19EE10026

HARSH KUMAR JHA

Date ____/____/____

Question 11.14)

given, G_1 (machine) = 50 MVA

G_2 (machine) = 100 MVA

G (system) = 100 MVA

H_1 (machine) = 5 MJ/MVA

H_2 (machine) = 3 MJ/MVA

$n_1 = 4$, $n_2 = 3$

so equivalent inertia for combined system will be

$$H_{eq} = n_1 \times \left(\frac{G_1 \text{(machine)}}{G \text{(system)}}\right) H_{1,\text{machine}} + n_2 \times \left(\frac{G_2 \text{(machine)}}{G \text{ system}}\right) \times H_{2,\text{machine}}$$

$$= 4 \times \left(\frac{50}{100}\right) \times 5 + 3 \times \left(\frac{100}{100}\right) \times 3$$

$$\boxed{H_{eq} = 19 \text{ MJ/MVA}}$$

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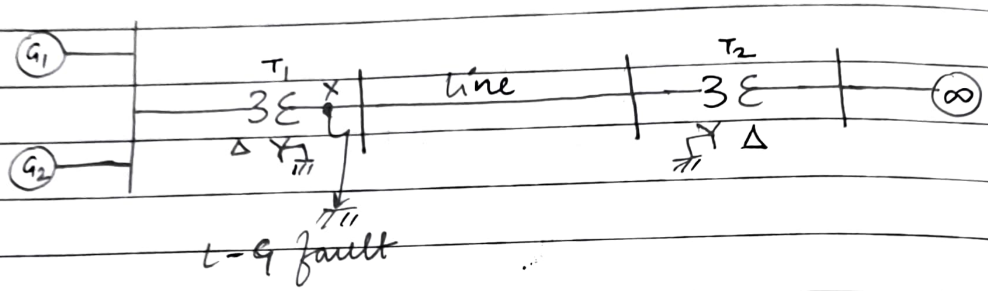
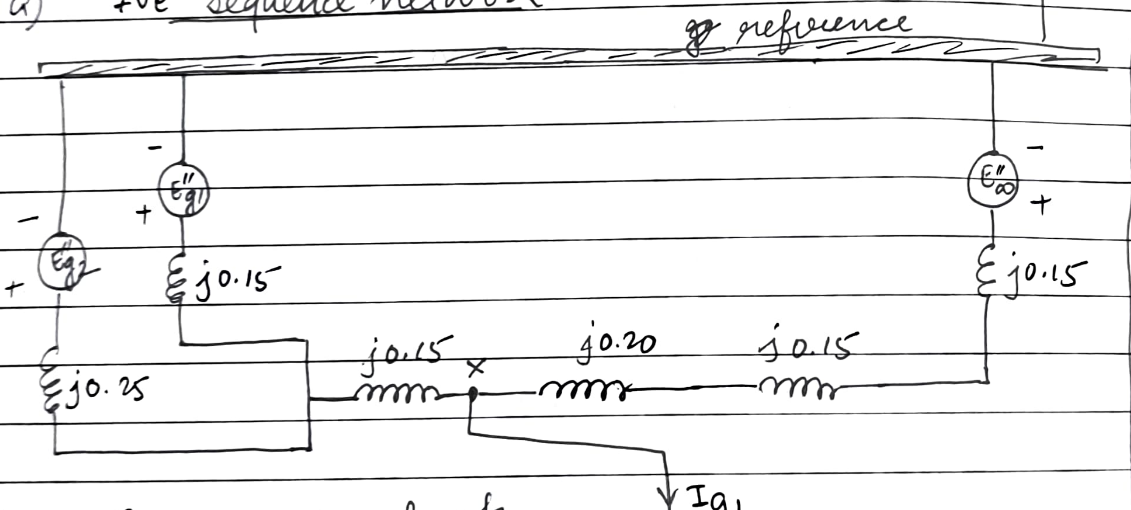
Exercise 10

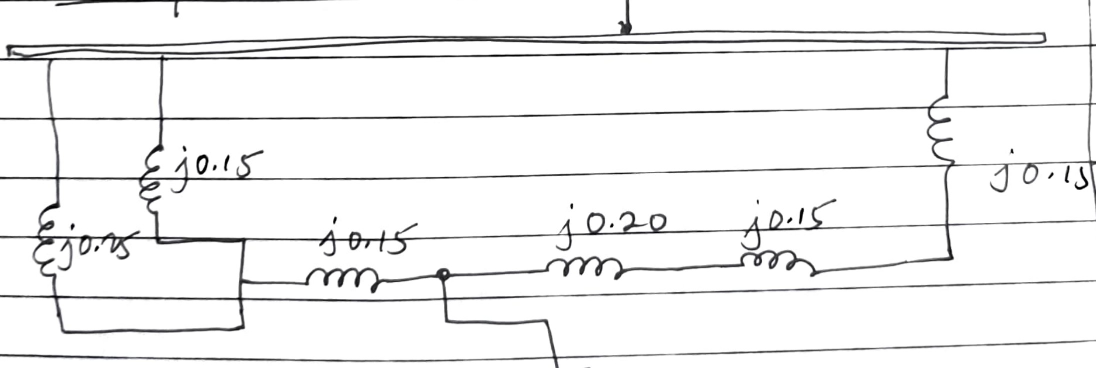
Q 10.1)



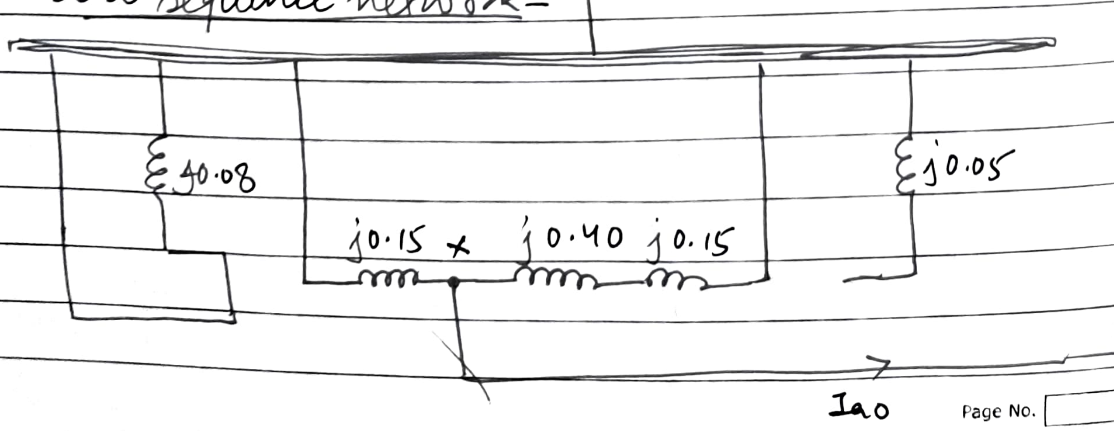
a) +ve sequence network-



b) -ve sequence network-



c) zero sequence network-



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b) Both generators and infinite bus operate at 1 pu voltage

~~so, equivalent voltage at the fault point~~

$$E_a = 1.0 \text{ pu}$$

let Z_1 = thevenin impedance of +ve sequence

Z_2 = " " of -ve sequence

Z_0 = " " of zero sequence

so $$Z_1 = \Big[\underbrace{(\underbrace{j0.15 \parallel j0.25}_{\cancel{0.0937j}}) + j0.15}_{0.2437j}\Big] \parallel \Big[\underbrace{j0.20 + j0.15 + j0.15}_{j0.50}\Big]$$

$$= j0.163$$

$$Z_2 = Z_1 = j0.163$$

$$Z_0 = (j0.15) \parallel (j0.55) = j0.1178$$

$$I_{a1} = \frac{E_a}{Z_1 + Z_2 + Z_0} = -j\,2.253 = I_{a0}$$

so fault current, $I_f = 3 I_{a0} = \underline{-j\,6.759 \text{ pu}}$

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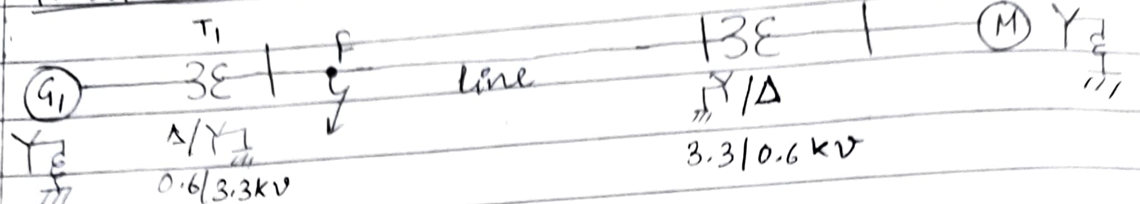
Question 10.2



Double line to ground fault

To find fault current in phase c of G_1

Machines → $1.2\,MVA,\ 0.6\,kV,\ x_1 = x_2 = 0.1\,pu,\ x_0 = 0.05\,pu$

T_1, T_2 → $1.2\,MVA,\ 0.05\,pu$ leakage reactance

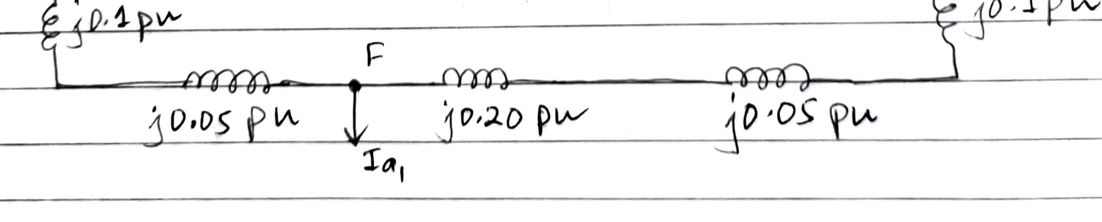
line → $x_{L1} = x_{L2} = 0.2\,pu,\quad x_{L0} = 0.40\,pu$

$1.2\,MVA,\ 3.3\,kV$ base

$x_n = 0.5\,pu$

Ans)

+ve sequence network -



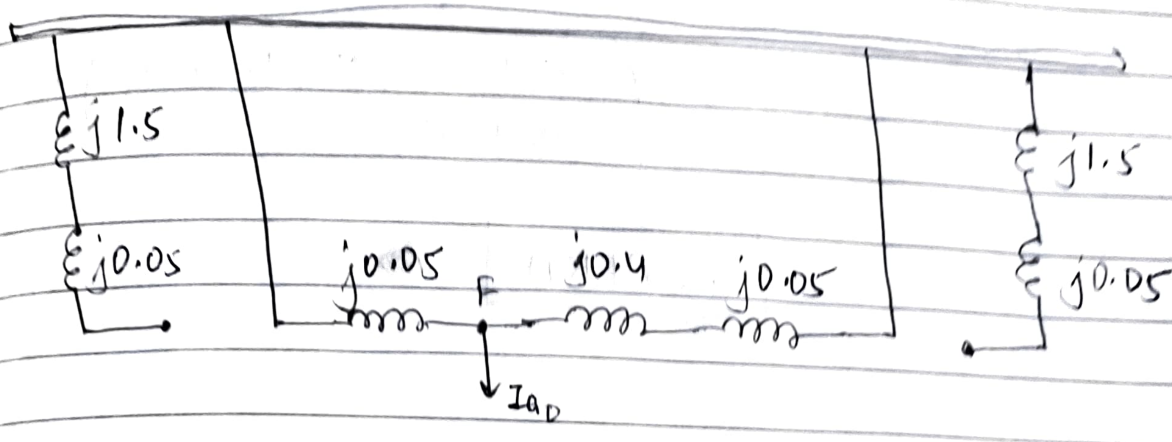
Z_1 = thevenin equivalent reactance for +ve sequence

$= (j0.1 + j0.05) \parallel (j0.2 + j0.05 + j0.1)\ pu$

$= j0.105\ pu$

so $\boxed{Z_1 = j0.105\,pu = Z_2}$

zero sequence network-



$$Z_0 = (j0.05) \,||\, (j0.4 + j0.05)$$

$$\boxed{Z_0 = j0.045}$$

so, $I_{a_1} = \dfrac{E_a}{Z_1 + \dfrac{Z_2 Z_0}{Z_2 + Z_0}}$ $(Z_f = 0)$

using the values of Z_1, Z_2 and Z_0 and $E_a = 1$ pu

$$\boxed{I_{a_1} = j-7.32 \text{ pu}}$$

$$I_{a2} = -\frac{(E_a - I_{a_1} Z_1)}{Z_2} = j2.20 \text{ pu}$$

$$I_{a0} = -\frac{(E_a - I_{a_1} Z_1)}{Z_0} = j5.142 \text{ pu}$$

now, $I_c = \dfrac{1}{3}\left[\beta I_{a_1} + \beta^2 I_{a2} + I_{a0}\right]$

$$= \frac{1}{3}\left[(j-7.32)\angle 120^\circ + j2.20\angle 240^\circ + j5.142\right]$$

$$\boxed{I_c = 3.76\angle 43^\circ \text{ pu}}$$

PTO

so component of phase C current in G_1

$$= I_c \times \left(\frac{0.35}{0.35+0.15}\right) \times \left(\frac{1.2\times10^6}{0.6\times10^3}\right) A$$

$$= \boxed{5.264\,KA}$$

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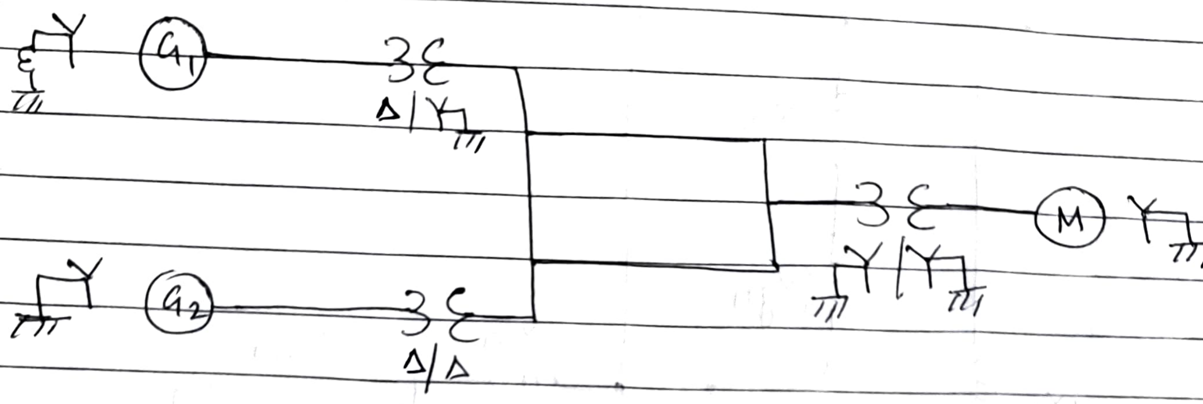
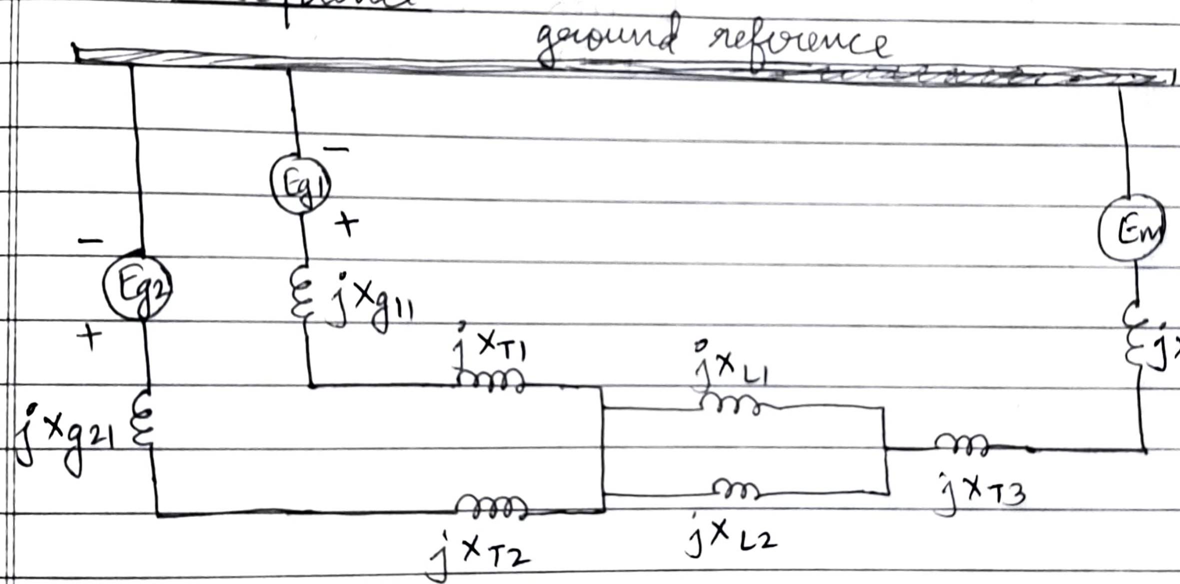
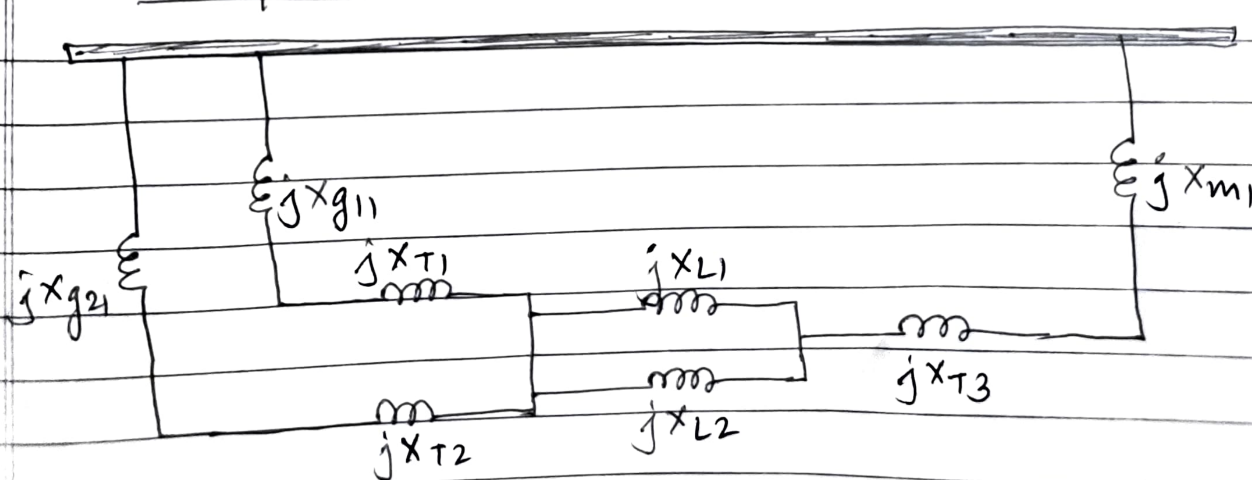
Question 9.4)



• +ve sequence -



• -ve sequence -



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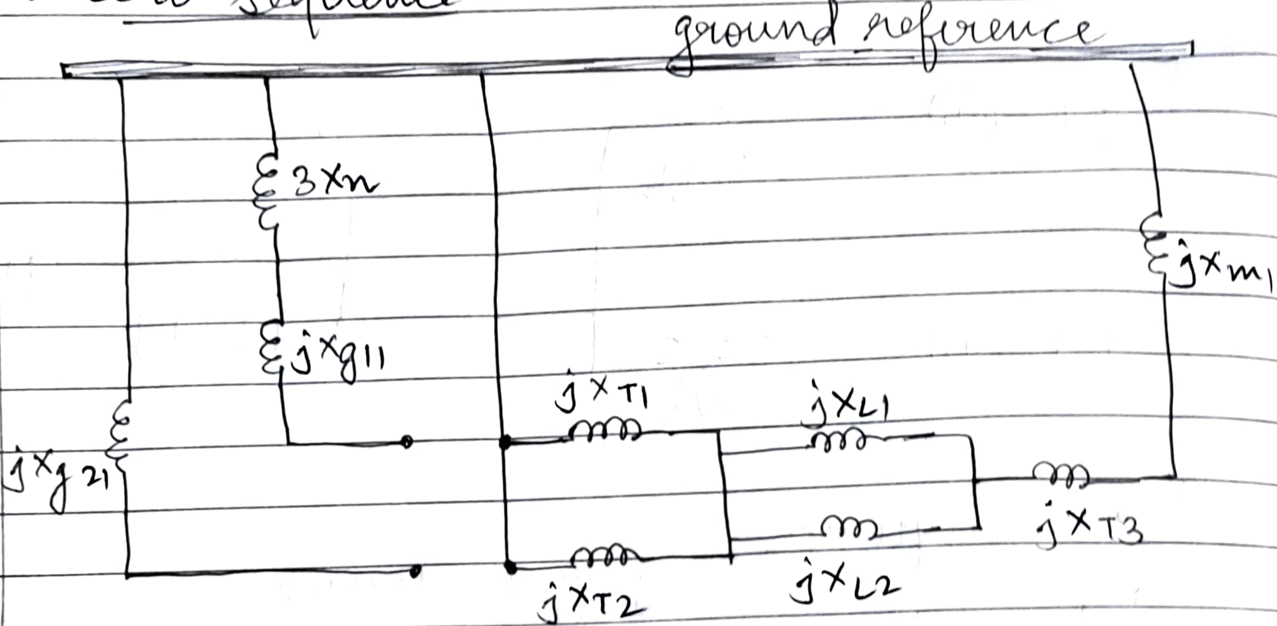
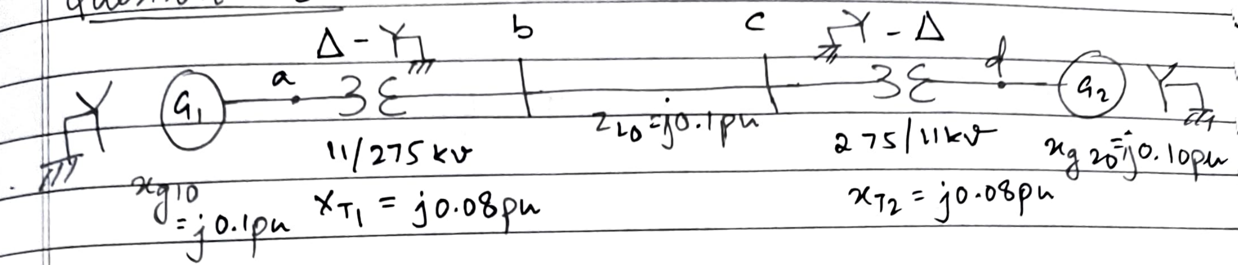
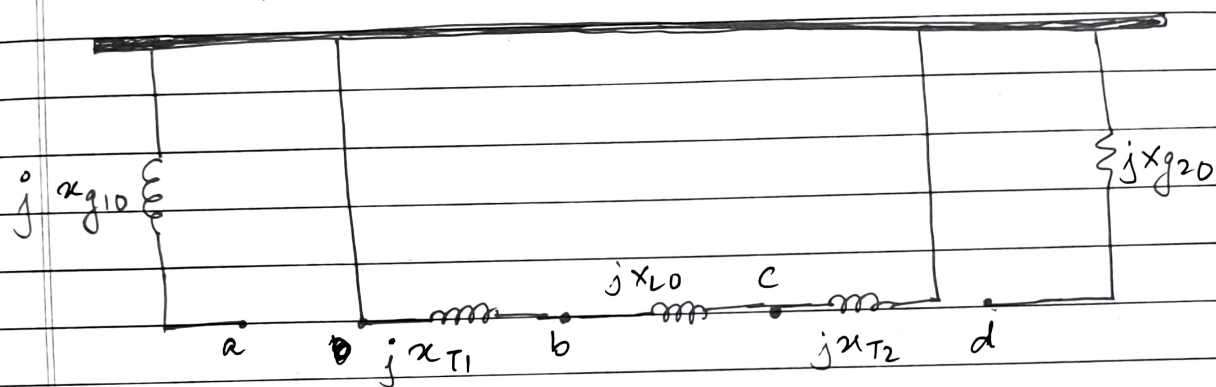
- Zero sequence -



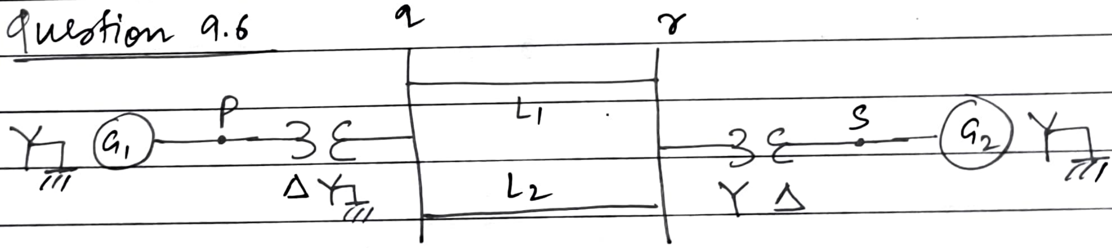
Question 9.5



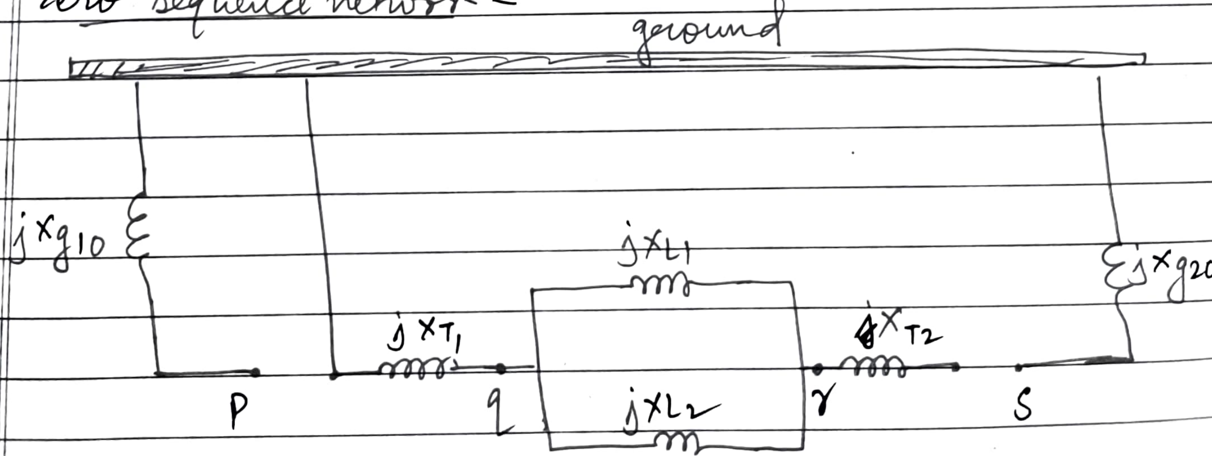
zero sequence network -



Question 9.6



zero sequence network -



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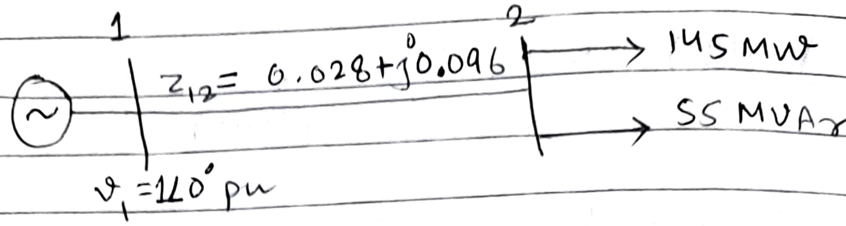
7.5)



assuming base = 100 MVA

$$y_{12} = \frac{1}{z_{12}} = y_{21} = 10\angle -73.74^\circ$$

$$y_{10} = 0, \quad y_{20} = 0$$

$$Y_{11} = y_{10} + y_{12} = 10\angle -73.74^\circ$$

$$Y_{22} = y_{20} + y_{21} = 10\angle -73.74^\circ$$

$$Y_{12} = Y_{21} = -y_{12} = 10\angle 106.26^\circ$$

so
$$Y_{bus} = \begin{bmatrix} 10\angle -73.74^\circ & 10\angle 106.26^\circ \\ 10\angle 106.26^\circ & 10\angle -73.74^\circ \end{bmatrix}$$

$$P_2 = \sum_{j=1}^{2} |v_2||v_j||Y_{2j}| \cos(\theta_{2j} - \delta_2 + \delta_j)$$

$$\frac{\partial P_2}{\partial \delta_2} = \sum_{\substack{k=1 \\ k\neq 2}}^{2} |v_2||v_k||Y_{2k}| \sin(\theta_{2k} - \delta_2 + \delta_k)$$

$$= |v_2||v_1||Y_{21}| \sin(\theta_{21} - \delta_2 + \delta_1)$$

$$\frac{\partial P_2}{\partial |v_2|} = 2|v_2||Y_{22}| \cos(\theta_{22}) + |v_1||Y_{21}| \cos(\theta_{12} - \delta_2 + \delta_1)$$

$$\frac{\partial Q_2}{\partial \delta_2} = |v_2||v_1||Y_{21}| \cos(\theta_{21} - \delta_2 + \delta_1)$$

$$\frac{\partial Q_2}{\partial |v_2|} = -|v_1||Y_{21}| \sin(\theta_{21} - \delta_2 + \delta_1) - 2|v_2||Y_{22}| \sin(\theta_{22})$$

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slack voltage $= 1\angle 0^\circ$ pu $= v_1$

$|v_2^0| = 1.0$, $\delta_2^{(0)} = 0$

$S_2^{sch} = -\dfrac{(145 + j55)}{100}$ pu $= -1.45 - 0.55j$ pu

$P_2^{(0)} = 10\cos(106.26^\circ - 0 + 0) + 10\cos(-73.740)$

$= 0$

$\Rightarrow \Delta p^{(0)} = p^{sch} - P_2^{(0)} = -1.45$ pu

$Q_2^{(0)} = -10\sin(106.26^\circ) - 10\sin(-73.740) = 0$

$\Rightarrow \Delta Q^{(0)} = -0.55$ pu

• Jacobian elements -

$J_1^{(0)} = \left(\dfrac{\partial P_2}{\partial \delta_2}\right)^{(0)} = 10\sin(106.26^\circ) = 9.6$

$J_2^{(0)} = \left(\dfrac{\partial P_2}{\partial |v_2|}\right)^{(0)} = 2\times 10\cos(-73.79^\circ) + 10\cos(106.26^\circ)$

$= 2.8$

$J_3^{(0)} = \left(\dfrac{\partial Q_2}{\partial \delta_2}\right)^{0} = 10\cos(106.26^\circ) = -2.8$

$J_4^{(0)} = \left(\dfrac{\partial Q_2}{\partial |v_2|}\right)^{0} = 9.6$

so $\begin{bmatrix} \Delta P_2^{(0)} \\ \Delta Q_2^{(0)} \end{bmatrix} = \begin{bmatrix} 9.6 & 2.8 \\ -2.8 & 9.6 \end{bmatrix} \begin{bmatrix} \Delta \delta_2^{(0)} \\ \Delta |V_2|^{(0)} \end{bmatrix}$

$\Rightarrow \begin{bmatrix} -1.45 \\ -0.55 \end{bmatrix} = \begin{bmatrix} 9.6 & 2.8 \\ -2.8 & 9.6 \end{bmatrix} \begin{bmatrix} \Delta \delta_2^{(0)} \\ \Delta |V_2|^{(0)} \end{bmatrix}$

3.

$\Rightarrow \Delta\delta_2^{(0)} = -0.1238 \quad \Rightarrow \delta_2^{(1)} = 0 - 0.1238 = \underline{-0.1238}$

$\Delta|V_2|^{(0)} = -0.0934 \quad \Rightarrow |V_2|^{(1)} = 1 - 0.0934 = \underline{0.9066}$

now,

$P_2^{(1)} = 0.9066 \times 10 \times \cos(106.26^\circ + 0.1238 \times 180/\pi)$
$= -1.29$ pu

$Q_2^{(1)} = -0.9066 \times 10 \sin(106.26^\circ + 0.1238 \times 180/\pi)$
$= -0.433$ pu

$\therefore \Delta P^{(1)} = -1.45 + 1.29 = -0.16$ pu
$\Delta Q^{(1)} = -0.55 + 0.433 = -0.117$ pu

$$\begin{bmatrix} \Delta\delta_2^{(1)} \\ \Delta|V_2|^{(1)} \end{bmatrix} = J^{-1} \begin{bmatrix} -0.16 \\ -0.117 \end{bmatrix} = \begin{bmatrix} -0.012084 \\ -0.015712 \end{bmatrix}$$

$\therefore \delta_2^{(2)} = -0.1238 - 0.012089 = -0.1359$ pu
$V_2^{(2)} = 0.9066 - 0.015712 = 0.891$ pu

so voltage after 2 iteration = ~~0.87~~ 0.891 pu
δ at bus after 2 iteration = -0.1359 rad

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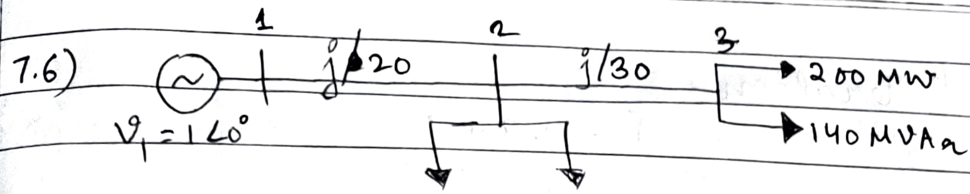
7.6)



$y_{12} = 20/j = -20j$, $y_{13} = 0$, $y_{23} = -30j$

$y_{10} = y_{20} = y_{30} = 0$

$Y_{11} = y_{10} + y_{12} + y_{13} = -20j$

$Y_{22} = y_{20} + y_{12} + y_{23} = -50j$

$Y_{33} = y_{30} + y_{13} + y_{23} = -20j$

$Y_{12} = Y_{21} = 20j$, $Y_{23} = Y_{32} = 30j$, $Y_{13} = Y_{31} = 0$

a) GS method -

$$S_2^{sch} = \frac{-j60 - 90}{100} = -0.9 - 0.6j \text{ pu} = P_2 + jQ_2$$

$$S_3^{sch} = \frac{-200 - 140j}{100} = -2 - 1.4j = P_3 + jQ_3$$

now, $$V_2^{(P+1)} = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{(V_2^{(P)})^*} - Y_{21}V_1 - Y_{23}V_3^{(P)}\right]$$

and $$V_3^{(P+1)} = \frac{1}{Y_{33}}\left[\frac{P_3 - jQ_3}{(V_3^{(P)})^*} - Y_{31}V_1 - Y_{32}V_2^{(P)}\right]$$

slack bus power →

$$P_1 = \sum_{k=1}^{3} |V_1||V_k||Y_{1k}| \cos(\theta_{1k} - \delta_1 + \delta_k)$$

$$Q_1 = -\sum_{k=1}^{3} |V_1||V_k||Y_{1k}| \sin(\theta_{1k} - \delta_1 + \delta_2)$$

$V_2^{(0)} = 1 + j0$, $V_3^{(0)} = 1 + j0$

-0,12

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- **1st iteration-**

$$V_2^{(1)} = \frac{1}{-50j}\left[\frac{-0.9+0.6j}{(V_2^{(0)})^*} - 20j - 30j \times V_3^{(0)}\right]$$

$$V_2^{(1)} = 0.988 \angle -1.044^\circ$$

$$V_3^{(1)} = \frac{-1}{20j}\left[\frac{-2+1.4j}{1} - 0 - 30j\, V_2^{(0)}\right] = 1.433 \angle -4^\circ$$

- **2nd iteration-**

$$V_2^{(2)} = \frac{j}{50}\left[\frac{-0.9+0.6j}{0.988\angle 1.044^\circ} - 20j - 30j \times 1.433\angle -4^\circ\right]$$

$$= \underline{1.247 \angle -3.6^\circ}$$

$$V_3^{(2)} = \frac{j}{20}\left[\frac{-2+1.4j}{1.433\angle 4^\circ} - 0 - 30j \times 0.988\angle -1.044^\circ\right]$$

$$= \underline{1.433 \angle -3.73^\circ}$$

$$P_1 = |V_1|^2 |Y_{11}| \cos(\theta_{11} - \delta_1 + \delta_1) + |V_1||V_2||Y_{12}|\cos(\theta_{12} - \delta_1 + \delta_2) + |V_1||V_3||Y_{13}|\cos(\theta_{13} - \delta_1 + \delta_3)$$

$$\underline{P_1 = 1.566 \text{ pu}}$$

similarly, $\underline{Q_1 = -4.89 \text{ pu}}$

$$\Rightarrow \boxed{S_1 = 1.566 \text{ pu} - j4.89 \text{ pu} = (156.6 - j489) \text{ MVA}}$$

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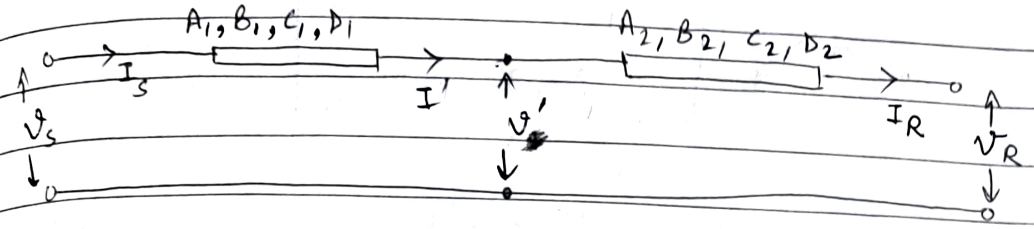
Q 6.11)

(i) series connection -



$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} V' \\ I' \end{bmatrix}$$

and $$\begin{bmatrix} V' \\ I' \end{bmatrix} = \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix}^{-1} \begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

or $$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$= \begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

where $A' = A_1 A_2 + B_1 C_2$, $B' = A_1 B_2 + B_1 D_2$

$C' = A_2 C_1 + D_1 C_2$, $D' = C_1 B_2 + D_1 D_2$

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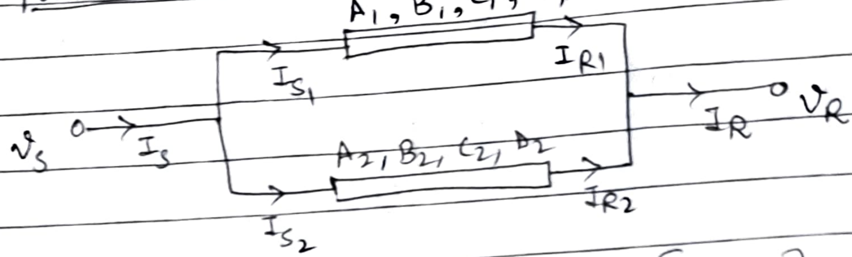
(ii) Parallel connection–



$$\begin{bmatrix} V_S \\ I_{S1} \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} V_R \\ I_{R1} \end{bmatrix} \text{ and } \begin{bmatrix} V_S \\ I_{S2} \end{bmatrix} = \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} V_R \\ I_{R2} \end{bmatrix}$$

$$\text{and } \begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

and $I_S = I_{S1} + I_{S2}$, $I_R = I_{R1} + I_{R2}$

now, $V_S = A_1 V_R + B_1 I_{R1}$ and $V_S = A_2 V_R + B_2 I_{R2}$

$I_{S1} = C_1 V_R + D_1 I_{R1}$ $\quad$ $I_{S2} = C_2 V_R + D_2 I_{R2}$

$$\Rightarrow \frac{V_S}{B_1} + \frac{V_S}{B_2} = V_R\left(\frac{A_1}{B_1} + \frac{A_2}{B_2}\right) + I_{R1} + I_{R2}$$

$$\Rightarrow V_S\left(\frac{B_1 + B_2}{B_1 B_2}\right) = V_R\left(\frac{A_1 B_2 + A_2 B_1}{B_1 B_2}\right) + I_R$$

or $\boxed{V_S = \left(\frac{A_1 B_2 + A_2 B_1}{B_1 + B_2}\right) V_R + \frac{B_1 B_2}{B_1 + B_2} I_R}$

and $\boxed{I_S = I_{S1} + I_{S2} = V_R(C_1 + C_2) + I_R(D_1 + D_2)}$

so $\boxed{A' = \frac{A_1 B_2 + A_2 B_1}{B_1 + B_2}}$ $\quad$ $\boxed{B' = \frac{B_1 B_2}{B_1 + B_2}}$

$\boxed{C' = C_1 + C_2}$ $\quad$ $\boxed{D' = D_1 + D_2}$

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Q 6.12) $V_R = 30\angle 0^\circ$ kV, pf = 0.8 lag, P = 10 MW
(given)

let current in parallel lines be I_1 and I_2

now, $|I_R| = \dfrac{10\text{ MW}}{|V_R| \times pf} = \dfrac{10\times 10^6}{30\times 10^3 \times 0.8} = 416.67\text{ A}$

so $I_R = 416.67\angle -36.87^\circ$
$= I_1 + I_2$ ——— (1)

and $V_R + I_1(5.5 + j13.5) = V_R + I_2(6 + j11)$

$\Rightarrow I_1 = I_2 \dfrac{(6+j11)}{(5.5+j13.5)} = 0.87\angle -8.28^\circ \times I_2$

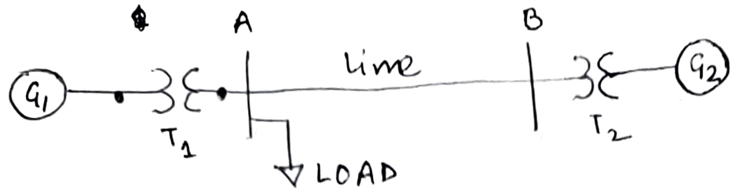
from (1), $416.67\angle -36.87^\circ = I_2\left[1 + 0.87\angle -8.28^\circ\right]$

$$\Rightarrow \boxed{\begin{aligned} I_2 &= 224.42\angle -33.89^\circ \text{ A} \\ I_1 &= 192\angle -40.33^\circ \text{ A} \end{aligned}}$$

so $P_2 = 30\, I_2 \cos\phi = 5585$ kW
$P_1 = 10\text{ MW} - P_2 = 4415$ kW

$(kVA)_2 = 30\angle 0^\circ \times I_2 = 6732\angle 33.89^\circ$ kVA
$(kVA)_1 = 30\angle 0^\circ \times I_1 = 5787\angle 40.33^\circ$ kVA

5.3)



G_1 : 90 MVA , 20 kV, $x_{g1} = 0.09$ pu

G_2: 90 MVA , 18 kV , $x_{g_2} = 0.09$ pu

T_1 : 80 MVA , 20/200 kV , $x_{t_1} = 0.16$ pu

T_2 : 80 MVA , 200/20 kV, $x_{t2} = 0.20$ pu

line : 200 kV, $x_{line} = 120\,\Omega$

load : 200 kV, $S = (48 + j64)$ MVA

Base : 100 MVA , 20 kV

Ans) $(MVA)_B = 100$

Base kV for generator G_1 and G_2 = 20 kV

now, for $G_1 \rightarrow$

$$x_{g1\,(new)} = 0.09 \times \frac{(MVA)_{B,new}}{(MVA)_{B,old}} \times \frac{(kV)^2_{B,old}}{(kV)^2_{B,new}}$$

$$= 0.09 \times \frac{100}{90} \times \frac{20^2}{20^2}$$

$$\boxed{x_{g1(new)} = 0.1\text{ pu}}$$

for $G_2 \rightarrow$

$$x_{g_2\,(new)} = 0.09 \times \frac{100}{90} \times \frac{18^2}{20^2}$$

$$\boxed{x_{g_2(new)} = 0.081\text{ pu}}$$

for T_1 →

$$x_{T_1,new} = 0.16 \times \frac{100}{80} \times \frac{20^2}{20^2}$$

$$\boxed{x_{t_1,new} = 0.2\,pu}$$

for T_2 →

$$x_{t_2,new} = 0.20 \times \frac{100}{80} \times \frac{20^2}{20^2}$$

$$\Rightarrow \boxed{x_{t_2,new} = 0.25\,pu}$$

for line →

$$(kV)_{B,line} = 20 \times \frac{200}{20}\,kV = \underline{\underline{200\,kV}}$$

$$Z_{B,line} = \frac{(kV)^2_{B,line}}{(MVA)_B} = \frac{200^2}{100} = 400\,\Omega$$

$$\text{so } x_{line} = \frac{120}{400}\,pu = \boxed{0.3\,pu = x_{line}}$$

ii) The load is ~~sp~~ given as $S = (48 + j64)$ MVA

a) Assuming series combination of resistance and inductance in load,

$$Z_{load} = \frac{(200)^2}{48 + j64} = 300 - 400j\,\Omega$$

$$\text{so, } Z_{load,\,pu} = \frac{Z_{load}}{Z_{B,line}} = \frac{300 - j400}{400}$$

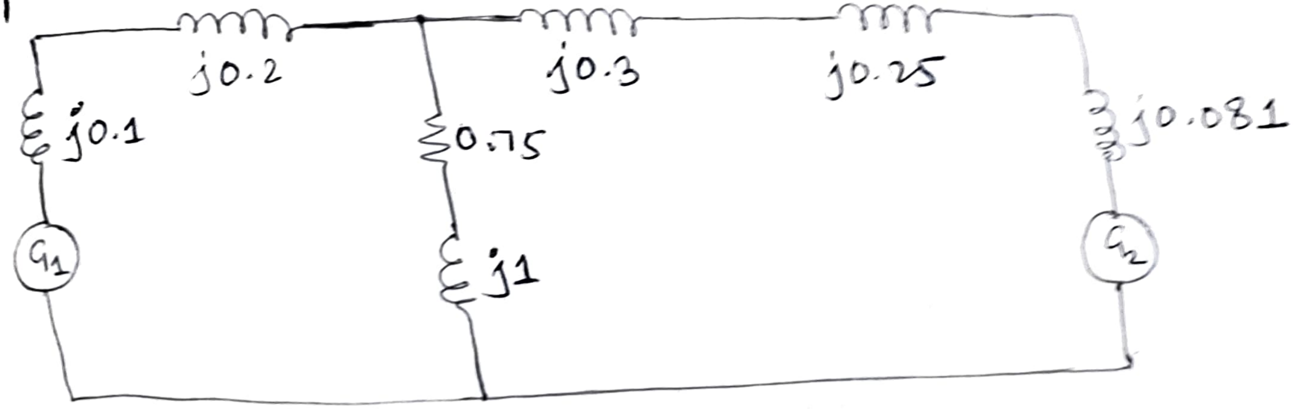
$$= (0.75 - j1)\,pu$$

so
$$\boxed{\begin{aligned} R_{series} &= 0.75\,pu \\ X_{series} &= j1\,pu \end{aligned}}$$

~~Reactance~~

~~Impedance~~ diagram will be →

Impedance



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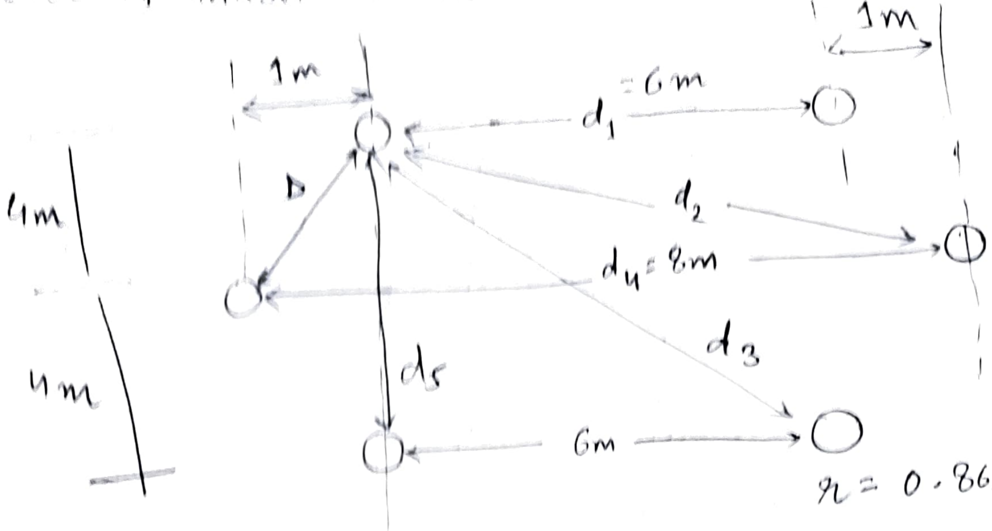
3.12)



$r = 0.865$ cm

~~no~~ now, capacitance to ~~nete~~ neutral, $C_{AN} = \dfrac{0.0242}{\log\left(\frac{D_{eq}}{D_s}\right)}$ µF/km

now, $d_1 = 6$ m (given)

$d_2 = \sqrt{4^2 + 7^2} = 8.062$ m

$d_3 = \sqrt{8^2 + 6^2} = 10$ m

$d_4 = 8$ m (given)

$d_5 = 8$ m

$D = \sqrt{4^2 + 1^2} = 4.123$ m

so, $D_{eq} = D^{1/3} \cdot d_2^{1/3} \cdot d_1^{1/6} \cdot d_5^{1/6} = 6.129$ m

and $D_s = r^{1/2} \cdot d_3^{1/3} \cdot d_4^{1/6} = 0.283$ m

so $C_{AN} = \dfrac{0.0242}{\log\left(\frac{6.129}{0.283}\right)}$ µF/km $= 0.0181$ µF/km

so capacitive admittance ~~reactance~~ to ~~net~~ neutral
$= 2\pi f C_{AN}$ ~~ohm~~/km mho $= \boxed{5.686 \times 10^{-6} \text{ mho/km}}$

now, charging current, $|I_{chg}| = 2\pi f C_{av} \times |V_{LN}|$

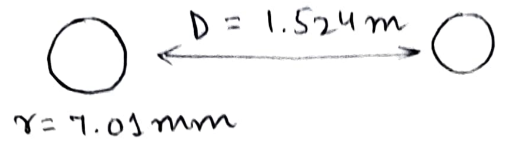
$= 2\pi \times 50 \times 0.0181 \times \frac{132}{\sqrt{3}} \times 10^{-3}$

$= 0.433$ Amp/ km

so charging current per conductor $= \frac{0.433}{2}$ Amp/km

$= 0.2166$ Amp/km

3.9)



line - to - line capacitance, $C_{12} = \dfrac{0.0121}{\log\left(\frac{D}{r}\right)}$ μF/km

$\Rightarrow C_{12} = \dfrac{0.0121}{\log\left(\frac{1.524}{7.01\times10^{-3}}\right)}$ μF/km

• so total line - to - line capacitance

$= \dfrac{0.0121}{\log\left(\frac{1.524}{7.01\times10^{-3}}\right)} \times 32.16$ μF

$\boxed{= 0.166 \text{ μF}}$

• line - to - line admittance $= j2\pi f \times C_{l-l}$

$= j6.27\times10^{-5}$ mho

(given $f = 60$ Hz)

• reactive power $= v^2 \times$ (admittance)

$= (20\times1000)^2 \times 6.27\times10^{-5}$ VAr

$= \boxed{25.08 \text{ kVAr}}$

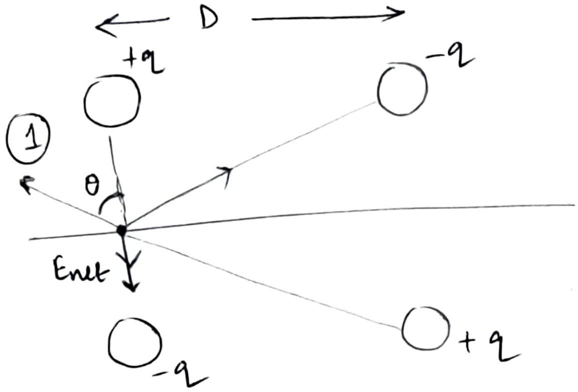
3.11) from 3.9

line-to-line capacitance = 0.166 μF

and length of conductor, L = 32.16 km

so charge per length, $\lambda = \frac{C}{L} = \frac{0.166 \times 10^{-6}}{32.16 \times 1000}$

$= 103.233 \times 10^{-9}$ C/m



(i) Surface electric field at conductor (1), E_1

E_1 won't have much effect from other charges.

so $E_1 = \frac{\lambda}{2\pi \epsilon_0 r} = \boxed{2.66 \text{ kV/cm}}$

(using r = 7.01 mm)

(ii) directly under the conductor on ground,

$$E_{net} = \frac{2\lambda}{2\pi\epsilon_0 \times h} - \frac{2 \times \lambda}{2\pi\epsilon_0 \sqrt{h^2+d^2}} \times \left(\frac{h}{\sqrt{h^2+d^2}}\right)$$

$$= \frac{2\lambda h}{2\pi\epsilon_0}\left(\frac{1}{h^2} - \frac{1}{h^2+d^2}\right)$$

$$= \boxed{0.0483 \text{ kV/m}}$$

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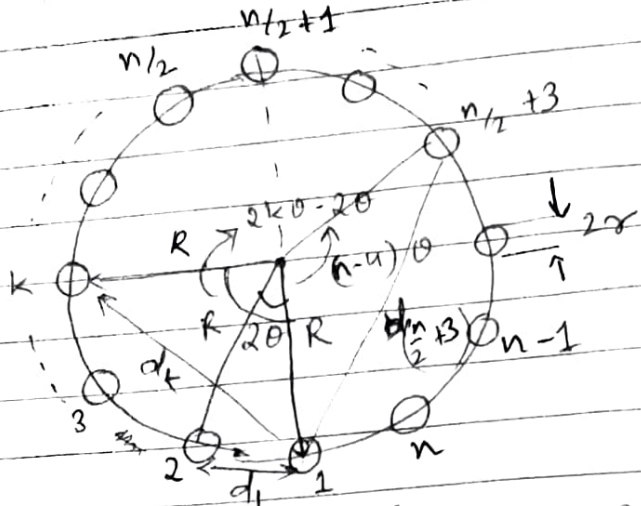
2.2)



now, $2\theta \times n = \cancel{180}\ 360°$ (n = no. of subconductors)

$\Rightarrow n\theta = 180°$

and $d^2 = 2R^2(1-\cos(2\theta))$

$\Rightarrow d = R\sin\theta$

see the figure for semiconductor labelling and d_k value

$\Rightarrow d_k = 2R\sin[(k-1)\theta]$

for $k = \frac{n}{2}+3$, $\boxed{d_{\frac{n}{2}+3} = 2R\sin\left(\left(\frac{n}{2}+2\right)\theta\right)}$

and from figure, $d_{(\frac{n}{2}+3)} = 2R\sin\left(\left(\frac{n-4}{2}\right)\theta\right)$

and $\left(\frac{n}{2}+2\right)\theta + \left(\frac{n-4}{2}\right)\theta = n\theta = 180°$

so $\sin\left(\left(\frac{n-4}{2}\right)\theta\right) = \sin\left(\frac{n+4}{2}\right)\theta$

$\therefore$ we can generalise the expression of d_k for all distances.

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$$GMR = \left\{ r^1 \cdot \prod_{k=2}^{n} 2R \sin(k-1)\theta \right\}^{1/n}$$

$$= \left\{ r^1 \cdot (2R)^{n-1} \cdot \prod_{k=2}^{n} \sin(k-1)\theta \right\}^{1/n}$$

$$\boxed{GMR = \left\{ r^1 \cdot (2R)^{n-1} \cdot \prod_{k=1}^{n-1} \sin(k\theta) \right\}^{1/n}}$$

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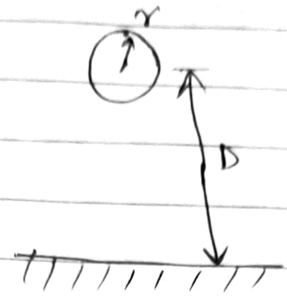
2.11)



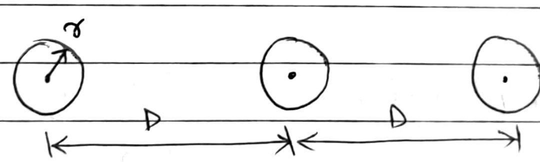
We need to consider charge imaging here.
so, distance between conductor and its image = 2D

so $L = 0.4605\left[\log\left(\frac{1}{r'}\right) \cdot \log\left(\frac{1}{2D}\right)\right]$

$= 0.4605\left[\log\left(\frac{100\times2}{e^{-1/4}\times1.956}\right) \cdot \log\left(\frac{1}{2\times6.705}\right)\right]$

$$\boxed{L = 1.493 \text{ mH/km}}$$

2.12)



$r = 1.25$ cm, $D = 3$ m (given)

~~La = 0.4605~~

$L_a = 2\times10^{-7}\left[\ln\left(\frac{1}{r'}\right) + \ln\sqrt{D\times2D} + j\sqrt{3}\ln\sqrt{\frac{D}{2D}}\right]$ H/m

$\Rightarrow \boxed{L_a = (1.22 - j0.12) \text{ mH/km}}$

$L_B = 2\times10^{-7}\left[\ln\left(\frac{1}{r'}\right) + \ln\sqrt{D\times D} + j\sqrt{3}\ln\sqrt{\frac{D}{D}}\right]$ H/m

$\Rightarrow \boxed{L_B = 1.14 \text{ mH/km}}$

$L_C = 2\times10^{-7}\left[\ln\left(\frac{1}{r'}\right) + \ln\sqrt{D\times2D} + j\sqrt{3}\ln\sqrt{\frac{2D}{D}}\right]$ H/m

$\Rightarrow \boxed{L_C = (1.22 + j0.12) \text{ mH/km}}$

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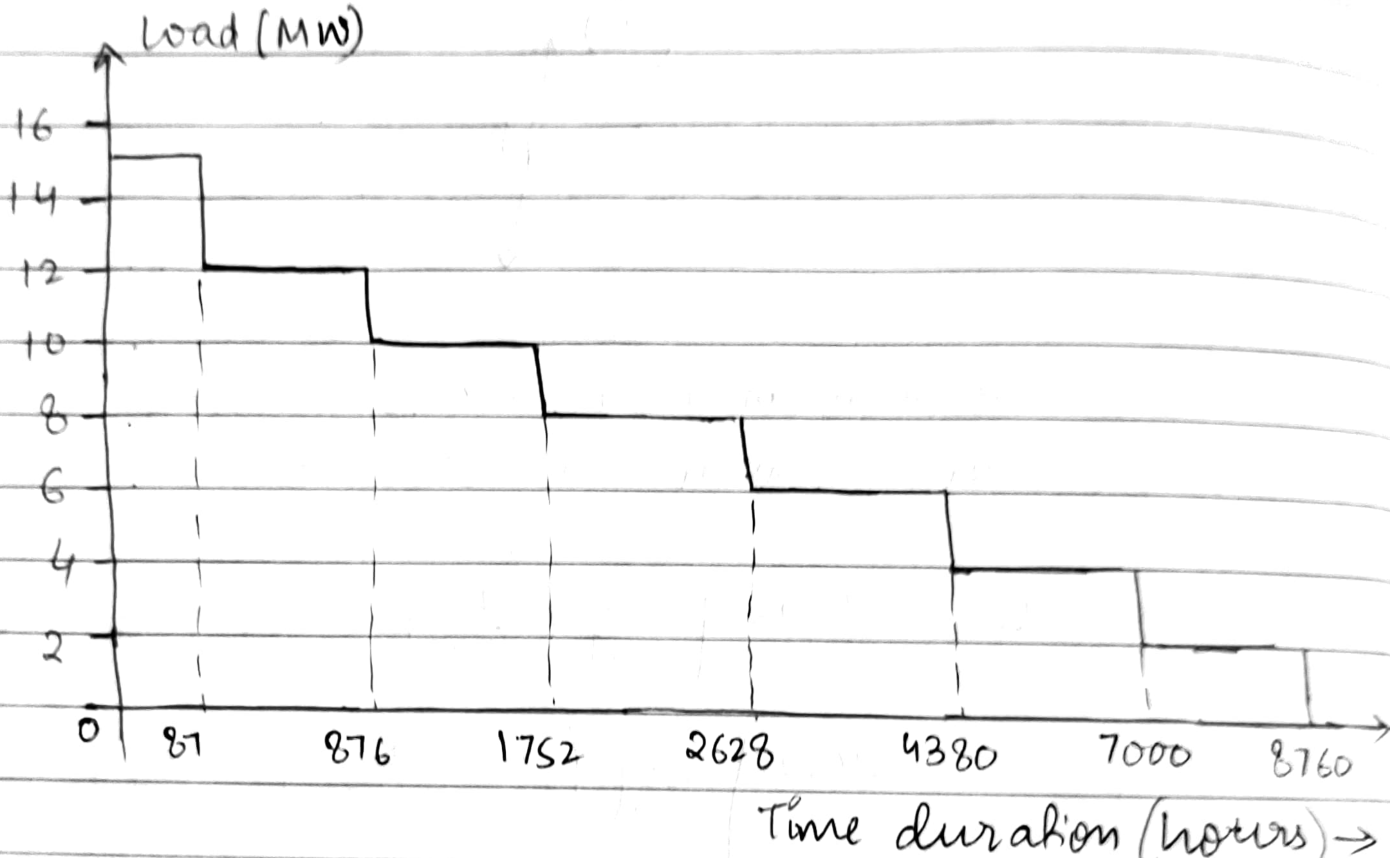
1.1) Load duration curve -



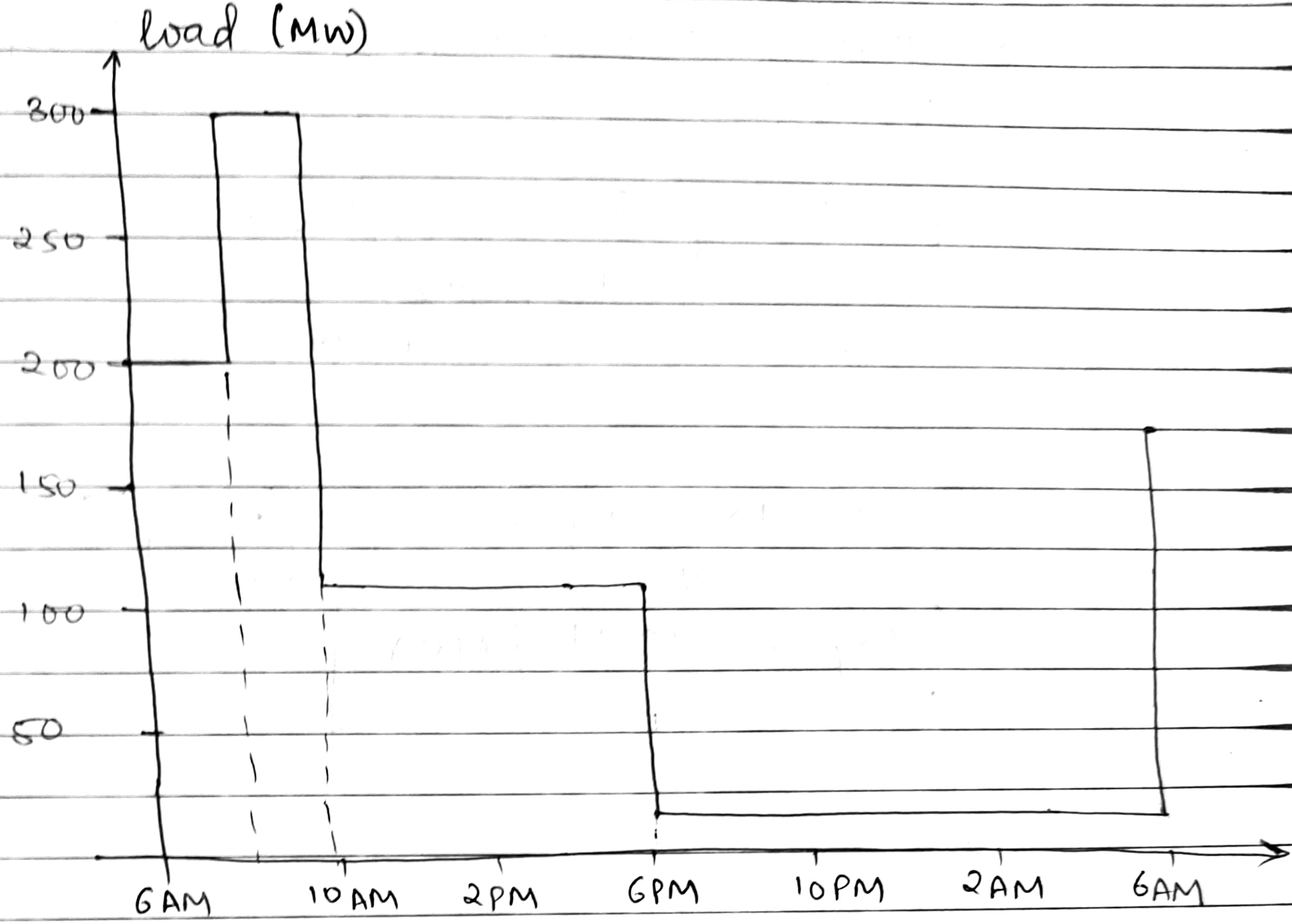
$$\text{Average load} = \frac{\text{Units generated}}{\text{Time}}$$

$$= 5.827 \text{ MW}$$

$$\text{so load factor} = \frac{\text{Average Load}}{\text{Max load}}$$

$$= \frac{5.827}{15} = \underline{\underline{0.389}}$$

1.4)



- daily energy produced = $(200 \times 2 + 300 \times 2 + 120 \times 8 + 20 \times 12)$

$= 2200$ MWhr

- load factor $= \left(\frac{2200}{24}\right) / 300 = 0.3055$

• Diversity factor = $\cancel{\dfrac{200+300+150+20}{300}}$

$= \dfrac{100+150+50+20}{300}$

$= \underline{1.067}$