Name: Okakuro Bruma
Mat No: 16/Eng04/041
Dept: Electrical/Electronics Eng
Course: Power Systems Engineering

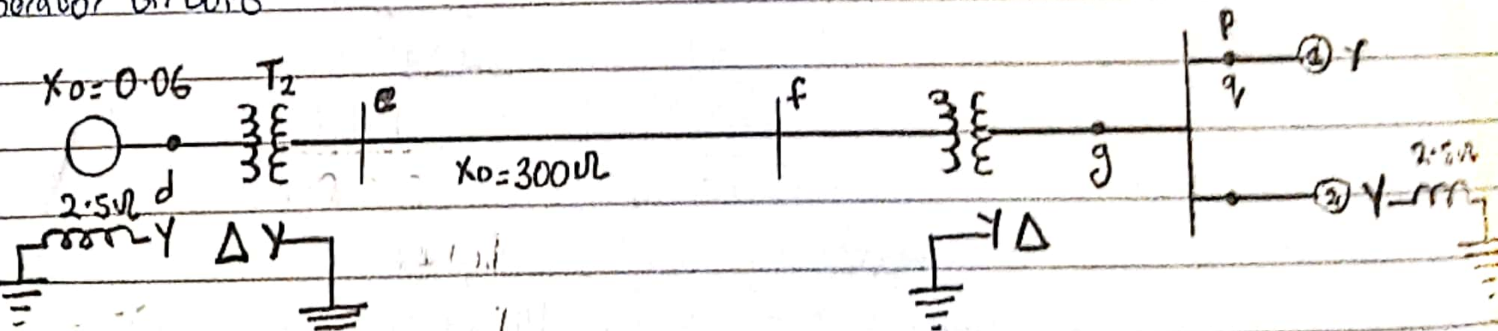
Assignment

A 25MVA, 11KV 3ϕ generator has a subtransient reactance of 20%. The generator supplies two motors over a transmission line with transformers at both sides as shown in the one-line diagram. The motors have rated inputs of 15 and 7.5MVA, both 10KV with 25% subtransient reactance. The 3ϕ transformers are both rated 30MVA, 10.8/11KV connection Δ-Y with leakage of 10% each. The series reactance of the line is 100Ω.

(a) Draw the positive, negative and the zero sequence networks of the system with reactances marked in per unit

(b) If the motors are loaded to draw 15 and 7.5MW at 10KV, 0.8 leading power factor before the occurence of a solid LG at bus g and the prefault current is neglected, calculate the fault current and subtransient current in all parts of the system

N/B Assume that the negative sequence reactance of each machine is equal to the subtransient reactance. Omit reactances. Select generator rating as base in the generator circuit



Solution

$Base = 25MVA$ $\quad X = 10\% = \frac{10}{100} = 0.1Ω$ $\quad X_m = 25\% = \frac{25}{100} = 0.25Ω$

$V_{Base} = 11KV$ $\quad X_s = 20\% = \frac{20}{100} = 0.2Ω$

(a) $T_L, V_{Base} = 11 \times \frac{11}{10.8}$ = ~~[illegible]~~ 11.2KV

(a) Motor $V_{Base} = \frac{11.2 \times 10.8}{11} = 11 KV$

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

The transformer, line and motor reactances are converted to pu values

(c) Transformer reactance

$$X_T = 0.1 \times \frac{25}{30}\left[\frac{10.8}{11}\right]^2$$

$$= 0.0803 pu$$

(d) line reactance

$$X_L = \frac{100 \times 25}{(123.2)^2} = 0.164 pu$$

(e) Motor reactance ; $X = 25\% = 25/100 = 0.25$

$$X_{m1} = 0.25 \times \frac{25}{15}\left[\frac{10}{11}\right]^2$$

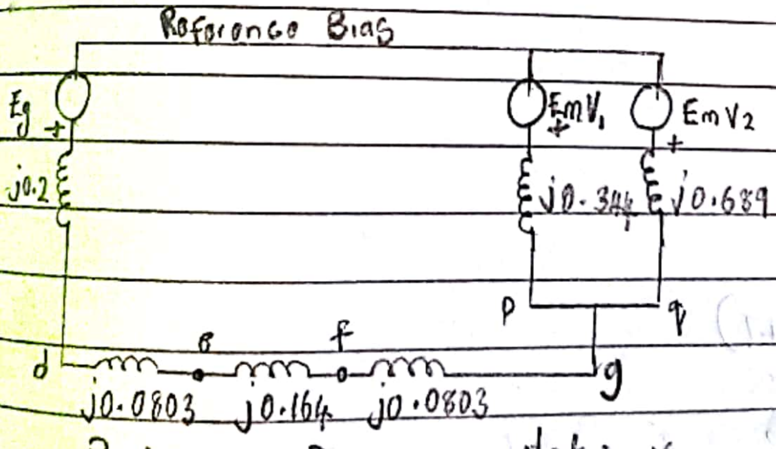
$$= 0.344 pu$$

$$X_{m2} = 0.25 \times \frac{25}{7.5}\left[\frac{10}{11}\right]^2$$

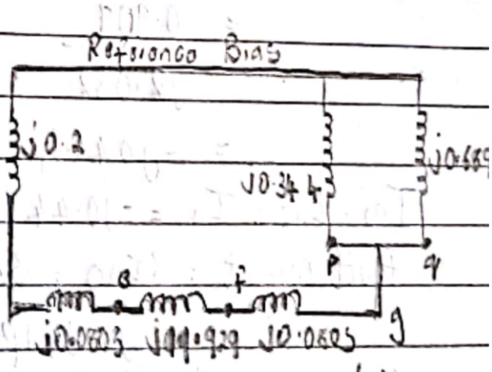
$$= 0.689 pu$$

(f) Zero sequence reactance of the transmission line

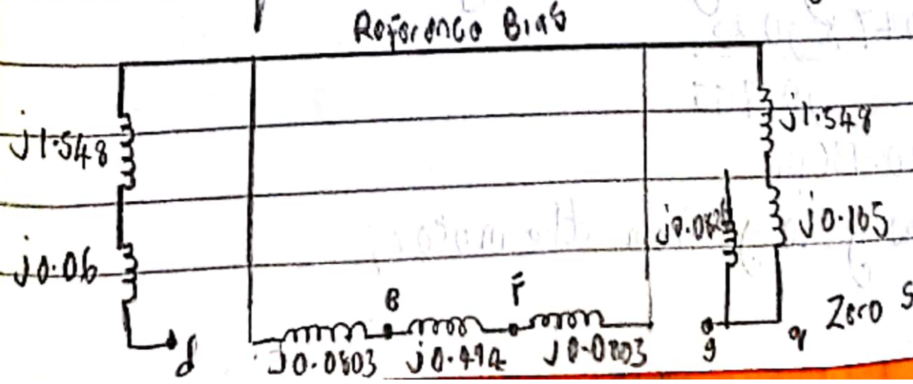
$$X_{0TL} = \frac{300 \times 25}{(123.2)^2} = 0.494 pu$$



Positive (+ve) Sequence Network



Negative (-ve) Sequence Network



Zero Sequence Network

- Reactance of Current limiting reactor $= \frac{2.5 \times 25}{(11)^2} = 0.516pu$
- Reactance of Current limiting reactor Included in the zero sequence network
$= 3 \times 0.516 = 1.548pu$

i. Zero Sequence reactance of Motor

ⓐ Motor 1

$$X_{zsRM1} = 0.06 \times \left[\frac{25}{15}\right] \times \left[\frac{10}{11}\right]^2$$

$= 0.0826pu$

ⓑ Motor 2

$$X_{zsRM2} = 0.06 \times \left[\frac{25}{7.5}\right] \left[\frac{10}{11}\right]^2$$

$= 0.165pu$

Calculate the fault and subtransient current in all parts of the system

solution

Neglecting Prefault currents

$E_g'' = E_{m1}'' = E_{m2}'' = V_f^0$ (Prefault voltage at g)

$= 10/11 = 0.909pu$

$Z_2 = Z_1 = j0.16pu$

from the sequence network;

$$I_{a1} = \frac{V_f^0}{Z_1 + Z_2 + Z_0}$$

$$= \frac{0.909}{j2.032}$$

$= -j0.447pu$

$I_{a2} = I_{a0} = I_{a1} = -j0.447pu$

Fault current $= 3I_{a0} = 3 \times (-j0.447)$

$= -j1.341pu$

I_{a1} component flowing to g from the generator:

$$-j0.447 \times \frac{j0.23}{j0.755}$$

$= -j0.136pu$

I_{a1} component flowing to g from the motor:

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$-j0.447 \times \frac{j0.525}{j0.755}$

$= -j0.311\ pu$

~~Iao flow to g~~

Fault currents from the generator towards g;

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix} \begin{bmatrix} -j0.136 \\ -j0.136 \\ 0 \end{bmatrix} = \begin{bmatrix} -j0.272 \\ -j0.136 \\ j0.136 \end{bmatrix} pu$$

Fault currents from the motor towards g;

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ \alpha^2 & \alpha & 1 \\ \alpha & \alpha^2 & 1 \end{bmatrix} \begin{bmatrix} -j0.311 \\ -j0.311 \\ -j0.447 \end{bmatrix} = \begin{bmatrix} -j1.06 \\ -j0.136 \\ -j0.136 \end{bmatrix} pu$$

~~Positive (+ve) sequence component of the transmission line current has phase shift -90^0~~

Negative (-ve) sequence component of the transmission line current is shift to $+90^0$

Positive sequence current $= j * (-j0.136) = -0.136\ pu$

Negative sequence current $= j * (-j0.136) = 0.136\ pu$

Zero sequence current $= 0$

line a current in the transmission line

$= -0.136 + 0.136 + 0$

$= 0$

Calculation for voltage behind subtransient reactances to be use if load currents are accounted for

Motor 1 : $\frac{15}{25 \times 0.909 \times 0.8} \angle 36.86^0$

$= 0.825 \angle 36.86^0$

$= 0.66 + j0.495\ pu$

Motor 2 : $\frac{7.5}{25 \times 0.909 \times 0.8} \angle 36.86$

$= 0.4125 \angle 36.86^0$

$= 0.33 + j0.248\ pu$

Total current drawn by both motors $= 0.99 + j0.743\ pu$

Total voltage behind subtransient reactances;

Motor 1; $E_{m1} = 0.909 - j0.345 \times 0.825 \angle 36.86^0$

$= 1.08 - j0.228$

$= 1.104 \angle -11.92\, pu$

Motor 2; $E_{m2} = 0.909 - j0.69 \times 0.4125 \angle 36.86^0$

$= 1.08 - j0.228$

$= 1.104 \angle -11.92\, pu$

Generator; $E_g = 0.909 + j0.525 \times 1.2375 \angle 36.86^0$

$= 0.52 + j0.52$

$= 0.735 \angle 45^0\, pu$

∴ the actual value of +ve sequence current from the generator towards fault is $0.99 + (-j0.73) - j0.136$

$= -0.99 - j1.054$

the actual value of +ve sequence current from the motors to the fault is

$-0.99 - j0.743 - j0.311$

$= -0.99 - j1.054$

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