Transmission Lines (Medium T.L)

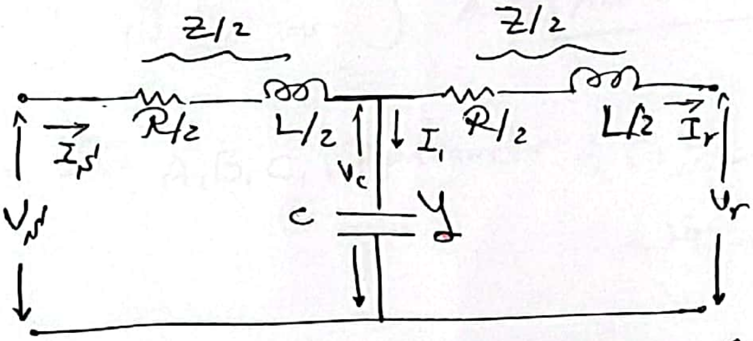
- يتم أخذ إعتبار ال Capacitance المؤثرة على الـ "T.L" في حالة الـ "Medium T.L"

- عند تمثيل الخط المتوسط الطول في منظومة الكهرباء يتم استخدام احدى الوسيلتين إما "T-model" أو "π-model"

- يتم تسهيل الـ "models" عن طريق الـ "A,B,C,D parameters"

[1] T-model for medium T.L

يتم تقسيم الخط إلى نصفين متماثلين مع وضع تأثير الـ Capacitance في المنتصف وبالتالي "Z" الخاصة بالخط تنقسم إلى (Z/2) لكل جزء كالتالي



$$Z/2 = R/2 + j\frac{x_L}{2} \Rightarrow Y = j\omega C = \omega C\angle 90^\circ \quad \text{as } Y = \frac{1}{x_C}$$

$$V_s = V_C + I_s\left(\frac{Z}{2}\right) \;;\; \text{And } V_C = V_r + I_r\left(\frac{Z}{2}\right)$$

$$\therefore V_s = V_r + I_r\left(\frac{Z}{2}\right) + I_s\left(\frac{Z}{2}\right)$$

$$\text{And } I_s = I_1 + I_r \Rightarrow \;;\; \text{And } I_1 = Y V_C$$

$$\text{So } I_1 = Y V_r + I_r\left(\frac{ZY}{2}\right)$$

$$\text{So } \boxed{I_s = Y V_r + I_r\left(1 + \frac{ZY}{2}\right)} \rightarrow \boxed{1}$$

$$V_s = V_r + I_r\left(\frac{Z}{2}\right) + \frac{ZY}{2}V_r + \frac{Z}{2}\left(1 + \frac{ZY}{2}\right)I_r$$

$$= \left(1 + \frac{ZY}{2}\right)V_r + I_r\left[\frac{Z}{2} + \frac{Z}{2}\left(1 + \frac{ZY}{2}\right)\right]$$

$$\therefore V_s = \left(1+\frac{ZY}{2}\right)V_r + I_r\left[\frac{Z}{2} + \frac{Z}{2} + \frac{Z^2Y}{4}\right]$$

$$= \left(1+\frac{ZY}{2}\right)V_r + I_r\left(Z + \frac{Z^2Y}{4}\right)$$

$$= \boxed{\left(1+\frac{ZY}{2}\right)V_r + Z\left(1+\frac{ZY}{4}\right)I_r} \longrightarrow \boxed{2}$$

So equation $V_s = AV_r + BI_r$

And $I_s = CV_r + DI_r$

Compare with $\boxed{1}$ & $\boxed{2}$

$$V_s = \left(1+\frac{ZY}{2}\right)V_r + Z\left(1+\frac{ZY}{4}\right)I_r$$

$$I_s = YV_r + \left(1+\frac{ZY}{2}\right)I_r$$

Keep → $\underline{\text{So}}$

$$\left.\begin{aligned} A = D &= \left(1+\frac{ZY}{2}\right) \\ B &= Z\left(1+\frac{ZY}{4}\right)\ \Omega \\ C &= Y\ \mho \end{aligned}\right\}$$

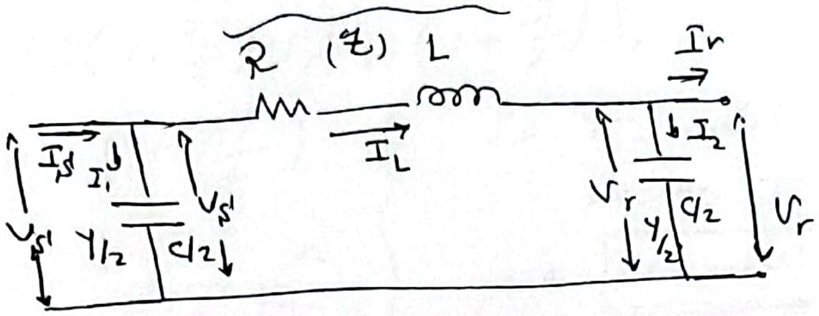
for T-model medium T.L

And $\boxed{AD - BC = 1}$

وبالتالي يمكن استخدام الـ A,B,C,D parameter مباشرة بدلاً من التحليل
للدائرة كما بيسهل لك.

[2] π-model for medium T.L

يتم تقسيم الـ Capacitance المؤثرة على الخط إلى نصفين متماثلين موزعة على بداية الخط ونهايته وما بينهما قيمة Z الخاصة بالخط ويكون كالتالي



$$I_s = I_1 + I_L \quad ; \quad \text{And} \quad I_L = I_2 + I_r$$

$$I_1 = (Y/2)\,V_s \quad \text{and} \quad I_2 = (Y/2)\,V_r$$

$$Z = R + jX_L \quad \text{and} \quad Y = j\omega C = \omega C \angle 90^\circ$$

$$V_s = I_L(Z) + V_r$$

$$I_s = I_1 + I_2 + I_r = \left(\frac{Y}{2}\right) V_s + \left(\frac{Y}{2}\right) V_r + I_r$$

$$V_s = \left[\left(\frac{Y}{2}\right) V_r + I_r\right](Z) + V_r = \left(1 + \frac{ZY}{2}\right) V_r + Z I_r$$

$$\therefore \boxed{V_s = \left(1 + \frac{ZY}{2}\right) V_r + Z I_r} \longrightarrow \boxed{1}$$

$$\text{so } I_s = \frac{Y}{2}\left(1 + \frac{ZY}{2}\right) V_r + \frac{YZ}{2} I_r + \left(\frac{Y}{2}\right) V_r + I_r$$

$$= \left(\frac{Y}{2} + \frac{ZY^2}{4} + \frac{Y}{2}\right) V_r + \left(1 + \frac{ZY}{2}\right) I_r$$

$$= \left(Y + \frac{ZY^2}{4}\right) V_r + \left(1 + \frac{ZY}{2}\right) I_r$$

$$\boxed{\therefore I_s = Y\left(1 + \frac{ZY}{4}\right) V_r + \left(1 + \frac{ZY}{2}\right) I_r} \longrightarrow \boxed{2}$$

So equation $V_s = A V_r + B I_r$

$$I_s = C V_r + D I_r$$

Compare with $\boxed{1}$ & $\boxed{2}$

$$V_s = \left(1+\frac{ZY}{2}\right) V_r + Z I_r$$

$$I_s = Y\left(1+\frac{ZY}{4}\right) V_r + \left(1+\frac{ZY}{2}\right) I_r$$

$$A = D = \left(1+\frac{ZY}{2}\right)$$

$$B = Z \quad \Omega$$

$$C = Y\left(1+\frac{ZY}{4}\right) \quad ℧$$

for π-model medium T.L

And $\boxed{AD - BC = 1}$

وبالتالي عليك استخدام الـ A, B, C, D parameter مباشرة بدلاً من تحليل

الدائرة كما ييسر الحل

So

T - model

$$A = D = (1 + ZY/2) \quad \text{unitless}$$

$$B = Z(1 + ZY/4) \quad \Omega$$

$$C = Y \quad ℧$$

π - model

$$A = D = (1 + ZY/2) \quad \text{unitless}$$

$$B = Z \quad \Omega$$

$$C = Y(1 + ZY/4) \quad ℧$$

problem (3) :- A 100 km transmission line is represented by T- model is supplying 50 MVA load at 0.6 p.f lead at 110 kV where the inductive reactance is 0.5 Ω/km, the resistance per phase is 0.2 Ω/km and the shunt admittance is 0.0005 ℧/km.

Find (i) the sending end voltage, (ii) the sending end current (iii) the efficiency ; (iv) the voltage regulation

Solution :- Given $l = 100\,km$, $S_r = 50\,MVA$, $\cos\phi_r = 0.6$ lead

$V_{r,Line} = 110\,kV$, $x_L = 0.5\,\Omega/km$, $R = 0.2\,\Omega/km$

$y = 0.0005\,℧/km$

- $Z = R + jx_L = (0.2)(100) + j(0.5)(100)$
$= 20 + j50 = 53.85\,\angle 68.2^\circ\ \Omega$

- $Y = 0.0005 * 100 = 0.05\,\angle 90^\circ\ ℧$

For T- model

$A = D = 1 + \frac{ZY}{2} = 0.56\,\angle 116.6^\circ$

$B = Z(1 + \frac{ZY}{4}) = 24.27\,\angle 101.8^\circ\ \Omega$

$C = Y = 0.05\,\angle 90^\circ\ ℧$

$V_s = AV_r + BI_r = \left(0.56\,\angle 116.6^\circ * \frac{110*10^3}{\sqrt{3}}\angle 0^\circ\right) + \left(24.27\,\angle 101.8^\circ * 262.43\,\angle 53.13^\circ\right)$

As $I_r = \frac{S_r}{\sqrt{3}V_r} = \frac{50*10^6}{\sqrt{3}(110)} = 262.43$ Amp

$\phi_r = \cos^{-1}(0.6) = 53.13^\circ$ lead الإشارة موجبة

$\therefore \boxed{I_r = 262.43\,\angle 53.13^\circ \text{ Amp}}$ #

$\therefore V_s = 40.75298\,\angle 122.16^\circ\ kV = \boxed{40.75\,\angle 122.16^\circ\ kV}$ #

* لاحظ أنه $V_{s,ph} > V_{r,ph}$ ← $(\frac{110}{\sqrt{3}})$ وهذا متفق مع ال lead P.f

$$I_s = C V_r + D I_r = \left(0.05\angle 90^\circ * \frac{110 \times 10^3}{\sqrt{3}}\angle 0^\circ + 0.56\angle 116.6^\circ * 262.43\angle 53.13^\circ\right)$$

$$= \boxed{3204.89\angle 92.58^\circ} \text{ Amp} \quad \# ②$$

$$\eta\% = \frac{P_r}{P_s}\%$$

$$P_r = S_r * \cos\phi_r = 50 * 0.6 = 30 \text{ Mwatt}$$

$$P_s = 3 V_{s\,ph} I_s \cos\phi_s \Rightarrow \phi_s = \theta_v - \theta_I$$

$$= 122.16 - 92.58 = 29.58^\circ$$

$$P_s = 340.76 \text{ Mwatt}$$

$$\%\eta = \frac{30}{340.76} * 100 = \boxed{8.8\ \%} \quad \# ③$$

$$V.R\% = \frac{\left|\frac{V_s}{A}\right| - |V_r|}{|V_r|} = \frac{(40.75 \times 10^3 / 0.56) - (110 \times 10^3/\sqrt{3})}{(110 \times 10^3/\sqrt{3})} * 100$$

$$= \boxed{14.6\ \%} \quad \# ④$$

* في بعض الحالات parameter (A) تكون قريبة من "1" وبالتالي تظهر علامة (-ve) في
V.R% لل p.f lead للحمل.

problem (4) :- A 3-phase, 50 Hz, OHTL, has the following Constants Resistance /ph = 9.6 Ω. Inductance /ph = 0.095 mH and Capacitance /ph = 0.75 μF. If the line is supplying a load of 24 MVA at 0.8 P.f Lagging at 66 KV. using nominal π-model, determine :-

(i) the sending end voltage, Current and power factor.
(ii) Voltage regulation
(iii) transmission losses

Solution :- Given :- $f = 50\,Hz$, $R = 9.6\,\Omega$, $L = 0.095\,mH$

$C = 0.75\,\mu F$, $S_r = 24\,MVA$; $\cos\phi_r = 0.8$ Lag, $V_r = 66\,kV$ line

$$x_L = 2\pi f L = 2\pi(50)(0.095 * 10^{-3}) = 0.0298\,\Omega$$

$$x_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(50)(0.75 * 10^{-6})} = 4244.13\,\Omega$$

$$Z = 9.6 + j\,0.0298\ \Omega$$

$$Y = \frac{1}{x_C} = 2.36 * 10^{-4} \angle 90^\circ\ \mho$$

π-model

$$A = D = 1 + \frac{ZY}{2} = 0.999 \angle 0.064^\circ$$

$$B = Z = 9.6 + j\,0.0298\ \Omega$$

$$C = Y\left(1 + \frac{ZY}{4}\right) = 2.36 * 10^{-4} \angle 90^\circ\ \mho$$

$$V_s = A V_r + B I_r \Rightarrow I_r = \frac{S_r}{\sqrt{3} V_r} = \frac{24 * 10^3}{\sqrt{3}(66)} = 209.95\ \text{Amp}$$

$$\cos\phi_r = 0.8\ \text{Lag} \Rightarrow \phi_r = 36.86$$

$$\therefore I_r = 209.95 \angle -36.86^\circ\ \text{Amp.}$$

$$\therefore V_s = (0.999 \angle 0.064 * \frac{66 * 10^3}{\sqrt{3}} \angle 0^\circ) + [(9.6 + j\,0.0298) * 209.95 \angle -36.86^\circ)$$

$$V_s = 39.7 \angle -1.76^\circ\ kV \quad \#\ 1$$

. وبالتالي ده منطقي P.f Lag ← $[V_{r\,ph} < V_{s\,ph}]$ -

$$I_s = CV_r + DI_r$$

$$= \left(2.36 \times 10^{-4} \angle 90^\circ * \frac{66 \times 10^3}{\sqrt{3}} \angle 0^\circ\right) + \left(0.999 \angle 0.064^\circ * 209.95 \angle -36.86^\circ\right)$$

$$= 204.23 \angle -36.83^\circ \text{ Amp}$$ # ?

$$\cos\phi_{s} = \cos(\theta_{v} - \theta_{I}) = \cos(-1.76 - (-36.83))$$

$$= 0.8 \text{ Lag}$$ # 1)

$$V.R\% = \frac{|V_s/A| - |V_r|}{|V_r|} = \frac{(39659.05/0.999) - 38105.12}{38105.12} * 100$$

$$= 4.2\%$$ # 2)

$$P_s = 3 V_{s_{ph}} I_{s_{ph}} \cos\phi_s = 3(39659.05)(204.23)(0.8)$$

$$= 19.44 \text{ Mwatt}$$

$$P_r = S_r \cos\phi_r = 24 * 0.8 = 19.2 \text{ Mwatt}$$

$$\therefore P_{losses} = P_s - P_r = (19.44) - (19.2) = 0.42 \text{ Mwatt}$$

$$= 420 \text{ Kwatt}$$

3)