have one or more than one core depending upon the type of service for which it is intended.

→ The conductors can made of tinned copper or aluminium and are usually stranded in order to provide the flexibility to the cable.

(ii) Insulation:-

→ Each core or conductor is provided with a suitable thickness of insulation, the thickness of layer depending upon the voltage to be withstood by the cable.

→ The commonly used materials for insulation are impregnated paper, varnished cambric or rubber mineral compound etc.

(iii) Metallic sheath:-

→ In order to protect the cable from moisture gases or other damaging liquids in the solide and atmosphere & metallic sheath of lead or aluminium is provided over the insulation.

(iv) Bedding:-

→ Over ~~the~~ the metallic sheath is applied a layer of bedding which consists of a fibrous material like jute or hessian tape.

→ The purpose of bedding is to protect the metallic sheath against corrosion and from mechanical injury due to armouring.

(v) Armouring:-

→ Over the bedding, armouring is provided which consists of one or two layers of galvanised steel wire or steel taps.

→ Its purpose is to protect the cable from mechanical injury while laying it and during the course of handling.

(vi) Serving:-

→ In order to protect armouring from atmospheric conditions a layer of fibrous material similar to bedding is provided over the armouring. This is known as serving.

Classification of cables:-

→ cable of underground to be classification are:-

(i) Low-tension (L.T) cables – upto 1000V.
(ii) High-tension (H.T) cables – upto 11,000 V
(iii) Super-tension (S.T) cables – from 22kV to 33kV.
(iv) Extra high-tension (E.H.T) cables – from 33kV to 66kV.
(v) Extra super voltage cables – beyond 132kV.

Cables for 3-phase service:-

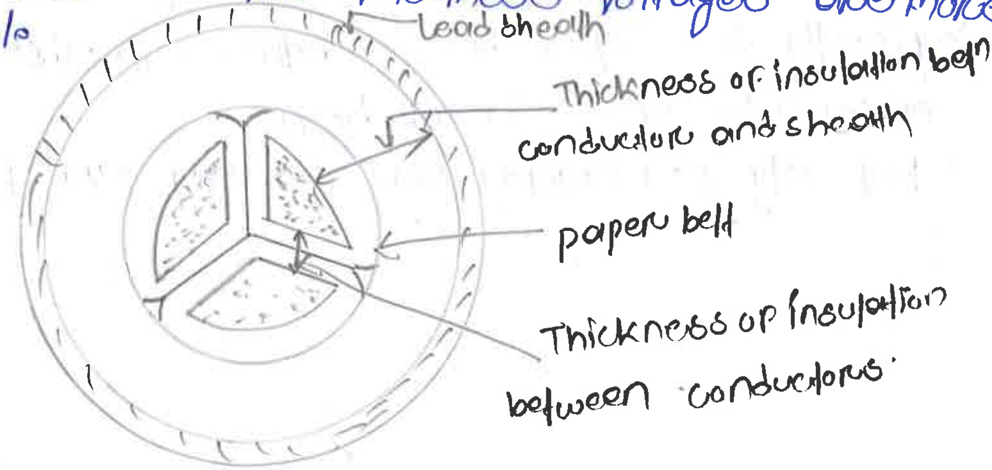
(i) Belted cables – upto 11kV.
(ii) Screened cables – from 22kV to 66kV.
(iii) Pressure cables – beyond 66kV.

(1) Belted cables:-

→ These cables are used for voltage upto 11kV.

→ The cores are insulated from each other by layers of of impregnated paper. Another layer of impregnted paper tape, called paper belt is wound round the ground the insulated cores. The gap between the insulated cores in filled with fibrous insulating material.

→ The belted type construction is suitable only for low & medium voltages as the electrostatic stresses the developed in the cables for these voltages are more or less radial.



(2) Screened cables:-

→ These cables are meant for use upto 33kV.

→ Two principle types of screened cable are H-type cable and S.L type cables.

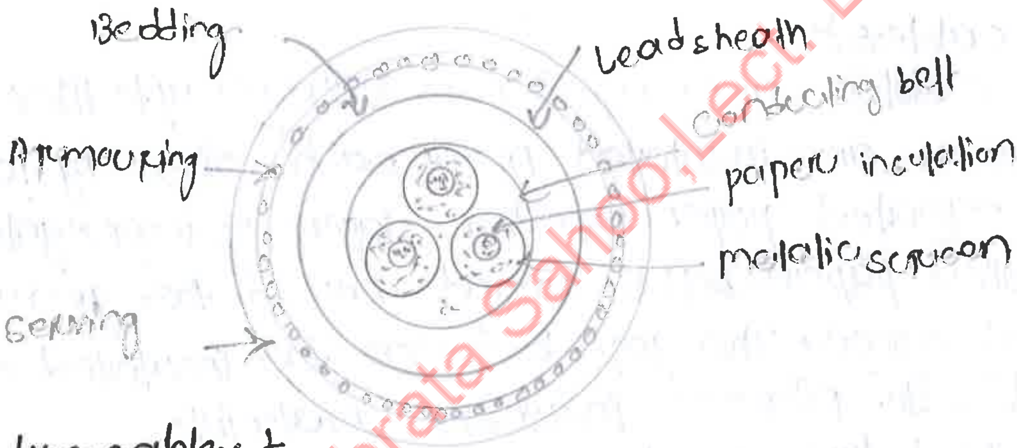
(i) H-type cable :-

→ The insulation on each core is covered with a metallic screen which usually consists of a perforated aluminium foil.

→ The cores are laid in such a way that metallic screens make contact with one another. An additional conducting belt is wrapped round the 3 cores. the each core one is contact with conducting belt and lides it. since all pole sceen and leads it are earth potential the spark electrical is only redial.

Advantages :-

→ the metallic screen increase the heat dissipating power of the cable.

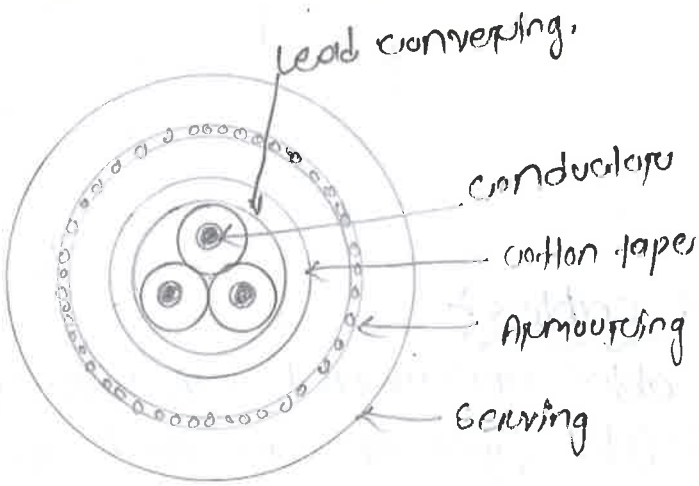


(ii) S.L-type cables :-

→ It is basically H-type cable but the screen round each core insulation is converted by its own lead sheath.

→ Finedly the separate. sheaths minimise the possibility of core-to-core breakdown.

→ but only armouring and serving are provided.



* Laying of underground cables:-

→ There are three main methods of laying underground cables.

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

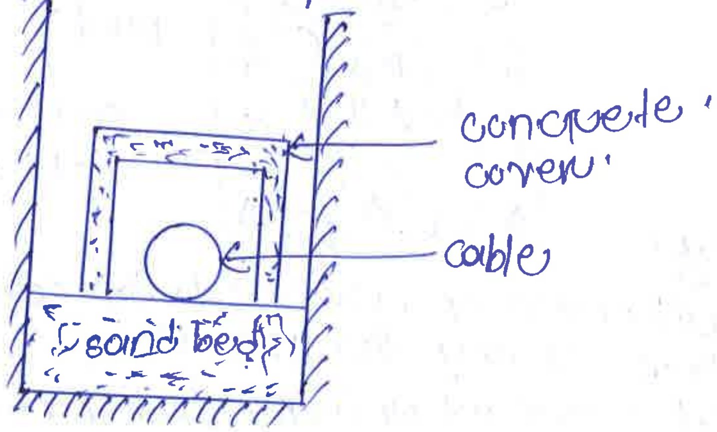
1. Direct laying:-

→ The above figure shows how the cable is laying in this method. A trench of about 1.5 meter deep and 45 cm wide is dug. Then the trench is convered with a layer of fine sand, about 10cm thick the cable is laid over the sand.

→ The sand does not allow the entry of moisture from the ground. Then the cable is convered with another layer of sand of about 10cm thickness.

→ After that the trench is convered with bricks and other materials to protect the cable from mechanical injury.

→ When more than one cable is to be laid in the same trench, a horizontal or vertical inter axial spacing of at least 30cm is provided in order to reduce the effect of mutual heating. This method of laying underground cables is simple and cheap.



→ Advantages:-

(i) It is a simple and less costly method.
(ii) It gives the best conditions for dissipating the heat generated in the cables.
(iii) It is a clean & safe method as the cable is invisible & free from external disturbances.

Dis-advantages:-

(i) The extension of load possible only for by a completely new excavation which may cost as much as the original work.

(ii) The alterations in the cable network cannot be made easily.

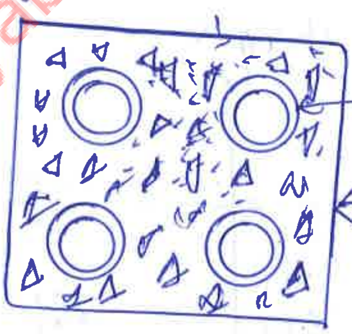
(iii) The maintenance cost is very high.

(iv) Localisation of fault is difficult.

(2) Draw-in system:-

→ This method of cable laying suitable for congested areas where excavation is inconvenient. In this method a line of conduits, ducts or tubes made of either iron, glazed stoneware clay or cement concrete and laid in ground with manholes at suitable positions along the cable route.

→ The cables are then pulled into position. separate pipes and ducts are provided for each cable laid in the same duct. care must be taken that where the duct line changes direction, depths, dine so that a large cable may be pulled easily between the manholes. The distance between the manholes should not be too long so as to simplify the pulling in the cables.



→ Advantages:-

(i) Repairs, alteration or additions to the cable network can be made without opening the ground.

(ii) As the cables are not armoured, therefore joints becomes simpler & maintenance cost is reduced considerably.

(iii) There are very less chances of fault occurrence due to the strong mechanical protection provided by the system.

→ Dis-Advantages:-

(i) The initial cost is very high.

(ii) The current carrying capacity of the cables is reduced due to the close grouping of cables and unfavourable conditions for the

③ Solid System :-

→ In this method the cable is laid in open pipes or the troughs dug out in earth along the cable route. The toughing is of cast iron, stoneware, asphalt or treated wood.

→ After laying the cable in position, the toughing is filled with a bituminous and covered over.

→ Dis-advantages :-

(i) It is more expensive than direct laid system.

(ii) It requires skilled labour and favourable weather conditions.

(iii) Due to poor heat dissipation facilities, the current carrying capacity of the cable is reduced.

→ Types of cable Faults :-

→ cables are generally laid directly in the ground or in ducts in the underground distribution system.

→ For this reason, there are little chances of faults in underground cables.

→ However, if a fault does occur, it is difficult to locate and repair the fault because conductor are not visible. the Nevertheless, the following are the faults most likely to occur in underground cables.

→ The open-circuit fault can be checked by a megger.

→ when two conductor of a multi-core cable come in electrical contact with each other due to insulation failure. It is called a short-circuit fault. Again we can seek the help of a megger to check this fault.

→ To identify this fault, one terminal of the megger is connected ~~it is called earth~~ to the conductor and the other terminal connected to earth.

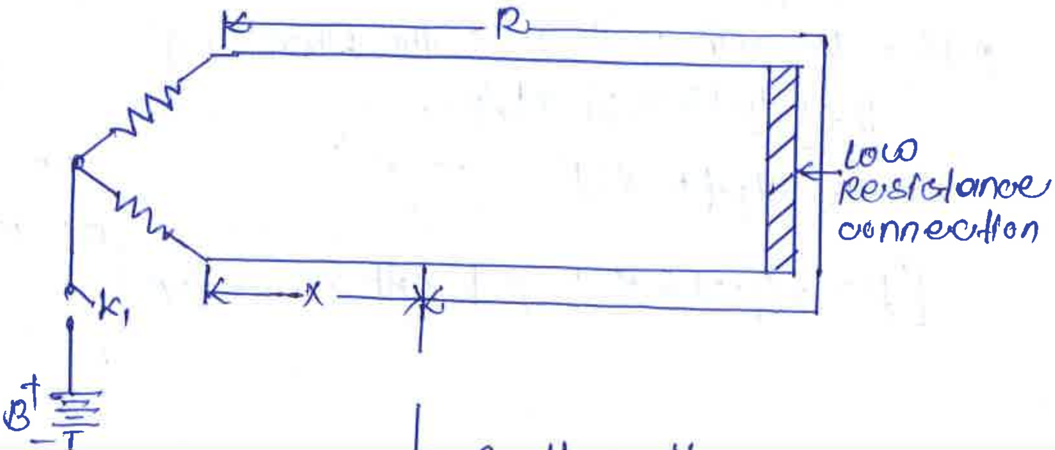
→ There are several methods for locating the faults in underground cables. However, two popular method known as loop tests are.

(i) Murray loop test.

(ii) Varley loop test.

(i) Murray loop Test :-

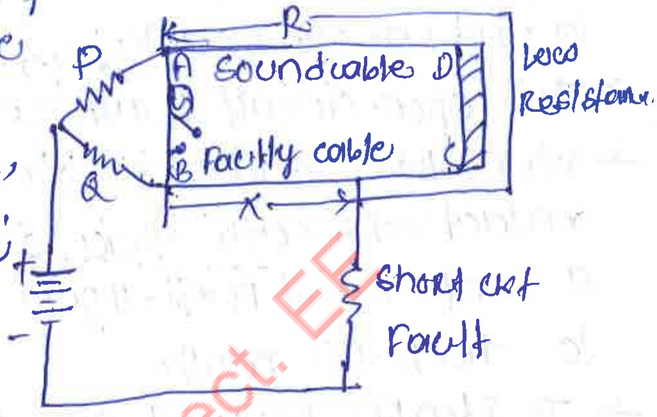
→ The murray loop test is the most common and accurate method of locating earth or short-circuit fault in underground cables.



(a) Earth fault :-

→ AB is the sound cable and CD is the faulty cable and the earth fault occurring at the point F. The end of fault the cable at point b' is connected with the point 'B' of the sound cable with a low resistance. Two variable the resistance P & Q are connected to ends A & C.

→ Let, R = Resistance of the conduct loop from the test end to point 'F' where the fault occurs.



→ X = Resistance from fault point F' to the rest of the faulty cable 'C'.

→ The resistance P & Q are the varied till the galvanometer indicates zero.

→ The balanced position of the wheatstone bridge where, P, Q, R, & X are the four arms is $P/Q = R/X$.

$$P/Q + 1 = R/X + 1$$

$$P+Q/Q = R+X/X$$

→ If 'R' is the resistance of each cable.

Then $R + X = 2r$

so $P+Q/Q = 2r/X$,

$X = Q/P+Q \times 2r$

→ If 'L' is the length of each cable in meter.

→ Then resistance per meter length of cable $= r/L$

→ Distance of fault point from test end is,

$$D = X/(r/l)$$

putting the values of X in the above eqn.

$$D = Q/P+Q \times 2r \times L/r$$

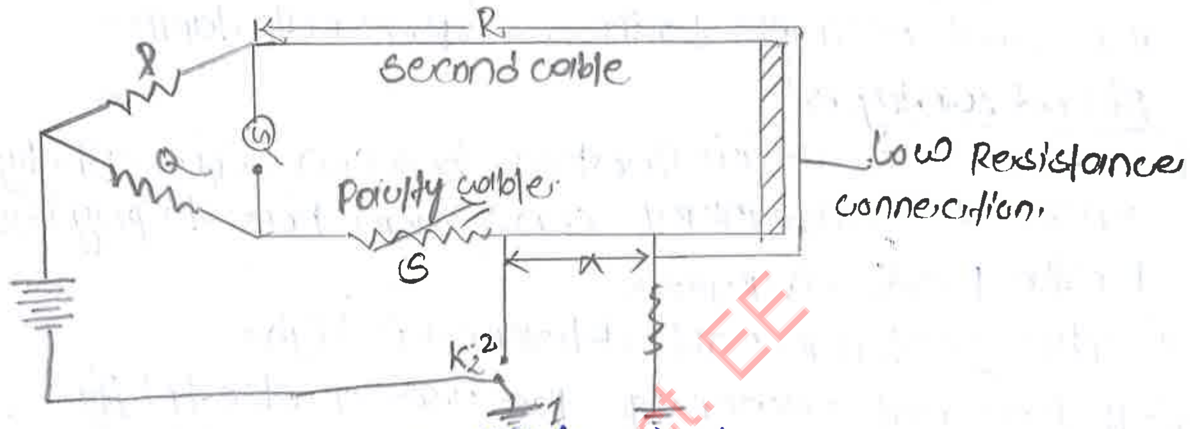
$$= Q/P+Q \times 2L$$

$$[D = Q/P+Q \times \text{loop length in meter}]$$

② Varley loop Test:-

→ The Varley loop test is also used to locate earth fault or short circuit fault in underground cables. This test also employs wheatstone bridge principle.

→ Balance is obtained by adjusting the variable resistance S connected to the test end of the faulty cable.



→ So $P/Q = R/X+S_1$ $\quad P/Q+1 = (R/X+S_1)+1$

$P+Q/Q = (R+X+S_1)/(X+S_1)$

$X = Q(R+X) - PS_1/P+Q$ ——— ①

→ Then the key K_2 is connected to position -2 and the bridge is balance to a new value of resistance:

$P/Q = R+X/S_2 \quad (R+X)Q = PS_2$ ——— ②

→ From the equation 1 & 2 we will get $X = P(S_2-S_1)/P+Q$

→ The loop resistance $= R+X = (P/Q)S_2$

→ If 'r' is the resistance of the cable per meter length. The distance of fault from the test end is $D = \frac{X}{r}$ meters.

Tariff

Tariff:-

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

Objectives of tariff:-

(i) Recovery of cost of producing electrical energy at the power station.

(ii) Recovery of cost on the capacital investment in transmission and distribution system.

(iv) A suitable profit on the capital investment.

Types of tariff:-

→ There are several 7 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.

Dis-advantages:-

(i) There is no discrimination between different types of consumers since every consumer has to pay equitably for the fixed charges.

(ii) The cost per unit delivered is high.

(iii) It does not encourage the use of electricity.

(2) Flat rate tariff:-

→ When different types of consumers are charged at the uniform per unit rates, it is called a flat rate tariff.

Dis-advantages:-

(i) Since the flat rate tariff varies according to the way the way the supply is used, separate meters are required for lighting load power load etc.

(3) Block rate tariff:-

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

(4). Two-part tariff:-

→ When the rate of electrical energy is charged on the basis of maximum demand of the consumer and the units consumed, it is called a two-part tariff.

Advantages:-

(i) It is easily understood by the consumers.

(ii) It recovers the fixed charges which depend upon the maximum demand of the consumer but are the

Dis-advantages:-

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

(ii) There is always error in assessing the maximum of demand of the consumer.

(5) Maximum demand tariff.

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

→ This type of tariff is mostly applied to big consumers.

(6) Power factor tariff:-

→ The tariff in which power factor of the consumer's load is taken into consideration is known as power factor tariff.

(7) Three-part tariff:-

→ When the total charge to be made from the consumer is split into three parts viz. fixed charge, semi-fixed charge and running charge. It is known as a three-part tariff.

i.e.

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

a = fixed charge made during each billing period. It includes interest and depreciation on the cost of secondary distribution & labour cost of collecting revenues.

b = charge per kW of maximum demand,

c = charge per kWh of energy consumed.

problem:-

① A consumer has a maximum demand of 200kW at 40% load factor. If the tariff is Rs.100 per kW of maximum demand plus 10 paise per kWh. Find the overall cost per kWh.

Solution

units consumed/year = max. demand × L.F × Hours in a year

$= (200 \times 0.4) \times 8760 = 7,00,800$ kWh.

or $= 200 \times \frac{40}{100} \times 365 \times 24$

$= 700800$ kWh.

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

$= Rs(100 \times 200 + 0.1 \times 7,00,800)$

$= Rs\ 90,080$

overall cost/kWh $= Rs\ \frac{90080}{700800} = Rs\ 0.1285 = 12.85$ paise.

② The maximum demand of a consumer is 20A at 220V and his total energy consumption is 8760 kWh. If the energy is charged at the rate of 20 paise per unit for 500 hours use of the maximum demand per annum plus 10 paise per unit for additional units. calculate (i) annual bill (ii) equivalent flat rate.

Soln

Assume the load factor and power factor to be unity

∴ maximum demand $= \frac{220 \times 20 \times 1}{1000} = 4.4$ kW.

(i) units consumed in 500 hrs = 4.4 x 500 = 2200 kwh.

charges for 2200 kwh = Rs 0.2 x 2200 = Rs 440

Remaining units = 8760 - 2200 = 6560 kwh.

charges for 6560 kwh = Rs 0.1 x 6560 = Rs 656.

∴ Total annual bill = Rs (440 + 656) = Rs 1096.

(ii) Equivalent flat rate = Rs $\frac{1096}{8760}$ = Re 0.125 = 12.5 paise

→ Sag in overhead lines :→

→ The difference in level between points of supports and the lowest point on the conductor is called sag.

→ This is an important consideration in the mechanical design of overhead lines.

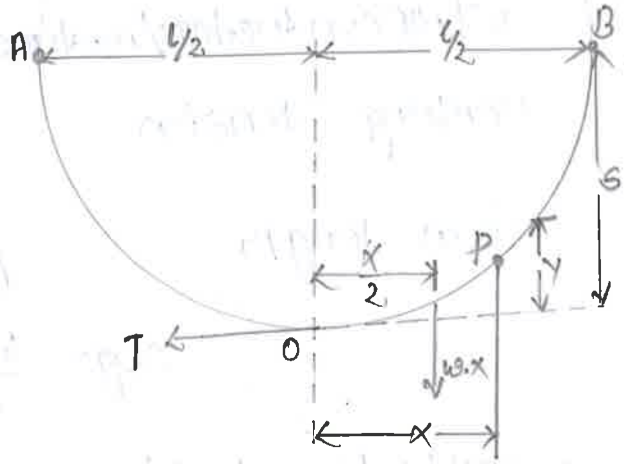
→ The conductor sag should be kept to a minimum in order to reduce the conductor material required and to avoid extra pole height for sufficient clearance above ground level.

Calculation of sag :→

(i) when supports are at equal levels.

~~→ conductor ...~~

→ consider a conductor between two equilevel the supports A and B with O as the lowest point.



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

Let,

L = Length of span

w = weight per unit length of conductor

T = Tension in the conductor

consider a point 'P' on the conductor.

→ There the two force acting on the portion of of the conductor.

(a) The weight wx of conductor acting at a distance $x/2$ from O.

(b) The tension T acting at O,

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

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

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

→ The maximum dip (sag) is represented by the value of y at either of the supports A and B At support A,

$$x = l/2 \text{ and } y = S$$

$$\therefore \text{Sag. } S = \frac{w(l/2)^2}{2T} = \frac{wl^2}{8T}.$$

problem:-

→ A 132 kV transmission line has the following data:-

wt. of conductor = 680 kg/km , Length of span = 260m

ultimate strength = 3100 kg , safety factor = 2,

calculate the height above ground at which the conductor should be supported. Ground clearance required is 10 metres.

Sol^n:

wt. of conductor/metre run, $w = 680/1000 = 0.68 kg$

working tension $T = \frac{\text{ultimate strength}}{\text{safety factor}} = \frac{3100}{2} = 1550 kg$

Span length $l = 260 m$

$$\text{sag} = \frac{wl^2}{8T} = \frac{0.68 \times (260)^2}{8 \times 1550} = 3.7 m$$

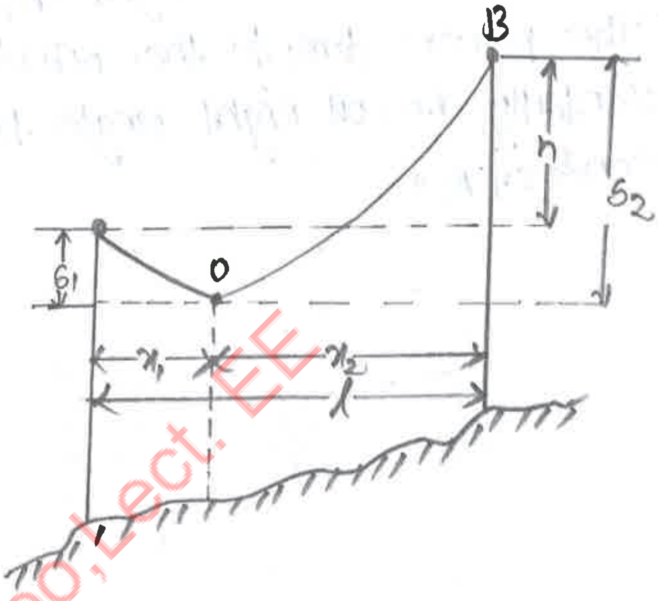
∴ Conductor should be supported at a height of 10+3.7

= 13.7 m

(ii) when supports are at unequal levels :-

→ In hilly areas, we generally come across conductors suspended between supports at unequal levels.

→ The conductor suspended between two support A and B which are at diffrent levels. The lowest point on the conductor is O.



Let,

l = Span length

h = Difference in levels betn two supports

x_1 = Distance of support at lower level (i.e, A) from O.

x_2 = Distance of support at higher level (i.e, B) from O.

T = Tension in the conductor.

if w is the weight per unit length of the conductor, then.

$$\text{Sag } S_1 = \frac{w x_1^2}{2T}$$

$$\text{Sag } S_2 = \frac{w x_2^2}{2T}$$

$$x_1 + x_2 = l$$

Now $S_2 - S_1 = \frac{w}{2T}\left[x_2^2 - x_1^2\right] = \frac{w}{2T}(x_2 + x_1)(x_2 - x_1)$

$$S_2 - S_1 = \frac{wl}{2T}(x_2 - x_1)$$

$$S_2 - S_1 = h$$

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

$x_2 - x_1 = \frac{2Th}{wl}$ —— (i) $\quad x_1 + x_2 = l$ —— (ii)

Solving eqns (i) and (ii) we get,

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

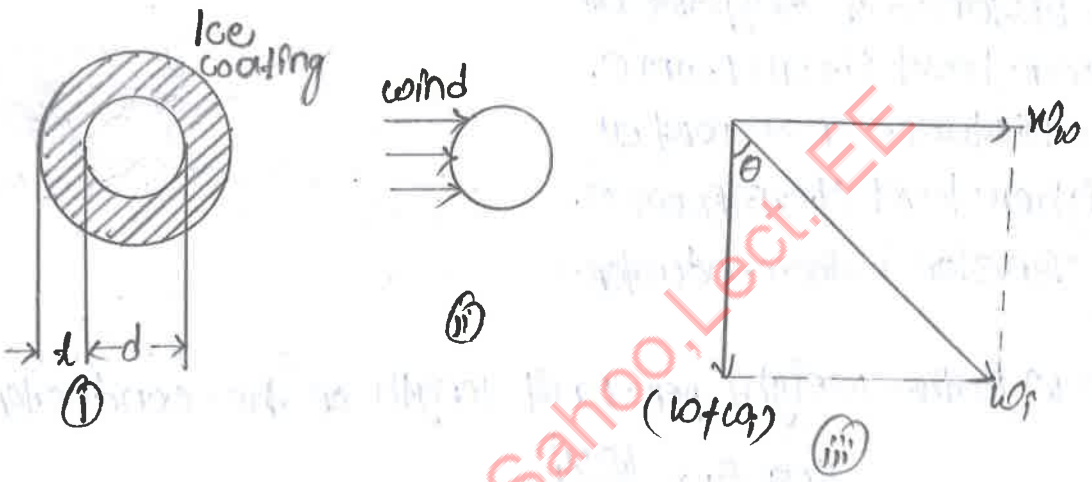
$$x_2 = \frac{l}{2} + \frac{Th}{wl}$$

→ Effect of wind and ice loading :-

→ The conductor may have ice coating and simultaneously subjected to wind pressure.

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

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



Total weight of conductor per unit length is

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

where

w = weight of conductor per unit length
= conductor material density × volume per unit length

w_i = weight of ice per unit length
= density of ice × volume of ice per unit length
= density of ice × $\frac{\pi}{4}[(d+2t)^2 - d^2] \times 1$
= density of ice × $\pi t(d+t)$

w_w = wind force per unit length
= wind pressure per unit area × projected area per unit length
= wind pressure × [(d+2t) × 1]

(i) The conductor sets itself in a plane at an angle θ to the vertical where.

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

(ii) The sag in the conductor is given by.

$$S = \frac{w_t l^2}{2T}$$

→ If this sag is called slant sag.

(iii) The vertical sag = $S\cos\theta$

problem:

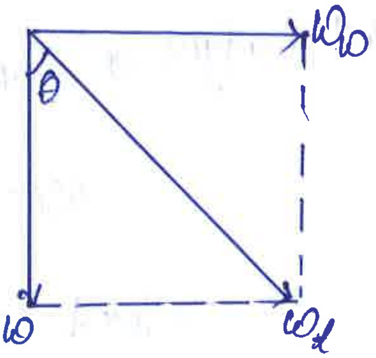
→ A transmission line has a span of 150m between level support. The conductor has a cross-sectional area of $2\,cm^2$. The tension in the conductor is 2000kg. If the specific gravity of the conductor material is $9.9\,gm/cm^3$ and wind pressure is 1.5kg/m length. calculate the sag. what is the vertical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

Soln

Span length, $l = 150m$.

working tension, $T = 2000kg$

wind force/m length of conductor, $w_w = 1.5kg$



wt. of conductor/m length, w = sp. Gravity × Volume of 1m conductor

$= 9.9 \times 2 \times 100 = 1980gm = 1.98kg$

Total weight of 1m length of conductor is -

$$w_t = \sqrt{w^2 + w_w^2} = \sqrt{(1.98)^2 + (1.5)^2} = 2.48kg.$$

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

$$\theta = \tan^{-1}\left(\frac{w_w}{w}\right) = (1.5/1.98) = 0.76.$$

$$\theta = \tan^{-1} 0.76 = 37.23.$$

vertical sag $= S\cos\theta = 3.48 \times \cos 37.23 = 2.77m.$

Problem →

→ A transmission line has a span of 200 metres between level supports. The conductor has a cross-sectional area of 1.29 cm^2, weighs 1170 kg/km and has a breaking stress of 4218 kg/cm^2. Calculate the sag for a safety factor of 5, allowing a wind pressure of 122 kg per square metre of projected area. What is the vertical sag?

Soln. Given data:-

Span length $l = 200m$

wt. of conductor/m length, $w = 1170/1000 = 1.17kg$.

working tension $T = 4218 \times 1.29/5 = 1088kg$.

Diameter of conductor, $d = \sqrt{\frac{4 \times area}{\pi}} = \sqrt{\frac{4 \times 1.29}{\pi}} = 1.28\ cm.$

wind force/m length, w_w = pressure × projected area in m^2

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

Total weight of conductor per metre length is:

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

$$\text{Slant sag},\ S = \frac{w_t l^2}{8T} = \frac{1.95 \times (200)^2}{8 \times 1088} = 8.96m$$

The slant sag makes an angle θ with the vertical whose value of θ is given by.

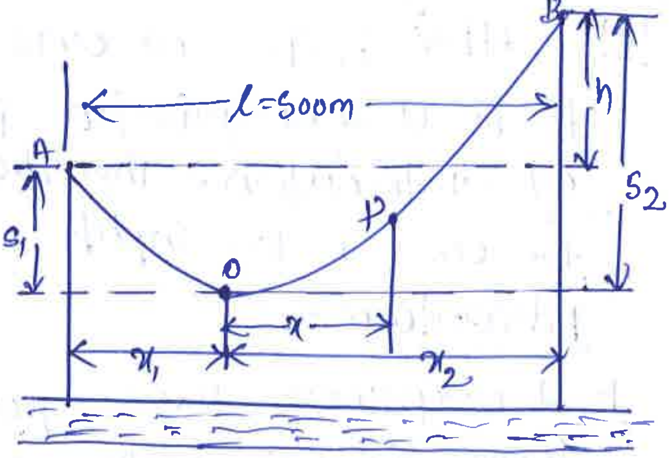
$$\theta = \tan^{-1}(w_w/w) = \tan^{-1}(1.56/1.17) = 53.13°$$

vertical sag $= S \cos\theta = 8.96 \times \cos 53.13° = 5.37\ m.$

* The towers of height 30 m & 90m respectively support a transmission line conductor at water crossing. The horizontal distance the towers is 500m. If the tension in the conductor is 1600 kg. Find the minimum clearance of the

the supports. weight of conductor is 1.5kg/m. Bases of the towers can be considered to be at water level.

Sol^n Given data :-



$l = 500m$

$w = 1.5kg$

$T = 1600kg$

Difference in levels between supports ; $h = 90 - 30 = 60m$.

Let the lowest point O of the conductor be at a distance x_1 from the support at lower level (i.e support A) & at a distance x_2 from the support at higher level (i.e support B).

obviously, $x_1 + x_2 = 500m$.

$$\text{Sag } S_1 = \frac{wx_1^2}{2T} \text{ \& sag } S_2 = \frac{wx_2^2}{2T}.$$

$$h = S_2 - S_1 = \frac{wx_2^2}{2T} - \frac{wx_1^2}{2T}$$

$$60 = \frac{w}{2T}(x_2 + x_1)(x_2 - x_1)$$

$$x_2 - x_1 = \frac{60 \times 2 \times 1600}{1.5 \times 500} = 256m.$$

eqn (i) & (ii), we get $x_1 = 122$; $x_2 = 378m$

$$S_1 = \frac{wx_1^2}{2T} = \frac{1.5 \times (122)^2}{2 \times 1600} = 7m$$

lowest point O from water level
$= 30 - 7 = 23m$

mid-point P be at a distance x from the lowest point O.

$$x = 250 - x_1 = 250 - 122 = 128m$$

sag at mid-point P, $S_{mid} = \frac{wx^2}{2T} = \frac{1.5 \times (128)^2}{2 \times 1600} = 7.68m$.

mid-point P from water level
$= 23 + 7.68 = 30.68m$,

* Explain HVDC transmission system with its advantages and limitations.

Ans ~~HDV~~ 'HVDC' means high voltage direct current. It is a transmission in which transmission occurs by distribution. The d.c is obtained by rectifying the a.c of the input.

Advantages:-

1. It requires less space as compared to HVDC transmission with same voltage rating and size.
2. Ground can be used as return conductor.
3. Less corona loss and radio interference (RI).
4. No charging current.
5. Cheaper for long distance transmission.
6. No skin and Ferranti effect.
7. No switching transient.
8. Asynchronous operations possible.
9. No stability problem.
10. No compensation problem.
11. No transmission of short circuit power in case of fault.
12. power control possible.
13. No reactive power loss.
14. Low short circuit current.
15. Fast fault clearing time.
16. No technical limit for transfer of power except terminal limit.

Limitation:-

(1) High cost of terminal equipment.

→ HVDC transmission system require expensive components

→ capacity.

(ii) Introduction of harmonics:→

→ converters generate considerable amount of harmonics both on ac and dc sides. Also the harmonics may interfere with communication system.

(iii) Blocking of reactive power:→

→ DC lines block the flow of reactive power from one end to another end.

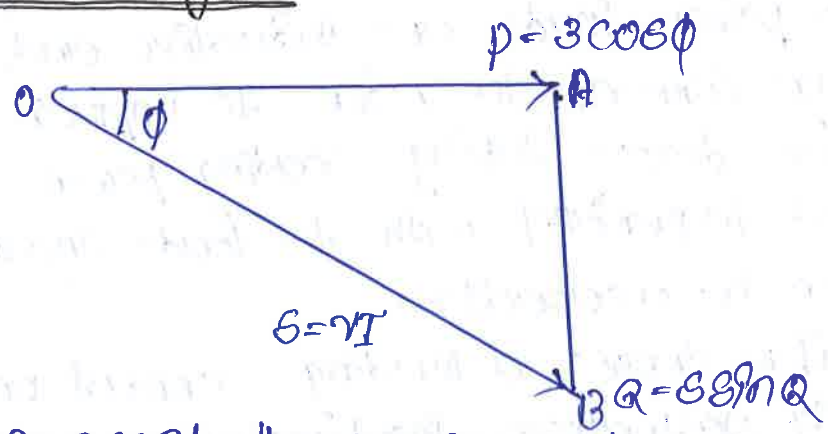
(iv) point to point transmission possible:→

→ It is not possible to tap dc power at several location in the line. whatever power is to be tapped, a control station is required and the co-ordinated with other terminals. This increases the complexity and cost of the system.

→ **power factor:-**

→ The cosine of angle between voltage and current in an a.c circuit is known as power factor.

→ **power triangle:-**



→ OAB represent the power factor.

→ OA = VI cosϕ and represents the active power in watts or unit-KW

→ AB = VI sinϕ and represents the reactive power in VAR

→ OB = VI and represents the apparent power in VA or kVA.

→ **Causes of low power factor:-**

→ Low power factor is undesirable from economic point of view. Normally, the power factor of the whole load on the supply system in lower than 0.8.

→ The following are the causes of low power factor.

(i) Most of the a.c. motors are of induction type (1ϕ and 3ϕ induction motors) which have low lagging power factor. These motors work at a power factor which is extremely small on light load (0.2 to 0.3) and rises to 0.8 or 0.9 at full load.

(ii) Arc lamps, electric discharge lamps and industrial heating furnaces operate at low lagging power factor.

(iii) The load on the power system is varying, being high during morning and evening and low at other times. During low period, supply voltage is increased which increases the magnetisation current. This results in the decreased power factor.

→ **Power factor Improvement:-**

→ The low power factor is mainly due to the fact that most of the power loads are inductive and, therefore take lagging current. In order to improve the power factor, some device taking leading power should be connected in parallel with the load. One of such devices can be a capacitor.

→ The capacitor draws a leading current and partly or completely neutralises the lagging reactive component of load current.

→ This raises the power factor of the load.

→ Power Factor Improvement Equipment :—

① Static capacitor :—

→ The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor generally known as static.

→ Static capacitors are invariably used for power factor improvement in factories.

Advantages :—

(i) They have low losses.
(ii) They require little maintenance as there are no rotating parts.
(iii) They can be easily installed as they are light and require no foundation.
(iv) They can work under ordinary atmospheric conditions.

Dis-advantages :—

(i) They have short service life ranging from 8 to 10 years.
(ii) They are easily damaged if the voltage exceeds the rated value.
(iii) Once the capacitors are damaged, their repair is uneconomical.

② Synchronous condenser :—

→ An over-excited synchronous motor running on no load is known as synchronous condenser. When such a machine is connected in parallel with the supply, it takes a leading current which partly neutralises the lagging reactive component of the load. Thus the power factor is improved.

Advantages :—

(i) The motor windings have high thermal stability to short circuit currents.
(ii) The faults can be removed easily.

→ Dis-advantages:-

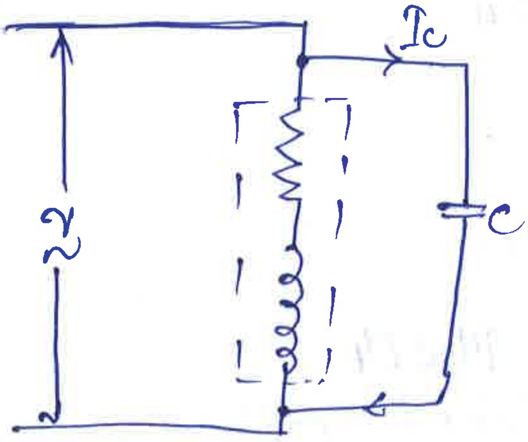
(i) There are considerable losses in the motor.
(ii) The maintenance cost is high.
(iii) It produces noise.

③ Phase advancers:-

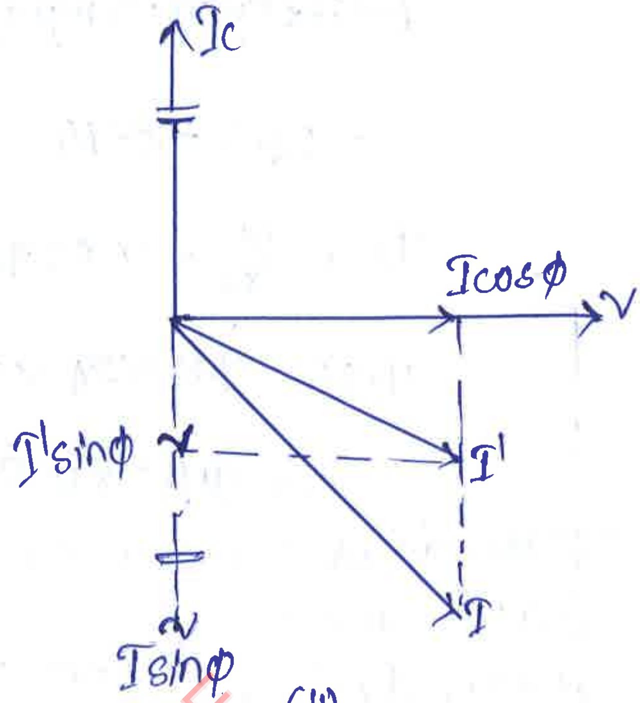
→ Phase advancers are used to improve the power factor of induction motors. The low power factor of an induction motor is due to the fact that its stator winding draws exciting current which lags behind the supply voltage by 90°.
→ This job is accomplished by the phase advancer which is simply an a.c exciter. The phase advancer is mounted on the same shaft as the main motor and is connected in the rotor circuit of the motor.
→ It provides exciting ampere turns to the rotor circuit at slip frequency.

Calculations of power factor correction:-

→ Consider an inductive load taking a lagging current 'I' at a power factor $\cos\phi_1$. In order to improve the power factor of the circuit, the remedy is to connect such an equipment in parallel with the load which takes a leading reactive component and partly cancels the lagging reactive component of the load.
→ The capacitor takes a current I_c which leads the supply voltage V by 90°.
→ The current I_c partly cancels the lagging the reactive component of the load.
→ It is clear that ϕ_2 is less than ϕ_1 so that new p.f $\cos\phi_2$ is more than the ~~po~~ previous p.f. $\cos\phi_1$.



(i)



(ii)

$$I'\sin\phi_2 = I\sin\phi_1 - I_C$$

$$\boxed{I_C = I\sin\phi_1 - I'\sin\phi_2}$$

$$C = \frac{I_C}{\omega V}$$

problem:-

→ A single phase motor connected to 400V, 50Hz supply takes 31.7A at a power factor of 0.7 lagging. Calculate the capacitance required in parallel with the motor to raise the power factor to 0.9 lagging.

Active component of load $= I\cos\phi$

$= 31.7 \times 0.7$

$= 22.19A$

Active component of improved p.f load $= I' \times 0.9$

Current $I = \frac{22.19}{0.9} = 24.65\,A$.

Reactive component $= I\sin\phi$

$= 31.7 \times 0.714 = 22.6A$

Reactive component of $I = I\sin\phi = 24.65\sqrt{1-(0.9)^2}$

$= 24.65 \times 0.436 = 10.75A$

I_c = Reactive component of I_m − Reactive component of I

$= 22.6 - 10.75 = 11.85\,A$

$I_c = \frac{V}{X_c} = V \times 2\pi f C$

$11.85 = 400 \times 2\pi \times 50 \times C$

$C = 94.3 \times 10^{-6} F = 94.3\,\mu F$

→ Max. demand on the system/plant can be known from the load curve.

Max. demand = $\frac{\text{Area under load curve}}{\text{No. of hrs. in a given period}}$

$= \frac{\text{No. of units consumed in a day/monthly/yearly}}{(24\,hrs)/(30 \times 24)/(8760)}$

→ Base load on the system is min. possible demand on the power system. So that actual load on power system is always greater than base load.

→ Based load is calculated from yearly load ~~current~~ curve. It is important for base load power plants.

Characteristics :- (Base load plant)

→ It should have a capacity to run through out the time.

→ It should supply power at low cost.

→ It should have a good efficiency.

→ Connected load is the sum of continuous rating of equipment which are connected to the power system.

Connected load > Generating capacity

Max. demand < Generating capacity

Max. demand < Generating load.

→ Demand factor = $\frac{\text{max. demand}}{\text{connected load}}$ (D.F < 1

→ load factor = $\frac{\text{avg. demand}}{\text{max. demand}}$ L.F < 1 = $\frac{\text{plant capacity factor}}{\text{plant utilisation factor}}$

(load factor alone is enough express the revenue of p.s)

avg. demand < max. demand.

→ If L.F ↑, Revenue of p.s ↑

→ plant utilisation factor = $\frac{\text{max. demand}}{\text{plant capacity}}$

(p.u.f alone can't express the revenue of p.s)

→ Diversity factor = $\frac{\text{sum of individual max. demand}}{\text{coincident max. demand}}$

→ various type of load:- Domestic load, commercial load, Industrial load, lighting load, Agriculture load, Traction load.

→ The min. value of D.F = 1, it is possible when the load are highly coincident.

→ In a practical p.s. D.F > 1 (as high as possible)

→ Diversity factor effects the fixed cost of p.s.

→ If diversity factor decreases, fixed cost of p.s. increases and Revenue increases.

→ plant capacity factor = $\frac{\text{Energy o/p the plant}}{\text{max. Energy that can be generated by the plant}}$

$= \frac{\text{Energy o/p the plant (no. of units generated)}}{\text{plant capacity} \times \text{time}}$

$= \frac{\text{avg. demand}}{\text{plant capacity}}$

$$\text{plant capacity factor} = \text{plant utilisation factor} \times \text{load factor}$$

→ plant use factor = $\dfrac{\text{Energy o/p of the plant}}{\text{plant capacity} \times \text{service hrs}} = \dfrac{\text{avg. demand}}{\text{plant capacity}}$

→ Service factor = $\dfrac{\text{service hours}}{\text{Total no. of hours}}$

→ plant use factor = $\dfrac{\text{plant capacity factor}}{\text{service factor}}$

→ If plant is running all the time then plant use factor = plant capacity factor.

→ If plant is running all the time with max. demand equal to plant capacity

$$\text{plant use factor} = \text{plant capacity factor} = \text{load factor}$$

→ Reserve capacity = plant capacity − max. demand

$$= \text{avg. demand} \left[\frac{1}{\text{plant capacity factor}} - \frac{1}{\text{load factor}} \right]$$

$$= \frac{\text{max demand}\,(L.F - C.F)}{P.C.F.}$$