CMR

INSTITUTE OF

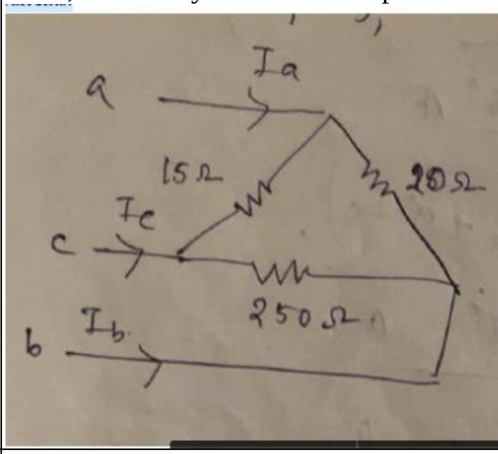
TECHNOLOGY

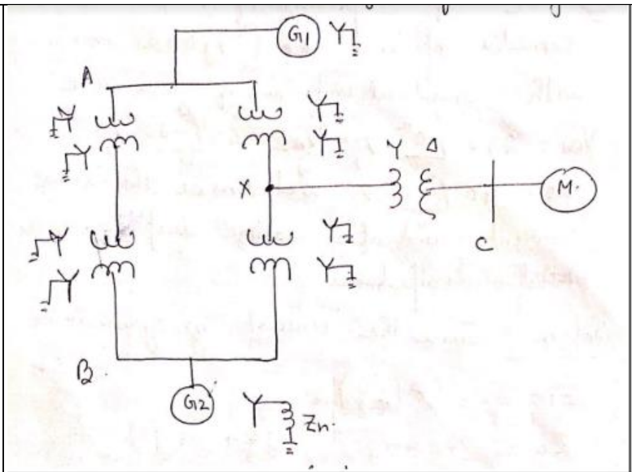
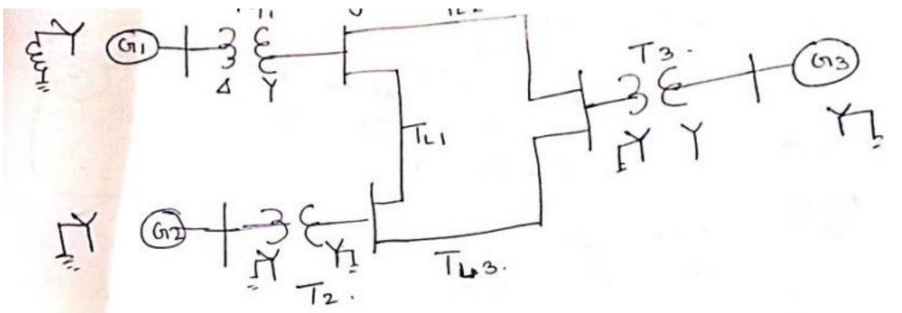
USN

Internal Test 2 –June 2022

Sub:	Power System Analysis-1							Code:	18EE62
Date:	08/06/2022	Duration:	90 mins	Max Marks:	50	Sem:	6th	Branch:	EEE

Answer Any FIVE FULL Questions. Assume missing Data

		Marks	OBE	
			CO	RBT
1.	Derive the expression of phasor voltages in terms of sequence components of voltages with necessary phasor diagram.	10	CO3	L2
2.	Prove that in a three phase symmetrically wound alternator generator only positive sequence components of voltage.	10	CO3	L2
3.	Discuss about the zero sequence network of a transformer for following connections. a) Y-Δ, b) Y with neutral directly grounded –Δ, c) Δ-Δ, d) Y-Y with both the neutral grounded through Zn.	10	CO3	L3
4.	Derive the expression of complex power in terms of symmetrical components.	10	CO3	L2
5a	A delta connected resistive load is connected across a balanced three phase supply of 400V, find the symmetrical components of line currents and delta currents.  	5	CO3	L3
5b	Obtain the zero sequence network for following one line diagram.	5	CO3	L3

				
6	Obtain the positive, negative and zero sequence network for following one line diagram. 	10	CO3	L3
7.	In a three phase system, the sequence quantities are : Va1=(0.9+j0.2) pu, Va2=(0.2+j0.1) pu, Va0=(0.1+j0.005)pu. Ia1=(0.9-j0.1)pu, Ia2= (0.2-j0.1)pu, Ia0=(0.05-j0.02)pu. Find three phase complex power in pu and in MVA, on a base of 100MVA. Also compute active and reactive power.	10	CO3	L3

Q1. Symmetrical Component Transformation

A set of three balanced voltages (phasors) V_a, V_b, V_c is characterized by equal magnitudes and interphase differences of 120°. The set is said to have a phase seq. (abc) called positive sequence if V_b lags V_a by 120° and V_c lags V_b by 120°.

$V_a = V_a$, $V_b = \alpha^2 V_a$, $V_c = \alpha V_a$.

where $\alpha \Rightarrow$ complex number operator.

$\alpha = e^{j120°}$ ★ Convert into current:

If phase sequence is negative i.e acb, then

$V_a = V_a$, $V_b = \alpha V_a$, $V_c = \alpha^2 V_a$.

Thus a set of balanced phasors is fully characterized by its reference phasor (say V_a) and its phase sequence (+ve / −ve).

Suffix 1 $\Rightarrow$ to indicate +ve sequence.

V_{a1}, $V_{b1} = \alpha^2 V_{a1}$, $V_{c1} = \alpha V_{a1}$ — 1)

Suffix 2 $\Rightarrow$ to indicate −ve sequence.

V_{a2}, $V_{b2} = \alpha V_{a2}$, $V_{c2} = \alpha^2 V_{a2}$ — 2)

A set of 3 voltages (phasors) equal in magnitude and having same phase ~~seq.~~ is called

Zero sequence, written as

V_{a0}, $V_{b0} = V_{a0}$, $V_{c0} = V_{a0}$. — 3).

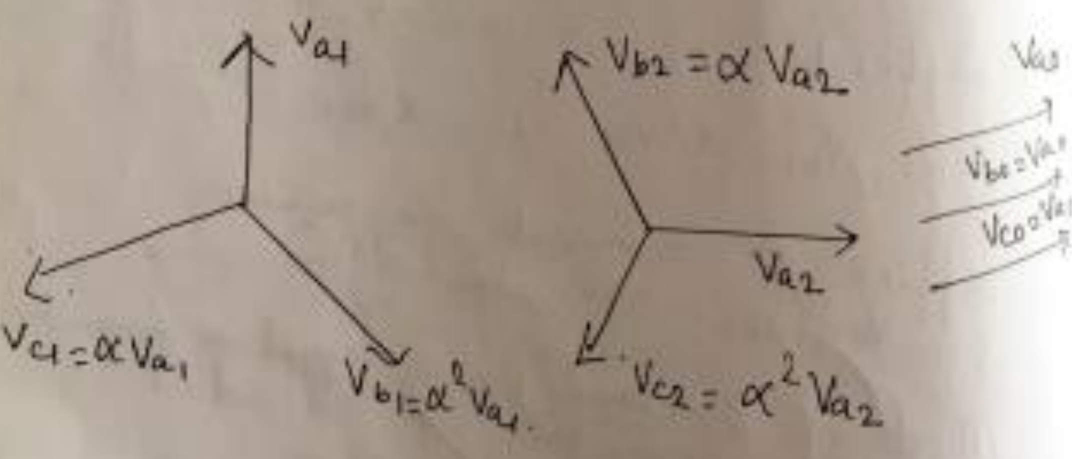
Consider, a set of three voltages (phasors) $V_a, V_b,$
which in general may be unbalanced.

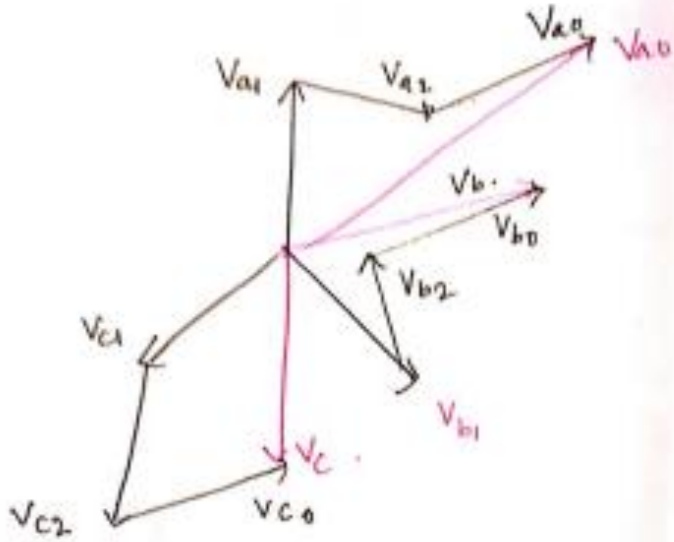
Acc to Fortesque's theorem, three phasors (applies to the case of n phasors), expressed as the sum of +ve / -ve and zero sequence phasor.

$$V_a = V_{a1} + V_{a2} + V_{a0} \quad \text{--- } 4$$
$$V_b = V_{b1} + V_{b2} + V_{b0} \quad \text{--- } 5$$
$$V_c = V_{c1} + V_{c2} + V_{c0} \quad \text{--- } 6$$

The three phasor sequences (+ve, -ve, zero) are called <u>symmetrical components</u> of original phasor set V_a, V_b, V_c

Addition of Symmetrical Components result in V_a, V_b, V_c.





Graphical addition to sym comp to obtain set of phasors V_a, V_b, V_c (unbalanced in general).

$$\therefore V_a = V_{a1} + V_{a2} + V_{a0} \quad \text{--- } 7\rangle$$

$$V_b = \alpha^2 V_{a1} + \alpha V_{a2} + V_{a0}. \quad \text{--- } 8\rangle$$

$$V_c = \alpha V_{a1} + \alpha^2 V_{a2} + V_{a0} \quad \text{--- } 9\rangle.$$

In matrix form

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \underbrace{\begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix}}_{A} \begin{bmatrix} V_{a1} \\ V_{a2} \\ V_{a0} \end{bmatrix} \quad \text{--- } 10\rangle.$$

Page No.:

$$\vec{V_p} = A\vec{V_s}$$

where $V_p = \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$ = vector of original phasor

$$V_s = \begin{bmatrix} V_{a1} \\ V_{a2} \\ V_{a0} \end{bmatrix} = \text{vector of symmetrical components}$$

$$A = \begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix} \quad \text{—11}\rangle$$

$$\therefore V_s = A^{-1} V_p \quad \text{—12}\rangle$$

$$A^{-1} = \frac{1}{3}\begin{bmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{bmatrix} \quad \text{—13}\rangle$$

give sym comp of original phasors

$$V_{a1} = \frac{1}{3}\left(V_a + \alpha V_b + \alpha^2 V_c\right) \quad \text{—14}\rangle$$

$$V_{a2} = \frac{1}{3}\left(V_a + \alpha^2 V_b + \alpha V_c\right) \quad \text{—15}\rangle$$

$$V_{a0} = \frac{1}{3}\left(V_a + V_b + V_c\right) \quad \text{—16}\rangle$$

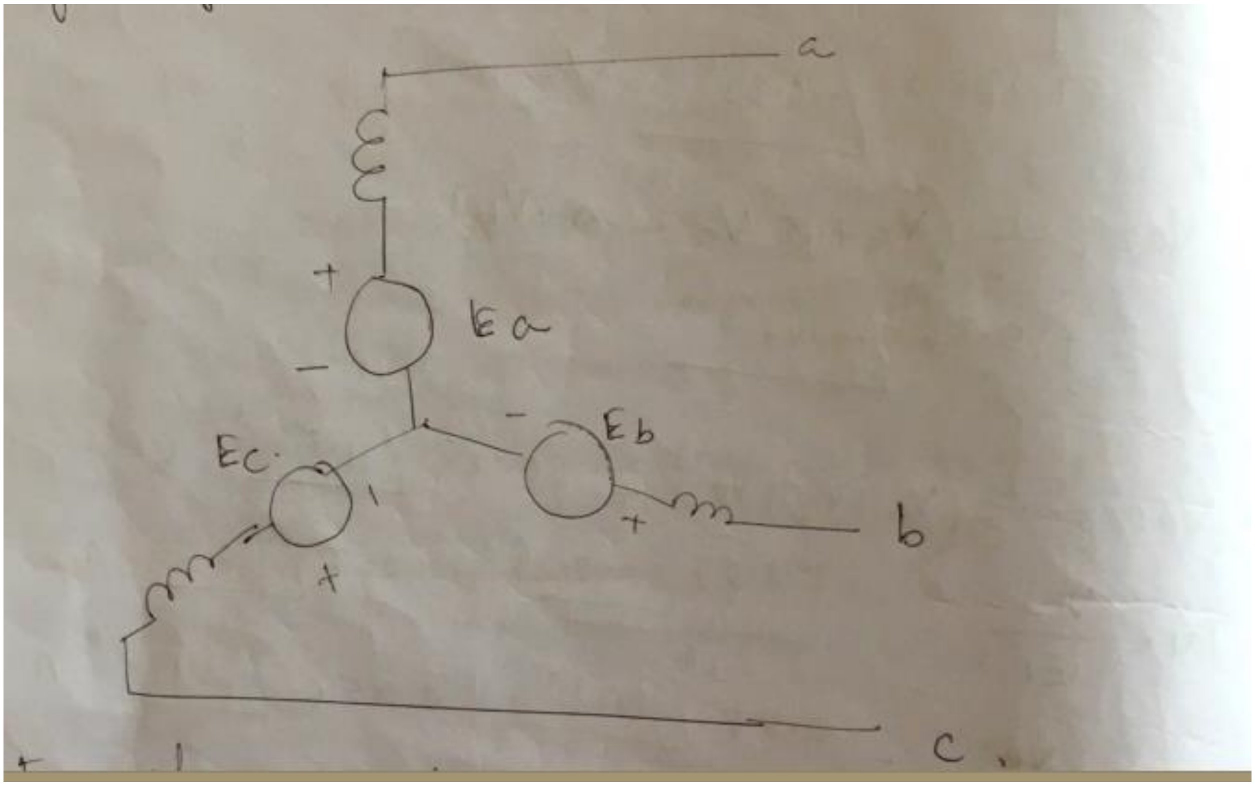


Fig shows an unloaded syn gen E_a, E_b and E_c are the induced emf of 3ϕ.

Since the windings are symmetrical, the induced emfs are perfectly balanced

$$|E_a| = |E_b| = |E_c| = V_p.$$

If abc phase seq.

$$E_a = V_P\angle 0^\circ,\quad E_b = V_P\angle -120^\circ,\quad E_c = V_P\angle +120^\circ$$

the seq. components of voltages are.

$$E_{a0} = \frac{1}{3}\left(E_a + E_b + E_c\right)$$

$$= \frac{1}{3}\left[V_P\angle 0^\circ + V_P\angle -120^\circ + V_P\angle 120^\circ\right].$$

$$= \frac{1}{3}\left[V_P - 0.5V_P - j0.866V_P - 0.5V_P + j0.866V_P\right]$$

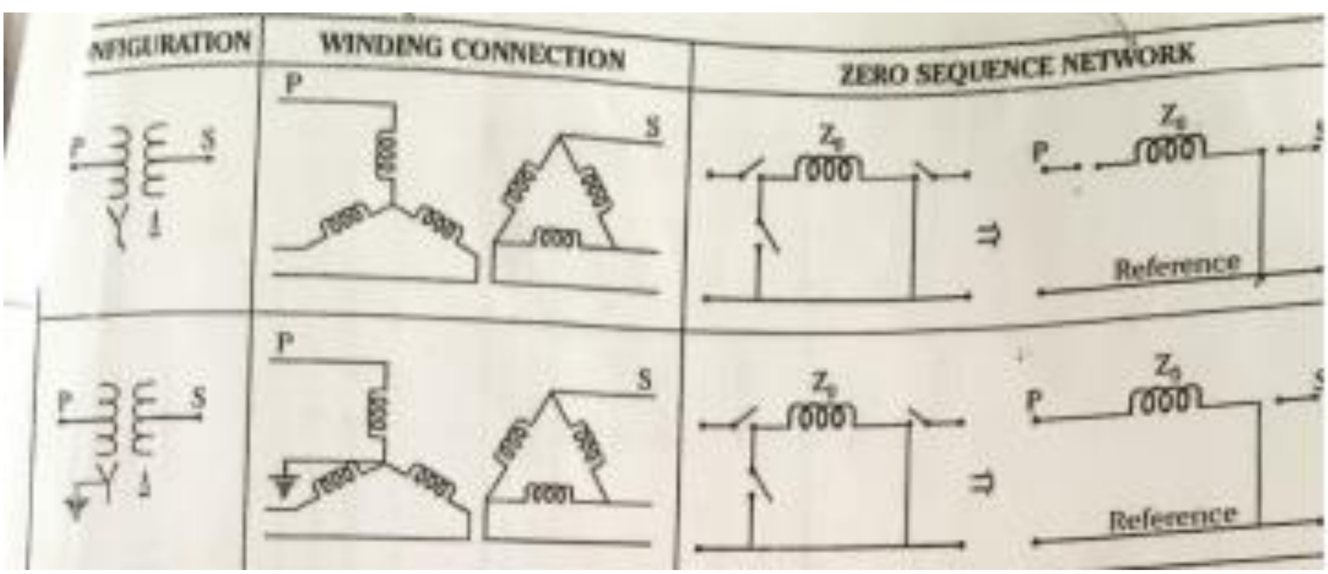
$$= 0.$$

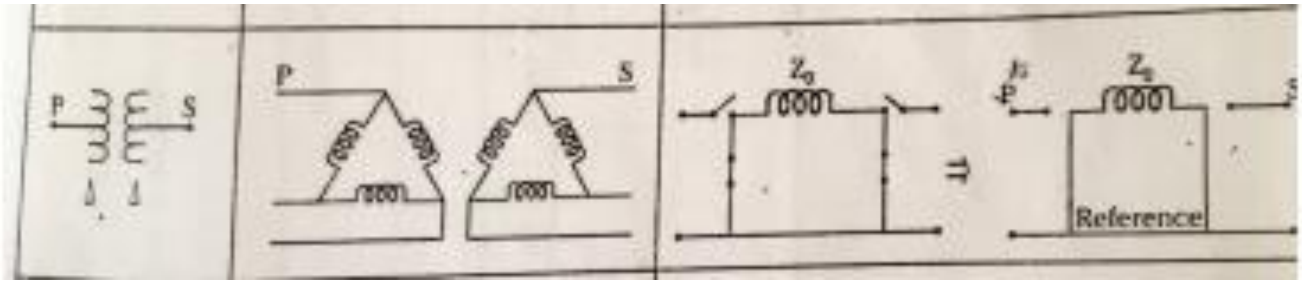
$$E_{a1} = \frac{1}{3}\left[E_a + \alpha E_b + \alpha^2 E_c\right].$$

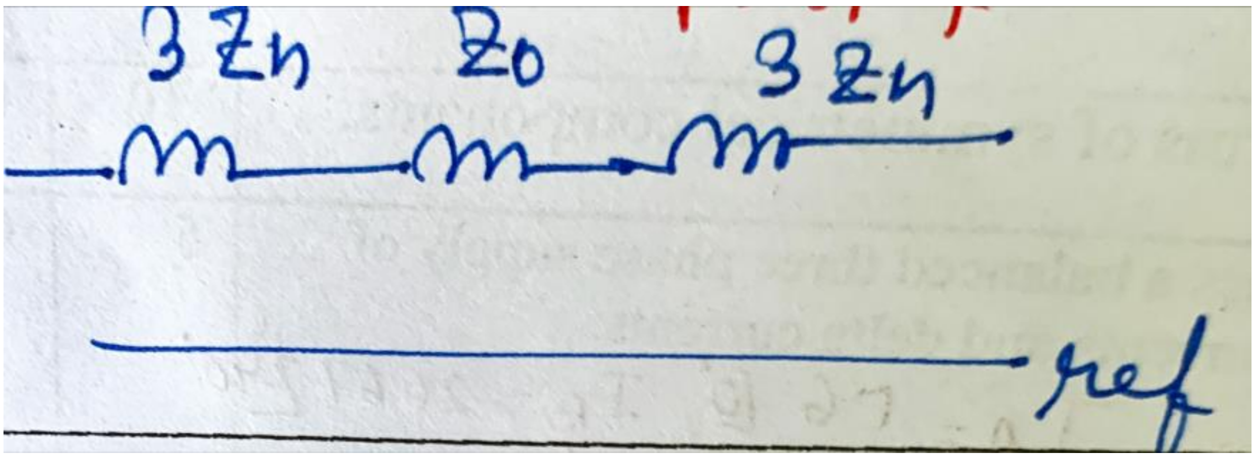
$$= V_P = E_a.$$

$$E_{a2} = \frac{1}{3}\left[E_a + \alpha^2 E_b + \alpha E_c\right] = 0.$$

3.







4.

Q4) Complex Power in terms of symmetrical Components

The total complex power flowing into a 3ϕ circuit is

$$S = P + jQ = V_a I_a^* + V_b I_b^* + V_c I_c^*.$$

S = total complex power

P ⇒ active power,

Q ⇒ Reactive power.

$$S = P + jQ = \begin{bmatrix} V_a & V_b & V_c \end{bmatrix} \begin{bmatrix} I_a^* \\ I_b^* \\ I_c^* \end{bmatrix}.$$

$$\begin{bmatrix} V_a & V_b & V_c \end{bmatrix} = \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}^T = \left\{ \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} \right\}^T$$

$$= \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix}^T \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix}.$$

$$\{[A][B]\}^T = [B]^T [A]^T.$$

$$\begin{bmatrix} I_a^* \\ I_b^* \\ I_c^* \end{bmatrix} = \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}^* = \left\{ \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \right\}^*$$

$$\left([A][B] \right)^* = [A]^* [B]^*.$$

$$= \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix}^* \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix}^*.$$

$$\alpha^* = \alpha^2.$$

$$(\alpha^2)^* = \alpha.$$

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix}^*.$$

$$\therefore S = P + jQ = \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix}^T \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix}^*$$

$$= \begin{bmatrix} V_{a0} & V_{a1} & V_{a2} \end{bmatrix} \begin{bmatrix} 3 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 3 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix}^*$$

$$S = P + jQ = 3 \left\{ V_{a0} I_{a0}^* + V_{a1} I_{a1}^* + V_{a2} I_{a2}^* \right\} VA.$$

Spu=S/Sbase

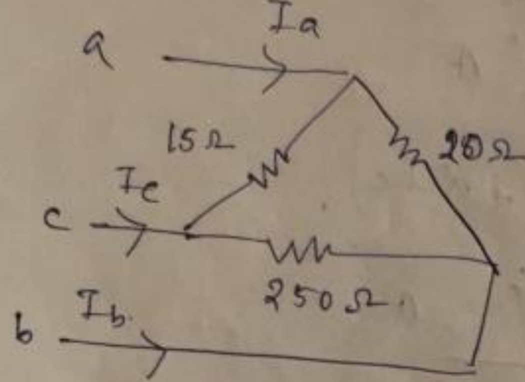
$$S_{pu} = \left\{ V_{a0} I_{a0}^{*} + V_{a1} I_{a1}^{*} + V_{a2} I_{a2}^{*} \right\}$$

Where all are pu quatities

5.a

~~Let~~ soln Let $I_a, I_b, I_c \Rightarrow$ line currents.

$I_A, I_B, I_C \Rightarrow$ phase currents.



As supply system is balanced.

$\therefore V_A = 400 \angle 0^\circ$

$V_B = 400 \angle 240^\circ$

$V_C = 400 \angle 120^\circ$

In a delta connected system phase voltage = line voltage.

$$I_A = \frac{V_A}{Z_A} = \frac{400\angle 0^\circ}{250} = 1.6 \angle 0^\circ \text{ A}$$

$$I_B = \frac{V_B}{Z_B} = \frac{400\angle 240^\circ}{15} = 26.67 \angle 240^\circ \text{ A}$$

$$I_C = \frac{V_C}{Z_C} = \frac{400\angle 120^\circ}{}$$

$I_C = \frac{V_C}{Z_C} = \frac{400 \angle 120^\circ}{20} = 20 \angle 120^\circ$ A.

$\therefore$ seq. component of delta current

$I_{A0} = \frac{1}{3}(I_A + I_B + I_C)$.

$= -7.25 - j1.93$ A.

$I_{A1} = \frac{1}{3}(I_A + \alpha I_B + \alpha^2 I_C) = 16.1$ A.

$I_{A2} = \frac{1}{3}(I_A + \alpha^2 I_B + \alpha I_C)$.

$= 7.5 \angle 165^\circ$ A

* this is a case of unbalanced load connected to a balanced supply.

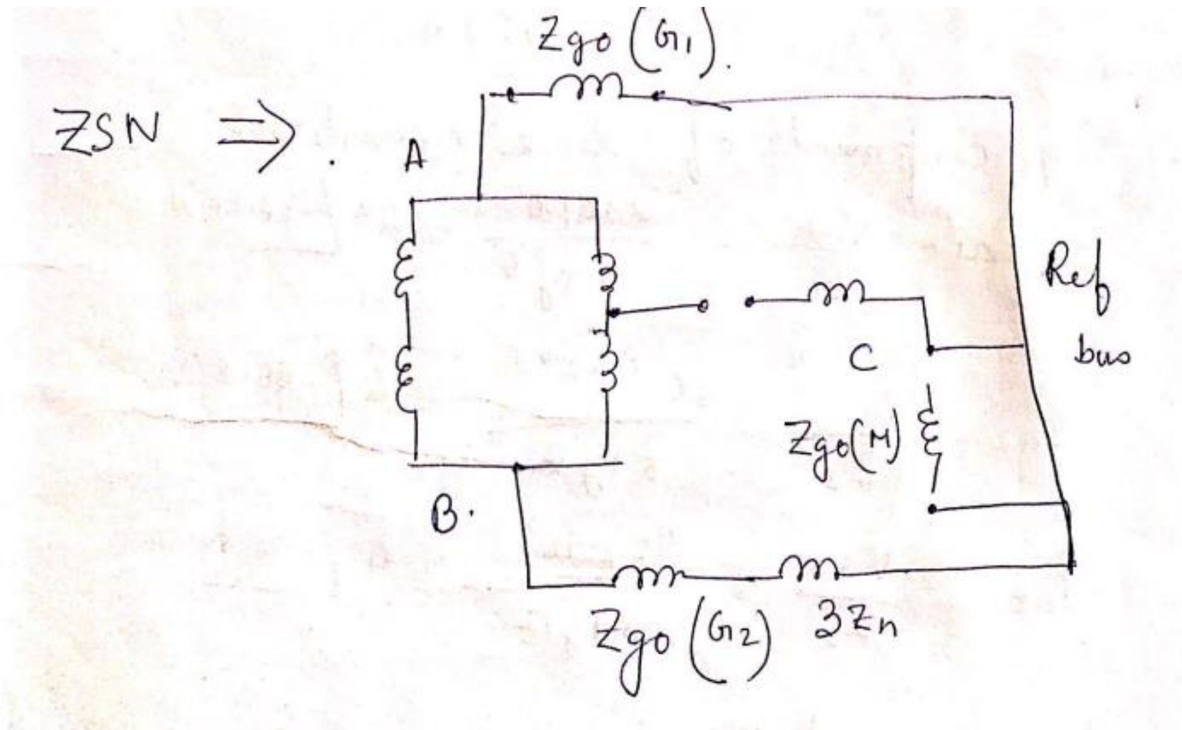
As Line currents are entering delta connected load

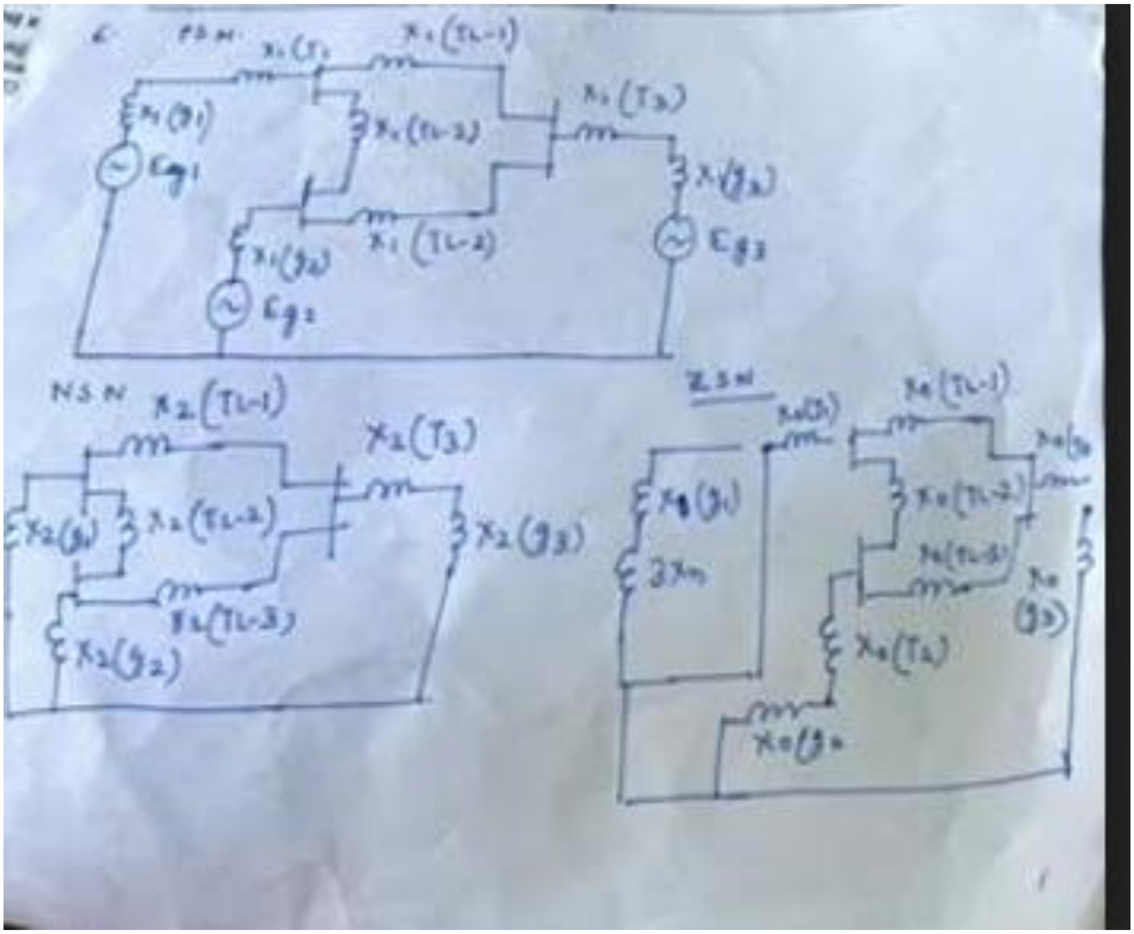
$\therefore$ seq. components of line currents are:

$I_{a1} = j\sqrt{3}\, I_{A1} = 27.89 \angle 90^\circ$ A

$I_{a2} = -j\sqrt{3}\, I_{A2} = 13 \angle 75^\circ$ A.

5b. Zero Sequence Network



6. 
PSN
Eg1
Eg2
Eg3
NSN
X2(TL-1)
X2(T3)
X2(TL-2)
X2(g3)
X2(TL-3)
X2(g2)
ZSN
X0(TL-1)
X0(T2)

7.

$$S_{pu} = V_{a0} I_{a0}^{*} + V_{a1} I_{a1}^{*} + V_{a2} I_{a2}^{*}$$

$$= (0.1 + j0.05)(0.05 - j0.02)^{*} + (0.9 + j0.2)(0.9 - j0.1)^{*}$$

$$+ (0.2 + j0.1)(0.2 - j0.1)^{*}.$$

$$= 0.817 + j0.3126 \text{ p.u}$$

Next $S = S_{pu} \times S_B = (0.817 + j0.3126) \times 100 \text{ MVA}$

$$= 81.7 + j31.26 \text{ MVA}$$

active power $P = 81.7 \text{ MW}$

$Q = 31.26 \text{ MVAR}.$