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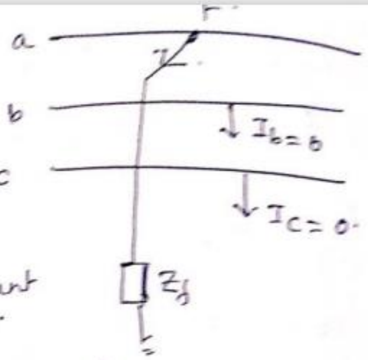
Internal Test 3 –July 2022

Sub:	Power System Analysis-1							Code:	18EE62
Date:	08/07/2022	Duration:	90 mins	Max Marks:	50	Sem:	6th	Branch:	EEE

Answer Any FIVE FULL Questions. Assume missing Data

		Marks	OBE CO	OBE RBT
1.	Find out the expression of fault current when power system , is subjected to a) LG fault through a fault impedance with necessary diagrams.	10	CO4	L2

LG Fault.



Terminal Conditions.

$V_a = I_a Z_f$

$I_b = 0$

$I_c = 0$.

Symmetrical Component Relations

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

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

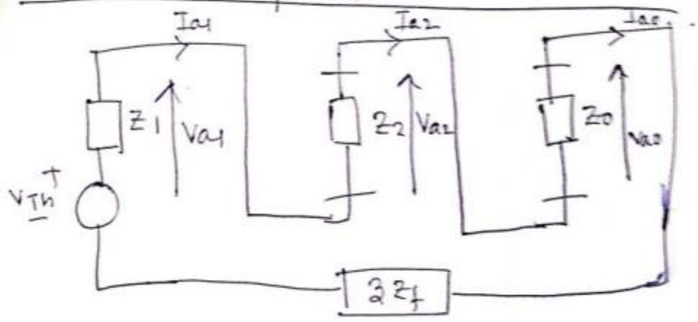
$$I_{a2} = \frac{1}{3}(I_a + \alpha^2 I_b + \alpha I_c) = \frac{1}{3} I_a$$

$$I_{a1} = I_{a2} = I_{a0} = \frac{1}{3} I_a$$

as $V_a = I_a Z_f$

$$V_{a0} + V_{a1} + V_{a2} = I_a Z_f = 3 I_{a0} Z_f$$

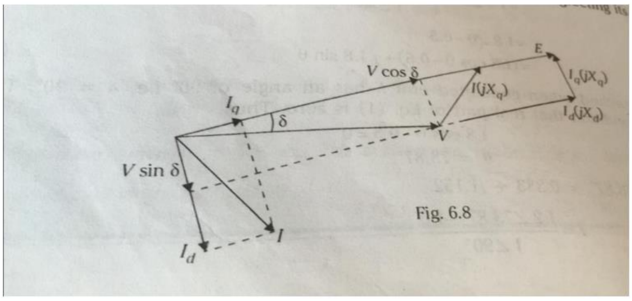
Interconnection of sequence networks



Page No.:

Fault Current

$$I_f = I_a = 3 I_{a0} = \frac{3 V_{Th}}{Z_1 + Z_2 + Z_0 + 3Z_f}$$

2.	Derive Power angle equation of synchronous machine for salient with necessary graph.  Fig. 6.8	10	CO5	L3

<table>
<tr><td></td><td>

$E\angle\delta \Rightarrow$ Generated emf in the syn m/c.

$V\angle 0^\circ$ = Bus bar voltage (taken as ref).

X_d = direct axis syn reactance.

X_q = quadrature axis syn reactance.

I = current delivered at lagging pf ϕ.

$$P = |V|\cos\delta\,|I_q| + |V|\sin\delta\,|I_d|.$$

$$|I_q X_q| = |V\sin\delta|.$$

$$|I_q| = \frac{|V|\sin\delta}{X_q}.$$

$$|I_d X_d| = |E - V\cos\delta|.$$

$$|I_d| = \frac{|E| - |V|\cos\delta}{X_d}.$$

$$P = |V|\cos\delta\,\frac{(|V|\sin\delta)}{X_q} + |V|\sin\delta\,\frac{(|E|-|V|\cos\delta)}{X_d}.$$

$$= \frac{|V|^2\sin2\delta}{2X_q} + \frac{|V||E|\sin\delta}{X_d} - \frac{V^2\sin2\delta}{2X_d}$$

$$= \frac{|V|^2\sin2\delta}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right) + |V||E|\frac{\sin\delta}{X_d}$$

$$P = \frac{|V||E|\sin\delta}{X_d} + \frac{|V|^2\sin2\delta}{2}\left(\frac{X_d - X_q}{X_d\cdot X_q}\right)$$

Reluctance Power.

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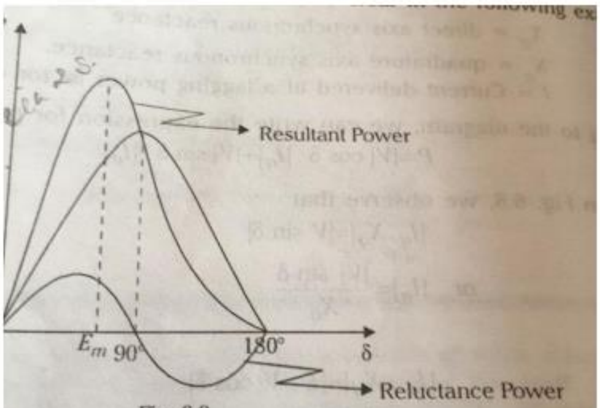
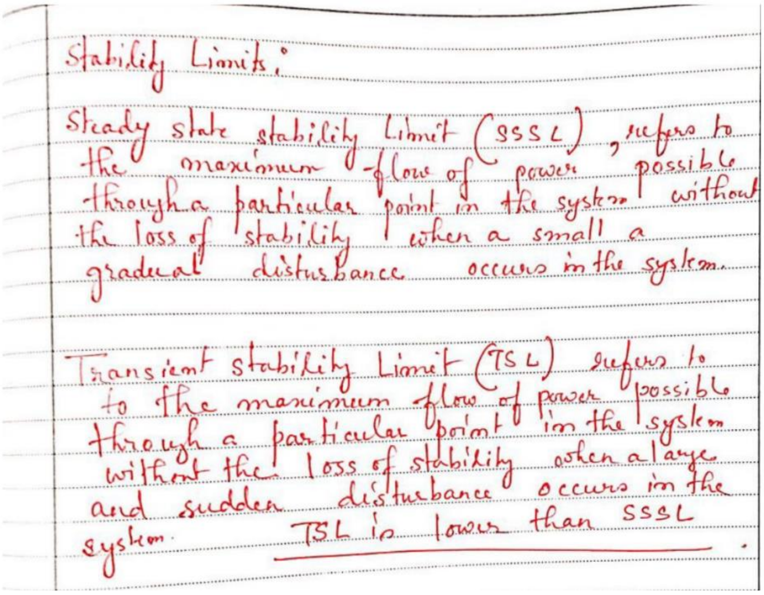
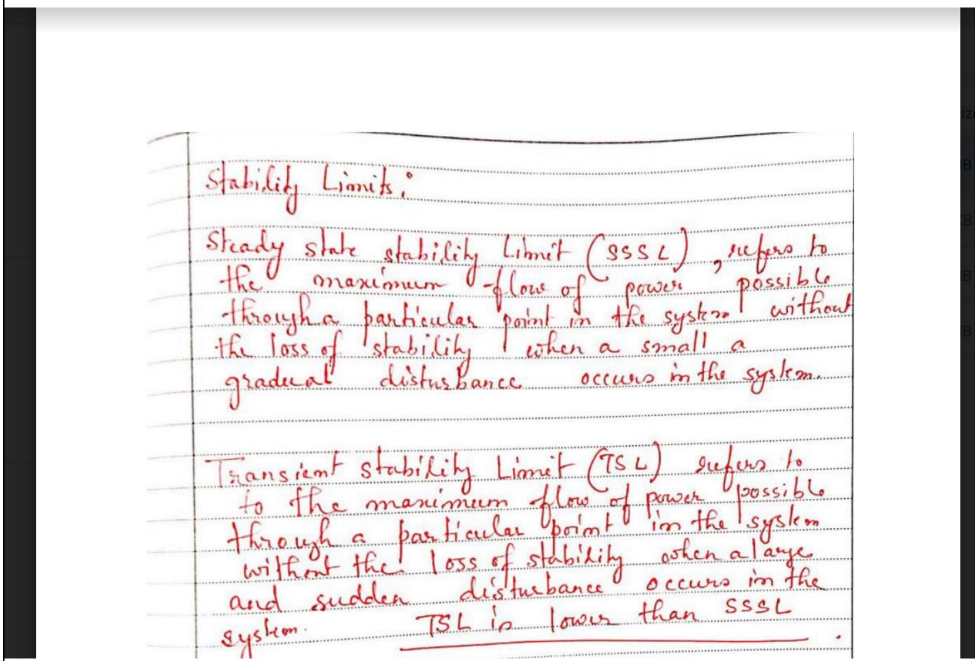
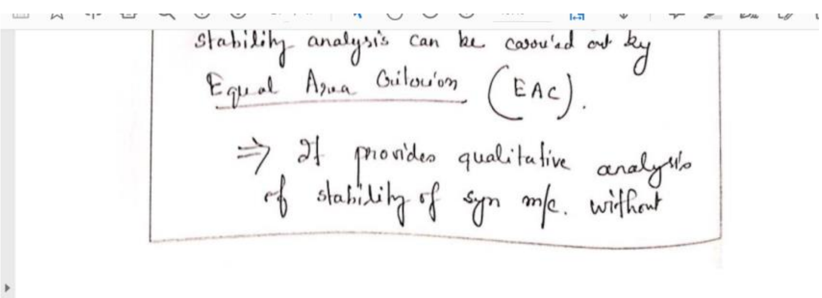


Fig. 6.9

</td><td></td><td></td><td></td></tr>
<tr><td>3.</td><td>Define a) steady state stability, b) transient stability, c) steady state stability limit, d) transient stability limit.</td><td>10</td><td>CO5</td><td>L1</td></tr>
</table>

	 Stability Limits: Steady state stability Limit (SSSL), refers to the maximum flow of power possible through a particular point in the system without the loss of stability when a small & gradual disturbance occurs in the system. Transient stability Limit (TSL) refers to the maximum flow of power possible through a particular point in the system without the loss of stability when a large and sudden disturbance occurs in the system. TSL is lower than SSSL.  Stability Limits: Steady state stability Limit (SSSL), refers to the maximum flow of power possible through a particular point in the system without the loss of stability when a small & gradual disturbance occurs in the system. Transient stability Limit (TSL) refers to the maximum flow of power possible through a particular point in the system without the loss of stability when a large and sudden disturbance occurs in the system. TSL is lower than SSSL.			
4.	Derive equal area criteria, and find its application with respect to following: sudden change in input.  Stability analysis can be carried out by Equal Area Criterion (EAC). ⇒ It provides qualitative analysis of stability of syn m/c. without	10	CO5	L2

...ng swing equation

Consider swing equation of a single machine connected to an infinite bus.

$$M\frac{d^2\delta}{dt^2} = P_a.$$

Multiplying both sides of the equation by

$\frac{2}{M}\frac{d\delta}{dt}$, we get

$$2\frac{d\delta}{dt} \times \frac{d^2\delta}{dt^2} = \frac{2}{M} P_a \frac{d\delta}{dt}$$

$$\frac{d}{dt}(x^2) = 2x\frac{dx}{dt}.$$

or $$\frac{d}{dt}\left(\frac{d\delta}{dt}\right)^2 = \frac{2}{M} P_a \frac{d\delta}{dt}$$

$$\left(\frac{d\delta}{dt}\right)^2 = \frac{2}{M}\int_{\delta_0}^{\delta} P_a \frac{d\delta}{dt} \cdot dt$$

$$= \frac{2}{M}\int_{\delta_0}^{\delta} P_a \, d\delta$$

$$\frac{d\delta}{dt} = \sqrt{\frac{2}{M}\int_{\delta_0}^{\delta} P_a . d\delta}$$

$\frac{d\delta}{dt} = 0.$ i.e $\sqrt{\frac{2}{M}\int_{\delta_0}^{\delta} P_a . d\delta} = 0$

$$\int_{\delta_0}^{\delta} P_a \, d\delta = 0.$$

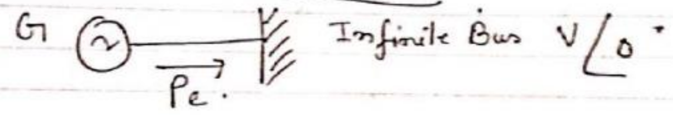
Applications of Equal Area Criterion

Illustration of EAC of stability for several types of disturbances in SMIB

Assumption.

1) T.L and syn m/c resistance are neglec
2) Rotor speed of syn m/c is constant.
3). Mech I/P to m/c constant.
4) Voltage behind transient reactance const
5). Effect of damper winding neglected.

a) Sudden Change in I/P



Let us consider sudden increase in mechanical I

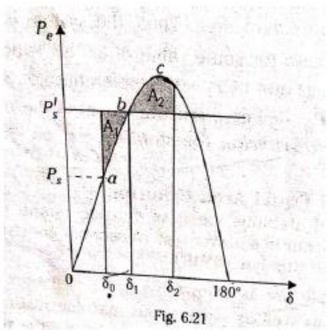


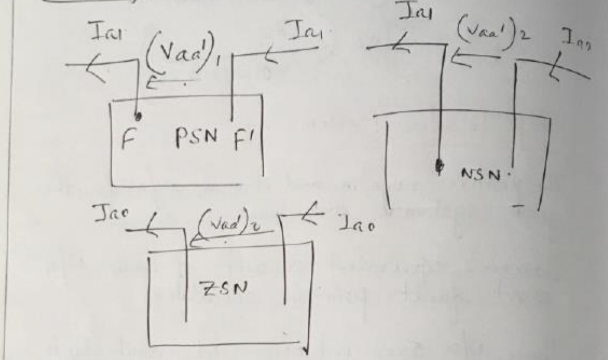
Fig. 6.21

	Curve $P_e - \delta$ shows the power angle curve with the system operating at point a corresponding to I/P P_s. Let mechanical I/P be P_s. ∴ Accelerating Power $P_a = P_s' - P_e$ causes rotor to accelerate. $\delta \uparrow \Rightarrow$ electric power transfer $\uparrow$, $P_a \downarrow$ till a point b at which $P_a = 0$. But rotor angle δ continue to $\uparrow$ because of inertia of rotor. and P_a becomes (−ve) causing to rotor decelerate. At point c where area A_1 = area A_2 on $\int_{\delta_0}^{\delta_2} P_a d\delta = 0 \Rightarrow \frac{d\delta}{dt} = 0$ (rotor vel.). and then starts to become negative owing to continued negative P_a Rotor angle reaches the max value δ_2 and			

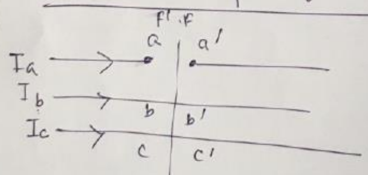
	then starts to decrease. $A_1 = \int_{\delta_0}^{\delta_1} (P_s' - P_e)\, d\delta$ $A_2 = \int_{\delta_1}^{\delta_2} (P_e - P_s')\, d\delta$ Find $(\delta_2)_{max}$ such that $A_1 = A_2$. As P_s is increased a limiting condition is finally reached when area A_1 equals the entire area A_2 above the line P_s' (as in fig 2). Under this condition δ_2 acquires the max. value δ_m. $\delta_2 = \delta_m = 180^\circ - \delta_1$ ⇒ System is <u>critically stable</u>. If P_s' increases further $A_2 < A$ ⇒ system is unstable			
5a	Discuss about how to improve transient stability.	5	CO5	L2

	the generator terminals. Load compensates for at least some of the reduction of load on generators and so reduces the acc. of the machine. (c) Fast valving or bypass valving: ⇒ the stability of a unit is improved by decreasing the mechanical I/P power to the turbine. When a fault occurs control scheme detects the diff betn mech I/P and reduced electrical o/p of the generator initiates the closing of a turbine valve to reduce the power I/P. (d) Full load rejection technique: (e) Using superconducting fault current limitors (SFCL).			
5b	Write short notes on series type of fault.	5	CO4	L2

Series types of Faults



One Conductor open fault



Terminal Condition

$$I_a = 0$$

$$V_{bb'} = 0$$

$$V_{cc'} = 0.$$

Symmetrical Component Relation.

$$(V_{aa'})_1 = \frac{1}{3}\left(V_{aa} + \alpha V_{bb'} + \alpha^2 V_{cc'}\right).$$

$$= \frac{1}{3}\left(V_{aa'} + 0 + 0\right) = \frac{1}{3} V_{aa'}$$

(-ve) seq. voltage is.

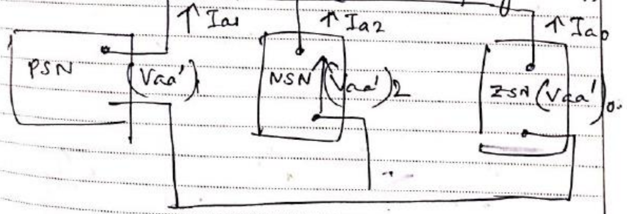
$$(V_{aa'})_2 = \frac{1}{3}\left(V_{aa'} + \alpha^2 V_{bb'} + \alpha V_{cc'}\right).$$

$$= \frac{1}{3} V_{aa'}.$$

$$(V_{aa'})_0 = \frac{1}{3}\left(V_{aa'} + V_{bb'} + V_{cc'}\right) = \frac{1}{3} V_{aa'}.$$

as $I_a = 0$ $\quad I_{a0} + I_{a1} + I_{a2} = 0.$

Similar to LLG fault (in terms of sym comp)



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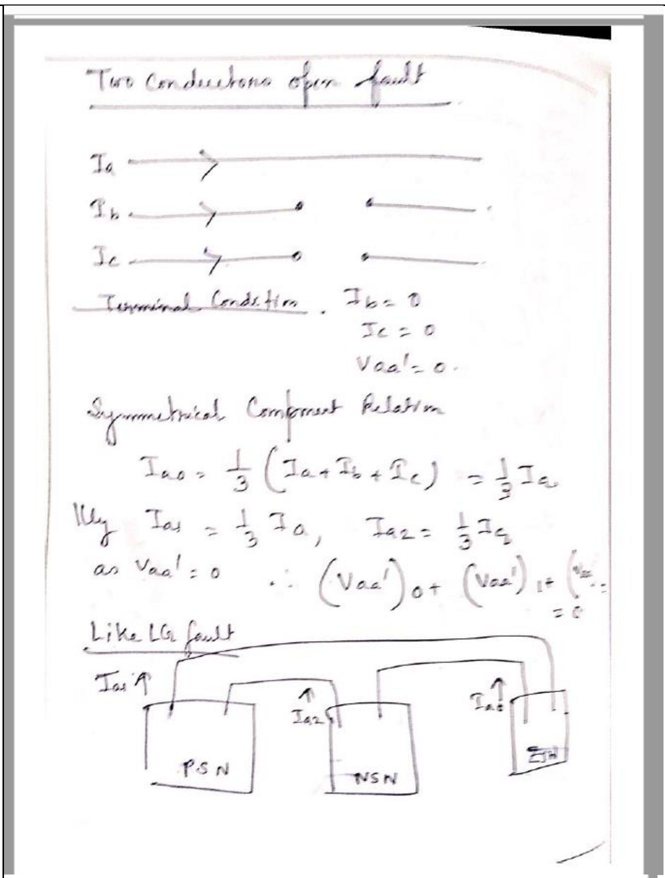
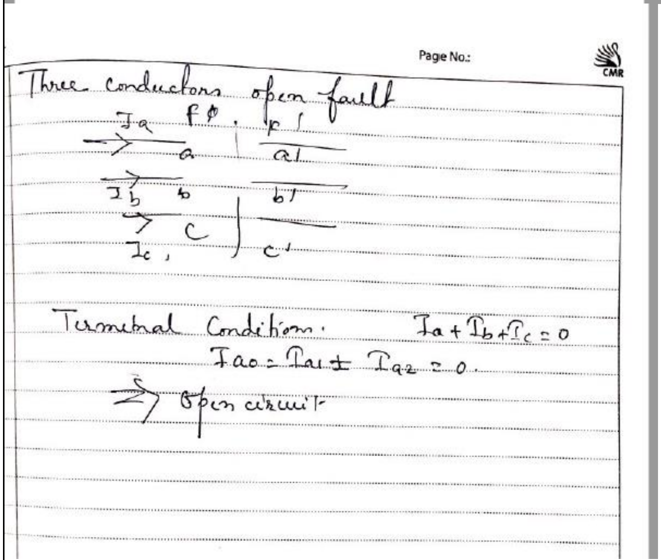
<tr><td></td><td>


</td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>A synchronous motor is receiving 10MW of power at 0.8pf lag at 6kV. An LG fault takes place at the middle point of the transmission line as shown in figure. Find the fault current. The ratings of the generator, motor and the transformer areas under:

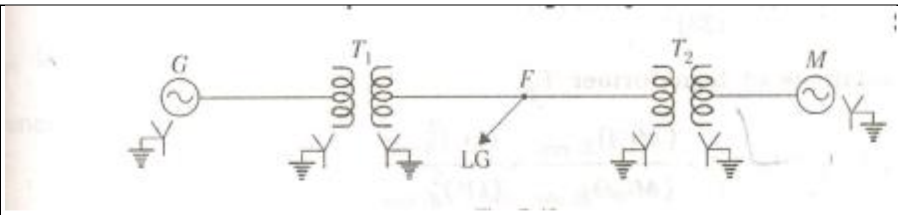
Generator:20 MVA, 11kV, X1=0.2 pu, X2=0.1 pu, X0=0.1 pu

Transformer T1: 18MVA, 11.5Y-34.5YkV, X=0.1 pu

Transmission Line:X1=X2=5Ω, X0=10Ω

Transformer T2: 15MVA, 6.9Y-34.5 Y kV, X=0.1 pu

Motor: 15MVA, 6.9kV, X1=0.2 pu, X2=X0=0.1 pu</td><td>10</td><td>CO4</td><td>L4</td></tr>
</table>



Solution.

Base Values. Let the base power for entire system be

$(MVA)_{B,new} = 20\ MVA$

Base voltage of gen $= 11\ KV$

" " of T.L $= 11 \times \frac{34.5}{11.5} = 33\ KV$.

" " of motor $= 33 \times \frac{6.9}{34.5} = 6.6\ KV$

Sequence reactances of generator

$X_1 = 0.2 \times \frac{20}{20} \times \frac{11^2}{11^2} = 0.2\ p.u.$

$X_2 = 0.1 \times \frac{20}{20} \times \frac{11^2}{11^2} = 0.1\ p.u.$

$X_0 = 0.1 \times \frac{20}{20} \times \frac{11^2}{11^2} = 0.1\ p.u$

Sequence reactance of T1

$X_1 = X_2 = X_0 = X \times \frac{(MVA)_{B,new}}{(MVA)_{B,old}} \times \frac{(KV)^2_{B,old}}{(KV)^2_{B,new}}$

$= 0.1 \times \frac{20}{18} \times \frac{11.5^2}{11^2} = 0.12\ p.u$

Sequence reactance of T.L

$X_1 = X_2 = X(\Omega) \times \frac{(MVA)_{B,new}}{(KV)^2_B}$

$= ~~50~~\ 5 \times \frac{20}{33^2} = 0.092\ p.u$

$X_0 = 10 \times \frac{20}{33^2} = 0.184\ p.u$

Sequence reactance of T2

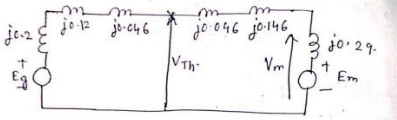
$X_1 = X_2 = X_0 = X \times \frac{20}{15} \times \frac{6.9^2}{6.6^2} = 0.146\ p.u.$

Sequence reactances of Motor

$X_1 = 0.2 \times \left(\frac{20}{15}\right) \times \left(\frac{6.9^2}{6.6^2}\right) = 0.29\ p.u$

$X_2 = X_0 = 0.1 \times \frac{20}{15} \times \frac{(6.9)^2}{(6.6)^2} = 0.145\ p.u.$

Positive Sequence Network



To find the voltage at the fault point (V_{Th})

The current drawn by the motor.

$I_m = \frac{10 \times 10^6}{\sqrt{3} \times 6 \times 10^3 \times 0.8} \angle -\cos^{-1} 0.8$

$= 1202.8 \angle -36.87^\circ A$.

Base current in the motor $(I_m)_B = \frac{20 \times 10^6}{\sqrt{3} \times 6.6 \times 10^3} = 1749.55 A$

$I_m|_{p.u} = \frac{1202.8}{1749.55} \angle -36.87^\circ$

$= 0.687 \angle -36.87^\circ$ pu.

V_m in pu $= \frac{6}{6.6} = 0.909 \angle 0^\circ$ p.u.

∴ Voltage at the fault point

$V_{Th} = V_m + I_m (j0.046 + j0.146)$

$= 0.909 \angle 0^\circ + 0.687 \angle -36.87 \times 0.192 \angle 90$

$= 0.994 \angle 6.1^\circ$ pu.

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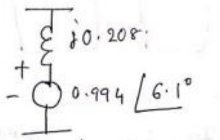
To find Thevenin's Impedance Z_{Th} at point F

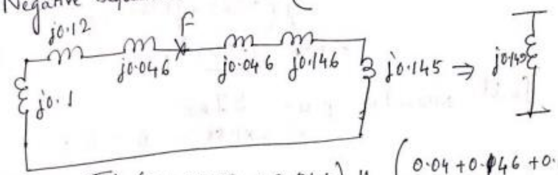
$Z_{1TH} = j[(0.2 + 0.12 + 0.046) \parallel (0.046 + 0.146 + 0.29)]$

$= j0.208$ p.u.

Equivalent PSN

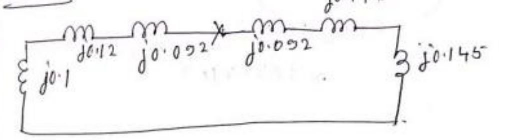


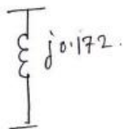
Negative Sequence Network (NSN).



$Z_{2Th} = [j(0.1 + 0.12 + 0.046) \parallel (0.04 + 0.046 + 0.145)]$

ZSN





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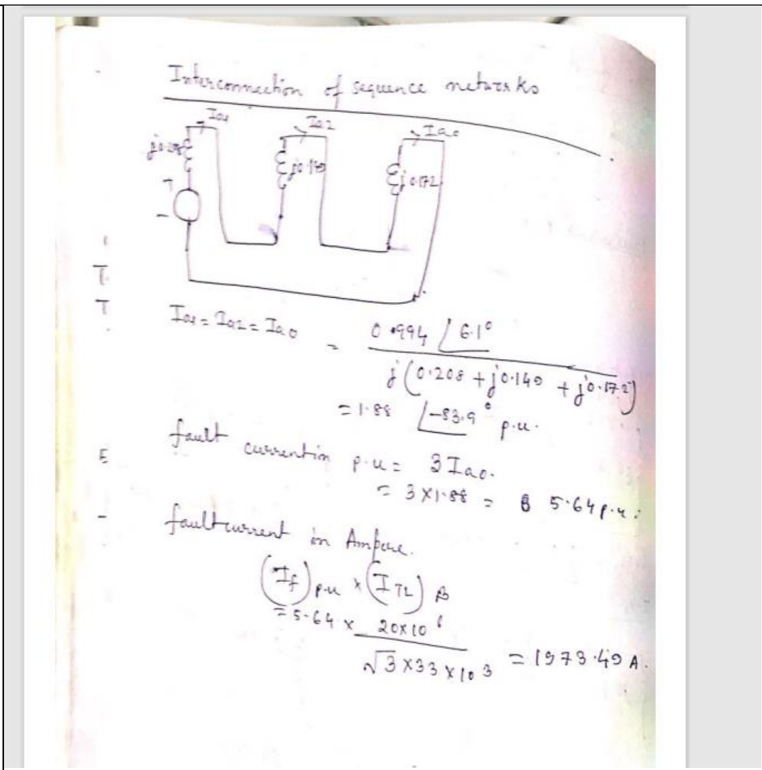
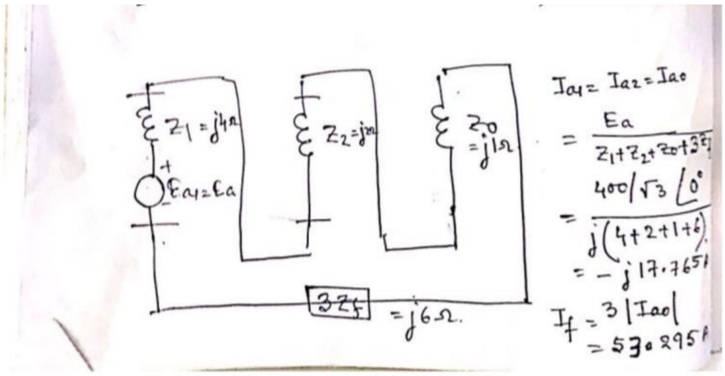
<tr><td></td><td>
</td><td></td><td></td><td></td></tr>
<tr><td>7.</td><td>A three phase generator with an open circuit voltage of 400V is subjected to an LG fault through a fault impedance of j2Ω. Determine the fault current if Z1=j4Ω, Z2=j2Ω, Z0=j1Ω

</td><td>10</td><td>CO3</td><td>L3</td></tr>
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