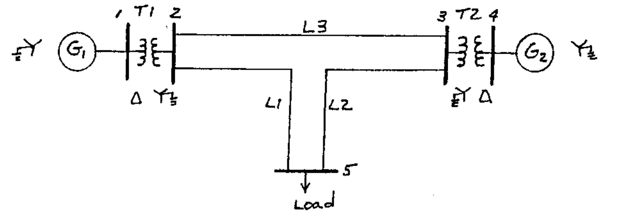
EE 4222 - Homework Set 3
Due: March 1, 2006 Name Key No.____

1. In the 3-phase system below, the elements have the following values:

G1: 250 MVA, 15.0 kV, X_0 = .05, X_1 = .25, X_2 = .20
G2: 500 MVA, 15.0 kV, X_0 = .05, X_1 = .25, X_2 = .20
T1: three single-phase units, high voltage side connected wye, low voltage side connected delta, Each unit is 15 kV:200 kV, 300 MVA, with a reactance of .10
T2: A three-phase transformer, 345 kV wye:15 kV delta, 500 MVA, with a reactance of .10.
L1: Z_0 = j40 ohms/phase, Z_1 = Z_2 = j20 ohms/phase
L2: Z_0 = j20 ohms/phase, Z_1 = Z_2 = j10 ohms/phase
L3: Z_0 = j30 ohms/phase, Z_1 = Z_2 = j15 ohms/phase

Choose a base of 345 kV, 1,000 MVA at the load and draw the per unit zero, positive, and negative impedance diagrams. Show all the impedance values on the diagrams. Assume all pre-fault bus voltages are 1.0 per unit. Neglect the load.



2. Construct the Thevenin equivalent zero, positive, and negative sequence networks for the system of problem 1 looking into the network at bus 3.

3. For a L-G fault with an impedance of j.1 per unit on bus 3 in the problem above, find the a-b-c line currents flowing toward the fault:
A. Coming from line L2
B. Coming from generator G1

4. Repeat problem 3 for a solid L-L fault on bus 3

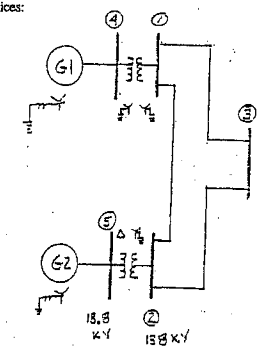
5. Repeat problem 3 for a solid 2L-G fault on bus 3

6. The 5-bus system shown below has the bus impedance matrices:

$$Z_0 = j\begin{bmatrix} .12847 & .02431 & .06597 & .10278 & .00000 \\ .02431 & .04514 & .03681 & .01944 & .00000 \\ .06597 & .03681 & .22847 & .05278 & .00000 \\ .10278 & .01944 & .05278 & .12222 & .00000 \\ .00000 & .00000 & .00000 & .00000 & .20000 \end{bmatrix}$$

$$Z_1 = j\begin{bmatrix} .13014 & .09589 & .10959 & .10411 & .07192 \\ .09589 & .12329 & .11233 & .07671 & .09247 \\ .10959 & .11233 & .17123 & .08767 & .08425 \\ .10411 & .07671 & .08767 & .12329 & .05753 \\ .07192 & .09247 & .08425 & .05753 & .10685 \end{bmatrix}$$

$$Z_2 = j\begin{bmatrix} .15517 & .12069 & .13448 & .12931 & .09655 \\ .12069 & .14943 & .13793 & .10057 & .11954 \\ .13448 & .13793 & .19655 & .11207 & .11034 \\ .12931 & .10057 & .11207 & .14943 & .08046 \\ .09655 & .11954 & .11034 & .08046 & .13563 \end{bmatrix}$$



Ignore pre-fault currents and assume a pre-fault voltage of 1.0. For a line-to-ground fault with an impedance of j.06792 on bus 3, find the a-b-c per unit line currents:

A. In the fault itself
B. From generator 2, which has: X_0 = .05, X_1 = .15, X_2 = .20, X_n = .05
C. In line 1-3, which has: X_1 = X_2 = .15, X_0 = .45

7. Repeat problem 6 for a line-to-line fault on bus 3 with an impedance of j .13222

8. Find the a-b-c fault current for a solid two-line-to-ground fault at bus 3 of the systme of problem 6.

①

1.) FINDING New Base Voltages:

V_{Base} ② 2, 3, 5 = 345 kV; V_{Base} ④ 4 = $\frac{15}{345}\times 345$ = 15kV;

V_{Base} ① 1 = $\frac{15}{200\sqrt{3}}(345) = \left(\frac{15}{346.41}\right)(345)$ = 14.93894 kV

FINDING Per Unit Values on new 1,000 MVA base.

G1: $X_0 = .05\left(\frac{15}{14.939}\right)^2\left(\frac{1000}{250}\right) = \underline{.20164}$; $X_1 = .25\left(\frac{15}{14.939}\right)^2\left(\frac{1000}{250}\right) = \underline{1.00819}$; $X_2 = .8X_1 = \underline{.80655}$

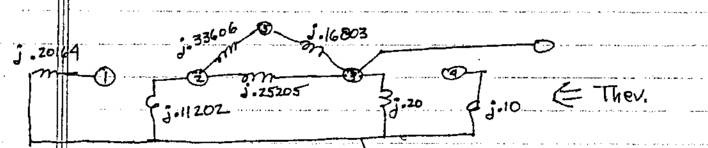
T1: $X = .10\left(\frac{15}{14.939}\right)^2\left(\frac{1000}{900}\right) = \underline{.11202}$; L_1: $X_0 = \frac{40}{\frac{(345\times10^3)^2}{1{,}000\times10^6}} = .33606$

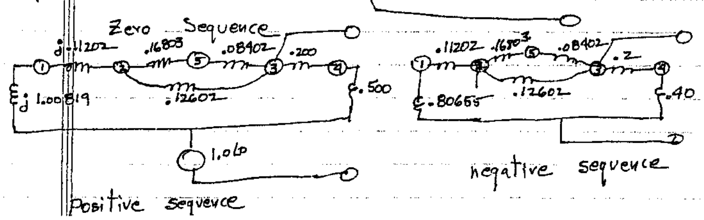
L_1: $X_1 = X_2 = \frac{1}{2}X_0 = \underline{.16803}$ | L_2: $X_0 = X_1$ of L_1 = $\underline{.16803}$, $X_1 = X_2 = \frac{1}{2}X_0 = \underline{.08402}$

L_3: $X_0 = \frac{30}{\frac{(345\times10^3)^2}{1000\times10^6}} = \underline{.25205}$; $X_1 = X_2 = \frac{15}{\frac{(345)^2}{1000}} = \underline{.12602}$

T2: $X = .10\left(\frac{1000}{500}\right) = .20$

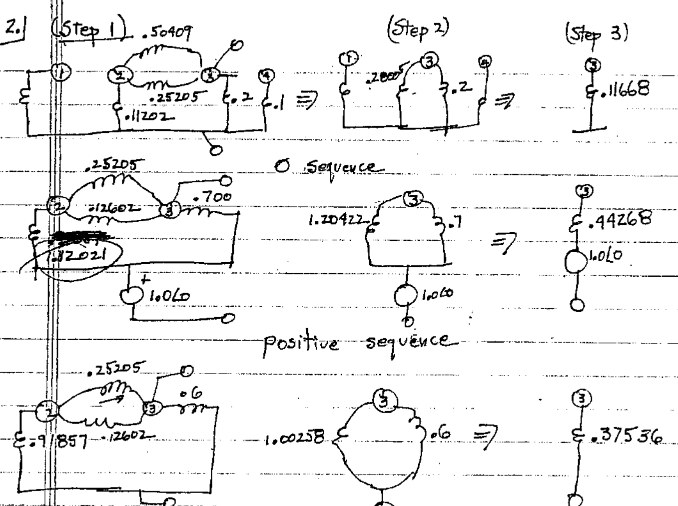
G2: $X_0 = .05\left(\frac{15}{15}\right)^2\left(\frac{1000}{500}\right) = \underline{.10}$; $X_1 = 5X_0 = \underline{.50}$, $X_2 = 4X_0 = \underline{.40}$





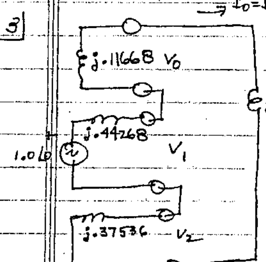
②

2.)



3.)

$I_0 = I_1 = I_2$



$I_1 = \frac{1.0\angle 0}{j(.11668+.44268+.37536+.3)}$

$= .80990\angle{-90}$

From bus 2 (Gen 1 pos & neg)

$I_0 = \left(\frac{.2}{.28006+.2}\right)(.80990\angle{-90}) = .33742\angle{-90}$

$I_1 = \left(\frac{.7}{.7+1.20422}\right)(.80990\angle{-90}) = .29778\angle{-90}$

$I_2 = \left(\frac{.6}{.6+1.00258}\right)(.80990\angle{-90}) = .30322\angle{-90}$

③

From Line 2:

$I_0 = \left(\frac{.25205}{.25205+.50409}\right).33742\angle{-90} = .11247\angle{-90}$

$I_1 = \left(\frac{.12602}{.12602+.25205}\right).29777\angle{-90} = .09924\angle{-90}$

$I_2 = \left(\frac{.12602}{.12602+.25205}\right)(.30328\angle{-90}) = .10108\angle{-90}$

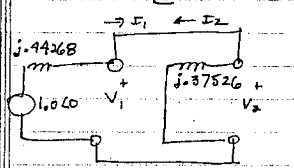
3-A)

$$I_{a,b,c} = [A]\begin{bmatrix} .11247\angle{-90} \\ .09924\angle{-90} \\ .10108\angle{-90} \end{bmatrix} = \begin{matrix} .31278\angle{-90} \\ .01242\angle{-82.667} \\ .01242\angle{-97.333} \end{matrix}$$

3-B)

$$I_{a,b,c} = [A]\begin{bmatrix} 0 \\ .29772\angle{-120} \\ .30328\angle{-60} \end{bmatrix} = \begin{matrix} .52044\angle{-89.697} \\ .52044\angle{86.697} \\ .00550\angle{180.00} \end{matrix}$$

4)



$I_1 = -I_2 = \frac{1.0\angle 0}{j(.44268+.37526)} = 1.22258\angle{-90}$; $I_0 = 0$

From Bus 2: $I_1 = \left(\frac{.7}{.7+1.20422}\right)(1.22258\angle{-90}) = .44943\angle{-90}$

$I_2 = \left(\frac{.6}{.6+1.00258}\right)(1.22258\angle{90}) = .45773\angle{90}$

From Line 2: $I_1 = \left(\frac{.12602}{.12602+.25205}\right).44943\angle{-90} = .14981\angle{-90}$

$I_2 = \left(\frac{.12602}{.12602+.25205}\right)(.45773\angle{90}) = .15257\angle{90}$

A)

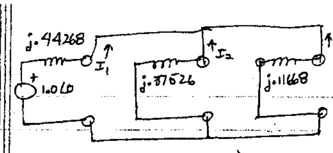
$$I_{a,b,c} = [A]\begin{bmatrix} 0 \\ .14981\angle{90} \\ .15257\angle{90} \end{bmatrix} = \begin{matrix} .00276\angle{90} \\ .26187\angle{-179.70} \\ .26187\angle{-.30} \end{matrix}$$

B)

$$I_{a,b,c} = [A]\begin{bmatrix} 0 \\ .44943\angle{-120} \\ .45773\angle{120} \end{bmatrix} = \begin{matrix} .45364\angle{179.09} \\ .45364\angle{-179.09} \\ .90716\angle{0} \end{matrix}$$

④

5.)



$I_1 = \frac{1.0\angle 0}{j(.44268+(.37526\,||\,.11668))} = 1.8081\angle{-90}$

$I_2 = 1.8081\angle{90}\left(\frac{.11668}{.11668+.37526}\right) = .44610\angle{90}$; $I_0 = -(I_1+I_2) = 1.43471\angle{90}$

$$I_{a,b,c} = [A]\begin{bmatrix} 1.43471\angle{90} \\ 1.88081\angle{-90} \\ .44610\angle{90} \end{bmatrix} = \begin{matrix} 0 \\ 2.94826\angle{133.118} \\ 2.94826\angle{46.882} \end{matrix}$$

6.)

$I_{F(0)} = I_{F(1)} = I_{F(2)} = \frac{1.0\angle 0}{j(.22847+.17123+.19655+3(.06792))} = 1.25\angle{-90}$

A)

$$I_{A,B,C} = [A]\begin{bmatrix} 1.25\angle{-90} \\ 1.25\angle{-90} \\ 1.25\angle{-90} \end{bmatrix} = \begin{bmatrix} 3.75\angle{-90} \\ 0 \\ 0 \end{bmatrix}$$

B) $V_{5(0)} = 0$; $V_{5(1)} = 1.0 - (1.25\angle{-90})(.08425\angle{90}) = .89469$; $V_{5(2)} = (1.25\angle{90})(.11034\angle{90}) = -.13793$

$I_{g(0)} = 0$, $I_{g(1)} = \frac{1-.89469}{.15\angle{90}} = .70208\angle{-90}$; $I_{g(2)} = \frac{0-(-.13793)}{j.2} = .68963\angle{-90}$

$$I_{a,b,c\ g2} = [A]\begin{bmatrix} 0 \\ .70208\angle{-120} \\ .68963\angle{-60} \end{bmatrix} = \begin{bmatrix} 1.2053\angle{-90.296} \\ 1.2053\angle{90.296} \\ .01245\angle{0} \end{bmatrix}$$

C) $I_{13(0)} = \frac{V_{1(0)} - V_{3(0)}}{Z_{line(0)}} = \frac{1.25\angle{-90}(.22847\angle{90} - .06597\angle{90})}{.45\angle{90}} = .45139\angle{-90}$

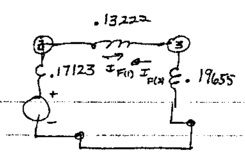
$I_{1-3(1)} = \frac{V_{1(1)} - V_{3(1)}}{Z_{line(1)}} = \frac{(.17123\angle{90} - .10959\angle{90})(1.25\angle{-90})}{.15\angle{90}} = .51367\angle{-90}$

$I_{1-3(2)} = \frac{V_{1(2)} - V_{3(2)}}{Z_{line(2)}} = \frac{(.19655\angle{90} - .13448\angle{90})1.25\angle{-90}}{.15\angle{90}} = .51725\angle{-90}$

$$I_{a,b,c} = [A]\begin{bmatrix} .45139\angle{-90} \\ .51367\angle{-90} \\ .51725\angle{-90} \end{bmatrix} = \begin{bmatrix} 1.48231\angle{-90} \\ .06414\angle{87.2296} \\ .06414\angle{92.7704} \end{bmatrix}$$

⑤

7)



$I_{F(1)} = -I_{F(2)} = \frac{1.0}{j(.17123+.13222+.19655)} = 2\angle{-90°}$

$$I_{a,b,c\ Fault} = [A]\begin{bmatrix} 0 \\ 2\angle{-90} \\ 2\angle{90} \end{bmatrix} = \begin{bmatrix} 0 \\ 3.4641\angle{180} \\ 3.4641\angle{0} \end{bmatrix}$$

$I_{g2(1)} = \frac{+.08425\angle{90}(2\angle{-90})}{.15\angle{90}} = 1.12333\angle{-90}$

$I_{g2(2)} = \frac{(+.11034\angle{90})(2\angle{90})}{.20\angle{90}} = 1.10340\angle{90}$

$$I_{A,B,C} = [A]\begin{bmatrix} 0 \\ 1.12333\angle{-120} \\ 1.10340\angle{+120} \end{bmatrix}$$

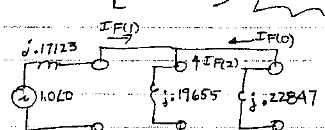
$$I_{A,B,C} = \begin{bmatrix} 1.1135\angle{-179.1} \\ 1.1135\angle{+179.1} \\ 2.22673\angle{0} \end{bmatrix}$$

$I_{1-3(1)} = \frac{2\angle{-90}(.17123\angle{90} - .10959\angle{90})}{.15\angle{90}} = .82187\angle{-90}$

$I_{1-3(2)} = \frac{2\angle{90}(.19655\angle{90} - .13448\angle{90})}{.15\angle{90}} = .82760\angle{90}$

$$I_{A,B,C} = [A]\begin{bmatrix} 0 \\ .82187\angle{-90} \\ .82760\angle{+90} \end{bmatrix} = \begin{matrix} .00573\angle{90} \\ 1.42849\angle{-179.885} \\ 1.42849\angle{-.115} \end{matrix}$$

8)



$I_{F(1)} = \frac{1.0\angle 0}{j\left[.17123 + \frac{(.19655)(.22847)}{.19655+.22847}\right]}$

$I_{F(1)} = 3.61160\angle{-90}$

$I_{F(2)} = -I_{F(1)}\left(\frac{.22847}{.22847+.19655}\right) = 1.94142\angle{90}$

$I_{F(0)} = -(I_{F(1)} + I_{F(2)}) = 1.67018\angle{90°}$

$$I_{a,b,c\ fault} = [A]\begin{bmatrix} 1.67018\angle{90} \\ 3.61160\angle{-90} \\ 1.94142\angle{90} \end{bmatrix} = \begin{bmatrix} 0 \\ 5.42249\angle{152.48} \\ 5.42249\angle{27.52} \end{bmatrix}$$