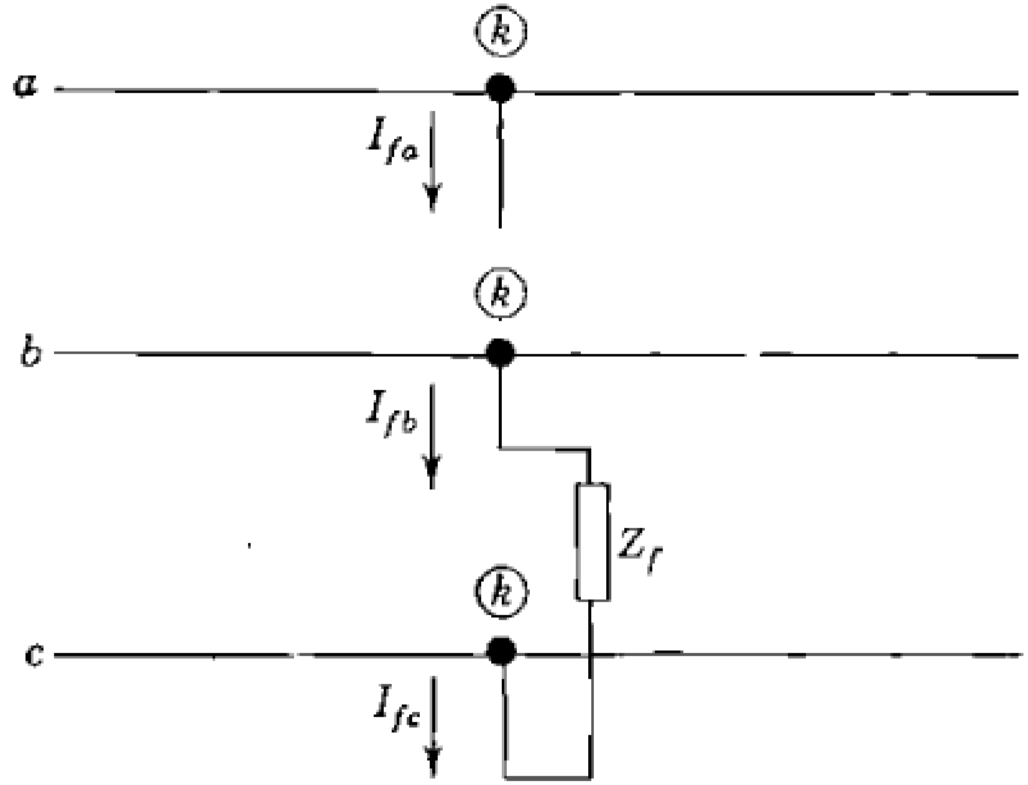
Line- Line Fault



$$I_{fa} = 0 \qquad I_{fb} = -I_{fc} \qquad V_{kb} - V_{kc} = I_{fb} Z_f$$

Since $I_{fb} = -I_{fc}$ and $I_{fa} = 0$, the symmetrical components of current are

$$\begin{bmatrix} I_{fa}^{(0)} \\ I_{fa}^{(1)} \\ I_{fa}^{(2)} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} 0 \\ I_{fb} \\ -I_{fb} \end{bmatrix}$$

and multiplying through in this equation shows that

$$I_{fa}^{(0)} = 0$$

$$I_{fa}^{(1)} = -I_{fa}^{(2)}$$

$$V_{kb} - V_{kc} = \left(V_{kb}^{(1)} + V_{kb}^{(2)}\right) - \left(V_{kc}^{(1)} + V_{kc}^{(2)}\right) = \left(V_{kb}^{(1)} - V_{kc}^{(1)}\right) + \left(V_{kb}^{(2)} - V_{kc}^{(2)}\right)$$

$$= (a^2 - a)V_{ka}^{(1)} + (a - a^2)V_{ka}^{(2)} = (a^2 - a)\left(V_{ka}^{(1)} - V_{ka}^{(2)}\right)$$

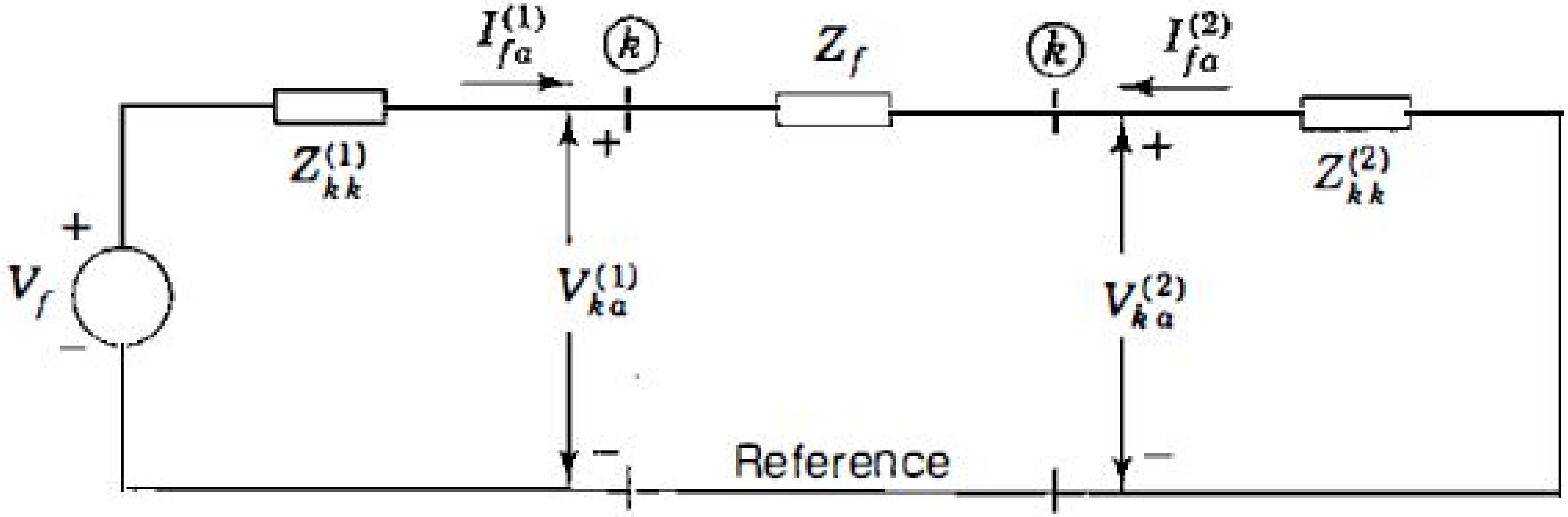
$$I_{fb}Z_f = \left(I_{fb}^{(1)} + I_{fb}^{(2)}\right)Z_f = \left(a^2 I_{fa}^{(1)} + aI_{fa}^{(2)}\right)Z_f$$

Equating both terms and setting $I_{fa}^{(2)} = -I_{fa}^{(1)}$

$$(a^2 - a)\left(V_{ka}^{(1)} - V_{ka}^{(2)}\right) = (a^2 - a)\, I_{fa}^{(1)}Z_f$$

or

$$V_{ka}^{(1)} - V_{ka}^{(2)} = I_{fa}^{(1)}Z_f$$



$$I_{fa}^{(1)} = -I_{fa}^{(2)} = \frac{V_f}{Z_{kk}^{(1)} + Z_{kk}^{(2)} + Z_f}$$

$$I_{fa}^{(1)} = -I_{fa}^{(2)} = \frac{V_f}{Z_{kk}^{(1)} + Z_{kk}^{(2)} + Z_f}$$

Example 12.3. The same system as in Example 12.1 is operating at nominal system voltage without prefault currents when a bolted line-to-line fault occurs at bus ③. Using the bus impedance matrices of the sequence networks for subtransient conditions, determine the currents in the fault, the line-to-line voltages at the fault bus, and the line-to-line voltages at Bus bar 2

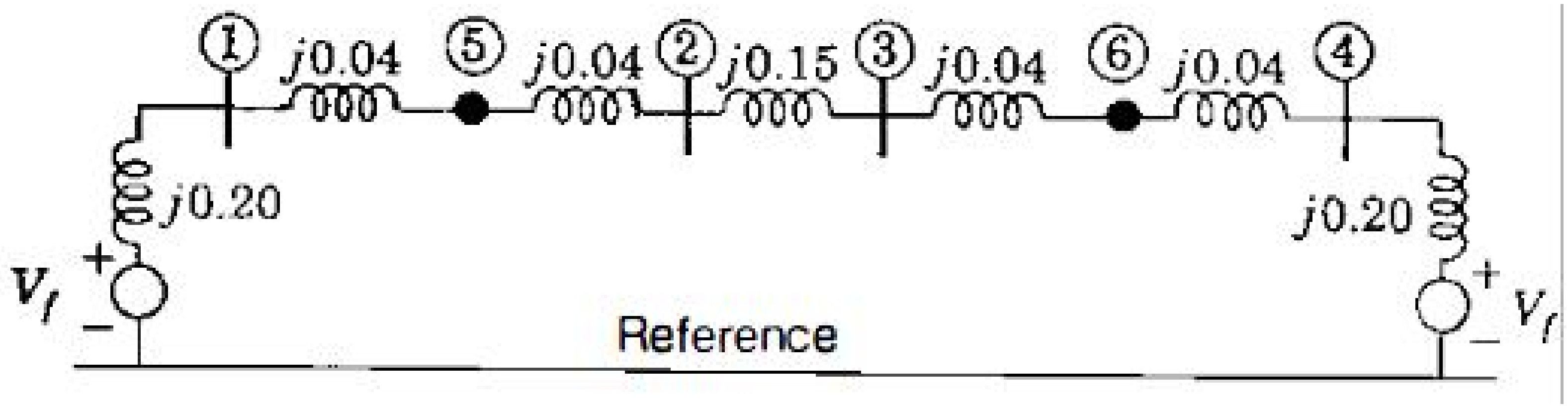
Example 12.1. Two synchronous machines are connected through three-phase transformers to the transmission line shown in Fig. 12.5. The ratings and reactances of the machines and transformers are

Machines 1 and 2: 100 MVA, 20 kV; $X_d'' = X_1 = X_2 = 20\%$,

$X_0 = 4\%, \quad X_n = 5\%$

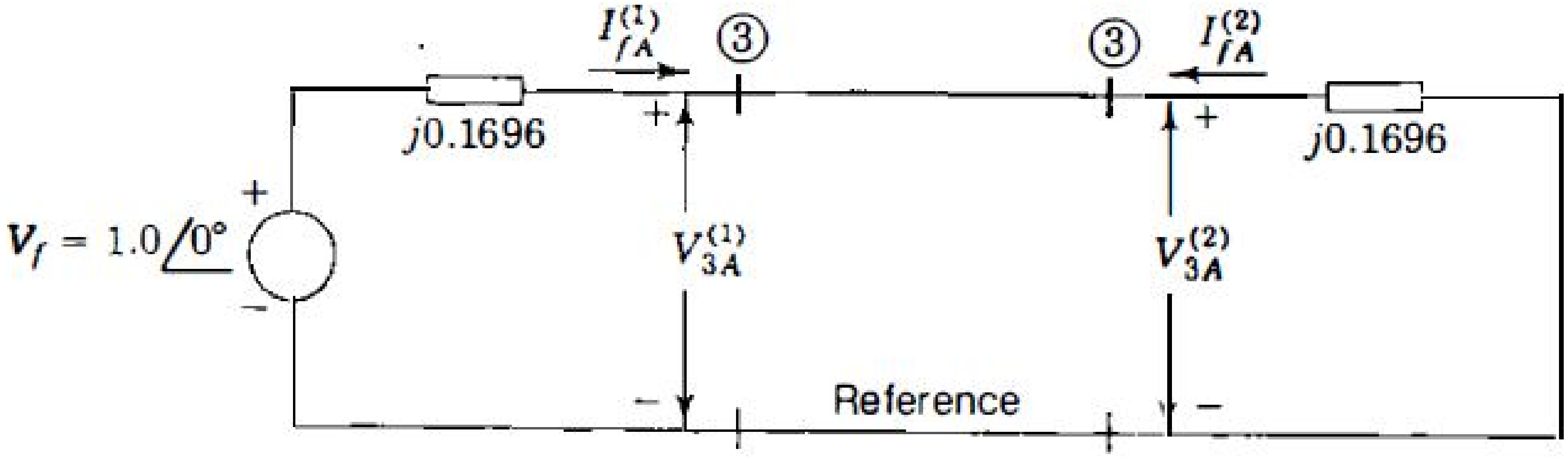
Transformers T_1 and T_2: 100 MVA, 20/345 kV ; $X = 8\%$

Both transformers are solidly grounded on two sides. On a chosen base of 100 MVA, 345 kV in the transmission-line circuit the line reactances are $X_1 = X_2 =$ 15% and $X_0 = 50\%$. The system is operating at nominal voltage without prefault



Positive Sequence Network

Z(positive sequence)=Z(negative sequence)=j0.1696 p.u.



$$I_{fA}^{(1)} = -I_{fA}^{(2)} = \frac{V_f}{Z_{33}^{(1)} + Z_{33}^{(2)}} = \frac{1 + j0}{j0.1696 + j0.1696} = -j2.9481 \text{ per unit}$$

Since $I_{fA}^{(0)} = 0$, the components of currents in the fault are calculated from

$$I_{fA} = I_{fA}^{(1)} + I_{fA}^{(2)} = -j2.9481 + j2.9481 = 0$$

$$I_{fB} = a^2 I_{fA}^{(1)} + a I_{fA}^{(2)} = -j2.9481(-0.5 - j0.866) + j2.9481(-0.5 + j0.866)$$

$$= -5.1061 + j0 \text{ per unit}$$

$$I_{fC} = -I_{fB} = 5.1061 + j0 \text{ per unit}$$

Current In kA

$$I_{fA} = 0$$

$$I_{fB} = -5.1061 \times 167.35 = 855\angle 180^\circ \text{ A}$$

$$I_{fC} = -5.1061 \times 167.35 = 855\angle 0^\circ \text{ A}$$

$$V_{3A}^{(0)} = 0$$

$$V_{3A}^{(1)} = V_{3A}^{(2)} = 1 - Z_{kk}^{(1)} I_{fA}^{(1)} = 1 - (j0.1696)(-j2.9481) = 0.5 + j0 \text{ per unit}$$

Line-to-ground voltages at fault bus ③ are

$$V_{3A} = V_{3A}^{(0)} + V_{3A}^{(1)} + V_{3A}^{(2)} = 0 + 0.5 + 0.5 = 1.0\angle 0^\circ \text{ per unit}$$

$$V_{3B} = V_{3A}^{(0)} + a^2 V_{3A}^{(1)} + a V_{3A}^{(2)} = 0 + a^2 0.5 + a0.5 = 0.5\angle 180^\circ \text{ per unit}$$

$$V_{3C} = V_{3B} = 0.5\angle 180^\circ \text{ per unit}$$

Line-to-line voltages at fault bus (3) are

$$V_{3,AB} = V_{3A} - V_{3B} = (\ \ 1.0 + j0) - (-0.50 + j0) = 1.5\angle 0^\circ \text{ per unit}$$

$$V_{3,BC} = V_{3B} - V_{3C} = (-0.5 + j0) - (-0.50 + j0) = 0$$

$$V_{3,CA} = V_{3C} - V_{3A} = (-0.5 + j0) - (\ \ 1.0 + j0) = 1.5\angle 180^\circ \text{ per unit}$$

For calculation of voltage at Bus Bar **2**

$$I_{f2-3}^{(1)} = \frac{(-j2.95) * (j0.28)}{j0.28 + j0.43}$$

$$I_{f2-3}^{(1)} = -j1.1634\, p.u.$$

$$I_{f2-3}^{(2)} = j1.1634\, p.u.$$

$$V_{2a}^{(1)} = 1 - [(-j1.1643)(j0.28)] = 0.6742\ p.u.$$

$$V_{2a}^{(2)} = -(j1.1634)(j0.28) = 0.3258\ p.u.$$

$V_{2a} = 1$ p.u.

$V_{2b} = 0.584 \angle -150^0$ p.u.

$V_{2c} = 0.584 \angle 150^0$ p.u.

$V_{2ab}=V_{2a}-V_{2b}$

$V_{2bc}=V_{2b}-V_{2c}$

$V_{2ca}=V_{2c}-V_{2a}$