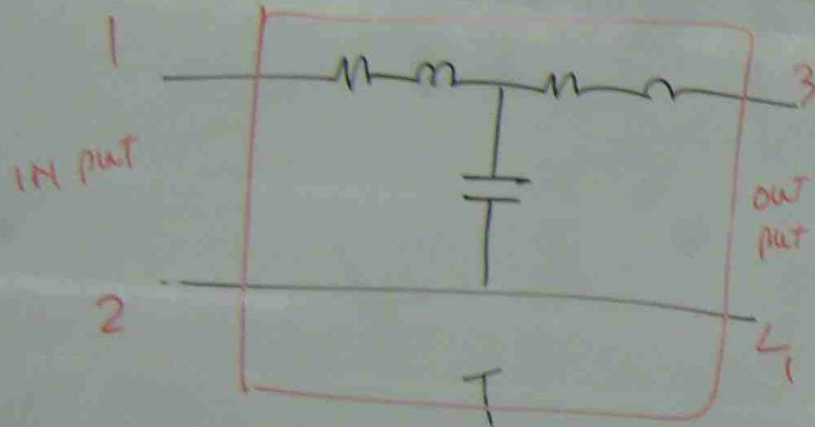
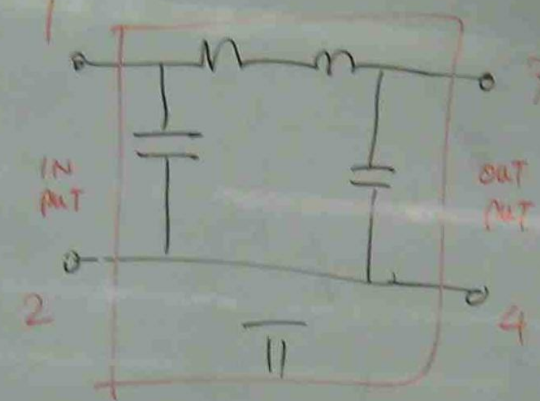
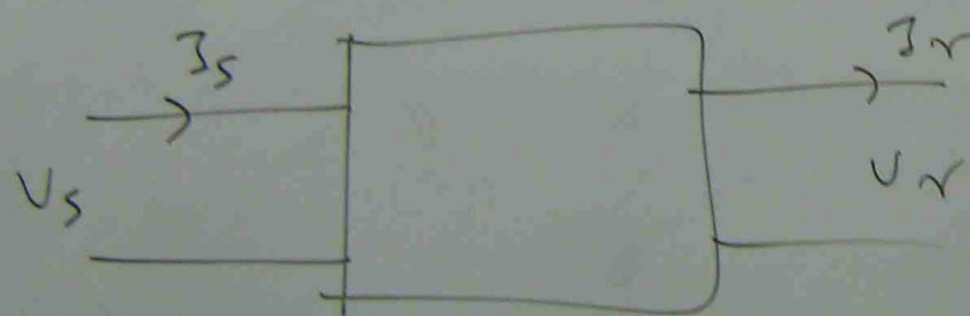
FOUR TERMINAL NETWORKS ABCD CONSTANTS

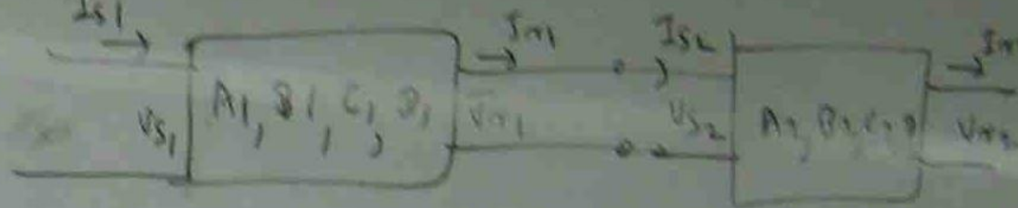






$$\overline{V_s} = A\,\overline{V_r} + B\,\overline{I_r}$$

$$\overline{I_s} = C\,\overline{V_r} + D\,\overline{I_r}$$



$$A_{eq} = A_1 A_2 + B_1 C_2 \quad , \quad C_{eq} = C_1 A_2 + D_1 C_2$$

$$B_{eq} = A_1 B_2 + B_1 D_2 \quad , \quad D_{eq} = C_1 B_2 + D_1 D_2$$

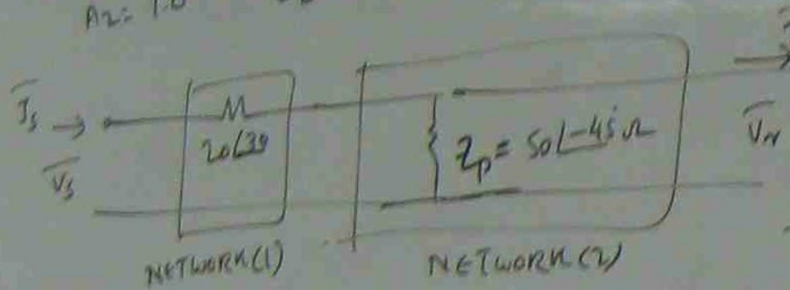
$$\bar{V}_s = A_{eq} \bar{V}_r + B_{eq} \bar{I}_r$$

$$\bar{I}_s = C_{eq} \bar{V}_r + D_{eq} I_r$$

pb) DETERMINE THE EQUIVALENT A, B, C, D CONSTANTS OF THE NETWORK ... CONNECTED

$A_1 = 1.0 \quad B_1 = 20\angle 30^\circ\ \Omega, \quad C_1 = 0\ \mho, \quad D_1 = 1.0$

$A_2 = 1.0 \quad B_2 = 0 \quad C_2 = 0.02\angle 45^\circ\ \mho, \quad D_2 = 1.0$



$C_2 = Y_p = \frac{1}{Z_p} = \frac{1}{50\angle -45} = 0.02\angle 45^\circ\ \mho$

$A_{eq} = A_1 A_2 + B_1 C_2 = 1.0 \times 1.0 + 20\angle 30 \times 0.02\angle 45 = 1.0 + 0.4\angle 75$

$A_{eq} = 1.0 + 0.104 + j0.386 = 1.104 + j0.386 = 1.17\angle 14.3$

$B_{eq} = A_1 B_2 + B_1 D_2 = 1.0 \times 0 + 20\angle 30 \times 1.0 = 20\angle 30$

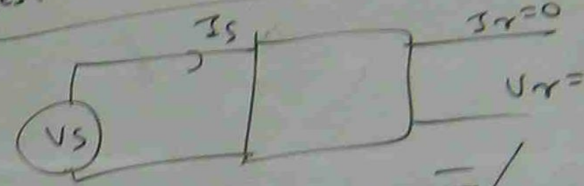
$C_{eq} = C_1 A_2 + D_1 C_2 = 0 \times 1.0 + 1.0 \times 0.02\angle 45^\circ$

$= 0.02\angle 45^\circ\ \mho$

$D_{eq} = C_1 B_2 + D_1 D_2 = 0 \times 0 + 1.0 \times 1.0 = 1.0$

DETERMINATION OF A, B, C, D PARAMETERS BY EXPERIMENT

TEST (1) OPEN CIRCUIT



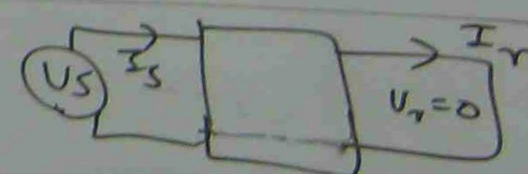
$$\bar{V}_s = A_{eq}\bar{V}_r + B_{eq}\underbrace{\cancel{\bar{I}_r}}_{0}$$

$$\bar{V}_s = A_{eq} \times \bar{V}_r \longrightarrow A_{eq} = \frac{\bar{V}_s}{\bar{V}_r}$$

$$\bar{I}_s = C_{eq}\bar{V}_s + D_{eq}\underbrace{\cancel{\bar{I}_r}}_{0}$$

$$\bar{I}_s = C_{eq}\bar{V}_s \longrightarrow C_{eq} = \frac{\bar{I}_s}{\bar{V}_s}$$

TEST (2) SHORT CIRCUIT



$$\bar{V}_s = A_{eq}\underbrace{\cancel{\bar{V}_r}}_{0} + B_{eq}\bar{I}_r$$

$$B_{eq} = \frac{\bar{V}_s}{I_r}$$

$$I_s = C_{eq}\underbrace{\cancel{\bar{V}_r}}_{0} + D_{eq}\bar{I}_r$$

$$D_{eq} = \frac{I_s}{I_r}$$

Qb

DETERMINE THE A B C D CONSTANTS OF THE NETWORK IN WHICH THE FOLLOWING TEST RESULTS HAVE BEEN OBSERVED.

RECEIVER OPEN CIRCUIT

$\bar{V}_s = 100\angle 0° \; V$

$\bar{V}_r = 70.7\angle -45° \; V$

$I_s = 1.41\angle -45° \; A$

$I_r = 0$

RECEIVER SHORT CIRCUIT

$\bar{V}_r = 0$

$\bar{V}_s = 100\angle 0° \; V$

$I_s = 2.0\angle -90° \; A$

$I_r = 2.0\angle -90 \; A$

OPEN

$$A = \frac{V_s}{V_r} = \frac{100\angle 0}{70.7\angle -45} = 1.41\angle 45°$$

$$C = \frac{I_s}{V_s} = \frac{1.41\angle -45}{100\angle 0} = 0.0141\angle -45°$$

SHORT

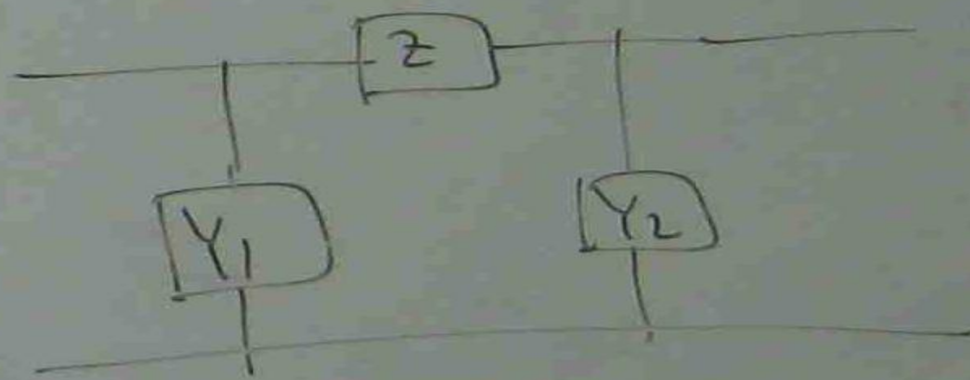
$$B = \frac{V_s}{I_r} = \frac{100\angle 0}{2\angle -90} = 50\angle 90$$

$$D = \frac{I_s}{I_r} = \frac{2\angle -90}{2\angle -90} = 1$$

APPLICATION OF ABCD CONSTANTS IN

TRANSMISSION LINE

Π EQUIVALENT CIRCUIT



$$A = 1 + Y_1 Z$$

$$B = Z$$

$$C = Y_2 + Y_1 + Y_1 Y_2 Z$$

$$D = 1 + Z Y_1$$

**** RESOLVE THE FOLLOWING PHASORS IN TO THEIR SYMMETRICAL COMPONENTS. DRAW THE PHASOR DIAGRAM OF SEPARATE COMPONENTS AND CHECK THAT THE SUM OF THE COMPONENTS IS EQUAL TO ORIGINAL SET OF PHASORS

$I_A = 120\angle 0^\circ$ Amp, $I_B = 0$ Amp, $I_C = 0$ Amp.

$$\left.\begin{matrix} I_{A0} & I_{A1} & I_{A2} \\ I_{B0} & I_{B1} & I_{B2} \\ I_{C0} & I_{C1} & I_{C2} \end{matrix}\right\} \text{SYMMETRICAL COMPONENTS}$$

$$I_{A0} = I_{B0} = I_{C0} = \frac{1}{3}(I_A + I_B + I_C)$$
$$= \frac{1}{3}(120\angle 0 + 0 + 0) = 40\angle 0 \text{ Amp.}$$

$$a = 1\angle 120^\circ$$

$$I_{A1} = \frac{1}{3}(I_A + aI_B + a^2 I_C)$$
$$= \frac{1}{3}(120\angle 0 + 1\angle 120 \times 0 + (1\angle 120)^2 \times 0) = 40\angle 0^\circ \text{ Amp}$$

$$I_{A2} = \frac{1}{3}(I_A + a^2 I_B + aI_C) = \frac{1}{3}(120\angle 0 + (1\angle 120)^2 \times 0 + 1\angle 120 \times 0)$$
$$= 40\angle 0^\circ \text{ Amp}$$

TRICAL

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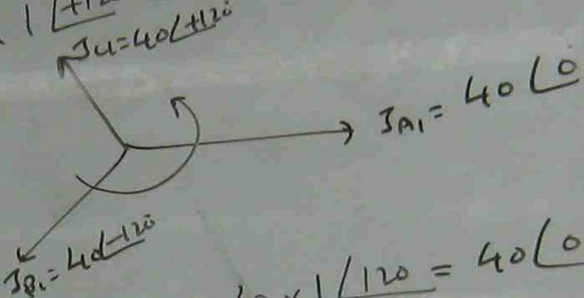
S IS

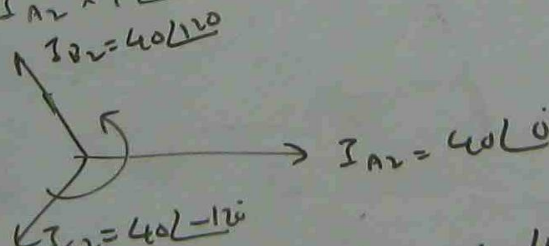
$I_{B_1} = I_{A1} \times 1\angle{-120} = 40\angle{0} \times 1\angle{-120} = 40\angle{0-120} = 40\angle{-120}$ Amp

$I_{C_1} = I_{A1} \times 1\angle{+120} = 40\angle{0} \times 1\angle{+120} = 40\angle{0+120} = 40\angle{120^\circ}$ Amp



$I_{B_2} = I_{A2} \times 1\angle{+120^\circ} = 40\angle{0} \times 1\angle{120} = 40\angle{0+120} = 40\angle{120^\circ}$ Amp

$I_{C_2} = I_{A2} \times 1\angle{-120} = 40\angle{0} \times 1\angle{-120} = 40\angle{0-120} = 40\angle{-120^\circ}$ Amp



CHECK

$I_{A0} + I_{A_1} + I_{A_2} = 40\angle{0} + 40\angle{0} + 40\angle{0} = 120\angle{0^\circ} = I_A$

$I_{B_0} + I_{B_1} + I_{B_2} = 40\angle{0} + 40\angle{-120} + 40\angle{+120}$

$= 40 + 40(\cos 120 - j\sin 120) + 40(\cos 120 + j\sin 120)$

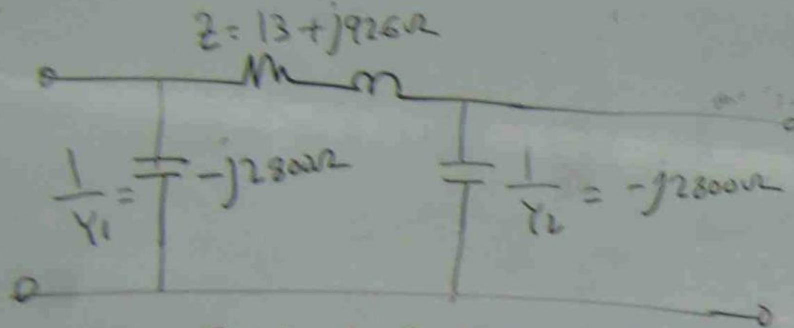
$= 40 + (-20) - j40\sin 120) + (-20) + j\,40\sin 120$

$= 0 = I_B$

$I_{C_0} + I_{C_1} + I_{C_2} = 40\angle{0} + 40\angle{120} + 40\angle{-120} = 40 + 40(\cos 120 + j\sin 120)$

$+ 40(\cos 120 - j\sin 120)$

$= 0 = I_C$



FIND A, B, C, D CONSTANTS of ABOVE Π CIRCUIT.

$$A = 1 + Y_2 Z$$
$$B = Z$$
$$C = Y_1 + Y_2 + Y_1 Y_2 Z$$
$$D = A$$

$$Z = 13 + j92.6 = 93.5 \angle 82^\circ \, \Omega$$

$$Y_1 = \frac{1}{-j2800} = 0.00357 \angle 90^\circ \, ℧$$

$$Y_2 = \frac{1}{-j2800} = 0.00357 \angle 90^\circ \, ℧$$

$$A = 1 + Y_2 Z = 1 + 0.00357\angle 90 \times 93.5\angle 82$$

$$= 1 + 0.0334\angle 172$$

$$= 1 + 0.0334\,(\cos 172 + j\sin 172)$$

$$= 0.967 + j0.00465$$

$$A = 0.967\angle 0.3$$

$$B = Z \longrightarrow B = 93.5\angle 82^{\circ}\ \Omega$$

$$C = Y_1 + Y_2 + Y_1 Y_2 Z = 0.00357\angle 90 + 0.00357\angle 90 + 0.00357\angle 90 \times 0.00357\angle 90 \times 93.5\angle 82$$

$$= 0.00714(\cos 90 + j\sin 90) + (0.00357)^2 \times 93.5\angle 262$$

$$= 0.00714(0 + j1) + (0.00357)^2 \times 93.5(\cos 262 + j\sin 262)$$

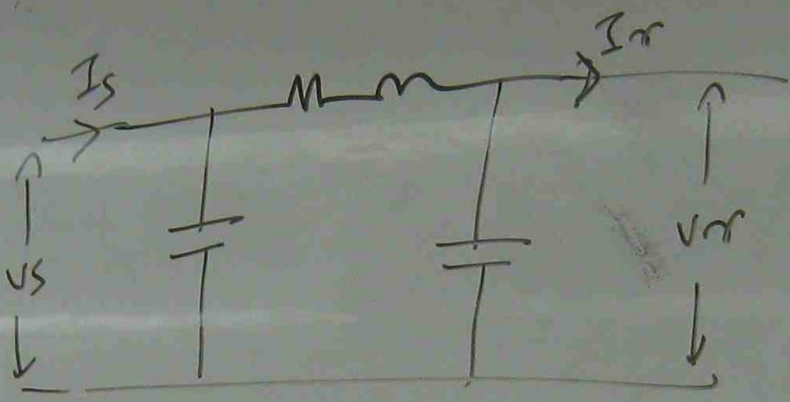
$$= -0.0000017 + j0.000702$$

$$C = 0.000702\angle 90^{\circ}\ \mho$$

$$D = A = 0.967\angle 0.3$$

ENTS

Amp.



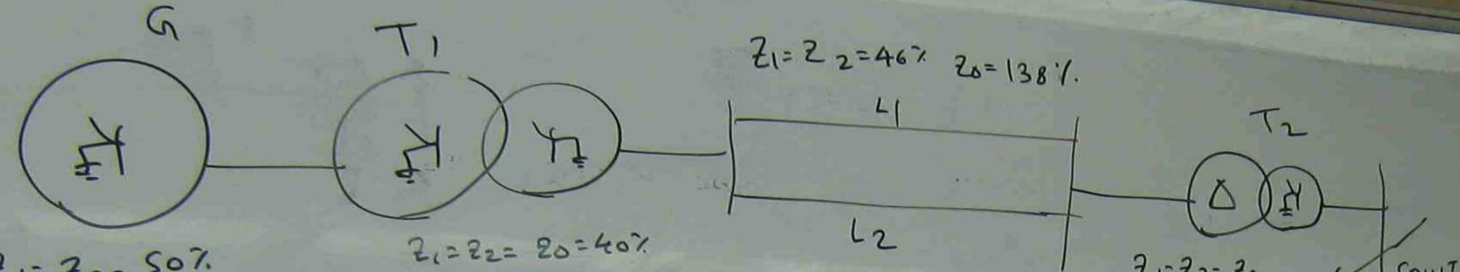
$$\bar{V}_s = A\bar{V}_r + B\bar{I}_r$$

$$\bar{V}_s = 0.0967\angle 0.3\,\bar{V}_r + 93.5\angle 82\,\bar{I}_r \quad (1)$$

$$I_s = C\bar{V}_s + D\bar{I}_r$$

$$I_s = 0.000702\angle 90\,\bar{V}_s + 0.967\angle 0.3\,\bar{I}_r \quad (2)$$

Pb



$Z_1 = Z_2 = 50\%$
$Z_0 = 66.6\%$

$Z_1 = Z_2 = Z_0 = 40\%$

$Z_1 = Z_2 = 46\%$
$Z_0 = 138\%$

$Z_1 = Z_2 = Z_0$
$= 33.3\%$

BASE
MVA = 100
BASE VOLTAGE = 33 KV

PLANT DETAILS

GENERATOR 11 KV, 30 MVA, $Z_1 = Z_2 = 15\%$ $Z_0 = 20\%$

TRANSFORMER (1) 11 KV / 33 KV 30 MVA $Z = 12\%$

TRANSFORMER (2) 33 KV / 11 KV 30 MVA $Z = 10\%$

TRANSMISSION LINE (1) & (2)

LENGTH 5 Km, $Z_1 = Z_2 = j1\ \Omega/\text{Km}$

$Z_0 = j3\ \Omega/\text{Km}$

USE 100 MVA BASE

DRAW - POSITIVE, NEGATIVE AND ZERO
SEQUENCE DIAGRAMS

CALCULATE (i) L→L FAULT
(ii) L→G FAULT
(iii) 2L→G FAULT

$$Z_2 = \frac{\text{BASE MVA}}{\text{MVA}_1} \times Z_1$$

GENERATOR

$$Z_1 = Z_2 = \frac{100}{30} \times 15 = 50\%$$

$$Z_0 = \frac{100}{30} \times 20 = 66.6\%$$

TRANSFORMER (1)

$$Z_1 = Z_2 = Z_0 = \frac{100}{30} \times 12 = 40\%$$

TRANSFORMER (2)

$$Z_1 = Z_2 = Z_0 = \frac{100}{30} \times 10 = 33.3\%$$

LINE (1)(2)

$Z_1 = Z_2 = j1 \times 5 = j5\,\Omega$

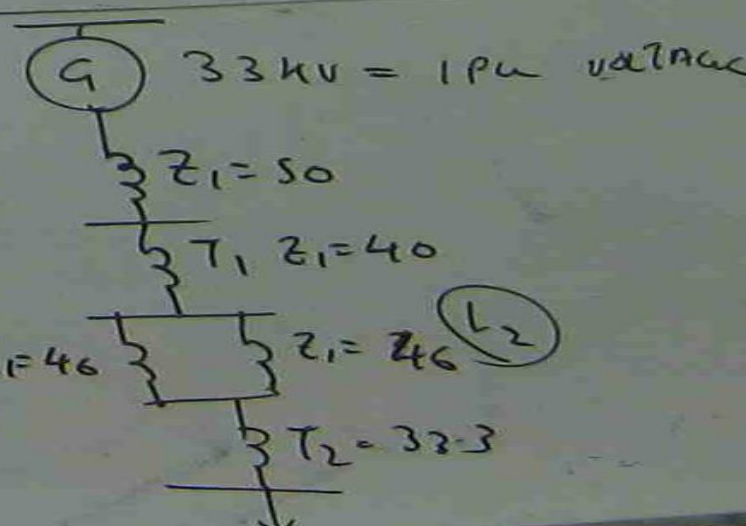
$Z_0 = j3 \times 5 = j15\,\Omega$

$$Z(\%) \text{ OR } Z(pu) = \frac{Z(\Omega) \times \text{MVA BASE}}{(\text{BASE KV})^2}$$

$$Z_1 = Z_2 = \frac{5 \times 100 \times 10^6}{(33 \times 10^3)^2} = 46\%$$

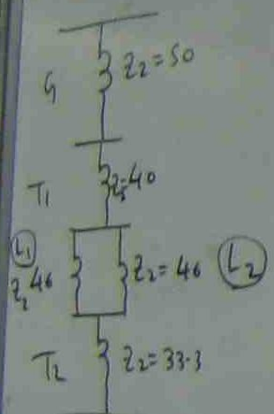
$$Z_0 = \frac{15 \times 100 \times 10^6}{(33 \times 10^3)^2} = 138\%$$

POSITIVE SEQUENCE DIAGRAM



$$Z_{1\,TOTAL} = Z^{+} = 50 + 40 + \frac{46 \times 46}{46 + 46} + 33.3$$
$$= 146.3\ \%$$

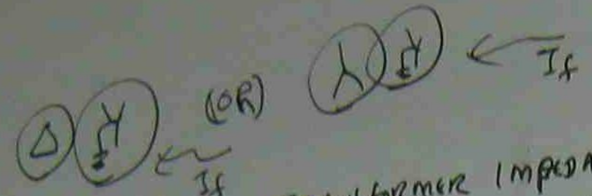
NEGATIVE SEQUENCE DIAGRAM



$$Z_{2\,TOTAL} = \bar{Z} = 50 + 40 + \frac{46 \times 46}{46 + 46} + 33.3$$
$$= 146.3\%$$

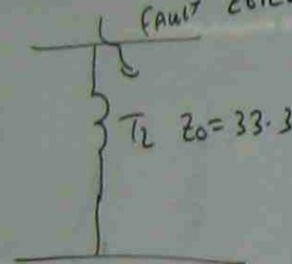
I_0 CAN PASS → INCLUDE IN DIAGRAM

I_0 CAN NOT PASS → REMOVE FROM DIAGRAM



ONLY INCLUDE THE TRANSFORMER IMPEDANCE IN DIAGRAM. ELIMINATE ALL EQUIPMENTS BEYOND Δ & Y POINT OF THE TRANSFORMER

FAULT ZERO SEQUENCE DIAGRAM



(ii) L → G FAULT

$$Z_T = Z^{+} + \bar{Z} + Z_0 = 146.3 + 146.3 + 33.3$$
$$= 325.9\ \text{pu}$$

$$I_{A_1} = I_{A_2} = I_{A_0} = \frac{\text{BASE MVA}}{Z_T \times \text{BASE VOLTAGE} \times \sqrt{3}} \times 100$$

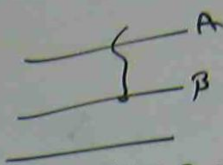
$$= \frac{100 \times 10^6}{325.9 \times 33 \times 10^3 \times 1.7321} \times 100 = 536.13\ \text{Amp}$$

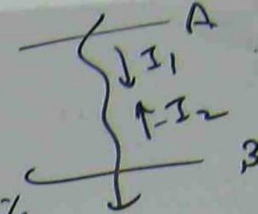
$$I_A = 3 I_{A_1} = 3 \times 536.13 = 1608\ \text{Amp}$$

(iii)

$Z_T =$

(i) $L \to L$ FAULT





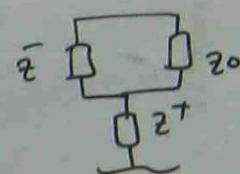
$$Z_T = Z^+ + Z^- = 146.3 + 146.3 = 292.6\%$$

$$I_1 = (-I_2) = \frac{\text{BASE MVA}}{Z_T \times \text{BASE VOLTAGE} \times \sqrt{3}} \times 100$$

$$= \frac{100 \times 10^6}{292.6 \times 33 \times 10^3 \times \sqrt{3}} \times 100 = 597 \text{ Amp}$$

$$I_A = I_B = \sqrt{3}\, I_1 = 1.7321 \times 597 = 1034.06 \text{ Amp}$$

(ii) $2L \to G$ FAULT



$$Z_T = Z_+ + \frac{Z(-) \times Z_0}{Z(-) + Z_0}$$

$$= 146.3 + \frac{146.3 \times 33.3}{146.3 + 33.3} = 173.4\ \%$$

$$I_1 = \frac{\text{BASE MVA}}{Z_T \times \text{BASE VOLTAGE} \times \sqrt{3}} \times 100 = \frac{100 \times 10^6 \times 100}{173.4 \times 33 \times 10^3 \times 1.7321} = 1008.9 \text{ Amp}$$

$$I_2 = I_1 \times \frac{Z_0}{Z_0 + Z^-} = 1008.9 \times \frac{33.3}{146.3 + 33.3} = 187.06 \text{ Amp}$$

$$I_0 = I_1 \times \frac{Z(-)}{Z_0 + Z(-)} = 1008.9 \times \frac{146.3}{146.3 + 33.3} = 821.83 \text{ Amp}$$

Amp

$$I_A = I_1\angle 0 + I_2\angle 60 + I_0\angle -60$$

$$I_B = I_1\angle 120 + I_2\angle 180 + I_0\angle -60$$

$$I_C = I_1\angle 120 + I_2\angle -60 + I_0\angle -60$$

$$I_f = I_A + I_B + I_C$$

$$I_A = I_1\angle 0 + I_2\angle 60 + I_0\angle -60$$
$$= 1008.9\angle 0 + 187.06\angle 60 + 821.83\angle -60$$
$$= 1008.9 + 93.4 + j161.5 + 410.9 - j710.6$$
$$= 1511.45 - j549.1 \text{ Amp}$$

$$I_B = I_1\angle 120 + I_2\angle 180 + I_0\angle -60$$
$$= 1008.9\angle 120 + 187.06\angle 180 + 821.83\angle -60$$
$$= -503.82 + j872.62 + (-187.06 + j0) + 410.38 - j710.62$$
$$I_B = -280.25 + j162 \text{ Amp}$$

$$I_C = I_1\angle 120 + I_2\angle -60 + I_0\angle -60$$
$$= 1008.9\angle 120 + 187.06\angle -60 + 821.83\angle -60$$
$$= -504.45 + j873.64 + 504.45 - j873.69$$
$$= 0$$

$$I_{fault} = I_A + I_B + I_C$$
$$(2L \to G)$$

$$I_{\substack{fault \\ 2L \to G}} = 1511.45 - j549.1 + (-280.25 + j162) + 0$$

$$= 1231.2 - j387.1$$

62

$$= 1290.61 \angle -17.45 \ \underline{\underline{\text{Amp}}}$$