Generalized circuit constants.

A three ph. T.L. can be represented by a circuit consisting of two terminals where the power enters & two terminals from where the power leaves the circuit. The circuit is said to be passive, linear & bilateral. It is passive because it contains no sources, linear because the impedances are independent of amount of current passing through it and bilateral because the impedances are independent of direction of current. ~~He~~ Incidently, the T.L. is a 4 terminal n/w, two sending end terminals & 2 receiving end terminals. Therefore, the sending end vltg (V_s) & sending end current (I_s) of a three ph. T.L. can be written as,

$$\bar{V_s} = \bar{A} \cdot \bar{V_R} + \bar{B} \cdot \bar{I_R} \quad \text{——— (1)}$$

$$\bar{I_s} = \bar{C}\,\bar{V_R} + \bar{D}\,\bar{I_R} \quad \text{——— (2)}$$

where, $\bar{A}, \bar{B}, \bar{C}$ & $\bar{D}$ (generally complex numbers) are the constants known as generalised circuit constants of the T.L.

The values of these constants depend upon the particular method adopted for solving a T.L. Once values of these constants are known performance calculations can be done easily.

Imp. points —

1. $\bar{A}, \bar{B}, \bar{C}, \bar{D}$ are generally complex nos
2. $\bar{A}$ & $\bar{D}$ are dimensionless and dimensions of $\bar{B}$ & $\bar{D}$ are ohms & mho resp.
3. For a given T.L., $\bar{A} = \bar{D}$

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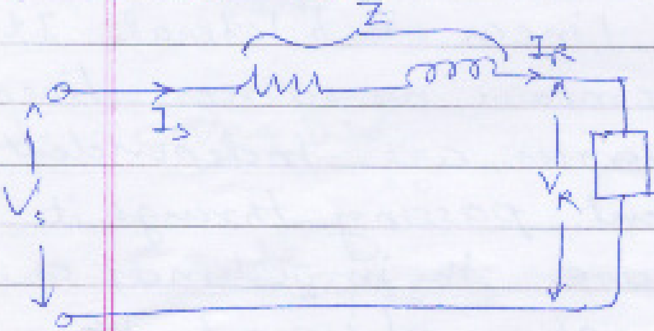
(4) For a given T.L.,

$$\bar{A}\bar{D} - \bar{B}\bar{C} = 1$$

Determination of generalised constants.

1. Short lines.



Effect of capacitance is neglected

∴ Only series impedance

Here,

$$I_S = I_R \quad \&$$

$$V_S = V_R + I_R Z$$

Comparing it with eqⁿ (1) & (2) of earlier page,

$\bar{A} = 1$

$\bar{B} = Z$

$\bar{C} = 0$

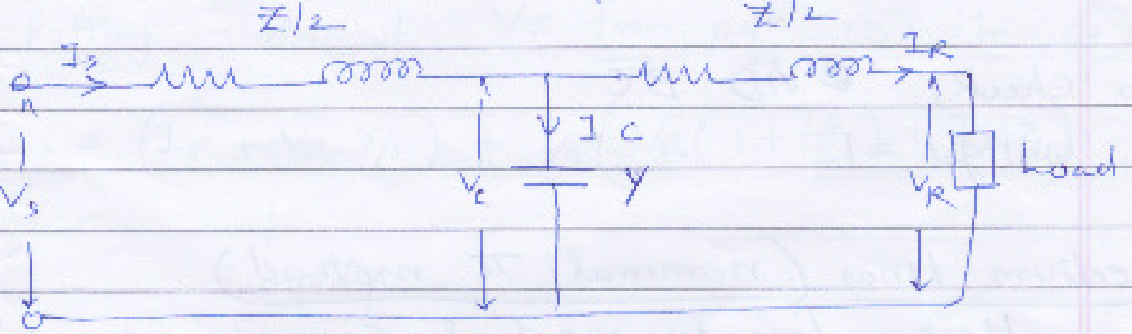
$D = 1$

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

$$= 1$$

Medium lines. (Nominal T method).

Here the whole line to neutral capacitance is assumed to be concentrated at the middle point of the line & half the line resistance & reactance are lumped on either sides.



Here, $V_s = V_C + I_s \frac{Z}{2}$ ——— (1)

& $V_C = V_R + I_R \cdot \frac{Z}{2}$ ——— (2)

$I_C = I_S - I_R$ $\quad \therefore I_S = I_C + I_R$

$= V_C \cdot Y$ ... (where Y is shunt admittance)

$= Y\left(V_R + I_R \cdot \frac{Z}{2}\right)$ ——— (3)

$\therefore I_S = I_R + Y \cdot V_R + Y \cdot \frac{I_R Z}{2}$

$I_S = Y V_R + I_R \left(1 + \frac{YZ}{2}\right)$ ——— (4)

Substituting value of V_C in eqn (1),

$V_S = V_R + I_R \cdot \frac{Z}{2} + \frac{I_S \cdot Z}{2}$ ——— (5)

Substitute value of I_S from eqn (4) in (5)

$V_S = \left(1 + \frac{YZ}{2}\right) V_R + \left(Z + \frac{YZ^2}{4}\right) I_R$ ——— (6)

Comparing eqn (4) & (6) with basic eqns of V_S & I_S, we get

$$A = D = 1 + \frac{YZ}{2}$$

$$B = Z\left(1 + \frac{YZ}{4}\right)$$

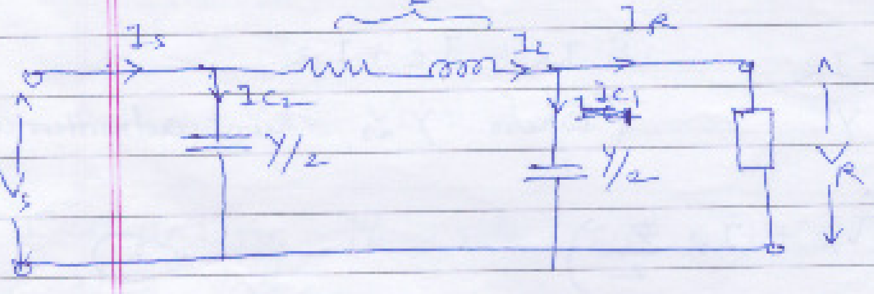
$$C = Y$$

To check, $AD - BC$

will get $= 1$

Medium lines (nominal π method)

Here, line-to-neutral capacitance is divided into two halves, one half is concentrated at sending end side & other half at the load side.



Here, $Z = R + jX_L$ ... series impedance

$Y = j\omega C$ ... shunt admittance

$$I_S = I_L + I_{C_2}$$
$$= I_L + V_S \cdot Y/2 \quad \text{——— (1)}$$

Also

$$I_L = I_R + I_{C_1}$$
$$= I_R + V_R \cdot Y/2 \quad \text{——— (2)}$$

Now,

$$V_S = V_R + I_L \cdot Z$$
$$= V_R + \left(I_R + V_R \cdot Y/2\right) Z$$
$$\therefore \quad = V_R\left(1 + \frac{YZ}{2}\right) + I_R \cdot Z \quad \text{——— (3)}$$

Putting value of $\cancel{V_s}$ I_L in eqⁿ (1),

$$I_s = I_L + V_S \cdot Y/2$$
$$= \left(I_R + V_R \cdot Y/2\right) + V_S \cdot Y/2 \quad \text{———} (4)$$

Putting value of V_s from eqn (3) in (4)

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

Simplify.

$$I_s = I_R\left(1+\frac{YZ}{2}\right) + V_R Y\left(1+\frac{YZ}{4}\right) \quad \text{———} (5)$$

Comparing standard eqⁿs of generalized constants with eqⁿ (3) & (5), we get,

$$A = D = 1 + \frac{YZ}{2}$$

$$B = Z$$

$$C = Y\left(1+\frac{YZ}{4}\right)$$

Check.– $AD - BC = 1$

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(1) Receiving end is open,

$\therefore I_R = 0$

$V_s = A V_R + B \underbrace{I_R}_{0}$

$\therefore A = V_s/V_R \Big|_{I_R=0}$ Vltg. ratio

$I_s = C V_R + D \underbrace{I_R}_{0}$

$\therefore C = \frac{I_s}{V_R}\Big|_{I_R=0}$ ℧ O.C admittance

(2) Receiving end S.C. $\therefore V_R = 0$

$V_s = 0 + B I_R$

$\therefore B = \frac{V_s}{I_R}\Big|_{V_R=0}$ Ω S.C. resis

$I_s = 0 + D I_R$

$\therefore D = I_s/I_R \Big|_{V_R=0}$ current ratio

4. Models & Performance of T.L.

The imp. considerations in the design & operation of a T.L. are the determination of voltage drop, line losses & transmission efficiency. These values are greatly influenced by the line constants R, L & C of the T.L.

These R, L & C of the T.L. are distributed uniformly throughout the length of the line. The R & L in series form the series impedance. The capacitance betn two conductors of 1-ph line or betn a conductor to neutral for a 3-ph line forms a shunt path throughout the length of the line. Hence, these capacitance effects introduce complications in T.L. calculations.

Depending upon the manner in which capacitance is taken into account, the Overhead T.L. are classified as,

i) Short T.L. – Length less than 100 km & line vltg. comparatively low (< 20 kV) are short T.L. Due to smaller length capacitance effect is small & hence neglected. Only R & L of the line are taken into account.

ii) Medium T.L. – Length betn 100 km to 250 km & vltg. betn 20 kV & 100 kV. Due to sufficient length, capacitance effect is taken into account. For calculation purpose, the distributed capacitance of the line is divided & lumped in the form of condensers shunted across the line at the one or two places. ~~receiving end~~.

iii) Long T.L. – Length more than 250 km & Vltg. more than 100 kV. The parameters of the line are not lumped but distributed uniformly throughout the length are considered.

Prob.

1. A 150 km, 3 ph, 110 V, 50 Hz ~~T.L.~~ T.L. transmits a load of 40000 kW at 0.8 lag. pf at R.E.

resis/km/ph = $0.15\,\Omega$

reactance/km/ph = $0.6\,\Omega$

susceptance/km/ph = 10^{-5} ℧

Calculate A, B, C & D const. assuming it as a nominal π circuit

Soln

For 150 km length,

$R = 0.15 \times 150 = 22.5\,\Omega$

$X = 0.6 \times 150 = 90\,\Omega$

$Y = 1 \times 150 \times 10^{-5} = 15 \times 10^{-4}$ ℧

$Z = R + jX$

$= 22.5 + j90$

$= 92.8 \angle 75^\circ$

$Y = 15 \times 10^{-4} \angle 90^\circ$ ℧

$A = D = 1 + \frac{YZ}{2} = 0.9675 + j\,0.01688$

$= 0.968 \angle 1.0^\circ$

$B = Z = 92.8 \angle 75^\circ$

$C = Y\left(1 + \frac{YZ}{4}\right) = -0.00001266 + j\,0.00145$

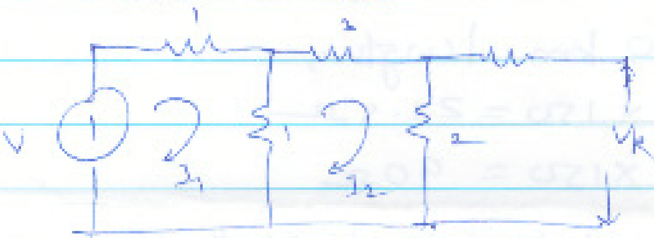
$= 0.00145 \angle 90.5^\circ$

$V_S = AV_R + BI_R$

$I_S = CV_R + DI_R$

at O-C,

$V_S = AV_R$



We get $V_R = 2/11$ V.

$1 = \frac{2}{11} A$ $\quad A = \frac{11}{2}$

$I_s = C \cdot V_R$

I_1 is I_s

$\therefore C = \frac{I_1}{V_R} = \frac{6/11}{2/11} = 3$ ℧

At S-C.

$V_s = B \cdot I_R$ $\quad B = \frac{V_s}{I_R} = \frac{1}{2/36} = 18\,\Omega$

$I_s = DI_R$ $\quad D = \frac{I_s}{I_R} = \frac{20/36}{2/36} = 10$