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161116041043 - ELECTRICAL ELECTRONICS

EEE553 - POWER SYSTEMS

Assignment:

\*changing  $T_1$  &  $T_2$  to  $10.8/121$  kV

Parameters:

$$S_{base} = 25 \text{ MVA}, V_{base_1} = 11 \text{ kV}, V_{base_2} = 10.8 \text{ kV}$$

$$X_{motor} = 25\% = 0.25, X_{gen} = 20\% = 0.2, X_L = 100 \Omega, X_{T_{1,2}} = 10\%$$

$$M_1 = 15 \text{ MVA}, 10 \text{ kV}, 25\%$$

$$M_2 = 7.5 \text{ MVA}, 10 \text{ kV}, 25\%$$

$$T_1 = T_2 = 30 \text{ MVA}, 10.8 \text{ kV}, 10\%$$

$$G_1 = 25 \text{ MVA}, 11 \text{ kV}, 20\%$$

finding base voltages for

$$1) \text{ transmission line} = \frac{11 \times 121}{10.8} = 123.2 \text{ kV}$$

$$2) \text{ motor, } \frac{123.2 \times 10.8}{121} = 11 \text{ kV}$$

finding p.u. values for various reactances.

$$X_{gen, p.u.} = X_{old, p.u.} \times \frac{S_{base, new}}{S_{base, old}} \times \left( \frac{V_{base, old}}{V_{base, new}} \right)^2$$
$$= \frac{0.20}{j100} \times \frac{25}{25} \times \left( \frac{11}{11} \right)^2 = j0.2 \text{ p.u.}$$

$$X_{motor, p.u.} = X_{old, p.u.} \times \frac{S_{base, new}}{S_{base, old}} \times \frac{M^2}{M_{old}^2} = j0.344 \text{ p.u.}$$

$$X_{motor, p.u.} = X_{old, p.u.} \times \frac{S_{base, new}}{S_{base, old}} \times \left( \frac{V_{base, old}}{V_{base, new}} \right)^2$$
$$= \frac{25}{100} \times \frac{25}{15} \times \left( \frac{10}{11} \right)^2 = j0.344 \text{ p.u.}$$

$$X_{motor, p.u.} = \frac{25}{100} \times \frac{25}{7.5} \times \left( \frac{10}{11} \right)^2 = j0.689$$

$$X_{transmission, p.u.} = X_{old, p.u.} \times \frac{S_{base, new}}{S_{base, old}} \times \left( \frac{V_{base, old}}{V_{base, new}} \right)^2$$

$X_{Trans1}^{p.u.}$

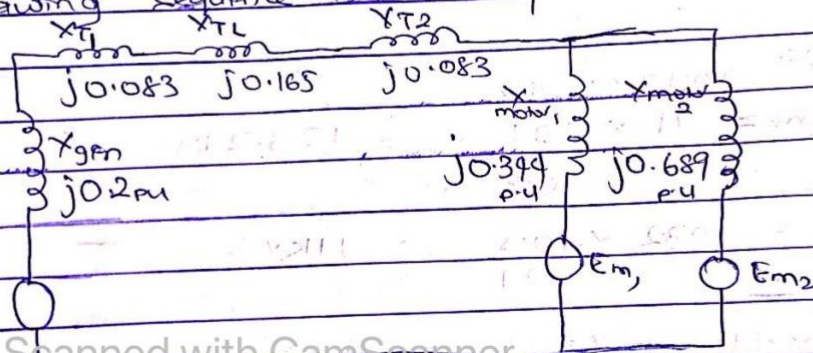
$$X_{Trans1}^{p.u.} = \frac{10}{100} \times \frac{25}{30} \times \left( \frac{10.8}{10.8} \right)^2 = j0.083 p.u.$$

$$X_{Trans2}^{p.u.} = \frac{10}{100} \times \frac{25}{30} \times \left( \frac{10.8}{10.8} \right)^2 = j0.083 p.u.$$

$$X_{Transmission\ line\ p.u.} = X_{TL} \times \frac{S_{base}}{V_{base}^2}$$

$$= 100 \times 25 \times \frac{1}{(123.2)^2} = j0.164 p.u.$$

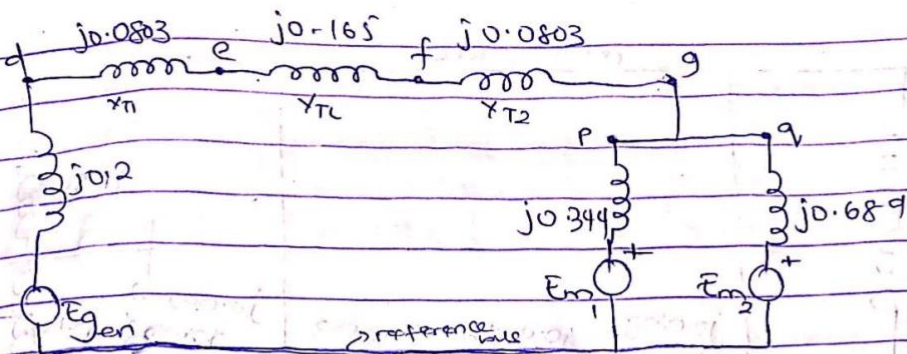
Drawing sequence network p.u. of system.



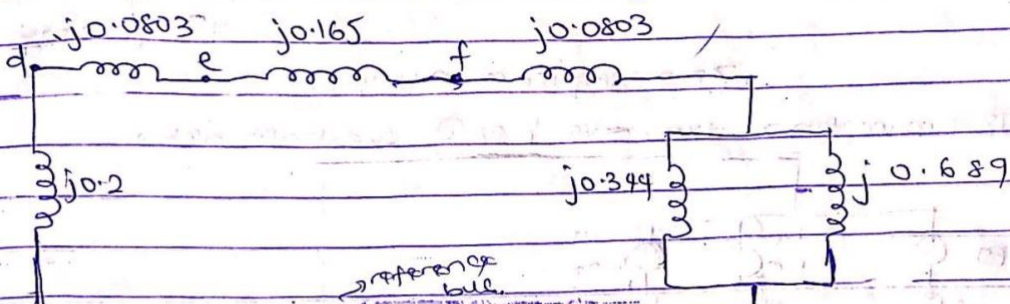
CS Scanned with CamScanner

per unit diagram of the system





POSITIVE SEQUENCE NETWORK



NEGATIVE SEQUENCE NETWORK

To obtain zero sequence

reactance of current limiting reactor =  $\frac{2.5 \times 25}{11^2} = j0.516 \text{ pu}$

reactance included in zero seq. network

$= 3 \times j0.516 = j1.548 \text{ pu}$

zero sequence reactance of generator

$= \frac{0.06 \times 25}{25} \times \left(\frac{11}{11}\right)^2 = j0.06 \text{ pu}$

zero sequence reactance of motor 1 =  $\frac{0.06 \times 25}{13} \times \left(\frac{10}{11}\right)^2 = j0.083$

zero seq. reactance of motor 2 =  $\frac{0.06 \times 25}{7.5} \times \frac{10^2}{11^2} = j0.165$

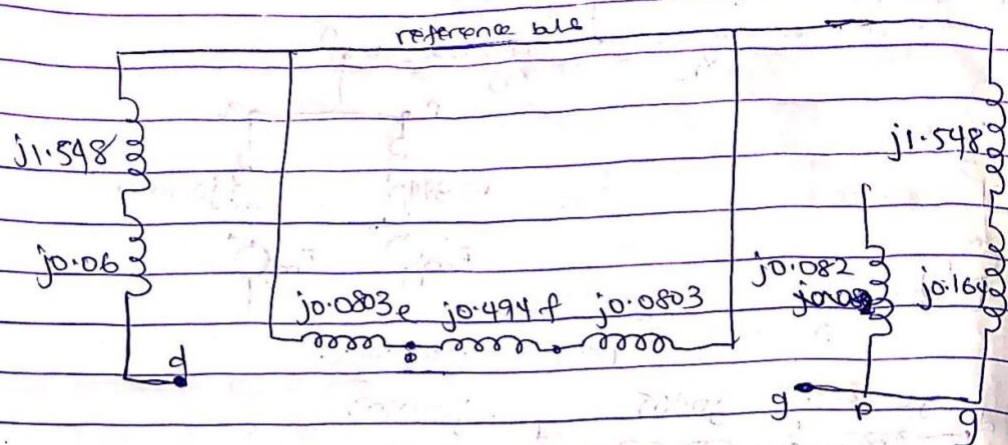
zero seq. reactance of transmission line =  $\frac{300 \times 25}{(123.2)^2}$

$= j0.494 \text{ pu}$

Note!

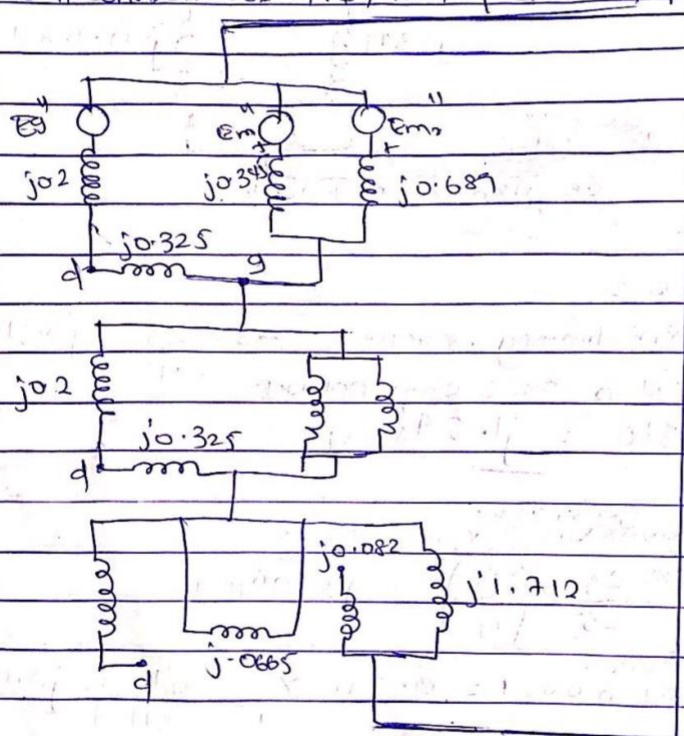
Zero seq. reactance of transformer = positive sequence reactance

matrny transformer zero sequence = 0.0803



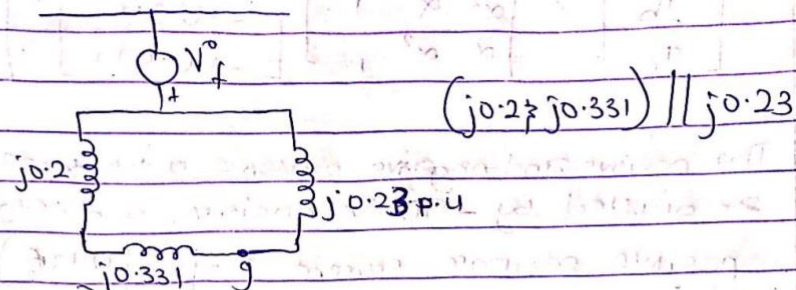
Zero sequence network

Total connection of the 2 zero sequence network





By Taking Thevenin's equivalent at the sequence network.



$$Z_1 = \frac{(j0.2 + j0.331) \times j0.23}{(j0.2 + j0.331) + j0.23} = j0.161 \text{ p.u.}$$

$$Z_1 = Z_2 = j0.161 \text{ p.u.}$$

from sequence connection

$$I_{a1} = \frac{V_f^0}{Z_1 + Z_2 + Z_0}$$

$$V_f^0 = E_g^0 = E_m^0 + E_{m_g}^0 \quad (\text{Pre-fault voltage at } g)$$

$$\frac{10}{11} = 0.909 \text{ p.u.}$$

$$I_{a1} = \frac{0.909}{j2.032} = -j0.447 \text{ p.u.}$$

$$I_{a1} = I_{a2} = I_{a0} = -j0.447 \text{ p.u.}$$

$$\text{fault current} = 3I_{a0} = 3 \times (-j0.447) = -j1.341 \text{ p.u.}$$

The component of  $I_{a1}$  flowing through the generator using current divider principle

$$\frac{-j0.447 \times j0.23}{j0.755} = -j0.136 \text{ p.u.}$$

- Its component flowing towards  $g$  from the motor side using

$$KCL = -j0.447 + j0.136 = -j0.311 \text{ p.u.}$$

fault current from generator towards  $g$  are,

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ a^2 & a & 1 \\ a & a^2 & 1 \end{bmatrix} \begin{bmatrix} -j0.136 \\ -j0.311 \\ 0 \end{bmatrix} = \begin{bmatrix} -j0.272 \\ -j0.136 \\ j0.136 \end{bmatrix} \text{ p.u.}$$



fault current from the motor toward g.

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix} \begin{bmatrix} -j0.311 \\ -j0.311 \\ -j0.477 \end{bmatrix} = \begin{bmatrix} -j1.069 \\ -j0.136 \\ -j0.136 \end{bmatrix} \text{ pu}$$

The positive and negative sequence of the transmission currents are shifted by  $-90^\circ$  for positive, and  $+90^\circ$  for negative

positive sequence current  $= -j(-j0.136) = -0.136 \text{ pu}$

negative sequence current  $= j(-j0.136) = 0.136 \text{ pu}$

Zero sequence current  $= 0$

line a current of the transmission line  $I_a = \text{total}$

$$-0.136 + 0.136 + 0 = 0$$

To find voltages behind subtransient reactances to be used if the load changes

the pu motor current  $= 15 < 36.86^\circ$

$$25 \times 0.909 \times 0.8$$

$$= 0.825 < 36.86^\circ = 0.66 + j0.495 \text{ pu}$$

motor 2  $7.5 < 36.86^\circ$

$$25 \times 0.909 \times 0.8$$

$$= 0.4125 < 36.86^\circ = 0.33 + j0.248 \text{ pu}$$

Total current drawn by both motors  $= 0.99 + j0.743 \text{ pu}$

voltage behind subtransient reactances as calculated

motor 1  $= E_{m1} = 0.909 - j0.345 \times 0.825 < 36.86^\circ$

$$= 1.08 - j0.228 = 1.104 < -11.92^\circ$$

motor 2  $E_{m2} = 0.909 - j0.69 \times 0.4125 < 36.86^\circ$

$$= 1.08 - j0.228$$

$$1.1042 < -11.92^\circ \text{ pu}$$

generator  $E_g = 0.909 + j0.525 \times 1.2375 < 36.86^\circ$

$$= 0.52 + j0.52 = 0.735 < 45^\circ$$

NB: the thevenin circuit would still be the same regardless of the voltages behind subtransient reactance. If

Finding fault current and putting pre-fault loading condition into consideration, there's no need to calculate  $E_m$ ,  $E_m'$  &  $E_g$ . Thevenin method has eliminated all that.

Thus, the actual value of positive sequence current from generator towards fault is

$$0.99 - j0.743 - j0.136 = 0.99 + j0.607$$

And the actual value of the positive sequence current from the motor to the fault is

$$-0.99 - j0.743 - j0.311 = -0.99 - j1.054$$