NAME: CHERUIYOT ISAAC LANG'AT

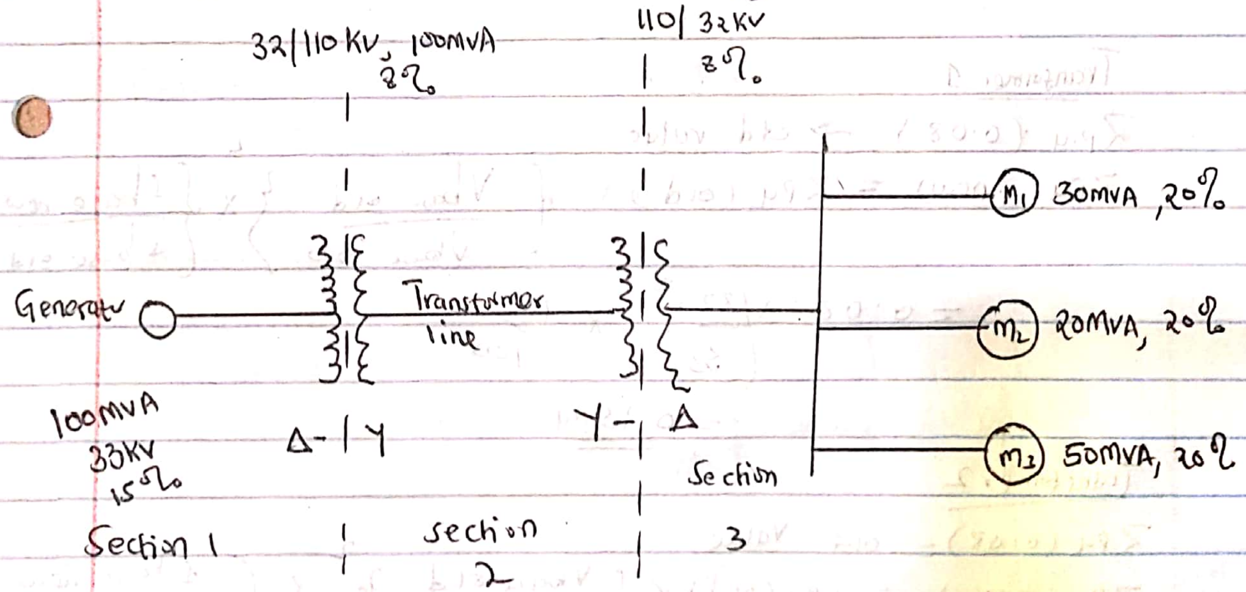
REG NO: EC134118

COURSE TITLE: POWER SYSTEMS II

COURSE CODE: ECE 471

TASK: CAT 1

1. A 100 MVA, 33KV, 3-Phase generator has a sub-transient reactance of 15%. The generator supplies 3 motors through a step-up transformer - transmission-line - step-down transformer arrangement. The motors have rated inputs of 30MVA, 20MVA and 50MVA at 30KV with 20% sub-transient reactance each. The three-phase transformers are rated at 100 MVA, 32KV-Δ / 110 KV-Y with 8% leakage reactance. The line has a reactance of 50 ohms. By selecting the generator ratings as base values in the generator circuit, determine the base values in all other parts of the systems. Hence evaluate the corresponding pu values and draw the equivalent per unit reactance diagram.



Power system is sub-divided into 3 sections, section 1, section 2, and section 3

Taking base values be generator ratings;

Section 1:

Vbase = 33KV

Sbase = 100MVA

For transformer 1 : ($V_1 = 33kv$)

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

$$V_2 = \frac{N_2}{N_1} \times V_1 = 33 \times \frac{110}{32} = \underline{\underline{113.44\,KV}}$$

For transformer 2

$$\frac{V_2}{V_1} = \frac{N_2}{N_1} \quad \therefore \quad V_2 = V_1 \times \frac{N_2}{N_1} = 113.44 \times \frac{32}{110} = \underline{\underline{33KV}}$$

section 1	section 2	section 3
Sbase = 100MVA	Sbase = 100MVA	Sbase = 100MVA
V base = 33KV	Vbase = 113.44KV	Vbase = 33KV

The corresponding per unit (P.u) values

- The generator p.u reactance is given as 0.15 since the base values have not changed for the generator, the p.u reactance of the generator will be same with values of $\underline{\underline{0.15}}$

Transformer 1

Zp.u (0.08) → old value

$$Zpu\,(new) = Zpu\,(old) \times \left\{\frac{Vbase\ old}{Vbase\ new}\right\}^2 \times \left\{\frac{Sbase\ new}{Sbase\ old}\right\}$$

$$= 0.08 \times \left(\frac{32}{33}\right)^2 \times \frac{100}{100}$$

$$= \underline{0.75pu}$$

Transformer 2

Zpu (0.08) = old Value

$$Zpu\,(new) = Zpu\,(old) \times \left\{\frac{Vbase\ old}{Vbase\ new}\right\}^2 \times \left\{\frac{Sbase\ new}{Sbase\ old}\right\}$$

$$= 0.08 \times \left\{\frac{110}{113.44}\right\}^2 \times \frac{100}{100} \qquad = \underline{\underline{0.075\,p.u}}$$

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Motor 1

$Z_{pu} = 0.2$, $S_{old} = 30MVA$

$V_{base} = 30kV$, New base $= 33kV$

$$Z_{pu} = Z_{pu\,old}\left(\frac{V_{base\,old}}{V_{base\,new}}\right)^2 \times \frac{S_{base\,new}}{S_{base\,old}}$$

$$= 0.2 \times \left(\frac{30}{33}\right)^2 \times \frac{100}{30}$$

$$= \underline{\underline{0.55\,pu}}$$

Motor 2

$Z_{pu\,old} = 0.2$, $S_{old} = 20MVA$

$V_{base\ old} = 30kV$

$Z_{pu\ new} =$

$$0.2 \times \left(\frac{30}{33}\right)^2 \times \frac{100}{20}$$

$$= \underline{\underline{0.826\,p.u}}$$

Motor 3

$Z_{pu} = 0.2$, $S = 50MVA$

$V_{base} = 30kV$

$Z_{pu} =$

$$0.2 \times \left(\frac{30}{33}\right)^2 \times \frac{100}{50}$$

$$= \underline{\underline{0.33\,p.u}}$$

Transmission line:

line reactance $= 50\Omega$

lines in section 2:

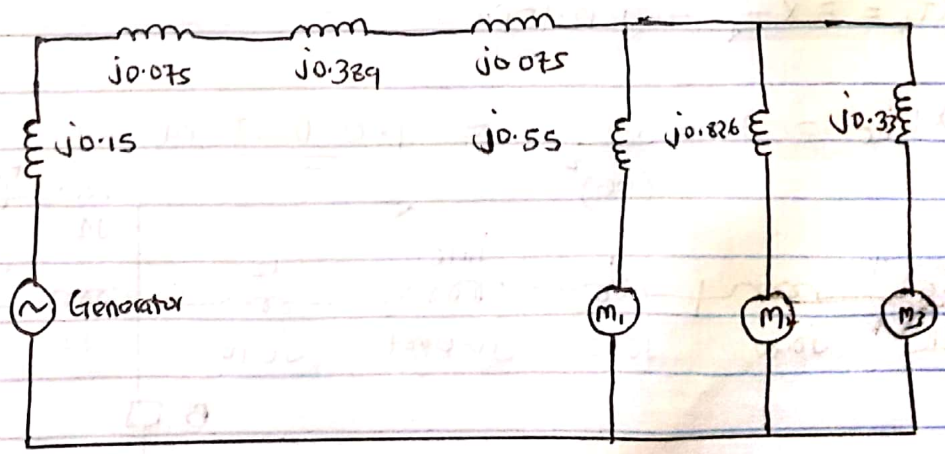
$S_{base} = 100MVA$ and $V_{base} = 113.44kV$

$$Z_{base} = \frac{(V_{base})^2}{S_{base}} = \frac{113.44kV^2}{100MVA}$$

$$= \frac{(113.44\times10^3)^2}{100\times10^6} = \underline{\underline{128.69\Omega}}$$

$$Z_{pu}\ (\text{transmission line}) = \frac{50\Omega}{128.69} = \underline{\underline{0.389\ p.u}}$$

Equivalent per unit reactance diagram



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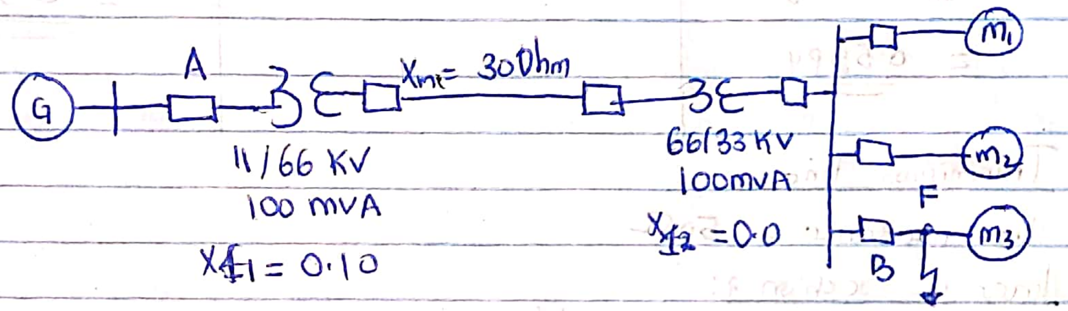
Q. A 100 MVA, 11 KV generator with $X'' = 0.2$ p.u is connected through a transformer and line to a bus bar that supplies three identical motors as shown in fig. and each motor has $X'' = 0.20$ p.u and $X' = 0.25$ p.u on a base of 20 MVA, 33 KV. The bus voltage at the motors is 33 KV when a three-phase balanced fault occurs at the point F. Calculate.

(i) Sub-transient current in the fault

(ii) Sub-transient current in the circuit breaker B



Solution

Let base MVA = 100

Base voltage = 11 KV

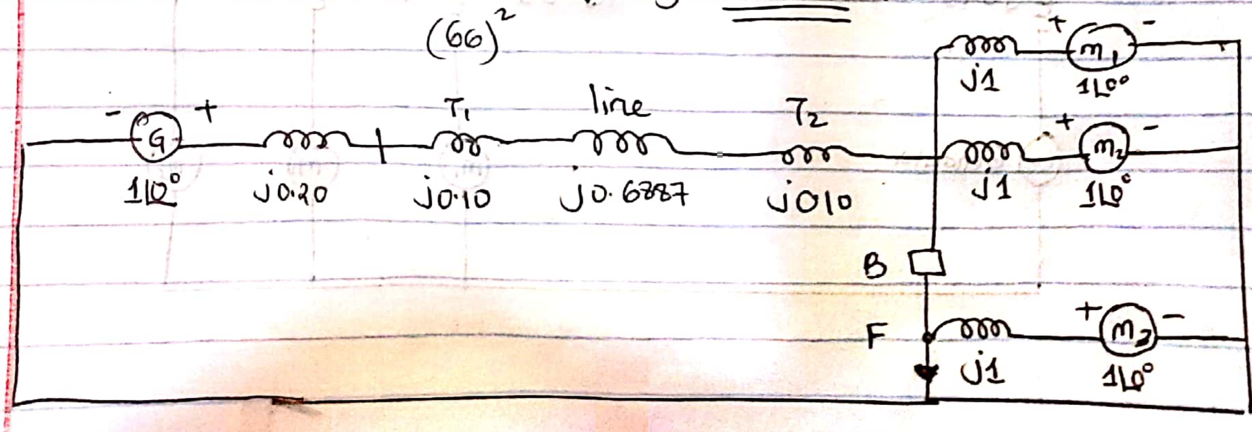
$X'_g = j0.20$ p.u

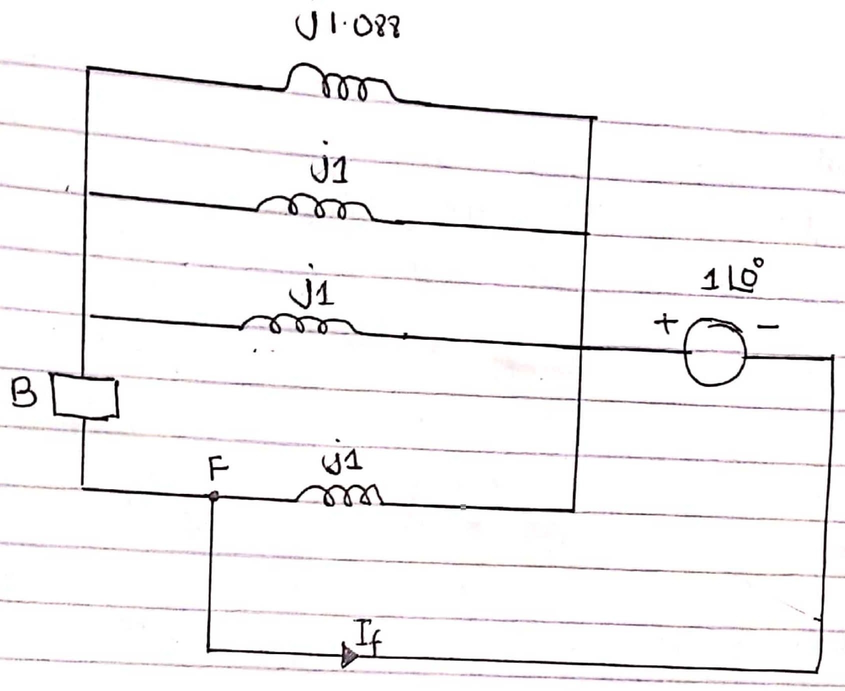
$X'_m = X'_{m_1} = X'_{m_2} = X'_{m_3} = j0.2 \times \frac{100}{20} = j1.0$ pu

$X'_m = X'_{m_1} = X'_{m_2} = X'_{m_3} = j0.25 \times \frac{100}{20} = j1.25$ pu

$X_{T_1} = X_{T_2} = j0.10$ pu

$X_{line} = 30 \times \frac{100}{(66)^2} = j0.6887$ pu





$$X_{equivalent} = \frac{j}{3.919} = j0.255$$

$$I_f = \frac{1\angle 0^\circ}{j0.255} = -j3.919 \text{ pu}$$

Base current for 33kV circuit

$$I_B = \frac{100 \times 1000}{\sqrt{3} \times 33} = \underline{\underline{1.75\text{ KA}}}$$

$$|I_f| = 3.919 \times 1.75 = \underline{\underline{6.85\text{ KA}}}$$

(b) current through circuit breaker B is

$$I_{fB} = \frac{2}{j1} + \frac{1}{j1.088} = -j2.919 \text{ p.u.}$$

$$|I_{fB}| = 2.919 \times 1.75 = \underline{\underline{5.108\text{ KA}}}$$