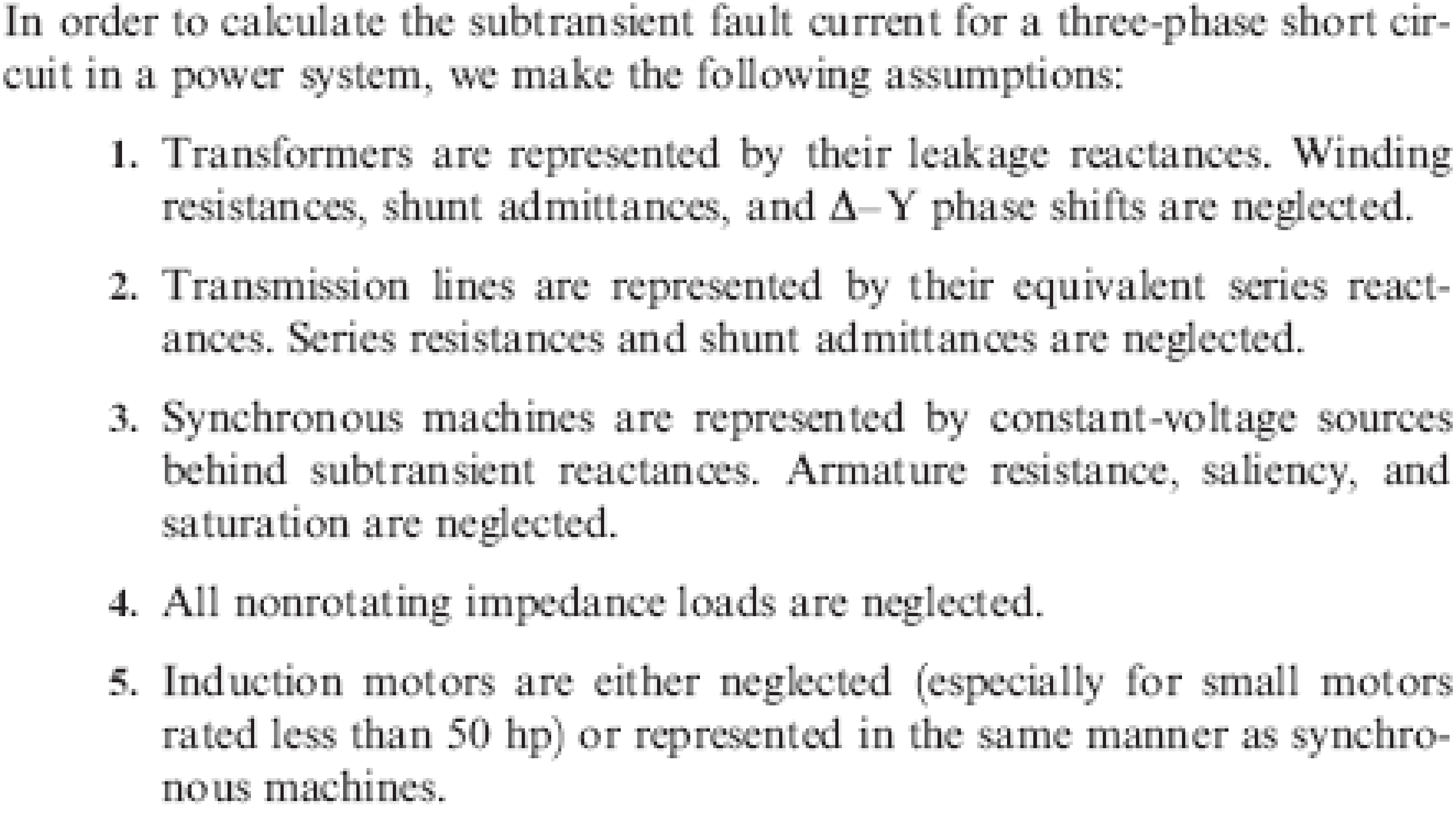
Menganalisa arus gangguan dengan menggunakan metode Thevenin



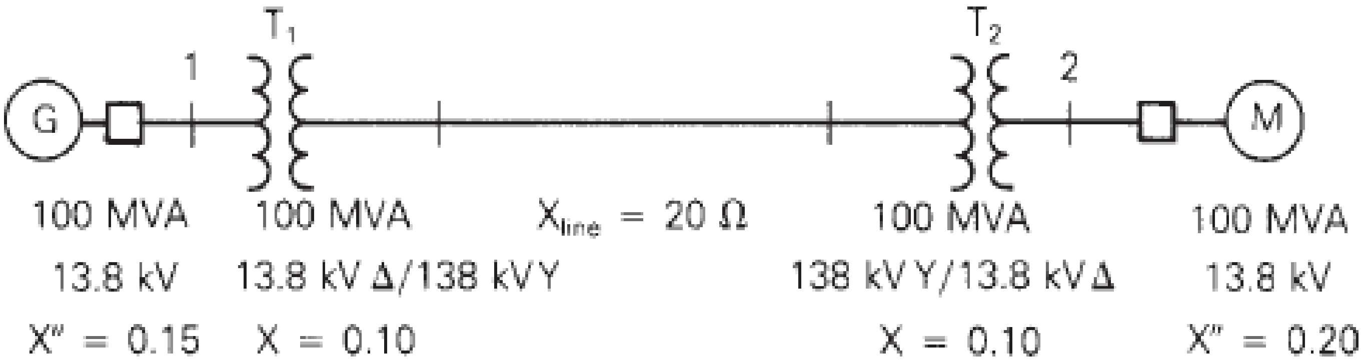
In order to calculate the subtransient fault current for a three-phase short circuit in a power system, we make the following assumptions:

1. Transformers are represented by their leakage reactances. Winding resistances, shunt admittances, and Δ–Y phase shifts are neglected.
2. Transmission lines are represented by their equivalent series reactances. Series resistances and shunt admittances are neglected.
3. Synchronous machines are represented by constant-voltage sources behind subtransient reactances. Armature resistance, saliency, and saturation are neglected.
4. All nonrotating impedance loads are neglected.
5. Induction motors are either neglected (especially for small motors rated less than 50 hp) or represented in the same manner as synchronous machines.

Figure 7.3 shows a single-line diagram consisting of a synchronous generator feeding a synchronous motor through two transformers and a transmission line. We shall consider a three-phase short circuit at bus 1. The positive-sequence equivalent circuit is shown in Figure 7.4(a), where the voltages E_g'' and E_m'' are the prefault internal voltages behind the subtransient reactances of the machines, and the closing of switch SW represents the fault. For purposes of calculating the subtransient fault current, E_g'' and E_m'' are assumed to be constant-voltage sources.

FIGURE 7.3

Single-line diagram of a synchronous generator feeding a synchronous motor



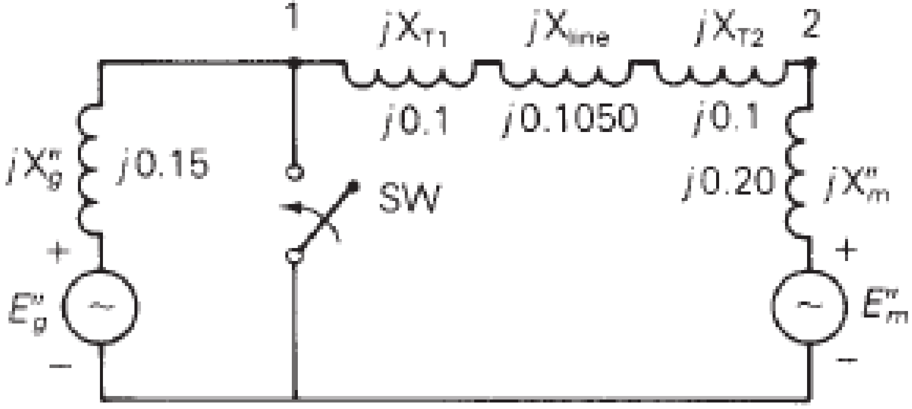
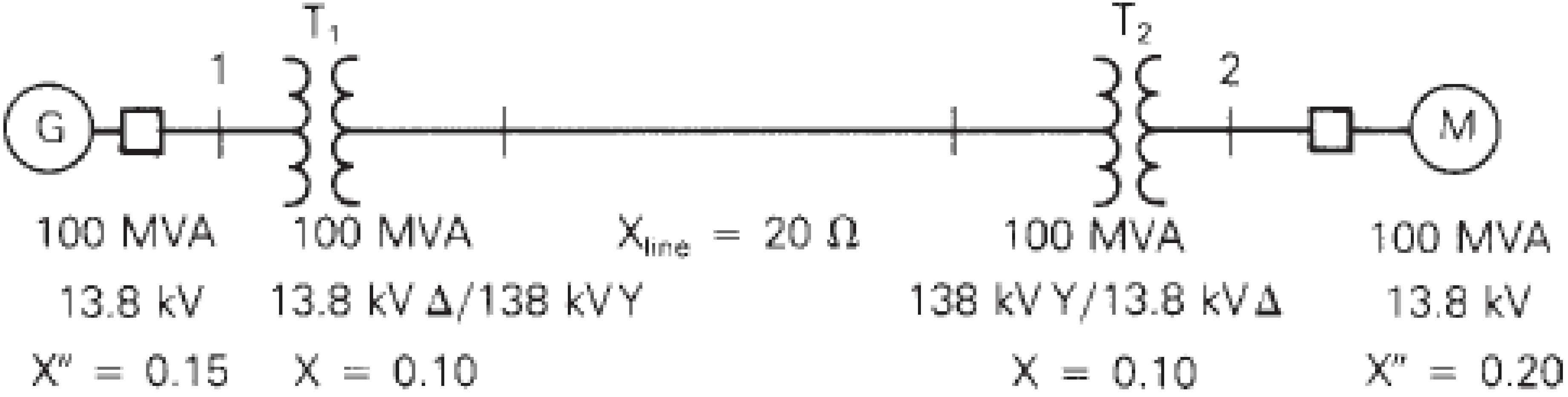
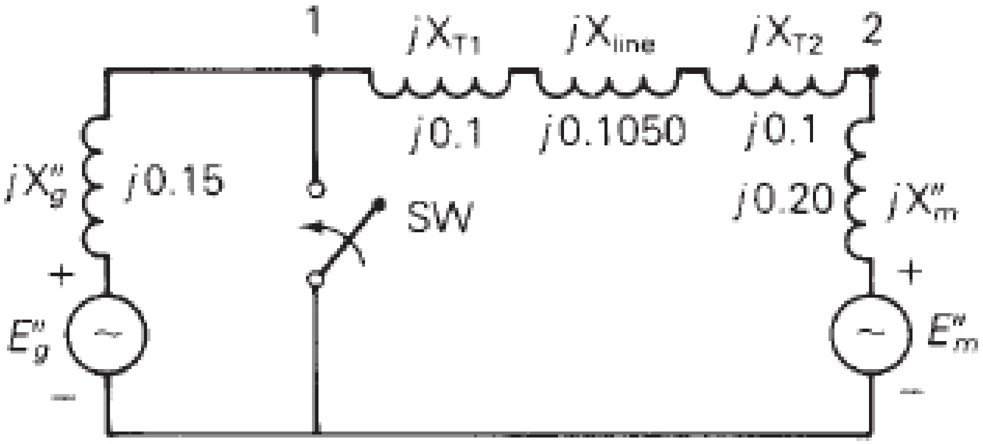


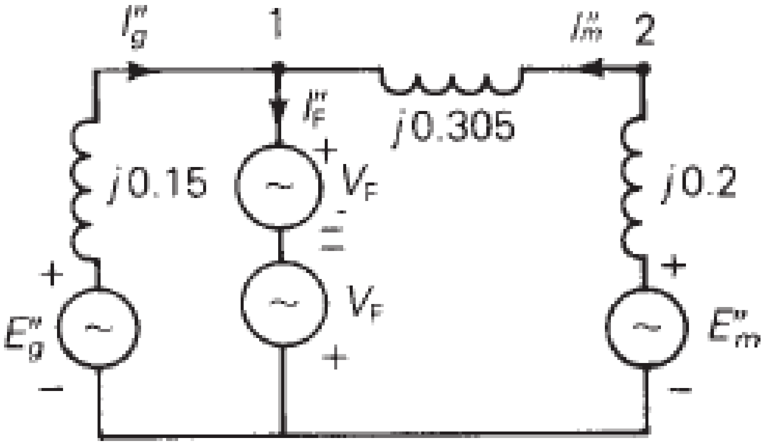
FIGURE 7.4 Application of superposition to a power system three-phase short circuit

(a) Three-phase short circuit



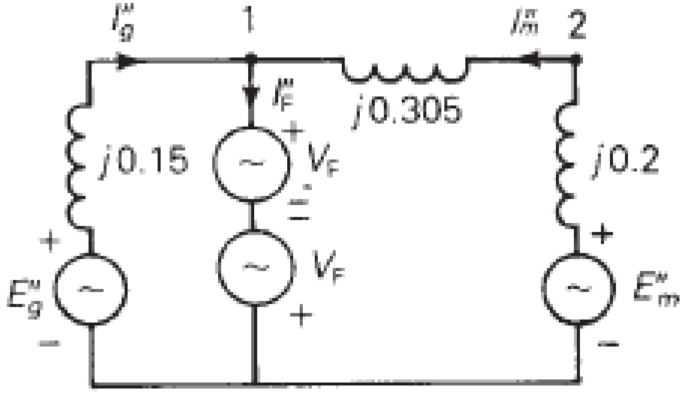


(a) Three-phase short circuit

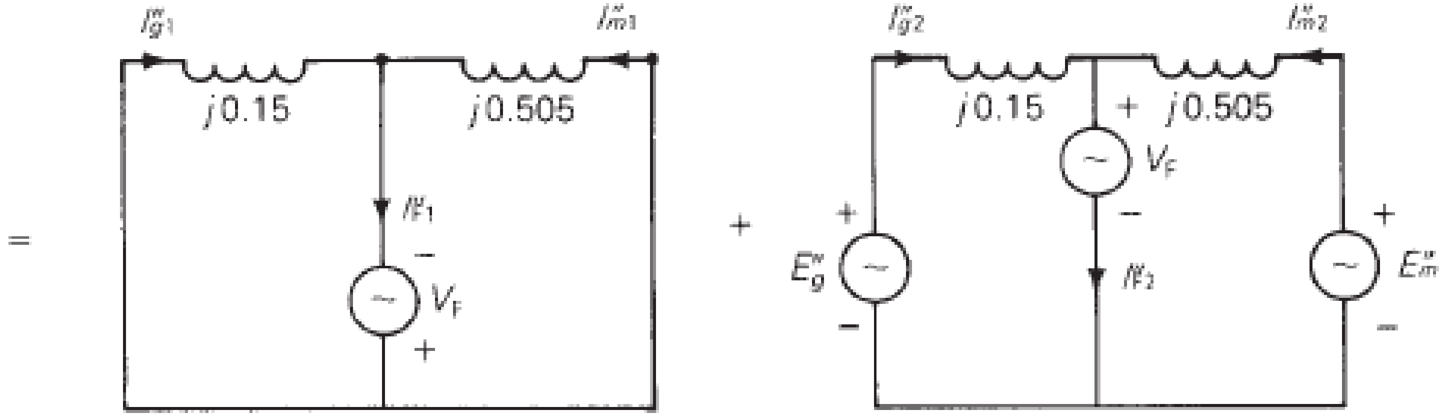


(b) Short circuit represented by two opposing voltage sources

In Figure 7.4(b) the fault is represented by two opposing voltage sources with equal phasor values V_{F}. Using superposition, the fault current can then be calculated from the two circuits shown in Figure 7.4(c). However, if V_{F} equals the prefault voltage at the fault, then the second circuit in Figure 7.4(c) represents the system before the fault occurs. As such, $I''_{\mathrm{F2}} = 0$ and V_{F},

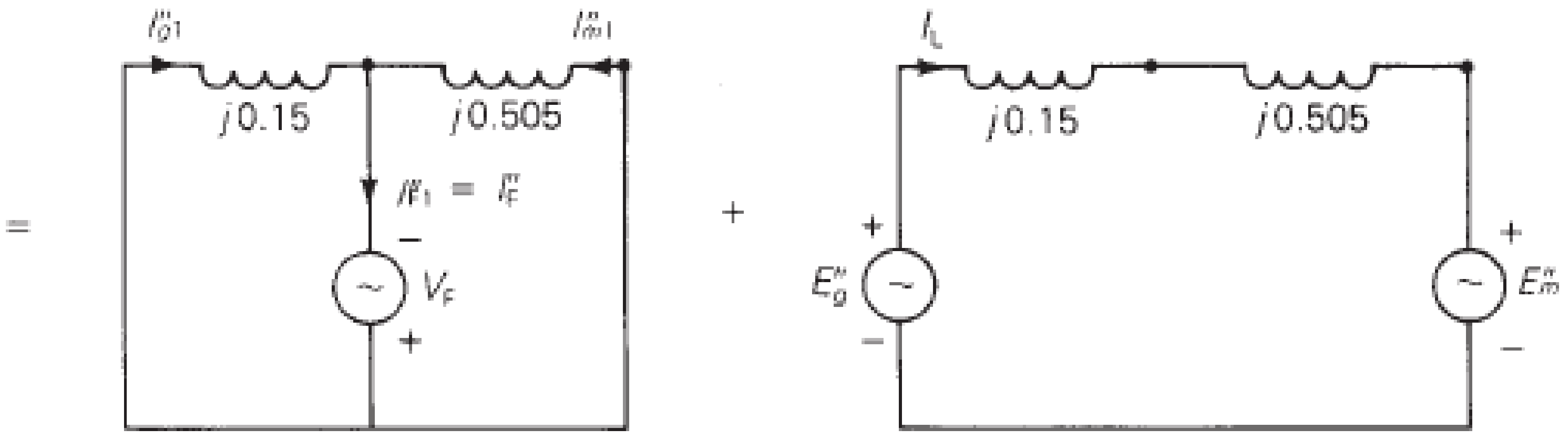


(b) Short circuit represented by two opposing voltage sources



(c) Application of superposition

FIGURE 7.4 Application of superposition to a power system three-phase short circuit which has no effect, can be removed from the second circuit, as shown in Figure 7.4(d). The subtransient fault current is then determined from the first circuit in Figure 7.4(d), $I''_F = I''_{F1}$. The contribution to the fault from the generator is $I''_g = I''_{g1} + I''_{g2} = I''_{g1} + I_L$, where I_L is the prefault generator current. Similarly, $I''_m = I''_{m1} - I_L$.



(d) V_F set equal to prefault voltage at fault

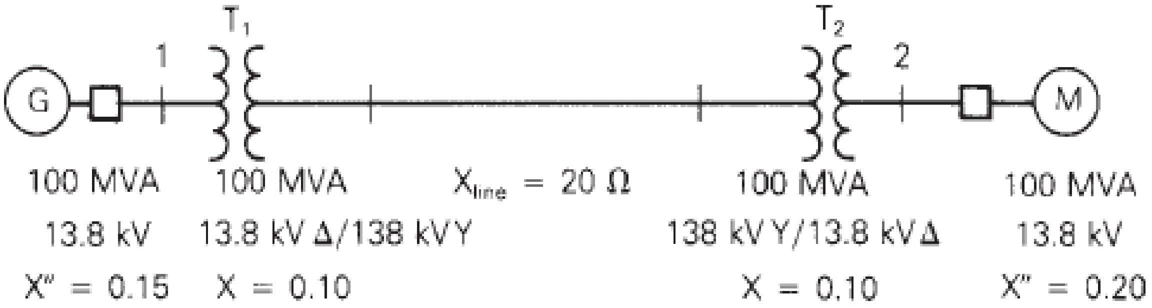
FIGURE 7.4 Application of superposition to a power system three-phase short circuit

EXAMPLE 7.3 Three-phase short-circuit currents, power system

The synchronous generator in Figure 7.3 is operating at rated MVA, 0.95 p.f. lagging and at 5% above rated voltage when a bolted three-phase short circuit occurs at bus 1. Calculate the per-unit values of (a) subtransient fault current; (b) subtransient generator and motor currents, neglecting prefault current; and (c) subtransient generator and motor currents including prefault current.

FIGURE 7.3

Single-line diagram of a synchronous generator feeding a synchronous motor



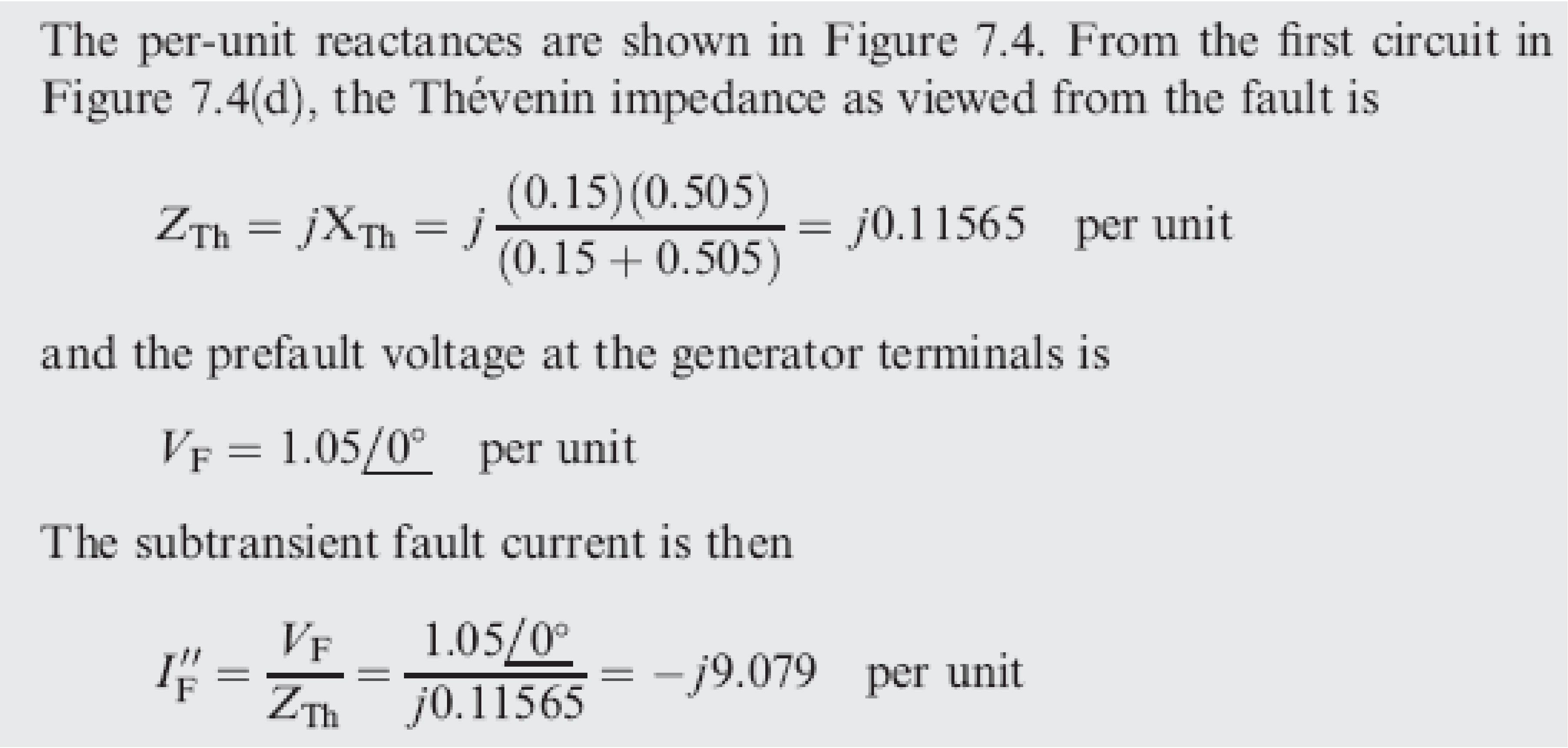
SOLUTION

a. Using a 100-MVA base, the base impedance in the zone of the transmission line is

$$Z_{\text{base, line}} = \frac{(138)^2}{100} = 190.44 \quad \Omega$$

and

$$X_{\text{line}} = \frac{20}{190.44} = 0.1050 \quad \text{per unit}$$



The per-unit reactances are shown in Figure 7.4. From the first circuit in Figure 7.4(d), the Thévenin impedance as viewed from the fault is

$$Z_{\mathrm{Th}} = jX_{\mathrm{Th}} = j\,\frac{(0.15)(0.505)}{(0.15+0.505)} = j0.11565 \quad \text{per unit}$$

and the prefault voltage at the generator terminals is

$$V_{\mathrm{F}} = 1.05\underline{/0^\circ} \quad \text{per unit}$$

The subtransient fault current is then

$$I''_{\mathrm{F}} = \frac{V_{\mathrm{F}}}{Z_{\mathrm{Th}}} = \frac{1.05\underline{/0^\circ}}{j0.11565} = -j9.079 \quad \text{per unit}$$

b. Using current division in the first circuit of Figure 7.4(d),

$$I''_{g1} = \left(\frac{0.505}{0.505+0.15}\right) I''_{\mathrm{F}} = (0.7710)(-j9.079) = -j7.000 \quad \text{per unit}$$

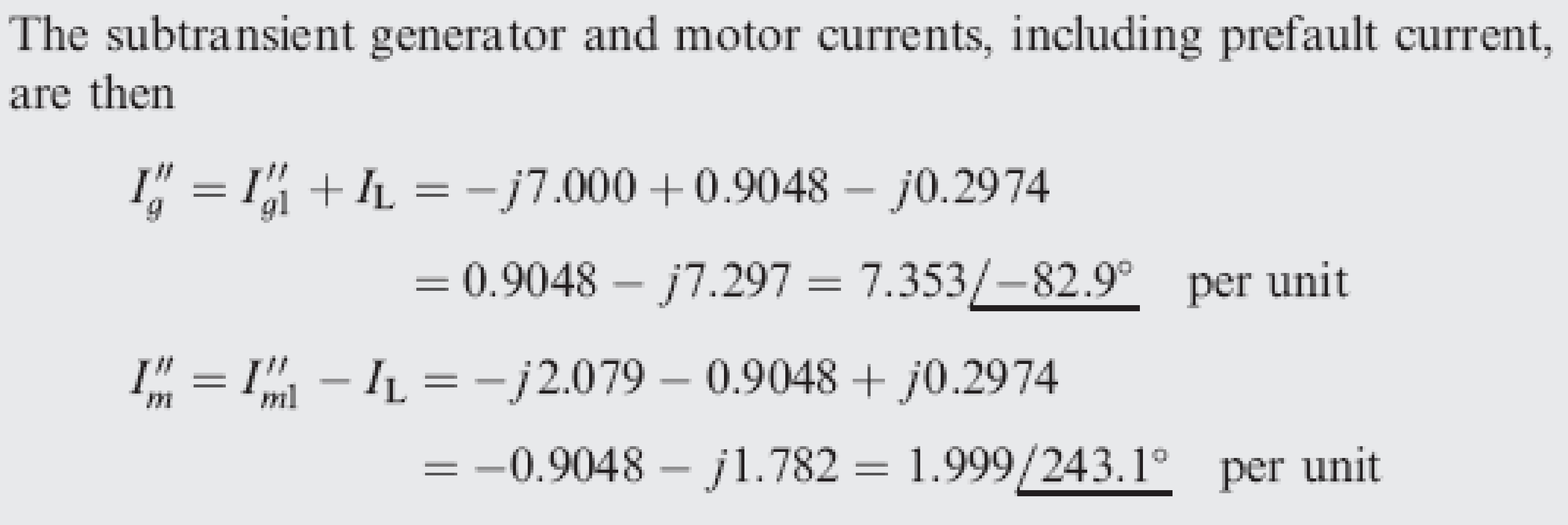
$$I''_{m1} = \left(\frac{0.15}{0.505+0.15}\right) I''_{\mathrm{F}} = (0.2290)(-j9.079) = -j2.079 \quad \text{per unit}$$

c. The generator base current is

$$\mathrm{I}_{\text{base, gen}} = \frac{100}{(\sqrt{3})(13.8)} = 4.1837 \quad \text{kA}$$

and the prefault generator current is

$$\begin{aligned} I_{\mathrm{L}} &= \frac{100}{(\sqrt{3})(1.05 \times 13.8)} \underline{/-\cos^{-1} 0.95} = 3.9845\underline{/-18.19^\circ} \quad \text{kA} \\ &= \frac{3.9845\underline{/-18.19^\circ}}{4.1837} = 0.9524\underline{/-18.19^\circ} \\ &= 0.9048 - j0.2974 \quad \text{per unit} \end{aligned}$$



The subtransient generator and motor currents, including prefault current, are then

$$\begin{aligned} I''_g = I''_{g1} + I_{\mathrm{L}} &= -j7.000 + 0.9048 - j0.2974 \\ &= 0.9048 - j7.297 = 7.353\underline{/-82.9^\circ} \quad \text{per unit} \end{aligned}$$

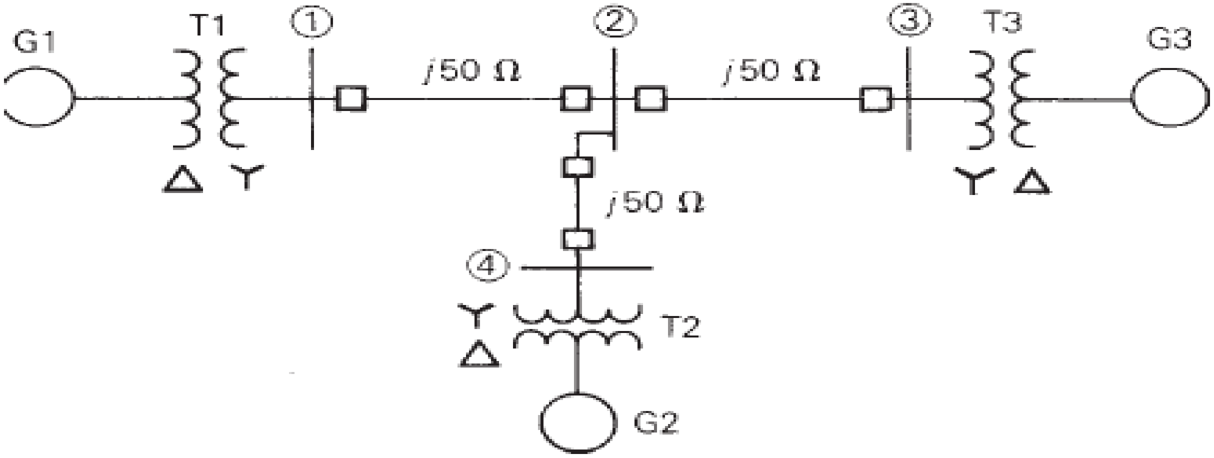
$$\begin{aligned} I''_m = I''_{m1} - I_{\mathrm{L}} &= -j2.079 - 0.9048 + j0.2974 \\ &= -0.9048 - j1.782 = 1.999\underline{/243.1^\circ} \quad \text{per unit} \end{aligned}$$

TUGAS 3

Equipment ratings for the four-bus power system shown in Figure 7.14 are as follows:

Generator G1: 500 MVA, 13.8 kV, $X'' = 0.20$ per unit
Generator G2: 750 MVA, 18 kV, $X'' = 0.18$ per unit
Generator G3: 1000 MVA, 20 kV, $X'' = 0.17$ per unit
Transformer T1: 500 MVA, 13.8 Δ/500 Y kV, $X = 0.12$ per unit
Transformer T2: 750 MVA, 18 Δ/500 Y kV, $X = 0.10$ per unit
Transformer T3: 1000 MVA, 20 Δ/500 Y kV, $X = 0.10$ per unit
Each 500-kV line: $X_1 = 50\ \Omega$

A three-phase short circuit occurs at bus 1, where the prefault voltage is 525 kV. Prefault load current is neglected. Draw the positive-sequence reactance diagram in



per-unit on a 1000-MVA, 20-kV base in the zone of generator G3. Determine (a) the Thévenin reactance in per-unit at the fault, (b) the subtransient fault current in per-unit and in kA rms, and (c) contributions to the fault current from generator G1 and from line 1–2.