MODULE - 3

14/2/17

Performance of Transmission Lines.

The important considerations in design and operation of the transmission line are the determination of voltage drop line lossess and efficiancy of transmission these values are greatly influanced by the line constant (Resistance, inductance, capacitance) of the transmission line. For instance, the line ~~drop~~ depends upon the above three line constants. Simillerly the resistance of transmission lines conductors is the most important cause of power loss in the line and determines the transmission efficiency. in this module I will develope formulas by which I can calculate voltage regulation, line lossess and efficiancy of transmission lines these formulae important for two prinicipal resions firstly they provide an opportunaty to understand the effects of parameters of lines on Bus voltages and the flow of power secondly they help in understanding of what is occuring in electric power system.

Imp Classification of Overhead Transmission Lines.

Transmission line has 3 line constants R L & C distributed uniformaly along the whole length of the line The resistance and inductance for series impidence. The capacitance existing between conductors for single phase line or from a conductor to nutral. for a three phase line falls a shunt path throut the length of the line therefore capacitance effects introduced complications in transmission line calculation depending upon the manner in which capacitance taken in to account, the over head transmission lines are devided as (1) short transmission lines (2) medium transmission lines and (3) Long transmission. lines.

(1) Short Transmission Line.

When the length of an overhead transmission line up to 50km and the line voltage is comparitivly low (<20KV) it is usually considerd as short transmission due to smaller length and lower voltage the capacitance effect are lower and hence can be neclected they are while studying the perform. of the short transmission line only resistance and inductance of the line are taken into account

② Medium Transmission Line.

When the length of an overhead transmission line is up to 50 to 150 km and the line voltage is modratly high 100 kV & < 100 kV it is considered as medium transmission line due to sufficient length & voltage of the line the capacitance effect of taken into account for purposes of calculations the distributed capacitance of the line is lumped in the form of condensers shunted a/c the line at 1 or more points

③ Long Transmission Lines.

When the length of an overhead transmission line is more than 150 km and line voltage is very high (> 100 kV) it is considerd as the long transmission line for the treatment of such a line the line constants are consider uniformaly distributed the whole length of line thar regrrous methods are employed for solution of long transmission line.

Important terms.

While studying the performance of transmn lines it is desirable to design its voltage regulation & transmission efficiancy.

① Voltage regulation : When a transmission line is carrying current their is voltage drop in line due to resistance of line The result is that recieving an voltage V_R of the line is generally less than sending an voltage V_S. this voltage drop $(V_S - V_R)$ in the line is expressed as a percentage of recieving an voltage V_R is called voltage regulation

The difference in voltage at the recieving end of a transmission line between the conditions of no load and full load is called and is expressed at percentage of reciving end voltage. between the N&I...

Mathamatically, % voltage regulation is equal to $\frac{V_S - V_R}{V_R} \times 100$

Obviously it is disirable that the voltage regulation of Line should be low i.e increase in load current should make the difference in recieving end

(2) Transmission Efficiancy: The power obtained at the recieving end of T Line is generally less than sending end of line due to losses in line resistance.

The ratio of recieving end power to sending end of power of T line is called transmission efficiancy of line.

$$\% \text{ Transmission efficiancy } \eta_T = \frac{\text{recieving end Power}}{\text{Sending end power}} \times 100$$

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

Where V_R, I_R & $\cos\phi_R$ are the recieving end voltage & current & p.f

while V_S, I_S & $\cos\phi_S$ are the corresponding values at the sending end.

15-02-17

Performance of single phase short transmission lines

As stated earlier the effects of line capacitance are neglected for short transmission line. Therefore while studying performance of such a line only resistance and inductance of the line are taken into account. The equivalent ckt of single phase short transmission line is shown in fig 3.1 Here the total line resistance and inductance are shown as concentrate or lumped instead of being distributed the ckt is simple A C series ckt

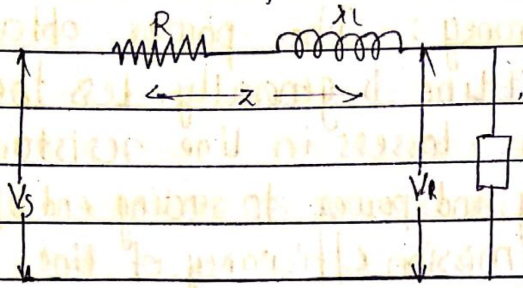


fig - 3.1

Let I = load c/o

R = Loop resistance ie resistance of both conductor

X_L = Loop reactance in Ohm

V_R = Recieving end vtg in V

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

V_S = Sending end vtg in V

$\cos\phi_S$ = sending end p.f (lag)

The phasor diagram of the line for lagging load p.f is as shown in fig 3.2

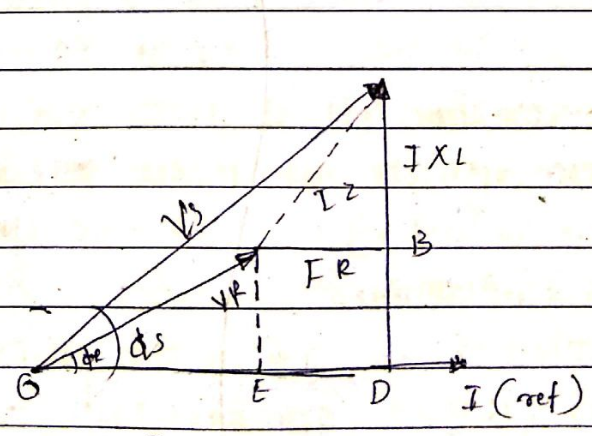


fig (3.2)

From right angled ΔODC

~~$OC^2 + OD$~~

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

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

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

$V_S = \sqrt{(V_R \cos\phi_R + IR)^2 + (V_R \sin\phi_R + IX_L)^2}$ —— (3.1)

% Voltage regulation $= \frac{V_S - V_R}{V_R} \times 100$ —— (3.2)

Sending end p.f $\cos\phi_S = \frac{OD}{OC}$

$\cos\phi_S = \frac{V_R \cos\phi_R + IR}{V_S}$ —— 3.3

Power delivered $P_d = V_R I_R \cos\phi_R$ —— (3.4)

Line losses $= P_L = I^2R$ —— (3.5)

Power send out $= P_S = V_R I_R \cos\phi_R + I^2R$ —— (3.6)

% transmission eqn $= \eta_T = \frac{\text{Power delivered}}{\text{Power send out}} \times 100$

$\% \eta_T = \frac{V_R I_R \cos\phi_R}{V_R I_R \cos\phi_R + I^2R} \times 100$ —— (3.7)

Key Point :-

Phasor diagram.

Current I is taken as refference phasor. OA represents recieving end vtg V_R leading I by ϕ_R. AB represents the drop IR (Resistive drop) in phase with I

BC represents the inductive drop IX_L and leads I by 90°. OC represents the sending end vtg V_S and lead current I by ϕ_S

Keeping V_R as a refference

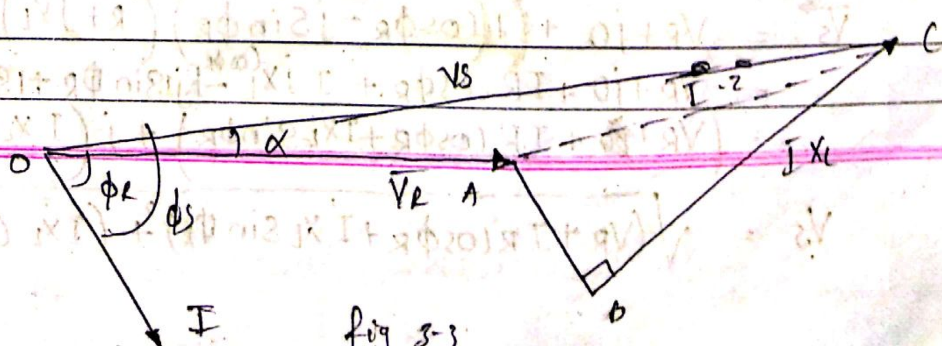
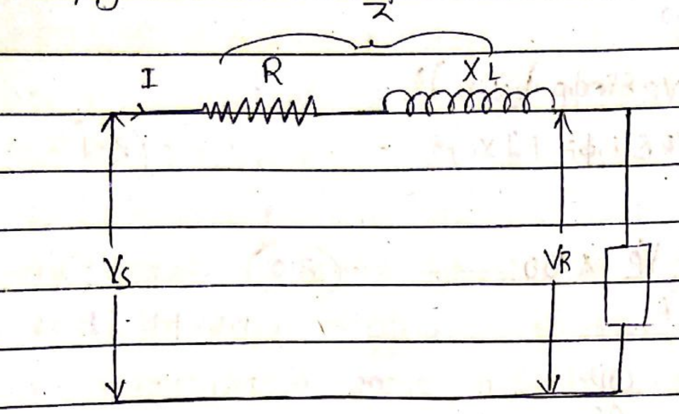
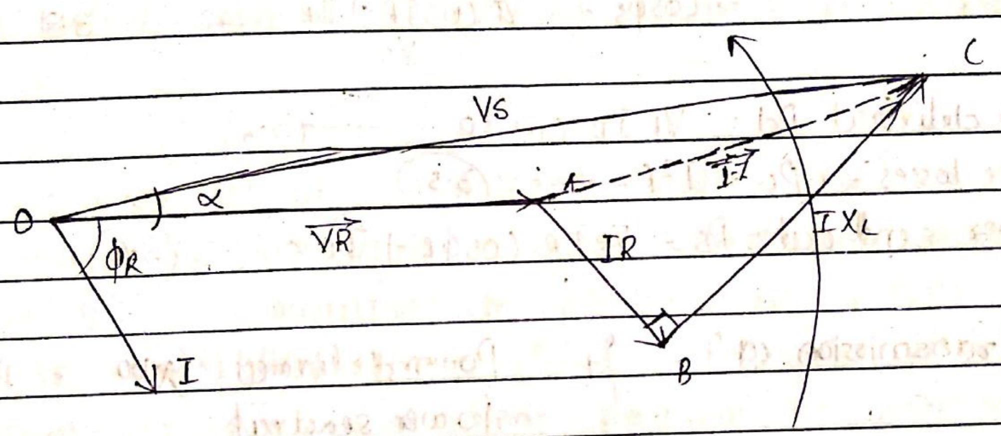


fig 3.3

Solution in Complex Notation.

It is of one convinient & Profitable to make line configuration in complex notation





Taking $\vec{V_R}$ as the refference phasor as shown in the fig-3.3 it is clear that $\vec{V_S}$ is the sum of $\vec{V_R}$ and $\vec{I}.\vec{Z}$

$\vec{V_R} = V_R + j0$ (Refference) —— (3.8)

$\vec{I} = I\angle -\phi_R$ —— (3.9)

$\vec{I} = I[\cos\phi_R - j\sin\phi_R]$ —— (3.10)

$\vec{Z} = R + jX_L$ —— (3.11)

$\therefore \vec{V_S} = \vec{V_R} + \vec{I}.\vec{Z}$ —— (3.12)

$\vec{V_S} = V_R + j0 + \{I(\cos\phi_R - j\sin\phi_R)(R + jX_L)$ —— (3.13)

$= V_R + j0 + IR\cos\phi_R + IjX_L\cos\phi_R - RjI\sin\phi_R + I\sin\phi_R X_L$

$= (V_R + IR\cos\phi_R + IX_L\sin\phi_R) + j(IX_L\cos\phi_R - IR\sin\phi_R)$

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

(3.14)

The second term under the squre root eqn (3.14) is quit small and can be neglected with reasonable accuracy.
∴ Approximate expression for Vs becomes

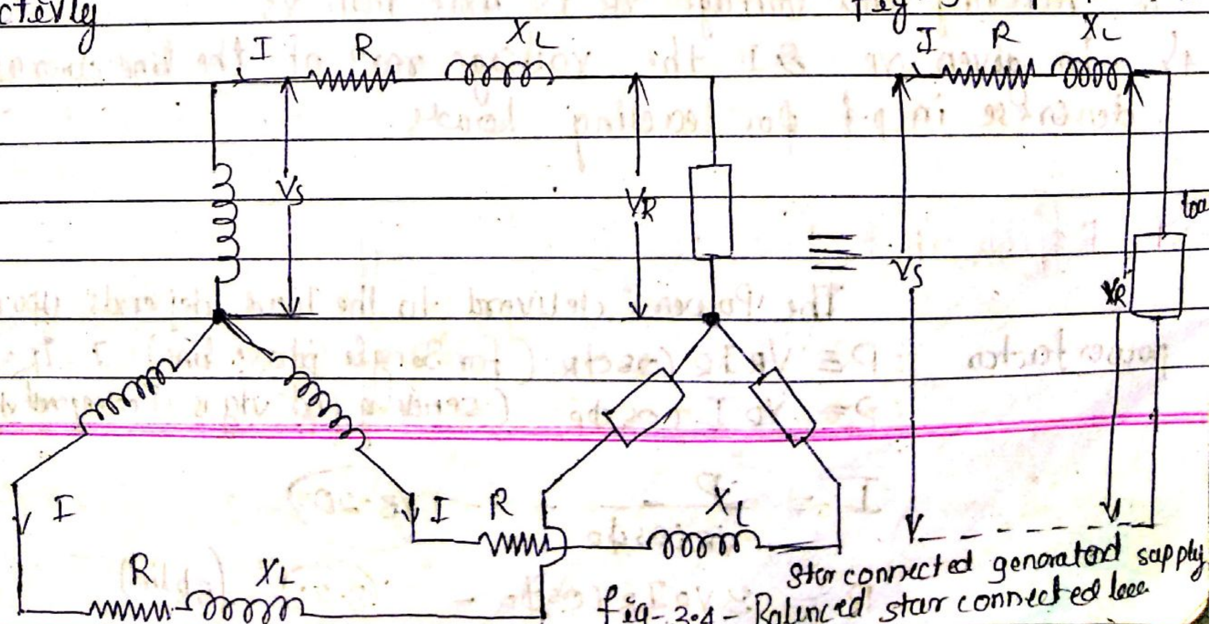
$$V_S = V_R + I R \cos\phi_R + I X_L \sin\phi_R \longrightarrow (3.15)$$

Key Points.
1) The approximate formula for Vs is eqn no. (3.15) gives fairly correct results for lagging powerfactors however appreciable error is coused for leading powerfactor. therefor approximate expression for Vs shoulbe used for lagging powerfactor only
2) The solution in complex notation is in more present tablefor

Three phase short transmission lines. 20-02-17

For reasons associated with economics, transmission of electric power is done by 3ϕ system these system may be regarded as as consisting of 3 1ϕ circuits which wire transmitting 1/3rd of the total power as a matter of convenience we generally analyse 3ϕ system by considering one phase only. therefor expression for regulation efficiancy etc derived for a single phase line can also be applied to 3ϕ system sence only one phase is considered, phase 21-02-17 value of 3ϕ system should be taken. thus Vs & VR are the phase vtgs, where R & XL are resistance and inductive reactance respectivly

fig-5- eqnt 1ϕ ckt of 3



Star connected generated supply

fig-3.4- Balunced star connected load

Fig 3.4 shows a star connected Generator supplying a balanced star connected load via transmission lines each conductor has resistance of R Ω and inductive reactance of X_L Ω fig 3.5 shows 1ϕ separately. The calculations can now be made in same way as for a single phase line.

* Effect of Load Powerfactor on regulation & Efficiency

The regulation & eff of TL depends on considerable extent the p.f of the load

1) Effect on Regulation:

The expression for p.f of vtg regⁿ of short TL is given by

$$\%\ \text{Voltage regulation} = \frac{IR\cos\phi_R + IX_L\sin\phi_R}{V_R} \times 100 \quad (3.16)$$

(For lagging Powerfactor)

$$\%\ \text{Voltage regulation} = \frac{IR\cos\phi_R - IX_L\sin\phi_R}{V_R} \times 100 \quad \text{(For Leading p.f)} \quad (3.17)$$

The following conclusions can be main by 3.16 & 3.17

1) When the p.f is lagging or unity of such leading that $IR\cos\phi_R > IX_L\sin\phi_R$ then voltage regulation is +ve that is recieving end voltage V_R will be less than

2) For a given V_R & I the vtg regulation of line increases with decrease in p.f for Lagging loads

3) When the load power factor is leading to this extent that $IR\cos\phi_R < IX_L\sin\phi_R$, then voltage regulation is negative i.e recieving end voltage V_R is more than V_S

4) For given V_R & I the voltage regⁿ of the line decreases with decrease in p.f for leading loads

* Effect of P.f on Transmission Efficiency

The Power delivered to the load depends upon the power factor

$P = V_R I_R \cos\phi_R$ (for Single phase line) $I = I_R = I_S$ (3.18)

$P = V_R I \cos\phi_e$ (sending end vtg is = Recieving end vtg) (3.19)

$$I = \frac{P}{V_R\cos\phi_R} \quad (3.20)$$

$$P = 3V_R I_R \cos\phi_R \quad (3.21) \quad \text{(3ϕ line)}$$

$$P = 3 V_R I \cos\phi_R \quad \text{(3.20)}$$

$$\therefore I = \frac{P}{3 V_R \cos\phi_R}$$

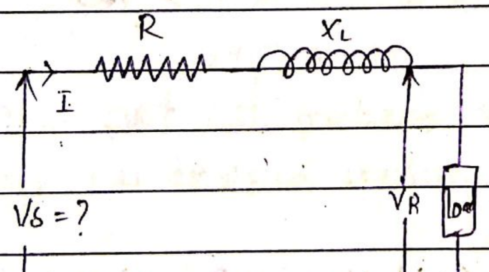
$$I = \frac{P}{\sqrt{3} \times \sqrt{3} \frac{V_l}{\sqrt{3}} \cos\phi}$$

$$I = \frac{P}{\sqrt{3} \cdot V_L \cos\phi_R} \quad \text{(3.24)}$$

It is clear that in each case for a give amount of power to be transmitted (P) & Recieving end voltage V_R the load current I is iversly propotional to $\cos\phi_R$ consequenty, with the decrease in load power factor the load current and hence the line lossess are increased. $\cos\phi_R \downarrow$ $I \uparrow$ loss $\uparrow$ $\eta \downarrow$ This is leads to the conclussion that transmission efficiancy of the line decreases with decreasing load power factor & vice verca.

$\frac{\Delta R}{R} \times 100$ (3.16) (3.17)

Example 3.1) A single phase overhead transmission line deliverse 1100 KW at 33 KV at 0.8 powerfactor lagging. The total resistance and inductive reactance of the line are 10 Ω and 15 Ω resply. determine I) sending end voltage II) sending end powerfactor III) transmission efficiancy



Given

$P = 1100$ KW

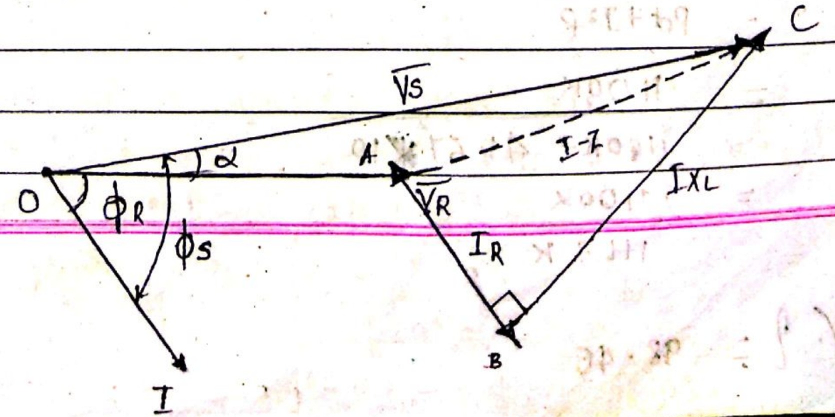
V_R(phase) = 33 KV

$\cos\phi_R = 0.8$ lag

$R = 10\,\Omega$

$X_L = 15\,\Omega$

$I = I_R + I_S$



Sol^n - Total line impedence $\bar{Z} = R + jX_L$

$\bar{Z} = 10 + j15$

$\vec{V_R} = 33000V \Rightarrow 33K + j0 = \vec{V_R}$

line current (load) $I = \frac{P}{V_R \cos\phi_R}$

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

$I = 41.67A$

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

$= 41.67 (0.8 - j0.6)$

$\bar{I} = 33.336 - j25.0023$

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

$= (33K + j0) + (33.336 - j25.0023 \times 10 + j15)$

$\vec{V_S} = 33709.39 + j250.02$

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$V_S = \sqrt{(\text{Real } V_S)^2 + (\text{Img } V_S)^2}$

$= \sqrt{(33709.39)^2 + (250.02)^2}$

$= 33708.4V$

$= 33.70 KV$

$\alpha = \tan^{-1}\left(\frac{\text{Img } V_S}{\text{Real } V_S}\right)$

$= \tan^{-1}\left(\frac{250.02}{33709.39}\right)$

$\alpha = 0.425°$

$\cos\phi_S = \cos(\phi_R + \alpha)$

$= \cos(36.86 + 0.425)$

$= 0.795$ lag

$\% \eta = \frac{P_d}{P_S}$

$= \frac{P_d}{P_d + P_l}$

$= \frac{P_d}{P_d + I^2R}$

$= \frac{1100K}{1100K + 41.67^2 \times 10}$

$= \frac{1100K}{1117K}$

$\% \eta = 98.45$

% Voltage reg^n $= \frac{V_S \text{phase} - V_R \text{phase}}{V_R \text{phase}}$

$= 2.147\%$

Alternate

$V_S = V_R + I \cdot R \cos\phi_R + I \cdot X_L \sin\phi_R$

$= 33708\ V$

$\cos\phi_S = \dfrac{V_R \cos\phi_R + IR}{V_S}$ % Voltage regⁿ.

$= 33K$

Imp ★

(3.2) An Overhead 3-ϕ transmission line delivers 5000KW at 22KV at 0.8 p.f lagging the resistance and reactance of each conductor is 4Ω and 6Ω respectivly determine i> Vs ii> Voltage reg? iii> % transmission ? (iv) Sending end p.f

$P_d = 5000\ KW$

V_R Line $= 22KV$

V_R phase $= \dfrac{V_R\ \text{Line}}{\sqrt{3}} = 12.70\ KV$

$\cos\phi_R = 0.8$ lag.

$R = 4\ \Omega$

$Z = R + jX_L = (4 + j6)\ \Omega$

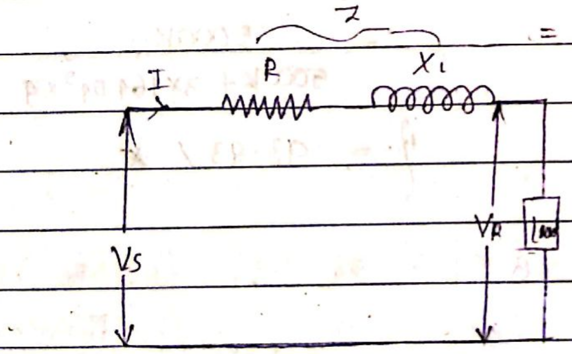
$X_L = 6\ \Omega$

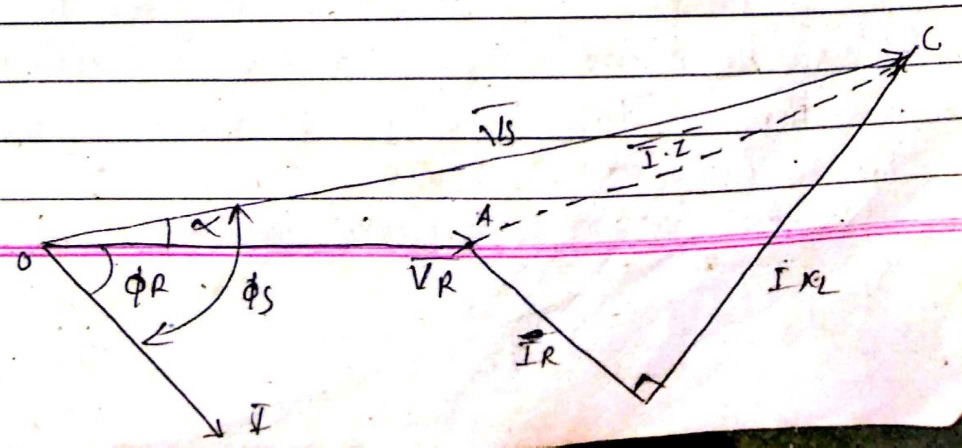
$I = \dfrac{P_d}{3 V_R \cos\phi_R}$

$V_{R\,phas} = (12.70 + j0)\ V$

$= \dfrac{5000k}{3 \times 12.70k \times 0.8}$

$= \cancel{492.12A}$ 164.04





i) $\overline{V_S} = \overline{V_R} + [I(\cos\phi_R - j\sin\phi_R)] \cdot [R + jX_L]$

$= ~~12.7K+0~~$

$= (12.70K + 0j) + [164.04(0.8 - j0.6)(4+j6)]$

$\overrightarrow{V_S} = 13815.2 + 393.6j$

$V_{S\,phase} = 13820.880$ $\alpha = 1.632$

$V_{S\,line} = \sqrt{3} \times 13820.880 \times 23.95$

ii) Voltage regulation $= \dfrac{V_{S\,phase} - V_{R\,phase}}{V_{R\,phase}} \times 100$

$= \dfrac{13820.80 - 12.70K}{12.70K} \times 100$

$= 8.82\%$

iv) Sending end p.f $= \cos\phi_S = \cos(\phi_R + \alpha)$

$= \cos(36.86 + 1.632)$

$= 0.783$

iii) Percentage of transmission efficiency $= \dfrac{P_d}{P_s}$

$P_d = 93.93 \times P_s$ $= \dfrac{P_d}{P_d + P_l}$

$= 93.93 \times (5000K + 3 \times 164.04^2 \times 4)$

$P_d = 5000K$ $= \dfrac{P_d}{P_d + 3I^2R}$

$= \dfrac{5000K}{5000K + 3 \times 164.04^2 \times 4}$

$\eta = 93.93\%$

HW

3.3 A 3ϕ line delivers 3600 kW at 0.8 p.f lag to a load if the sending end voltage is 33kV determine 1) the receiving end voltage 2) line current 3) transmission efficiency. The resistance and reactance of each conductor is 5.31 Ω & 5.54 Ω respectively. (Refer "principles of power system" by VK mehta Pg. 236, Ex - 10.5)

ex 10.6 pg - 237 of VK Mehta and 10.7

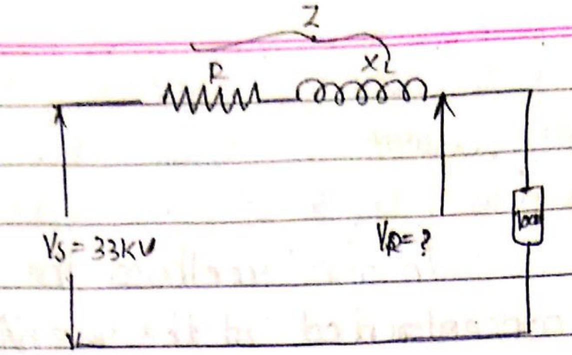
Pd = 3600 KW

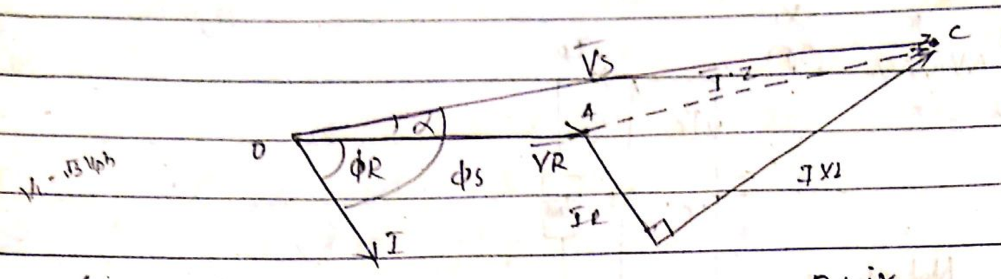
$\cos\phi_R = 0.8$ lag

$V_s = 33$ KV

$R = 5.31\ \Omega$

$X_L = 5.54\ \Omega$





V_s Line = 33KV $\qquad Z = R + jX_L$

$V_s$phase $= \dfrac{33K}{\sqrt{3}} = 19.052$ KV $\qquad Z = (5.31 + j5.54)\ \Omega$

$I = \dfrac{Pd}{3 V_{Rphs} \cos\phi_R} = \cancel{\dfrac{3600k}{3 \times 19.052k \times 0.8} = 78.73\,A}$ $\quad \cancel{I = 62.985 + j47.238}$

$\vec{V_s} = (V_R + j0) + I.Z$

$= \cancel{(19.052k + j0) + (62.985 + j47.238)(5.31 + j5.54)}$

$= 91.$

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* Medium Transmission line.

1) End Condensor Methoed

In this methoed the capacitance of line is lumped or concentrated at the receiving end as shown in the fig-6

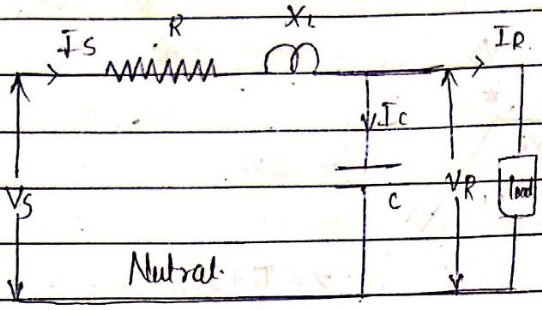


fig-3.6

This methoed of localising the line capacitance at the load end over estimates the effect of capacitance fig-3.6 is one phase of the 3-ϕ transmission line which is shown as it is more conveniant to work in phase instead of Line to line values

Let I_R = load current per phase,

R = Resistance per phase.

V_R = Recieving end vtg

X_L = Inductive reactance per phase

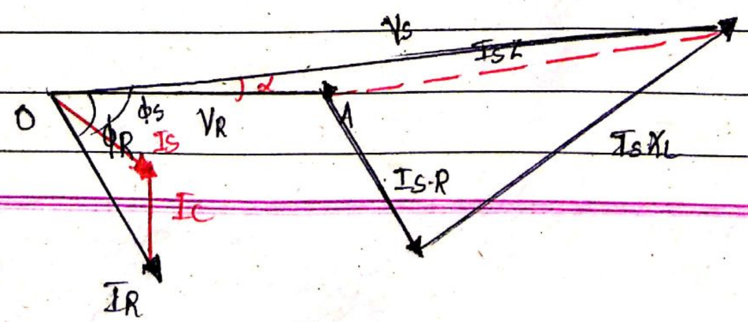
C = Capacitance per phase.

$\cos\phi_R$ = Reciving end p.f (lag)

V_S = Sending end voltage per phase.

I_S = sending end current per phase

The phaser diagram of circuit diagram 3.6 is shown in fig 3.7 taking V_R as refference phaser



$I_S = I_R + I_C$

$\overrightarrow{V_R} = V_R + j0$ —— (3.25)

load current or line current $= \overline{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$ —— (3.26)

Capacitive current $= \overline{I_C} = \dfrac{\overrightarrow{V_R}}{X_C} = \dfrac{\overrightarrow{V_R}}{1/j\omega C} = j\omega C V_R$

Susceptance (℧) . $Y = G + jB$ $\quad \overline{I_C} = jY\overrightarrow{V_R}$ $\therefore \overline{I_C} = j2\pi f C \overline{V_R}$ —— (3.27)

Sending end current I_s is the sum of load current I_R & capacitive current I_C.

$\therefore \overrightarrow{I_S} = \overrightarrow{I_R} + \overrightarrow{I_C}$ —— (3.28)

$\overrightarrow{I_S}$. Substituting the value of I_R & I_C.

$\overline{I_S} = I_R(\cos\phi_R - j\sin\phi_R) + j\, 2\pi f C \overline{V_R}$

$\overline{I_S} = I_R\cos\phi_R + j(-I_R\sin\phi_R + 2\pi f C \overline{V_R})$ —— (3.29)

Voltage drop per phase $= \overline{I_S}\,\overline{Z}$ —— (3.30)

$= I_R\cos\phi_R + j(2\pi f C V_R - I_R\sin\phi_R)(R + jX_L)$ —— (3.31)

Sending end voltage / phase $= \overrightarrow{V_S} = \overrightarrow{V_R} + \overline{I_S}\,\overline{Z}$

$\overrightarrow{V_S} = \overrightarrow{V_R} + \overline{I_S}(R + jX_L)$ (3.32)

Thus the magnitude of sending end voltage V_S can be calculated.

% Voltage regulation $= \dfrac{V_S - V_R}{V_R} \times 100\,\%$ —— (3.33)

% Transmission efficiency $= \dfrac{\text{Power delivered / Phase}}{\text{Power delivered / phase + losses / phase}} \times 100$ —— (3.34)

Example

(3.3) A medium single phase transmission line 100 Km has the following constantce:

Resistance per km $= 0.25\,\Omega$

Reactance per km $= 0.8\,\Omega$

Susceptance per km $= 14 \times 10^{-6}$ ℧

Receiving end line voltage $= 66000$ V

Assuming the total capacitance of line localised at the receiving end a load, Determine 1) Sending end vtg 2) sending end current 3) regulation 4) supply power factor, The line is delivering 15000 kW at 0.8 lagging p.f, draw the phasor diagram to illustrate your calculation.

Given

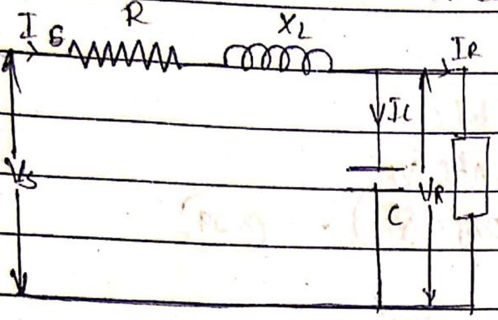
Total resistance $= R = 0.25 \times 100 = 25\,\Omega$

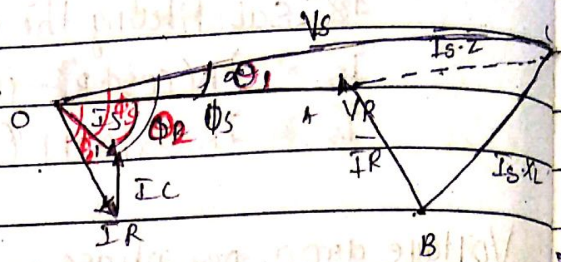
Total reactance $= X_L = 0.8 \times 100 = 80\,\Omega$

" Susceptance $= B = 14 \times 10^{-6} \times 100 = 1.4 \times 10^{-3}\,℧$

$V_R = 66KV$ $\quad P = 15000\,KW \quad \cos\phi_R = 0.8$ (lag)

load current $I_R = \dfrac{P}{V_R \cos\phi_R} = \dfrac{15000K}{66K \times 0.8} = 284A$





$\overline{V_R} = V_R + j0$ $\qquad \overline{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

$= 66000 + j0$ $\qquad = 284(0.8 - j0.6)$

$\overline{V_R} = 66000$ $\qquad \overline{I_R} = 227.2 - j170.4$

$Y = G + jB$

$= 0 + j1.4 \times 10^{-3}$ $\qquad Z = R + jX_L$

$Y = 1.4 \times 10^{-3}\,℧$ $\qquad Z = (25 + j80)\,\Omega$

$I_C = jY\overline{V_R}$

$= j1.4 \times 10^{-3} \times 66000$

$= j92.4$

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

$= (\overline{V_R}) + (\overline{I_R} + \overline{I_C}) \cdot (R + jX_L)$

$= (66K + j0) + [(227.2 - j170.4) + (j92.4)] \cdot (25 + j80)$

$\overline{V_S} = 77920 + j16226$ $\qquad \theta_1 = \tan^{-1}\left(\dfrac{\text{Img } V_S}{\text{Real } V_S}\right)$

$V_S = 79593 \angle 11.75$ $\qquad \alpha = 11.75^\circ$

$\theta_1 = \tan^{-1}\left(\dfrac{16226}{77920}\right)$

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

$= 227.2 - j170.4 + j92.4$ $\qquad = 11.75$

$\overline{I_S} = 227.2 - j78$

$I_S = 240.21 \angle -18.95$ $\qquad \theta_2 = \tan^{-1}\left(\dfrac{\text{Img } I_S}{\text{Real } I_S}\right)$

$= \tan^{-1}\left(\dfrac{-78}{227.2}\right)$

$\theta_2 = -17.99$

$\phi_S = \theta_1 + \theta_2$
$= 11.75 - 18.95$
$= -7.2$
$\cos\phi_s = \cos(-7.2)$
$\cos\phi_s = 0.992$

$\%R = \frac{V_S - V_R}{V_R} \times 100$
$= \frac{79593 - 66K}{66K} \times 100$
$\%R = 20.59\%$

$\%\eta_T = \frac{P_d}{P_d + I_S^2 R} \times 100$

$= \frac{15000K}{15000K + (240.216)^2\, 25} \times 100$

$\%\eta_T = 91.23\%$

6/3/17

May 16
Jun 14

Nominal 'T' method

In this method the whole capacitance is assumed to be concentrated at the mid point of the line and half the line resistance and half the line reactance are lumped on its either side as shown in the fig 3.8

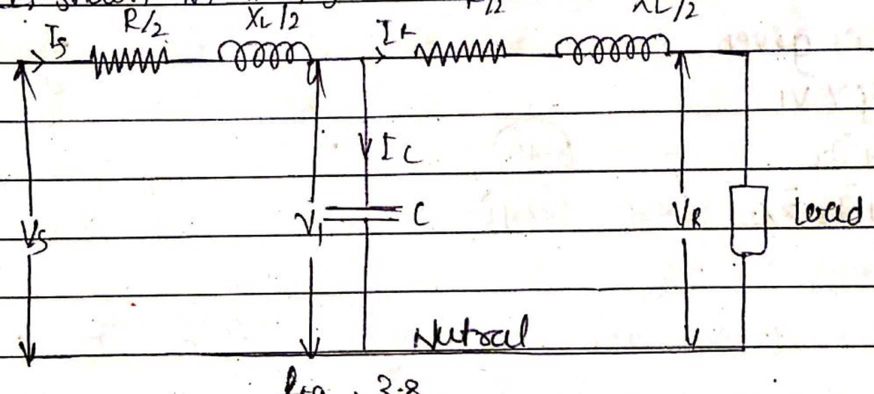


fig. 3.8

In this arrangement the full charging current flows over half of the T.L in fig 3.8 above fig shows 1ϕ of a 3ϕ TL as it has advantage to work on 1ϕ instead of line to line values let

V_S = Sending end voltage / phase.
R = resistance / phase.
I_R = Load current per phase
X_L = Inductive reactance per phase.
C = Capacitance per phase
$\cos\phi_R$ = Receiving end p.f
V_R = Receiving end vtg. per phase
V_1 = Voltage a/c capacitor C.
$\cos\phi_S$ = Sending end p.f

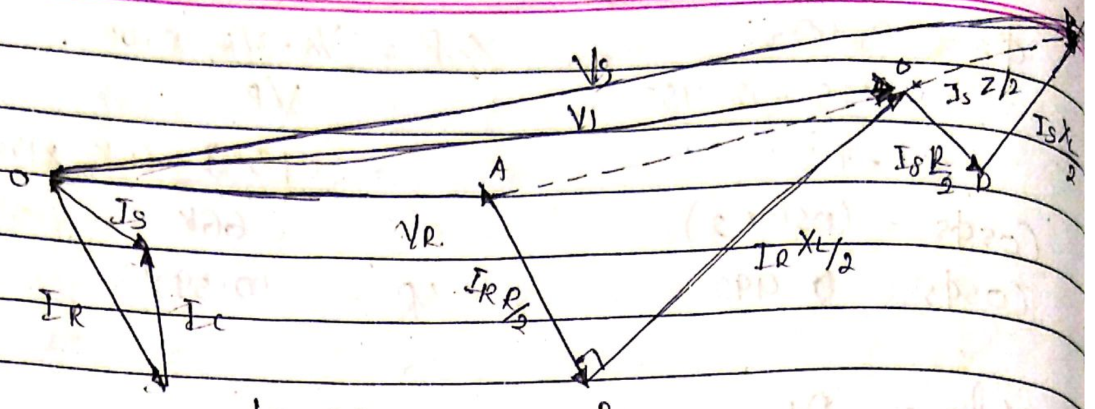


fig 3.9

$I_c \perp V_1$ I_s in phase with $I_s \frac{R}{2}$

$\overline{V_R} = V_R + j0$ ——— (3.35)

$\overline{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$ ——— (3.36)

voltage a/c capacitor.

$\overline{V_1} = \overline{V_R} + \overline{I_R}\,\overline{Z/2}$ ——— (3.37)

$\overline{V_1} = (V_R + j0) + I_R(\cos\phi_R - j\sin\phi_R)\cdot\left(\frac{R}{2} + j\frac{X_L}{2}\right)$ ——— (3.38)

$\overline{I_c} = \frac{\overline{V_1}}{X_C} = \frac{V_1}{\frac{1}{j\omega C}} = j\omega C V_1$

$I_c = j2\pi f C.\overline{V_1}$ ——— (3.39)

If Y or B is given

$\overline{I_c} = jY\overline{V_1}$

$\overline{I_S} = \overline{I_R} + \overline{I_c}$ ——— (3.40)

$\overline{V_S} = \overline{V_1} + \overline{I_S}\,\overline{Z/2}$ ——— (3.41)

3.4 A 3φ 50Hz overhead T.L 100km long has the following constant resistance/km/phase = 0.1 Ω
Capacitive susptance /km/phase = 0.04×10⁻⁴ seimens
Determine 1) I_s 2) V_s 3) $\cos\phi_s$ 4) η_T
when supplieng a balanced load of 10000 KW at 66 KV at 0.8 p.f (lag) use nominal 'T' method

$R = 0.1 \times 100 = 10\,\Omega$

$X_L = 0.2 \times 100 = 20\,\Omega$

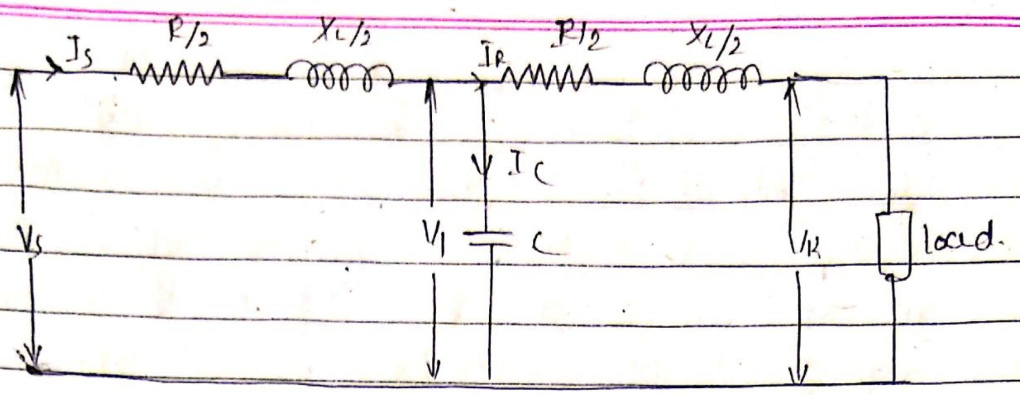
$B = 0.04 \times 10^{-4} \times 100 = 4 \times 10^{-4}\,℧$ $I_R = 109A$

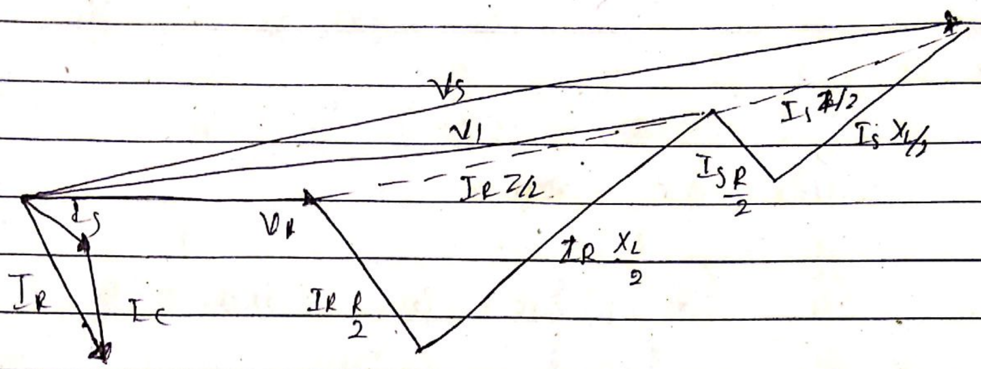
$P_d = 10,000\,KW$ $Z = R + jX_L$

$V_{RL} = 66\,KV$ $Z = R + jX_L$

$Z = (10 + j20)\,\Omega$

$V_{Rph} = 38.105\,KV$ $\overline{V_R} = 38.105 + j0$





I will solve the above problem as erlier as possible and I know how to solve the problem. and I will be difinatly solve it & I will very happy after solving the problem

$I_R = \frac{P_d}{V_R \cos\phi_R}$ $\qquad \overline{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

$\qquad\qquad\qquad\qquad = 0.328(0.8 - j0.6)$

$I_R = \frac{10000}{38.105K \times 0.8}$ $\qquad \overline{I_R} = 0.2624 - j0.1968$

$I_R = 0.328$ $\qquad \overline{V_1} = \overline{V_R} + \overline{I_R}\,\overline{Z}/2$

$I_c = jY\overline{V_1}$ $\qquad = 38.105 + [(0.2624 - j0.1968)(5 + 10i)]$

$\overline{I_c} = j\,4 \times 10^{-4} \times 41.385 + 1.64i$ $\qquad \overline{V_1} = 41.385 + 1.64i$

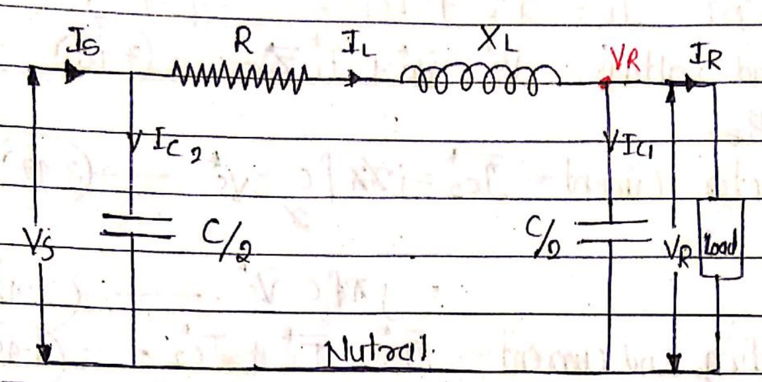
$=$

Jan 19 T-mee

3.5 HW 10.12 pg 245

Nominal 'π' Methoed

In this methoed capacitance of each condector (i.e line to nutral) is devided into halves; one half is being lumped at the sending end and the other half at the reciving end as shown in the fig-3-10 It is obivious that capacitance at the sending end has low effect on the line drop however its charging end must be aded to obtain the total sending End current



Taking the VR as 0 refference.

fig 3-10

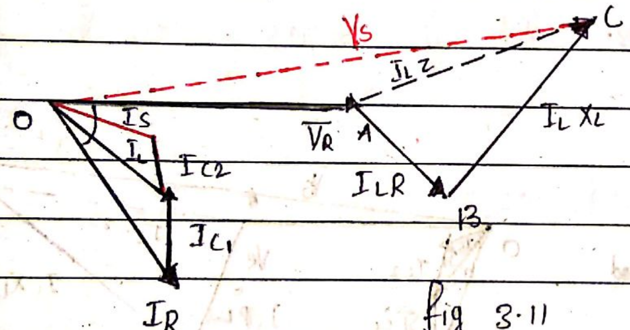


fig 3-11

Let I_R = load current per phase,
R = resistance per phase ; X_L = reactance per phase.
V_R = recieving end voltage per phase.
C = Capacitor per phase
$\cos\phi_R$ = receiving end power factor
V_S = sending end voltage perphase.
I_S = Sending end current per phase.

The phasor diagram is as shown in fig 3.11 taken receiving end voltage as refference vtg.

$\vec{V_R} = V_R + j0$ —— (3.42)

Load current $\vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$ —— (3.43)

charging c/n of capacitor at reciving end $I_{C1} = j2\pi f C \vec{V_R}$ —— (3.44)

$I_{C1} = jY V_R$

Line current $\vec{I_L} = \vec{I_R} + \vec{I_{C1}}$ —— (3.45)

Sending end voltage $= \vec{V_S} = \vec{V_R} + \vec{I_L}\vec{Z}$ —— (3.46)

(3.6) ~~A 3ϕ 50Hz~~

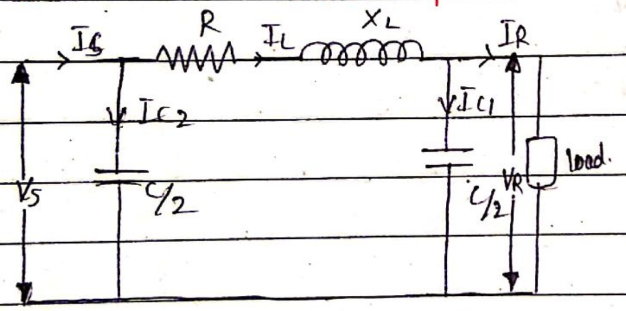
2nd capacitor current $= \vec{I_{C2}} = j2\pi f \frac{C}{2} \vec{V_S}$ —— (3.47)

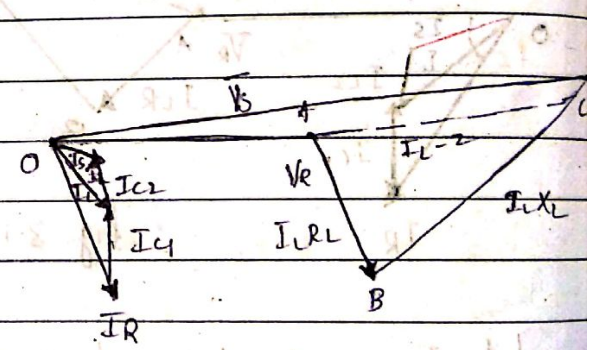
$= j\pi f C \vec{V_S}$. —— (3.48)

Sending end current $= \vec{I_S} = \vec{I_L} + \vec{I_{C2}}$ —— (3.49)

10/3/17

(3.6) A 3ϕ 50Hz, 150km line has resistance, inductive reactance capacitive admittance are 0.1Ω, 0.5Ω & 3×10^{-6} sem/km/ph respectivly If the line delivers 50MW at 110KV and 0.8 pf (lag) determine the sending end vtg & current assume nominal π circuit for line





Sending end voltage $= \vec{V_S} = \vec{V_R} + \vec{I_L}\cdot\vec{Z}$

$V_R = 110K$

$\vec{V_R} = \frac{110K}{\sqrt{3}} = 63.508K + j0$ V

$\vec{I_R} = \frac{P}{\sqrt{3} V_{R\,line} \cos\phi_R}$ or $\frac{P}{3 V_{R\,phase} \cos\phi_R} = I_R(\cos\phi_R - j\sin\phi_R)$

$= \frac{50M}{\sqrt{3}\ 110K \times 0.8}$ or $\frac{50M}{3\times63.508.52\times0.8}$

$I_R = 328.03$ A

$\vec{I_L} = I_L\,\cancel{(\cos\phi_R - j\sin\phi_R)}$

$= \cancel{328.03\,(0.8 - j0.6)}$

$= \cancel{262.429 - j196.81}$

$I_R = \dfrac{P}{3 \times V_{Rphase} \cos\phi_R}$

$= \dfrac{50M}{3 \times 63.508K \times 0.8}$

$= 328.042$

$I_{C1} = j\dfrac{Y}{2} \cdot V_{Rph}$

$= j\dfrac{3 \times 10^{-6} \times 150}{2} \times 63.508K$

$\vec{I_{C1}} = j14.30\,A$

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

$= 328.042\,(0.8 - j0.6)$

$= 262.43 - j196.825$

$\vec{Z} = 15 + j75\,\Omega$

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

$= 262.43 - j196.825 + j14.30$

$= 262.43 - j182.525\,A$

$\vec{V_S} = \vec{V_{Rphase}} + \vec{I_L}\,Z_{ph}$

$= 63.508K + (262.43 - j182.525)(15 + j75)$

$\vec{V_S} = 81.133K + 16.94K$

$\vec{V_S} = 82884.3 \angle 11.79$

$\boxed{V_S = 82.884\,KV}$

$\vec{I_{C2}} = j\,Y/2\,\vec{V_S}$

$= j\dfrac{4.5 \times 10^{-4}}{2} \cdot (81126 + j16941)$

$\vec{I_{C2}} = -3.81 + j18.25\,A$

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

$= 262.43 - j182.525 + (-3.81 + j18.25)$

$\boxed{\vec{I_S} = 258.62 - j164.275}$

$I_S = 306.38.$

Problem May-16

HW

Pg - 248   Ex-10.14

11/3/17

Methoed ~~regrous~~ - Carfull attention with calculation

Long Transmission Lines

It is wellknown to me that line constant of transmission line are uniformaly distributed over the entire length of line however reasonable accuracy can be obtained in line calculation for short and medium transmission line by considering these constants are lumped

If such an assumptions of lumped constant is applied to long T.L (having length excess of about 150 km), it is found that ~~series~~ or serious errors are introduced in performance calculation. Therefore in order to obtain the fair degree of accuracy in Performace calculations in long transmission line. The long constants are uniformaly distrubuted throughout the length, rigrous mathamatical treatment is requried for the solution of Long transmission lines

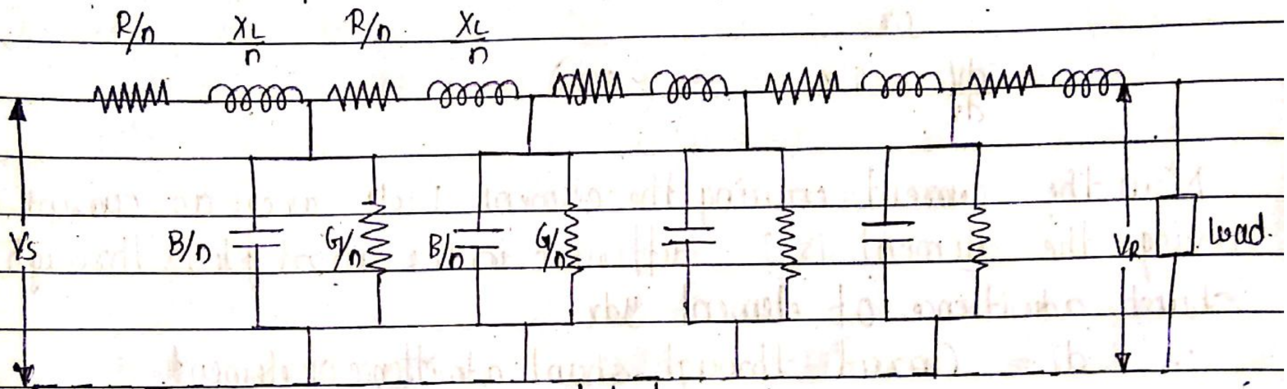


fig - 3.12

Fig 3.12 shows the equevelent ckt of a 3ϕ long transmission line on a phase to nutral bases. The whole length of line is devided into ~~a~~ 'n' sections each section having line constants $\frac{1}{n^{th}}$ of those for the line.

Imp Analysis of long transmission line (Rigorous Methoed)

Fig 3.13 below shows 1ϕ and nutral connection of a 3ϕ line with impidence and shunt admsttence of line is uniformally distributed.

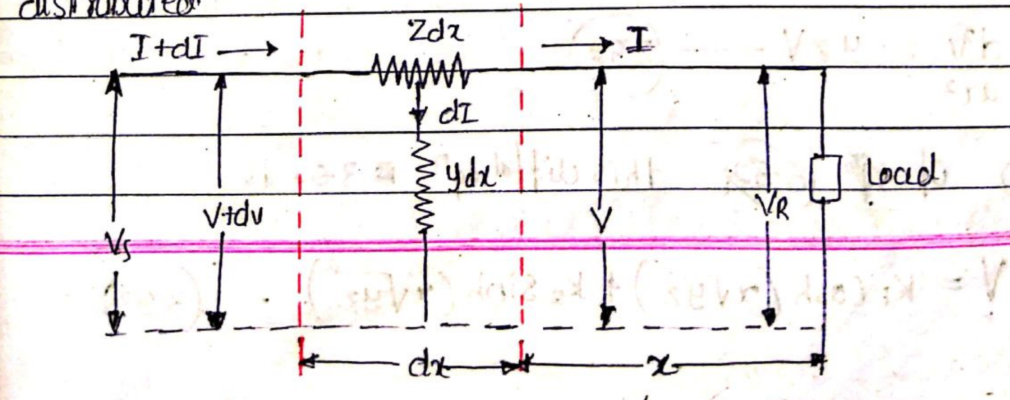


fig 3.13

Consider a small element in the line of length 'dx' suituated at x from the recieving end.

Let z = Series impidence of the line per unit length
y = Shunt Admittence of the line per unit length
V = Voltage at end of element toward recieving end.
V+dv = Voltage at the end of element toword sending end,
I + dI = Current entering the element dx.
I = Current Leaving the element dx.

then for the small element dx,
z dx = Series impidence of element dx
y dx = shunt admittence.

Abiously, $dV = IZdx$

or

$$\frac{dV}{dx} = IZ \quad \text{——— (3.50)}$$

Now the current entiring the element I+dI where as current leving the element is I difference in the current flows through shunt admittence of element ydx

$\therefore$ dI = Current through shunt admittence of element

$$dI = Vydx$$

then $$\frac{dI}{dx} = Vy \quad \text{——— (3.51)}$$

differentiating eqn (3.50) wrt x we get

$$\frac{d^2V}{dx^2} = z\frac{dI}{dx}$$

Substituting (3.51) in above eqn (1)

$$\frac{d^2V}{dx^2} = z(Vy)$$

$$\frac{d^2V}{dx^2} = yzV \quad \text{——— (3.52)}$$

The solution of ~~eqn~~ ~~(3.52)~~ this diffal eqn. 3.52 is

$$V = K_1 \cosh(x\sqrt{yz}) + K_2 \sinh(x\sqrt{yz}) \quad \text{-- (3.53)}$$

differentiating 8.53 wrt x we have

$$\frac{dV}{dx} = K_1 \sinh(x\sqrt{yz})\sqrt{yz} + K_2 \cosh(x\sqrt{yz})\sqrt{yz}$$

But $\frac{dV}{dx} = IZ$ ($\because$ by 3.50

$$IZ = K_1\sqrt{yz}\cdot\sinh(x\sqrt{yz}) + K_2\sqrt{yz}\cdot\cosh(x\sqrt{yz})$$

$$I = \sqrt{\frac{y}{z}}\left[K_1 \sinh(x\sqrt{yz}) + K_2\cosh(x\sqrt{yz})\right] \text{---} (3.54)$$

eqns 3.53 and 3.54 give the expressions and V & I in the form of unknown constants K_1 and K_2 the values of K_1 and K_2 can be formed by applying end conditions as under,

At $x = 0$, $V = V_R$ and $I = I_R$

Putting these values in eqn 3.53 we have.

$$V_R = K_1\cosh(0) + K_2\sinh(0)$$

$$V_R = K_1(1)$$

$$\therefore V_R = K_1$$

Similleraly putting $x=0$ $V = V_R$ & $I = I_R$ in eqn 3.54

$$I_R = \sqrt{\frac{y}{z}}\left[K_1\sinh(0) + K_2\cosh(0)\right]$$

$$I_R = K_2\sqrt{\frac{y}{z}}$$

$$K_2 = I_R\sqrt{\frac{z}{y}}$$

Substituting the values o K_2 and K_1 in eqn 3.53 & 3.54 we get

$$V = V_R\cosh(x\sqrt{yz}) + \cancel{K_2}\, I_R\sqrt{\frac{z}{y}}\sinh(x\sqrt{yz})$$

The sending end vtg V_s and sending end current I_s are obtained by putting $x = l$ in the above eqns i.e taking V as V_s and I as I_s

$$V_s = V_R\cosh(l\sqrt{yz}) + I_R\sqrt{\frac{z}{y}}\sinh(l\sqrt{yz})$$

$$I_s = \sqrt{\frac{y}{z}}\left[V_R\sinh(l\sqrt{yz}) + I_R\sqrt{\frac{z}{y}}\cosh(l\sqrt{yz})\right]$$

$l\sqrt{yz} = \sqrt{ly\,lz} = \sqrt{YZ}$

$$\sqrt{\frac{y}{z}} = \sqrt{\frac{yl}{zl}} = \sqrt{\frac{Y}{Z}}$$

Y = total shunt of admittance of line

Z = total series impidence of line.

∴ expression for Vs and Is becomes

$$V_S = V_R \cosh\sqrt{YZ} + I_R\sqrt{\frac{Z}{Y}}\sinh\sqrt{YZ} \quad --- (3.55)$$

$$I_S = V_R\sqrt{\frac{Y}{Z}}\sinh\sqrt{YZ} + I_R\cosh\sqrt{YZ} \quad --- (3.56)$$

13/3/17

It is helfull to expand hyperbolic sin and cosin in terms of their power series

$$\cosh\sqrt{YZ} = \left(1 + \frac{YZ}{2} + \frac{Y^2Z^2}{24} + ---\right) \text{ approx}$$

$$\sinh\sqrt{YZ} = \left(\sqrt{YZ} + \frac{(YZ)^{3/2}}{6} + ---\right) \text{ approx}$$

(3.7) A 3ϕ TC 200km long has followoing constants
Resistance per phase per km is 0.16 Ω
Reactane per phase per km is 0.25 Ω
Shunt admittence per phase per km is 1.5×10^{-6} ℧
Calalate by regraous methoed sending end vtg & sending end current when the line is delivering a load of 20MW at 0.8pf (lag) the receiving end vtg is kept constant at 110kV

$l = 200$ km $\qquad P_d = 200$ MW

total $R = 0.16\times200 = 32\,\Omega$

total $X_L = 0.25\times200 = 50\,\Omega$

total $Y = j1.5\times10^{-6}\times200 = j0.0003 = 0.0003\angle90°$ ℧

Total impidence $= Z = R + jX_L$

$Z = 32 + j50\,\Omega$

$Z = 59.36\angle57.38°$

$V_{R(line)} = 110$k

$V_{R(phase)} = \frac{110k}{\sqrt3} = 63508.53$ V

$$I_R = \frac{P_d}{\sqrt3\,V_{R\,line}\cos\phi} = \frac{P_d}{3V_{Rph}\cos\phi} = \frac{200MW}{3\times63508.53\times0.8} = 1312A$$

$\overline{V_S} = 67018 + j6840$ V

$V_S = 67.366 \angle 5.5^\circ$ V

$\overline{I_S} = 129.83 + j19.42$ A

$I_S = 131.1 \angle 8^\circ$ A

$\frac{90+58}{2} = \angle 74$

$\sqrt{YZ} = \sqrt{0.0003 \angle 90 \times 59.36 \angle 57.38} = \sqrt{0.0178 \angle 147.38} = 0.133 \angle 74$

$YZ = 0.0178 \angle 147.38$

$Y^2Z^2 = (0.0003 \angle 90)^2 \times (59.36 \angle 57.38)^2 = 0.00032 \angle 296^\circ$

$\sqrt{\frac{Z}{Y}} = \cancel{445} \sqrt{\frac{59.36 \angle 57.38}{0.0003 \angle 90}} = 445 \cancel{80} \angle \frac{58-90}{2} = \angle -16^\circ$

$\sqrt{\frac{Y}{Z}} = \sqrt{\frac{0.0003}{59.36}} \angle \frac{90-58}{2} = 0.0024 \angle 16^\circ$

$\cosh\sqrt{YZ} = \left(1 + \frac{YZ}{2} + \frac{Y^2Z^2}{24} + \cdots\right)$

$\cosh\sqrt{YZ} = \left(1 + \frac{0.0178 \angle 147.38}{2} + \frac{0.00032 \angle 296}{24}\right) = 0.992 \angle 0.2762$

$\sinh\sqrt{YZ} = \left(\sqrt{YZ} + \frac{(YZ)^{3/2}}{6} + \cdots\right)$

$= \left(0.133 \angle 74 + \left(\left(0.0178 \angle 147.38\right)^{1/2}\right)^3\right)$

$= 0.1325 \angle 74.6^\circ$

Jun 14

Ferranti effect on transmission line

* Generalised Circuit constants of a transmission line

In any four terminal network ; The input voltage (V_S) & input current (I_S) can be expressed interms of o/p vtg (V_R) & o/p current (I_R) incidently a transmission line is a four terminal network : Two input terminals where power enters the n/w and two o/p terminals where power leaves the n/w

The input voltage $\vec{V_R}$ ~~(phase)~~ and input current $\vec{I_S}$ of a 3ϕ TL can be expressed as

$$\vec{V_S} = \vec{A}\,\vec{V_R} + \vec{B}\,\vec{I_R} \quad \text{---} \quad (3.57)$$

$$\vec{I_S} = \vec{C}\,\vec{V_R} + \vec{D}\,\vec{I_R} \quad \text{---} \quad (3.58)$$

Where $\vec{V_S}$ = Sending end ~~voltage~~ vtg /ph

$\vec{I_S}$ = -- -- current /ph

$\vec{I_R}$ = Recieving end current /ph

$\vec{V_R}$ = ———— vtg /ph

And $\bar{A}, \bar{B}, \bar{C}$ & $\bar{D}$ (Generally complex numbers are the constant known as generalised ckt constant of the TL the value of constant depends upon the perticular methoed adopted for solving TL. Once the values of these constants are known, performance calculation of the line can be easilly

Determination of Generalised Constants of T.L

As stated previosly the send end voltage ($\bar{V_s}$) and sending end C/n $\bar{I_s}$ of the TL can be expressed as

$\bar{V_S} = \bar{A}\bar{V_R} + \bar{B}\bar{I_R}$ —— (3.59)

$\bar{I_S} = \bar{C}\bar{V_R} + \bar{D}\bar{I_R}$ —— (3.60)

We shall now determine the values of constants for diff Transmission lines

(i) Short Transmission Line

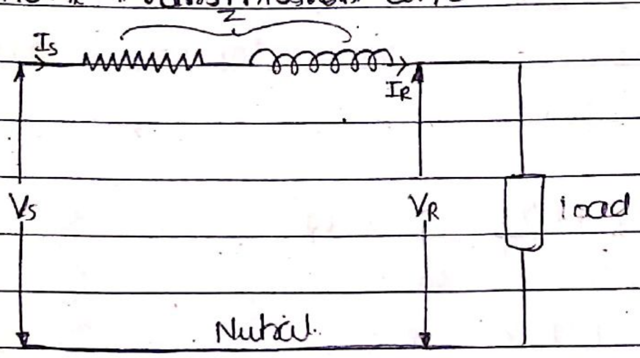


fig 3.14

In the short TL the effect of line capacitance is neglected there for the Line is considerd to have series impidence. fig 3.14 above shows 3ϕ TL on single ϕ bases

$\bar{I_S} = \bar{I_R}$ —— (3.61) and

$\bar{V_S} = \bar{V_R}\bar{I_R}\bar{Z}$ —— (3.62)

Comparing eq^n 3.59 and 3.60 we have.

$\bar{A} = 1$; $\bar{B} = \bar{Z}$, $\bar{C} = 0$. and $\bar{D} = 1$

Identically $\bar{A} = \bar{D}$

and $\bar{A}\bar{D} - \bar{B}\bar{C} = 1 \times 1 - \bar{Z} \times 0 = 1$

(iii) Medium Transmission Line. (Nominal 'T')

In this methoed the whole line to nutral capacitance is assumed to be connected at the midle point of the line and either side shown fig - 3.15

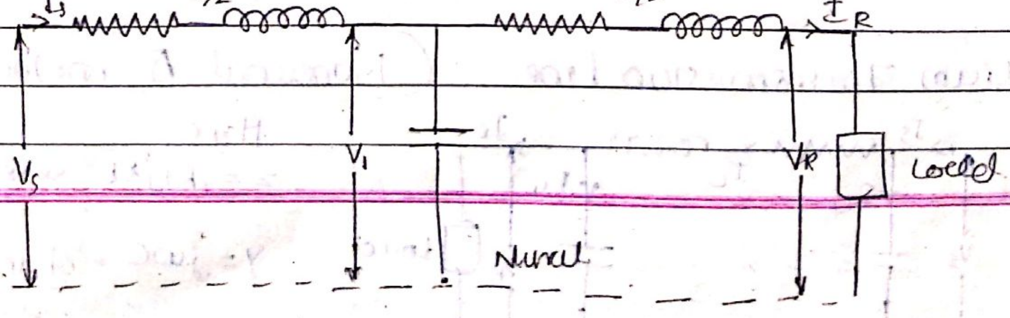


fig 3.15

Here $\overline{V_S} = \overline{V_1} + \overline{I_S}\, Z/2$ —— (3.63)

$\overline{V_1} = \overline{V_R} + \overline{I_R}\, Z/2$ —— (3.64)

$\overline{I_C} = \overline{I_S} - \overline{I_R}$ —— (3.65)

$\overline{I_C} = \overline{V_1}.\overline{Y}$

where Y = shunt admittance.

$$I_C = \overline{Y}\left(\overline{V_R} \cdot \frac{I_R Z}{2}\right) \quad \text{—— (3.66)}$$

$$\therefore \overline{I_S} = \overline{I_R} + \overline{Y}\left(\overline{V_R} + \frac{\overline{I_R Z}}{2}\right)$$

$$\vec{I_S} = I_R + Y\overline{V_R} + \frac{Y I_R Z}{2}$$

$$\overline{I_S} = Y\overline{V_R} + \overline{I_R}\left(1 + \frac{YZ}{2}\right) \quad \text{—— (3.67)}$$

and
$$\overline{V_S} = \overline{V_R + I_R Z/2} + \frac{\overline{I_S} Z}{2}$$

$$\overline{V_S} = \left(1 + \frac{YZ}{2}\right)\overline{V_R} + \left(Z + \frac{\overline{YZ^2}}{2}\right) I_R \quad \text{—— (3.68)}$$

Comparing 3.59 with 3.68 and 3.60 with 3.67 we have

$$A = \left(1 + \frac{\overline{YZ}}{2}\right), \quad B = \left(Z + \frac{\overline{YZ^2}}{4}\right) = Z\left(1 + \frac{YZ}{4}\right)$$

$$C = Y \qquad D = \left(1 + \frac{YZ}{2}\right)$$

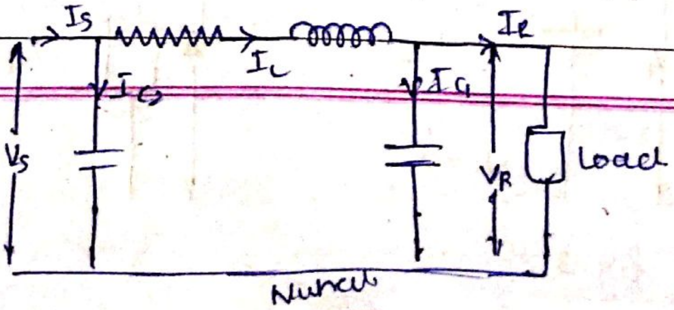
$\therefore$ A = Z

and
$$AD - BC = \left(1 + \frac{\overline{YZ}}{2}\right)^2 - YZ + \frac{Y^2Z^2}{4}$$

$$= 1 + \frac{Y^2Z^2}{4} + \frac{\cancel{2}YZ}{\cancel{2}} - YZ + \frac{Y^2Z^2}{4}$$

$$\overline{AD - BC} = 1$$

Medium Transmission line (Nominal π method)



Here.

$Z = R + jX_L$ series impedance/phase

$Y = j\omega C$ = shunt admittance

$I_S = I_L + I_{C_2}$

$\bar{I_s} = \bar{I_L} + \bar{I_{C_1}}$

$\bar{I_s} = \bar{I_L} + \bar{V_s} \cdot Y/2$

$\bar{I_L} = \bar{I_R} + \bar{I_{C_2}}$

$\bar{I_L} = \bar{I_R} + \bar{V_R}\, Y/2$

$\therefore \bar{V_s} = \bar{V_R} + \bar{I_L} Z = \bar{V_R} + (\bar{I_R} + \bar{V_R}\, Y/2)\bar{Z}$ Putting I_L.

$\bar{V_s} = \bar{V_R} \cdot \left(1 + \frac{YZ}{2}\right) + \bar{I_R} Z$

$\bar{I_s} = \bar{I_L} + V_s\, Y/2$

$\bar{I_s} = (\bar{I_R} + \bar{V_R}\, Y/2) + \bar{V_s}\, Y/2$ ($\because$ putting I_L)

Putting value of $\bar{V_s}$

$$\bar{I_s} = \bar{I_R} + \bar{V_R}\frac{Y}{2} + \frac{Y}{2}\left\{ \bar{V_R}\left(1 + \frac{YZ}{2}\right) + \bar{I_R} Z \right\}$$

$$= \bar{I_R} + \bar{V_R}\frac{Y}{2} + \bar{V_R}\frac{Y}{2} + \bar{V_R}\frac{Y^2 Z}{4} + \frac{Y}{2}\bar{I_R} Z$$

$$\vec{I_s} = \left(1 + \frac{YZ}{2}\right) I_R + \bar{Y}\left(1 + \frac{\bar{Y}\bar{Z}}{4}\right)\vec{V_R}$$

$\bar{A} = \bar{D} = 1 + \frac{\bar{Y}\bar{Z}}{2}$ $C = \bar{Y}\left(1 + \frac{YZ}{4}\right)$ $\because$ comparing

$\bar{B} = Z$

Long Transmission Lines

$$\bar{V_s} = \bar{V_R} \cosh\sqrt{YZ} + I_R \sqrt{\frac{Z}{Y}} \cdot \sinh\sqrt{YZ}$$

$$\bar{I_s} = \bar{V_R}\sqrt{\frac{Y}{Z}} \sinh\sqrt{YZ} + I_R \cosh\sqrt{YZ}$$

$\vec{V_s} = A\bar{V_R} + B\bar{I_R}$

$\bar{I_s} = C\bar{V_R} + D\bar{I_R}$

$A = D = \cosh\sqrt{YZ}$

$B = \sqrt{\frac{Z}{Y}} \sinh\sqrt{YZ}$

$C = \sqrt{\frac{Y}{Z}} \sinh\sqrt{YZ}$

Mod-1
electrical power sm by Ashfaq Hussain
3.12 — 3. Conductor copper, ACSR

1) A 132kV 50Hz 3ϕ TL delivers a load of 50MW at 0.8 Pf Lag at the recieving end the generalised constants of 3ϕ TL are $A = D = 0.95 \angle 1.4^\circ$, $B = 96 \angle 78^\circ$, $C = 0.0015 \angle 90^\circ$. Find the regn of the line and charging c/n Use nominal T

Given

$V_R(\text{line}) = 132\text{kV}$

$V_R(\text{ph}) = 76210.23$

$I_R = \dfrac{P_R}{\sqrt{3}\, V_R \cos\phi} = \dfrac{50M}{\sqrt{3}\ 132K \times 0.8}$ or $\dfrac{50M}{3 \times 76210.23 \times 0.8} = 273.3$

$\cos\phi_R = 0.8$

$\sin\phi_R = 0.6$

Taking recieving end vtg at refference phasor

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

$\vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R) = I_R \angle -\phi_R = 273.3 \angle -36.86$

Sending end voltage.

$\vec{V_S} = A\bar{V}_R + B\bar{I}_R$

$= (0.95 \angle 1.4^\circ \times 76210.23 \angle 0^\circ) + (96 \angle 78^\circ \times 273.3 \angle -36.86)$

$\bar{V_s} = 94.056K \angle 11.66\ kV$

$\bar{I_s} = (0.0015 \angle 90^\circ)(76.21k) + (0.95 \angle 1.4)(273. \angle -36.86$

$\vec{I_s} = 214.315 \angle -9.71$

$\% R = \dfrac{V_S - V_R}{V_R} \times 100 = \dfrac{94.056k - 76210}{76210} \times 100 = \cancel{23.41}$

$\bar{I_C} = \bar{I_S} - \bar{I_R}$

$= 128.2 \angle 93.1\ A$

$\cancel{\% R = \dfrac{V_S - V_R}{V_R} \times 100 = 23.41}$

$\bar{V_S} = \bar{A}\bar{V_R} + \bar{B}\bar{I_R}$

as At no load $\bar{I_R} = 0$

$\therefore \bar{V_S} = \bar{A}\bar{V}_{R0}$

$\therefore \% R = \left(\dfrac{V_S}{A} - V_R\right) / V_R \times 100$