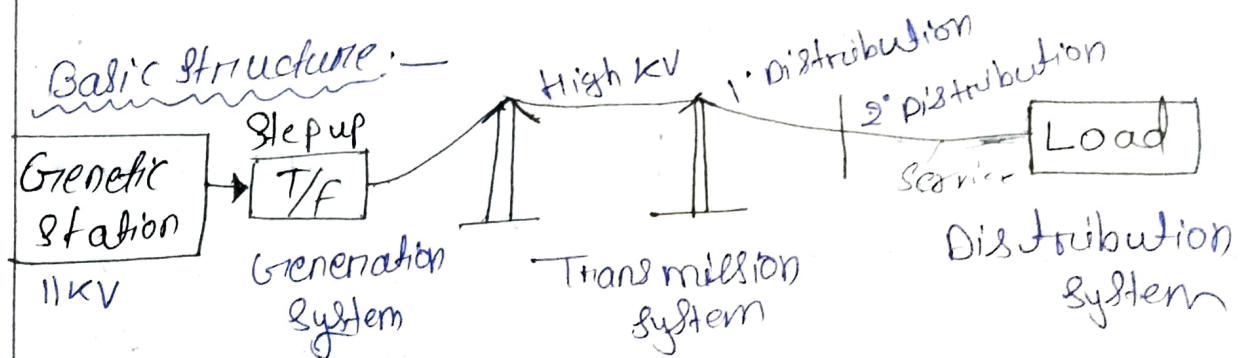


Defⁿ

- An electric power system is a network of electrical components organised in proper way to supply transfer & use electric power
- It is broadly divided into three parts i.e.
- Generation → Supply the power
- Transmission → Carries the power from the genetk station to load centers
- Distribution → It feeds power to nearby homes & industries



Sources of energy:-

- Genetic Stations are two types i.e
- 1) Conventional → traditional
 - 2) Non-Conventional

Difference betⁿ conventional & non-conventional source of energy.

Conventional Source	Non-conventional Sources
→ They are those sources of energy which have been in use for a long time → Ex:- Coal, hydnal, natural gas etc--- → Conventional energy are non-renewable → They cause pollution → Fuels produce from conventional sources of energy are comparatively expensive → It meet a major portion of power requirement	→ They are comparatively new sources of energy → Ex:- Solar, wind, tidal, geothermal etc, → Non-conventional sources of energy are renewable sources. → They cause little pollution or no-pollution. → fuels produce from non-conventional sources of energy are comparatively cheaper. → meet our requirement on a limited scale

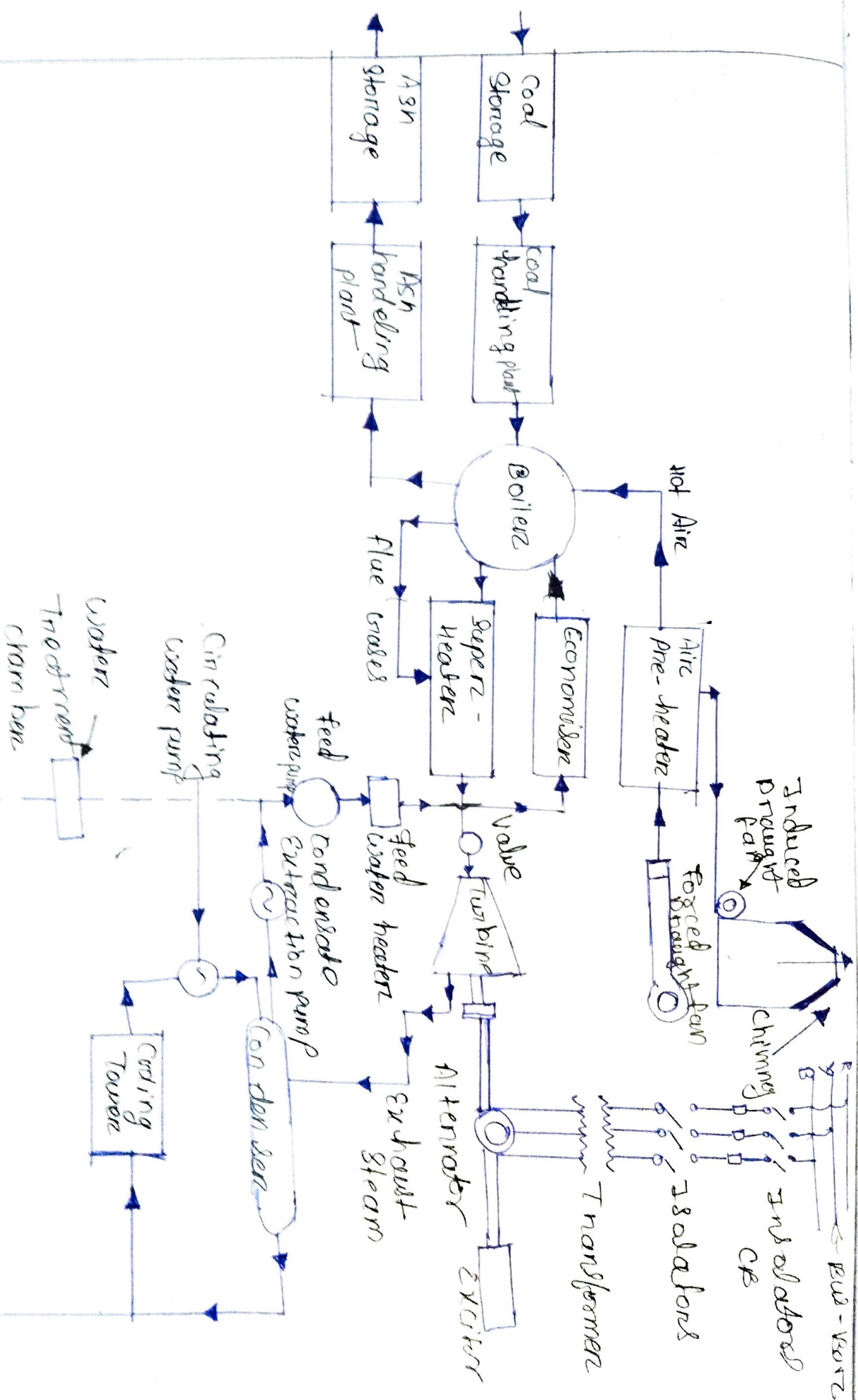
Power Station

- Thermal (Coal)
- Hydro (water)
- Nuclear (radio active element)
- Solar (Sun)

Requirement

- machines
- Raw material
- land
- transmission
- man power
- cost

Generability



Thermal
A ge
of co
Know
pow
Select
The
that
it s
Lan
The
trisi
Fec
Reg
Ra
La
cos
w
ma
I
F
CA
Tr

Thermal power plant:-

A generating station which converts heat energy of coal combustion into electrical energy is known as steam power plant or thermal power plant.

Selection of site for thermal power plant:-

- The site should be nearest to the coal mines so that transportation cost of fuel is minimum or it should have proper rail connectivity.
- Large quantity of water should be available
- The site should not be surrounded by residential building to avoid noise smoke etc...
- Facility for the disposal of ash

Requirement for thermal power plant:-

- Raw material (coal)
- Land
- Cost & manpower
- Water
- Machinery
 - IDF → Induced Draft Fan
 - FDF → Forced Draft Fan
- Capital
- Transportation facility.

Main & Auxiliary equipments in a thermal power plant:-

- Coal & Ash handling plant
- Steam Generator or Boiler
- Super heaters
- Economizer
- Air pre-heater
- Steam turbine
- Condenser
- Cooling tower
- Feed water heater
- Alternator
- Electrostatic precipitator

① Coal & Ash handling plant:-

- The coal is transported to the power station by road or rail & stored in the coal storage plant. Then the coal is delivered to the coal handling plant where it is pulverized to increase its surface exposed. The pulverized coal is fed to the boiler by belt conveyor.
- The coal is burnt in the boiler & the ash produced after the complete conversion of coal is removed to the ash handling plant & delivered to the ash storage plant for disposal.

Types of coals:-

- pit → (worst coal) → (Ash content)
- Lignite
- Bituminous
- Anthracite → (best coal) → (High carbon content)

Boiler:-

- It is a device where water is converted into steam by utilizing the heat of combustion

Super heater:-

- The steam produced in the boiler is wet & it passes through a super heater where it is dried & super heated by the flue gases on the way of chimney
- The main function of the super heater is to increase the overall efficiency of plant
- The super heated steam from the super heater is fed to the steam turbine → heater is fed to the turbine through the main valve

Economizer:-

The feed water from condenser is fed to the economizer before supplying to the boiler. The economizer extracts a part of heat of flue gases to increase the feed water temp.

Air pre heater:-

~~The feed water~~

The air pre heater extracts heat from blue gases & increase the temp of air used for coal combustion & overall it increase the efficiency of plant

Steam turbine:-

- The dry & super heated steam from the super heater is fed to the steam turbine through main valve
- Heat energy of steam when passing over the blades of turbine is converted into mechanical energy
- After giving heat energy to the turbine the steam is exhausted to the condenser where it is converted into water.

Alternators:-

- The steam turbine is coupled to one alternator
- The alternator converts mechanical energy of turbine into electrical energy
- The electrical output from the alternator is delivered to the bus bar through transformer circuit breaker & isolators

Cooling Arrangement:-

Due to scarcity of water, hot water from the condenser is passed on through the cooling tower where it is cooled.

Electrostatic precipitation:-

It absorbs the dust particles present in the flue gas & discharges the purified air to the atmosphere.

Advantages:-

- It requires less space as compared to hydro electric power station.
- It can be installed at any place irrespective of the existence of coal.
- Low initial cost as compared to other generating station.

Disadvantages

- Pollution of atmosphere due to coal combustion.
- Huge quantity of water required.
- High maintenance & operating cost.

Imp

* Efficiency of a steam power plant is quite low i.e. about 29-30%.

* Thermal power plants work on the principle of Rankine cycle.

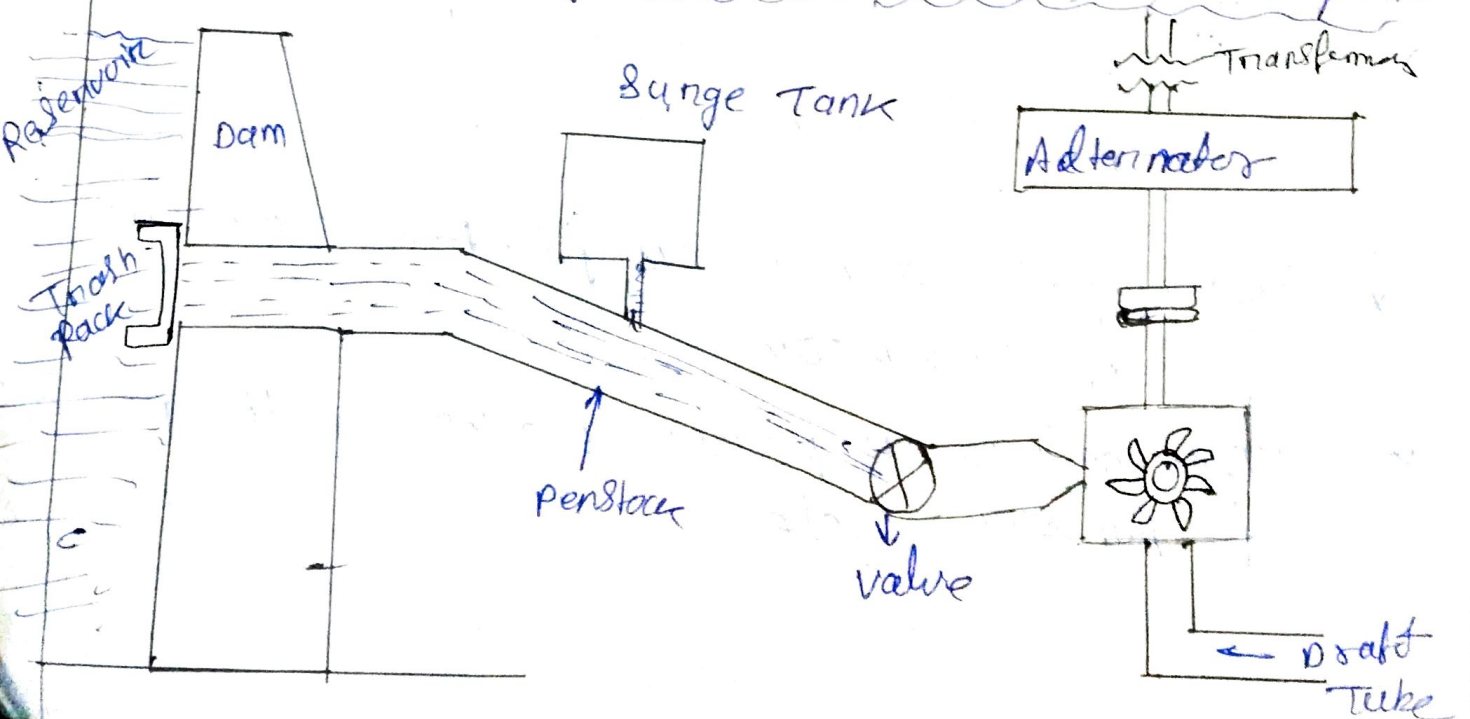
Hydro power plant

A generating station which utilises the potential energy of water at a high level for the generation of electrical energy is known as hydro electric power plant - Station

Selection of site for hydro electric station

- Sufficient quantity of water at a reasonable head should be available
- more area which require for dam and reservoir and
- distance of power station from load centres must not be longer to minimise the transmission cost
- Good road and rail connectivity for the transportation of the construction material and heavy machineries

Schematic arrangement of Hydro-electric plant



The Constituents of hydroelectric plant are

- 1 Hydraulic structure
- 2 Water turbine
- 3 Electrical components

1 Hydraulic Structure

1) Reservoir :- It is a basic structure of a hydro electric power plant

→ Its purpose is to store water which is utilised to run the turbine to generate electrical power

2) Dam :- A dam is a structure which stores water and create water head

- The main function of dam is to provide a head of water to be utilised in the water turbine

3) Spill ways :- It act as a safety valve for a dam

- A spill ways serves to discharge excess water from the reservoir

4) Trash Rack :- The purpose of providing trash Rack is to prevent entering of debris which might damage the turbine runners

- It is made up of steel bar

5) Surge tank :- When the turbine is running at a steady load there are no surges in the flow of water to the penstock

- When the load on the turbine decreases the governor closes the gates of the turbine

Reducing water supply to the turbine

The excess water at the lower end of the penstock rushes back to the surge tank and increases water level and prevent it from bursting.

On the other hand when load on the turbine decreases additional water is drawn from the surge tank to meet the increase load requirement.

The main function of surge tank is to prevent water hammer effect.

v) Penstock: penstock are the conduits which carry water to the turbine.

They are generally made up of steel or reinforced concrete.

② Water turbine: water turbines are used to convert the energy of flowing water into mechanical energy.

The main types of water turbines are impulse turbine, Reaction turbine.

Impulse - use for high head

Reaction - low and medium head

③ Electrical equipment: The electrical equipment of a hydro electric power plant includes generators, transformers, circuit breakers and other switching and protecting devices.

Advantages of

- 1- It is quite neat and clean as no smoke or ash is produced
- It requires very small running charges because water is source of energy which is available free of cost
- It doesn't require a long starting time like a steam power plant
- It is robust and has longer life.
- It can be used as multipurpose project i.e. in addition to the generation of electricity they also help in flood control

Disadvantages

- It involves high capital cost due to construction of dam
- Weather condition may affect its production capacity
- Skill and experienced men are required to build the plant

Nuclear power plant

A generating station in which nuclear energy is converted into electrical energy is known as nuclear power plant

Site Selection for nuclear power plant (Station)

- As sufficient water is required for cooling purpose the plant site should be located where ample quantity of water is available
- The waste produced in a nuclear power station is generally Radio active which must be disposed of properly to avoid health hazards
- The site selected should have proper transportation facility
- The site selected for a nuclear power station should be quite away from the populated areas

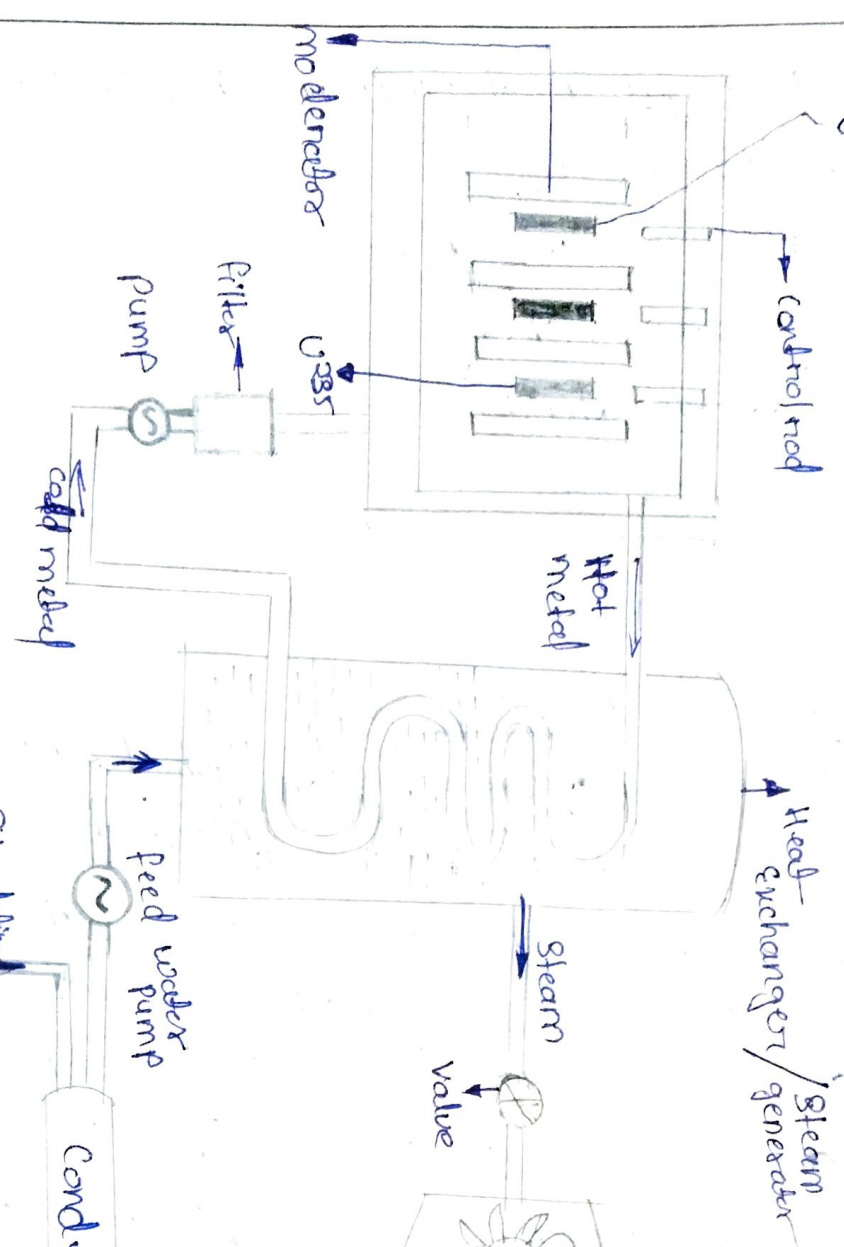
Schematic Arrangement of N. Requirement of Nuclear plant

- Fuel (U, Th)
- Land
- Capital
- Mechanisms
- Man power
- Source of water

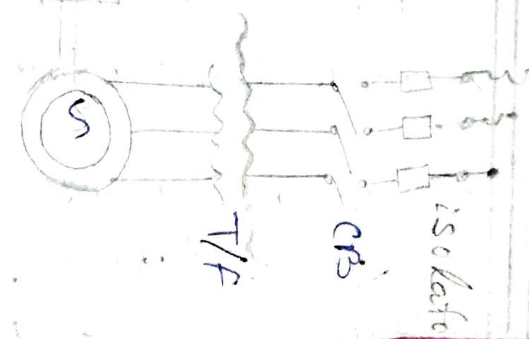
U-235
U-238
Control rod

Control Rod
Boron
cadmium
Hafnium

moderator
D₂O, graphite



Busbar



Water H₂O

Nuclear power station mainly consist of the following.

Fusion - Sun
 U^{235}

- ① Nuclear Reactor
- ② Heat exchanger
- ③ Steam turbine
- ④ Condenser
- ⑤ Alternator

① Nuclear Reactor

It is an apparatus in which, nuclear fuel U^{235} is subjected to nuclear fission.

- It controls the chain reaction that starts once the fission is done. If the chain reaction is not controlled the result will be an explosion due to fast increase in the energy released.
- A nuclear reactor is a cylindrical vessel which houses fuel rods of uranium (U), moderators and control Rod.
- The fuel Rod constitute the fission material and release huge amount of energy and when bombarded with slow moving neutron.
- The moderator consist of graphite Rod which enclose the fuel Rods. The moderator slows down the neutrons before they bombarded the fuel Rod.

- The control Rods are of cadmium and are inserted into the Reactor. Cadmium is strong neutron absorber and thus, regulates the supply of neutron per fission
- When the control rods are pushed in deep enough they absorb most of fission neutron. and hence ~~a~~ ^{the} fuel ~~is~~ ^{is} not available for chain Reaction
- However, as they are being withdrawn more and more of this fission neutrons cause fission and intensity of chain Reaction increases
- The lowering or raising of control Rods is done automatically according to the load requirement
- The heat produced in the reactor is removed by the coolant. the coolant carries the heat to the heat exchanger

b Heat exchanger :- The coolant gives up heat to the heat exchanger which is utilised in raising the steam after giving off heat the coolant is again ~~a~~ ^{is} fed to the reactor

c Steam turbine

- The steam produced in the heat exchanger is fed to the steam turbine through a valve
- After ~~a~~ ^{doing} a useful work in the turbine the steam is exhausted to the condenser

- The condenser condenses the steam which is fed to the heat exchanger through heat water pump

Alternator :- The steam turbine drives the alternator which converts mechanical energy into electrical energy.

Advantages

- Amount of fuel required is quite small ~~heat~~
- It requires less space as compared to any other type
- Low running charges as small amount of fuel is used for producing bulk electrical energy
- Economical for producing bulk electric power
- It ensures ~~reliability~~ reliability of operation

Disadvantages

- The fuel used is expensive and is difficult to remove
- Capital cost is very high
- The erection and commissioning of the plant requires greater technical knowledge

The by products are generally radio active and may cause dangerous amount of radio active pollution

Solar power plant

A power plant that convert solar energy into electrical energy is called solar power plant.

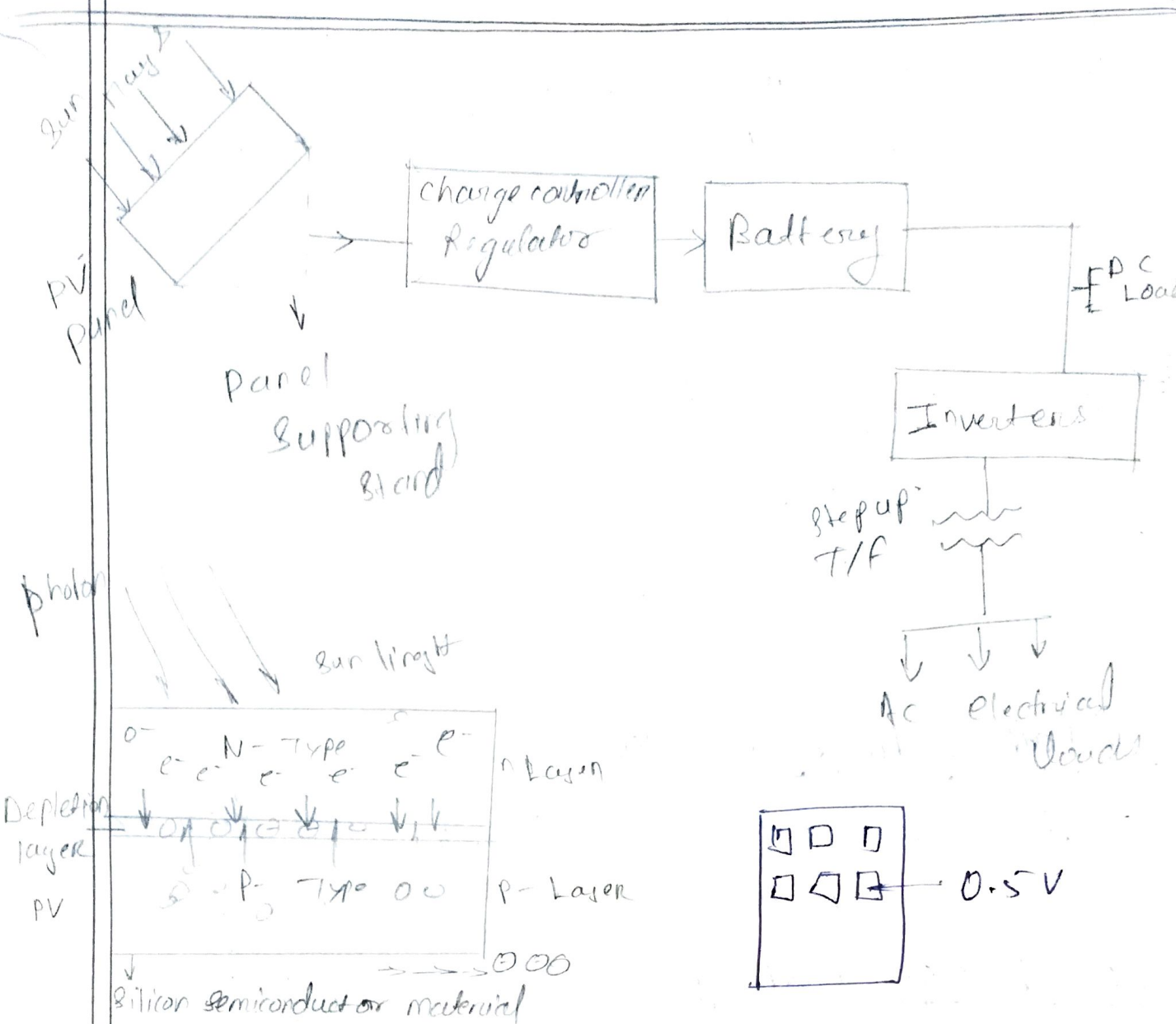
~~Solar power plant is based on the conversion of sun light into electricity.~~

PV ~~modules~~
concentrated (Reflectors)

Solar power plant is based on the conversion of sun light into electricity, either directly using photovoltaic (PV) or indirectly using concentrated solar power.

Concentrated solar power system use lenses or mirrors and tracking system to focus a large area of sun light into a small beam.

PV converts light into electric current using the photo electric effect.

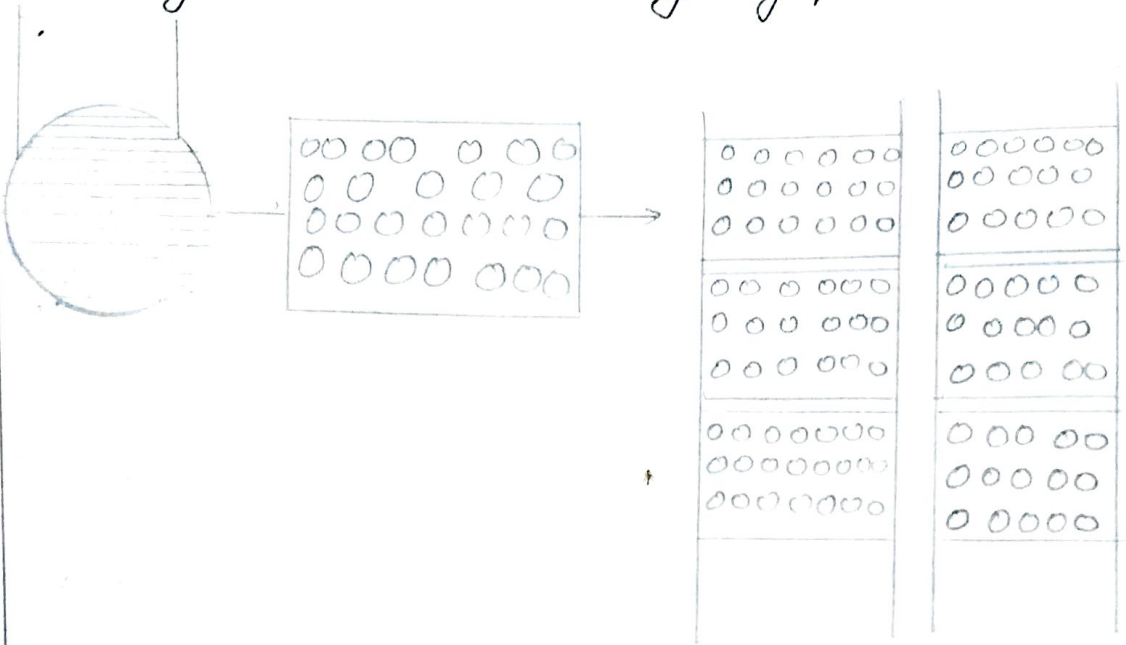


Solar panel:-

It Refers to a panel design to absorb the sun rays as a source of energy for generating electricity.

Solar PV panels constitute the solar module of a PV system that generate and supplies solar electricity in commercial and residential application.

Its function is to convert energy of sun light directly into Dc electricity by photo voltaic effect



(b) Battery charge controller

- > It's function is to increase life of storage battery
- It protects battery from over charging

(c) Storage Battery

- It's function is to store Dc electrical energy generated by pv ~~set~~ cells which can be used whenever required
- It has long life
- Commonly used batteries are Lead acid Battery
Nickel-cadmium battery

Inverter

- It convert Dc supply into ac supply.

Step up transformer

- It's step up then put voltage to utilization voltage

Process

As Sun light hits the solar panel the solar radiation is converted into direct electricity DC

The direct current flows from the panels and is converted into AC by inverters which is used by Local electric utility

Finally the electricity travels through transformer and the voltage is Boosted for delivery onto transmission lines

Types

1) Stand alone system

2) Grid connected system / Grid

Free of cost

Advantages

- Solar energy is clean and renewable source of energy
- It causes no pollution
- Very little maintenance is needed to keep solar cells running. There are no moving parts in a solar cell which makes it impossible to damage them

Disadvantages

- Solar panel can be expensive to install
- Electricity generation depend on the intensity of a sunlight
Exposure to Sun light
- Solar power station do not match the power output of similar sized conventional power station
- The batteries can upon be large and heavy taking of space and needing to be replaced from time to time

Ques

Q Write down the name of material used as control rod in nuclear power plant

Q write down the name of material used as moderator

Q write down the numbers of nuclear power plant and there location in india

→ nuclear reactor 22

Chapter-2

Transmission of electrical power

Elect. Supply System :- The conveyance of electric power from a generating station to a consumer's premises is known as electric supply system. An electric supply system consists of three principal components or three main components

- (*) generating station, Transmission System, Distribution System

generating station :- Electric power is produced at the power station which are ~~located~~ located in a favourable place generally quite away from the consumer.

Transmission lines :- ~~It is that~~ Electric power is then transmitted over large distances to load centers with the help of conductors known as transmission lines.

Distribution system :- Finally it is distributed to a large no. of small and big consumers through a distribution network.

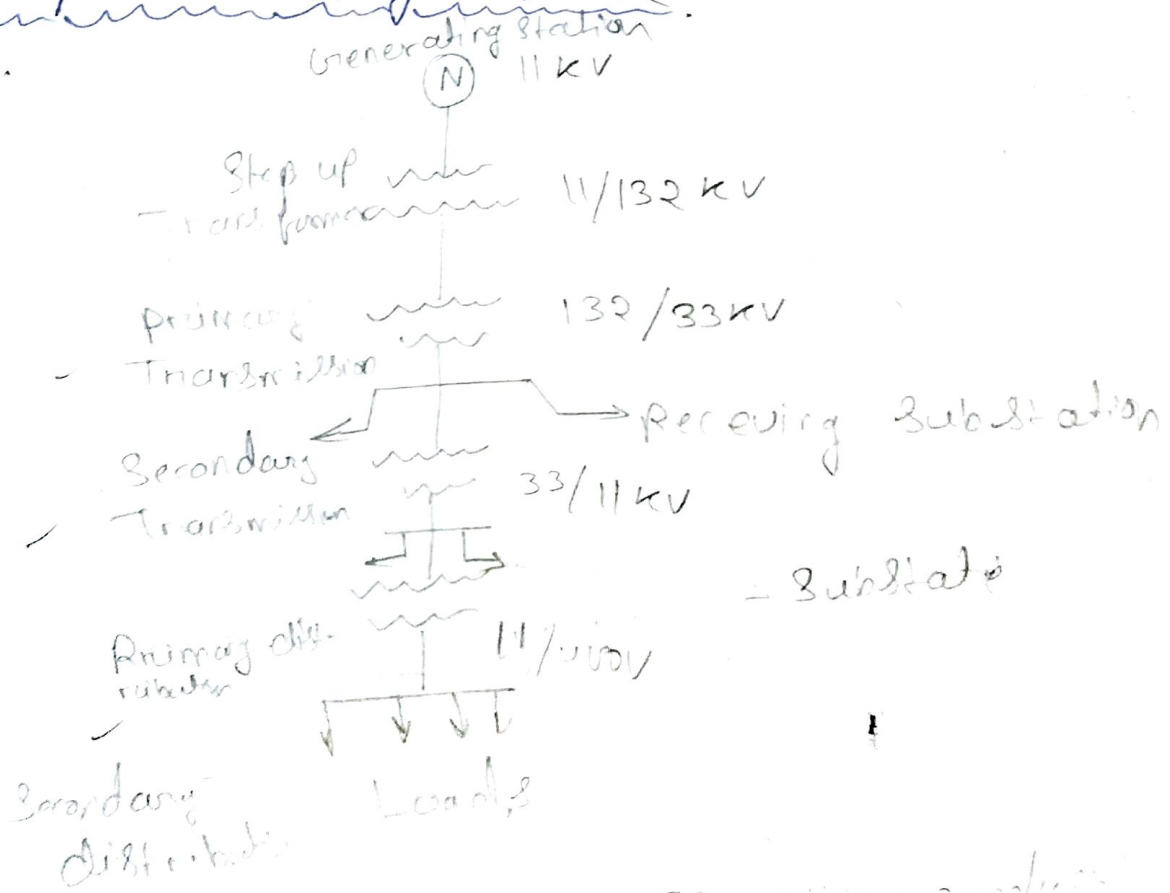
Classification

The elect. Supply System can be classified into

- i) Ac or Dc System
- ii) Over head and underground system
- iii) Three phase 3 wire system
- iv) Three phase four wire system

Imp

A.c power Supply Scheme



33 → 11 kV conductor

system

⑧ Distribution System

- > Feeder (Conduct use 33 kV to 11 kV)
- > Distributor (11 to 400 V)
- > Service mains (pole to house)

Generating Station:-

- > It is the set-up where electric power is produced by 3 phase alternators operating in parallel
- > The usual generation voltage is stepped ~~up~~ up to 132 kV at the generating station with the help of 3ph Transformer.
- > The Transmission of electric power at high voltages has the advantage of saving of conductors material & high Transmission efficiency.
- > We ~~not~~ don't increase the voltage beyond certain limit because it increase in Transmission voltage introduces insulation problems as well as cost of switchgear & T/F equipment is increased
- > Generally the primary Transmission is carried at 66 kV , 132 kV , 220 kV & 400 kV

Primary Transmission

- Electric power at 132kV is transmitted by 3ph 3 wire or system to the outside of the city this forms the primary Transmission

Secondary Transmission

- The primary Tx line terminates at the receiving station which usually lies at the outside of the city
- At the receiving station the voltage is reduced to 33kV by step down transmission
- From this station, electric power is transmitted at 33kV by 3ph 3 wire or system to various substation located at diff. points in the city. This forms the secondary Tx system

Primary Distribution

- The secondary Transmission line terminates at the substation where voltage is reduced from 33kV to 11kV 3ph, 3 wire
- The 11kV lines run along the important road sides of the city. This forms primary distribution.

Secondary

- The distribution near the distribution

~~The voltage between~~

- The connection as

3ph

- The (a)

(ii)

(iii)

Feeder

Supply

The this

Secondary Distribution

→ The 11kV distribution line delivers to the distribution substation, which is located near the consumer's localities & step down the voltage to 400V, 3ph wire for local distribution.

→ The voltage b/w any 2 phases is 400V & voltage between any phase & neutral is 230V

→ The 1-ph residential lighting loads are connected between any phase & neutral whereas 3ph 400V motor load is connected across 3ph line directly.

→ The secondary distribution system consists of

(i) Feeder ← primary dist. / from a to distributed

(ii) Distributors

(iii) Service mains

Feeders radiating from distribution substation supply power to the distributors

The consumers are connected to distributors through service mains

Voltage Regulation :- It is used to maintain a constant voltage on the transmission line

It is defined as the ratio of difference betⁿ the sending voltage and receiving end voltage to the receiving end voltage of a transmission line betⁿ condition of no load full load

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

where V_S = Sending end voltage

V_R = Receiving end voltage

Efficiency :- It is defined as the ratio of the power delivered at the receiving station or Receiving end to the power sent from sending end

$$\text{Efficiency } (\eta) = \frac{\text{O/P}}{\text{inpt.}} = \frac{V_R}{V_S} = \frac{P_R}{P_S}$$

$$\text{Power Efficiency} = \frac{P_R}{P_S}$$

$$= \frac{P_R}{P_R + \text{loss}}$$

$$= \frac{P_R}{P_R + \text{loss}}$$

$$\text{loss} = \kappa I^2 R$$

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

— for single phase system $\kappa = 1$
3 phase system $\kappa = 3$

Imp

Economic of power transmission

— The two fundamental economic principles which closely influence the electrical design of a transmission line are

- (i) - Economic choice of conductor size
- (ii) - Economic choice of transmission voltage

(i) Economic choice of conductor size

Kelvin's Law

It states that the most economical area of conductor is that for which the total annual cost of transmission line is minimum ~~that is~~ (i.e) the variable part of annual charge is equal to the cost of energy loss per year

The total cost of transmission line can be broadly divided into two parts

- (a) Annual charge on capital outlay
- (b) Annual cost of energy wasted in the conductor.

~~(a)~~

(a) Annual charge on capital outlay

In case of overhead system it will be the annual interest and depreciation on the capital cost of conductor, support and insulators and the cost of erection

→ So annual charge on an overhead transmission line can be expressed as

$$\text{annual charge} = P_1 + P_2 a \quad \text{--- (1)}$$

where $P_1, P_2 = \text{Constant}$

$a = \text{area of cross section of conductor}$

(b) Annual cost of energy wasted in the conductor

→ The amount of energy lost in a conductor

Due to $I^2 R$ loss

→ The energy loss in a conductor is proportional to 'R'

→ And this 'R' is inversely proportional to the area of cross section of conductor

i.e. $R \propto \frac{1}{a}$

∴ P loss = $I^2 R$

$$P_{\text{loss}} \propto R$$

$$P_{\text{loss}} \propto \frac{1}{a}$$

$$P_{\text{loss}} \propto \frac{1}{a}$$

Therefore the energy loss in the conductor is conventional proportional to the area of cross-section.

— So annual cost of energy wasted in an overhead transmission line can be expressed as

$$\text{annual cost of energy wasted} = \frac{P_3}{a} \quad \text{--- (11)}$$

where $P_3 = \text{constant}$

From equation (1) and (11)

$$\text{Total cost (C)} = P_1 + P_2 a + \frac{P_3}{a} \quad \left(\text{here only 'a' is variable} \right)$$

Total annual cost of the transmission line will be minimum if differentiation of 'C' with respect to 'a' is zero

$$\text{i.e. } \frac{dC}{da} = 0$$

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

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

$$\Rightarrow 0 + P_2 + (-P_3 a^{-2}) = 0$$

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

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

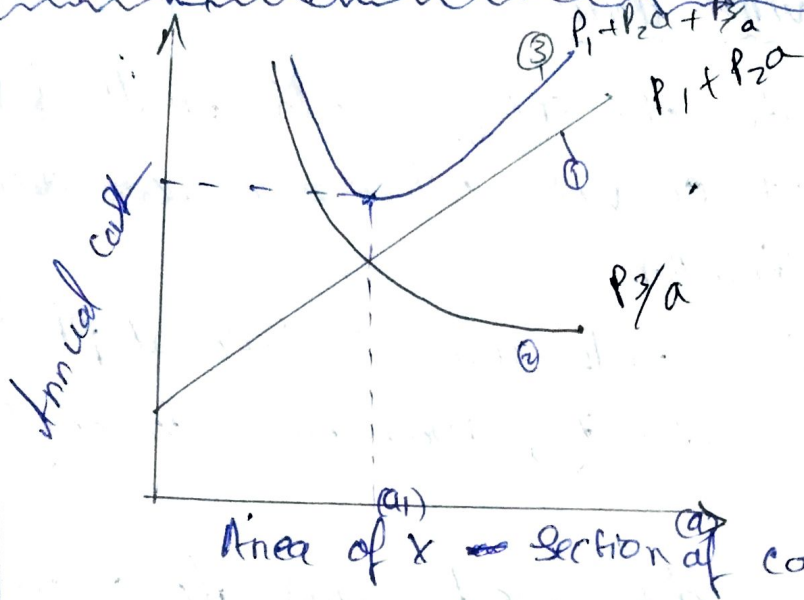
$$\Rightarrow P_2 = \frac{P_3}{a^2}$$

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

 $\rightarrow$ Kelvin's law
~~P₂a~~

That is variable part of annual charge equal to annual cost of energy wasted

Graphical Representation of Kelvin's Law



- It is the graph between annual cost and the area of x-section of conductor
- The Straight line 1 represents the relation betⁿ annual charge $P_1 + P_2a$ and the area of x-section of the conductor
- The graph '2' represents the relation betⁿ annual cost of energy wasted and area of x-section a
- Graph '3' represents the relation between total annual cost $P_1 + P_2a + P_3/a$ of transmission line and area of x-section a
- From the graph it is found that the cost will be minimum that is i.e. $P_2a = P_3/a$

Limitation of Kelvin's law

- It is really difficult to estimate the energy loss in the line without actual load curves which are not available at the time of estimation.
- This law does not take into account several physical factors like current density, mechanical strength, corona loss etc.
- The conductor size determined by this law may not always be practicable.
- Interest and depreciation on the capital outlay in the form of ~~in the form of~~ cannot be determined accurately.
- The assumption that annual cost on account of interest and depreciation on the capital outlay in the form $P_1 + P_2 a$ is not practically true.

Numerical

- Q. A two conductor cable one is 1 kilometer is required to supply a constant current of 200 Amp through out the year. The cost of cable including installation is $(20a + 20)$ per meter where 'a' is area of x-section of conductor in cm^2 . The cost of energy is 5 paise per kWh and interest and depreciation charges amount to 10%.

Calculate most economical conductor size
 (Assume Resistivity of conductor material to be $1.73 \mu\Omega/\text{cm}$)

Ans → Given Length of cable = 1 km
 $I = 200 \text{ amp}$

Annual energy cost of cable = $(20a + 20) \cdot P_1 + P_2 = [20 + 20a]$

energy cost = 5 paise / kWh

Interest = 10 %

(3) Resistivity = $1.73 \mu\Omega/\text{cm}$
 $= 1.73 \times 10^{-6} \Omega/\text{cm}$

find a ?

energy loss in the conductor

energy = $P \times t$
 Power $\times$ Time

1 km = 1000 m
 $= 1000 \times 10^2 \text{ cm}$
 $= 100000$
 $= 10^5$

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

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

$$R = \frac{0.173 \Omega}{a}$$

For 2 conductors $R_T = 2 \times R$

$$= \frac{2 \times 0.173 \Omega}{a}$$

$$= \frac{0.346 \Omega}{a}$$

$$\text{Annual energy waste} = I^2 R t$$

$$= (200)^2 \times \frac{0.346}{a} \times 8760$$

$$= \frac{121238400}{a} \text{ Wh}$$

Note

$$= 365 \text{ day} \times 24$$

$$= 8760$$

$$\text{kWh} = \frac{121238400}{1000 \times a} \text{ kWh}$$

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

Annual cost of energy ~~cost~~ ~~cost~~

$$= \text{annual energy waste} \times \text{cost/kWh}$$

$$= \frac{121238.4}{a} \times \frac{5}{100}$$

$$= \frac{12123840 \times 5}{100 \times a}$$

$$= \frac{60619200}{a}$$

$$= \frac{6062}{a}$$

(P.39)

The capital cost of cable is £ 20a / ~~per~~ meter

$$\text{for 1 km length of cable the capital cost} = 20a \times 1000$$

$$= 20 \times 10^3 a$$

pa

Variable annual charge = annual interest and depreciation on capital cost of cable

$$= 0.1 \times 2.0 \times 10^3 a$$

$$= 200a$$

According to Kelvin's law for most economical
* section of conductor
variable annual charge = annual energy waste

$$200a = \frac{6062}{a}$$

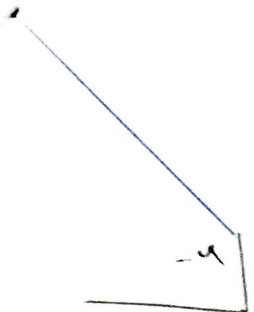
$$200a^2 = 6062$$

$$a^2 = \frac{6062}{200}$$

$$a^2 = 3.031$$

$$a = \sqrt{3.031}$$

$$a = 1.7409 \text{ cm}^2$$



d

→ a_{res} Annual variable charge = cost of annual energy loss
 $d_{ind} = a$ x-sectional area of conductor

$$\Rightarrow P_2 a = P_3 / a$$

P_3 - energy loss

$$\text{energy} = I^2 R t$$

$$R = 2 \times \frac{l}{a}$$

$$= \frac{2 \times 1.73 \times 10^{-6} \times 10^5}{a}$$

$$\rightarrow \boxed{R = \frac{0.346 \Omega}{a}}$$

$$t = (365 \times 24) \text{ hr}$$

$$\rightarrow \boxed{t = 8760}$$

$$\frac{a d}{d = 1 \text{ Km}}$$

$$1 \text{ km} = 1000 \text{ m}$$

$$1 \text{ m} = 100 \text{ cm}$$

$$1000 \times 100$$

$$= 10^5 \text{ cm}$$

$$\text{Annual energy loss} = I^2 R t$$

$$= 200^2 \times \frac{0.346}{a} \times 8760$$

$$= \frac{121238400}{a} \text{ wh}$$

$$P_2 a = \frac{121238400}{a \times 1000} \text{ kWh}$$

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

cost of annual energy lost .
 1 kWh $\rightarrow$ 5 p

$$\frac{121238.4}{a} \rightarrow \frac{5p}{100} \times \frac{121238.4}{a}$$

$$\frac{P_3}{a} = \frac{6062}{a}$$

P2. cost of conductor

$$20a / \text{mtr}$$

$$1 \text{ meter} - 20a$$

$$1 \text{ km (or) } 1000 \text{ m} \rightarrow 20a \times 1000$$

$$= 20 \times 10^3 \times a$$

10%
Interest

10% .

$$\text{Variable annual cost with annual interest and depreciation charge} = 0.1 \times 20 \times 10^3 \times a$$

$$= \boxed{2000a} \quad P_2 a$$

Annual variable charge

According to Kelvin's law for most economical cost of conductor variable annual charge = cost of annual energy loss

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

$$\Rightarrow 2000 a = \frac{6062}{a}$$

$$\Rightarrow \frac{2000 a^2}{6062}$$

$$= 2000 a^2 = 6062$$

$$\Rightarrow a^2 = \frac{6062}{2000}$$

$$= a = \sqrt{\frac{6062}{2000}}$$

$$= 1.73 \text{ cm}$$

CORONA

- violet glow
- hissing sound
- formation of ozone (O_3)

The phenomenon of violet glow, hissing sound and production of ozone gas in an overhead transmission line is known as corona.

- It also causes power loss and radio interference in transmission lines.
- The glow is maximum over rough and dirty surfaces of the conductor.

Corona formation

Some ionisation is always present in air due to cosmic rays, Radio activity and UV Radiation.

- In normal condition the air surrounding the conductor contains some ionised particles and neutral molecules.
- When potential difference is applied between conductors, potential gradient is set up in the air which has maximum value at the surface of conductor.
- Under the influence of potential gradient the existing free electrons acquire greater velocity.

when the potential gradient at condⁿ surface reaches about 30 kV per cm the velocity of free electrons sufficient to strike the neutral molecule with enough force to dislodge one or more electron from it.

This produces another ions and one more free electron which in turn excited and collide with other neutral molecules thus producing another ions. the result of this ionisation is that either corona or spark is produced.

Some important terms

- (1) Critical Disruptive voltage
- (2) Normal critical voltage

(1) Critical Disruptive voltage

- It is the minimum voltage at which corona occurs

mathematically

$$V_c = 30 g \sin \log_e \frac{d}{r} \text{ kV/ph}$$

$$\frac{d}{2} = R$$

(polish $m = 1$)

where m_0 = irregularity factor

g_0 - Breakdown strength of air at 76 cm of mercury at 25°C

30 kV/cm (max)

Δ - air density factor

r = Radius of conductor

d - Spacing betⁿ the conductors

② visual critical voltage

- It is the minimum voltage at which corona glow appears all along the conductors

mathematically.

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

Power loss due to corona

- Formation of corona is always accompanied by energy loss which is dissipated in the form of light, heat, sound, chemical action

$$P = 242 \cdot 2 \left(\frac{f+25}{8} \right) \sqrt{\frac{\pi}{d}} (v-v_c)^2 \times 10^{-5} \text{ kW/km/ph}$$

Power loss $\propto (f + 25)$

Q 50 Hz ... = 6000

70 Hz ... ?

power loss $\propto (f + 25)$

$$\frac{P_2}{P_1} = \frac{f_2 + 25}{f_1 + 25}$$

$$\frac{P_2}{6000} = \frac{70 + 25}{50 + 25}$$

$$\frac{P_2}{6000} = \frac{95}{75}$$

Factors Affecting Corona

- Atmospheric condition
- Line voltage
- Spacing between the conductors
- Conductor size

Factors affecting corona:-

i) Atmospheric condition:-

- As corona is formed due to ionisation of air surrounding the conductors, therefore it is affected by the physical state of atmosphere
- In stormy weather the no. of ionisation than normal & as such corona occurs at much less voltage as compared with fair weather

ii) Conductor size

- The corona is affected by the size (diameter) shape (stranded or smooth) & surface condition (dirty / clean) of the conductor
- The rough & irregular surface will give rise to more corona because uneven of the surface decreases the value of break down voltage
- Thus a stranded conductor less irregular surface & hence gives rise to more corona than a solid conductor

- Corona decreases with increase in diameter of conductor

(iii) Spacing between conductors

→ If the spacing between the conductors is made very large as compared to their diameters there may be not be any corona effect

- Distance between conductors reduces the electrostatic stresses at the conductors surfaces thus avoiding corona formation

(iv) Line voltage

→ If line voltage is low there is no charge in the condition of air surrounding the conductors hence no corona is formed

- If the line voltage is more & has such a value that electrostatic stress developed at the conductor surface make the surrounding air conducting hence corona is formed

Advantage-2

- Due to corona the air surrounding the conductor becomes conducting and hence virtual diameter of conductor ~~becomes~~ increased hence it reduces the electrostatic stresses between the conductors.
- Corona reduces the effects of transients produced by surges.

Disadvantages

- Corona cause power loss, this affects the transmission efficiency of the line.
- (ii) ozone is produced by corona & may causes ~~corrosive~~ corrosion 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, this may cause inductive interference with neighbouring communication lines.

Methods of Reducing corona effect

- By increasing conductor size the voltage at which corona occurs is raised & hence corona effects are considerably reduced
- Thus ACSR conductors are used which have larger cross-sectional area
- ii) By increasing conductor spacing
 - By increasing between conductors the voltage at which corona occurs is raised & hence corona effects can be reduced to a certain limit

CH-3

Components of OH Tx Lines

- Conductor - ACSR
- Tower
- Poles — Steel, Iron, RCC, wood
- Circuit breaker
- Isolator
- Insulator — porcelain,
- Jumper
- ✓ Damper
- Earthing wire
- Lightning arrestor
- ~~Stay~~. Stay
- CT, PT
- Corona ring

Q. A Three conductor cable 3 kilometer long is required to supply a constant current of 300 Amp through out the year the cost of cable including installation is ~~Rs~~ \$ (3000 + 4000a) per kilometer where a is area of x-section of conductor in cm^2 .
 the cost of energy is \$20/~~per~~ kWh and interest and depreciation charges amount to 20%.
 calculate the most economical conductor size
 assume Resistivity $(1.8 \times 10^{-6} \text{ ohm-cm})$

Ans

$$P + P_a + \frac{P_s}{a}$$

$$\frac{P_s}{a} - \text{energy loss}$$

$$\begin{aligned} \underline{\text{energy}} &= I^2 R t \\ &= 300^2 \cdot R \cdot 8760 \\ &= 300^2 \times \frac{1.62}{a} \times 8760 \\ &= \frac{1277208000}{a} \text{ Wh} \end{aligned}$$

$$\begin{aligned} &\text{1 year} \\ &365 \times 24 \\ &= 8760 \\ &R = 3 f \frac{d}{a} \\ &= \frac{3 \times 1.8 \times 10^{-6} \times 3 \times 10^5}{a} \\ &= \frac{1.62}{a} \end{aligned}$$

$$l = 3 \text{ kilometer}$$

$$= 1 \text{ kilom} = 1000 \text{ meter}$$

$$3 \text{ ki} = 3000 \text{ meter}$$

$$1 \text{ m} = ~~1000~~ 100 \text{ cm}$$

$$3 \text{ m} = 300 \text{ cm}$$

$$\begin{aligned} & \cancel{3000 \times 300} \\ & - \cancel{900000} \\ & - \phi \quad 3 \times 10^5 \end{aligned}$$

~~6a~~

$$\frac{P_3}{a} = \frac{1277208000}{a \times 1000} \text{ kWh}$$

$$\boxed{\frac{P_3}{a} = \frac{1277208}{a} \text{ kWh}}$$

Cost of energy lost

$$1 \text{ kWh} \rightarrow \text{₹ } 20$$

$$= \frac{1277208}{a} \times 20$$

$$\frac{P_3}{a} = \frac{25544160}{a}$$

cost of energy conductor

$$P_2 a = 4000 a \text{ Kilometre}$$

$$= 4 \times 10^3 a$$

Variable annual cost with annual interest and dep. charge 20%

$$= 0.2 \times 4 \times 10^3 \times a$$

$$= 800 a \text{ P/a}$$

annual variable cost

$$(P_2 a = \frac{P_2}{a})$$

$$= 800 a = \frac{2554160}{a}$$

$$= 800 a^2 = 2554160$$

$$\rightarrow a^2 = \frac{2554160}{800}$$

$$\rightarrow a = \sqrt{\frac{2554160}{800}}$$

$$= 56.503 \text{ cm}$$

COMPONENT OF OH. T_w LINE

⇒ Conductor:-

Copper

- High conductivity
- High tensile strength
- High scrap value

Limitation

- High cost
- Specific gravity high

Aluminium

- good conductivity (60% copper)
- High tensile strength
- low specific gravity
- low cost

Limitation

conductivity ↓ → x-section area ↑ → Size of conductor ↑

Size of cross arm ↑ Strength or support ↓ → Size ↑

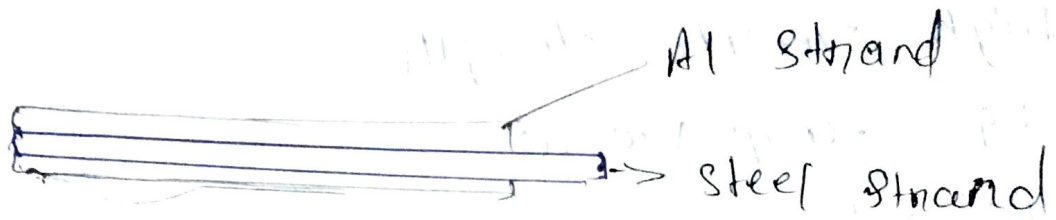
AAC - All Aluminium conductor

AAAC - All aluminium alloy conductor

ACSR - Aluminium conductor steel Reinforced

ACSS - Aluminium Conductor Steel Supported

ACSR



Overall diameter of ACSR conductor

$$D = (2n - 1)d$$

where n = no. of strands

d - diameter of each strand

no. of Al Strand
denoted $\frac{30}{7}$ — no. of steel strand

$1 + 6 + 12 + 18 + 24 + 30$
7 Steel Strand Al. Strand

→ Dog

→ Zebra

→ Panther

→ moose

→ Rabbit

Tx Line ACSR conductors

(ACSR) Conductor name	used for	no. of Al strand
Dog	33 or 66 kv	6
Panther	66 or 132 kv	3
zebra	220 kv	54
moose	220 (or) 400 kv	54

ACSR

- Hard drawn Al
- Low flexibility as compared to ACSS

ACSS

- Annealed Al
- High flexibility as compared to ACSR

Galvanised Steel

- Short Range Transmission
- Low conductivity

Cadmium copper

100% 2% Cd + 98% copper

UNIT-3

3.1 Main components of overhead lines

- An overhead line may be used to transmit or distribute electric power, As the overhead lines are subjected to different weather conditions and other external interference the successful operation of an overhead line depends upon the mechanical design of the line
- While constructing an overhead line, it should be ensured that mechanical strength of the line is such that it can withstand every worst condition caused by the interference
- The main components of an overhead line are given as follows

conductors

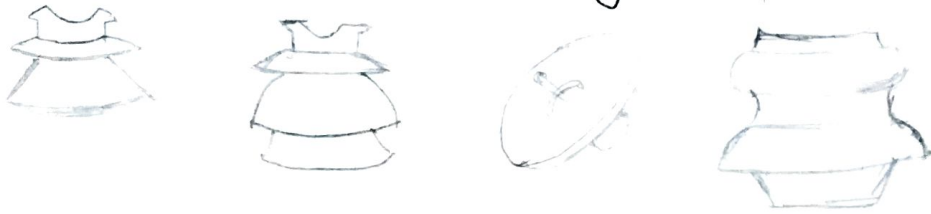
Conductors are the medium that carry electric power from the sending end station to the receiving end station

ii) Supports

- These are the structures used to keep the conductors at a suitable level above the ground
- It may be poles or towers made up of wood, steel or RCC

iii) Insulators

They are attached to support and insulate the conductors from the ground



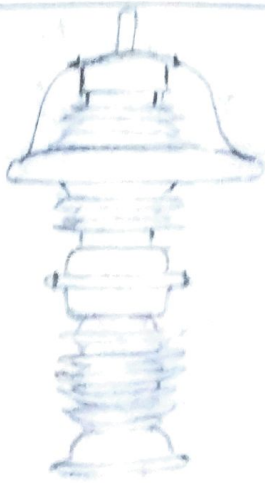
iv) Cross arms

- They are used to support the insulators and conductors



v. Lightening Arresters

- A lightning arrester is a device used in electrical power system and telecommunication system to protect the instruments from the effect of lightning.



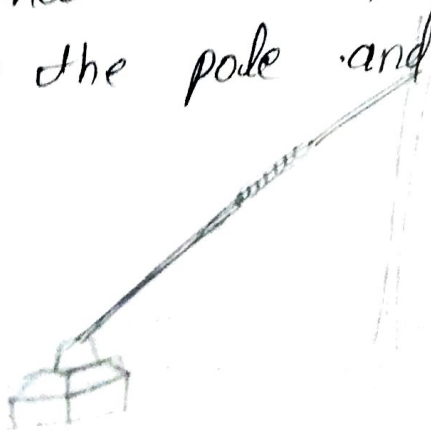
vi. Earth wire

- > Earth wire is present at the top of the towers to protect the line against lightning discharge.



vii. Guy and stays

- > Stay wire are galvanized steel wire strands that are used to provide mechanical support to the pole and towers.



viii. Vee guards

- These are the structures provided below bare overhead lines running along on aerials. Public streets to make the line safe if it should break



ix. Miscellaneous items

- plates like phase, danger plate, guard wire corona ring etc.

3.2 Conductor material

- The conductor is one of the important items as most of the capital outlay is invested for it
- Therefore importance should be given for the choice of material and size of the conductor
- The conductor material used for transmission and distribution of electric power should have the following properties

- i) high electrical conductivity
 - ii) high tensile strength in order to withstand mechanical 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.
- Some commonly used conductor materials are

1. Copper

- The benefits of using copper as a conductor
- Copper has high electrical conductivity
- It has high tensile strength
- It is durable and has high scrap value

→ Limitations:-

- It is costly
- Easily not available

Aluminium

- Aluminium is cheaper in cost and lighter in weight and easily available
- It has smaller conductivity and tensile strength

The conductivity of aluminium is 60% that of copper. As the conductivity of aluminium is smaller, so for any rated value of power transmission the x-sectional area of conductor must be larger than in copper. For the same resistance, the diameter of aluminium conductor is about 1.26 times the diameter of copper conductor.

→ The increased x-section of aluminium exposes a greater surface to wind pressure and therefore supporting towers must be designed for greater strength. This often requires the use of higher towers with consequence of greater sag.

→ The specific gravity of aluminium (2.71 gm/cc) is lower than that of copper (8.9 gm/cc). Therefore an aluminium conductor has almost one-half the weight of equivalent copper conductor. For this reason, the supporting structures for aluminium need not be made so

Strong as that of Copper conductor

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

from cost, conductivity, tensile strength weight etc. point of view Aluminium is preferred over Copper

AAC :- All Aluminium conductor

- They are mainly used for low voltage distribution overhead line having short span of upto 65m
- mainly used near sea coasts

AAAC :- All Aluminium Alloy conductor

- more prone to corrosion as compared to AAC
- mainly used in rivers and road crossings

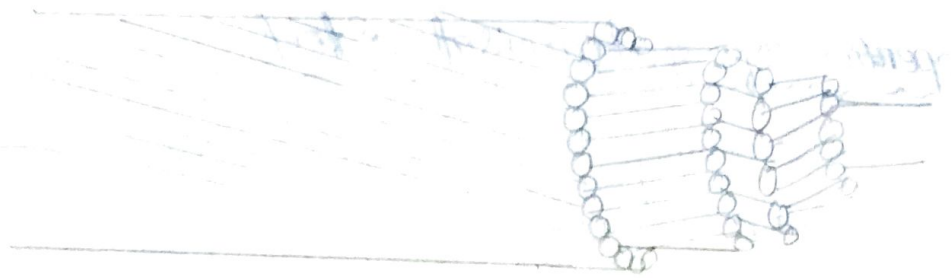
2) Steel cored Aluminium

A.C.S.R

- Due to low tensile strength aluminium conductor produce greater sag.

This prohibits their use for longer spans and makes them unsuitable for long distance transmission

- In order to increase the tensile strength, the aluminium conductor is reinforced with a core of galvanised steel wires
- The composite conductor thus obtained is known as steel cored (aluminium conductor steel reinforced)



Advantages of ACSR:-

- ACSR has high tensile strength produces small sag, therefore it can be used
- Due to longer span the number of line supports may be reduced. So the overall cost of supports, foundations, insulators and erection is reduced, maintenance cost is also reduced

3. Galvanised Steel

- > Galvanised steel has poor conductivity but has very high tensile strength
- > Due to high tensile strength, galvanised steel can be used for extremely long span
- > But due to its poor conductivity it is used to transmit a small power over a small distance

Properties of galvanised steel

- > poor conductivity 15% that of copper
- > high internal reactance
- > It is subjected to eddy current and hysteresis

5. Cadmium Copper

- > In some cases 1% or 2% cadmium is added to copper to increase the tensile strength by about 50% and the conductivity is only reduced by 15% below that of pure copper
- > due to high cost of cadmium such conductors will be economical only for lines of small x-section

→ Cadmium copper conductors are also employed for telephone and telegraph lines where the current involved are quite small but due to less availability of copper they are replaced with ACSR conductors.

93 Line Supports

- The supporting structures for overhead line conductors are various types of poles and towers called line supports.
- In general, the line supports should have the following properties.
 - i) High mechanical strength to withstand the weight of conductors and wind loads etc.
 - ii) Light in weight without the loss of mechanical strength.
 - iii) Cheap in cost and economical to maintain.
 - iv) Longer life.
 - v) Easy accessibility of conductors for maintenance.
- The line supports used for transmission and distribution of electric power are wooden.

Poles : R.C.C poles and Lattice Steel towers

wooden pole

- These are made of seasoned wood (Sal or Chir) and are suitable for lines of moderate $\times$ - section of area and of relatively shorter spans, say upto 50 metres.
- Such supports are cheap, easily available provide insulating properties and there are widely used for distribution purposes in rural areas.
- The wooden poles generally tend to rot below the ground level, causing foundation failure. In order to prevent this, the portion of the pole below the ground level is impregnated with preservative compounds like creosote oil.
- 'A' and 'H' shape poles are used for distribution purpose.
- The main objections to wooden supports are
 - (1) Tendency to rot below the ground level
 - (2) comparatively smaller life (20-25 years)

- iii) Cannot be used for voltages higher than 20kV
- iv) less mechanical strength and
- v) require periodical inspection.

2. Steel poles

- Wooden poles are replaced by steel poles due to its limitations
- They possess greater mechanical strength longer life and permit longer spans to be used
- Such poles are genett. generally used for distribution purposes in the cities
- This type of supports needs to be galvanised or painted in order to prolong its life
- Steel poles are used for transmission purposes for 11kV - 33kV
- The steel poles are of three types
 - (i) nail poles
 - (ii) tubular poles and
 - (iii) rolled steel joints

2. RCC poles

- RCC. Reinforced cement concrete
- It is used for distribution purpose upto 33kV
- They have greater mechanical strength longer life span and permit longer spans (80-200 mtr) than steel poles
- They give good outlook require little maintenance and have good insulating properties
- The main difficulty with the use of these poles is the high cost of transport owing to their heavy weight
- These large such poles are often manufactured at the site in order to avoid heavy cost of transportation

4. Steel Tower

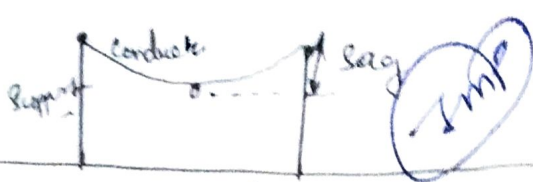
- for distribution purposes wooden, steel and reinforced concrete poles are used for low voltages, say upto 11kV
- However, for long distance transmission at higher voltage. Steel towers are

invariably employed

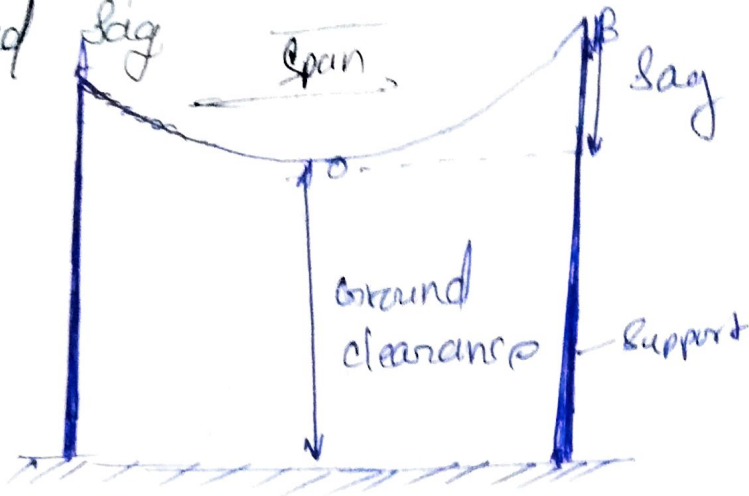
- Steel towers have greater mechanical strength longer life span, can withstand most severe climate conditions and permit the use of longer span (300 mtr. or more)
- Narrow base lattice steel towers are used for transmission at 11 kv to 33 kv and broad base lattice steel towers are used for transmission purpose at 66 kv and above
- Tower footings are usually grounded by driving rods into the earth. This minimises the lightning troubles as each tower acts as a lightning conductor

Good

Sumedh
21/04/22



Sag:- The difference in level between point of support and the lowest point on the conductor is called sag.



When the conductor is suspended between two supports at same level it assumes the shape of a Catenary.

Factor affecting Sag

- Weight of conductor
- Tension
- Span
- wind pressure
- Temperature

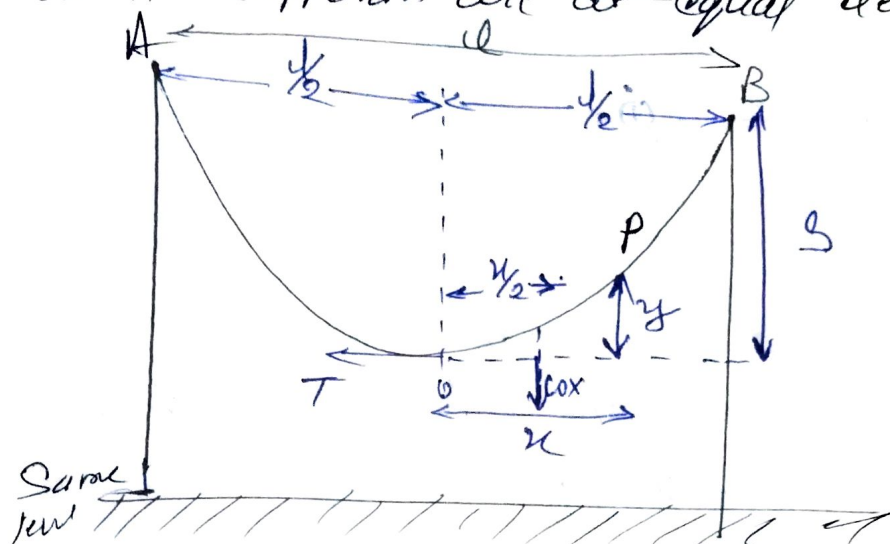
In an overhead transmission line the sag should be adjusted that tension in the conductor is within the safe limit.

The tension is governed by the conductor weight, effect of wind, ice loading, and temp. variations

So there is need of calculating sag and tension of a conductor.

Calculation of sag

a) When supports are at equal level :-



Consider a conductor 'AB' suspended freely between supports 'A' and 'B' which are at same level

- where L = length of span

W = weight per unit length of conductor

T = Tension in the conductor

P = Consider a point 'P' on the conductor.

Let the coordinates of point P be x and y
i.e. $P(x, y)$

- The two forces acting on the portion of conductor 'OP' of the conductor are

(i) the weight W_x of conductor acting at a distance $x/2$ from O

(b) The tension T acting at O

Now equating the moments of above two force about point O , we get,

$$T_y = wx \frac{x}{2}$$

$$y = \frac{wx \cdot \frac{x}{2}}{2T}$$

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

This is generalised for a small area of the conductor.

Now if we consider the whole conductor

that is $y = l$ and $x = \frac{l}{2}$

$$l = \frac{w(\frac{l}{2})^2}{2T}$$
$$= \frac{w \frac{l^2}{4}}{2T}$$

$$l = \frac{wl^2}{8T}$$

$$T \cdot y = wx \cdot \frac{x}{2}$$

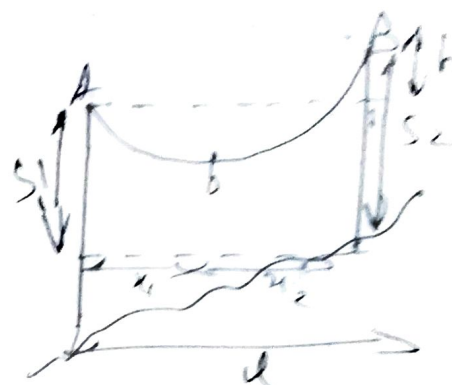
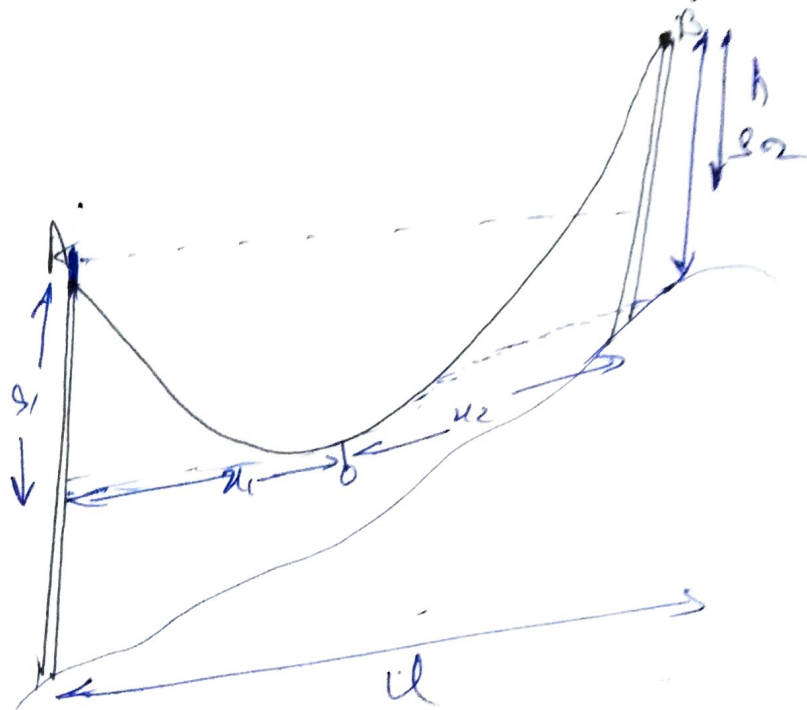
$$y = \frac{wx^2}{2T}$$

where

$$S = \frac{w(d/2)^2}{2T}$$

$$\Rightarrow \boxed{S = \frac{w d^2}{8T}}$$

(b) when supports are at different level.



where :
 O = Lowest point on the conductor
 h = difference in levels betⁿ two supports
 u₁ = distance of support at lower level from O
 u₂ = distance of support at higher level from O

where

$$u_1 + u_2 = d \quad \text{--- (1)}$$

$$s_1 = \frac{w u_1^2}{2T} \quad \text{--- (2)}$$

$$s_2 = \frac{w u_2^2}{2T} \quad \text{--- (3)}$$

here we are at

Now eqⁿ (3) - eqⁿ (2)

$$= \frac{\omega x_2^2}{2T} - \frac{\omega x_1^2}{2T}$$

21

we

$$S_2 = \frac{\omega x_2^2}{2T}$$

$$S_1 = \frac{\omega x_1^2}{2T}$$

$$S_2 - S_1 = \frac{\omega x_2^2}{2T} - \frac{\omega x_1^2}{2T}$$

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

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

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

$$\because x_2 + x_1 = d$$

$$S_2 - S_1 = d$$

$$\Rightarrow S_2 - S_1 = \frac{\omega}{2T} (x_2 - x_1)(x_2 + x_1)$$

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

$$= d = \frac{\omega d}{2T} (x_2 - x_1)$$

$$x_2 - x_1 = \frac{2hT}{\omega d}$$

④

from eqⁿ ① and ④

$$x_1 + x_2 = d$$

$$x_1 + x_2 = \frac{2hT}{\omega d}$$

$$\frac{d + \frac{2hT}{\omega d}}{\omega d^2 + 2hT}$$

$$2x_2 = \frac{2hT}{\omega d}$$

$$x_2 = \frac{\omega d^2 + 2hT}{2\omega d}$$

$$2x_2 = \frac{d + 2hT}{\omega d}$$

$$x_2 = \frac{d}{2} + \frac{hT}{\omega d}$$

$$x_2 = \frac{d}{2} + \frac{hT}{\omega d}$$

from eqⁿ ①

$$x_1 + x_2 = d$$

$$x_1 + \frac{d}{2} + \frac{hT}{\omega d} = d$$

$$x_1 = d - \frac{d}{2} - \frac{hT}{\omega d}$$

$$x_1 = \frac{d}{2} - \frac{hT}{w}$$

x_1 and x_2 can easily be calculated using x_1, x_2

EFFECT OF ICE LOADING AND WIND PRESSURE

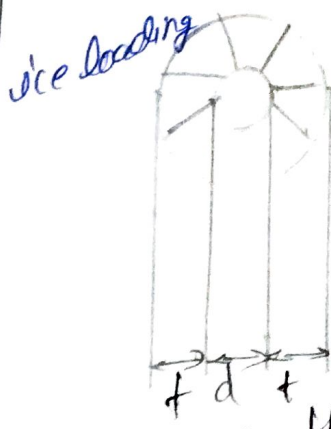
~~A above us~~

The previous derivation is for calculation of sag when the conductor are in still air and at normal temp.

But in practice a conductor may have ice loading or subjected to wind pressure

- The weight of the ice acts vertically downward
- The force due to wind is assumed to be horizontal, $\rightarrow$ the

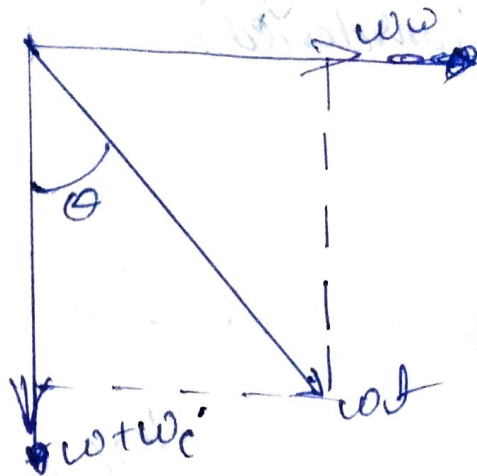
Total force on the conductor is the vector sum of horizontal and vertical forces



wind pressure

$d \rightarrow$ thickness of ice

Resultant



$$wt = \sqrt{(wt + wi)^2 + (wo)^2}$$

where

wt = Total weight of conductor per unit length

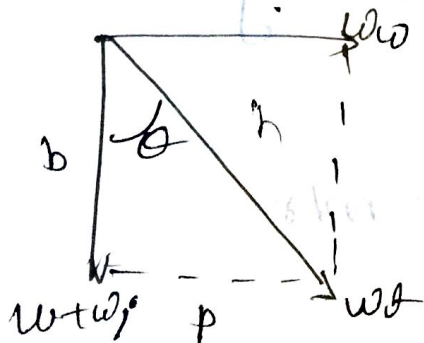
w = weight of conductor per unit length

w_i = weight of ice per unit length

w_o = wind force per unit length

→ The conductor ~~sags~~ sags itself in a plane at angle θ to the vertical

where



$$\tan \theta = \frac{p}{b} = \frac{w_o}{w + w_i}$$

$$S = \frac{w_d l^2}{8T} \quad (\text{when ice loading and wind pressure is considered})$$

$$\rightarrow \text{vertical sag} = S \cos \theta$$

Q A 132 kV Tx Line has the following data

weight of conductor = 680 kg/km

Length of span = 260 meters

Ultimate strength = 3100 kg

Safety factor = 2

calculate the height, above ground at which the conductor should be supported.

Ground clearance required is 10 meters

Given

$$w = \text{weight of conductor} = 680 \text{ kg/km} \quad \left| \frac{680 \text{ kg}}{1000 \text{ m}} \right| = 0.68 \frac{\text{kg}}{\text{m}}$$

$l = \text{Length of span} = 260 \text{ mtr}$

Ultimate strength = 3100 kg

Safety factor = 2

Ground clearance = 10 mtr

$$s = \frac{wL^2}{8T}$$

$$= \frac{0.68 \times (260)^2}{8 \times 1550}$$

$$= \frac{45968}{12400}$$

$$= 3.70 \text{ meters}$$

$$\text{Tension} = \frac{\text{ultimate strength}}{\text{Safety factor}}$$

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

$$= 1550 \text{ kg}$$

$$h = \text{ground clearance} + \text{sag}$$

$$= 10 \text{ m} + 3.70 \text{ m}$$

$$= 13.7 \text{ m}$$

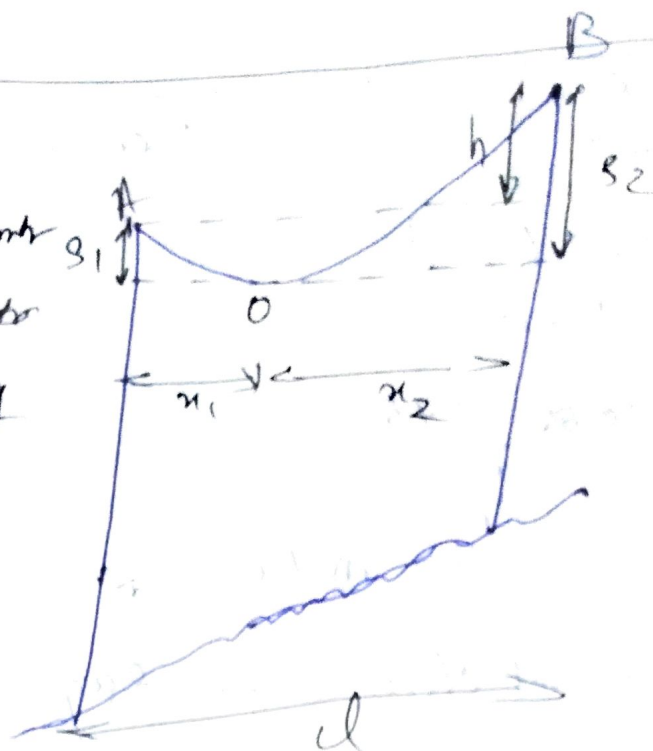
Q2 The Towers of height 30mtr and 40 mtr respectively support a transmission line conductor at water crossing. The horizontal distance betⁿ the towers is 500 mtr. If the tension in the conductor is 1600 kg find the minimum clearance of the conductor ~~at~~ and water. proded weight of conductor is 1.5Kg per meter. Assume Bases of the towers are at water level

Ans Given

$h = 30 \text{ mtr}, 90 \text{ mtr}$

horizontal distance between supports

$T = 1600 \text{ kg}$



horizontal distance between supports
A & B $d =$

$$x_1 + x_2 = 500 \text{ mtr}$$

- level difference between supports $= 90 \text{ m} - 30 \text{ m}$
 $= 60 \text{ mtr}$

- weight of conductor $= 1.5 \text{ kg/mtr}$

Ground clearance - ?

$$s_1 = \frac{Bag}{s_1} = \frac{w x_1^2}{2T}$$

$$x_1 = \frac{d}{2} - \frac{hT}{wd}$$

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

$$= 122 \text{ mtr}$$

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

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

$$= 6.97 \text{ mtr}$$

$$= 7 \text{ mtr}$$

$$\text{G.C.} = \text{Height of 1st tower} - \text{Sag}$$

$$= 30 - 7$$

$$= 23 \text{ mtr}$$

Q3 A Transmission line has a span of 150 mtr betⁿ level support the conductor has a cross sectional area of 2 cm^2 the tension in the conductor is 2000 kg if the specific gravity of the conductor material is $9.9 \frac{\text{gram}}{\text{cm}^3}$.

and wind pressure is 1.5 kg/m length
calculate the sag and vertical sag

Given

$$\text{Span } d = 150 \text{ mtr}$$

$$\text{X-section area of conductors} = 2 \text{ cm}^2$$

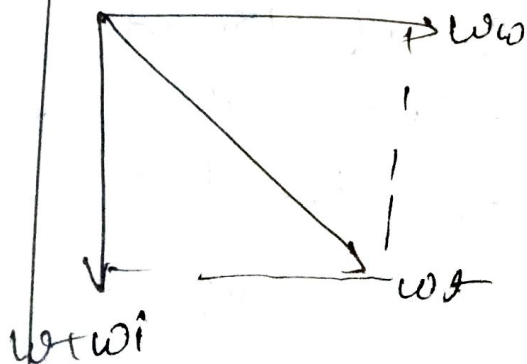
$$\text{Tension } (T) = 2000 \text{ kg}$$

$$\text{Specific gravity conductor material} \\ = 9.9 \text{ gm/cm}^3$$

$$\text{Wind pressure} = 1.5 \text{ kg/m}$$

$$s = \frac{w_l^2}{8T}$$

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



$$w_t = \sqrt{w^2 + w_h^2}$$

area $\times$ length

$$\text{weigh. of conductor} = \text{s.p gravity} \times \text{volume of 1 mt conductor}$$

$$\Rightarrow 9.9 \text{ gm/cm}^2 \times 2 \times 100$$

$$= 1980 \text{ gm}$$

$$(w) \Rightarrow 1.980 \text{ kg}$$

$$W = \sqrt{w^2 + w_0^2}$$

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

$$= 2.48 \text{ kg}$$

$$\text{Sag} = \frac{W d^2}{8T}$$

$$= \frac{2.48 (150)^2}{8 \times 2000}$$

$$= \frac{44400}{16000}$$

$$= 3.48 \text{ mtr}$$

Vertical Sag = $8 \cos \theta$

$$= 3.48 \cos 37.14^\circ$$

$$\Rightarrow 2.77 \text{ mtr}$$

$$\theta = \tan^{-1} \left(\frac{w_0}{w} \right)$$

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

$$= \cancel{26.9^\circ}$$

$$37.14^\circ$$

3.3 Insulators

- The overhead line conductors should be placed on the poles or towers in such a way that currents from conductors do not flow to earth through supports i.e. line conductors must be properly insulated from supports. This is achieved with the help of the insulators.
- The insulators provide necessary insulation between line conductors and supports and prevent any leakage current from conductors to earth.

The insulators should have the following desirable properties :-

- High mechanical strength in order to withstand conductor load, wind load etc.
- High electrical resistance of insulator material in order to avoid leakage currents to earth.
- High relative permittivity of insulator material in order that dielectric strength is high.
- The insulator material should be non-porous free from impurities and cracks otherwise the permittivity will be lowered.

→ High ratio of puncture strength to flashover

The most commonly used material for insulators of overhead line are:-

→ Porcelain

→ glass

→ Steatite

→ Special composition materials are also used to a limited extent.

Types of insulators:-

→ Pin type insulator -

→ Suspension type -

→ Strain insulator -

→ Shackle insulator

→ Stay insulator

→ Post insulator

1. Pin insulator

→ Pin type insulators are used for transmission and distribution of electric power at voltage upto 33kV

→ They are generally used in distribution line which is mounted to an electrical cross arm of the utility pole with the

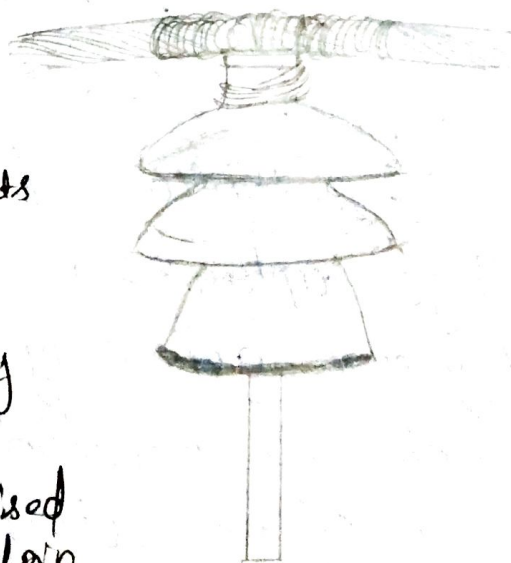
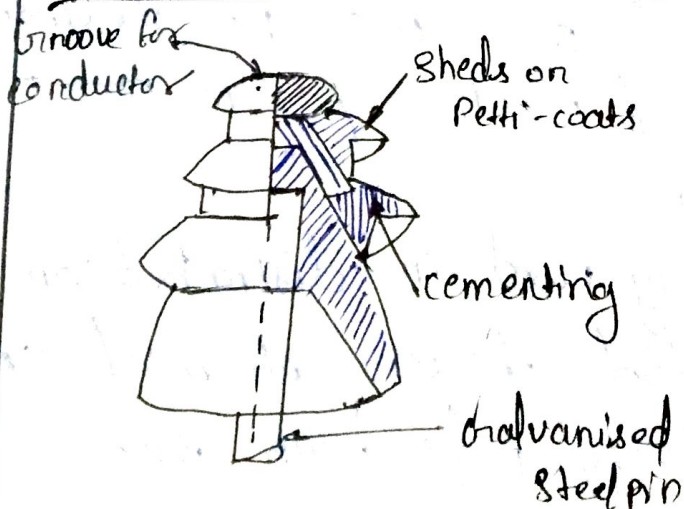
Support of various bolls on pole top pins

→ pin insulator is widely used in the power distribution systems with the features of low price, high mechanical strength, simple design, and easy maintenance

→ There is a groove on the upper end of the insulator for clamping the conductor, the conductor passes through this groove and is bound by the annealed wire of the same material as the conductor

→ The pin type insulators become too bulky for beyond 33 kV and hence it is uneconomical

→ pin type insulator can be made of ceramic, porcelain, polymer, glass, or silicon rubber





Advantages of pin insulator

- It has high mechanical strength
- The pin type insulator has good creepage distance
- It is used on the high voltage distribution line
- The construction of the pin type insulator is simple and requires less maintenance
- It can be used vertically as well as horizontally

Disadvantage of pin insulator

- It should be used with the spigot
- It is only used in the distribution line
- The voltage rating is limited i.e. up to ~~13~~ 15 kV
- The pin of the insulator damaged the insulator thread

Causes of insulator failure

- Insulators are required to withstand both mechanical and electrical stresses
- The electrical stresses is due to line voltage and may cause the breakdown of the insulator
- The electrical breakdown of the insulator can occur either by flash-over or puncture

Flashover

- An arc occurs between the line conductors and insulator pin and the discharge jumps across the air gaps, following shortest distance
- In case of flash-over the insulator will continue to act in its proper capacity unless extreme heat produced by the arc destroys the insulator

Puncture

- The discharge occurs from conductor to pin through the body of the insulator, when such breakdown is involved, the insulator is permanently destroyed due to excessive heat in practice

- Sufficient thickness of porcelain is provided in the insulator to avoid puncture by the line voltage

Safety factor

- The ratio of puncture strength to flashover voltage is known as safety factor i.e.

$$\text{Safety factor of insulator} = \frac{\text{Puncture strength}}{\text{Flashover voltage}}$$

- It is desirable that the value of safety factor is high so that flash-over takes place before the insulator gets punctured. For pin type insulator, the value of safety factor is about 10.

2. Suspension type

- For high voltage, beyond 33kV pin type insulators become uneconomical because of its size, weight etc. So suspension type insulators are generally used.

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

- The conductor is suspended at the bottom end of this string while the other end of the string is connected to the cross-arm of the tower.
- Each unit or disc is designed for low voltage i.e. 11KV. The
- So for desired voltage rating the number of discs are connected to form a string. For example if the working voltage is 66KV, then six discs in series will be provided in the string.

Advantages

- i) Suspension type insulators are cheaper than pin type insulators for ~~for~~ voltages beyond 33KV.
- ii) Each unit ~~for~~ or disc of suspension type insulator is designed for low voltage usually 11KV. Depending upon the working voltage the desired number of discs can be connected in series.
- iii) If any disc is damaged the whole string does not become useless because the damaged disc can be replaced by the ~~sound~~ second one.



12)

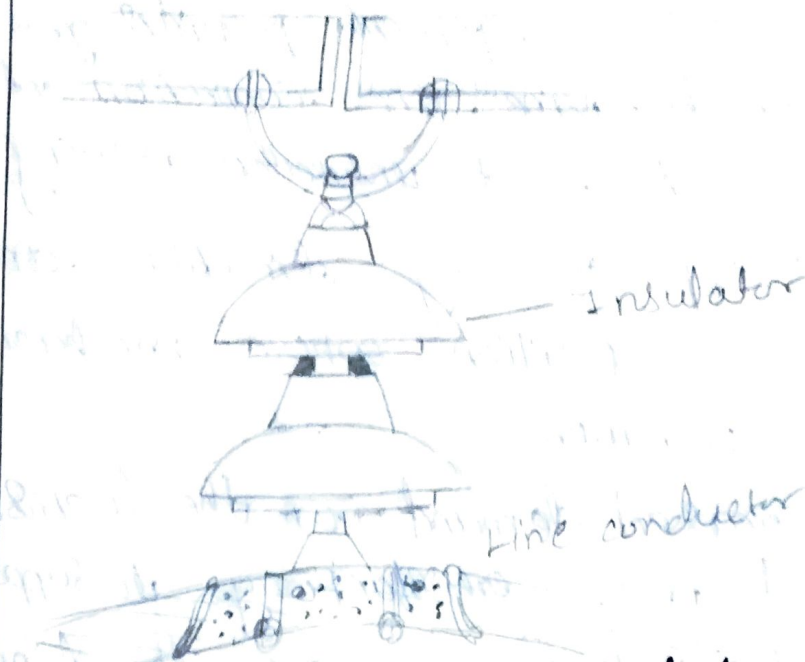
The suspension arrangement provides greater flexibility to the line. The connection at the cross arm is such that insulator string is free to swing in any direction and can take up the position where mechanical stresses are minimum.

13)

In case of increased demand on the transmission line, it is found more satisfactory to supply the greater demand by raising the line voltage than to provide another set of conductors. The additional insulation required for the raised voltage can be easily obtained in the suspension arrangement by adding the desired number of discs.

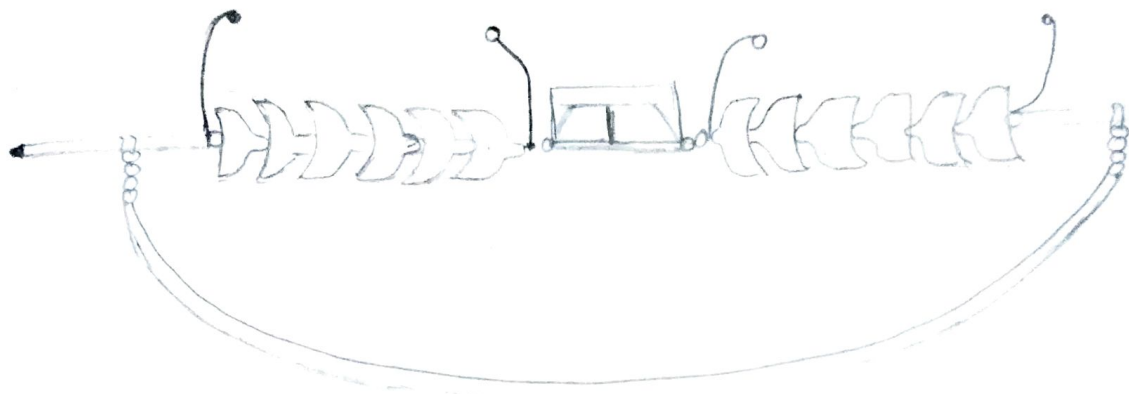
14)

The suspension type insulators are generally used with steel towers. As the conductors run below the earthed cross-arm of the tower, therefore, this arrangement provides partial protection from lightning.



3. Strain insulator

- when there is a dead end of the line or there is corner or sharp curve, the line is subjected to greater tension in order to relieve the line of excessive tension, strain insulators are used
- For low voltage lines (< 11 kV) shackle insulators are used as strain insulators
- However for high voltage transmission line strain insulator consists of an assembly of 3 suspension insulators
- The discs of strain insulators are used in the vertical plane
- when the tension in lines is exceedingly high as at long river spans, two or more strings are used in parallel



Number of discs in string insulators
voltage level No. of discs

11 kV

1

33 kV

3

66 kV

5

132 kV

9

220 kV

13-15

400 kV

20

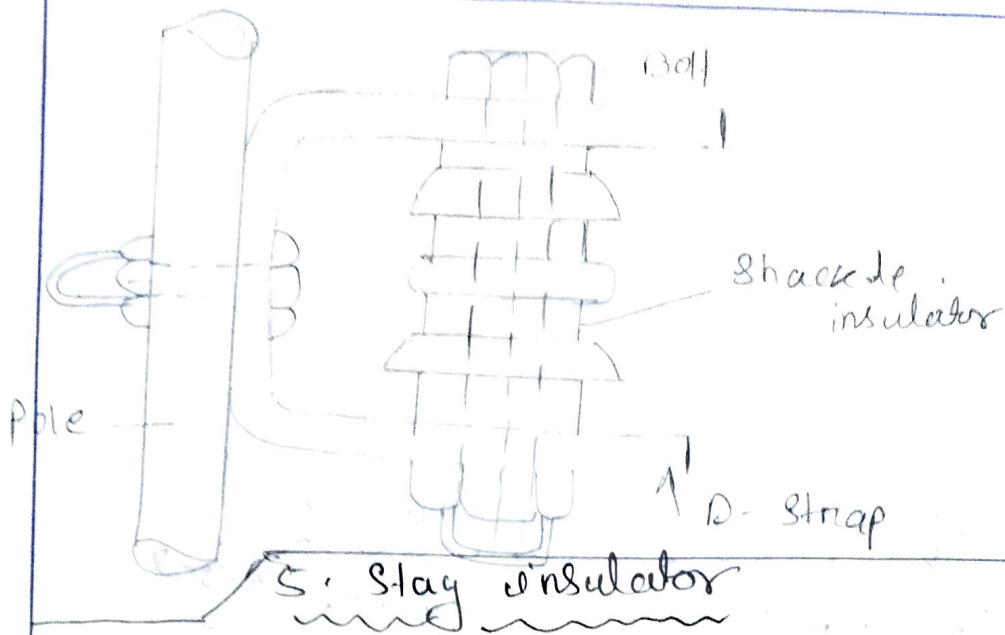
No. of discs in strain type insulators = 1 + No. of
 discs in suspension type insulators

Shackle type

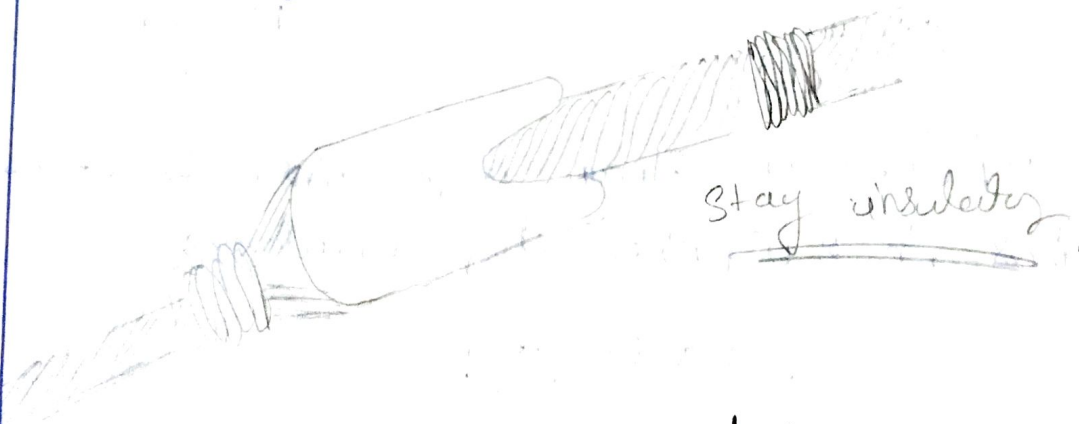
→ The shackle insulator is usually used in low
 voltage distribution network

→ It can be used in both the horizontal or
 vertical positions. It is also known as a

Spool insulator



- The insulator used in the stay wire is called as the stay insulator and is usually of porcelain
- It provides insulation between stay wire and cross arm

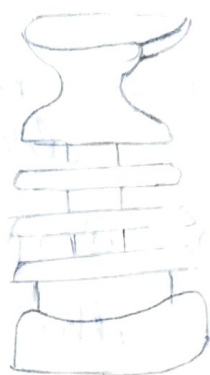


6 post insulators

- post insulators are similar to pin insulators but post insulators are more suitable for higher voltage applications

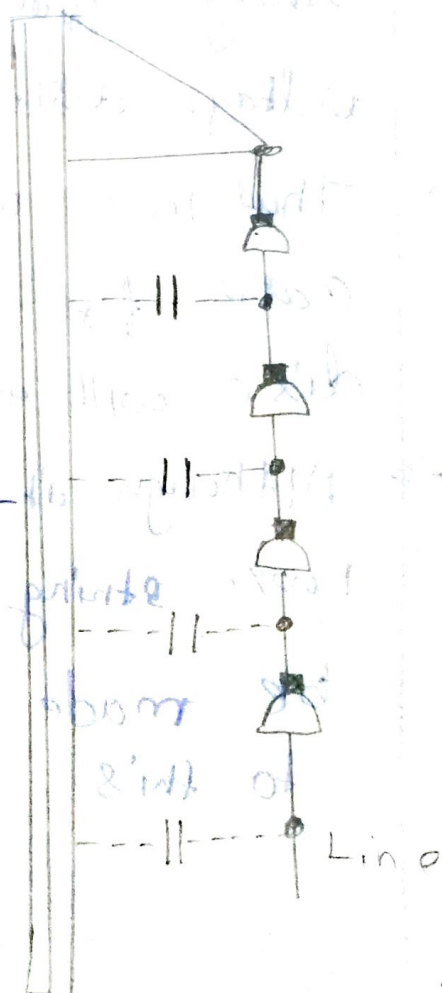
post insulators have a higher number of pelltcoals and a greater height compared to pin insulators

we can mount this type of insulator on supporting structure horizontally as well as vertically.



Calculation of string efficiency of suspension insulators string

- The voltage applied across the string of suspension insulators is not uniformly distributed across various units or discs
- The disc nearest to the conductor has much higher potential than the other discs
- This unequal potential distribution is undesirable and is usually expressed in terms of 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 i.e.

$$\eta = \frac{\text{voltage across string}}{n \times \text{voltage across nearest disc}}$$

→ String efficiency is an important consideration since it decides the potential distribution along the string. The greater the string efficiency, the more uniform is the voltage distribution.

→ Thus 100% string efficiency is an ideal case for which the voltage across each disc will be exactly the same.

→ Although it is impossible to achieve 100% string efficiency yet efforts should be made to improve it as close to this value as possible.

Performance Analysis of Short & medium lines

- Short transmission line — upto 50 km.
- medium transmission line — upto 50-150 km
- ~~long~~ Long transmission line — upto more than 150 km.

Short $< 20 \text{ kv}$

medium $20-100 \text{ kv}$

The important consideration in the design and operation of a transmission line are the determination of voltage drop, line loss and efficiency of transmission.

— These values are greatly influenced by the line constants R, L and C of transmission line. For instance the voltage drop in the line depends upon the values of above three line constants.

— Similarly the resistance of transmission line conductor is the most important cause of power loss in the line and determines the transmission efficiency.

— So for analysis the transmission lines are classified into three types

- (1) Short tx line
- (ii) medium transmission line

Long transmission line

① Short transmission line

When the length of an overhead transmission line is up to about 50 km and the line voltage is comparatively low, that is less than 20 kV, it is usually considered as a short transmission line.

→ Due to smaller length and lower voltage the capacitance effects are small and can be neglected (i.e.) during the analysis of short transmission line only resistance and inductance are taken into account.

Medium transmission line

When the length of an overhead transmission line is about 50 to 150 km and the line voltage is moderately high that is 20 kV to 100 kV it is considered as a medium transmission line.

Due to sufficient length and voltage of the line the capacitance effect are

Taken in to account

Long Tx line

When the length of an overhead transmission line is more than 150 km and the line voltage is very high that is more than 100 kV it is considered as a long transmission line.

Some Imp. Terms

Voltage Regulation

When a transmission line is carrying current there is voltage drop in the line due to resistance and inductance of the line. The result is that receiving end voltage (V_R) of the line is generally less than the sending end voltage (V_S). This voltage drop $\text{drop} = (V_S - V_R)$ in the line is expressed as a percentage of receiving end voltage V_R and is called voltage regulation.

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

It is the ratio of the difference between the sending end voltage and receiving end voltage

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

mathematically

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

- It is desirable that the voltage regulation of a transmission line should be low

Transmission Efficiency:- The power obtained at the receiving end of the tx line is generally less than the sending end power due to losses because of line resistance

- *- The ratio of Receiving end power to the sending power of a transmission line is known as the Transmission efficiency of the line

Mathematically

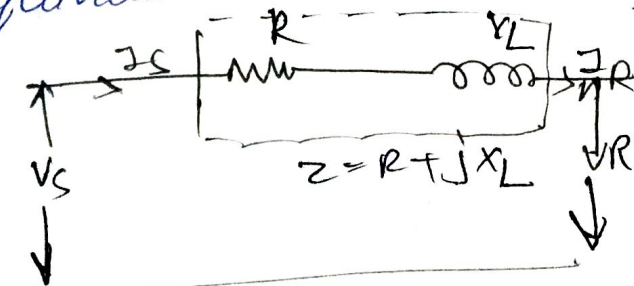
$$\% \eta = \frac{P_R}{P_s} = \frac{V_R I_R \cos \phi}{V_s I_s \cos \phi} \times 100$$

P_R - ~~Receiving~~ power Receiving

P_s - Sending power

Analysis of Short Tx Line

Equivalent circuit of short Tx line:-



where V_s = Sending end voltage

V_R = Receiving end voltage

I_s = Sending end current

I_R = Receiving end current

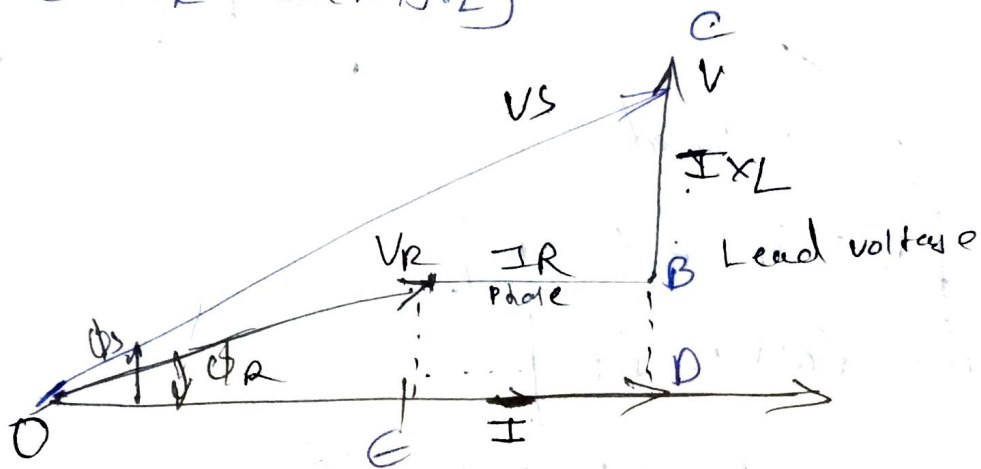
R = Resistance of entire length of Tx Line

L = Inductance of entire length of Tx Line

Hence $I_s = I_R$

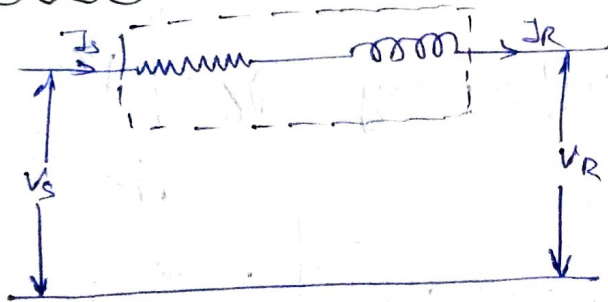
Same current (series)

$$\vec{V}_s = \vec{V}_R + \vec{I}(R + jX_L)$$

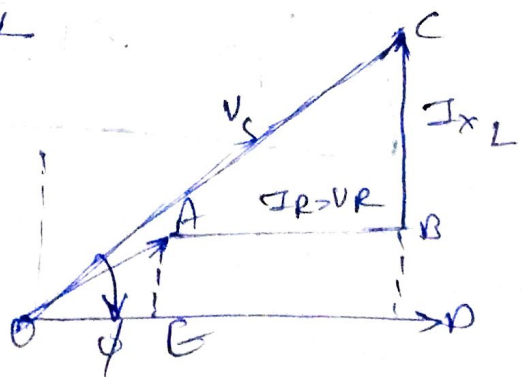


I_R - in phase (Resistive (KT))

Eq. ckt of short Tx line:-

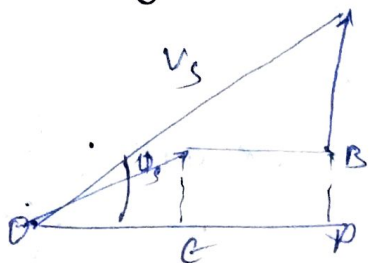


Phasor diagram:-



1) percentage of voltage regulation :- $\frac{V_S - V_R}{V_R} \times 100$

11) Sending end power factor :-



$$\cos \phi_S = \frac{R}{h} = \frac{OD}{OC}$$

$$= \frac{OE + ED}{V_S}$$

$$\cos \phi = \frac{V_R \cos \phi_R + I R}{V_S}$$

14) power delivered

$$P_R = V_R I_R \cos \phi_R$$

$$\text{line loss} = I^2 R$$

$$\begin{aligned} \text{Power sent out} &= V_S I_S \cos \phi \\ &= \text{power delivered} + \text{line loss} \end{aligned}$$

10) Transmission efficiency = $\eta = \frac{\text{Power delivered}}{\text{Power sent out}}$

$$= \frac{\text{Power delivered}}{\text{power delivered} + \text{line loss}}$$

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

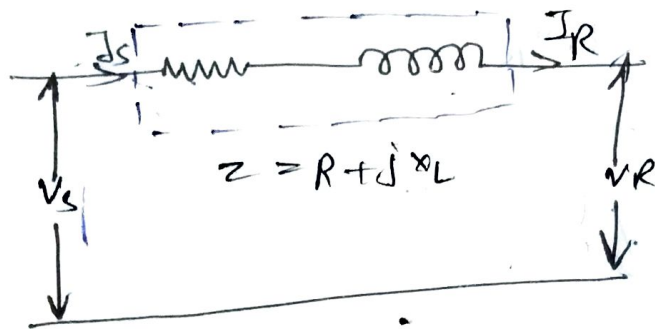
ABCD Parameters of Short Tx line

The standard equation ABCD parameters of a 2 port given network

$$V_s = AV_R + BI_R \quad \text{--- (I)}$$

$$I_s = CV_R + DI_R \quad \text{--- (II)}$$

Equivalent circuit of short transmission line :-



Apply K.V.L

$$V_s = I_R + I_{XL} + V_R$$

$$V_s = I(R + X_L) + V_R$$

$$V_s = V_R + IZ \quad \text{--- (3)}$$

Here

$$I_s = I_R$$

$$\Rightarrow I_s = 0 \cdot V_R + 1 \cdot I_R \quad \text{--- (4)}$$

① Comparing equation ① & ③

$$A=1, B=Z$$

$$V_S = V_R + Z I_R$$

$$V_S = V_R + I_Z$$

② Comparing equation 2 & 4

$$C=0, D=1$$

$$I_S = 0 \cdot V_R + 1 \cdot I_R$$

$$I_S = 0 \cdot V_R + 1 \cdot I_R$$

So in matrix form

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

Q. A single phase overhead transmission line delivers 1100 kW at 33 kV at 0.8 power factor lagging the total resistance and inductive reactance of the line are 10 Ω or 15 Ω respectively determine

i) Sending end voltage ✓

ii) Sending end power factor ✓

iii) Transmission efficiency ✓

→
given

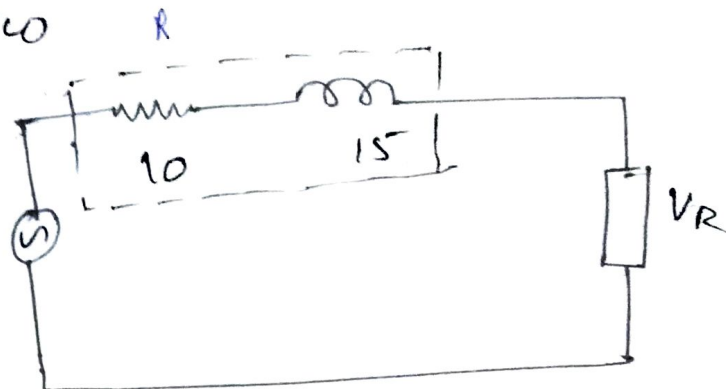
$$P_{\text{delivered}} = 1100 \text{ kW}$$

$$V_R = 33 \text{ kV}$$

$$\cos \phi = 0.8$$

$$R = 10 \Omega$$

$$X_L = 15 \Omega$$



$$Z = 18.02$$

$$\theta = 56.30$$

$$I = \frac{V}{Z} = \frac{33000}{18.02} = 1831.29 \text{ Amp}$$

$$\text{P.f} = \cos \phi = 0.8$$

$$\phi = \cos^{-1}(0.8) = 36.86$$

$$\sin \phi = \sin 36.86$$

$$= 0.6$$

$$P_{\text{delivered}} = V_R I_R \cos \phi$$

$$I_R = \frac{\text{Power delivered}}{V_R \times \cos \phi}$$

$$= \frac{1100 \times 10^3}{33 \times 10^3 \times 0.8}$$

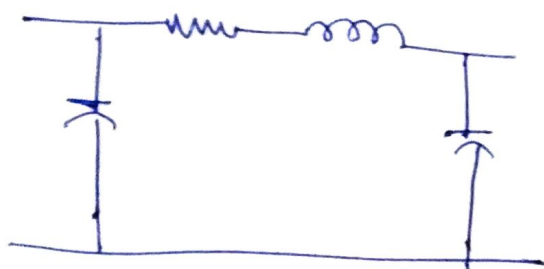
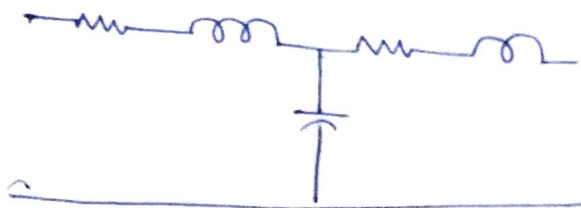
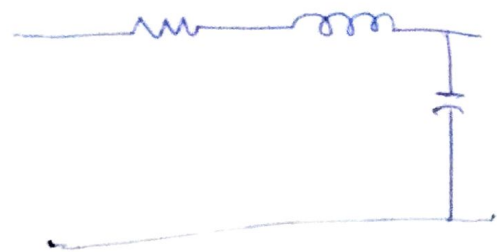
$$= 41.6 \text{ Amp}$$

Analysis of medium π Line

i) End Condenser method $\rightarrow$

ii) Nominal τ method

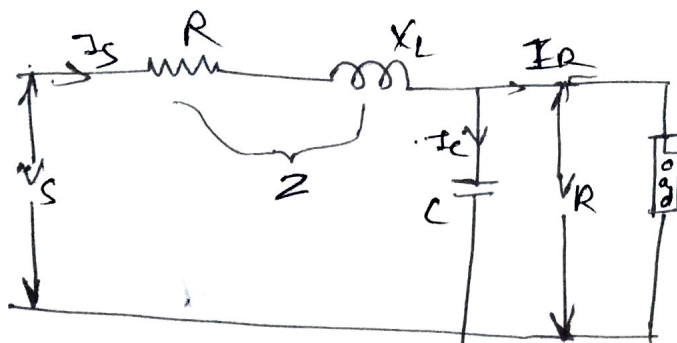
iii) Nominal π method



The performance of the medium π line can be analysed by the above three methods

(i) End condenser method :- In this method the capacitance of the line is lumped or concentrated at the receiving or load end

equivalent circuit diagram for analysis



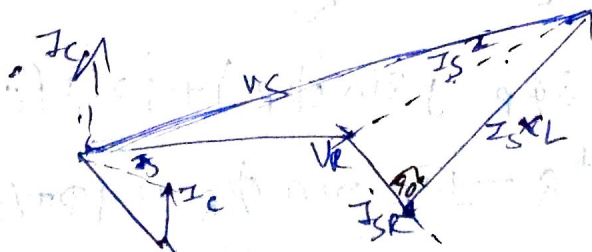
where V_s = Sending end voltage
 I_s = Sending end current
 V_R = Receiving end voltage
 I_R = Receiving end current
 R = Resistance per phase
 C = Capacitance per phase
 $\cos\phi_R$ = Receiving end power factor
 X_L = inductive Reactance
 X_C = capacitive Reactance

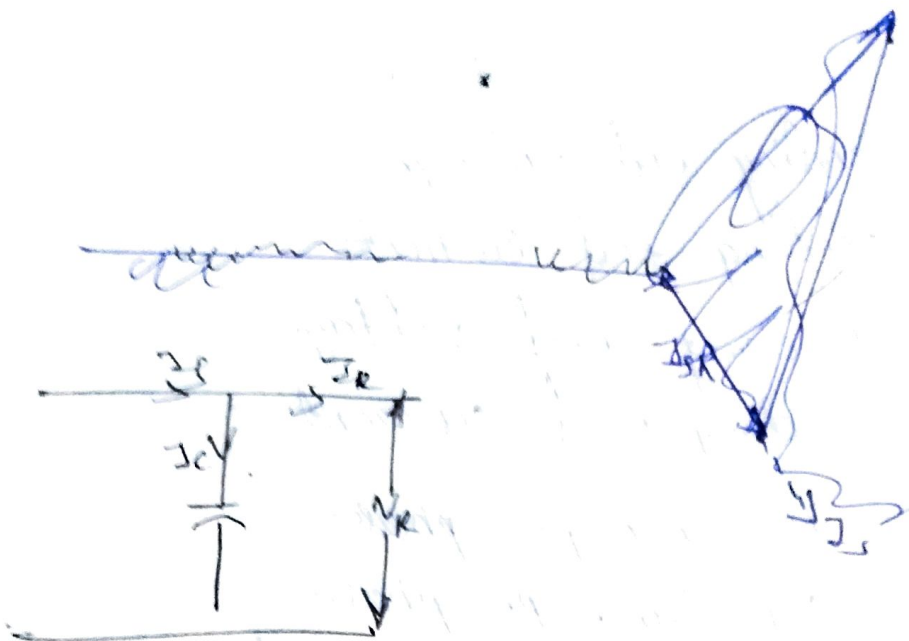
here $\vec{I}_s = \vec{I}_R + \vec{I}_C$ ————— ①

$$\vec{V}_s = I_s R + I_s X_L + I_s X_C$$

$$\vec{V}_s = \vec{V}_R + \vec{I}_s (R + jX_L)$$

$$= \vec{V}_R + \vec{I}_s Z$$
 ————— ②





$$\vec{I}_C = j \frac{V_R}{X_C}$$

$$\Rightarrow \vec{I}_C = j \frac{V_R}{\frac{1}{2\pi f C}}$$

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

from eqn (i)

$$\vec{I}_s = \vec{I}_R + \vec{I}_C$$

$$\Rightarrow \vec{I}_s = I_R \angle -\phi_R + j 2\pi f C V_R$$

$$\Rightarrow I_s = I_R (\cos \phi_R - j \sin \phi_R) + j 2\pi f C V_R$$

$$\Rightarrow I_s = I_R \cos \phi_R - j I_R \sin \phi_R + j 2\pi f C V_R$$

$$\Rightarrow \vec{I}_s = I_R \cos \phi_R + j(-I_R \sin \phi_R + 2\pi f C V_R)$$

(i) voltage drop per phase

$$= \vec{I}_s \vec{Z}$$

$$= \vec{I}_s (R + jX_L)$$

(ii) sending end voltage

$$\vec{V}_s = \vec{V}_R + \vec{I}_s \vec{Z}_s$$

$$\vec{V}_s = \vec{V}_R + \vec{I}_s (R + jX_L)$$

(iii) voltage Regulation $\frac{V_s - V_R}{V_R} \times 100$

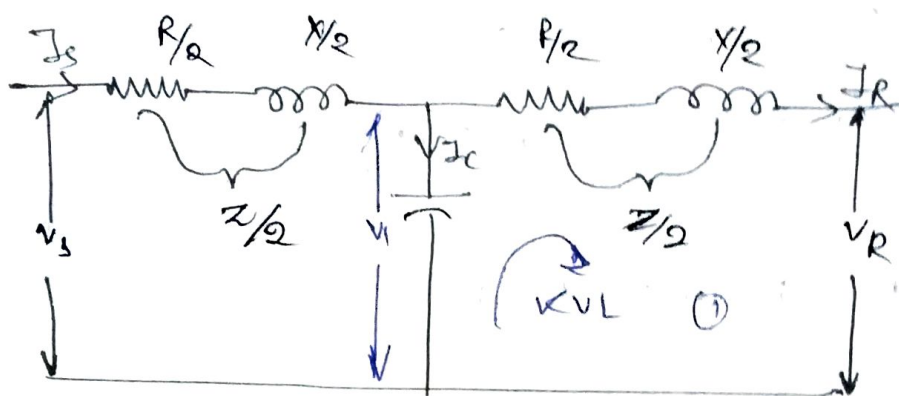
(iv) $\% \eta = \frac{\text{Power delivered}}{\text{P. deliver} + \text{loss}} \times 100$

$$\frac{V_R I_R \cos \phi_R}{V_R I_R \cos \phi_R + I_s^2 R}$$

① Nominal T method

In this method the total line capacitance is Assume to be concentrated at the middle point of the line and half of the line Resistance and reactance are lumped on it's either side

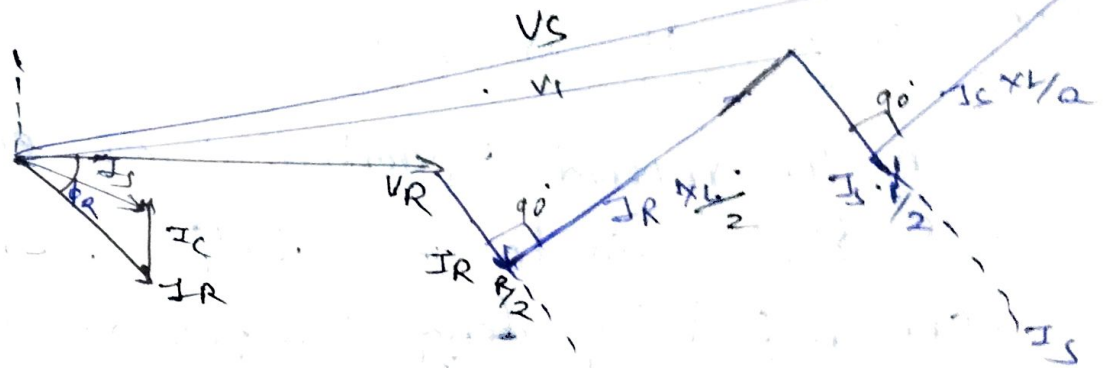
Equivalent circuit diagram for Analysis



where

- V_s - Sending end voltage per phase
- V_R - Receiving end voltage per phase
- R - Resistance per phase
- X_L - Inductive Reactance per phase
- I_s - Sending current per phase
- I_R - Receiving end current per phase
- $\cos\phi_R$ - Receiving end power factor

Phasor Diagram



$$V_1 = V_R + I_R \left(\frac{R}{2} + j \frac{X_L}{2} \right)$$

$$V_S = V_1 + I_S \left(\frac{R}{2} + j \frac{X_L}{2} \right)$$

From the fig ^

$$\vec{I}_S = \vec{I}_R + \vec{I}_C$$

$$\vec{I}_C = \frac{V_1}{X_C}$$

$$= \frac{V_1}{X_{C_0}} = 2\pi f C V_1 \quad \text{--- (1)}$$

$$\vec{V}_1 = \vec{V}_R + \vec{I}_R \frac{R}{2} + \vec{I}_R j \frac{X_L}{2}$$

$$= \vec{V}_R + \vec{I}_R \left(\frac{R}{2} + j \frac{X_L}{2} \right)$$

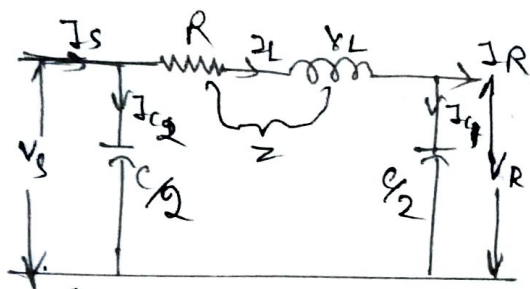
$$= \vec{V}_1 = \vec{V}_R + \vec{I}_R \frac{Z}{2} \quad \text{--- (3)}$$

$$\vec{V}_S = \vec{V}_1 + \vec{I}_S \left(\frac{R}{2} + j \frac{X_L}{2} \right)$$

$$\vec{V}_1 + \vec{I}_s \cdot \frac{Z}{2} \text{ ————— (4)}$$

9) Nominal π method

In this method Capacitance of each conductor is divided into two halves, one half being ~~long~~ lumped at the sending end and the other half at the receiving end

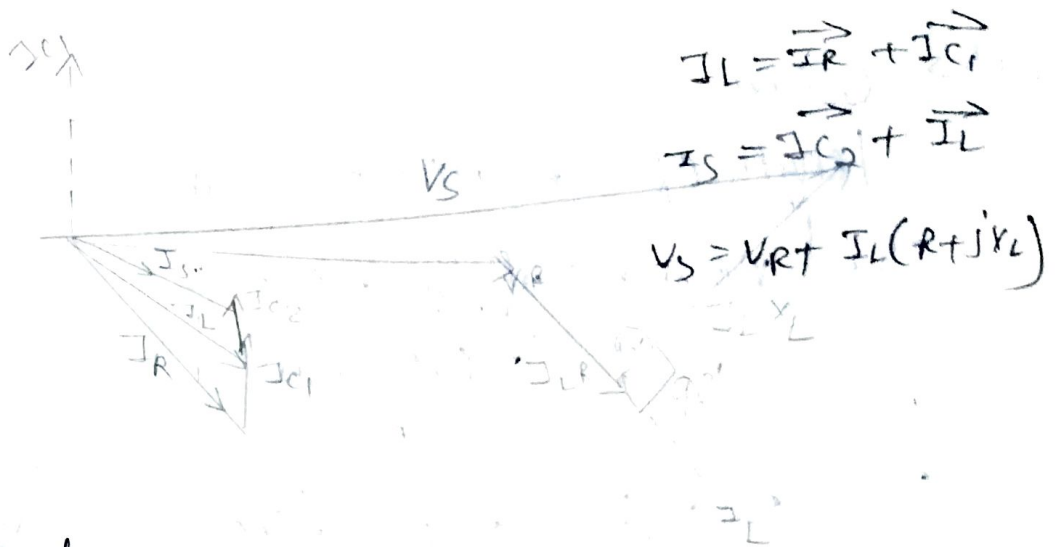


↑
Equivalent circuit diagram for analysis

Where

- V_s - Sending end voltage per phase
- V_R - Receiving end voltage " "
- I_R - Receiving end current " "
- I_s - Sending end current " "
- R - Resistance per phase
- X_L - Inductance Reactance " "
- C - Capacitance per phase
- $\cos\phi$ - Receiving end power factor

Phasor diagram



From the fig

$$I_{C1} =$$

A ~~medium~~ medium single phase Tx line ~~two~~ two km long as the following constants

(1) Resistance / km = 0.25Ω Susceptance / km = 14×10^{-6} Siemens, Reactance / km = 0.8Ω ,

Receiving end line voltage ~~6600V~~ ~~0.8002 Receiving end line~~

voltage = 6600V: volt assuming that total capacitance of the line is localised at the receiving end alone determine

- (i) Sending end current ✓
- (ii) Sending end voltage ✓
- (iii) Regulation ~~not~~ ✓
- (iv) Supply power factor ✓

The line is delivering 15000 kW at 0.8 power factor lagging. Draw the phasor diagram also

Ans

Given

length of the line = 100 km

Total Resistance of the line

$$= 0.25 \times 100$$

$$= 25 \Omega$$

Total Susceptance of the line

$$= 14 \times 10^{-6}$$

$$= 400 \times 10^{-3}$$

$$= 14 \times 10^{-4}$$

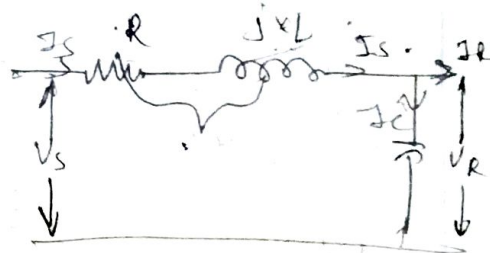
$$\begin{aligned} & 5 \times 10^{-6} \times 100 \\ & 20 \times 10^{-6} \times 100 \\ & 20 \times 10^{-6} \times 100 \\ & 20 \times 10^{-6} \times 100 \end{aligned}$$

Reactance $X_L = 0.8 \Omega$

For 100 km = 0.8×100

$$= 80 \Omega$$

power factor = 0.8



$$\textcircled{1} \vec{I}_s = \vec{I}_R + \vec{I}_C$$

$$\vec{I}_R$$

$$\text{Power delivered} = V_R I_R \cos \phi_R$$

$$15000 \times 10^3 = 66000 \times I_R \times 0.8$$

$$= 15000000 = 66000 \text{ W}$$

$$52800 \text{ W}$$

$$I_R = \frac{15000000}{52800}$$

$$I_R = I_R = \frac{15000000}{52800}$$

$$= 284.09 \text{ Amp} \angle -36.86^\circ$$

$$A (\cos \phi_R + j \sin \phi_R)$$

$$= 284.09 (0.8 + j0.6)$$

$$= 227.272 - j170.45$$

$$\vec{I}_R = 227.272 - j170.45 \text{ A}$$

$$\vec{I}_C = jY \cdot V_R$$

$$= j14 \times 10^{-4} \times 66000$$

$$= j92.4 \text{ A}$$

$$\vec{I}_S = \vec{I}_R + \vec{I}_C$$

$$= 227.272 - j170.45 + j92.4$$

$$= 227.272 - j78.05$$

✓

$$\begin{aligned}
 I_m &= \sqrt{227.27^2 + \frac{170.03}{78^2} j} \\
 &= \sqrt{51651 + \frac{28917}{6084}} \\
 &= \frac{2303.89}{240} \text{ A}
 \end{aligned}$$

① Sending end voltage

$$\vec{V}_S = \vec{V}_R + \vec{I}_S (R + jX_L)$$

$$= 66000 + (227.27 - j78)(25 + j80)$$

$$= 66000 + 227.27(25 + j80) -$$

$$j78(25 + j80)$$

$$\vec{V}_R = 66000 \text{ V}$$

$$\vec{V}_e = 66000 \text{ V}$$

$$\begin{aligned}
 j &= \sqrt{-1} \\
 j^2 &= -1
 \end{aligned}$$

$$= 66000 + \cancel{227.27} \cdot 5681.75 + 18181.6j - 1950j + 6240$$

$$= 66000 + 5681.75 + 6240 + 18181.6j - 1950j$$

$$= 77921.75 + j16231.6$$

$$= \sqrt{(77921.75)^2 + (16231.6)^2}$$

$$= 795904.37142 \text{ Volt}$$

voltage Regulation %

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

$$= \frac{79594.37 - 66000}{66000} \times 100$$

$$> \quad \cancel{79594.37}$$

$$\frac{13594.37}{66000} \times 100$$

$$> 0.2059 \times 100$$

$$= 20.59 \%$$

Supply power factor ($\cos \phi_s$)

$$\phi_s = \angle V_R V_S + \angle V_A \angle I_S$$

$$\vec{V}_S = 77921.75 + j16231.0$$

$$\vec{V}_S = \tan^{-1} \left(\frac{16231.0}{77921.75} \right)$$

$$= 11.75^\circ$$

$$I_S = \tan^{-1} \left(\frac{-78}{277} \right) = 18.94^\circ$$

$$\frac{28}{24}$$

$$= 11.75 + 18.97$$

$$\phi_s = 30.69$$

$$= (\cos \phi_s)$$

$$= (\cos 30.69)$$

$$= 0.86 \text{ lagging}$$

Q2 A Three phase 50Hz overhead tr line 100 km long has the following constants Resistance per km per phase = 0.1Ω

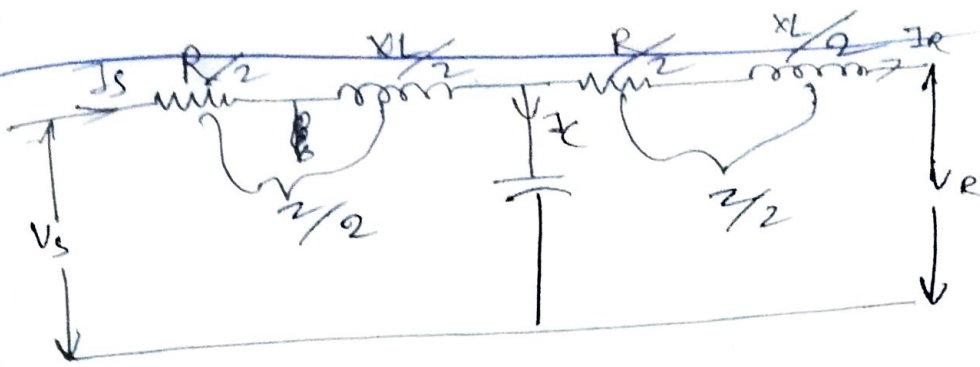
Inductive reactance per km per phase = 0.2Ω

Capacitive susceptance per km per phase = 0.04×10^{-4}

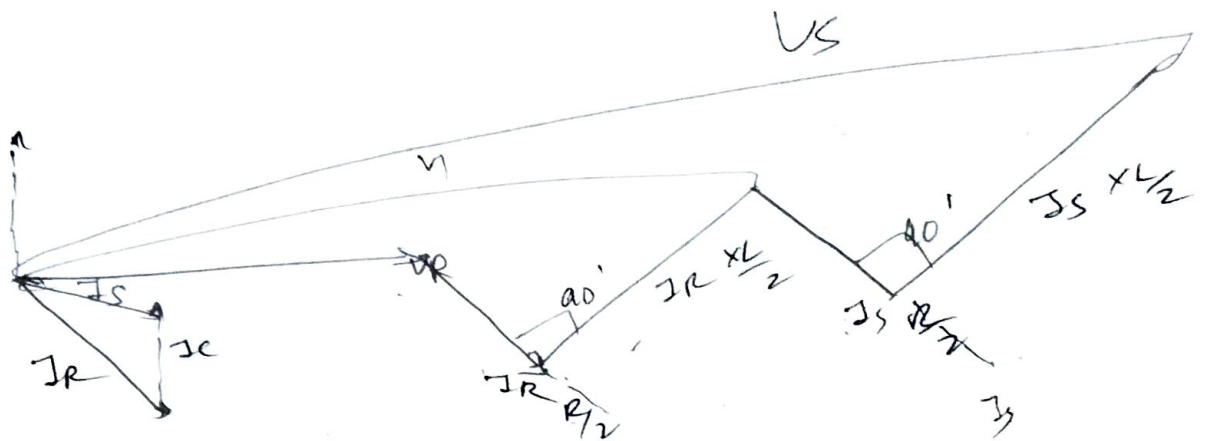
Simen (S) determine the

- (i) Sending end current
- (ii) Sending end voltage
- (iii) sending end p.f
- (iv) Transmission efficiency

When supplying a Balance load of 10000 kW at 66 kV and 0.8 p.f lagging use nominal π method



Phasor



Given

length of the transmission line = 100 km

total Resistance per phase = 10Ω
 $0.1 \Omega \times 100$

Total Reactance per phase = 0.2×100
 $= 20 \Omega$

Total Capacitance substance = $0.04 \times 10^{-4} \times 10^2$
 $= 0.04 \times 10^{-2}$

Receiving end voltage $V_r = \frac{66000}{\sqrt{3}}$
 $= 38105.11$

$$\vec{I}_S = \vec{I}_C + \vec{I}_R$$

$$\vec{P}_R =$$

$$\text{Power delivered} = V_R I_R \cos \phi_R$$

$$=$$

$$\text{Power} = \sqrt{3} V_R I_R \cos \phi_R$$

$$10000 = \sqrt{3} \times \frac{66000}{\cancel{1000}} \times I_R \times 0.8$$

$$\cancel{10000} = \underline{\underline{52799.98 I_R}}$$

$$I_R = \frac{100000}{91452.28}$$

$$I_R = 109.34 \angle -36.86^\circ$$

$$=$$

$$\therefore \text{angle} \therefore$$

$$\frac{I_R}{I_R} = \cos \phi_R = 0.8$$

$$\phi_R = \cos^{-1} 0.8$$

$$= 36.86^\circ$$

$$109.34 (\cos \theta + j \sin \theta)$$

$$= 109.34 (0.8 + j0.6)$$

$$= 87.472 + j65.60$$

$$\vec{I}_C = j4.01$$

$$\text{angle bet}^n = \theta_R \text{ \& } I_R$$

$$\begin{aligned}
 V_1 &= \vec{V_R} + \vec{I_R} \cdot \frac{\vec{Z}}{2} \\
 &= \vec{V_R} + \vec{I_R} \left(\frac{R}{2} + j \frac{X_L}{2} \right) \\
 &= 66000 + 87.472 + j65.60 \left(\frac{10}{2} + \frac{20}{2} \right) \\
 &= 66000 + 87.47 + j65.60 \left(\frac{10+20}{2} \right) \\
 &= 66000 + 87.47 + j65.60 \left(\frac{30}{2} \right) \\
 &= 66000 + 87.47 + j65.60(15) \\
 &= 8
 \end{aligned}$$

$$\begin{aligned}
 V_1 &= \vec{V_R} + \vec{I_R} \frac{\vec{Z}}{2} \\
 &= 38105.11 + 87.472 + j65.60 \left(\frac{10}{2} + j \frac{20}{2} \right) \\
 &= 38105.11 + (87.472 + j65.60) (5 + j10) \\
 &= 38105.11 + 5(87.472 - j65.60) + j10(87.47 - j65.60) \\
 &= 38105.11 + 437.35 - j328 + 874.7j - 656j^2 \\
 &= 38105.11 + 437.35 - j328 + 874.7j + 656 \\
 &= 39198.46 + 546.7j
 \end{aligned}$$

$$\begin{aligned}
 \vec{I_C} &= j \times V_1 \\
 &= j 4 \times 10^{-4} (39195 + j545) \\
 &= j15.678 - 0.218 \\
 &= -0.218 + 15.678j
 \end{aligned}$$

$$= \sqrt{(0.218)^2 + (15.678)^2}$$

$$= \sqrt{0.0475 + 245.799}$$

$$= 15.67$$

$$\vec{I}_S = \vec{I}_E + \vec{I}_R$$

$$= -0.218 + j15.678 + 87.47 + j65.60j$$

$$= 87.252 - 49.922j$$

$$\vec{V}_S = \vec{V}_E + \vec{I}_S \left(\frac{R}{2} + j \frac{X_L}{2} \right)$$

$$= 39198.46 + 545.7j + (87.25 - 49.92j) \left(\frac{10}{2} + j \frac{20}{2} \right)$$

$$= 39198.46 + 545.7j + (87.25 - 49.92j)(5 + j10)$$

$$= 39198.46 + 545.7j + 5(87.25 - 49.92j) + j10(87.25 - 49.92j)$$

$$= 39198.46 + 545.7j + 436.25 - 249.6j + 872.5j - 499.2j^2$$

$$= 39198.46 + 545.7j + 436.25 - 249.6j + 872.5j + 499.2$$

$$= 40133.91 + 1168.6j$$

$$P_{01} = 40145 \angle 1.40$$

Sender end line voltage $\sqrt{3} \times 40145 \angle 1.40$
 $= 69533.179 \Rightarrow 69.533 \text{ kV}$

$$\text{Sending end } \theta_s = \tan^{-1} \left(\frac{1}{P} \right)$$

$$= \tan^{-1} \left(\frac{1168.6j}{4033.91} \right)$$

$$= 1.667$$

$$\theta_s = \tan^{-1} \left(\frac{49.922}{87.252} \right)$$

$$= 29.77$$

$$= 1.667 + 29.77$$

$$= 31.443$$

$$\phi_s = 31.443$$

$$(\cos 31.443)$$

$$= 0.853 \text{ lagging}$$

A three phase 50 Hz, 150 km has a Resistance Inductance and Capacitance shunt admittance of 0.1Ω , 0.5Ω and $3 \times 10^{-6} \text{ S}$ per km per phase. If the line delivers 50 MW at 110 kV and 0.8 power factor lagging, determine the sending end voltage and current. Assume a nominal π circuit for the line

Given

$$\text{length of line} = 150 \text{ km}$$

$$= \frac{150}{1000}$$

$$= 0.15 \text{ AA}$$

$$\text{Total Resistance of line per phase} = 0.1 \times 150 = 15 \Omega$$

$$\text{Total Inductive Reactance} = 0.5 \times 150 = 75 \Omega$$

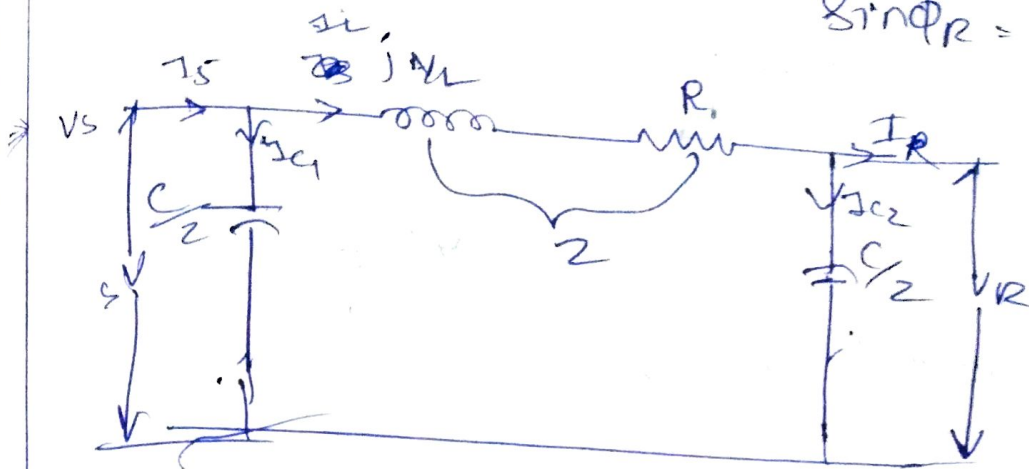
$$\text{Total capacitive admittance} = 3 \times 10^{-6} \times 150 = 45 \times 10^{-5} \text{ S}$$

$$\text{power delivered} = 50 \text{ MW} = 50 \times 10^6 \text{ Watts}$$

$$V_R = \frac{1.10 \times 10^3}{\sqrt{3}} = 63508.52 \text{ V}$$

Receiving end power factor $PF = \cos \phi_R = 0.8$ lag

$$\sin \phi_R = 0.6$$



$$P_{del} = \sqrt{3} V_R I_R \cos \phi_R$$

$$\Rightarrow 50 \times 10^6 = \sqrt{3} \times 110 \times 10^3 \times I_R \times 0.8$$

$$\Rightarrow 50 \times 10^6 = 152420.4711 I_R$$

$$= 152420.47 I_R = 50000000$$

$$\Rightarrow I_R = \frac{50000000}{152420.47}$$

$$I_R = 328.03 \text{ Amp}$$

$$\Rightarrow 328 (\cos \phi_R + j \sin \phi_R)$$

$$= 328 (\cos \phi_R + j \sin \phi_R)$$

$$I_R = 262.4 + j 196.8$$

$$\boxed{\begin{aligned}\vec{I}_S &= \vec{I}_L + \vec{I}_C \\ &= \vec{I}_R + \vec{I}_{C_2} + \vec{I}_{C_1}\end{aligned}}$$

$$\vec{I}_{C_2} = j \frac{1}{2} V_R$$

$$= j \frac{45 \times 10^{-5}}{2} \times 63508$$

$$= j 14.28$$

$$Y = \frac{1}{2}$$

$$=$$

$$\vec{I}_{C_1} =$$

$$\begin{aligned}\text{Total line current } \vec{I}_L &= \vec{I}_R + \vec{I}_{C_2} \\ &= 262.4 - 196.8j + 14.28j \\ &= 262.4 - 182.52j\end{aligned}$$

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

$$= 262.4 - 182.52j (15 + j75) + 63508.52$$

$$= 15(262.4 - 182.52j) + j75(262.4 - 182.52j) + 63508.52$$

$$= \cancel{11198.52} = 3936 - 2737.5j + 19680j + 13687.5j + 63508.52$$

$$\Rightarrow 3936 - 2737.5j + 19680j + 13687.5 + 63508.5$$

$$V = 81132 + 16942.5j$$

$$= 82882.14$$

$$\text{line to line sending end voltage} = \sqrt{3} \cdot 82882.14 \\ = 143555.83 \text{ V}$$

$$\vec{I}_{C1} = j \frac{7}{2} \text{ Vs}$$

$$= j \frac{45 \times 10^5}{2} \times \frac{143555.83}{(81131.5 + j16942.5)}$$

$$= \frac{j36.50 - 7.62}{2}$$

$$= 18.25j - 3.81$$

sending end current (I_s)

$$\vec{I}_s = \vec{I}_{C1} + \vec{I}_L$$

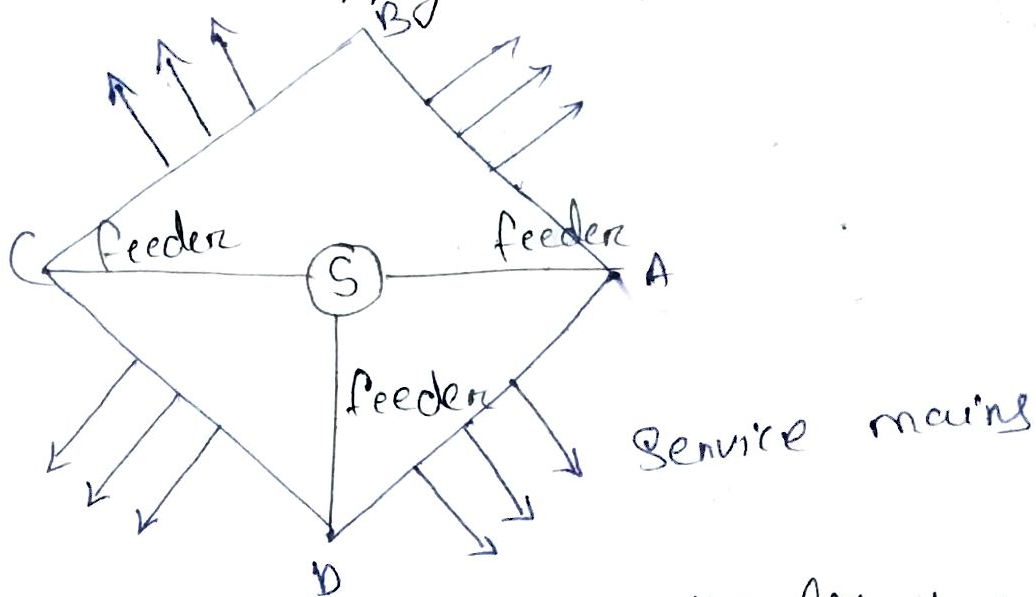
$$= -3.81 + 18.25j + 262.4 - 182.52j$$

$$= 258.59 - 164.27j$$

The main consideration in the design of a feeder is the current carrying capacity ~~disturb~~

Distributors

A distributor is a conductor from which tapping are taken for supply to the consumers



Here AB, BC, CD, AD are the distributors
the current through a distributor is not constant because tapping are taken at various points along its length

Service mains

A service mains is generally a small cable which connect the distributor to the consumer terminal

Classification of distribution system

A distribution system may be classif

Nature of Current:-

According to nature of current the distribution system may be classified as a

- (i) AC distribution system
- (ii) DC distribution system

ii) Type of connection

According to some of connection the distribution system may be classified as a

- (i) Ring main system
- (ii) Radial system
- (iii) Inter connection system

iii) Type of construction

According to type of construction the distribution system may be classified as

- (i) Over head system
- (ii) Under ground system

The over head system is generally employed for distribution as it is ~~high~~ ⁵ to 10 times cheaper than the equivalent under ground system.

- In general the under ground system is used at places where overhead construction is impracticable.

or pro — by the local loads

AC Distribution

Ac System is generally preferred in generation Tx and distribution because

1. Alternating voltage can be conveniently change in magnitude by means of transformers. Transformer has made it possible to transmit Ac power at high voltage and utilised it at a safe potential.
- high transmission and distribution voltage have greatly reduced the current in the conductors and the resulting line losses

The Ac distribution system is classified into

- (a) primary distribution system
- (b) Secondary distribution system

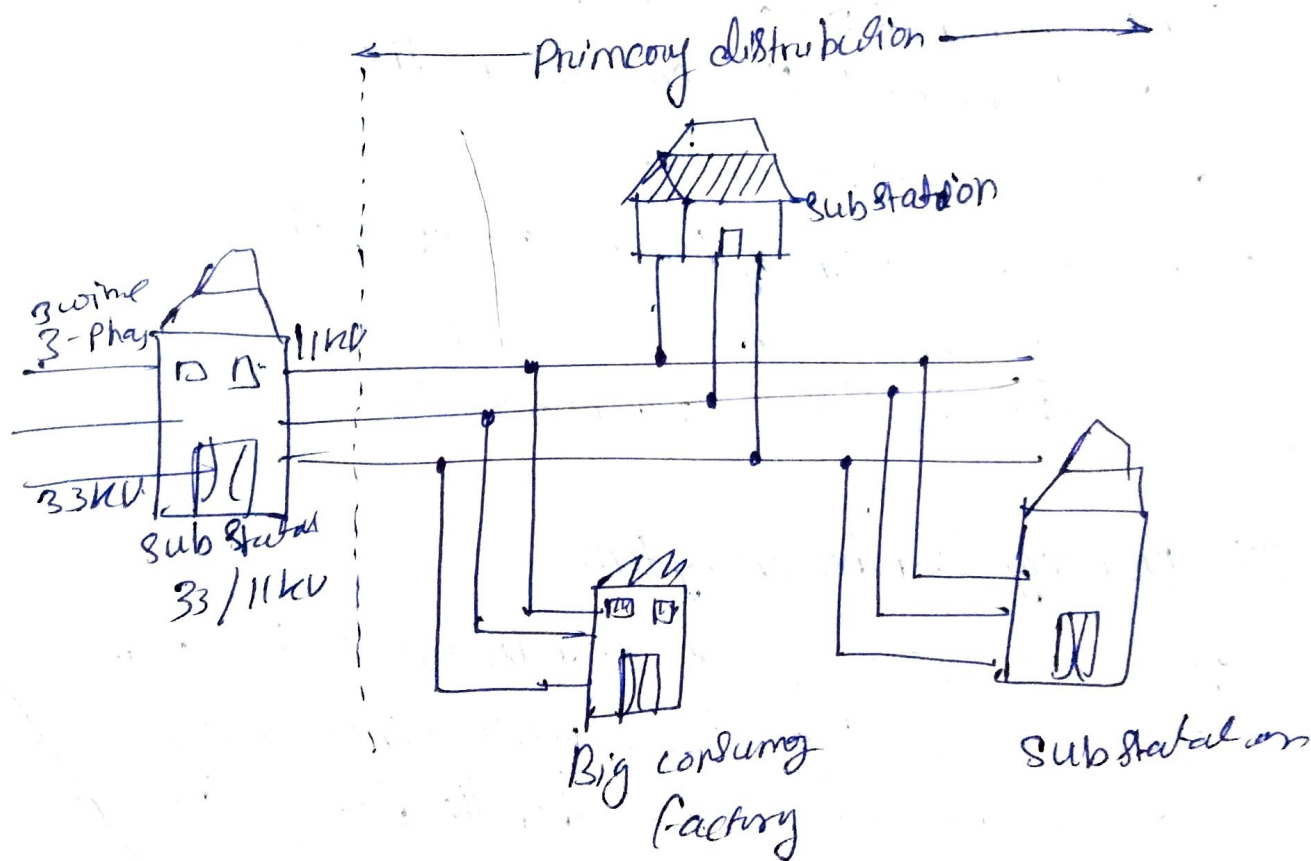
(a) primary distribution system

It is that part of 'Ac' distribution system which operates at voltage some ~~with~~ in general utilisation and handle electrical energy than the consumer uses

The most commonly used primary are 11 kV, 6.6 kV, 3.3 kV

Due to economic consideration primary distribution is carried out by three phase three wire system

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



(c) Secondary distribution system

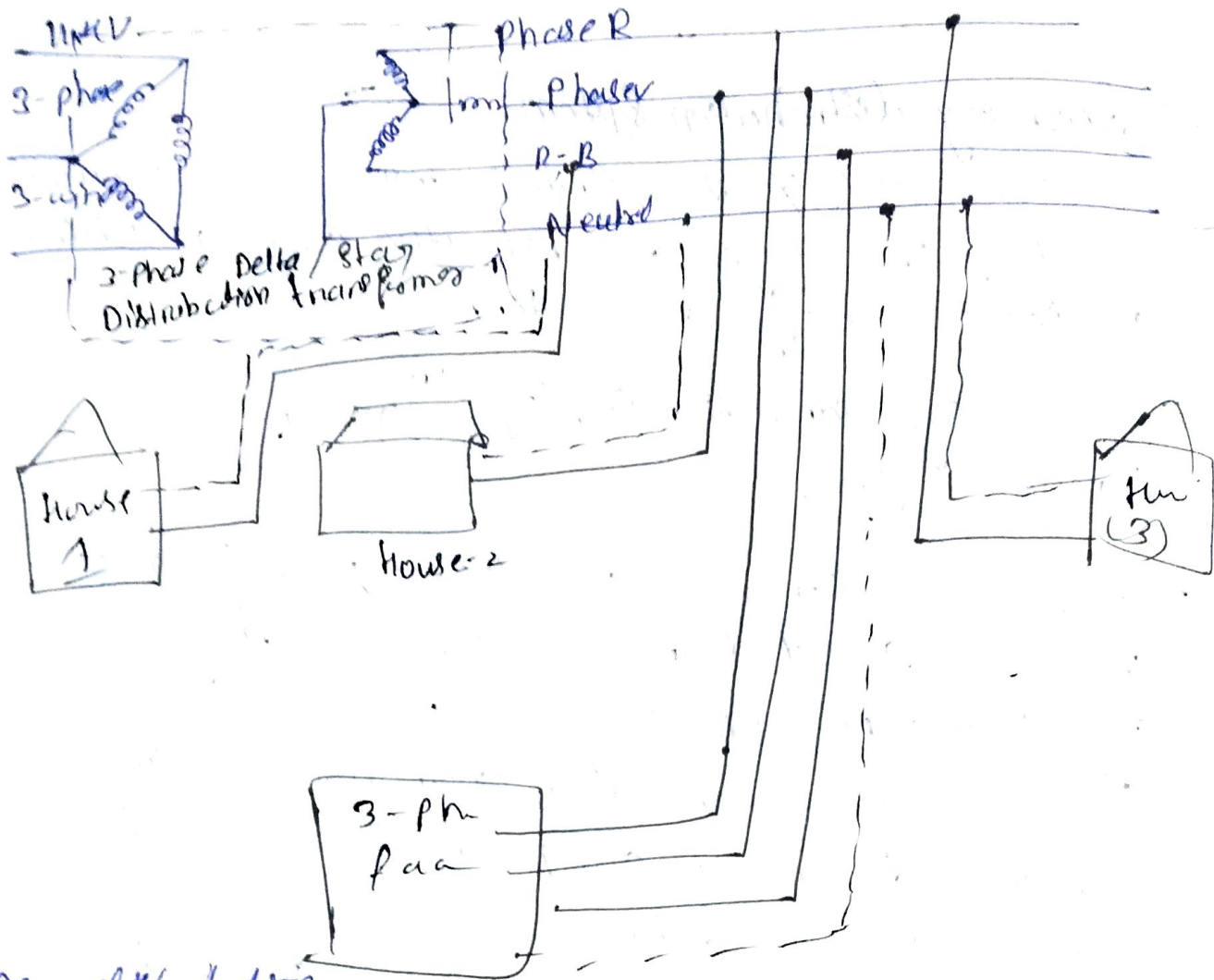
→ It is that part of AC distribution system which includes the range of voltages at which the consumers utilise the electrical energy delivered to them

The secondary distribution employs $\frac{400}{230}V$, 3 phase 4 wire system

- The primary distribution cat delivers power to various substation called distribution substation the substation are situated near the consumers localities and contain step-down transformers at it distribution substation stepdown to 400 volt and power is delivered by three phase four wire AC system

- The voltage between any two phases is 400 volt and between any phase and neutral is 230 volt

The single phase domestic load are connected between any one phase and the neutral, where is three phase 400 volt motor loads are connected across three phase lines directly

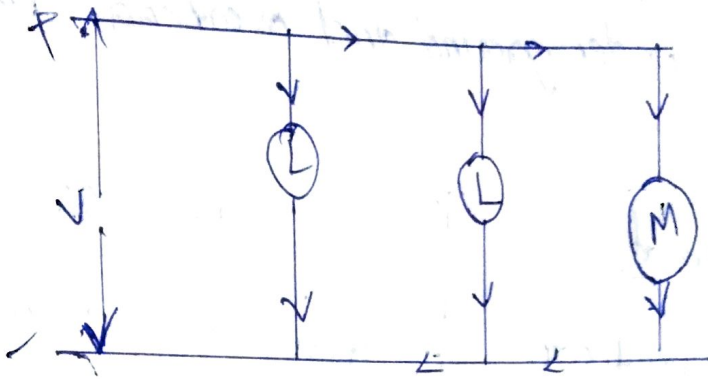


DC distribution

For certain application, 'DC' supply is necessary for example DC supply is required for the operation of variable speed machinery drives (DC motors), for electro chemical works and for congested areas where storage battery reserve are necessary. For this purpose AC power is converted into DC power at the substation by using converting machinery. The DC supply from the substation may be obtained in the form of two wire or three wire for distribution.

Two wire Dc System

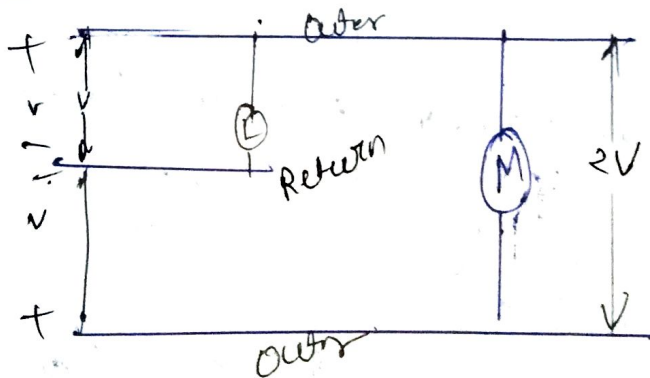
- (1) This system of distribution consist of two wires one is outgoing or positive wire and the other is neg the return or negative wire
- The load such as lamp, motor etc are connected in parallel between the two wires



3 wire Dc System

It consist of two outer and a middle or neutral wire which is earthed at the substation

- The voltage between the outer is twice the voltage between either outer and neutral wire



The principle advantage of this system is that it's makes available two voltage at the consumer terminal ~~there is~~ i.e. voltage V and outer and the neutral and $2V$ between 2 outer.

Loads requiring high voltages (Ex - motor) are connected across the outer, where it's damp and heating ckt requiring less voltage are connected between either outer and the neutral

Type of construction

Comparison betⁿ underground and overhead distribution system.

Over head

3 conductor for the overhead transmission and distribution lines the bare, conductor used

Size - The size of the conductor is smaller as compared to the

Current Capacity - The overhead line has a higher current carrying capacity than the underground

Voltage - It carries a high voltage (400 kV)

Work - It can easily visualize it

Under ground

insulated conductor is used

The size of conductor is large due to the coated insulator

- It has lesser carrying capacity

It carries a limited voltage (66 kV)

As these cables are underground it can not visualize them

> production of chlorine gas, Am

reference) Overhead line
interfere with
communication line

It requires less
insulation on the
contact point of the
tower

Cheaper

low maintenance

easily join extra
connection

easy to repair and
clear fault

it doesn't interfere
with communication
line

It requires
more insulation
for each & every
conductor

- expensive

- High maintenance

- not

- difficult

point goes on decreasing.

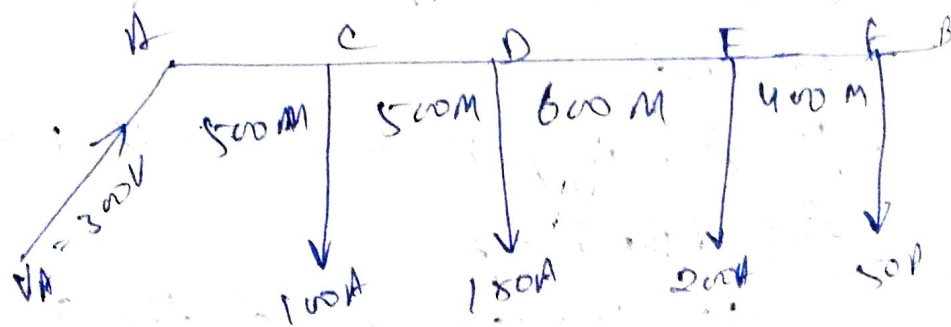
Thus current in section AB is more than the current in section CD

and current in section CD is more than the current in section DE

In case The voltage across the loads away from the feeding point goes on decreasing thus in fig the minimum voltage occurs 'E' in case of fault on any section of the distributor the whole distributor will have to be disconnected from the supply mains. Therefore continuity of supply is interrupted.

Q. A Two wire DC distributor cable A, B is 2000 meters long and supplies load of 100 A, 150 A, 200 A and 50 A. Situated 500 mtr, 1000 mtr, 1600 mtr and 2000 mtr from the feeding point 'A' each conductor has a Resistance of 0.01 Ω per 1000 mtr. Calculate the potential difference at each load point if a potential difference of 300 volt is to maintain at point 'A'.

Ans - Given



Resistance of one conductor per 1000 m = 0.01Ω

for two conductor cable $(R) = 2 \times 0.01 = 0.02 \Omega$

Resistance of section AC $(R_{AC}) = 0.01 \Omega$

$0.01 \times 1000 = 10$
 $0.02 \times 1000 = 20$
 $0.01 \times 1000 = 10$
 $0.02 \times 1000 = 20$
 $0.01 \times 1000 = 10$
 $0.02 \times 1000 = 20$

for 1000 m = 0.02

$$1 = \frac{0.02}{1000}$$

$$\text{for 500 mtr} = \frac{0.02}{1000} \times 500$$
$$= 0.01 \Omega$$

Resistance of section AD = $0.02 \times \frac{500}{1000}$

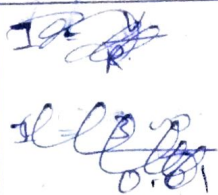
$$= 0.01 \Omega$$

$$R - DE = \frac{0.02 \times 600}{1000}$$

$$= \frac{0.06}{5}$$
$$= 0.012 \Omega$$

$$R - EF = \frac{0.02 \times 400}{1000}$$

$$= 0.008 \Omega$$



$$E_f(I) = 50 \text{ A}$$

$$DE(I) = 250 \text{ A}$$

$$CD(I) = 400 \text{ A}$$

$$AC(I) = 500 \text{ A}$$

Voltage drop across AC $\Rightarrow V = I \times R$

$$= 500 \times 0.01$$

$$= 5 \text{ volt}$$

$$\underline{CD} \Rightarrow 400 \times 0.01$$

$$= 4 \text{ volt}$$

$$\underline{DE} = 250 \times 0.012$$

$$= 3 \text{ volt}$$

$$\underline{EF} \Rightarrow 50 \times 0.008$$

$$= 0.4 \text{ volt}$$

Potential difference at point c = $300 - 5$

$$= \boxed{295 \text{ volt}}$$

Potential difference at point b = $295 - 4$

$$= \boxed{291 \text{ volt}}$$

potent differ at point E = $291 - 3$

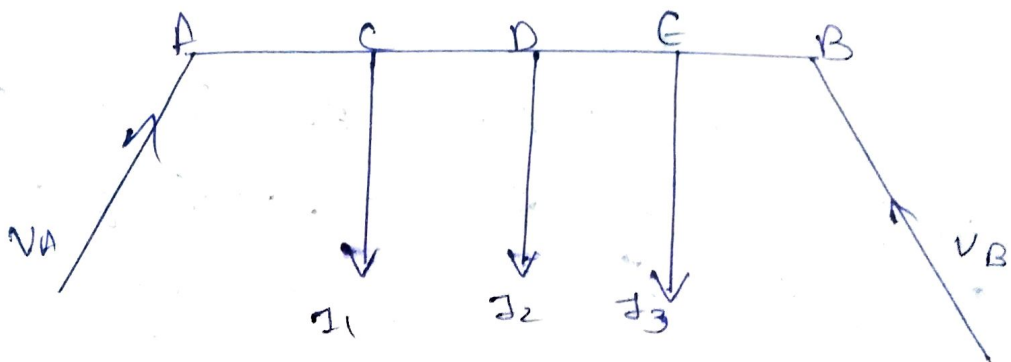
$$= \boxed{288 \text{ volt}}$$

potential difference at point F = $288 - 0.4$
 $= 287.6$
 $= \boxed{287.6 \text{ volt}}$

1) Distributor fed at both end

In this type of feeding the distributor is connected to the supply mains at both ends and loads are tap off at different point along the length of the distributor.

- The voltage at the feeding point may be equal



- fig 3 shows a distributor AB fed at the end A and B and loads I_1, I_2, I_3 are tap off at point C, D, E respectively.
- Hence the load voltage goes on decreasing as we move away from one feeding point.

The minimum ~~point~~ voltage occurs at sum load point and is never fixed. It is fixed with the variation of load on different sections of the distributor.

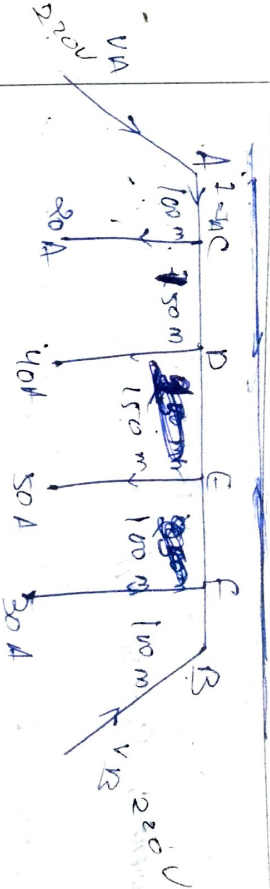
Advantage

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

The area of x-section required for a ~~double~~ fed distributor is much less than that of a single fed distributor.

Q A Two wire DC, Street mains AB 600 m long is fed from both end at 250 volt. loads of 20 amp, 40 amp, 50 amp, and 30 amp are tapped at distance of 100 m, 250 m, 400 m, and 500 m from the point A respectively. If the area of x-section of distributor is ~~of~~ conduction is ~~over~~ 1 cm^2 . Find the minimum conductor voltage. Take $\rho = 1.7 \times 10^{-6} \text{ } \Omega \text{ cm}$.

600 mtr



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

=

Resistance of 1 mtr length of distributor

$$= 2 \times 1.7 \times 10^{-6} \times 100$$

$$R = 3.4 \times 10^{-4} \Omega$$

$$R_{AC} = I_{AC} \times 100 \text{ mtr}$$

$$= 3.4 \times 10^{-4} \times 10^2$$

$$= 3.4 \times 10^{-2}$$

$$\frac{AC}{A} = \boxed{0.034} \Omega$$

$$R_{ACD} = 3.4 \times 10^{-4} \times 150$$

$$CD = \boxed{0.051} \Omega$$

$$R_{ACDE} = 0.051 \Omega$$

$$R_{ACDEF} = 3.4 \times 10^{-4} \times 100$$

$$= \boxed{0.034} \Omega$$

$$R_B =$$

$$\boxed{0.034}$$

Let the current flow from point A = I_A
 current in Section CD = $I_A - 20A$

$$I_A = 20A$$

$$I_{DE} = I_A - 60A$$

$$I_A = 60A$$

$$I_{EF} = I_A - 110A$$

$$I_A = 110A$$

$$I_{FB} = I_A - 140A$$

$$I_A = 140A$$

$$\text{Voltage drop across AC} = I \times R = 140 \times R$$

$$= 20 \times 0.034$$

Voltage at point B =

Voltage at point B = voltage at point A (V) =

voltage drop along the length of the distributor

$$220V = 220V - [I_A R_A + I_{ED} R_{ED} + I_{EF} R_{EF} + I_{FB} R_{FB}]$$

$$+ I_{GF} R_{GF} + I_{EB} R_{EB}]$$

$$220V = 220V - [5A(0.034) + (5A - 20)(0.051) + (5A - 60)(0.05) + (5A - 110)(0.034) + (5A - 140)(0.034)]$$

$$+ (5A - 110)(0.034) + (5A - 140)(0.034)]$$

use of

include ground and can also be used for

control and

$$I_{CD} = 0.034 I_A + 0.051 I_A - 1.02 + 0.051 I_A - 3.06 + 0.034 I_A - 3.74 + 0.034 I_A - 4.76$$

$$I_{CD} = 0.204 I_A - 12.58$$

$$0 = 0.204 I_A + 12.58$$

$$0.204 I_A = 12.58$$

$$I_A = 12.58$$

$$0.204$$

$$I_A = 61.67 \text{ A}$$

$$I_{CD} = I_A - 20 \text{ A}$$

$$= 61.67 - 20$$

$$I_{CD} = 41.67 \text{ A}$$

$$I_{DE} = I_A - 60 \text{ A}$$

$$= 61.67 - 60 \text{ A}$$

$$I_{DE} = 1.67 \text{ A}$$

$$I_{GF} = I_A - 110 \text{ A}$$

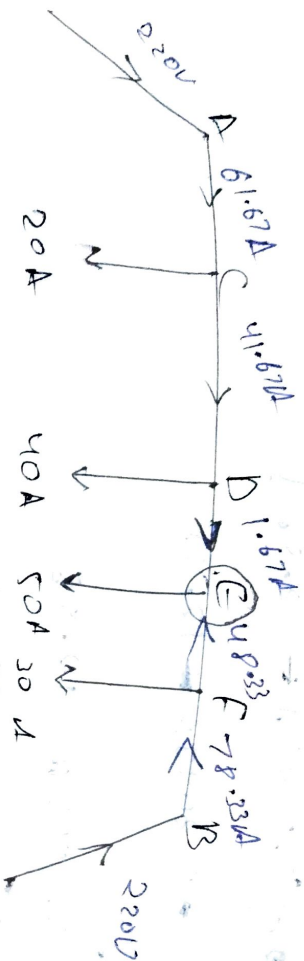
$$= 61.67 - 110 \text{ A}$$

$$I_{GF} = -48.33$$

$$I_a - I_b$$

$$= 61.67 - 140$$

$$I_{FB} = \boxed{-78.33A}$$



minimum voltage will occurs at point ~~E~~

$$V_E = V_A - \text{Voltage drop } AE$$

$$V_E = 220 - [(61.67)(0.037) + (41.67)(0.051) +$$

$$(1.67)(0.051)]$$

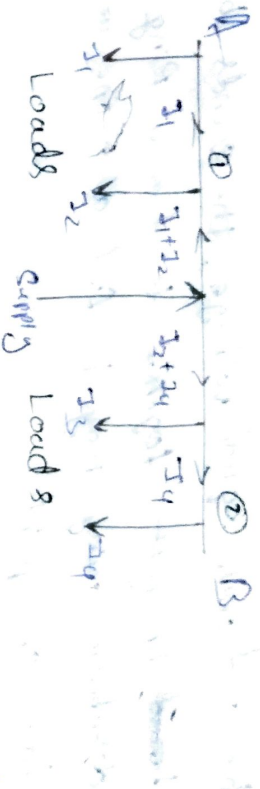
$$V_E = 220$$

$$- [4.307]$$

$$V_E = 220 - 4.307$$

$$= 215.58 \text{ Volt}$$

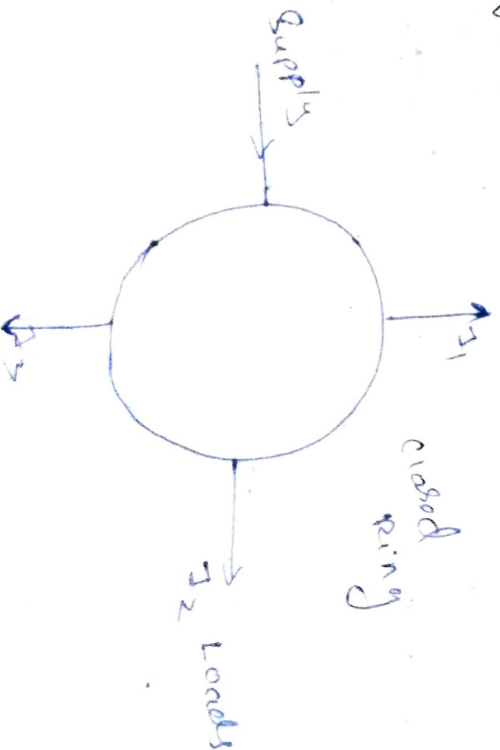
③ Distributor fed at centre i.e.



In this type of feeding the center of the distributor is connected to the supply mains.

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

④ Ring main distributor



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