19EE10039.
Mansi Uniyal.

3/4/2022

11.14

$G1 = 50MVA$ }
$G_2 = 100MVA$. } machine.
$G = 100MVA$ - system

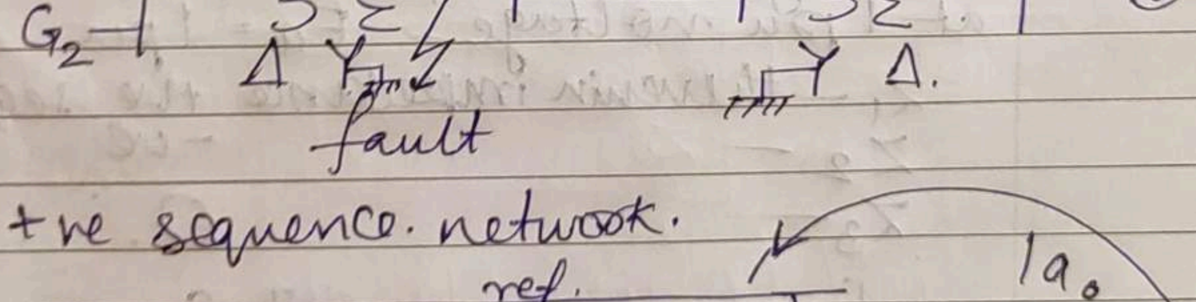
$H_1 = 5MJ/MVA$ }
$H_2 = 3MJ/MVA$ } machine.

$n_1 = 4, n_2 = 3$.

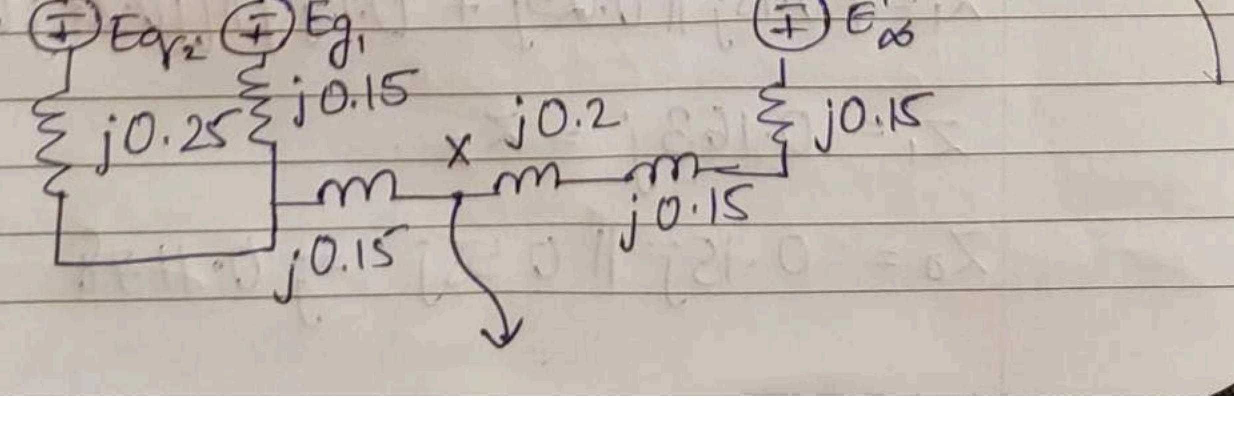
$$H_{eq} = n_1\left(\frac{G1}{G}\right)H_1 + n_2\left(\frac{G2}{G}\right)H_2.$$

$\underline{H_{eq} = 19 MJ/MVA}$

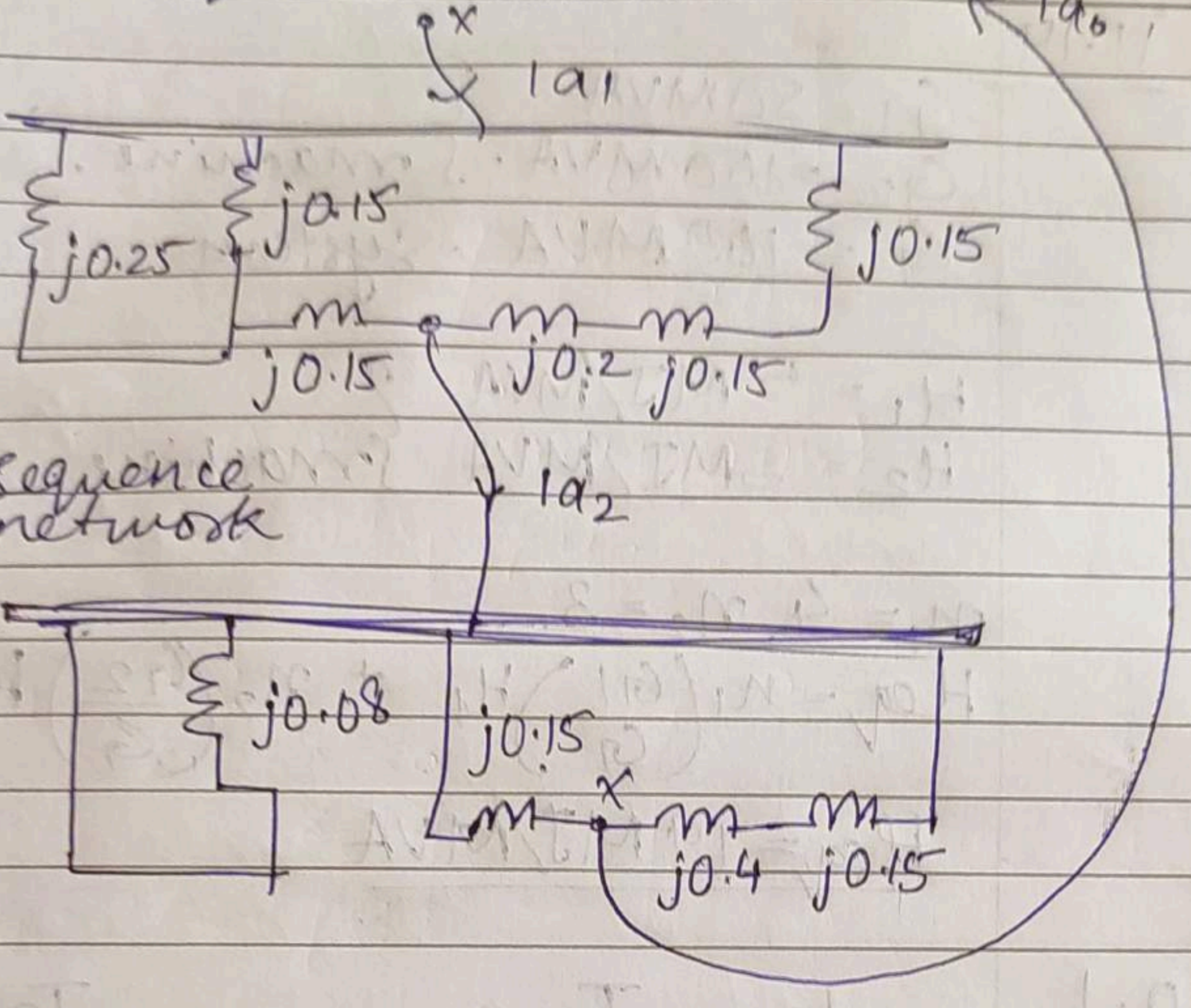
10.1



a) +ve sequence network.



b) -ve sequence network.



c) 0 sequence network

B) Both generator + infinite Bus operate at 1 pu voltage $E_a = 1$ pu

Z_1 — thevenin impedance +ve sequence

Z_2 — -ve

Z_3 — 0.

$$Z_1 = [0.15j \parallel 0.25j + 0.15j] \parallel [j0.2 + j0.15 + j0.15]$$

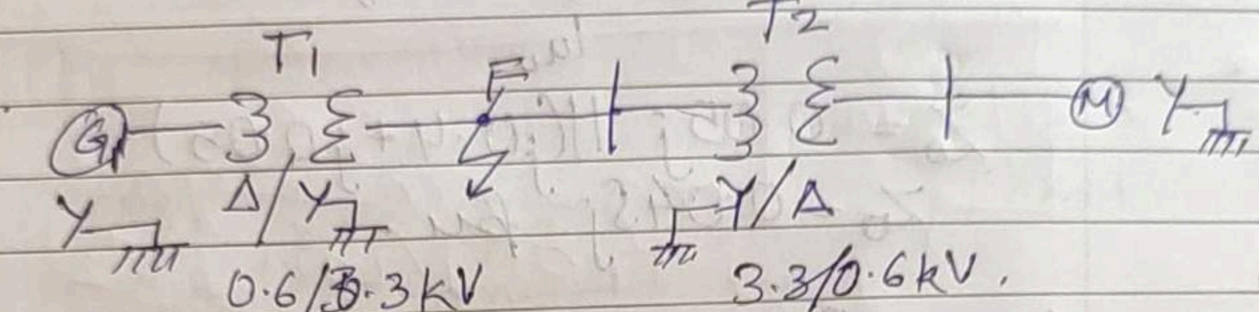
$$Z_1 = 0.163j = Z_2.$$

$$Z_0 = 0.15j \parallel 0.55j = j0.1178$$

$$I_{a_1} = \frac{E_a}{Z_1 + Z_2 + Z_0} = -j2.253 = I_{a_0}.$$

So fault current $I_f = 3I_{a_0} = -j6.759$ pu.

10.2



$x_1 = x_2 = 0.1$ pu $\quad x_0 = 0.05$ pu

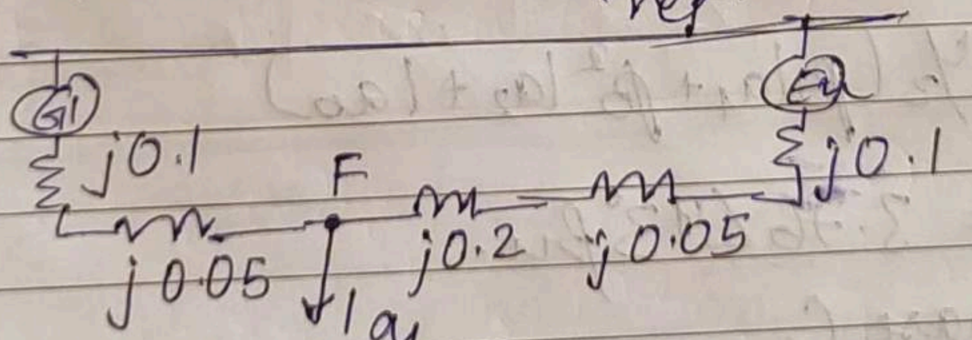
$T_1 \rightarrow 1.2$ MVA $\quad T_2 - 0.05$ pu.

$x_{L_1} = x_{L_2} = 0.2$ pu

$x_{L_0} = 0.4$ pu.

$x_n = 0.5$ pu.

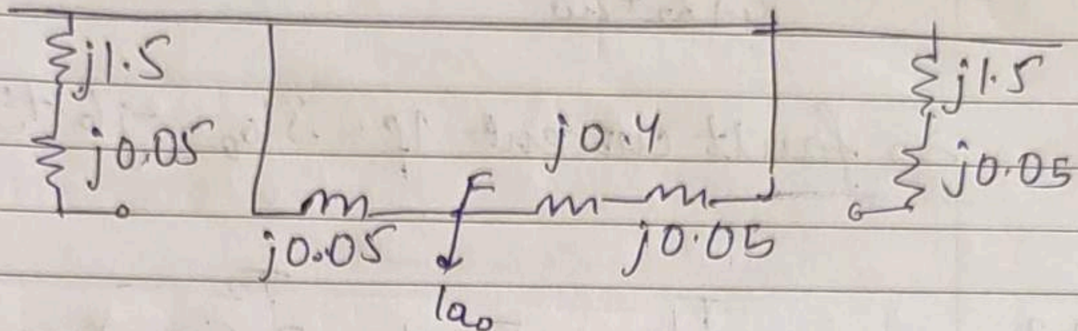
+ve sequence.



$Z_1 = (0.1j + 0.05j) \,||\, (0.2j + 0.05j + 0.1j)$

$Z_1 = 0.105j$ pu $= Z_2$.

O sequence



$$Z_0 = 0.05j \parallel (j0.4 + j0.05)$$
$$Z_0 = 0.045j \text{ pu.}$$

$$I_{a1} = \frac{E_a}{Z_1 + \frac{Z_2 Z_0}{Z_2 + Z_0}} \qquad Z_f = 0.$$

$$I_{a1} = -j7.32 \text{ pu.}$$

$$I_{a2} = -\frac{(E_a - I_{a1}Z_1)}{Z_2} = j2.2 \text{ pu.}$$

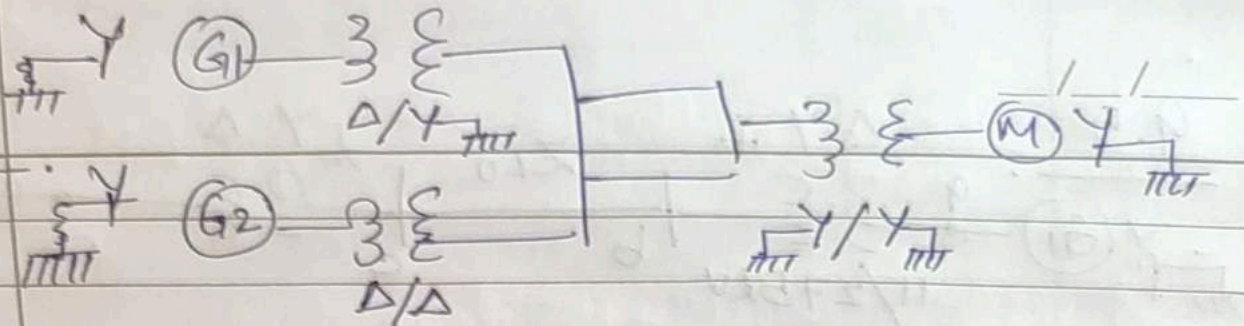
$$I_{a0} = -\frac{(E_a - I_{a1}Z_1)}{Z_0} = j5.142 \text{ pu.}$$

$$I_c = \frac{1}{3}(\beta I_{a1} + \beta^2 I_{a2} + I_{a0})$$

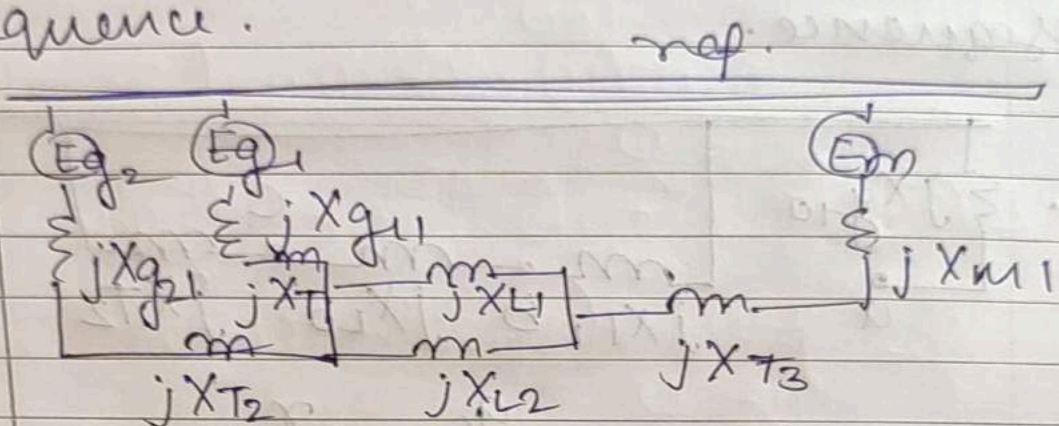
$$I_c = 3.76\angle 43^\circ \text{ pu.}$$

comp. of phase C in $G_1 = I_c \left(\frac{0.35}{0.5}\right)\left(\frac{1.2 \times 10^6}{0.6 \times 10^3}\right) = \underline{5.264 \text{ KA}}$

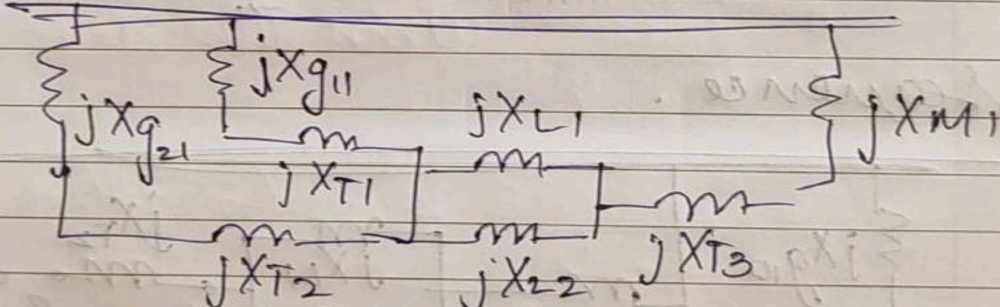
9.4



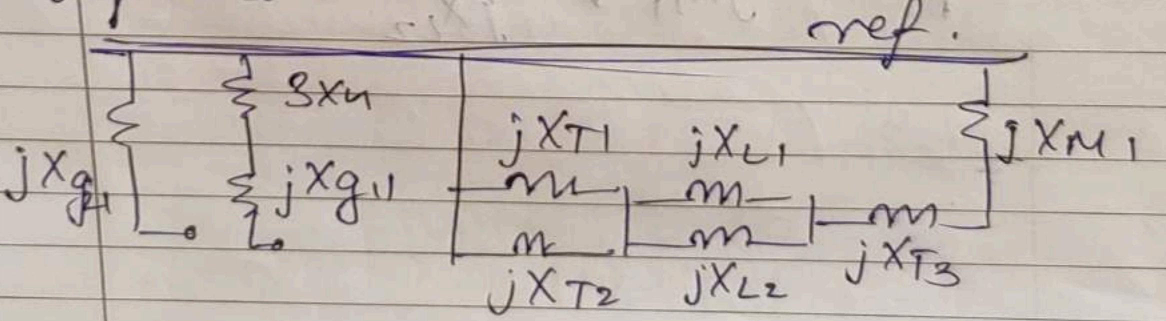
+ve sequence.



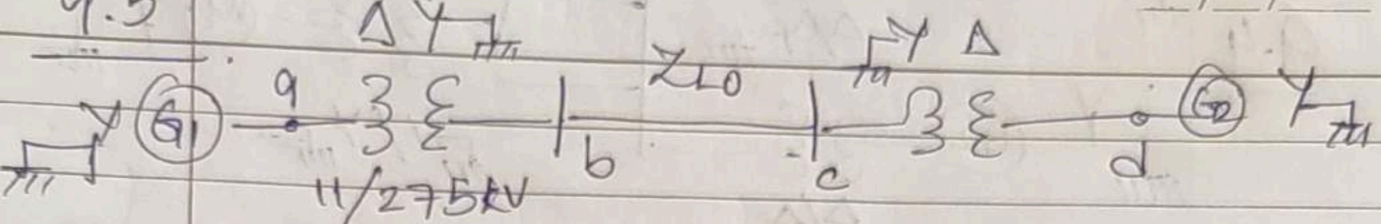
-ve sequence.



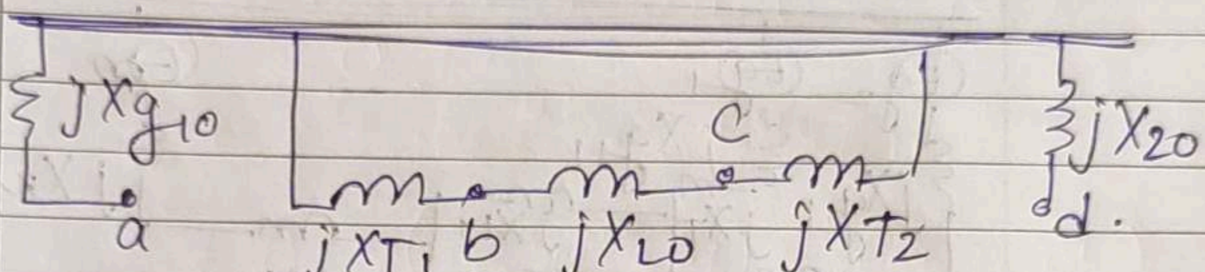
Zero sequence.



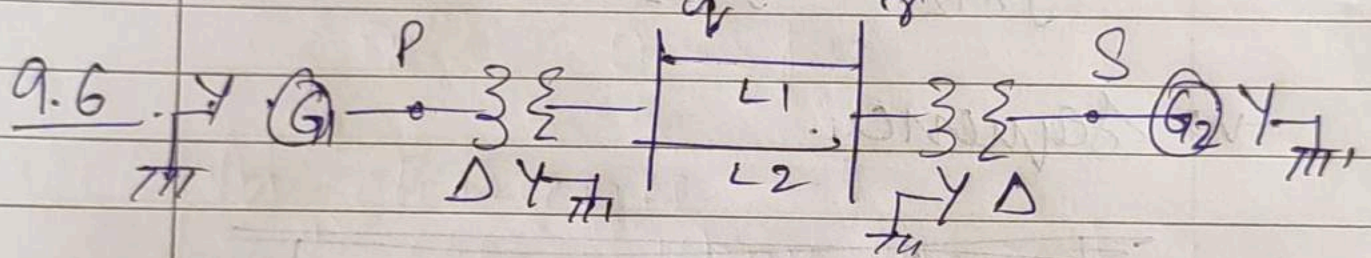
9.5



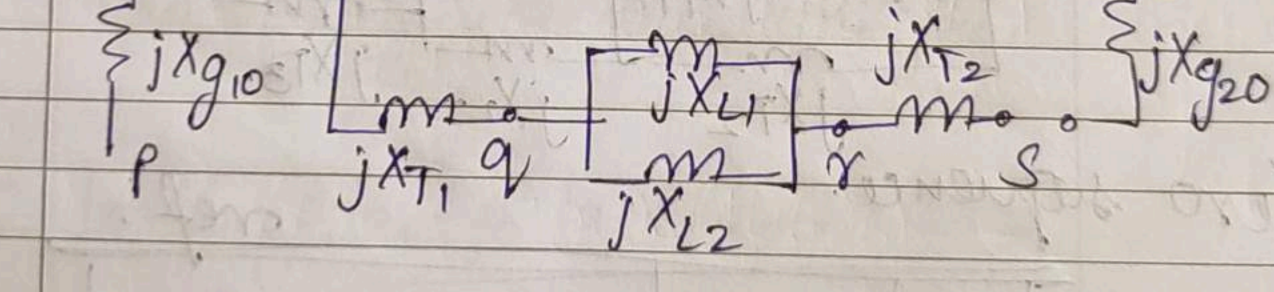
Zero sequence.



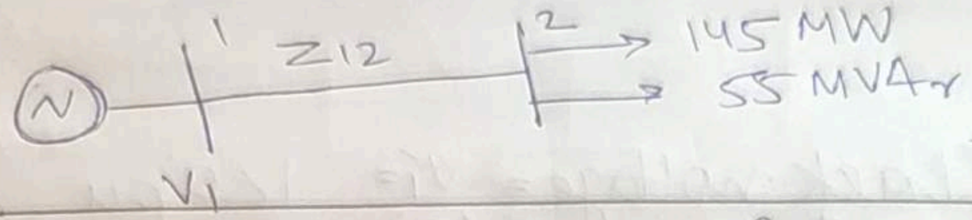
9.6



Zero sequence.



7.5



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Base = 100 MVA

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

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

$$Y_{11} = y_{10} + y_{12} = y_{12}$$

$$Y_{22} = y_{20} + y_{21} = y_{21} = y_{12}.$$

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

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

$$P_2 = \sum_{j=1}^{2} |V_2||V_j||Y_{2j}| \cos(\theta_{2j} - \delta_2 + \delta_j)$$

$$\frac{\partial P_2}{\partial \delta_2} = \sum_{k=1, k\neq 2}^{2} |V_2||V_k||Y_{2k}| \sin(\theta_{2k} - \delta_2 + \delta_k)$$

$$= |V_2||V_1||Y_{21}| \sin(\theta_{21} - \delta_2 + \delta_1)$$

$$\frac{\partial P_2}{\partial |V_2|} = 2|V_2||Y_{22}| \cos\theta_{22} + |V_1||Y_{21}| \cos(\theta_{21} - \delta_2 + \delta_1)$$

$$\frac{\partial Q_2}{\partial \delta_2} = |V_1||V_2||Y_{21}| \cos(\theta_{21} - \delta_2 + \delta_1)$$

$$\frac{\partial Q_2}{\partial |V_2|} = -|V_1||Y_{21}| \sin(\theta_{21} - \delta_2 + \delta_1) - 2|V_2||Y_{22}| \sin(\theta_{22})$$

Slack voltage $= V_1 = 1\angle 0°$ pu.

$|V_2^0| = 1 \quad \delta_2^{(0)} = 0$

$S_2^{sch} = -\frac{(145 + j55)}{100}$ pu

$P_2^{(0)} = 10\cos(106.26°) + 10\cos(-73.74°)$
$= 0$

$\Delta P^{(0)} = P^{sch} - P_2^{(0)} = -1.45$ pu.

$Q_2^{(0)} = -10\sin(106.26°) - 10\sin(-73.74°)$
$= 0$

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

Jacobian elements :—

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

$J_2^{(0)} = \left(\frac{\partial P_2}{\partial |V_2|}\right)^{(0)} = 20\cos(-73.74°) + 10\cos(106.26°)$
$= 2.8$

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

$J_4^{(0)} = \left(\frac{\partial Q_2}{\partial |V_2|}\right)^{(0)} = 9.6$

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

__/__/____

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

$\Delta \delta_2^{(0)} = -0.1238$ | $\delta_2^{(1)} = -0.1238$

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

$$P_2^{(1)} = 0.9066 \times 10 \cos\left(106.26 + 0.1238 \times \frac{180}{\pi}\right)$$
$$= -1.29 \text{ pu}$$

$$Q_2^{(1)} = -0.9066 \times 10 \sin\left(106.26 + 0.1238 \times \frac{180}{\pi}\right)$$
$$= -0.433 \text{ pu}$$

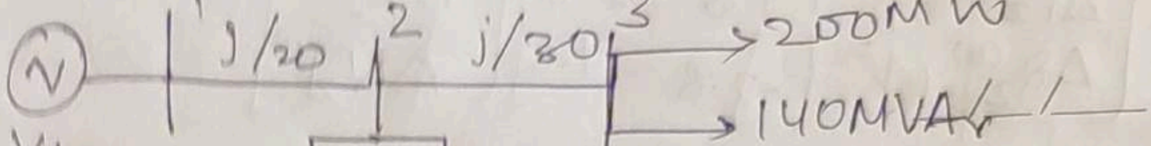
$$\Delta P^{(1)} = -1.45 + 1.29 = -0.16 \text{ pu}$$
$$\Delta Q^{(1)} = -0.55 + 0.433 = -0.117 \text{ pu}$$

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

$$\delta_2^{(2)} = -0.1238 - 0.012084 = -0.1359 \text{ pu}$$
$$|V|_2^{(2)} = 0.891 \text{ pu}$$

So, voltage after 2 iteration $= 0.891$ pu

δ at bus after 2 iter. $= -0.1359$ rad.



7.6 V_1

$1\angle 0$

$y_{12} = \frac{20}{j} = -20j$

$y_{13} = 0 = y_{10} = y_{20} = y_{30}.$

$y_{23} = -30j$

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

$Y_{22} = y_{20} + y_{21} + y_{23} = -50j$

$Y_{33} = \text{''} = -20j$

$Y_{12} = Y_{21} = 20j$

$Y_{23} = Y_{32} = 30j$

$Y_{13} = Y_{31} = 0.$

(a) GS Method:—

$S_2^{sch} = \frac{-60j - 90}{100} = P_2 + jQ_2.$

$S_3^{sch} = -2 - 1.4j$

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

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

Slack bus power :—

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

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

$V_2^{(0)} = 1 \quad V_3^{(0)} = 1$

1st iteration :—

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

$$V_2^1 = 0.988 \angle 1.044°$$

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

2nd iteration :—

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

$$= 1.247 \angle -3.6°$$

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

$$= 1.433\angle -3.73°$$

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

$P_1 = 1.586$ pu.

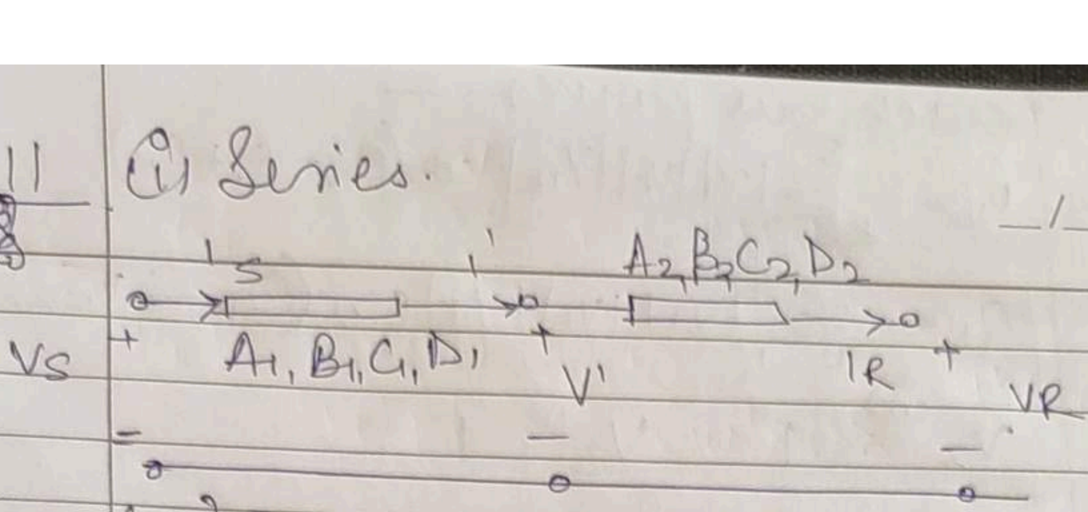
$Q_1 = -4.89$ pu.

$S_1 = (1.566 - j4.89)$ pu.

$= 156.6 - j489$ MVA

6.11

(i) Series.



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

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

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

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

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

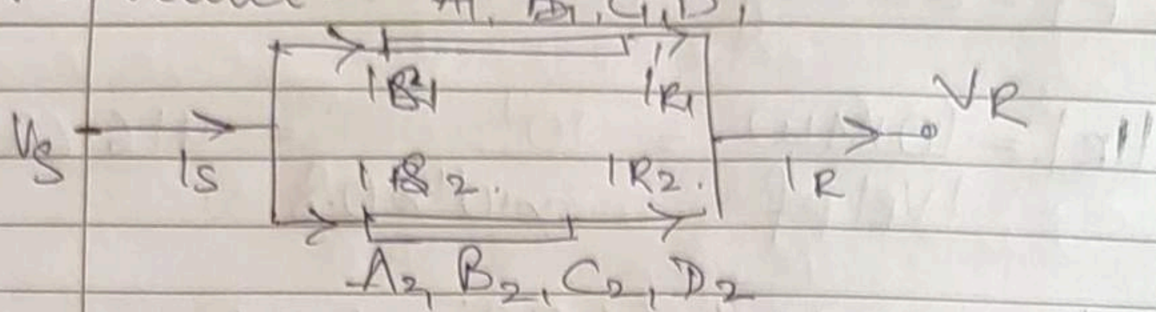
$A' = A_1 A_2 + B_1 C_2$

$B' = A_1 B_2 + B_1 D_2$

$C' = A_2 C_1 + D_1 C_2$

$D' = C_1 B_2 + D_1 D_2.$

(ii) Parallel.



$$\begin{bmatrix} V_S \\ I_{S1} \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} V_R \\ I_{R1} \end{bmatrix}$$

$$\begin{bmatrix} V_S \\ I_{S2} \end{bmatrix} = \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} V_R \\ I_{R2} \end{bmatrix}$$

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

$I_S = I_{S1} + I_{S2}$

$I_R = I_{R1} + I_{R2}$.

$V_S = A_2 V_R + B_2 I_{R2}$

$I_{S2} = C_2 V_R + D_2 I_{R2}$.

$V_S = A_1 V_R + B_1 I_{R1}$

$I_{S1} = C_1 V_R + D_1 I_{R1}$

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

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

$I_S = V_R(C_1 + C_2) + I_R(D_1 + D_2)$

$A' = \frac{A_1 B_2 + A_2 B_1}{B_1 + B_2}$

$B' = \frac{B_1 B_2}{B_1 + B_2}$

$C' = C_1 + C_2$.

$D' = D_1 + D_2$.

6.12 $V_R = 30\angle 0^\circ$ KV
$pf = 0.8$ lag $P = 10$ MW.

$$|I_R| = \frac{10\,MW}{|V_R|\,pf} = \frac{10^7}{3\times10^4\times0.8} = 416.67\,A.$$

$$I_R = 416.67\angle -36.87^\circ = I_1 + I_2$$

$$V_R + I_1(5.5 + 13.5j) = V_R + I_2(6 + 11j)$$

$$I_1 = I_2 \frac{(6+11j)}{(5.5+13.5j)} = I_2 (0.87\angle -8.28^\circ)$$

$$416.67\angle -36.87^\circ = I_2(1 + 0.87\angle -8.28^\circ)$$

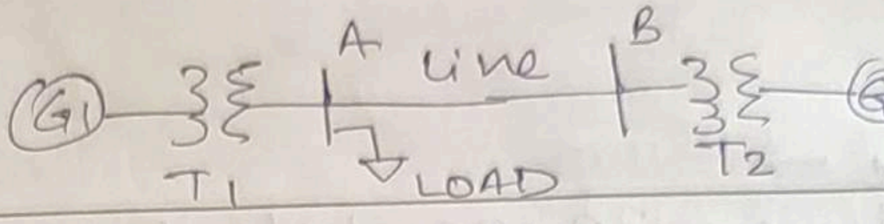
$$I_2 = 224.42\angle -33.89^\circ\,A$$
$$I_1 = 192\angle -40.33^\circ\,A.$$

$$P_2 = 30 I_2 \cos\phi = 5585\,kW$$

$$P_1 = 10\,MW - P_2 = 4415\,kW$$

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

5.3



$(MVA)_B = 100$

Base kV for Generator = 20 kV
G1 and G2

for $G_1 \rightarrow$

$$x_{g_1 new} = 0.09 \, \frac{MVA_{B new}}{MVA_{B old}} \, \frac{kV^2_{B old}}{kV^2_{B new}}$$

$$= 0.09 \times \frac{100}{90} \times \left(\frac{20}{20}\right)^2$$

$$x_{g_1 new} = 0.1 \text{ pu.}$$

for $G_2 \rightarrow$

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

$$= 0.081 \text{ pu.}$$

for $T_1 \rightarrow$

$$x_{t_1 new} = 0.06 \times \frac{100}{80} \times \left(\frac{20}{20}\right)^2$$

$$= 0.2 \text{ pu.}$$

for $T_2 \rightarrow$

$$x_{T_2 new} = 0.\overset{20}{\cancel{16}} \times \frac{100}{80} \times \left(\frac{20}{20}\right)^2$$

$$= 0.25 \text{ pu.}$$

for line →

$$KV_{B\,line} = 20 \times \frac{200}{20} kV = 200 kV$$

$$Z_{B\,line} = \frac{kV^2_{B\,line}}{MVA_B} = \frac{200^2}{100} = 400\,\Omega$$

$$x_{line} = \frac{120}{400} pu = 0.3 pu = x_{line}$$

$S = 48 + 64j$ MVA.

(a)

$$Z_{load} = \frac{200^2}{48+64j} = 300 - 400j\ \Omega$$

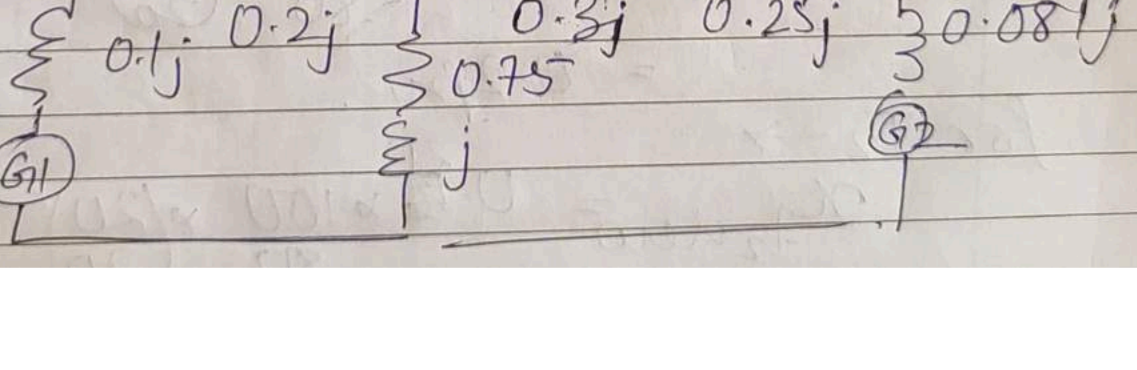
$$Z_{load_{pu}} = \frac{Z_{load}}{Z_{B\,line}} = \frac{300-400j}{400}$$

$$= (0.75 - j)\ pu.$$

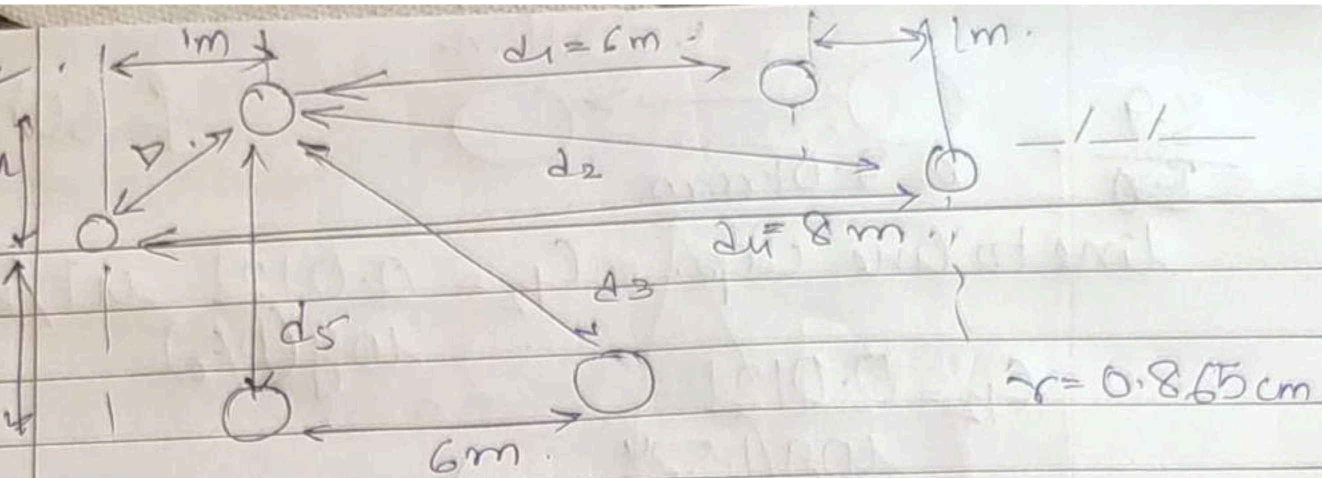
$R_{series} = 0.75 pu$

$X_{series} = j\ pu.$

Impedance diagram :—



3.12



capacitance to neutral $C_{avg} = \dfrac{0.0242}{\log\left(\frac{D_{eq}}{D_s}\right)}$ μF/km.

$d_1 = 6m$
$d_2 = \sqrt{4^2 + 7^2} = 8.062$ m.
$d_3 = 10m$
$d_4 = 8m$

$d_5 = 8m$
$D = \sqrt{4^2 + 1^2} = 4.123$
$D_{eq} = D^{1/3} d_2^{1/3} d_1^{1/6} d_5^{1/6}$
$= 6.129$ m.

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

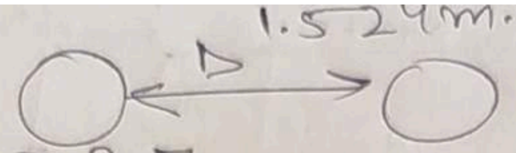
$$C_{avg} = \frac{0.0242}{\log\left(\frac{6.129}{0.283}\right)} = 0.0181 \text{ μF/km.}$$

capacitive admittance to neutral $= 2\pi f C_{avg}$ mho/km $= 5.686 \times 10^{-6}$ mho/km

charging current $= I_{chg} = 2\pi f C_{avg} (V_{LN})$
$= 0.433$ A/km.

charging current per conductor $= \dfrac{0.433}{2} = 0.2166$ A/km.

3.9



$r = 7.01\,mm$

$f = 60\,Hz$.

line to line cap. $C_{12} = \dfrac{0.0121}{\log(D/r)}\ \mu F/km$.

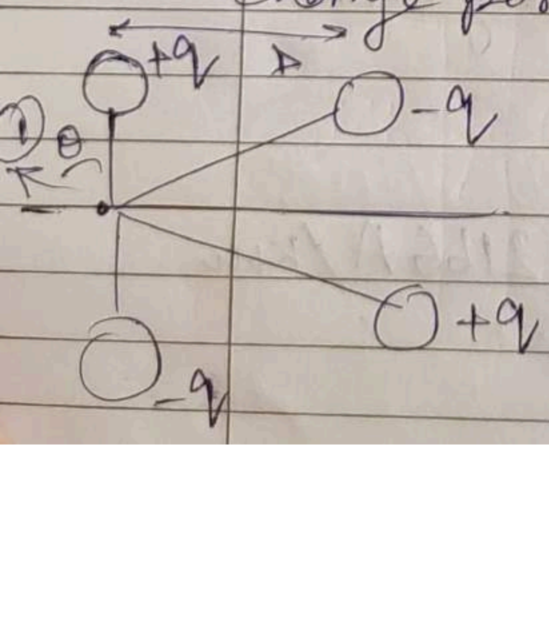
$$C_{12} = \frac{0.0121}{\log\left(\frac{1.524}{7.01\times10^{-3}}\right)}$$

total line to line cap. $= C_{12} \times 32.16\ \mu F$
$= 0.166\ \mu F$.

line to line admittance $= j\,2\pi f C_{LL}$
$= j\,6.27\times10^{-5}$ mho.

reactive power $= V^2 \times$ admittance
$= (2\times10^4)^2 \times 6.27\times10^{-5}$
$= 25.08$ kVAr.

3.11 from 3.9
line to line Cap. $= 0.166\ \mu F$
length of Cap. $= 32.16$ km.
charge per length $= \lambda = \dfrac{C}{L} = 103.23\times10^{-9}$ C/m



(i) Surface electric field at 1

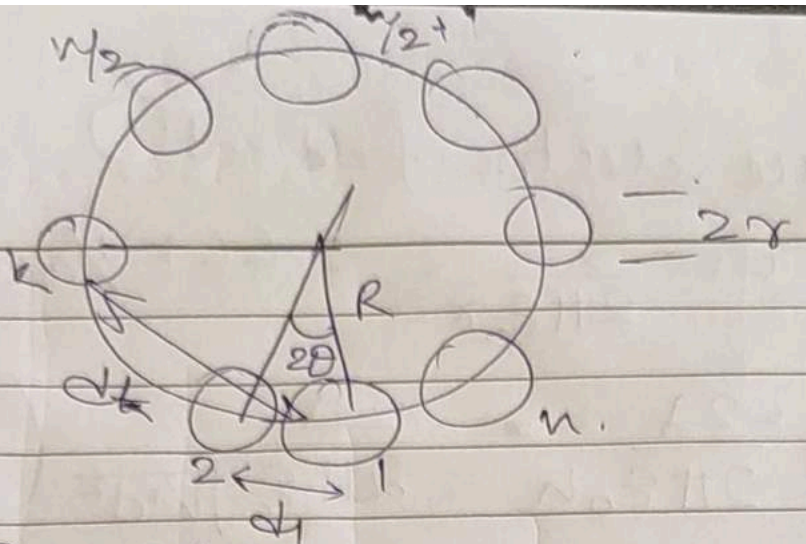
$$E_1 = \frac{\lambda}{2\pi\varepsilon_0 r} = 2.66\ kV/cm.$$

(ii) $$E_{net} = \frac{2\lambda}{2\pi\varepsilon_0 h} - \frac{2\lambda}{2\pi\varepsilon_0\sqrt{h^2+d^2}}\left(\frac{h}{\sqrt{h^2+d^2}}\right)$$

$$= \frac{2\lambda h}{2\pi\varepsilon_0}\left(\frac{1}{h^2} - \frac{1}{h^2+d^2}\right)$$

$$= 0.0483\ kV/m$$

2.2



$2\theta_n = 360^\circ$

$n\theta = 180^\circ$

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

$d = R\sin n\theta$

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

$k = \frac{n}{2}+3$ $\quad d_{n/2+3} = 2R\sin\left(\frac{n}{2}+2\right)\theta.$

$d_{n/2+3} = 2R\sin\left(\frac{n-4}{2}\right)\theta.$

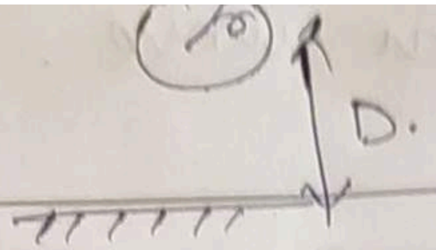
$\left(\frac{n}{2}+2\right)\theta + \left(\frac{n-4}{2}\right)\theta = n\theta = 180^\circ$

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

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

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

2·11

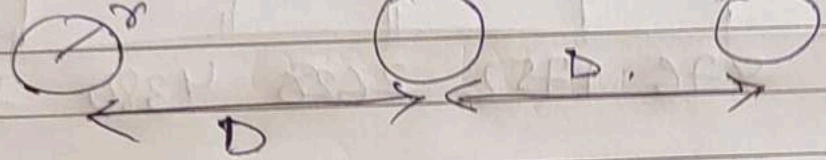


$$L = 0.4605\left(\log 1/r' \cdot \log 1/2D\right)$$

$$= 0.4605\left(\log \frac{200}{e^{-1/4}\times 1.956}\ \log \frac{1}{2\times 6.708}\right)$$

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

2·12



$r = 1.25$ cm

$D = 3$ cm

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

$$L_a = (1.22 - 0.12j)\ \text{mH/km}$$

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

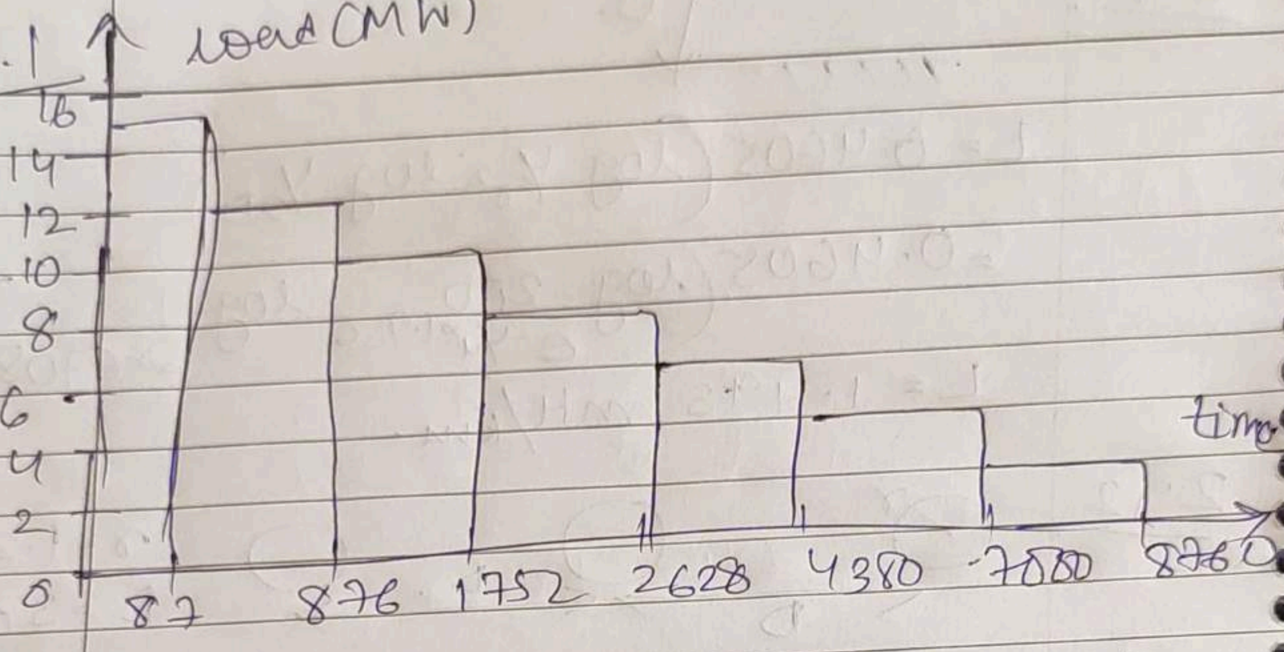
$$L_B = 1.14\ \text{mH/km}$$

$$L_c = 2\times10^{-7}\left(\ln 1/r' + \ln\sqrt{2D^2} + \sqrt{3}j \ln\sqrt{2}\right] \text{H/m}$$

$$L_c = (1.22 + 0.12j)\ \text{mH/km}$$

load duration curve.

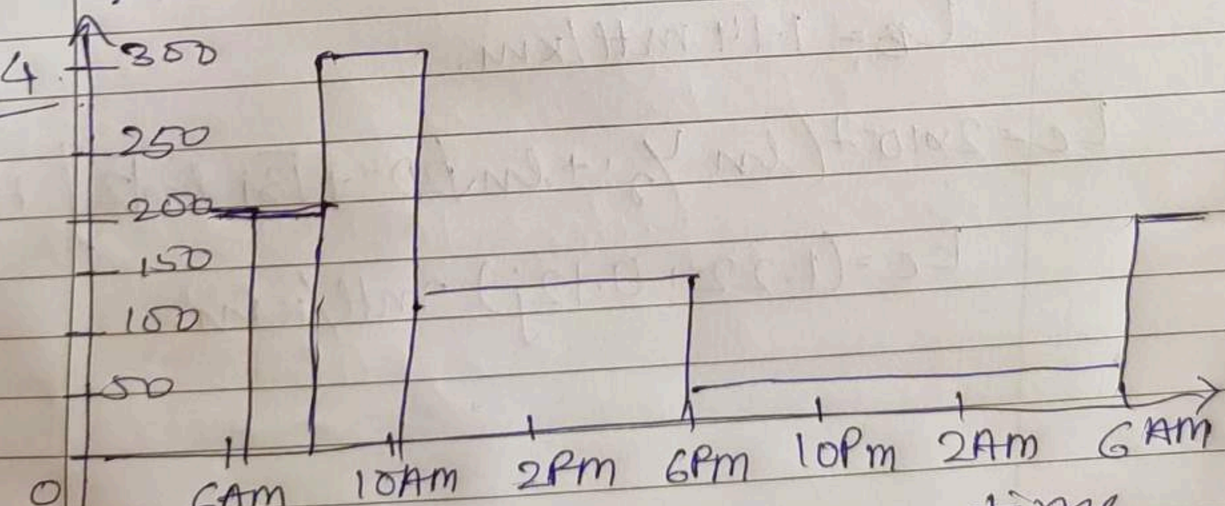
1.1



$$\text{avg load} = \frac{\text{Units generated}}{\text{time}} = 5.827 \text{ MVA}$$

$$\text{load factor} = \frac{\text{avg load}}{\text{max load}} = 0.389$$

1.4



daily energy produced = 2200 MWhr.

load factor = $\frac{2200}{24} / 300 = 0.3055$

diversity factor = $\frac{100+150+50+20}{300}$

$= 1.067$.