EE369, Test 9, Nov. 5. Name: KEY

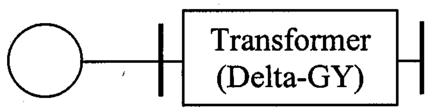
One sheet of notes permitted. Show all work.

A 30MVA, 12kV generator is connected to a delta - grounded wye transformer. The generator and transformer are isolated and not connected to a "power grid." Impedances are given on equipment bases.

A single-phase to ground fault, with zero impedance, suddenly appears on phase a of the 69kV transformer terminal. Find the resulting a-b-c generator currents (magnitude **in amperes** and phase). Regarding reference angle, assume that the pre-fault phase a voltage on the transformer's 69kV bus has angle = 0.

$$I_B = \frac{\frac{30\times10^6}{3}}{\frac{12\times10^3}{\sqrt{3}}} = \frac{10\times10^6}{6928} = 1443A$$

Gen
30MVA, 12kV
Subtransient reactances
X1 = X2 = 0.18pu
X0 = 0.12pu



Single phase to ground fault occurs on phase a

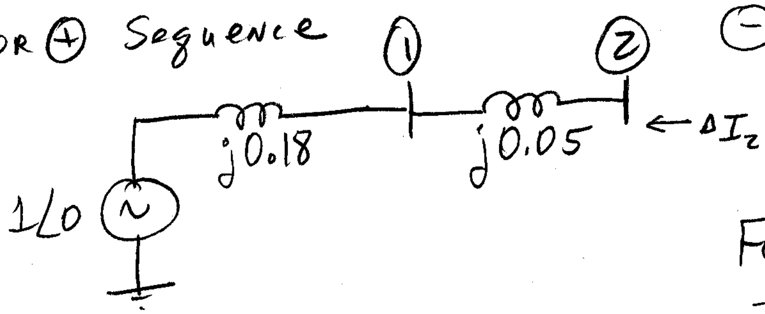
Generator is connected GY through a j0.5 ohm grounding reactor

X = 0.05pu
30MVA
12kV/69kV

$$Z_B = \frac{(12)^2}{30} = \frac{144}{30} = 4.8\Omega$$

So, $j0.5\Omega = j0.1042\Omega$

For ⊕ Sequence



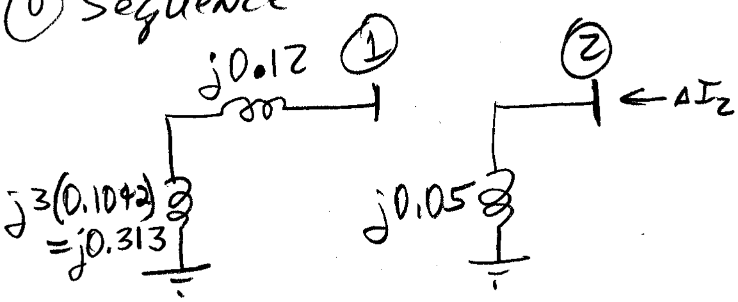
⊖ Sequence like ⊕, but source voltage is zero.

For ⊕ and ⊖ sequences,

$$Z_{22}^{(+,-)} = j(0.18 + 0.05) = j0.23$$

$$Z_{12}^{(+,-)} = \frac{\partial V_1}{\partial I_2} = \frac{j0.18\, I_2}{I_2} = j0.18$$

⓪ Sequence



For ⓪ sequence

$$Z_{22}^{(0)} = j0.05. \quad Z_{12}^{(0)} = 0$$

Now, for the fault current.

$$I_{2a}^F = \frac{3V_{2a}^{pre}}{Z_{22}^{(0)} + Z_{22}^{(1)} + Z_{22}^{(2)} + 3\cancel{Z_F}^{\,0}} = \frac{3\angle 0}{j0.05 + 2j(0.23)} = -j5.88pu$$

For a single phase fault, we know that

$$I_{K0}^F = I_{K1}^F = I_{K2}^F = \frac{1}{3} I_{Ka}^F, \quad \text{So } I_{2,0}^F = I_{2,1}^F = I_{2,2}^F = \frac{-j5.88}{3}$$

$$= -j1.960pu$$

Test 9, 11/5/04, continued

Now, ⊕ and ⊖ sequence currents are the same at the generator (except for phase shift) because we have a simple series path. Furthermore, the zero sequence current does not flow through the transformer. Thus, on the generator side, we have

ANSI shifts

$$I^F_{gen,1} = -j1.960\boxed{(1\angle -30)} = 1.960\angle -120°$$

$$I^F_{gen,2} = -j1.960\boxed{(1\angle +30)} = 1.960\angle -60$$

$$I^F_{gen,0} = 0.$$

Converting to abc

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 0 \\ 1.960\angle -120° \\ 1.960\angle -60° \end{bmatrix} = \begin{bmatrix} 1.960\angle -120° + 1.960\angle -60° \\ 1.960\angle 120° + 1.960\angle 60° \\ 1.960\angle 0 + 1.960\angle -180 \end{bmatrix}$$

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = 1.960 \begin{bmatrix} 1\angle -120 + 1\angle -60 \\ 1\angle 120 + 1\angle 60 \\ 0 \end{bmatrix} = 1.960 \begin{bmatrix} \sqrt{3}\angle -90 \\ \sqrt{3}\angle 90 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} -j3.39 \\ j3.39 \\ 0 \end{bmatrix}.$$ In Amps, $$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} -j4892 \\ j4892 \\ 0 \end{bmatrix}$$

Note – in the general case, you use the off-diagonal z elements. Doing the problem in the way . . .

$$V_{1,0}^{F} = \cancel{V_{1,0}^{pre}} - \cancel{Z_{12,0}} I_{2,0}^{F} = 0$$

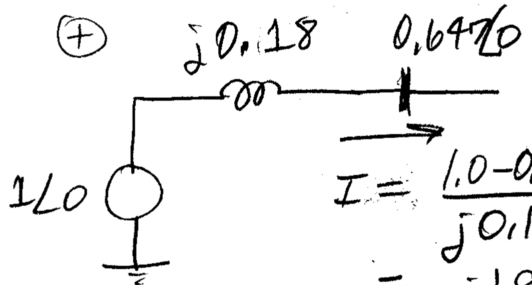
$$V_{1,1}^{F} = V_{1,1}^{pre} - Z_{12,1} I_{2,1}^{F} = 1.0 - j0.18(-j1.960)$$

$$= 1.0 - 0.353 = 0.647$$

$$V_{1,2}^{F} = \cancel{V_{1,2}^{pre}} - Z_{12,2} I_{2,2}^{F} = -j0.18(-j1.960) = -0.353$$

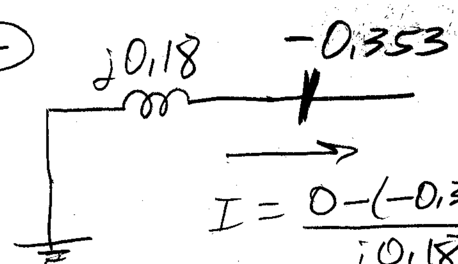
Then, using the network

⊕



$$I = \frac{1.0 - 0.647}{j0.18} = -j1.961$$

⊖



$$I = \frac{0 - (-0.353)}{j0.18} = -j1.961$$

You can see these currents match the previous ones. And so on.