USN :

CMR Institute of Technology, Bangalore
DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING
II - INTERNAL ASSESSMENT

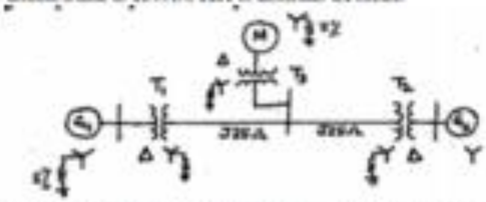
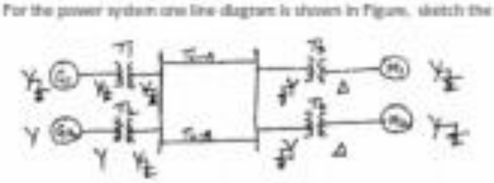
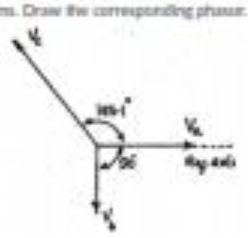
Semester: 6-CBCS 2018
Subject: POWER SYSTEM ANALYSIS – 1 (18EE62)
Faculty: Ms Keka Mukhopadhyaya

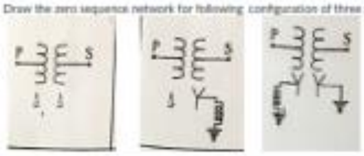
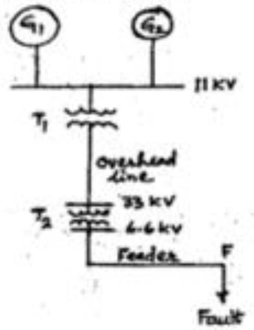
Date: 22 Jun 2021
Time: 09:00 AM - 10:30 AM
Max Marks: 50

Instructions to Students :

Answer Any FIVE FULL Questions.
Assume Data wherever necessary.

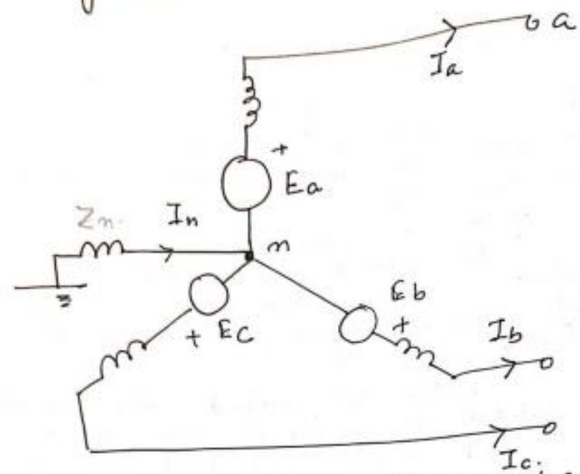
Answer any 5 question(s)

Q.No			Marks	CO	PO	BT/CL
1	a	Define positive, negative, zero sequence impedances and sequence network of a synchronous machine.	5	CO3	PO1,PO2,PO3,PO4,PO6,PO7,PO12	L1
	b	Show that a balanced three phase generator develops only positive sequence voltage.	5	CO3	PO1,PO2,PO3,PO4,PO6,PO7,PO12	L2
2		For the power system shown in the figure, draw the positive, negative and zero sequence networks. The ratings of power system components are as follows: Generator G1: 25MVA, 11kV, X1= 0.2 pu, X2= 0.15 pu, X0= 0.03 pu Generator G2: 15MVA, 11kV, X1= 0.2 pu, X2= 0.15 pu, X0= 0.03 pu Motor M: 25 MVA,11kV, X1=X2=0.2 pu, X0= 0.1 pu Transformer T1: 25 MVA, 11Δ/120 Y kV, X=10% Transformer T2: 12.5 MVA, 11Δ/120 Y kV, X=10% Transformer T3: 10 MVA, 120 Y/11Δ kV, X=10% Xs for T1, T2, T3 is 5% at the respective transformer ratings. Choose a base of 50 MVA, 11kV in Generator G1 circuit. 	10	CO3	PO1,PO2,PO3,PO4,PO6,PO7,PO12	L3
3	a	Derive the relation between sequence components of phase and line current in delta connected system with necessary diagram.	5	CO3	PO1,PO2,PO3,PO4,PO6,PO7,PO12	L2
	b	A balanced delta connected load is connected to a three phase symmetrical supply of abc phase sequence. The line currents are each 15 A in magnitude. If fuse in **line b** blows out, determine sequence component of line currents.	5	CO3	PO1,PO2,PO3,PO4,PO6,PO7,PO12	L3
4		For the power system one line diagram is shown in Figure, sketch the sequence networks. 	10	CO3	PO1,PO2,PO3,PO4,PO6,PO7,PO12	L4
5	a	The original set of voltage phases $V_a=4\angle 0$ degree, $V_b=3\angle -90$ degree, $V_c=8\angle 143.1$ degree as shown in figure. Find all the components for the positive, negative and zero sequence systems. Draw the corresponding phasor. 	5	CO3	PO1,PO2,PO3,PO4,PO6,PO7,PO12	L3

	b	Draw the zero sequence network for following configuration of three phase transformers.  	5	CO3	PO1,PO2,PO3,PO4,PO6,PO7,PO12	L1
6		For the radial network shown in the figure , a three phase fault occurs at point F. Determine the fault current. Choose te generator ratings as the base values. Generator G1: 10 MVA, 11kV, X''=20% Generator G1: 10 MVA, 11kV, X''=12.5% Transformer T1: 10 MVA, 11/33kV, x=10% Transformer T2: 10 MVA, 11/33kV, x=8.7% Over head line impedance Z=6+j10 Ω Feeder impedance Z= 0.5+ j0.15 Ω  	10	CO2	PO1,PO2,PO6,PO7,PO12	L4
7	a	Derive the expression for three phase power in terms of sequence components.	5	CO3	PO1,PO2,PO3,PO4,PO6,PO7,PO12	L2
	b	Discuss briefly the major points need to consider to select a circuit breaker.	5	CO2	PO1,PO2,PO6,PO7,PO12	L1

1a

Sequence Impedances And Networks Of Synchronous Machine.



Three-phase sym. gen with grounded neutral.

fig shows an unloaded sym machines (G/M), grounded through a reactor (impedance Z_n).

E_a, E_b and E_c are the induced emfs of the 3φ.

When a fault takes place at machine terminals, currents I_a, I_b and I_c flow in the lines.

Whenever the fault involves ground, current $I_n = I_a + I_b + I_c$ flows to neutral from ground via Z_n.

Unbalanced line currents can be resolved into their symmetrical components I_{a1}, I_{a2} and I_{a0}.

Because of winding symmetry currents of a particular seq. produce voltage drops of that seq. only.

Therefore, there is no coupling betn the eq. circuit of various sequences.

Positive Sequence Impedance and Network

Since synchronous machine is designed with symmetric winding, it induces emfs of positive seq. only. i.e no negative or zero sequence voltages are induced in it.

⇒ When machine carries positive sequence current only ⇒ balance mode.

⇒ The armature reaction field caused by positive seq. currents rotates at syn speed in the same direction as the rotor (i.e it is stationary w.r.t field excitation).

⇒ The machine equivalently offers a direct axis reactance (~~X_d~~), whose value reduces to X_d'' to X_d' and then finally X_d, as short circuit transient progresses in time.

If armature resistance is assumed negligible, the +ve seq. impedance of the machine is

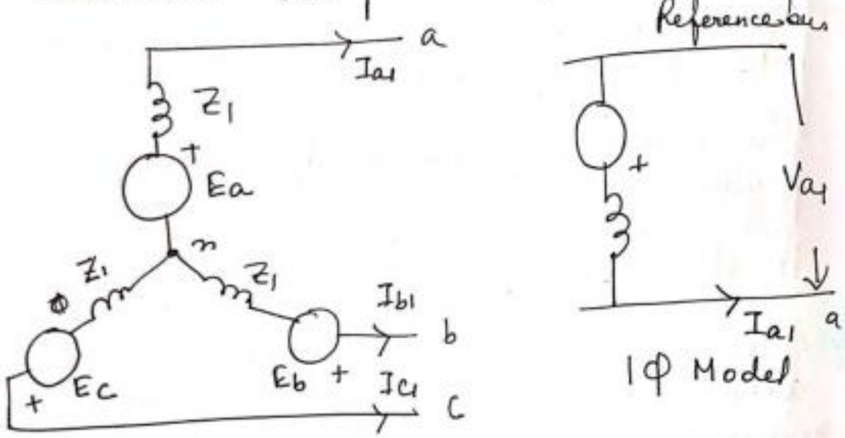
$Z_1 = jX_d''$ (if 1 cycle of transient is of interest)

$= jX_d'$ (if 3-4 cycle " " " ")

$= jX_d$ (if steady state value is of interest)

If the machine short circuit takes place from unloaded conditions, the terminal voltage constitutes the +ve sequence voltage.

If short circuit occurs from loaded conditions, the voltage behind appropriate reactance (subtransient, transient or synchronous) constitutes the positive sequence voltage.



3φ Model.

1φ Model.

Positve Seq. Network of Syn Machine.

- ☆ Z_n does not appear in the model as $I_n = 0$ for positive seq. currents.
- ☆ Balanced network can be represented by 1ϕ.
- ☆ Ref bus for +ve seq. network is at neutral potential.
- ☆ No current flows from ground to neutral so neutral at ground potential.

$$V_{a1} = E_a - Z_1 I_{a1} \quad \text{--- } 17.$$

Negative Sequence Impedance and Network

- ☆ Syn M/c has zero -ve seq. induced voltages
- ☆. With the flow of -ve seq. current in the stator a rotating field is created which rotates in the opposite direction to that of the +ve seq. field at therefore at double syn. speed w.r.t rotor.

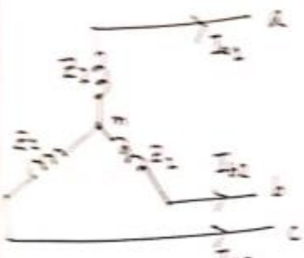
Currents at double the stator frequency are induced in rotor field and damper winding.

- ☆ In sweeping over the rotor surface, the -ve seq. mmf is alternately presented with reluctance & sp...

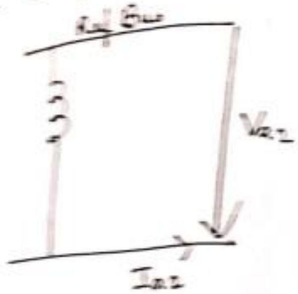
area.

* The negative seq. impedance presented by the machine with consideration given to damper windings, is defined as

$$Z_2 = j\,\frac{X_q'' + X_d''}{2}\ ; \quad |Z_2| < |Z_1|.$$



3 ϕ Model



1 ϕ Model.

Negative sequence network of a synchronous machine

* Ref bus is at neutral potential, same as ground potential.

$$V_{a2} = -I_{a2} Z_2$$

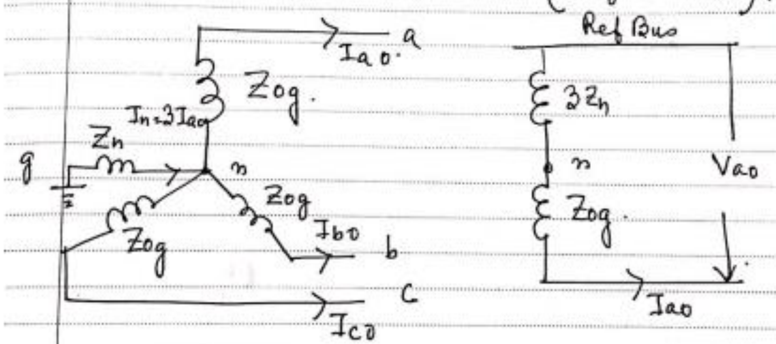
Zero Sequence Impedance and Network:

No zero seq. voltages are induced in a syn M/c.

The flow of zero seq. currents creates three mmfs which are in time phase but are distributed in space phase by 120'.

The resultant air gap field caused by zero seq. currents is zero.

Rotor windings present leakage reactance to the flow of zero seq. currents $(Z_{0g} < Z_2 < Z_1)$.



3 φ Model | 1 φ Model.

$$V_{a0} = -3Z_n I_{a0} - Z_{0g} I_{a0}$$
$$= -(3Z_n + Z_{0g}) I_{a0}.$$

$Z_{0g} \Rightarrow$ zero seq. imp / phase of the machine.

Since 1φ zero seq. network carries only per phase zero seq. current.

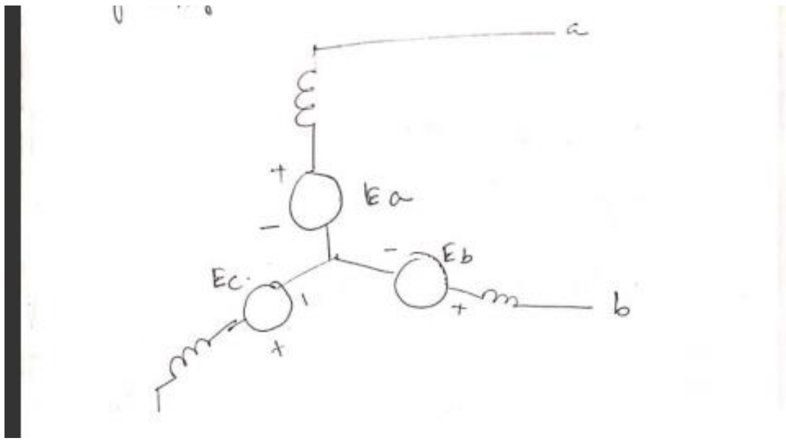
Zero seq. impedance $Z_0 = 3Z_n + Z_{0g}$

in order to have same ref voltage from a to ref bus.

Ref bus → ground potential

$$V_{a0} = -Z_0 I_{a0}$$

1b



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

the seq. components of voltages are

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

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

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

$$= 0$$

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

$$= V_p = E_a.$$

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

2.

(2) Base power = 50 MVA

Base voltage in Generator G1 = 11 kV

Base voltage of j25 TL = Base vlg of G_1 × Transformation ratio

$$= 11 \times \frac{120}{11}$$

$$(KV)_{BTL} = 120\ kV$$

Base voltage of Motor = $(KV)_{BTL} \times TR$

$$= 120 \times \frac{11}{120}$$

$$(KV)_{BM} = 11\ kV$$

Base voltage of Generator $G_2 = (KV)_{BTL} \times TR$

$$= 120 \times \frac{11}{120}$$

$$(KV)_{BG2} = 11\ kV$$

(i) Reactances of Generator 1 :

Positive seq reactance $X_1(G_1) = X_1 \times \frac{(MVA)_{B,new}}{(MVA)_{B,old}} \times \frac{(KV)^2_{B,old}}{(KV)^2_{B,new}}$

$$= j0.2 \times \frac{50}{25} \times \frac{11^2}{11^2}$$

$$X_1(G_1) = j0.4$$

Negative seq reactance $X_2(G_1) = X_2 \times \frac{(MVA)_{B,new}}{(MVA)_{B,old}} \times \frac{(KV)^2_{B,old}}{(KV)^2_{B,new}}$

$$= j0.15 \times \frac{50}{25} \times \frac{11^2}{11^2}$$

$$X_2(G_1) = j0.3$$

Generator neutral reactance X_n

$$X_n(G_1) = j0.05 \times \frac{50}{25} \times \frac{11^2}{11^2}$$

$$X_n(G_1) = j0.1$$

$$3X_n(G_1) = \underline{j0.3}$$

(ii) Reactance of Generator 2

$$X_1(G_2) = X_1 \times \frac{(MVA)_{B,new}}{(MVA)_{B,old}} \times \frac{(KV)^2_{B,old}}{(KV)^2_{B,new}}$$

$$= j0.2 \times \frac{50}{15} \times \frac{11^2}{11^2}$$

$$X_1(G_2) = \underline{j0.667}$$

$$X_2(G_2) = X_2 \times \frac{50}{15} \times \frac{11^2}{11^2}$$

$$= j0.15 \times \frac{50}{15}$$

$$X_2(G_2) = \underline{j0.5}$$

$$X_0(G_2) = X_0 \times \frac{50}{15} \times \frac{11^2}{11^2}$$

$$= j0.03 \times \frac{50}{15}$$

$$X_0(G_2) = \underline{j0.1}$$

(iii) Reactance of Transformer 1 :

$$X_1(T_1) = X_2(T_1) = X_{0T}(T_1) = X_1 \times \frac{(MVA)_{B,new}}{(MVA)_{B,old}} \times \frac{(KV)^2_{B,old}}{(KV)^2_{B,new}}$$

$$= j0.1 \times \frac{50}{25} \times \frac{11^2}{11^2}$$

$$= \underline{j0.2}$$

Transformer neutral reactance

$$X_n(T_1) = j0.05 \times \frac{50}{25} \times \frac{11^2}{11^2}$$

$$X_n(T_1) = j0.1$$

$$3X_n(T_1) = \underline{j0.3}$$

(iv) Reactance of Transformer 2:

$$X_1(T_2) = X_2(T_2) = X_0(T_2) = j0.1 \times \frac{50}{12.5} \times \frac{11^2}{11^2}$$

$$= \underline{j0.4}$$

Transformer neutral reactance

$$X_n(T_2) = j0.05 \times \frac{50}{12.5} \times \frac{11^2}{11^2}$$

$$X_n(T_2) = j0.2$$

$$3X_n(T_2) = \underline{j0.6}$$

(v) Reactance of Transformer 3:

$$X_1(T_3) = X_2(T_3) = X_{0}(T_3) = j0.1 \times \frac{50}{10} \times \frac{11^2}{11^2}$$

$$= \underline{j0.5}$$

Transformer neutral reactance

$$X_n(T_3) = j0.05 \times \frac{50}{10} \times \frac{11^2}{11^2}$$

$$X_n(T_3) = j0.25$$

$$3X_n(T_3) = \underline{j0.75}$$

(vi) Reactance of Motor :

$$X_1(M) = X_2(M) = j0.2 \times \frac{50}{25} \times \frac{11^2}{11^2}$$

$$X_1(M) = X_2(M) = j0.4$$

$$X_0(M) = j0.1 \times \frac{50}{25} \times \frac{11^2}{11^2}$$

$$X_0(M) = j0.2$$

Motor neutral reactance

$$X_n(M) = j0.05 \times \frac{50}{25} \times \frac{11^2}{11^2}$$

$$X_n(M) = j0.1$$

$$3X_n(M) = j0.3$$

(v) Reactance of Transmission line

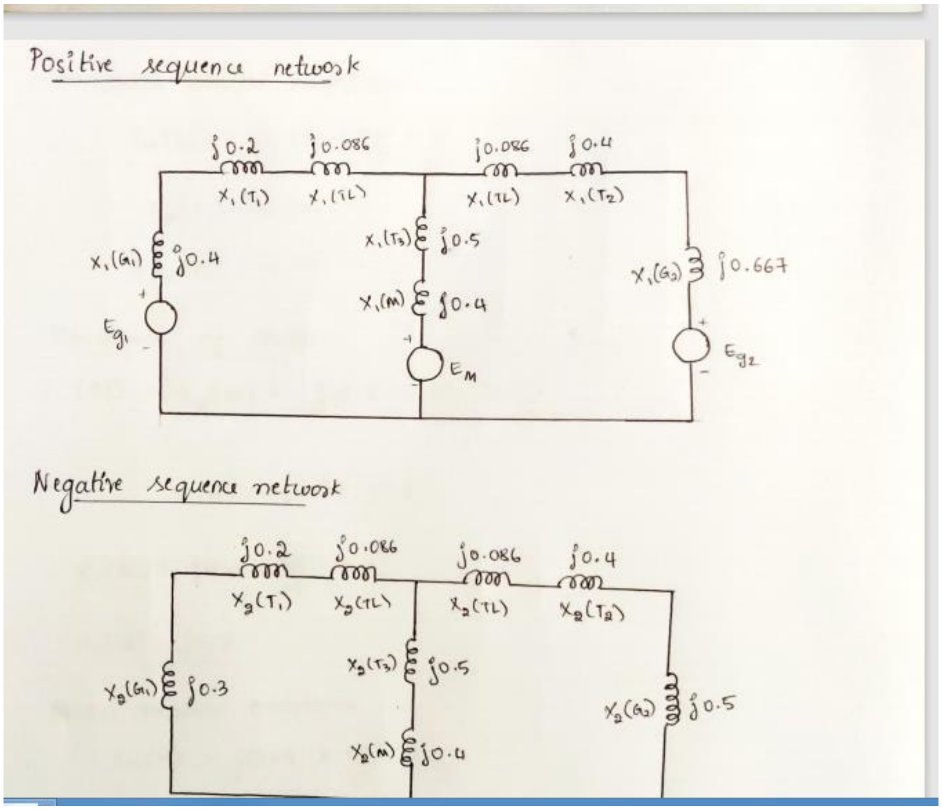
$$X_1(TL) = X_2(TL) = X(\Omega) \times \frac{(MVA)_{B.1}}{(kV)_B^2}$$

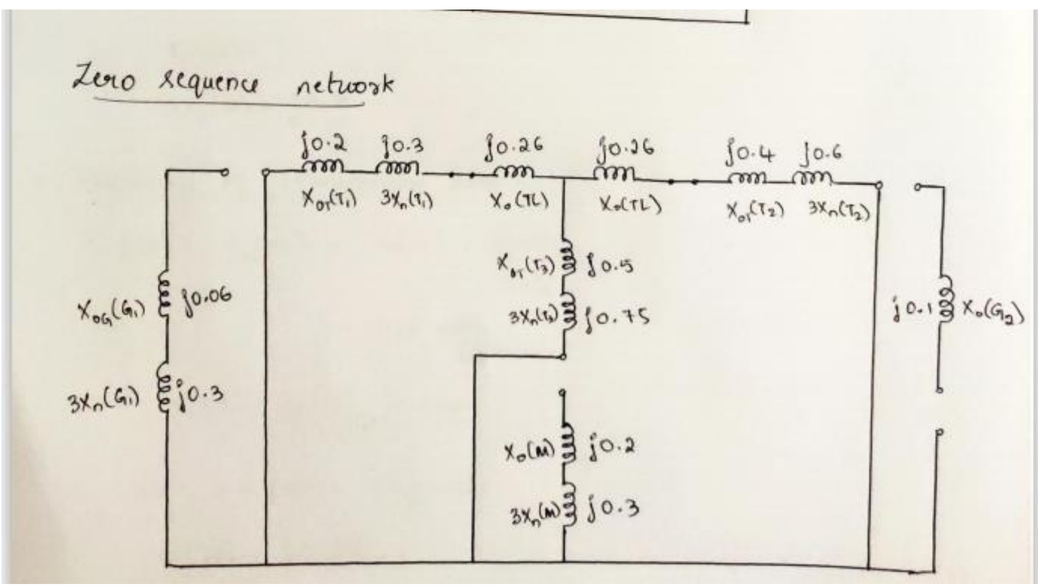
$$= j25 \times \frac{50}{120^2}$$

$$X_1(TL) = X_2(TL) = j0.086$$

$$X_0(TL) = 3X_1(TL) = 3 \times j0.086$$

$$X_0(TL) = j0.26$$

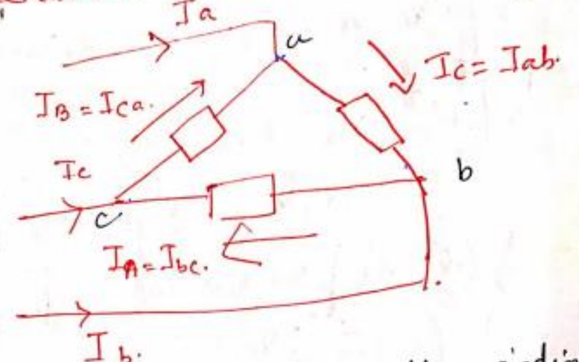

Positive sequence network
j0.2
j0.086
j0.086
j0.4
X1(T1)
X1(TL)
X1(TL)
X1(T2)
X1(T3) j0.5
X1(G1) j0.4
X1(G2) j0.667
X1(M) j0.4
Eg1
EM
Eg2
Negative sequence network
j0.2
j0.086
j0.086
j0.4
X2(T1)
X2(TL)
X2(TL)
X2(T2)
X2(T3) j0.5
X2(G1) j0.3
X2(G2) j0.5
X2(M) j0.4


Zero sequence network
j0.2
j0.3
j0.26
j0.26
j0.4
j0.6
X0T(T1)
3Xn(T1)
X0(TL)
X0(TL)
X0T(T2)
3Xn(T2)
X0T(T3) j0.5
3Xn(T3) j0.75
X0G(G1) j0.06
3Xn(G1) j0.3
j0.1 X0(G2)
X0(M) j0.2
3Xn(M) j0.3

3a

Q3 b) same Relation between seq. Components of line currents in delta connected system.

Δ connection



phase currents (currents in delta windings) are.

I_{ab}, I_{bc} and I_{ca}.

$$I_{ab} = I_C, \quad I_{bc} = I_A, \quad I_{ca} = I_B.$$

Applying KCL

$$\left.\begin{aligned} I_a &= I_C - I_B \\ I_b &= I_A - I_C \\ I_C &= I_B - I_A \end{aligned}\right]$$

Seq. component of line current are.

$$I_{a1} = \frac{1}{3}\left[I_a + \alpha I_b + \alpha^2 I_c\right].$$

$$= \frac{1}{3}\left[I_C - I_B + \alpha\left(I_A - I_C\right) + \alpha^2\left(I_B - I_A\right)\right]$$

$$= \frac{1}{3}\left[\alpha\left(I_A + \alpha I_B + \alpha^2 I_c\right) - \alpha^2\left(I_A + \alpha I_B + \alpha^2 I_c\right)\right]$$

$$= \frac{1}{3}\left(\alpha - \alpha^2\right)\left(I_A + \alpha I_B + \alpha^2 I_c\right).$$

$$\boxed{I_{a1} = \frac{1}{3} j\sqrt{3} \times 3 I_{A1}}$$

$$I_{a2} = \frac{1}{3}\left(I_a + \alpha^2 I_b + \alpha I_c\right).$$

$$= \frac{1}{3}\left[\left(I_c - I_B\right) + \alpha^2\left(I_A - I_c\right) + \alpha\left(I_B - I_A\right)\right].$$

$$= \frac{1}{3}\left[\alpha^2\left(I_A + \alpha I_B + \alpha^2 I_c\right) - \alpha\left(I_A + \alpha^2 I_B + \alpha I_c\right)\right]$$

$$= \frac{1}{3}\left(\alpha^2 - \alpha\right)\left(I_A + \alpha I_B + \alpha^2 I_c\right).$$

$$\boxed{I_{a2} = \frac{1}{3}\left(-j\sqrt{3}\right).\left(3 I_{A2}\right)}$$

∴ line currents in delta system is $\sqrt{3}$ times the phase currents.

The +ve seq. line current leads the respective phase currents by 90° whereas the -ve seq. line current lags the -ve seq. phase currents by 90°.

Zero seq. component of line current

$$I_{a0} = \frac{1}{3}\left(I_a + I_b + I_c\right).$$

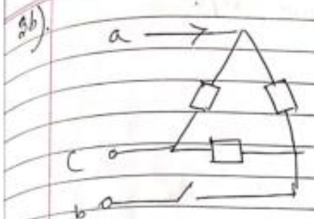
$$= \frac{1}{3}\left[\left(I_C - I_B\right) + \left(I_A - I_C\right) + \left(I_B - I_A\right)\right].$$

$$= 0.$$

though $I_{a0} = 0$ does not mean $I_{A0} = 0$

3b

3b).



$I_a = 15 \angle 0^\circ$ A

$I_c = 15 \angle -180^\circ$ A.

$I_b = 0$.

In a 3 wire system $I_a + I_b + I_c = 0$.

but $I_b = 0$ ∴ $I_a = -I_c$.

+ve sequence component of line current is.

$$I_{a1} = \frac{1}{3}\left(I_a + \alpha I_b + \alpha^2 I_c\right).$$

$$= \frac{1}{3}\left[15\angle 0^\circ + 15\angle -180^\circ + 240^\circ\right] = 8.66 \angle 30^\circ \text{ A}.$$

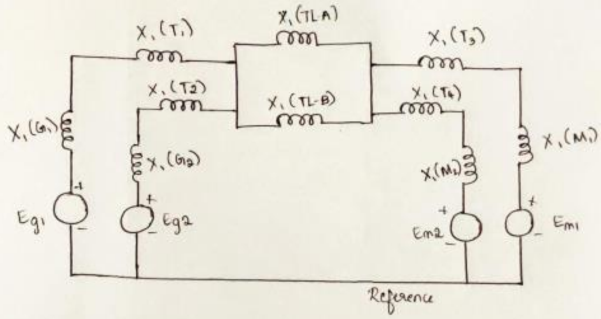
$$I_{a2} = \frac{1}{3}\left(I_a + \alpha^2 I_b + \alpha I_c\right).$$

$$= \frac{1}{3}\left[15\angle 0^\circ + 15\angle -180^\circ + 120^\circ\right] = 8.66 \angle -30^\circ \text{ A}.$$

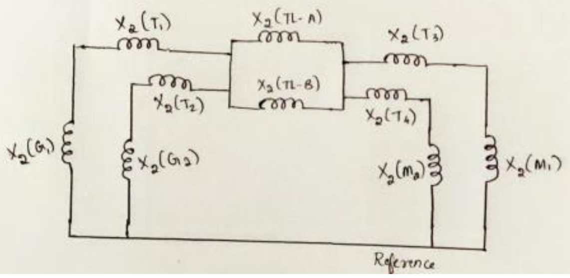
$I_{a0} = 0$.

(4)

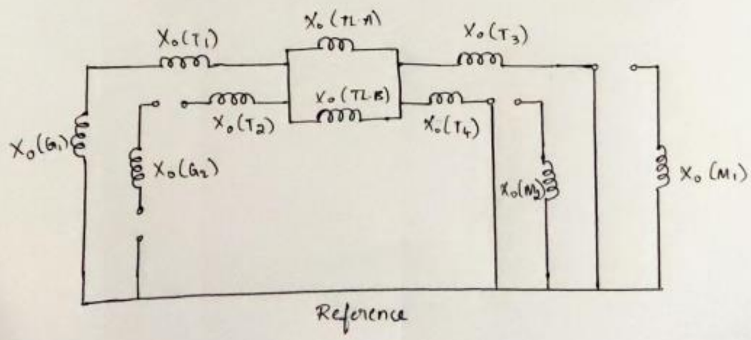
Positive sequence network



Negative sequence network



Zero sequence network



5a). $V_a = 4\angle 0^\circ$ V.

$V_b = 3\angle -90^\circ$ V.

$V_c = 8\angle 143.1^\circ$ V.

$V_{a0} = \frac{1}{3}(V_a + V_b + V_c)$. $= 1.00\angle 143.09^\circ$ V

$= \cancel{2.72\angle -107.07}$ V. $V_{b0} = 143.09^\circ$ V

$V_{c0} = 143.09^\circ$ V.

$\cancel{V_{b0} = 2.72\angle -107.07}$ V.

$\cancel{V_{c0} = 2.72\angle -107.07}$ V.

$V_{a1} = \frac{1}{3}(V_a + \alpha V_b + \alpha^2 V_c)$.

$= \frac{1}{3}(4\angle 0 + 3\angle 30^\circ + 8\angle 383.1^\circ)$ V.

$= 4.9\angle 18.31^\circ$ V.

$V_{b1} = 4.9\angle 258.31^\circ$ V.

$V_{c1} = 4.9\angle 138.31^\circ$ V

$V_{a2} = \frac{1}{3}(V_a + \alpha^2 V_b + \alpha V_c)$.

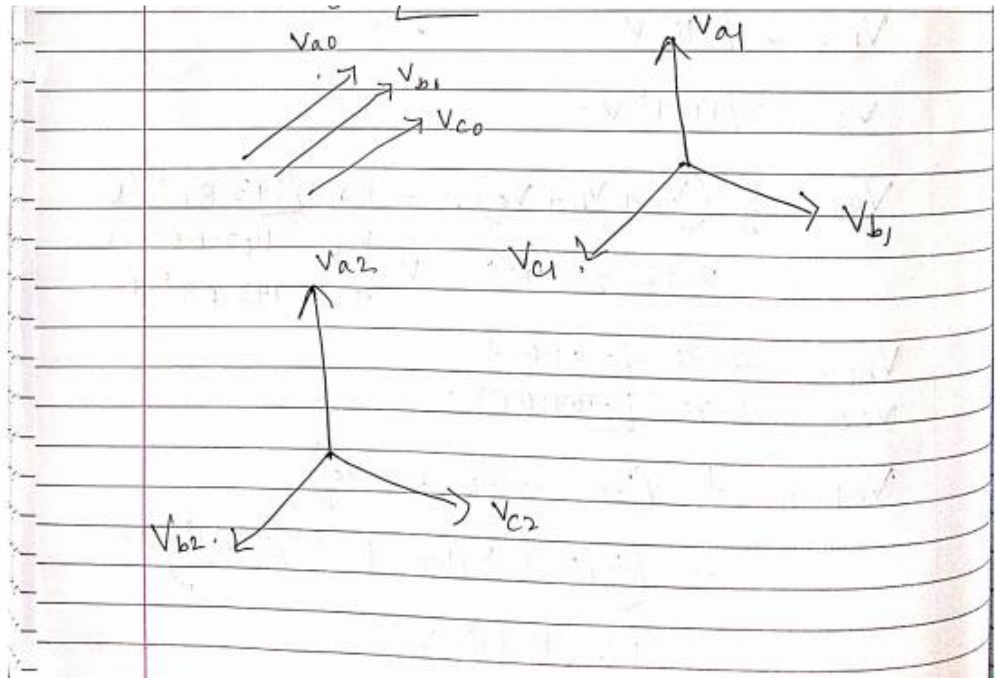
$= \frac{1}{3}(4\angle 0^\circ + 3\angle 150^\circ + 8\angle 263.1^\circ)$ V.

$= \cancel{3.3\angle 26.2^\circ}$ V. $2.15\angle -86.0^\circ$ V.

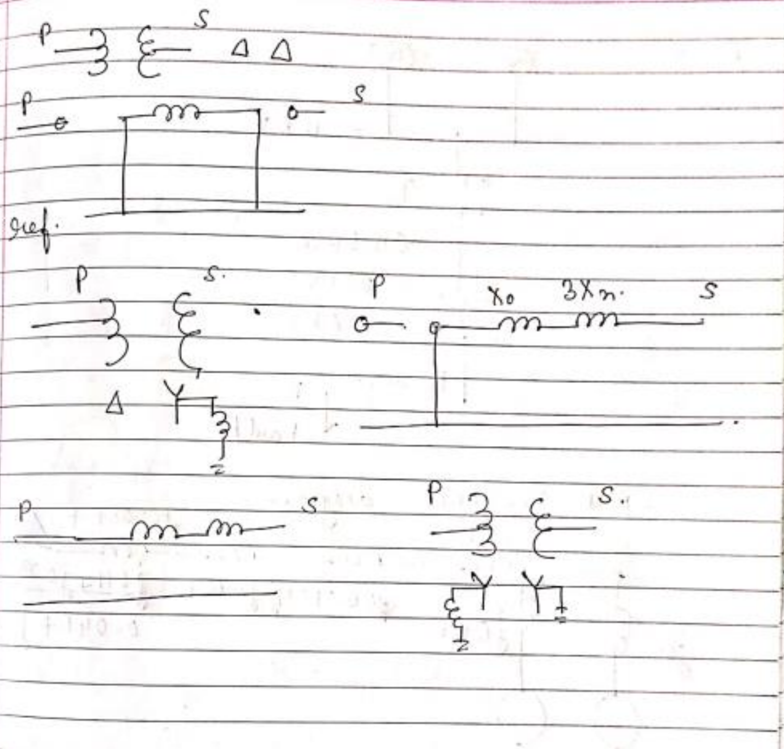
$V_{b2} = \cancel{3.3\angle 146.2^\circ}$ V $\quad V_{b2} = 2.15\angle 34^\circ$ V

$V_{c2} = 2.15\angle 154^\circ$ V.

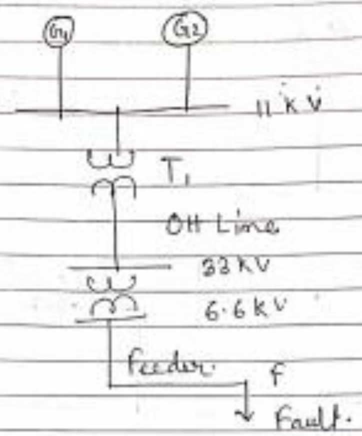
$V_{c2} = 3.3\angle 266.2^\circ$ V.


Va0
Vb1
Vc0
Va1
Vb1
Vc1
Va2
Vb2
Vc2

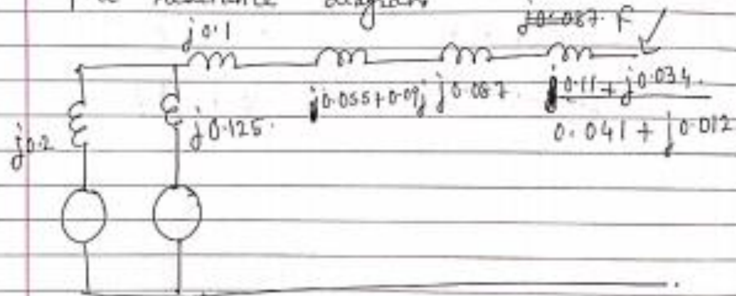
5b).


P
S
Δ Δ
P
S
ref.
P
S.
Δ Y
P
x0
3Xn.
S
P
S
P
S.
Y Y

6.



p.u reactance diagram



$$X_{OH}\,(pu) = (6+j10) \times \frac{10}{33^2}$$

$$X_{feeder}\,(pu) = (0.5 + j0.15) \times \frac{10}{6.6^2}.$$

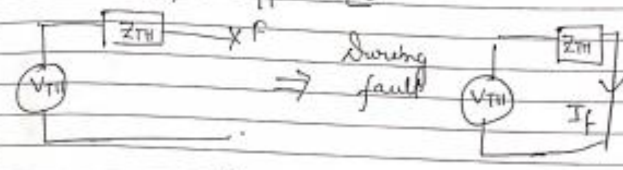
$Z_{TH} = \left(j0.2 \parallel j0.125\right) + \left(j0.1 + j\right.$

$0.055 + j0.09 + j0.087 + j0.041$

$\left. + j0.012\right]$

$= Z_{TH} = 0.096 + 0.3659j$

$V_{TH} = V_{pf} = \frac{11}{11} = 1\angle 0^\circ$



$$I_f = \frac{1\angle 0^\circ}{0.096 + 0.3659j}$$

$$= 2.64\angle -75.3^\circ \text{ pu.}$$

Base current $I_B = \frac{(MVA)_B \times 10^6}{\sqrt{3}(KV)_B \times 10^3}$

$$= \frac{10 \times 10^6}{\sqrt{3} \times 11 \times 10^3} = 524.86\,A$$

$$I_f = I_B \times (I_f)_{pu} = 524.86 \times 2.64\angle -75.3^\circ$$

$$= 1385.64\angle -75.3^\circ \;A.$$

Q4:-

Q3 Complex Power in terms of symmetrical Components

The total complex power flowing into a 3 ϕ. circuit is

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

S = total complex power

$P \Rightarrow$ active power,

$Q \Rightarrow$ Reactive power.

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

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

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

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

7a

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

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

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

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

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

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

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

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

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

7b

Two factors are of utmost importance of selection of CB.

1> The maximum instantaneous current that a breaker must withstand (called momentary duty of CB)

2> The total current when the breaker contacts part (called interrupting current)

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Two of the CB ratings which require the computation of SC current are : rated momentary current and rated symmetrical interrupting current.

★ Symmetrical SC current is obtained by using subtransient reactance for synchronous machines.

Momentary (r.m.s) current is then calculated by multiplying the symmetric momentary current by a factor of 1.6 to account for the presence of DC offset current.

★ Symmetrical current to be interrupted is computed by using X_d'' for syn gen and X_d' for syn motors — induction motors are neglected.

DC offset value to be added to obtain the current to be interrupted is accounted for by multiplying the symmetric SC current by a factor as follows:

CB speed.	Multiplying factor.
8 cycles or slower	1.0
5 cycles	1.1
3 cycles	1.2
2 cycles	1.4.