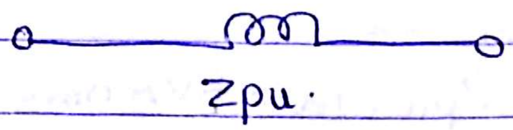
$$Z_{02\,pu} = \frac{Z_{01}\,(KVA_B)}{(KV_{B1})^2 \times 1000}$$

$$\therefore Z_{01\,pu} = Z_{02\,pu} = Z_{pu}$$



Q Three generators are rated as follows.

Gen 1 : 100 MVA, 33 KV, reactance = 10%

Gen 2 : 150 MVA, 32 KV, reactance = 8%

Gen 3 : 110 MVA, 30 KV, reactance = 12%

Choosing 200 MVA & 35 KV as base quantities, compute p.u reactance of 3 Gen reffered to these base quantities. Draw reactance diagram & mark p.u reactances. The three generators are connected to common bus-bars.

Gen 1 :

$$\rightarrow X_{pu\,new} = X_{pu\,old} \times \frac{KVA_{new}}{KVA_{old}} \times \left(\frac{KV_{old}}{KV_{new}}\right)^2$$

$$= \frac{10}{100} \times \frac{200 \times 10^3}{1000 \times 10^3} \times \left(\frac{33}{35}\right)^2$$

$$= 0.1777\ pu$$

• Gen 2

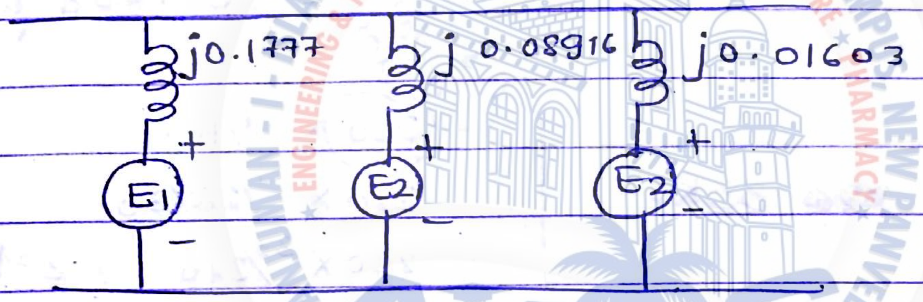
$$\rightarrow X_{pu}\ new = \frac{8}{100} \times \frac{200\times10^3}{150\times10^3} \times \left(\frac{32}{35}\right)^2.$$

$$= 0.08916\ p.u$$

• Gen 3

$$\rightarrow X_{pu}\ new = \frac{12}{100} \times \frac{200\times10^3}{110\times10^3} \times \left(\frac{30}{35}\right)^2.$$

$$= 0.16029\ pu$$



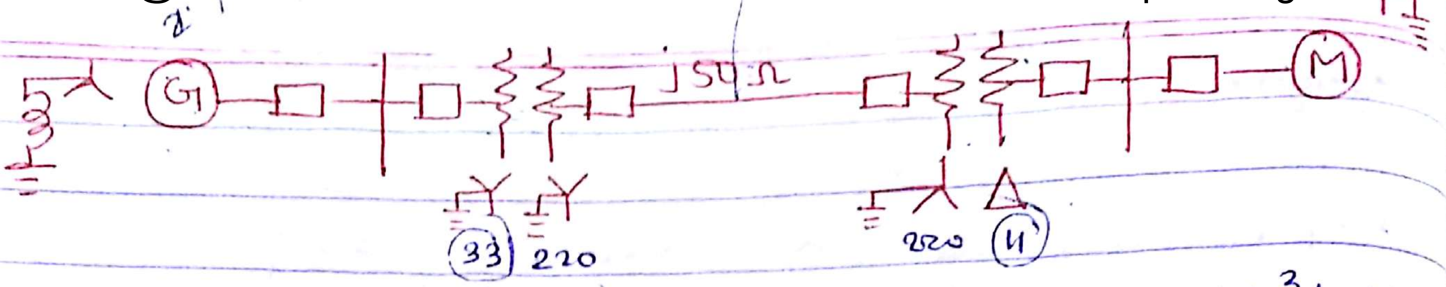
Q Draw pu impedence diagram for the power system shown. Neglect 'R'. & use base of 100MVA 220KV in 50Ω line. The rating of the generator motor, transformer are

Generator : 40 MVA, 25KV, X'' = 20%

Motor : 50 MVA, 11 kV, X'' = 30%

Y-Y xmer = 40 MVA, 33λ - 220 Y kV, X = 15%.

Y-Δ xmer = 30 MVA, $\underbrace{11\Delta - 220}_{220/11}$ Y kV, X = 15%.



→ Base KVA for complete ckt $= 100$ MVA $= 100 \times 10^3$ KVA

• Xmission line.

→ Base kv $= 220$ kV.
→ Actual 'X' $= j50\Omega$

→ X_{pu} of line $= \frac{X_{actual} \times KVA_B}{(KV_B)^2 \times 1000} = \frac{j50 \times 100 \times 10^3}{220^2 \times 1000}$.

$= j0.1033$ p.u

• Generator.

→ Base kv $= \cancel{220}$ 33 kV.

Base in xmission line
$= 220 \times 1/k$.
$= 220 \times 1/_{220/33}$
$= 220 \times 33/220 = 33$ kV.

→ $X_{pu\,new} = \frac{20}{100} \times \frac{100 \times 10^3}{40 \times 10^3} \times \left(\frac{25}{33}\right)^2$.

$= j\,0.287$ p.u.

• Motor

→ Base kv $= 11$ kV.

$= 220 \times k = \cancel{220 \times 220}/18 = 11$ kv,
$= 220 \times 11/220 = 11$ kv

→ $X_{pu\,new} = \frac{30}{100} \times \frac{100 \times 10^3}{50 \times 10^3} \times \left(\frac{11}{11}\right)^2$.

$= j0.6$. p.u

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· **Xmer 1** $(\lambda - \lambda)$

$\rightarrow$ Base kV $= 33$ kV $\quad = 220 \times \left(\frac{33}{220}\right)$

$$\rightarrow X_{pu\,new} = \frac{15}{100} \times \frac{100\times10^3}{40\times10^3} \times \left(\frac{33}{33}\right)^2.$$

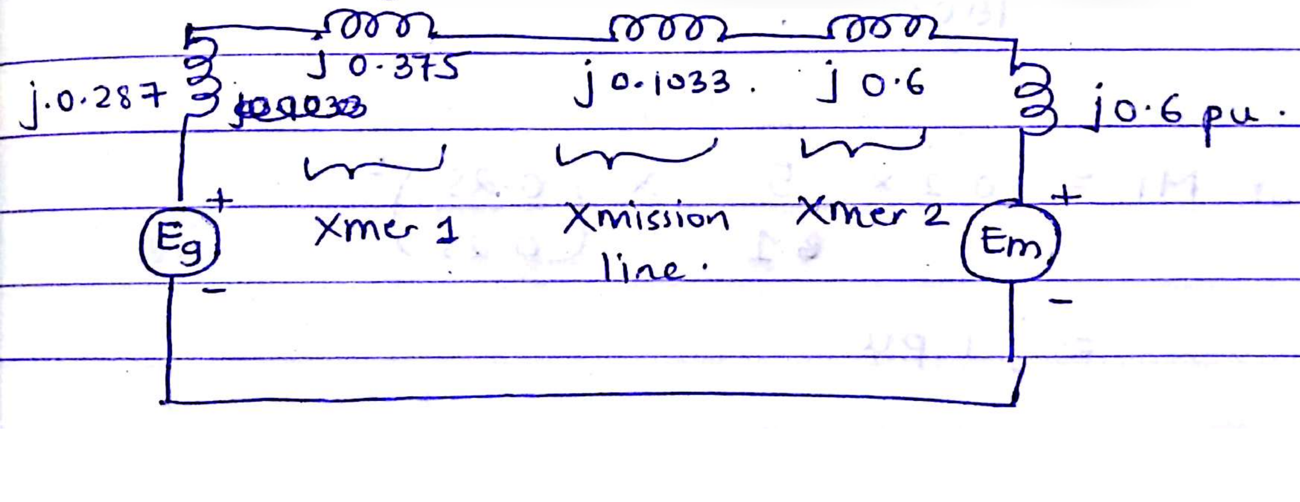
$$= j\,0.375 \text{ pu}$$

· **Xmer 2** $(\lambda - \Delta)$.

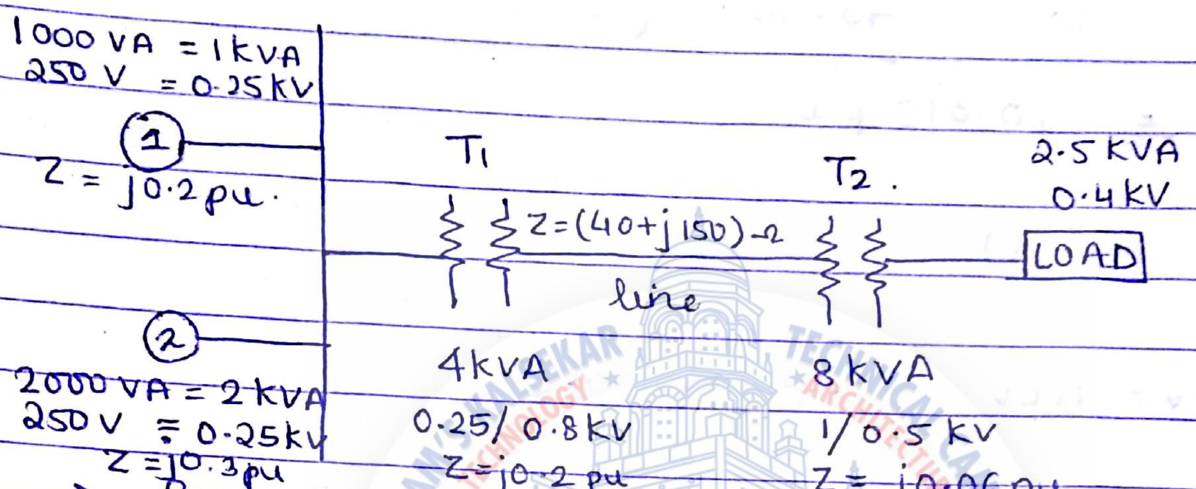
$\rightarrow$ Base kV $= 11$ kV $\quad = 220 \times \left(\frac{11}{220}\right).$

$$\rightarrow X_{pu\,new} = \frac{15}{100} \times \frac{100\times10^3}{30\times10^3} \times \left(\frac{11}{11}\right)^2.$$

$$= j\,0.5 \text{ p.u.}$$



Q A simple power system is shown. Redraw this system where the p.u impedances are represented on a common 5,000 VA base and common system base voltage of 250 V



→ $\text{Base kVA} = \frac{5000}{1000} = 5\,\text{kVA}$.

→ $\text{Base kV} = \frac{250}{1000} = 0.25\,\text{kV}$

→ $X_{pu} \text{ of } M_1 = j0.2 \times \frac{5}{1} \times \left(\frac{0.25}{0.25}\right)^2$

$= j1\,\text{pu}$.

→ $X_{pu} \text{ of } M_2 = j0.3 \times \frac{5}{2} \times \left(\frac{0.25}{0.25}\right)$

$= j0.75\,\text{pu}$.

→ $X_{pu} \text{ of } T_1 = j0.2 \times \frac{5}{4} \times \left(\frac{0.25}{0.25}\right)^2$.

$= j0.25\,\text{pu}$

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→ ~~X_{pu} of $T_2 = j0.06 \times \frac{5}{8} \times \left(\frac{0.25}{0.5}\right)^2$~~

=

→ Base voltage in Xmission line (TL) = Voltage in Gen ckt × Xformation ratio

$= 0.25 \times \left(\frac{0.8}{0.25}\right)$

$= 0.8\ kV.$

→ X_{pu} line $= \frac{(40+j150) \times KVA_B}{(KV_B)^2 \times 1000}$

$= \frac{(40+j150) \times 5}{(0.8)^2 \times 1000}$

$= (0.3125 + j1.17)$ p.u.

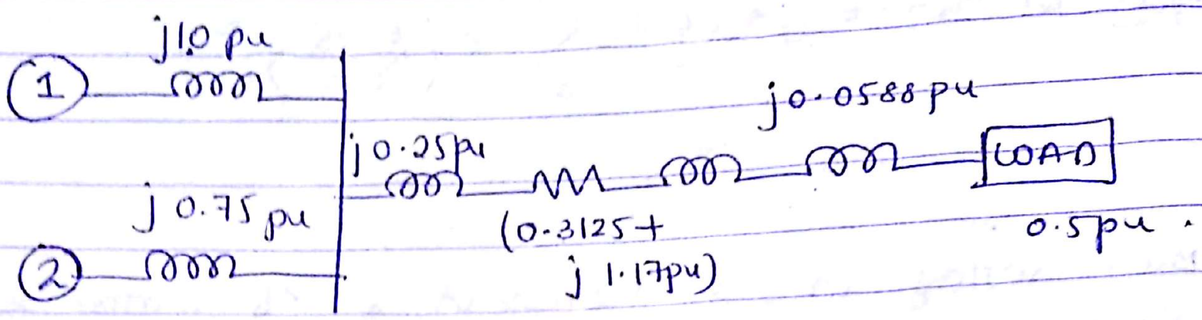
→ X_{pu} of $T_2 = j0.06 \times \frac{5}{8} \times \left(\frac{1}{0.8}\right)^2$.

$= 0.0586$ pu.

→ V_B of TL $= \frac{V_B \text{ of motor ckt}}{K}$

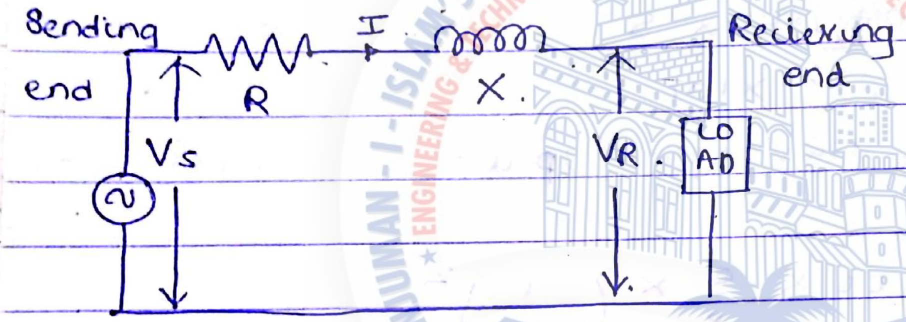
$= \frac{0.4}{\frac{0.5}{1}} = \frac{0.4}{0.5} = 0.8.$

→ KVA pu $= \frac{2.5}{5} = 0.5$ p.u.



* Short transmission lines :

- Shunt conductance & shunt capacitance is neglected and so only series resistance & inductive reactance is shown.

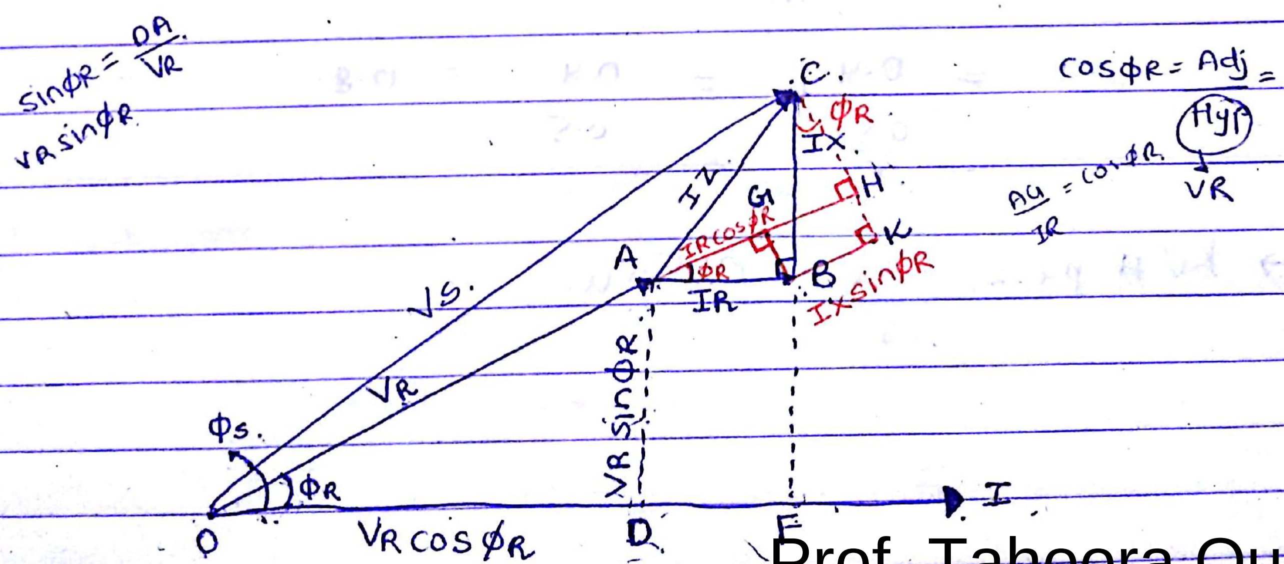


- From Above;

$$V_R = V_s - I(R+jX)$$

$= V_s - IZ \rightarrow$ vg drop across the line

OSHACHOTA



(Q): A 200km long 3ϕ overhead line has a R of 48.7 Ω/ph, X_L = 80.20 Ω/ph & C = 8.42 nF/km. It supplied a load of 13.5 MW at voltage of 88 kV & P.F = 0.9(lag). Find the Vs, Is, V.R, δ, η_s (power angle) for (i) Nominal 'T'
(ii) Nominal 'π'

*'Nominal T':

→ $Z = 48.7 + j\,80.20 = 93.8281\angle 58.732$

$Y = j\omega C l = j\,2\pi(50)(8.42\times10^{-9})\times 200$

$= (5.290\times10^{-4})\angle 90^\circ$

→ $I_R = \dfrac{P_R}{\sqrt{3}\,V_L\cos\phi_R} = \dfrac{13.5\times10^6}{\sqrt{3}\times 88\times10^3\times 0.9} = 98.4119\ A\ \angle -25.841$

→ $V_R = \dfrac{V_L}{\sqrt{3}} = 50806.823\ V\ \angle 0^\circ$

→ $V_S = V_R\left(1+\dfrac{ZY}{2}\right) + I_R\left(Z+\dfrac{Z^2Y}{4}\right)$

$= (50806.823\angle 0^\circ)\left(1+\dfrac{(93.828\angle 58.73)(5.290\times10^{-4})\angle 90^\circ}{2}\right)$

$+ (98.4119\angle -25.841)\left(93.8281\angle 58.732 + \dfrac{(93.8281\angle 58.732)^2(5.290\times10^{-4})\angle 90}{4}\right)$

$= 49733.401\angle 0.7540 + 9136.05\angle 33.263$

$= \underbrace{57647.31}_{\text{phase value }(V_{sph})}\angle \underbrace{5.6401}_{\phi_1}$

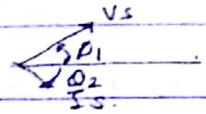
→ $V_{s(line)} = \sqrt{3}\times 57647.31 = 99848.07\ V$

δ (power angle) = 5.6401

$\rightarrow I_s = V_R\left(Y\right) + I_r\left(1+\frac{ZY}{2}\right)$.

$= (50806.823\angle 0^\circ)(5.290\times10^{-4})\angle 90^\circ +$

$98.4119\angle -25.841 \left(1+\frac{(93.828\angle 53.732)(Y)}{2}\right.$



$= 88.3561\angle 9.095 \rightarrow \phi_2$

$\cos(\phi_1-\phi_2) = \cos\phi$

$\rightarrow$ sending end P.F $\cos\phi_s = \cancel{0.9874} = \cos(5.64+9.095)$

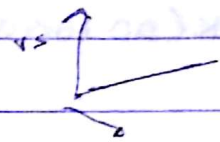
$= 0.96711$

$\rightarrow V.R = \frac{V_S - V_R}{V_R} \times 100$ ...

$= \frac{V_{R(noload)} - V_{R(full\,load)}}{V_{R(full\,load)}} \times 100$.

Deals with phase values.

$V_{R(noload)} = \frac{|V_S|}{\left|1+\frac{YZ}{2}\right|}$ $[\because I_R = 0]$.



$= \frac{|V_{sphase}|}{\left|1+\frac{YZ}{2}\right|} = \frac{57647.2}{|0.9788 + j\,0.0127|} = 58890.98\,V$.

$V_{R(fullload)} = 50806.823$.

$V.R = 0.159$ or 15.9%

$\rightarrow \eta = \frac{13.5\times10^6}{\sqrt{3}\,V_{S(line)}\,I_{S(line)}\cos\phi_s} \times 100$

$= \frac{13.5\times10^6}{\sqrt{3}.(99848.07)(88.3561)\cancel{\cos(9.095)}\,(0.96711)}$.

$= 89\%$.

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* Nominal 'π'

→ $V_S = V_R\left(1+\frac{ZY}{2}\right) + I_R Z.$

$= 57763 \angle 5.63°$

→ $V_{S_L} = \sqrt{3} \times 57763 = 100\times10^3$ V.

$\delta = 5.63°$

→ $I_S = V_R\left(Y+\frac{ZY^2}{4}\right) + I_R\left(1+\frac{ZY}{2}\right).$

$= 88.19 \angle -9.29°$

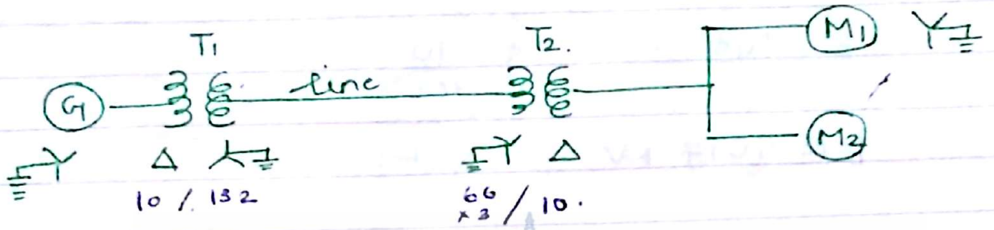
→ $V_R(\text{no load}) = \frac{|V_S|}{\left|1+\frac{ZY}{2}\right|} = \frac{57763}{[0.9788 + j0.0129]}$

$= 59009.4$ V

→ $V.R = \frac{59009.4 - 50808.3}{50808.3} = 0.16$ or 16.14%

(Q) A 300km 132KV, 3ϕ overhead line has a total series impedence of $52+j200\ \Omega$/ph & total shunt Admittance of $j1.5\times10^{-3}$ seimens/ph to neutral. The line is supplying 40 MVA at 0.8 P.F (lag) at 132KV. find V_s, I_s, $\cos\phi_s$, P_s using nominal π circuit.

Q] A 90 MVA, 11 kV, 3ϕ Generator has $X = 25\%$.
Xmer T_1 is 3ϕ Xmer, 100 MVA, 10/132 kV, $X = 6\%$.
Xmer T_2 is 1ϕ-3 Xmer, 30 MVA, 66/10 kV, $X = 5\%$.
Motor M_1, 50 MVA, 10 kV, $X = 20\%$
Motor M_2, 40 MVA, 10 kV, $X = 20\%$.
Take Generator rating as Base.
X of line = 100 Ω.



→ Base kVA for complete ckt,
Base kVA = 90×10^3 kVA.

(1) ~~Transmission line:~~
→ ~~Base kV =.~~

(1) Generator circuit:

Base kVA = 90×10^3 kVA
Base kV = 11 kV

p.u reactance of Generator (X_g) = $0.25 \times \frac{90 \times 10^3}{90 \times 10^3} \times \left[\frac{11}{11}\right]^2$

KVA New, KVA old, KV old, KV new

$= j0.25$ or 25%.

(2) ~~Transmission line~~ Transformer (T_1);
Base kV = 11 kV = Base kV in Generator ckt.
p.u reactance of T_1 = $0.06 \times \frac{90 \times 10^3}{100 \times 10^3} \times \left(\frac{10}{11}\right)^2$ · $j0.0446$ pu

(3) Transmission line:
Base kV (Xmission line) = Base kV (Generator) × k_{T_1}

$= 11 \times \frac{132}{10}$.

= 145.2 kV.

$I_{line\,(Base)} = \frac{\text{KVA base}}{\text{KV Base}} = \frac{90 \times 10^3}{145.2} = 619.834$ A.

$$Z_{line(Base)} = \frac{kV_{Base}}{I_{line(Base)}} = \frac{145.2\times10^3}{619.234} = j234.256\,\Omega$$

p.u 'Z' of line = Actual'Z'/Base'Z' = j100/234.256 = j0.427

(4) Transformer (T_2);

$$\text{Base kV}_{(motor\ ckt)} = \text{Base kV}_{(Xmission\ line)} \times K_{T2}$$

$$= 145.2 \times \frac{10}{(\sqrt{3})66} \longrightarrow \text{Note!}$$

Y

$$= 12.7017\text{ kV}$$

$$\text{p.u reactance of } T_2 = 0.05 \times \frac{90\times10^3}{(3\times30)\times10^3} \times \left(\frac{\overset{10}{\cancel{12.7017}}}{12.7017}\right)^2$$

$$= \cancel{j0.0929\,\Omega},\ j0.0309 \longrightarrow \text{Note!}$$

(5) Motor M_1

Base kV in motor ckt = 12.7017 kV.

$$\text{pu reactance of } M_1\ (X_{m1}) = 0.2 \times \frac{90\times10^3}{50\times10^3} \times \left(\frac{10}{12.7017}\right)^2$$

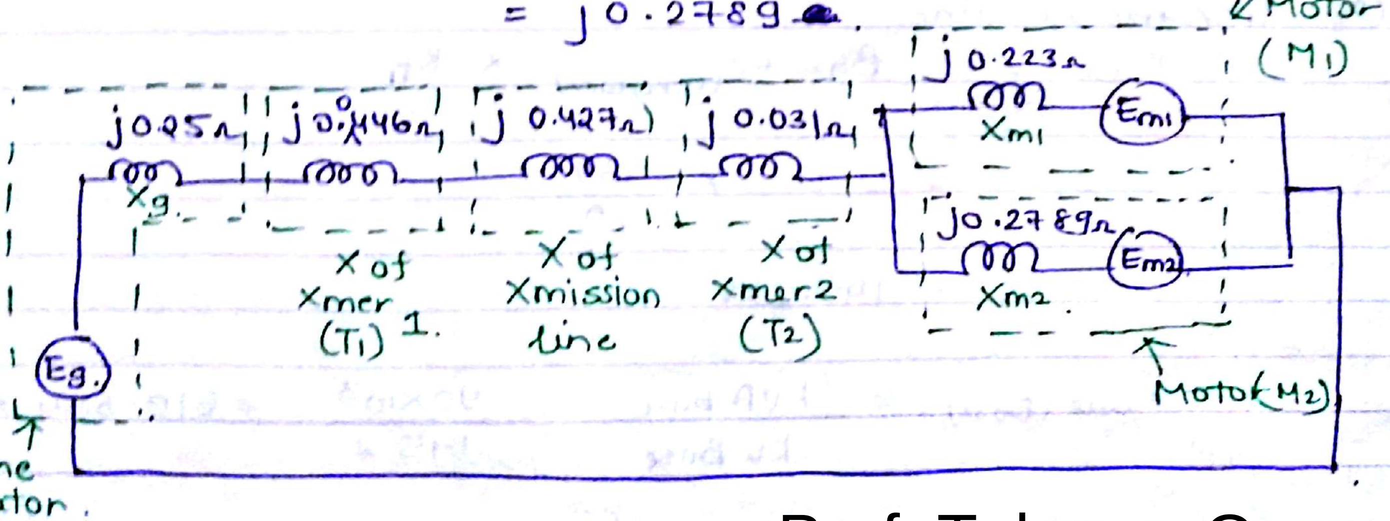
$$= j0.22314$$

(6) Motor M_2:

Base kV in motor ckt = 12.7017 kV.

$$\text{p.u reactance of } M_2\ (X_{m2}) = 0.2 \times \frac{90\times10^3}{40\times10^3} \times \left(\frac{10}{12.7017}\right)^2$$

$$= j0.2789$$



ratings of generators & transformers are:

G_{11} : 25 MVA, 6.6 kV, j0.2 pu.

G_{12} : 15 MVA, 6.6 kV, j0.15 pu

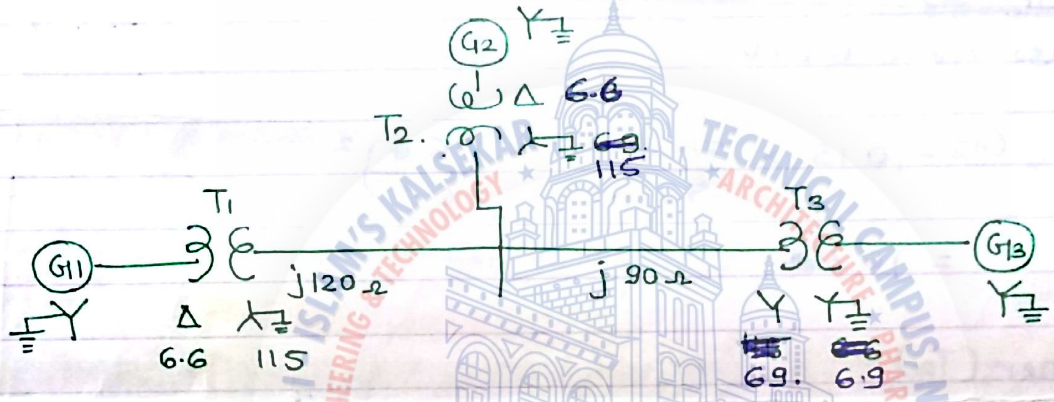
G_{13} : 30 MVA, 13.2 kV, j0.15 pu

T_1 : 30 MVA, 6.6 Δ — 115 Y kV, j0.1 p.u.

T_2 = 15 MVA, 6.6 Δ — 115 Y kV, j0.1 pu

T_3 : 1ϕ – 3 units each rated 10 MVA, 69/6.9 kV, j0.1 pu

$$\left.\begin{array}{l}\text{Base kVA} = 30\times10^3 \\ \text{Base kV} = 6.6\end{array}\right\}\text{ in generator ckt.}$$



Overall Base kVA = 30 MVA.

(1) Generator G_1

Base kVA = 30×10^3 kVA.

Base kV = 6.6 kV

$$\text{p.u 'X' of } G_1 = j0.2 \times \frac{30\times10^3}{25\times10^3} \times \left(\frac{6.6\times10^3}{6.6\times10^3}\right)^2.$$

$$= j0.24$$

(2) Transformer T_1;

Base kV = Base kV in Generator ckt = 6.6 kV

$$\text{pu 'x' of } T_1 = j0.1 \times \frac{30\times10^3}{30\times10^3} \times \left(\frac{6.6}{6.6}\right)^2.$$

$$= j0.1$$

(3) Xmission line of j120Ω:

$$\text{Base kV}_{(\text{line})} = \text{Base kV}_{(G_1)} \times K_{T1}$$

$$= 6.6 \times \frac{115}{6.6} = 115\text{ kV}.$$

$$I_{line(Base)} = \frac{KVA\,(Base)}{KV_{base}} = \frac{30\times10^3}{115} = j260.869\,A.$$

$$Z_{line(Base)} = \frac{KV(Base)}{I_{(Base)}} = \frac{115\times10^3}{260.869} = j440.833\,\Omega.$$

$$p.u\ 'Z_{line}' = \frac{Z\ actual}{Z\ Base} = \frac{j120}{440.833} = j0.2722.$$

(4) Generator G_{12}.

Base kV = 6.6 kV.

$$p.u\ 'x'\ of\ G_{12} = j0.15 \times \frac{30\times10^3}{15\times10^3} \times \left(\frac{6.6}{6.6}\right)^2$$

$$= j0.3.$$

(5) Transformer (T_2)

~~$Base\,kV = Base\,kV_{(G2)} \times K_{T2}$~~

$Base\,kV_{(T_2)}$ = Base kV in Generator (G_{12}) ckt. = 6.6 kV

$$p.u\ 'x'\ of\ Xmer(T_2) = j0.1 \times \frac{30\times10^3}{15\times10^3} \times \left(\frac{6.6}{6.6}\right)^2.$$

$$= j0.2189\,\Omega.$$

$$\simeq j0.2.$$

Use 6.6 kV since Generator is operated at 6.6 kV & ~~6.9 represents max kV sustained by xmer 2 (T_2)~~

~~(6) Generator G_{13};~~

~~Base kV = 13.2 kV~~

$$\cancel{p.u\ 'x'\ of\ G_{13} = j0.15 \times \frac{30\times10^3}{30\times10^3} \times \left(\frac{13.2}{13.2}\right)^2.}$$

$$\cancel{= j0.15\,\Omega.}$$

mission line of j90 Ω.

$$\text{Base kV}_{(90j\text{ line})} = \text{Base kV}_{(j120\Omega\text{ line})} = 115\text{ kV}.$$

$$I_{Base} = \frac{\text{KVA base}}{\text{KV base}} = \frac{30\times10^3}{115} = 260.8695\,A$$

$$Z_{Base} = \frac{V_{base}}{I_{base}} = \frac{115\times10^3}{260.8695} = j440.8333\,\Omega.$$

$$\text{p.u 'Z' of } j90\Omega\text{ line} = \frac{\text{'Z' actual}}{\text{'Z' Base}} = \frac{90}{440.8333} = j0.2041.$$

(7) Transformer T_3;

$$\text{Base KV}_{(T_3)} = \text{Base KV in }(G_{13})$$

$$\text{Base KV}(j90\Omega\text{ line}) = \text{Base KV}(G_{13}) \times K_{T3}.$$

$$115 = \text{Base KV}(G_{13}) \times \frac{\sqrt{3}\times 69}{\sqrt{3}\times 6.9}.$$

Note !

Note !

$$\therefore \text{Base KV}(G_{13}) = 11.5\text{ KV} = \text{Base KV}(T_3).$$

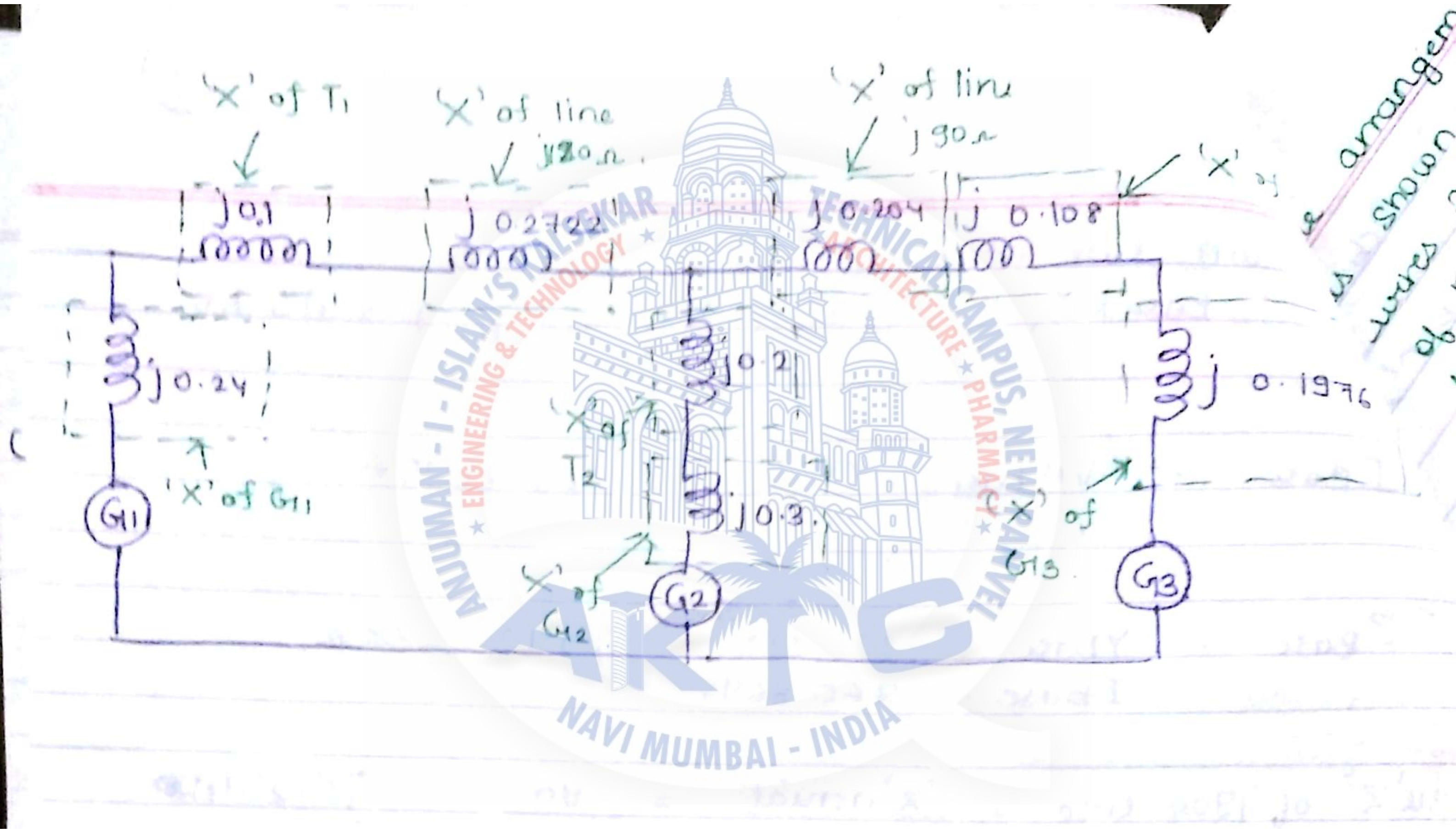
$$\text{p.u 'x' of } T_3 = j0.1 \times \frac{30\times10^3}{3\times15\times10^3} \times \left(\frac{6.9\sqrt{3}}{11.5}\right)^2 = j0.\cancel{072}\;108.$$

Note!

(8) Generator G_3;

$$\text{Base KV}_{(G_3)} = 11.5\text{ KV}.$$

$$\text{p.u 'x' of } G_3 = j0.15 \times \frac{30\times10^3}{30\times10^3} \times \left(\frac{13.2}{11.5}\right)^2 = j0.1976.$$


'X' of T1
'X' of line
j120Ω
'X' of line
j90Ω
'X' of
j0.1
j 0.27222
j 0.204
j 0.108
j0.24
'X' of G11
G1
j0.2
'X' of T2
j0.3
'X' of G12
G2
j 0.1976
'X' of G13
G3