

EEE DEPARTMENT

POWER SYSTEMS II

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UNIT I : Transmission Line Parameters

Types of conductors – calculation of resistance for solid conductors – Calculation of inductance for single phase and three phase, single and double circuit lines, concept of GMR & GMD, symmetrical and asymmetrical conductor configuration with and without transposition, Numerical Problems. Calculation of capacitance for 2 wire and 3 wire systems, effect of ground on capacitance, capacitance calculations for symmetrical and asymmetrical single and three phase, single and double circuit lines, Numerical Problems

UNIT-II

Performance of Short and Medium Length Transmission Lines

Classification of Transmission Lines – Short, medium and long line and their model representations – Nominal- T, Nominal- π and A, B, C, D Constants for symmetrical & Asymmetrical Networks, Numerical Problems. Mathematical Solutions to estimate regulation and efficiency of all types of lines – Numerical Problems.

UNIT-III

Performance of Long Transmission Lines

Long Transmission Line-Rigorous Solution, evaluation of A,B,C,D Constants, Interpretation of the Long Line Equations, Incident, Reflected and Refracted Waves -Surge Impedance and SIL of Long Lines, Wave Length and Velocity of Propagation of Waves – Representation of Long Lines – Equivalent-T and Equivalent π network models (numerical problems)

UNIT – IV

Power System Transients

Types of System Transients – Travelling or Propagation of Surges – Attenuation, Distortion, Reflection and Refraction Coefficients – Termination of lines with different types of conditions – Open Circuited Line, Short Circuited Line, T-Junction, Lumped Reactive Junctions (Numerical Problems). Bewley's Lattice Diagrams (for all the cases mentioned with numerical examples)

UNIT-V

Various Factors Governing the Performance of Transmission line

Skin and Proximity effects – Description and effect on Resistance of Solid Conductors – Ferranti effect – Charging Current – Effect on Regulation of the Transmission Line, Shunt Compensation. Corona – Description of the phenomenon, factors affecting corona, critical voltages and power loss, Radio Interference and power factor improving methods.

UNIT-VI

Sag and Tension Calculations and over head line insulators

Sag and Tension Calculations with equal and unequal heights of towers, Effect of Wind and Ice on weight of Conductor, Numerical Problems – Stringing chart and sag template and its applications Types of Insulators, String efficiency and Methods for improvement, Numerical Problems – voltage distribution, calculation of string efficiency, Capacitance grading and Static Shielding

UNIT - I

Transmission Line parameters

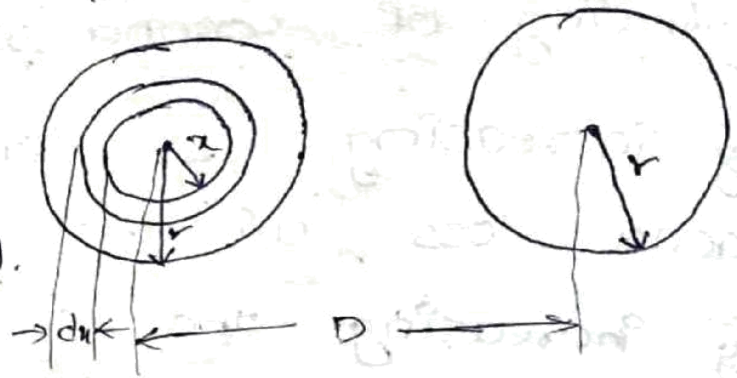
Inductance : $L = \frac{N\Phi}{I}$

Inductance means.

flux linkages for the two conductor is "D", and radius "x". in the thickness of the

Amp. Let us consider a ring of radius "r". distance b/w conductor and change in the ring is dx .

Here
 r = radius of the conductor.
 x = inner radius of the conductor.
 dx = distance b/w the conductor.



Assuming. Current density in the ring equal to the current density in the conductor.

$$\therefore \frac{I}{\pi r^2} = \frac{I_x}{\pi x^2}$$

$$I_x = \frac{I x^2}{r^2}$$

$$I_x = \frac{I x^2}{r^2} \quad \text{--- (1)}$$

Magnetic field strength in the ring

$$H_x = \frac{I_x}{2\pi x}$$

$$H_r = \frac{I_r}{2\pi r}$$

$$= \frac{I_r}{r^2} \times \frac{1}{2\pi r}$$

$$H_r = \frac{I_r}{2\pi r^2}$$

magnetic flux density $B_r = \mu H_r$.

$$B_r = \mu_0 \mu_r H_r \quad [\because \mu = \mu_0 \mu_r]$$

$$B_r = \mu_0 \mu_r \cdot \frac{I_r}{2\pi r^2} \quad \left[H_r = \frac{I_r}{2\pi r^2} \right]$$

Flux $\phi_r = B_r \times A_r$ [Let us Consider.
1 m length of conductor
and thickness dr]

$$\phi_r = B_r \times 1 \times dr.$$

$$\phi_r = \mu_0 \mu_r \cdot \frac{I_r}{2\pi r^2} \times dr \quad \text{--- (2)}$$

Now, flux linkages = $N_r \times \phi_r$.

where N_r is the ratio of inner and outer dia of conductors.

$$\text{flux linkages} = \frac{r}{r^2} \times \mu_0 \mu_r \cdot \frac{I_r}{2\pi r^2} \times dr$$

$$= \frac{r}{r^2} \times \mu_0 \mu_r \cdot \frac{I_r}{2\pi r^2} \times dr.$$

$$= \frac{1}{r} \times \mu_0 \mu_r \times I_r \times dr.$$

$$= \frac{\mu_0}{2\pi} \int_r^D \frac{1}{n} dn$$

$$= \frac{\mu_0}{2\pi} \left[\log n \right]_r^D \quad \left[\because \int \frac{1}{n} \cdot dn = \log n \right]$$

$$= \frac{\mu_0}{2\pi} \left[\log D - \log r \right]$$

$$= \frac{\mu_0}{2\pi} \left[\log \left(\frac{D}{r} \right) \right]$$

$$\therefore L = \frac{\mu_0}{2\pi} \left[\log \left(\frac{D}{r} \right) \right] \longrightarrow \textcircled{B}$$

Now, Total Inductance = Inductance in inside Conductor + Inductance in outside Conductor

Now, By adding equation $\textcircled{A}$ & $\textcircled{B}$

$$L = \frac{\mu_0 \mu_r}{8\pi} + \frac{\mu_0}{2\pi} \left[\log \left(\frac{D}{r} \right) \right]$$

$$L = \frac{\mu_0}{2\pi} \left[\frac{\mu_r}{4} + \log \frac{D}{r} \right] \text{ Henry}$$

$$\therefore L = \frac{2 \times 10^{-7}}{2\pi} \left[\frac{\mu_r}{4} + \log \frac{D}{r} \right]$$

For Consider Non-Magnetic Material.

$$L = 2 \times 10^{-7} \left[\frac{1}{4} + \log \frac{D}{r} \right]$$

$$\text{inductance/m} = \left[0.5 + 2 \log \frac{D}{r} \right] \times 10^{-7} \text{ Henry/meter}$$

$$\text{inductance/km} = \left[0.5 + 2 \log \frac{D}{r} \right] \times 10^{-7} \times 10^3 \text{ Henry/km.}$$

$$\text{inductance/km} = \left[0.5 + 2 \log \frac{D}{r} \right] \times 10^{-4} \text{ Henry/km.}$$

* For 3- ϕ Transmission System:

When the Spacing between the conductors are equal then, inductance for meter & km are

$$\text{inductance/m} = \left[0.5 + 2 \log \frac{D}{r} \right] \times 10^{-7} \times 10^3 \text{ Henry/km.}$$

$$\text{inductance/km} = \left[0.5 + 2 \log \frac{D}{r} \right] \times 10^{-4} \text{ Henry/km.}$$



* When conductors are unequally spaced :



$$D = \sqrt[3]{D_1 D_2 D_3}$$

$$\text{inductance/m} = \left[0.5 + 2 \log \frac{\sqrt[3]{D_1 D_2 D_3}}{r} \right] \times 10^{-7} \text{ Henry/m.}$$

* steps to find inductance :

* Current density.

$$I_x$$

$$H_x = \frac{I_x}{2\pi x}$$

$$B_x = \mu_0 H_x$$

$$\phi_x = B_x \times A_x$$

$$\text{Flux linkages} = \frac{\phi_x}{\mu} \times N_x \times \phi_x$$

$$\text{Inductance} = \int \frac{\text{linkages}}{I} \cdot dx$$

In When a 3- ϕ Transmission line having 3-conductors are equally spaced at a distance of 0.8 meters. are Conductor radius is 0.7cm. Find out the inductive reactance. when frequency is 50 Hz.

→ Given data:

In 3- ϕ Transmission line

Distance $D = 0.8$ meters.

radius of Conductor $r = 0.7$ cm.

frequency $f = 50$ Hz.

Inductive reactance = ?

$$\text{inductance } l_m = \left[0.5 + 2 \log \left(\frac{D}{r} \right) \right] \times 10^{-7}$$

$$= \left[0.5 + 2 \log \left(\frac{0.8}{0.7} \right) \right] \times 10^{-7}$$

$$= \left[0.5 + 0.05 \right] \times 10^{-7}$$

$$\text{induc } l_m = 0.55 \times 10^{-7} \text{ H/m} = 0.55 \times 10^{-5} \text{ H/m}$$

$$\text{Now } X_L = 2\pi f l$$

$$= 2 \times \pi \times 50 \times 0.55 \times 10^{-5}$$

$$X_L = 1.727 \times 10^{-3} \Omega/\text{m}$$

$$X_L = 1.9 \times 10^{-5} \Omega/\text{m}$$

→ Given data:

Distance $D_1 = 0.8$ meters.

$D_2 = 0.7$ meters.

$D_3 = 0.9$ meters.

radius of Conductor $r = 0.7$ cm.

Frequency $f = 50$ Hz.

Inductive Reactance = ?

$$\text{Inductance (M)} = 0.5 + 2 \log \left(\frac{\sqrt[3]{D_1 D_2 D_3}}{r} \right) \times 10^{-7}$$

$$= 0.5 + 2 \log \left(\frac{\sqrt[3]{0.9 \times 0.8 \times 0.7}}{0.7 \times 10^{-2}} \right) \times 10^{-7}$$

$$L = 4.61 \times 10^{-7} \text{ Henry (H)}$$

$$\text{Now } X_L = 2\pi f L$$

4.61

Let us consider two conductors, A and B

having radius a and distance D between the
Centre of conductors is a . Conductor A is
positive charge and Conductor B is negative
charge. Let a point "P" is taken at a
distance "x" from the Centre of the Conductor A.
The distance from point P to Centre of Conductor
B is $D-x$.

(field intensity.)

$$\text{Capacitance } 'C' = \frac{Q}{V}$$

Capacitance is the ratio of charge in coulomb
to the potential difference in volts.

$$\text{field intensity } E_A = \frac{Q}{2\pi\epsilon_0\epsilon_r x}$$

field intensity at point B is

$$E_B = \frac{-Q}{2\pi\epsilon_0\epsilon_r (D-x)}$$

$$\text{potential at A } V_A = E_A \cdot dx$$

$$V_A = \frac{Q}{2\pi\epsilon_0\epsilon_r x} \cdot dx \quad \left[\because E_A = \frac{Q}{2\pi\epsilon_0\epsilon_r x} \right]$$

$$V_B = \int \frac{-Q}{2\pi\epsilon_0\epsilon_r(D-x)} \cdot dx$$

$$\left[\because \frac{-Q}{2\pi\epsilon_0\epsilon_r(D-x)} \right]$$

potential difference at point 'p' is

$$V_p = V_A - V_B$$

$$= \frac{Q}{2\pi\epsilon_0\epsilon_r x} - \left[\frac{-Q}{2\pi\epsilon_0\epsilon_r(D-x)} \right] dx$$

$$V_p = \frac{Q}{2\pi\epsilon_0\epsilon_r x} dx + \frac{Q}{2\pi\epsilon_0\epsilon_r(D-x)} dx$$

$$V_p = \frac{Q}{2\pi\epsilon_0\epsilon_r} \left[\frac{1}{x} + \frac{1}{(D-x)} \right] \cdot dx$$

$$V_p = \frac{Q}{2\pi\epsilon_0} \left[\frac{1}{x} + \frac{1}{(D-x)} \right] \cdot dx \quad [\because \epsilon_r = 1]$$

$$(v) \text{ total potential difference} = \int_r^{D-r} \frac{Q}{2\pi\epsilon_0} \left[\frac{1}{x} + \frac{1}{(D-x)} \right] \cdot dx$$

$$V = \frac{Q}{2\pi\epsilon_0} \int_r^{D-r} \left[\frac{1}{x} + \frac{1}{(D-x)} \right] \cdot dx$$

$$V = \frac{Q}{2\pi\epsilon_0} \left[\log(D-r) - \log r - (\log(D-(D-r)) - \log(D-r)) \right]$$

$$V = \frac{Q}{2\pi\epsilon_0} \left[\log(D-r) - \log r - \log r + \log(D-r) \right]$$

$$V = \frac{Q}{2\pi\epsilon_0} \left[2 \cdot \log(D-r) - 2 \log r \right]$$

$$V = \frac{Q}{2\pi\epsilon_0} \times 2 \left[\log(D-r) - \log r \right]$$

$$V = \frac{2Q}{2\pi\epsilon_0} \left[\log\left(\frac{D-r}{r}\right) \right]$$

$$V_{\text{avg}} = \frac{Q}{\pi\epsilon_0} \left[\log\left(\frac{D}{r}\right) \right]$$

Now Capacitance $C = \frac{Q}{V} = \frac{Q}{\frac{Q}{\pi\epsilon_0} \left[\log\left(\frac{D}{r}\right) \right]}$

$$C = \pi\epsilon_0 \left[\log\left(\frac{D}{r}\right) \right] \quad C = \frac{\pi\epsilon_0}{\log(D/r)}$$

$$\therefore C = \pi\epsilon_0 \left[\log\left(\frac{D}{r}\right) \right]$$

$$C = \frac{\pi\epsilon_0}{\log(D/r)}$$

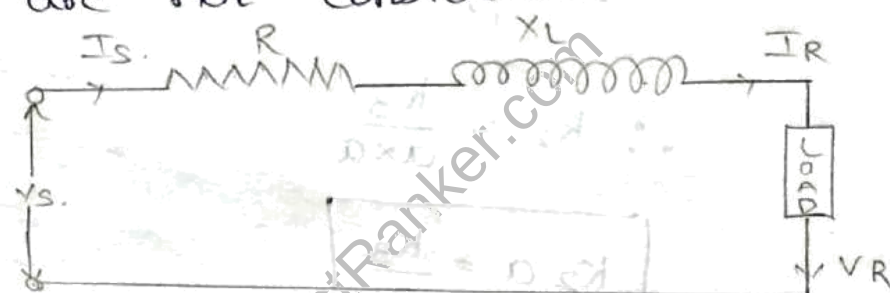
classification of Transmission Lines

The transmission lines are mainly divided into 3-types.

- (i) Short Transmission lines.
- (ii) medium Transmission lines.
- (iii) Long Transmission lines.

* Short Transmission Lines

These are used to ~~above~~ up to 50 km. and the rating of voltage is up to 20 kV. ~~the~~ It has low voltage and Capacitance effects so these are not considered.



where V_s = Sending voltage.

I_s = Sending current.

X_L = Reactance R = Resistance.

I_R = Receiving current

V_R = Receiving voltage.

* Voltage Regulation:



ending End voltage and Receiving End voltage
to the Receiving End voltage

$$\therefore \text{voltage Regulation} = \frac{V_S - V_R}{V_R}$$

$$\% \text{ of voltage Regulation} = \frac{V_S - V_R}{V_R} \times 100 \%$$

Consider ΔOBD .

According to pythagarous theorem,

$$OD^2 = OB^2 + BD^2$$

$$OD^2 = (OA + AB)^2 + (BC + CD)^2 \quad (\because \text{Vector diagram})$$

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

$$\left[\begin{aligned} \because \angle OEA &= \cos \phi_R = \frac{OA}{VR} \therefore OA = \cos \phi_R VR \\ \sin \phi_R &= \frac{BC}{VR} \Rightarrow BC = \sin \phi_R \cdot VR \end{aligned} \right]$$

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

$$IR = I_S (\cos \phi_R + \sin \phi_R)$$

* efficiency of Transmission lines:

$$\eta = \frac{O/P}{I/P} = \frac{V_R I_R \cos \phi_R}{V_S I_S \cos \phi_S} = \frac{V_R I_R \cos \phi_R}{V_R I_R \cos \phi_R + I^2 R}$$

The ratio of output power to the input power
is known as efficiency



voltage of 11 kV. and delivers a power of 200 kVA. and Resistance for phase equal to 5Ω and Reactance for phase is 3Ω . Find out the voltage Regulation, and efficiency of Transmission line at 0.85 power factor lag.

→ Given data:

$$V_R = 11 \text{ kV}$$

$$= 11 \times 1000 \text{ V}$$

$$= 11000 \text{ V}$$

$$P_R = 200 \times 1000 \text{ VA}$$

$$= 200000 \text{ VA}$$

$$R = 5 \Omega$$

$$X_L = 3 \Omega$$

$$\cos \phi_R = 0.85$$

$$\phi_R = \cos^{-1}(0.85)$$

$$= 31.78^\circ$$

$$\sin \phi_R = \sin(31.78^\circ)$$

$$= 0.52$$

$$\therefore I = \frac{P_R}{V_R} = \frac{200 \times 1000}{11000} = 18.18 \text{ Amp.}$$

$$I = 18.18 \text{ Amp.}$$

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

$$= \sqrt{[(11000 \times 0.85) + (18.18 \times 5)]^2 + [(11000 \times 0.52) + (18.18 \times 3)]^2}$$

$$= 11000 \text{ V}$$

$$V_s = \sqrt{81762796.5 + 35741518.5}$$

$$= 10978.1 \text{ V} \quad 11004.91294$$

$$V_s = 10978.1 \text{ V} \quad 11004.91294$$

$$\text{Now Voltage Regulation} = \frac{V_s - V_R}{V_R} = \frac{11004.91 - 11000}{11000}$$

$$\text{Voltage Regulation} = 4.46 \times 10^{-4}$$

$$\%V_R = 4.46 \times 10^{-4} \times 100 = \frac{11004.91 - 11000}{11000} \times 100 = 0.46 \times 100 = 4$$

* classification of overhead Transmission lines
These are divided into 3 types.

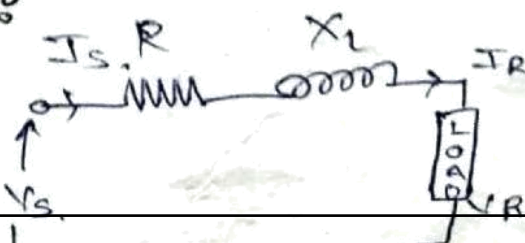
- (i) short Transmission line (50 km) 20 kv.
- (ii) Medium Transmission line (50 - 150 km) 100 kv.
- (iii) Long Transmission lines (above 150 km) Above 100 kv.

i) Short Transmission lines

where V_s = sending voltage,

I_s = sending current,

X_L = Reactance,

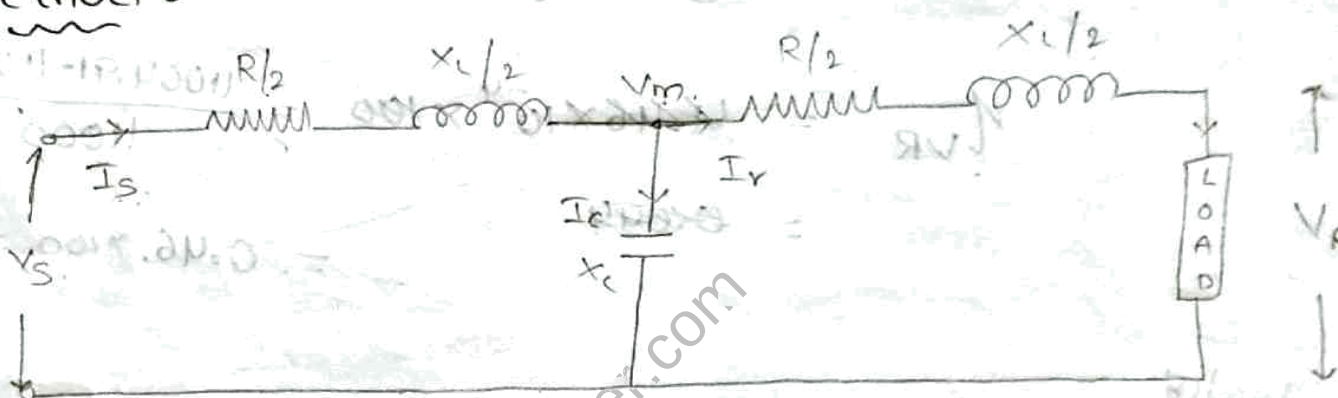


The length is $20 - 80$ km and voltage is $20 - 100$ kV. is called medium. Transmission lines.

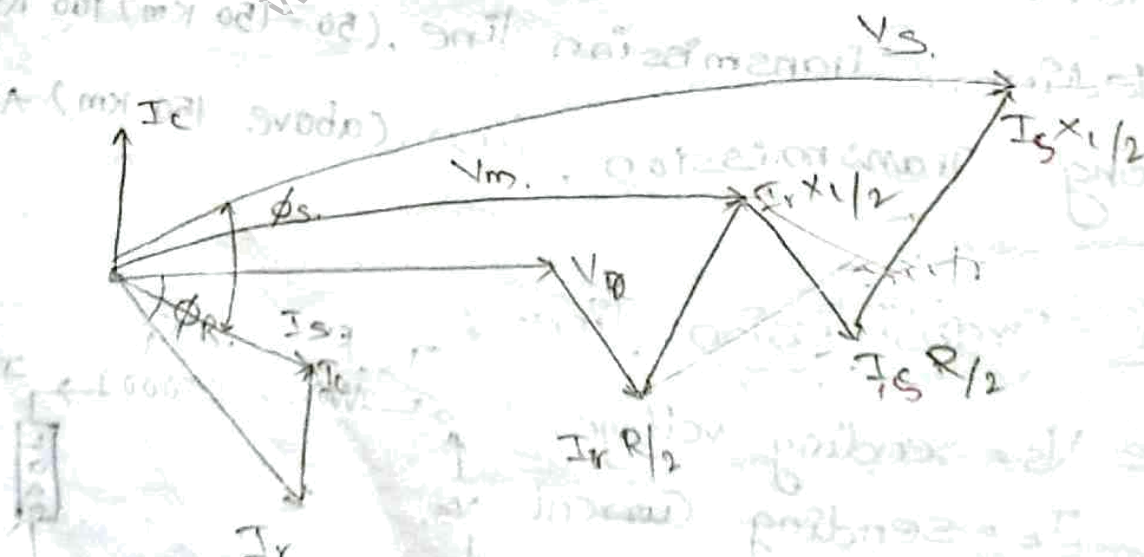
These are divided into 3 types.

- (i) End Condenser
- (ii) T - method.
- (iii) π - method.

* T - method :



* phasor diagram :



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

$$I_C = \frac{V}{X_C}$$

$$X_C = \frac{1}{2\pi f C}$$

$$V_m = V_R + I_R (R/2 + j X_L/2)$$

$$V_S = V_m + I_S (R/2 + j X_L/2)$$

* problems :

1. A medium Transmission line having a receiving End voltage 66 kV. and delivers a power of 150 kVA and Total Resistance is 6Ω and Inductive Reactance of 4Ω and the Capacitance value is 200 nF . Find the voltage Regulation and efficiency of Transmission line. if the $\cos\phi_R = 0.8$ lag and frequency 50 Hz . Assume any missing data.

→ Given data :

$$V_R = 66\text{ kV} = 66 \times 1000\text{ Volts}$$

$$P = 150\text{ kVA} = 150 \times 1000\text{ VA}$$

$$\text{Total Resistance} = 6\Omega$$

$$\therefore R/2 = 6/2 = 3\Omega$$

$$\text{Inductance} = 4\Omega$$

$$\therefore \frac{X_L}{2} = \frac{4}{2} = 2\Omega$$

$$\text{Capacitor value } C = 200\text{ nF}$$

$$= 200 \times 10^{-9}\text{ F}$$

$$\phi_R = 36.86^\circ$$

$$\sin \phi_R = 0.6$$

$$\text{Frequency} = 50 \text{ Hz}$$

$$\text{Voltage Regulation} = ?$$

Now we know that

$$V_m = V_R + I_R \left[\frac{R}{2} + j \frac{X_L}{2} \right]$$

$$I_r = I_r (\cos \phi_r + j \sin \phi_r)$$

$$I = \frac{P}{V} = \frac{150 \times 1000}{66 \times 1000} = 2.272$$

$$\therefore I_r = 2.272$$

$$\therefore I_r = I_r (\cos \phi_r + j \sin \phi_r)$$

$$= 2.272 (0.8 + j 0.6)$$

$$= 1.817 + j 1.363$$

$$\text{Now } V_m = V_R + I_r \left(\frac{R}{2} + j \frac{X_L}{2} \right)$$

$$= (66 \times 10^3) + (1.817 + j 1.363)(3 + j 2)$$

$$= (66 \times 10^3) + [2.724 + j 7.718]$$

$$V_m = 66002.724 + j 7.718$$

$$\therefore V_m = 66002.724 + j 7.718$$

$$V_s = V_m + I_s (R/2 + jX_L/2)$$

$$I_s = I_r + I_c$$

$$I_c = \frac{V_m}{X_c} = \frac{V_m}{1/2\pi fC} = V_m \times 2\pi fC$$

$$= [66002.724 + j7.718] \times 2 \times \pi \times 50 \times 200 \times 10^{-9}$$

$$= [66002.724 + j7.718] 6.283 \times 10^{-5}$$

$$I_c = 4.092 + j0.0004$$

Now $I_s = I_r + I_c$

$$I_s = [1.817 + j1.363] + [4.092 + j0.0004]$$

$$I_s = [7.434 + j5.571] [5.909 + j1.364]$$

Now Convert to polar = $9.88 \angle 38.84$
= $6.06 \angle 12.9$

Now $V_s = V_m + I_s (R/2 + jX_L/2)$

$$\times [V_s = [66002.724 + j7.718] + [7.434 + j5.571][3 + j2]$$

$$= [66002.724 + j7.718] + [23.482 \ 11.162 + j31.5]$$

$$V_s = [66002.724 + j7.718] + [5.909 + j1.364][3 + j2]$$

$$= [66002.724 + j7.718] + [14.99 + j15.91]$$

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

$$\frac{66041.3 - 66000}{66000} \times 100 =$$

$$= 0.0625$$

$$\text{Now efficiency} = \frac{V_R I_R \cos \phi_R}{V_S I_S \cos \phi_S}$$

$$= \frac{66 \times 10^3 \times 2.212 \times 0.8}{66041.3 \times 6.06 \times 0.97}$$

$$= 0.33 \times 100$$

$$\eta = 33\%$$

2. A 1- ϕ transmission line having a receiving end power of 18 kVA and receiving end current of 4.55 Amp. and the transmission line Resistance 12 Ω & Inductance value of 20 milli Henrys and frequency 50 Hz a Capacitor value of 250 NF Find out the voltage Regulation, & Transmission efficiency at 0.85 power factor lag.

Given data:

$$\text{power } P = 18 \text{ kVA.}$$

$$I_r = 4.55 \text{ Amperes.}$$

$$R = 12 \Omega \Rightarrow R/2 = 12/2 = 6 \Omega$$

$$X_L = 20 \text{ mH} \Rightarrow X_L/2 = 0.01$$

$$\cos \phi_R = 0.85 \Rightarrow \phi_R = \cos^{-1}(0.85) = \phi_R = 31.788^\circ$$

$$\sin \phi_R = 0.526$$

Now. voltage Regulation = ? ; efficiency = ?

$$V = P/I = \frac{18 \times 1000}{4.55} = 3956.043 \cdot V_R = 3.956 \times 10^3$$

$$I_R = I_R (\cos \phi_R + j \sin \phi_R) = 4.55 (0.85 + j 0.5)$$

$$I_R = (3.8675 + j 2.275)$$

$$\text{Now } V_m = V_R + I_R (R/2 + j X_L/2) = 3.9 \times 10^3 + (3.8675 + j 2.275) (6 + j 0.01)$$

$$= 3.9 \times 10^3 + (23.18225 + j 13.688)$$

$$V_m = (3923.18225 + j 13.688)$$

$$V_S = V_m + I_S (R/2 + j X_L/2) \Rightarrow$$

$$I_S = I_R + I_C \Rightarrow I_C = \frac{V_m}{1/2\pi f C} = V_m \times 2\pi f C$$

$$= (3923.18225 + j 13.688) \times 2 \times \pi \times 50 \times 250 \times 10^{-9}$$

$$I_C = (0.308 + j 0.015) \times 10^3 \quad 3923.18225 + j 13.688$$

$$\text{Now } I_S = I_R + I_C \Rightarrow$$

$$I_S = (3.8675 + j 2.275) + (3923.18225 + j 13.688)$$

$$I_S = 3927.049 + j 15.963 = 3927.08 \angle 0.0232^\circ = \phi_1$$

$$V_S = V_m + I_S (R/2 + j X_L/2) \Rightarrow [3923.18 + j 13.6] + [3927.049 + j 15.963] [6 + j 0.01]$$

$$V_S \Rightarrow [3923.18 + j 13.6] + [23562.13 + j 134.67] + [j 15.9] [6 + j 0.01]$$

$$= 27485.3 + j 148.27 = 27485.3 \angle 0.309^\circ = \phi_2$$

$$V_S = 27485.3 \angle 0.309^\circ \quad \phi_1 + \phi_2 = 0.02 + 0.30 = 0.32$$

pf = 0.85 lag

$$\cos \phi_R = 0.85 \Rightarrow \phi_R = \cos^{-1}(0.85) = \phi_R = 31.788^\circ$$

$$\sin \phi_R = 0.526$$

Now. voltage Regulation = ? , efficiency = ?

$$V = P/I = \frac{18 \times 1000}{4.55} = 3956.043 \text{ V} \quad V_R = 3.956 \times 10^3$$

$$I_R = I_R [\cos \phi_R + j \sin \phi_R] = 4.55 (0.85 + j 0.5)$$

$$I_R = (3.8675 + j 2.275)$$

$$\text{Now } V_m = V_R + I_R (R/2 + j X_L/2) = 3.9 \times 10^3 + (3.8675 + j 2.275) (6 + j 0.01)$$

$$= 3.9 \times 10^3 + (23.18225 + j 13.688)$$

$$V_m = (3923.18225 + j 13.688)$$

$$V_S = V_m + I_S (R/2 + j X_L/2) \Rightarrow$$

$$I_S = I_R + I_C \Rightarrow I_C = \frac{V_m}{1/2\pi f C} = V_m \times 2\pi f C$$

$$= (3923.18225 + j 13.688) \times 2 \times \pi \times 50 \times 250 \times 10^{-9}$$

$$I_C = (0.308 + j 0.015) \times 10^3 \quad 3923.18225 + j 13.688$$

$$I_S = I_R + I_C \Rightarrow 4.858 \angle \phi$$

$$I_S = (3.8675 + j 2.275) + (3923.18225 + j 13.688)$$

$$I_S = 3927.049 + j 15.963 \Rightarrow 3927.08 \angle 0.0232^\circ = \phi$$

$$V_S = V_m + I_S (R/2 + j X_L/2) \Rightarrow [3923.18 + j 13.6] + [3927.049 + j 15.963] [6 + j 0.01]$$

$$V_S \Rightarrow [3923.18 + j 13.6] + [23562.13 + j 134.67] + [j 15.963] [6 + j 0.01]$$

$$= 27485.3 + j 148.27 \Rightarrow 27485.3 \angle 0.309^\circ = \phi_2$$

$$V_S = 27485.3 \angle 0.309^\circ \quad \phi_S = \phi_1 + \phi_2 = 0.02 + 0.30 = 0.32$$

$$\cos \phi_C = 0.99$$

delivers a power voltage of 33 kV and a power of 120 KVA. The resistance for phase is 16Ω and inductive Reactance for phase is 8Ω and a capacitor is connected at mid point. The admittance value is 20 mS and delivers power factor of 0.9 lag. Find out the voltage Regulation, Efficiency, Sending End power factor, and Sending End voltage.

→ Given data:

$$V_R = 33 \text{ KV} = 33 \times 1000 \text{ V}, \quad V_{r/ph} = \frac{V_R}{\sqrt{3}} = \frac{33 \times 1000}{\sqrt{3}} = 19052.6 \text{ V}$$

$$P = 120 \text{ KVA} = 120 \times 1000 \text{ VA}, \quad P_r = \sqrt{3} V_r I_r$$

$$R/ph = 16 \Omega, \quad I_r = \frac{P_r}{\sqrt{3} V_r}$$

$$X_L/ph = 8 \Omega$$

$$\text{admittance value } y = \frac{P}{V^2} = \frac{120}{\sqrt{3} \times 33^2}$$

$$\cos \phi = 0.9$$

$$= \frac{120}{57.15} = 2.0$$

$$\text{Voltage Regulation} = ?$$

$$I_r = 2.0 \text{ A}$$

$$\text{Efficiency} = ?$$

$$\cos \phi_s = ?$$

$$\cos \phi_r = 0.9, \quad \phi_r = \cos^{-1}(0.9)$$

$$V_s = ?$$

$$= 25.84$$

$$\sin \phi_r = 0.43$$

$$\text{Now } \vec{I}_r = I_r [\cos \phi_r + j \sin \phi_r]$$

$$= 2 [0.9 + j 0.43]$$

$$= 1.8 + j 0.86$$

$$\vec{I}_r = 1.8 + j 0.86$$

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

$$19052.5 + [1.8 + j0.86] [8 + j4]$$

$$= 19052.5 + [10.96 + j14.08]$$

$$\vec{V}_m = 19063.46 + j14.08$$

Now We know that $\vec{V}_s = \vec{V}_m + \vec{I}_s \left(\frac{R}{2} + j \frac{X_L}{2} \right)$

$$\vec{I}_s = \vec{I}_r + \vec{I}_c$$

$$\vec{I}_c = \frac{\vec{V}_m}{X_c} \quad X_c = \frac{1}{Y_c} = \frac{1}{20 \times 10^{-3}} = 50$$

$$\vec{I}_c = \frac{19063.46 + j14.08}{50}$$

$$\vec{I}_c = 381.2692 + j0.2816$$

$$\text{Now: } \vec{I}_s = \vec{I}_r + \vec{I}_c$$

$$= [1.8 + j0.86] + [381.2692 + j0.2816]$$

$$\vec{I}_s = 383.06 + j1.1416$$

The above is converted in to polar.

$$\vec{I}_s = 383.06 \angle 0.170^\circ - \phi_1$$

$$\text{Now } \vec{V}_s = \vec{V}_m + \vec{I}_s \left[\frac{R}{2} + j \frac{X_L}{2} \right]$$

$$= [19063.46 + j14.08] + [383.06 + j1.1416] [8 + j4]$$

$$= [19063.46 + j14.08] + [3059.9 + j1541.3]$$

$$\vec{V}_s = 22123.3 + j1528.38 = \sqrt{38318.67 + 2647.2} = 38410.0 \angle 3.95^\circ$$

Converted in to polar

$$V_s = 22176.03 \angle 3.9519^\circ \quad \phi_2 \times \sqrt{3} \uparrow$$

Now. $\phi_s = \phi_1 + \phi_2$

$$= 0.170 + 3.9519$$

$$\phi_s = 4.1219^\circ$$

Now. $\cos \phi_s = 0.99$

Now. Voltage Regulation = $\frac{V_s - V_R}{V_R}$

$$= \frac{[22123.3 + j1528.38] - 33000}{33000}$$

V_s is Convert to line.

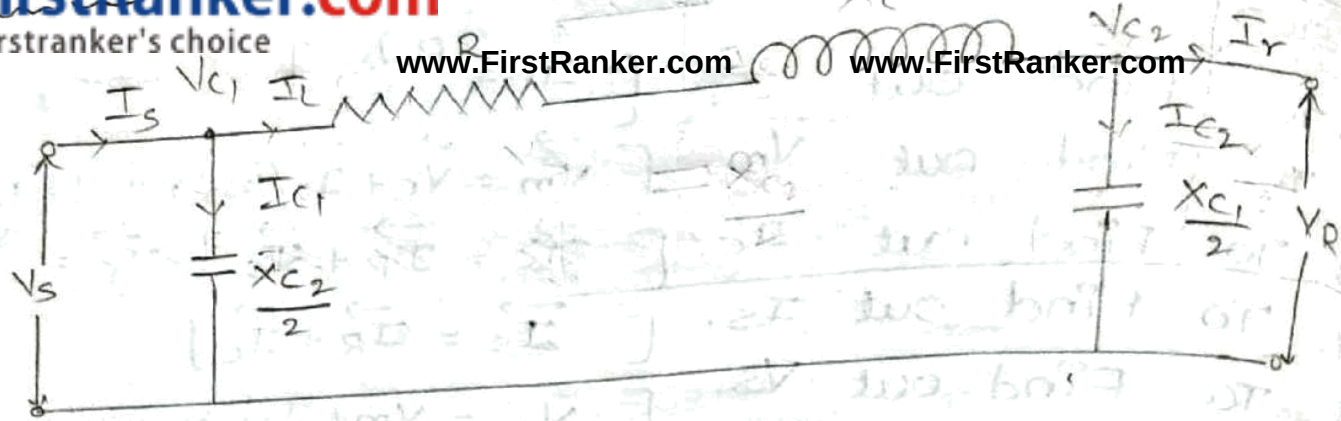
$$= \frac{38410.0 - 33000}{33000}$$

Voltage Regulation = $0.16 \times 100 = 1.60$

Now. Efficiency = $\frac{V_R I_R \cos \phi_R}{V_s I_s \cos \phi_s}$

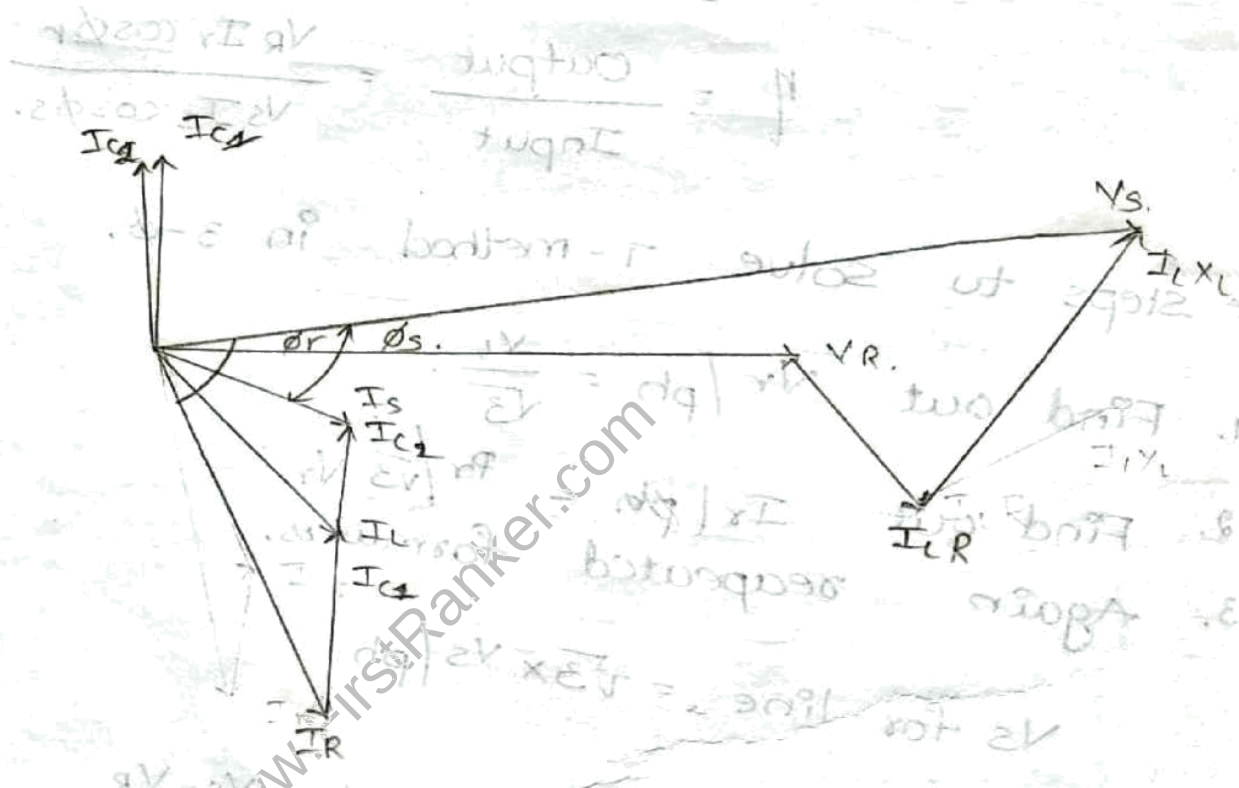
$$= \frac{(33 \times 10^3) \times 2 \times 0.9}{38410 \times 383.06 \times 0.99} \times 100$$

$$= 0.40\%$$



* Vector

diagram



* Formulas :

$$\vec{I}_r = I_r [\cos \phi_r + j \sin \phi_r]$$

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

$$I_{C1} = V_r / (X_{C1}/2) = \frac{2V_r}{X_{C1}}$$

$$V_s = V_r + I_L (R + jX_L)$$

UNIT: III
PERFORMANCE OF
LONG TRANSMISSION
LINE:

$$I = \frac{A_1 e^{\sqrt{z}x}}{\sqrt{z}l_y} - \frac{A_2 e^{-\sqrt{z}x}}{\sqrt{z}l_y}$$

$$I = \frac{A_1 e^{\delta x}}{zc} - \frac{A_2 e^{-\delta x}}{zc}$$

$$v = A_1 e^{\delta x} + A_2 e^{-\delta x}$$

$$A_1 = \frac{v_R + I_R zc}{2}$$

$$A_2 = \frac{v_R - I_R zc}{2}$$

$$I = I_R, v = v_R, x = l$$

$$I_S = \left(\frac{v_R + I_R zc}{2} \right) \frac{e^{\delta l}}{zc} - \left(\frac{v_R - I_R zc}{2} \right) \frac{e^{-\delta l}}{zc}$$

$$= \frac{v_R \cdot e^{\delta l}}{2zc} + \frac{I_R zc \cdot e^{\delta l}}{2zc} - \frac{v_R}{2} \cdot \frac{e^{-\delta l}}{zc} + \frac{I_R zc}{2} \cdot \frac{e^{-\delta l}}{zc}$$

$$I_S = \frac{v_R}{zc} \left(\frac{e^{\delta l} - e^{-\delta l}}{2} \right) + I_R \left(\frac{e^{\delta l} + e^{-\delta l}}{2} \right)$$

consider a long transmission line having a one

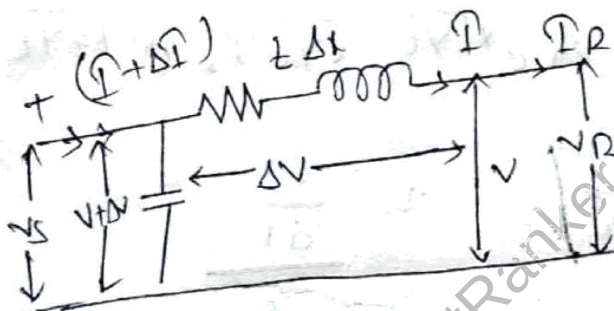
impedance $= z \Delta x$

capacitance admittance $= y \Delta x$

V_s, I_s are the sending voltage & sending current

I is the current flowing through the line of distance Δx

the current flowing through the capacitance is considered as ΔI



The voltage drop across $z \Delta x = \Delta V = I \Delta x$

$$\frac{\Delta V}{\Delta x} = I z$$

$$\frac{dV}{dx} = -I z \quad \text{--- (1)}$$

$$\Delta I = (V + \Delta V) y \Delta x$$

$$\Delta I = V y \Delta x + \Delta V y \Delta x$$

$$\Delta I = V y \Delta x$$

$$\frac{\Delta I}{\Delta x} = V y$$

$$I = \frac{V}{z}$$

$$\frac{dv}{dx} = \sqrt{t}$$

$$\frac{d^2v}{dx^2} = \frac{1}{2} \cdot \frac{dt}{dx}$$

$$\frac{d^2v}{dx^2} = \frac{1}{2} \cdot \frac{v}{x}$$

$$\frac{d^2v}{dx^2} - \frac{v}{2x} = 0$$

$$v = A_1 e^{\sqrt{2y}} + A_2 e^{-\sqrt{2y}}$$

$$\frac{dv}{dx} = \sqrt{2y} A_1 e^{\sqrt{2y}} - \sqrt{2y} A_2 e^{-\sqrt{2y}}$$

$$\frac{dv}{dx} \bigg|_{x=0} = \frac{dv}{dt} \bigg|_{t=0} = \frac{1}{2}$$

$$= \frac{\sqrt{2y} A_1 e^{\sqrt{2y}} - \sqrt{2y} A_2 e^{-\sqrt{2y}}}{2}$$

$$= \frac{\sqrt{2y} A_1 e^{\sqrt{2y}}}{2} - \frac{\sqrt{2y} A_2 e^{-\sqrt{2y}}}{2}$$

$$= \frac{\sqrt{2y} A_1 e^{\sqrt{2y}}}{\sqrt{2y} - \sqrt{2y}} - \frac{\sqrt{2y} A_2 e^{-\sqrt{2y}}}{\sqrt{2y} - \sqrt{2y}}$$

$$V_s = \left(\frac{V_R + Z_c I_R}{2} \right) e^{\beta L} + \left(\frac{V_R - Z_c I_R}{2} \right) e^{-\beta L}$$

$$= \frac{V_R \cdot e^{\beta L}}{2} + \frac{I_R Z_c e^{\beta L}}{2} + \frac{V_R e^{-\beta L}}{2} + \frac{I_R Z_c e^{-\beta L}}{2}$$

$$V_s = V_R \left(\frac{e^{\beta L} + e^{-\beta L}}{2} \right) + I_R Z_c \left(\frac{e^{\beta L} + e^{-\beta L}}{2} \right)$$

$$V_s = V_R \cosh \beta L + I_R Z_c \sinh \beta L$$

Q. A 3- ϕ long transmission line delivers a power of 150 MW and receiving end voltage is 66 kV at a p.f of 0.88 lag and the transmission line distance is 120 km & the line resistance is 0.2 Ω /ph/km & Inductance is 3 mH & the capacitance is 0.01 μ F And find the voltage regulation & efficiency & ABC constants for the transmission line.

$$V_s = ?$$

$$V_s = V_R \cosh \beta L + I_R Z_c \sinh \beta L$$

$$I_s = \frac{V_R}{Z_c} \sinh \beta L + I_R \cosh \beta L$$

$$Z_C = \sqrt{Z/4}$$

$$R = 0.2$$

$$L = 3 \text{ mH}$$

$$Z = \sqrt{R^2 + X_L^2}$$

$$X_L = 2\pi fL$$

$$= 2\pi \times 50 \times 3 \times 10^{-3}$$

$$X_L = 0.94 \Omega$$

$$Z = \sqrt{(0.2)^2 + (0.94)^2}$$

$$Z = 0.96$$

$$Y_C = ?$$

$$C = 0.01 \mu\text{F}$$

$$X_C = \frac{1}{2\pi fC}$$

$$Y_C = \frac{1}{X_C} = 2\pi fC$$

$$= 2\pi \times 50 \times 0.01 \times 10^{-6}$$

$$Y_C = 3.14 \times 10^{-6}$$

$$Y = \sqrt{Z Y_C}$$

$$= \sqrt{0.96 \times 3.14 \times 10^{-6}}$$

$$Y = 1.73 \times 10^{-3}$$

$$Z_L = (1.73 \times 10^{-3}) \times 100$$

$$= \sqrt{\frac{0.96}{3.14 \times 10^{-6}}}$$

$$Z_C = 552.93$$

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

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

$$I_R = \frac{150 \times 10^3}{\sqrt{3} \times 66 \times 10^3 \times 0.88}$$

$$I_R = 1.49 \text{ A}$$

$$V_S = V_R \cosh \beta l + I_R \cdot Z_C \sinh \beta l$$

$$= 66 \times 10^3 \{ \cosh(0.27) + 1.49 \{ 552.93 \times \sinh(0.27) \}$$

$$V_S = 67.70 \text{ kV}$$

$$I_S = \frac{V_R}{Z_C} \sinh \beta l + I_R \cosh \beta l$$

$$= \left(\frac{66 \times 10^3}{552.93} \times \sinh(0.207) \right) + 1.49 \cosh(0.207)$$

$$I_S = 26.4 \text{ A}$$

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

$$= \left(\frac{67700 - 66000}{66000} \right) \times 100$$

$$= 2.57\%$$

$$\eta = \frac{O/P}{I/P} = \frac{150 \times 10^3}{(150 \times 10^3) + I_3 R'} = \frac{150 \times 10^3}{(150 \times 10^3) + (26$$

$$A = \cosh \beta L \Rightarrow \cosh (0.207) = 1.02$$

$$B = Z_0 \sinh \beta L \Rightarrow 552.93 \sinh (0.207) = 1$$

$$C = \frac{\sinh \beta L}{Z_0} = \frac{\sinh (0.207)}{552.93} = 3.77 \times 10^{-4}$$

$$D = \cosh \beta L$$

$$= 1.02$$

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

$$\text{Resistance} = 10 \Omega$$

$$\text{Reactance } X_L = 15 \Omega$$

$$\text{Power} = 1100 \text{ kW}$$

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

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

$$I_R = 41.66 \text{ A}$$

$$V_S = \sqrt{(V_R \cos \phi_R + I_R)^2 + (V_R \sin \phi_R + I X_L)^2}$$

$$= \sqrt{(33 \times 10^3 \times 0.8 + 41.66 \times 10)^2 + (33 \times 10^3 \times 0.6 + 41.66 \times 15)^2}$$

$$= \sqrt{(26400 + 416.6)^2 + (19800 + 624.9)^2}$$

$$= \sqrt{719130035.6 + 4171765190}$$

$$= 3370914$$

$$V_S = 33.7 \text{ kV}$$

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

Regulation

$$= \frac{33.7 - 33}{33} \times 100$$

$$= 2.14\%$$

$$\cos \phi_s = \frac{V_R \cos \phi_R + I \cdot R}{V_s}$$

$$= \frac{33 \times 10^3 \times 0.8 + 41.66 \times 10}{33.709 \times 10^3}$$

$$= \frac{26400 + 416.6}{33709 \times 10^3}$$

$$= \frac{26816.6}{33709} = 0.8$$

$$\eta = \frac{33 \times 10^3 \times 41.66 \times 0.8}{33.709 \times 10^3 \times 41.66 \times 0.8} \times 100$$

$$= 97.8\%$$

A 3- ϕ stat transission line deliver a power 500 kW at a voltage of 22 kV at the p.f 0.85 lag
resistance of the line is 5 Ω & inductance 6 Ω Find
out the voltage regulation & efficiency of transmissin.

Line.

$$p.f = 0.85 \text{ lag}$$

$$\text{resistance} = 5 \Omega$$

$$\text{Inductance} = 6 \Omega$$

$$\text{voltage} = 22 \text{ kV}$$

$$\text{power} = 5000 \text{ kVA}$$

$$\cos \phi_v = 0.85 \quad \sin \phi_v = 0.52 \quad P_r = 5000 \times 10^3$$

$$= 0.8 \quad \quad \quad = 0.6$$

$$P_r = \sqrt{3} V_r I_r$$

$$\sin \phi_v = \cos^{-1}(0.85)$$

$$I_r = \frac{P_r}{\sqrt{3} V_r} = \frac{5000 \times 10^3}{\sqrt{3} \times 22 \times 10^3} = 131.21$$

$$\sin \phi_v = 31.78$$

$$V_s = \sqrt{(V_r \cos \phi_v + I_r R)^2 + (V_r \sin \phi_v + I_r X_L)^2}$$

$$I_r = 131.21 \left[(\cos(0.8) - j(\sin(0.6))) \right]$$

$$= 111.528 - j78.72$$

$$= 136.5 \angle -35.2$$

$$V_s = \sqrt{(V_r \cos \phi_v + I_r R)^2 + (V_r \sin \phi_v + I_r X_L)^2}$$

$$= \sqrt{(22 \times 10^3 \times 0.8 + 136.5 \angle -35.2)^2 + (22 \times 10^3 \times 0.6 +$$

UNIT - 4

Transient Analysis

Consider the Inductance outside the conductor.
is equal to overall Inductance of the conductor when
Inductance outside the conductor having a radius of
GMR (In place of r)

Inductance outside the conductor = overall Inductance

$$\frac{\mu_0}{2\pi} \left(\log \frac{D}{\text{GMR}} \right) = \frac{\mu_0}{2\pi} \left(\frac{1}{4} + \log \frac{D}{r} \right)$$

$$\log \frac{D}{\text{GMR}} = \frac{1}{4} + \log \frac{D}{r}$$

$$\log \frac{D}{\text{GMR}} = \log_e e^{1/4} + \log D/r$$

$$\frac{\mu_0}{2\pi} \log \frac{GD}{\text{GMR}}$$

$$\frac{D}{\text{GMR}} = e^{1/4} \frac{D}{r}$$

$$e^{1/4} \text{GMR} = r$$

$$\text{GMR} = r \cdot e^{1/4}$$

$$\text{GMR} = 0.7788 r$$

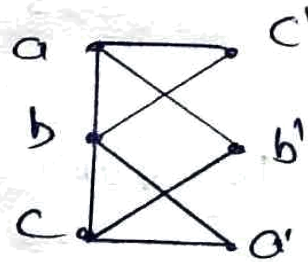
$$D_{ca'} D_{cb} D_{cb'}$$

GMD for double ct line:

consider a 6 conductors abc & a'b'c'.

Double ct:

GMR for Double ct line:



$$D_{aa'}, D_{bb'}, D_{cc'}$$

$$GMR_A = \sqrt{D_{aa'} \cdot r'}$$

$$GMR_B = \sqrt{D_{bb'} \cdot r'}$$

$$GMR_C = \sqrt{D_{cc'} \cdot r'}$$

$$r' = 0.7788 r$$

$$GMR = \sqrt[3]{GMR_A \cdot GMR_B \cdot GMR_C}$$

To find out the ABCD constants for transmission line:

consider a 2 port network it may be 'T' or 'π' steps

(a) medium transmission line

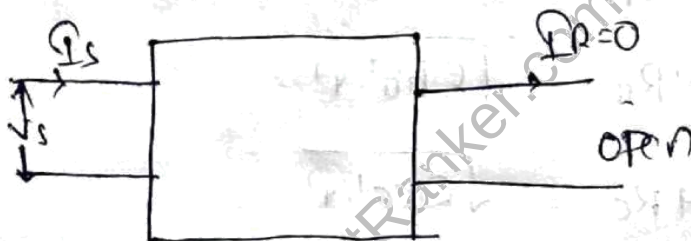


$$V_s = AV_R + B I_R$$

$$I_s = CV_R + D I_R$$

To find out the line constants A & C the receiving side of the transmission line should open

Hence $I_R = 0$



$$V_s = AV_R \quad | \quad I_R = 0 \quad \quad I_s = CV_R \quad | \quad I_R = 0$$

$$A = \frac{V_s}{V_R}$$

$$C = \frac{I_s}{V_R}$$

To find out the line constants B & D the secondary of 2 port network is short circuited



$$V_s = B I_R \bigg|_{V_R=0} \quad \bigg| \quad I_s = D I_R \bigg|_{V_R=0}$$

$$B = \frac{V_s}{I_R} \quad \bigg| \quad D = \frac{I_s}{I_R}$$

A 11 kV transmission line, having a receiving end voltage of 10 kV & sending end current of 140 A & receiving end power of 150 kW & receiving end p.f. 0.85 lagging find out the A, B, C, D constants for the given transmission line ($3-\phi$)?

G.O
 $V_s = 11 \text{ kV}$
 $V_R = 10 \text{ kV}$
 $I_R = 140 \text{ A}$

$P = 150 \text{ kW}$
 $(\cos \phi_r)$
 $\text{p.f.} = 0.85$

$$I_R = \frac{P}{\sqrt{3} V_R \cos \phi_r} = \frac{150 \times 10^3}{\sqrt{3} \times 10 \times 10^3 \times 0.85}$$

$I_R = 10.18 \text{ A}$

$$A = \frac{V_s}{\sqrt{P}}$$

$$= \frac{11 \times 10^3}{10 \times 10^3} = 1.1$$

$$I_s = \frac{V_s}{\sqrt{P}}$$

$$I_s = \frac{V_s}{\sqrt{P}} = \frac{11 \times 10^3}{10.18} = 1080.35$$

$$C = \frac{P_s}{V_P} = 0.014$$

$$D = \frac{P_s}{I_R} = 13.75$$

Types of conductors:

1. solid
2. standard
3. Bundle

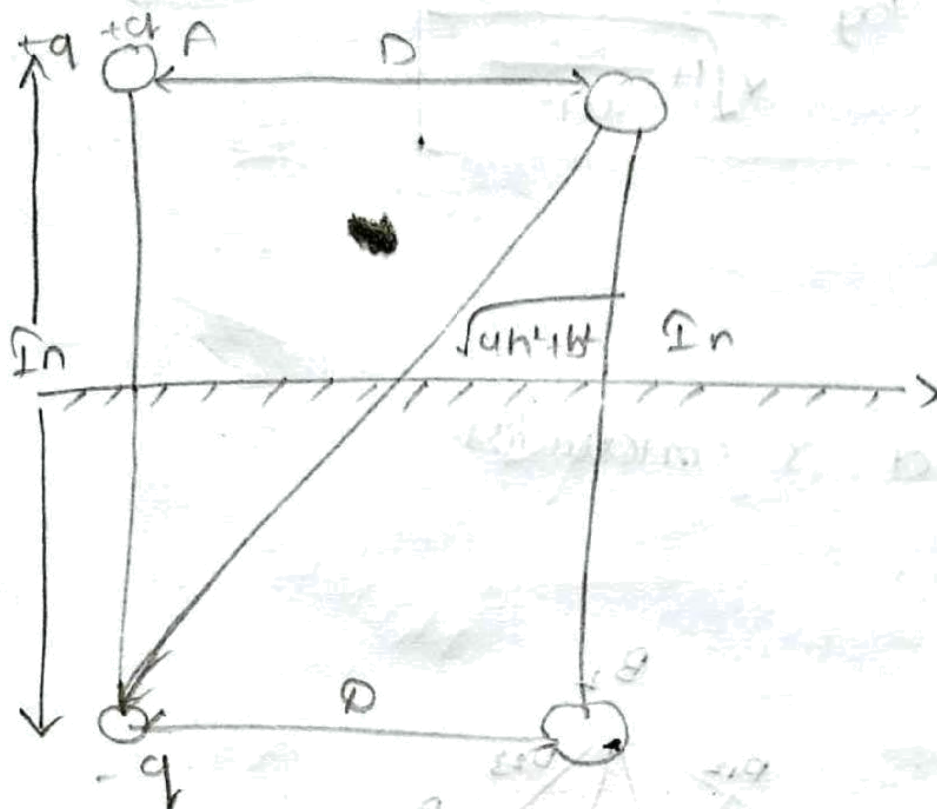
AAC:- All aluminium conductor

AAC:- All aluminium alloy conductor

ACSR:- Aluminium conductor steel reinforce

No. of strands $N = 3n(n-1)+1$

Overall diamn of ACSR conductor $D = G + n \cdot d$



potential diff between two conductors without
considering ground effect = $V_{ab} = \frac{q}{\pi \epsilon_0 \log \frac{D}{a}}$

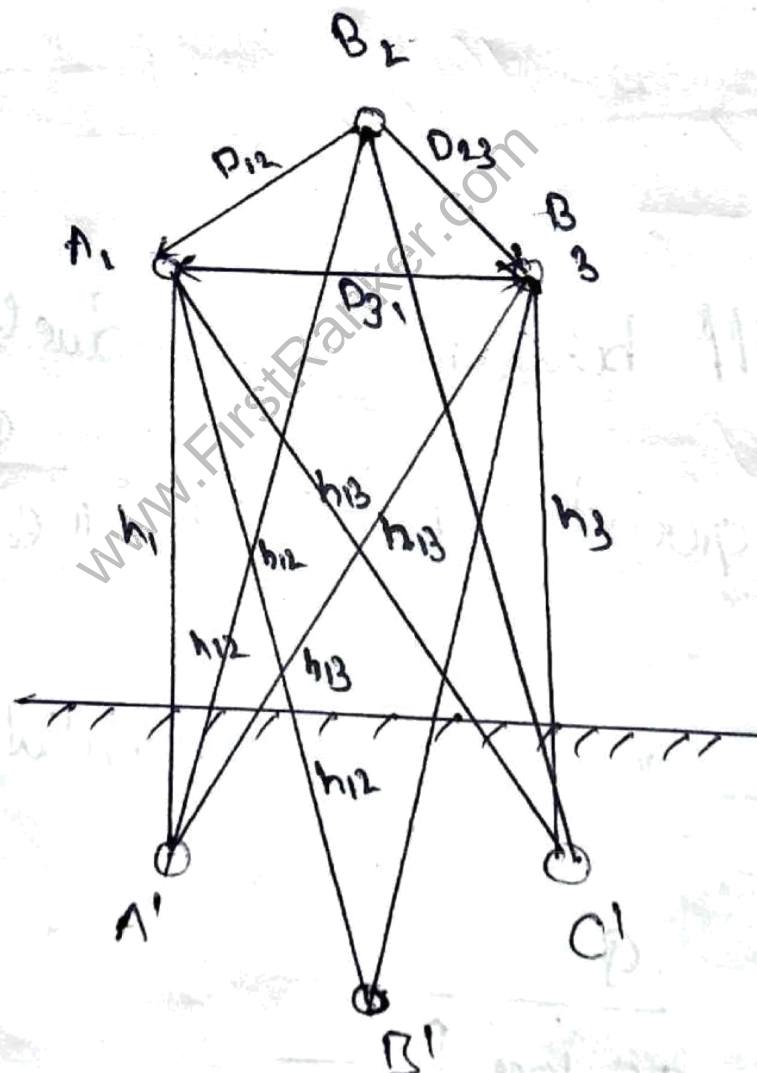
The potential diff is changes

$$V_{ab} = \frac{q}{\pi \epsilon_0 \log \frac{D}{\sqrt{\frac{D^2 + 4h^2}{4h^2}}}}$$

$$V_{ab} = \frac{q}{\pi \epsilon_0 \log \frac{D}{\sqrt{1 + \frac{D^2}{4h^2}}}}$$

$$C = \log \frac{D}{\sqrt{1 + \frac{D^2}{4h^2}}}$$

consider a 3 conductors



UNIT - 5

Transmission Line effects

www.FirstRanker.com

means to match the voltage and frequency.

The isolators are used for only OFF mode Load Conditions.

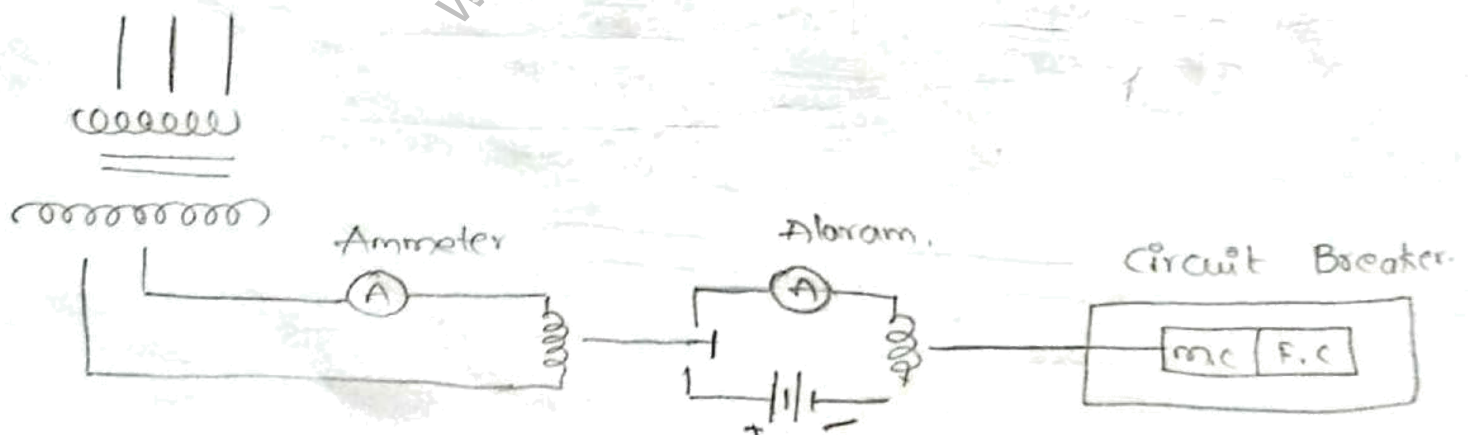
The circuit breakers are used for on load Condition. (These are operated manually).

Current Transformer means to increase the voltage and to decrease the current for measure the current. It is a step up Transformer.

potential transformer means to decrease the voltage and to increase the current for measure the voltage. It is step down T/P.

operation of circuit breaker :

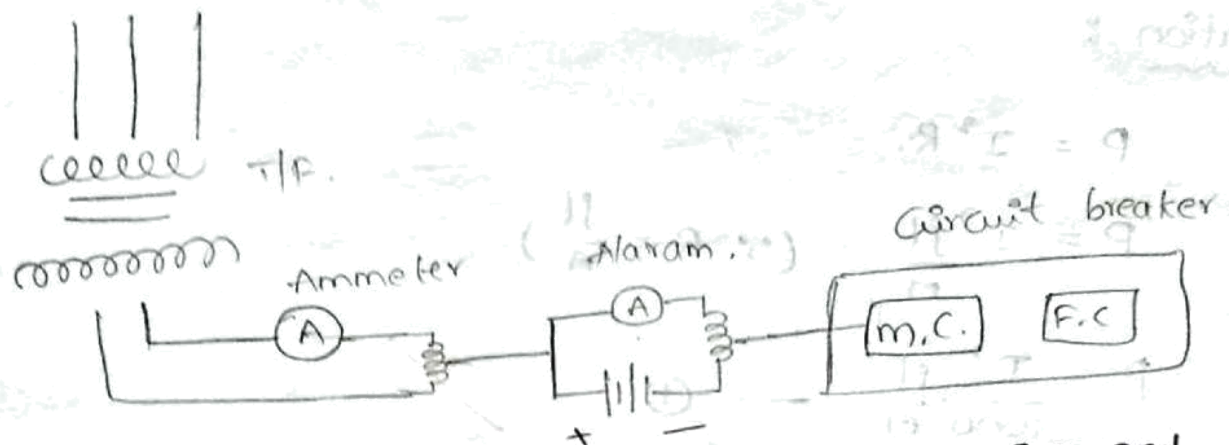
out of fault :



circuit breaker is used for find out fault easily. The fault out by

Before in fault the current is measured in Ammeter. if any fluctuations that current will be absorb by coil. This is the process before fault.

* In fault:



When the coil absorb the current then the coil will be magnetised then the iron piece is attracted then the circuit will be closed. when the circuit will be closed then alarm start ring then the second coil will be magnetised. then the coil attracts moving coil then the circuit will be opened. this is the process.

* Effect of voltage on current, efficiency, power loss:

(i) When increase the voltage then the current will be decreases ($\because V \propto \frac{1}{I}$).

(ii) When increase the voltage then the power loss will be decreases.

efficiency will also

iv) volume :

When the voltage increases then the volume will be decreases.

* derivation :

$$P = I^2 R.$$

$$P = I^2 \frac{\rho l}{A} \quad (\because R = \frac{\rho l}{A})$$

$$P = \frac{I^2 \times \rho l}{1000 \times A} \quad \text{--- (1)}$$

$$P = \frac{VI \cos \phi}{1000} = P = \frac{V \cos \phi}{1000} \times I.$$

we want to required

$$I = \frac{1000 \times P}{V \cos \phi} \quad \text{--- (2)}$$

Now (2) is Sub in (1)

$$P = \frac{\left[\frac{(1000)^2 \times P^2}{V^2 \cos^2 \phi} \right] \times \frac{\rho l}{A}}{1000} \times \frac{\rho l}{A}.$$

$$I = \frac{1000 \times P}{V^2 \cos^2 \phi} \times \frac{\rho l}{A} \Rightarrow a = \frac{1000 \times P}{V^2 \cos^2 \phi} \times \rho l \times l$$

$$V = \frac{1000 \times P}{V^2 \cos^2 \phi} \times \rho l^2 \Rightarrow V \propto \frac{1}{V^2}$$

Voltage : (above 50 km)

1 km = 655 V

actually maintenance
400 to 900.

$$V = \left(5.5 \sqrt{\frac{L}{1.61} + \frac{3P}{150}} \right) \text{ K.V.}$$

where L = length
 P = power
 V = volume.

Table :

Distance.	0-15 km.	15-30	31-80	81-120	120-240	240-400
voltage.	11 KV	11/22	33/66	66/110	110/132	132/220

above 400. the voltage is 220 used.

properties of conducting materials :

- (i) The Resistance will be low.
- (ii) The mechanical strength is high.
- (iii) High Conductivity.
- (iv) It should be easily available in market.
- (v) Low Cost.

* Differences between AC and DC.

* AC system :

- (i) Transmit high power.
- (ii) Can be step up (or) step down.
- (iii) Skin effect high.

proximity effect is high

DC supply system:

- i) The Transmit cost will be low.
- ii) It does not have skin effects.
- iii) The losses will be low.
- iv) The equipment cost will be very high.

Effects of voltage and frequency on Transmission line: (Transformer)

Transformer voltage equation $V = 4.44 f \phi_m N$.

- i) voltage of the Transformer depends upon the supply frequency.
- ii) if we change the frequency (decrease) then voltage will be changed. that means decreased.
- iii) maintain the voltage level is constant.
- iv) We must increase the no. of turns of the T/P and cost of the T/P will increase.
- v) If we change the frequency then the alternator speed will be changed it affects the system.

- of Conductors (4) :-
- i) Solid Conductors
 - ii) standard type.
 - iii) Hallow type.
 - iv) Bundled type.

i) Solid Conductors :



It has only single lead. and it is used in limited Applications. It is very low weight. So the more chances to break easily from wind force. Because of low weight.

ii) Standard :



It has large Cross sectional area compare to the solid conductors. In middle lead is surrounded by the no. of leads. It has more corona loss and skin effect.

$$\text{No of layers } N = (3n+1)+1$$

where N = No. of layers of Conductors.

n = no. of leads of Conductors.

and the conductor dia depends on the

formula is.

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

where D = total dia of conductor, d = dia of lead

* Current distrotion effect :-

The following effects are placed in Conductor

- (i) Skin effect
- (ii) proximity effect
- (iii) spirality effect
- (iv) kelvin's law

* skin effect :-

Due to this effect Current will flow through the surface of the Conductor only. At the middle of the Conductor No Current will flow. This effect is known as skin effect.

(i) voltage

If we increase the voltage the skin effect is also increased.

(ii) Frequency :

If we increase the frequency then skin effect is also increased ~~visiva~~ decreased.

(iii) Diameter :

The skin effect mainly depending on the diameter of the conductor.

(iv) permeability :

which allow the magnetic flux is known as permeability.

* proximity effect :

The effect of flux of another conductor is considered on the first conductor. due to this effect the flux of one conductor crowded one side of conductor. That means the flux in the one side conductor is more than another side of same conductor. If we increase the distance between the conductor then the proximity effect will be less.

* spirality effect :

A wire is surrounded by the same number of wires then the conductor internal resistance.

and Inductance will be increased.
This effect is known as spirality effect. for non-magnetic materials this effect will be less.

* kelvin's law:

kelvin's law is used to find the size of the Transmission line Conductor Economically is known as kelvin law. (1881) The cost of T/lon line depends upon the size of the Conductor so. The Annual Cost of transmission line is divided in to two types.

- (i) Annual charge on Capital Cost
- (ii) Annual Cost due to Energy losses.

$$\text{Annual Cost of capital Cost} = k_1 + k_2 a.$$

If we use increase the area of the Conductor then annual charge on capital cost increases k_1 is the fixed Cost (i.e, supports, insulators).

Annual Cost of Energy losses depends upon the $I^2 R$ losses. for Esuning Current as Constant. The Resistance. value changes by changing the area of the Conductor. This cost is inversely proportional to the area of the Conductor.

$$\text{Annual charge of Energy losses} = \frac{K_3}{A}.$$

Annual Charge on Capital Cost +
Annual Charge on Energy loss

$$= k_1 + k_2 a + \frac{k_3}{a}$$

For Economical Cost of the Conductor

$$\frac{d}{da} \left[k_1 + k_2 a + \frac{k_3}{a} \right] = 0$$

$$\frac{d}{da} [k_1] + \frac{d}{da} [k_2 a] + \frac{d}{da} \left[\frac{k_3}{a} \right] = 0$$

$$0 + k_2 \cdot 1 + k_3 \left(\frac{1}{a^2} \right) = 0$$

$$k_2 + \frac{k_3}{a^2} = 0$$

$$\therefore k_2 = -\frac{k_3}{a^2 a}$$

$$\boxed{k_2 a = \frac{k_3}{a}}$$

For Economical Cost of the Conductor at which the variable part of Capital Cost is equal to the Annual charge on Energy losses

* Limitations:

1. In Only Constant Current position this law was applicable.

2. The Energy loss wasted cost estimation is ~~difficult~~.

3. Capital Cost estimation is difficult.

UNIT-6

Sag Calculations & Tension

www.FirstRanker.com

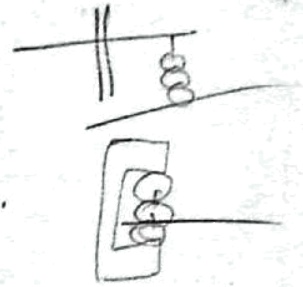
- i, pin type
- ii, strain
- iii, Suspension
- iv) Shaker.



* pin type : Only in Distribution System

* Strain type : distribution (11 kv, 440 v).

* Suspension : High voltage (66, 132, 33, kv)



* Shaker : Dead end poles, Distribution.

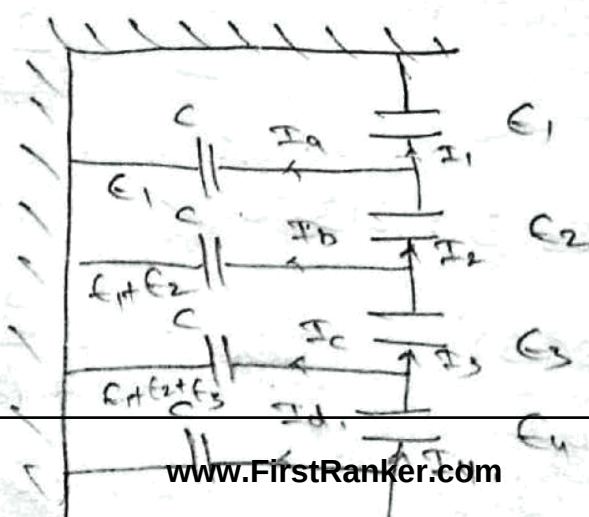
Due to dust particles the current passing from conductor to insulator is known as dry flashover.

Breaking insulator is called puncture insulator.

Due to water particles in the rainy seasons the current passing from conductor to insulator is known as wet flashover.

* string: the combination of insulators.

* Voltage Distribution Across Suspension Insulators:



A overhead transmission line having a conductor weight of 1.925 kg/m and Area of Cross-section of conductor is 2.2 cm^2 and ultimate strength is 8000 kg/cm^2 . The supports are 600 m apart having 15 m difference. Calculate Sag from two supports. Safety factor shall be 5 wind pressure is 16 kg/m^2 & ice density is 1 kg/m^3 thickness of ice is 0.8 cm .

→ Given data :

$$W_c = 1.925 \text{ kg/m}$$

$$A = 2.2 \text{ cm}^2$$

$$S = 8000 \text{ kg/cm}^2$$

$$L = 600 \text{ m}$$

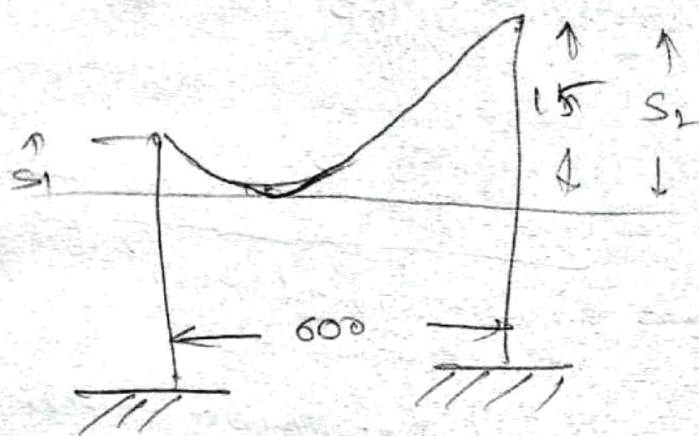
$$h = 15 \text{ m}$$

$$\text{Saf} = 5$$

$$W_p = 60 \text{ kg/m}^2$$

$$W_i = 1 \text{ kg/m}$$

$$t = 0.8 \text{ cm}$$



$$S_1 = \frac{W \times x_1^2}{2T}$$

$$S_2 = \frac{W \times x_2^2}{2T}$$

$$T = \frac{\text{Strength}}{\text{Saf f}}$$

$$= \frac{8000}{5} \times 2.2 \times 10^4$$

$$T = 16000$$

$$x_1 = \frac{d}{2} \frac{hT}{Wd}$$

$$= E_1 W C \left(3 + \frac{1}{m} + \frac{4}{m} \right) + E_1 W C \left(3 + \frac{1}{m} + m \right)$$

$$= E_1 W C \left(3 + \frac{1}{m^2} + \frac{4}{m} + 3 + \frac{1}{m} + m \right)$$

$$= E_1 W C \left(6 + \frac{1}{m^2} + \frac{5}{m} + m \right)$$

$$\therefore I_y = E_1 W C \left(6 + \frac{1}{m^2} + \frac{5}{m} + m \right)$$

$$\text{Now } E_y = I_y \times \frac{1}{W m C}$$

$$= \frac{E_1 W C \left(6 + \frac{1}{m^2} + \frac{5}{m} + m \right)}{W m C}$$

$$W m C$$

$$= E_1 \left(\frac{6 + \frac{1}{m^2} + \frac{5}{m} + m}{m} \right)$$

$$= E_1 \left(\frac{6}{m} + \frac{1}{m^3} + \frac{5}{m^2} + 1 \right)$$

$$E_y = E_1 \left(1 + \frac{6}{m} + \frac{5}{m^2} + \frac{1}{m^3} \right)$$

Considering of 3 insulators and voltage of Transmission line is 33 kV the mutual capacitance 9 times of the ground capacitance. Find the voltage distribution across each insulator?

Given data:

Insulators = 3

$$\text{Voltage} = 33 \text{ kV} = V_{ph} = \frac{33 \times 10^3}{\sqrt{3}}$$

$$\text{Condition } m\phi = 9C = 19052.54 \text{ V}$$

$$\boxed{m = 9}$$



Now. $E_T = E_1 + E_2 + E_3$

$$E_T = E_1 + E_1 \left(1 + \frac{1}{m}\right) + E_1 \left(1 + \frac{1}{m} + \frac{3}{m}\right)$$

$$E_T = E_1 \left(1 + 1 + \frac{1}{m} + 1 + \frac{1}{m} + \frac{3}{m}\right) = E_1 \left(3 + \frac{4}{m} + \frac{1}{m}\right)$$

$$E_T = E_1 \left(3 + \frac{4}{m} + \frac{1}{m}\right)$$

$$19052.54 = E_1 \left(3 + \frac{4}{9} + \frac{1}{9}\right)$$

$$19052.54 = E_1 (3 + 0.4 + 0.012)$$

$$19052.54 = E_1 (3.41)$$

$$E_1 = \frac{19052.54}{3.41}$$

$$E_1 = 5587.25$$

Now. $E_2 = E_1 \left(1 + \frac{1}{m}\right)$

$$= 5587.25 \left(1 + \frac{1}{9}\right) = 6208 \text{ V}$$

$$\rightarrow I_1 = \frac{\epsilon}{\frac{1}{\omega mc}} = \epsilon \omega mc.$$

$$I_a = \frac{\epsilon}{\frac{1}{\omega c}} = \epsilon \omega c.$$

$$I_2 = \frac{\epsilon}{\frac{1}{\omega n}} = \epsilon \omega n.$$

$$I_2 = I_1 + I_a$$

$$\epsilon \omega n = \epsilon \omega mc + \epsilon \omega c$$

$$\epsilon \omega n = \epsilon \omega (mc + c)$$

$$\epsilon \omega n = \epsilon \omega (mc + c).$$

$$\boxed{n = (mc + c)}$$

$$I_b = 2\epsilon \cdot \omega c.$$

$$I_3 = I_b + I_n$$

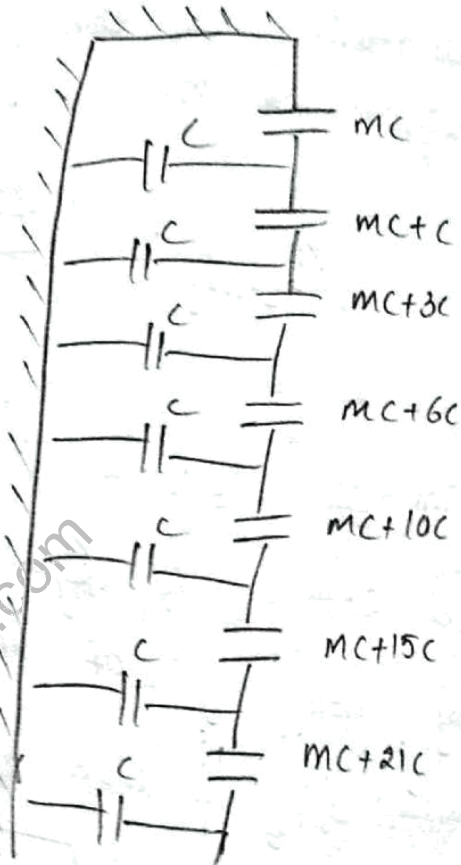
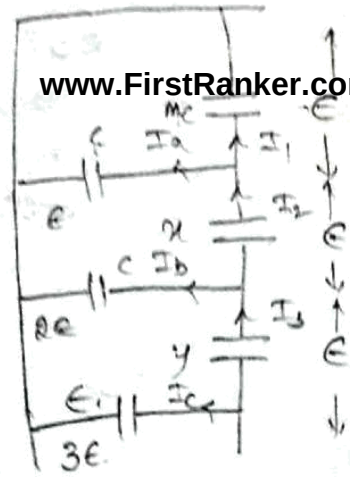
$$I_3 = 2\epsilon \cdot \omega c + \epsilon \omega n$$

$$I_3 = \frac{\epsilon}{\frac{1}{\omega y}} = \epsilon \omega y$$

$$\epsilon \omega y = 2\epsilon \cdot \omega c + \epsilon \omega n.$$

$$\epsilon \omega y = \epsilon \omega (2c + n)$$

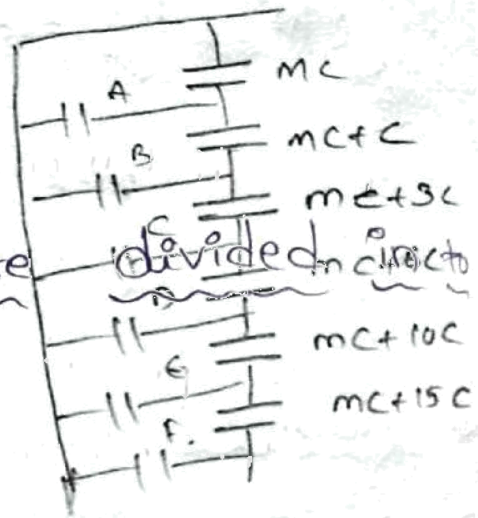
$$\boxed{y = (2c + n)}.$$



It is used for controlling 2 operation
A string consisting of 8 insulators is same and mutual
Converts distributed at each insulator potential T/F.
Eg: Transformers is the 8 times of the ground Capacitance
Capacitance of Insulators of bus bars.
find the Capacitance of
Circuit Breakers

Condition $mC = 8C$
Current T/F
 $m = 8$

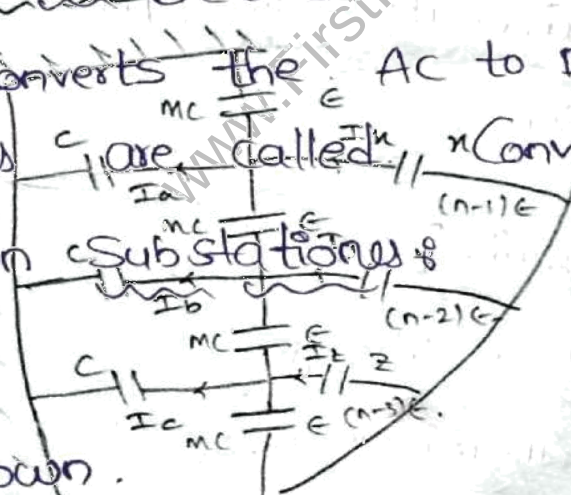
* Based on location Substations are divided into
Capacitance of B insulator = $mC + C$
 $= 8C + C = 9C$
i) Indoor
ii) Outdoor



Indoor: These are "D" = $mC + 6C = 8C + 6C = 14C$ protected from atmosphere by using wall.
Outdoor: These are "F" = $mC + 15C = 8C + 15C = 23C$ not-protected from atmosphere

* Converting Sub-Stations
which converts the AC to DC & DC to AC that Substations are called "Converting Substations."

* Distribution Substations
ii) step up
ii) step-down



* primary Substations: (or) Switch yards:
These are nearer to power plants & substations
power Transformers used in this Substations
 $\frac{E}{\omega mC} = \frac{(n-1)E}{\omega nC}$
 $\frac{E}{\omega mC} = \frac{(n-1)E}{\omega nC}$