RANGKAIAN URUTAN TRANSMISI

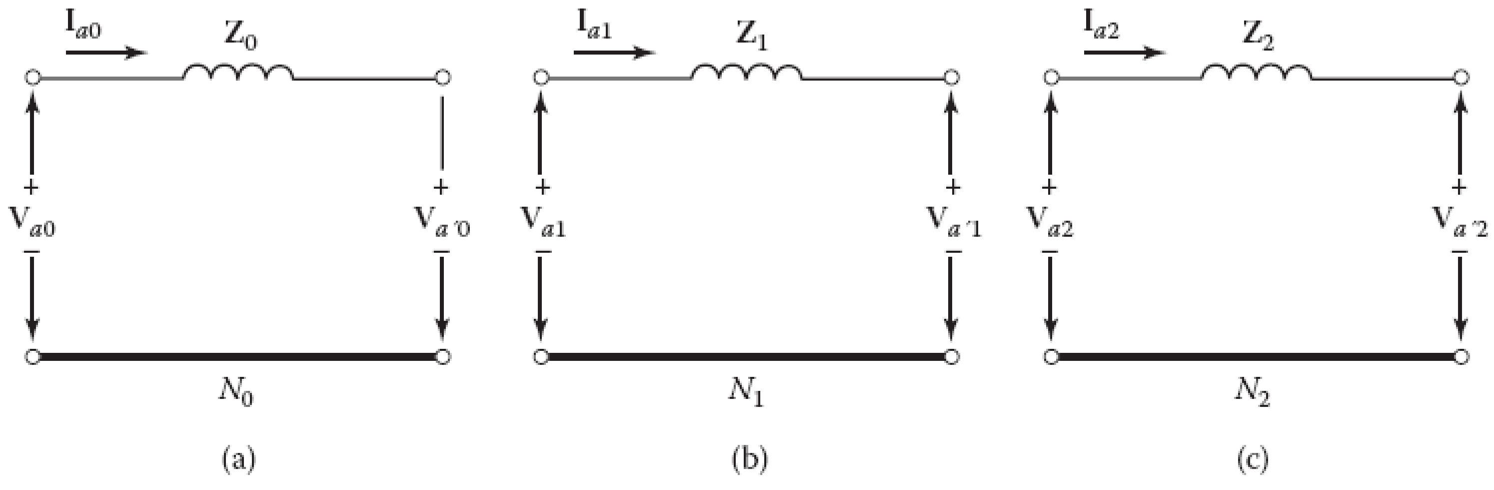


FIGURE 5.4 Sequence networks of a transmission line: (a) zero-sequence network; (b) positive-sequence network; (c) negative-sequence network.

$$\left[\mathbf{Z}_{012}\right]=\begin{bmatrix} \mathbf{Z}_0 & 0 & 0 \\ 0 & \mathbf{Z}_1 & 0 \\ 0 & 0 & \mathbf{Z}_2 \end{bmatrix}$$

RANGKAIAN URUTAN MESIN SINKRON

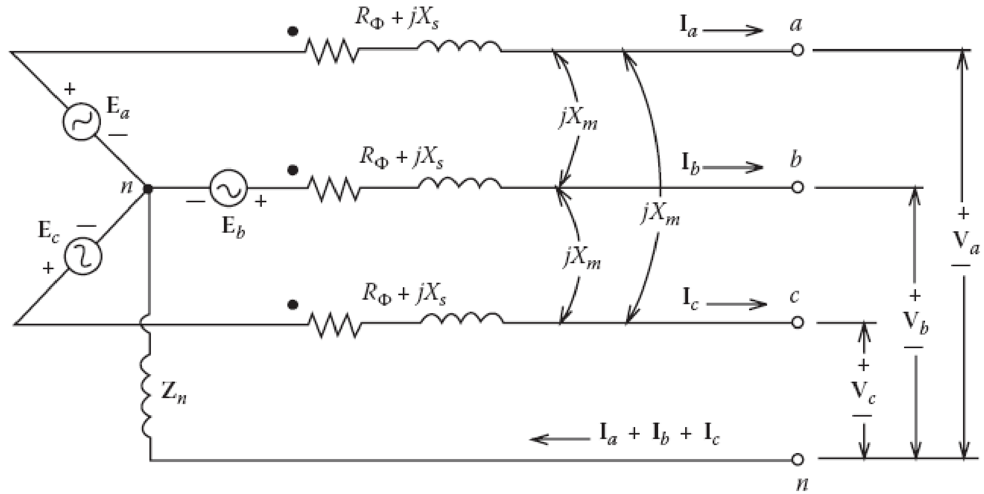


FIGURE 5.7 Equivalent circuit of cylindrical-rotor synchronous machine.

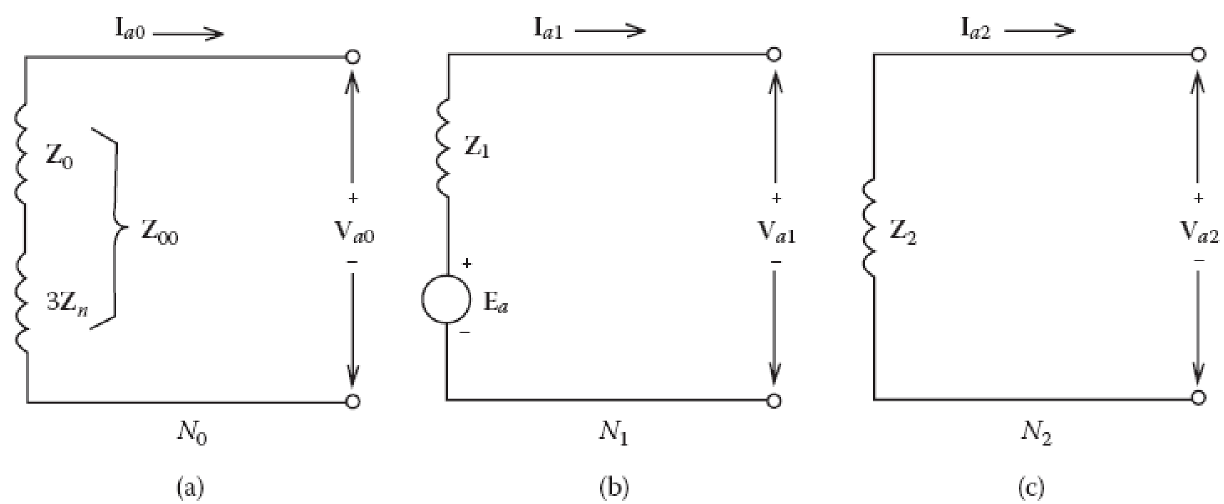


FIGURE 5.8 Sequence networks of synchronous machine: (a) zero-sequence network; (b) positive-sequence network; (c) negative-sequence network.

RANGKAIAN URUTAN NOL UNTUK BEBAN-BEBAN YANG TERHUBUNG BINTANG DAN DELTA

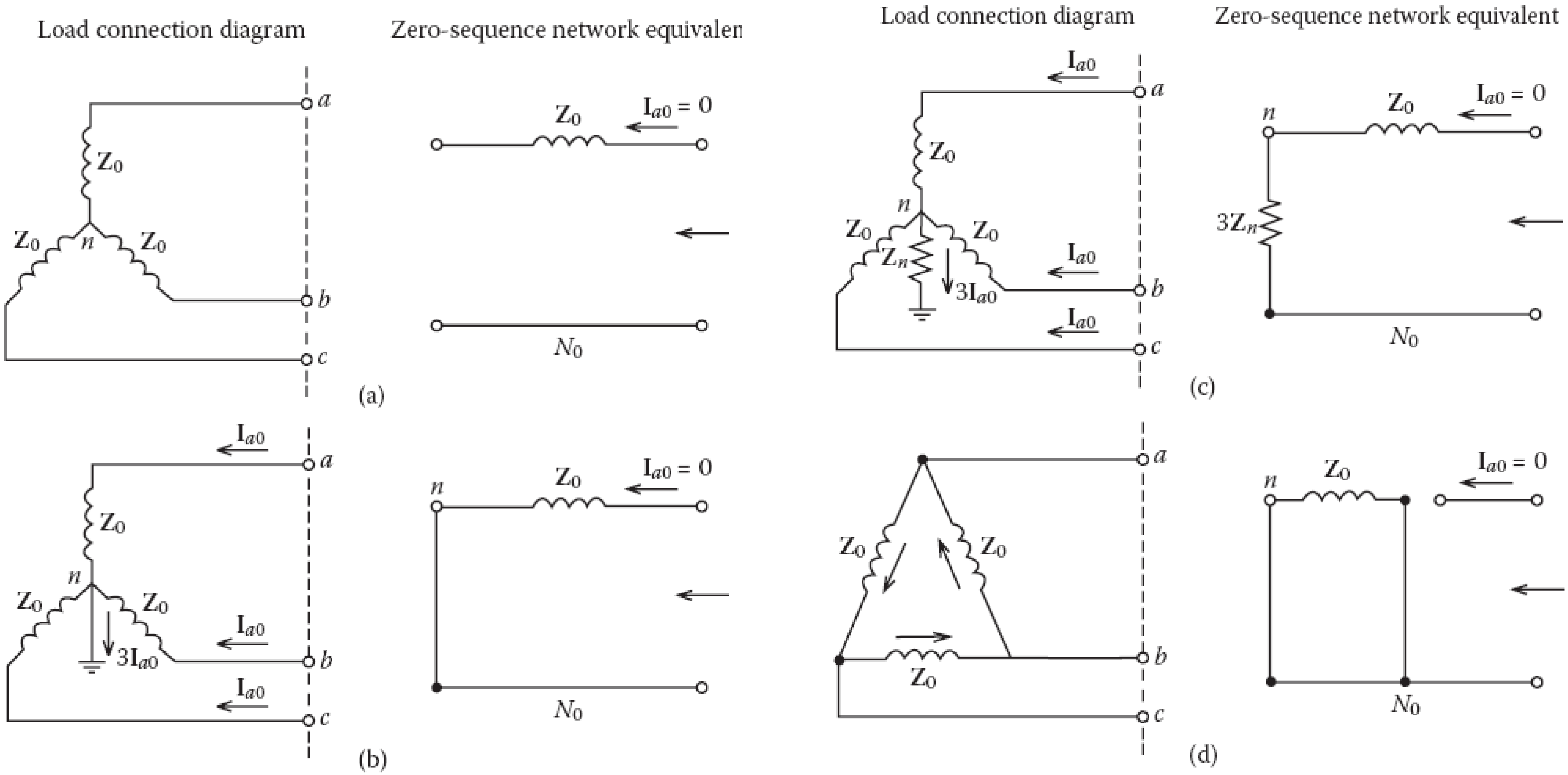
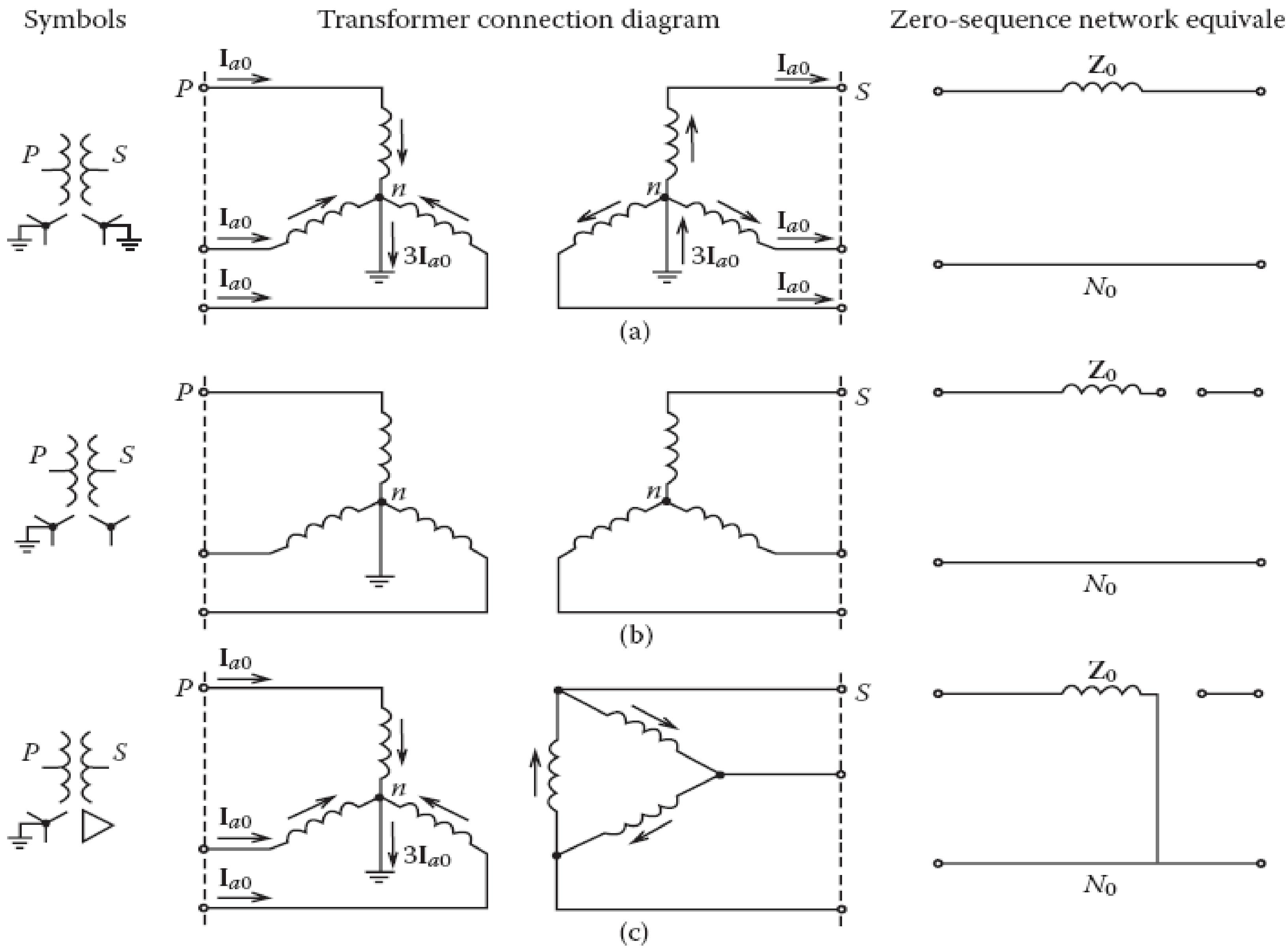


FIGURE 5.9 Zero-sequence network for wye- and delta-connected three-phase loads: (a) wye-connected load with undergrounded neutral; (b) wye-connected load with grounded neutral; (c) wye-connected load grounded through neutral impedance; (d) delta-connected load.

RANGKAIAN EKIVALEN URUTAN NOL TRANFORMATOR TIGA FASA



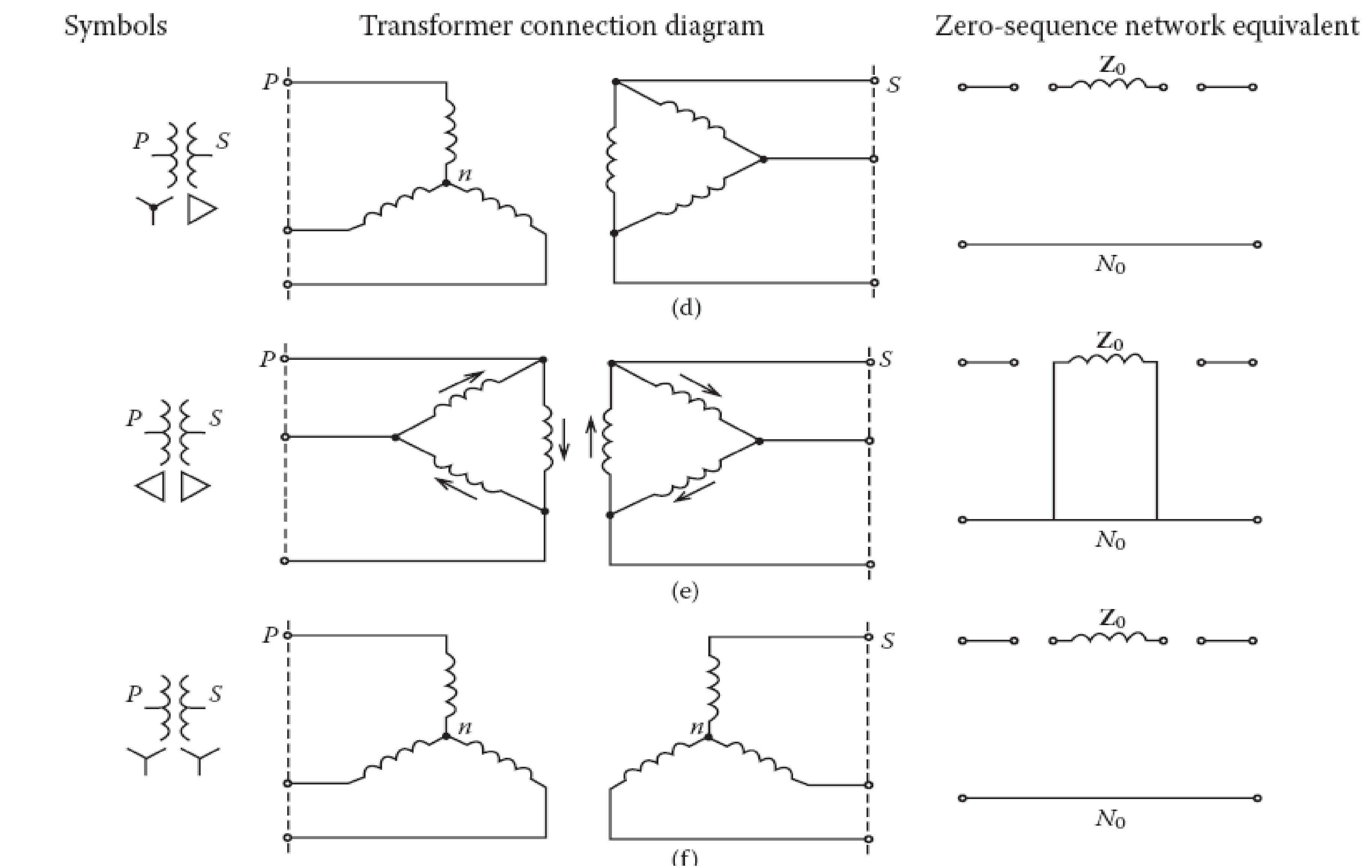
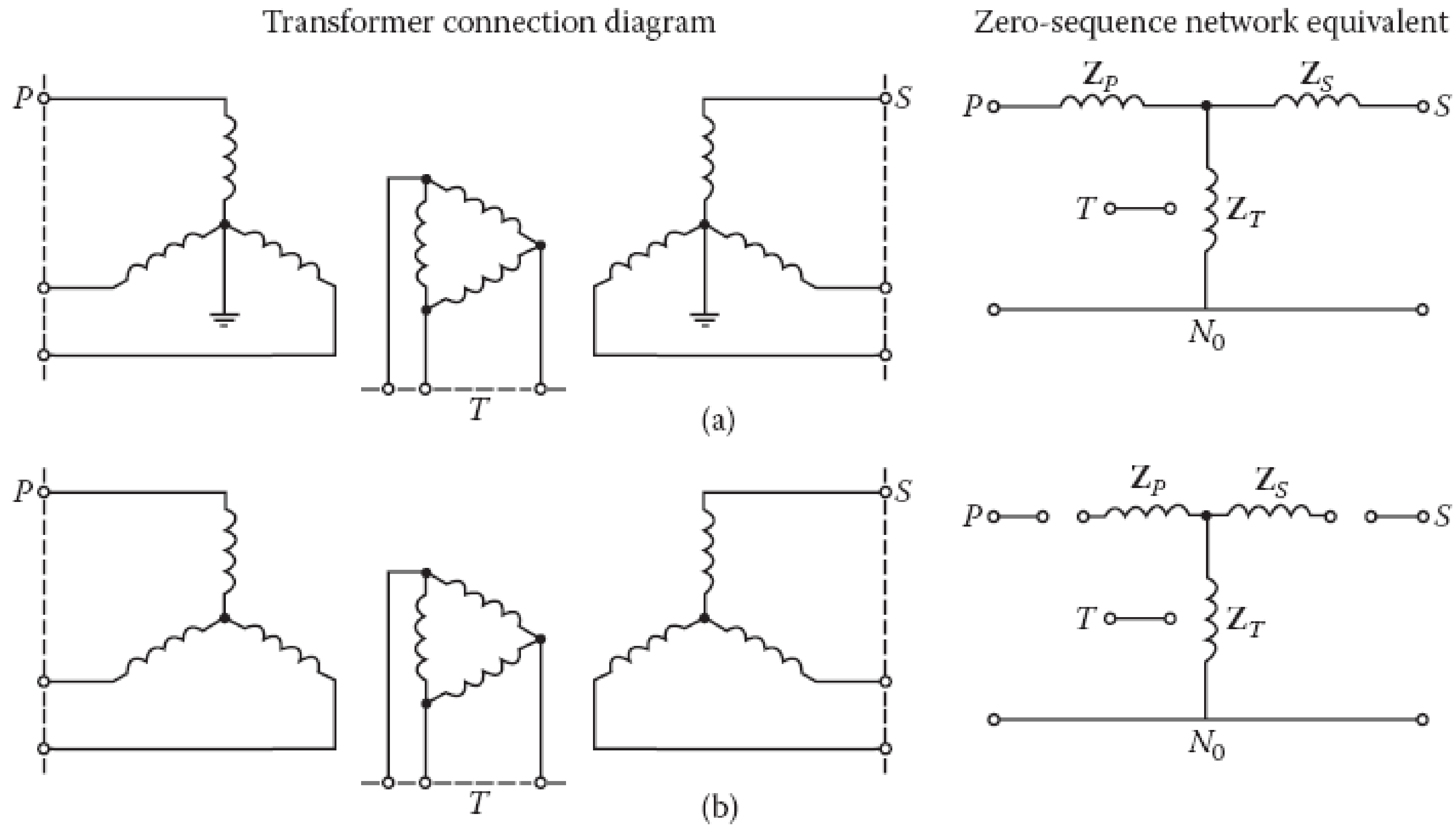


FIGURE 5.10 Zero-sequence network equivalents of three-phase transformer banks made of three identical single-phase transformers with two windings.


Transformer connection diagram
Zero-sequence network equivalent
P
S
T
(a)
Z_P
Z_S
Z_T
N_0
(b)

RANGKAIAN EKIVALEN URUTAN NOL TRANSFORMATOR TIGA FASA

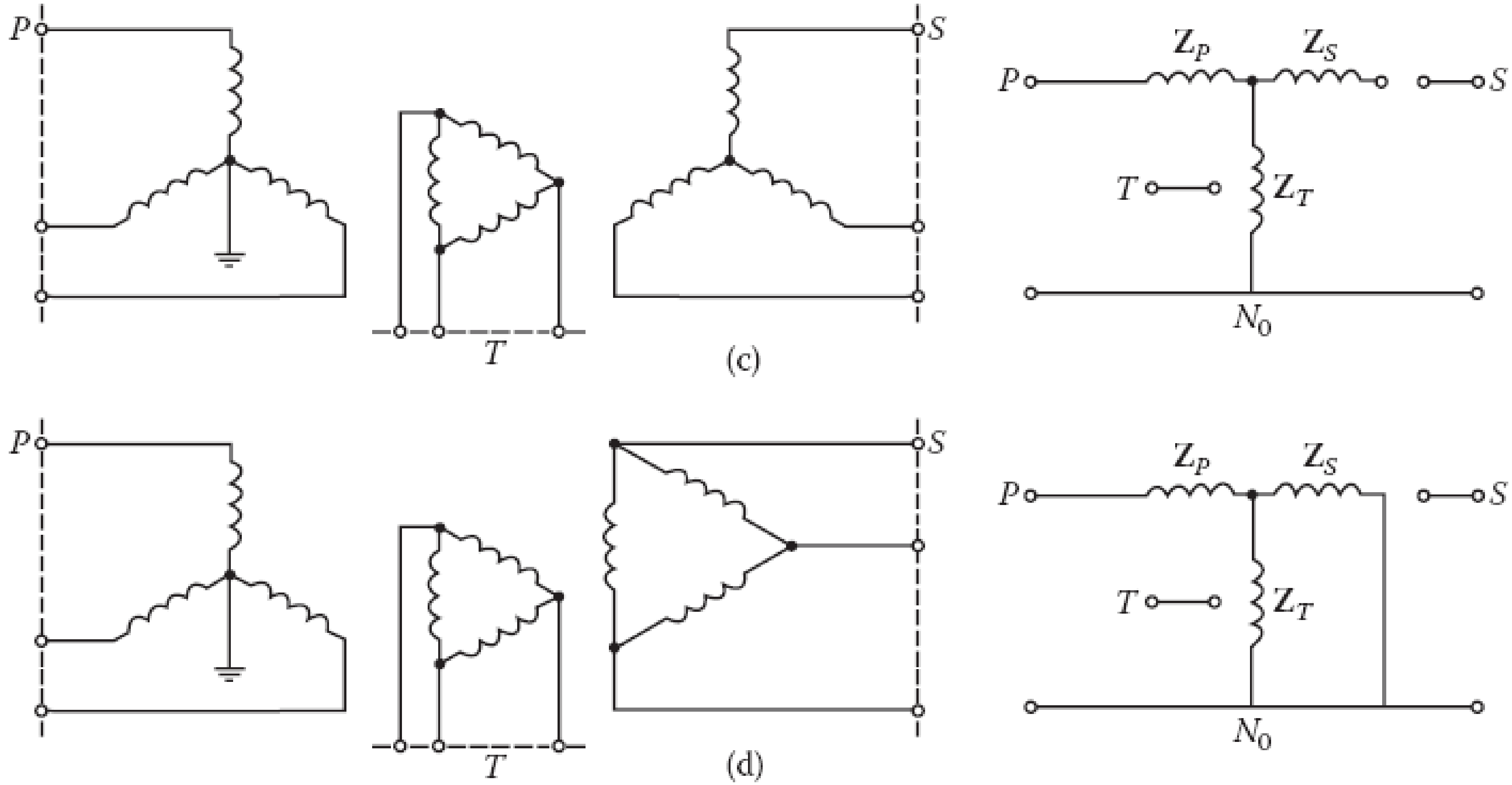


FIGURE 5.11 Zero-sequence network equivalents of three-phase transformer banks made of three identical single-phase transformers with three windings.

EXAMPLE 5.7

Consider the power system shown in Figure 5.12 and the associated data given in Table 5.4. Assume that each three-phase transformer bank is made of three single-phase transformers. Do the following:

(a) Draw the corresponding positive-sequence network
(b) Draw the corresponding negative-sequence network
(c) Draw the corresponding zero-sequence network

TABLE 5.4
System Data for Example 5.7

Network Component	MVA Rating	Voltage Rating (kV)	X_1 (pu)	X_2 (pu)	X_0 (pu)
G_1	200	20	0.2	0.14	0.06
G_2	200	13.2	0.2	0.14	0.06
T_1	200	20/230	0.2	0.2	0.2
T_2	200	13.2/230	0.3	0.3	0.3
T_3	200	20/230	0.25	0.25	0.25
T_4	200	13.2/230	0.35	0.35	0.35
TL_{23}	200	230	0.15	0.15	0.3
TL_{56}	200	230	0.22	0.22	0.5

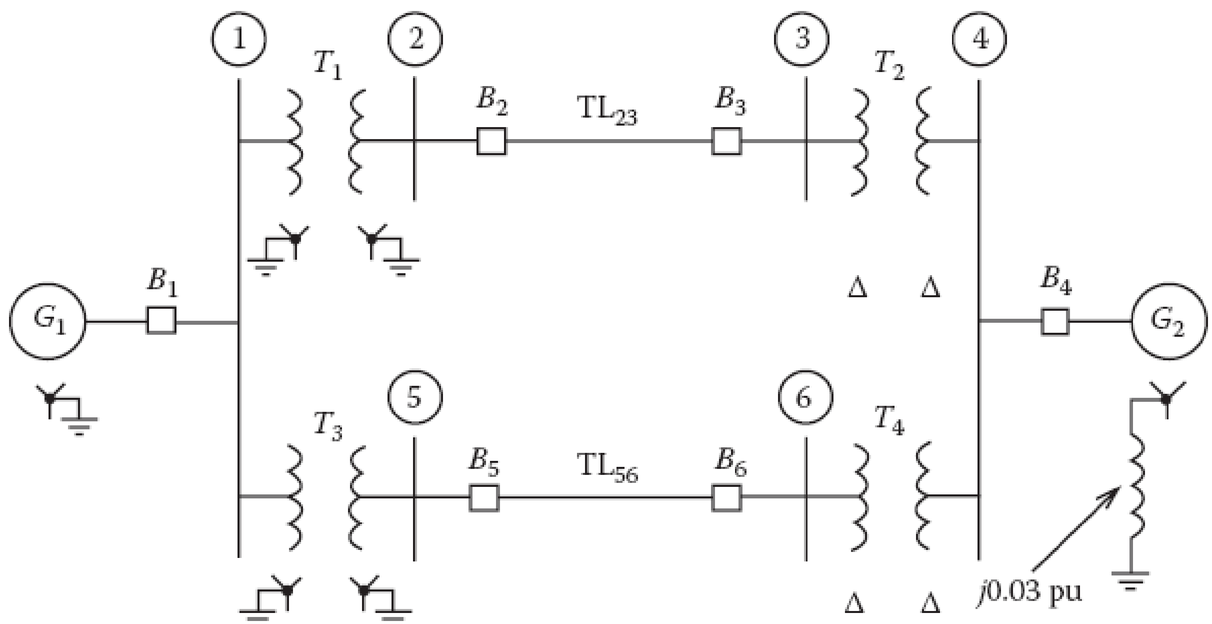


FIGURE 5.12 Power system for Example 5.7.

Solution

(a) The positive-sequence network is shown in Figure 5.13a
(b) The negative-sequence network is shown in Figure 5.13b
(c) The zero-sequence network is shown in Figure 5.13c

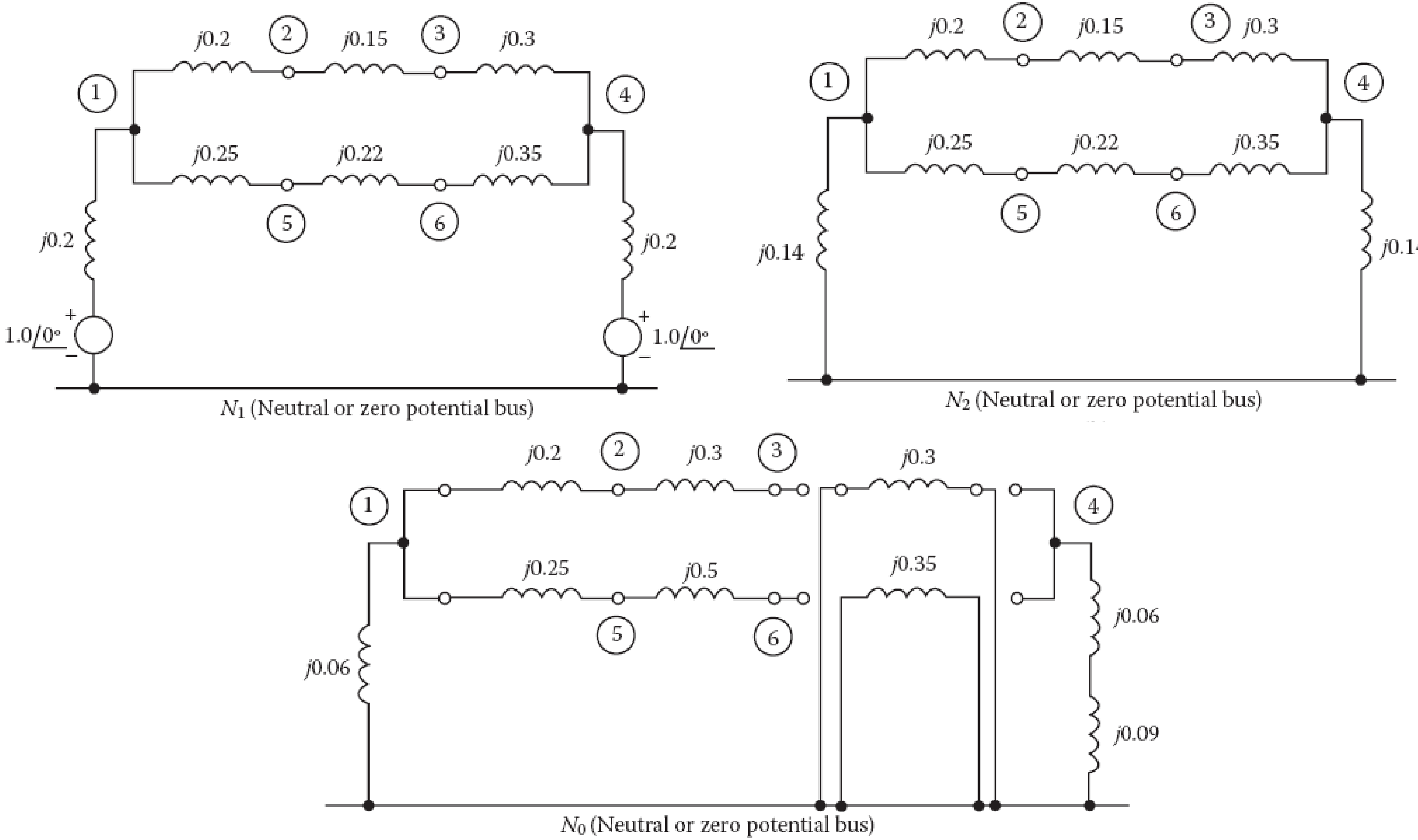


FIGURE 5.13 Sequence networks for Example 5.7.

EXAMPLE 5.8

Consider the power system given in Example 5.7 and assume that there is a fault on bus 3. Reduce the sequence networks drawn in Example 5.7 to their Thévenin equivalents "looking in" at bus 3.

(a) Show the steps of the positive-sequence network reduction
(b) Show the steps of the negative-sequence network reduction
(c) Show the steps of the zero-sequence network reduction

Solution

(a) Figure 5.14 shows the steps of the positive-sequence network reduction. Note that the delta that exits between nodes 1, 3, and 4, as shown in Figure 5.14a, must be replaced by its equivalent wye configuration, as shown in Figure 5.14b, by performing the following calculations:

$$\mathbf{Z}_1 = j\frac{0.35\times 0.82}{0.35+0.82+0.3} = j0.1952 \text{ pu}$$

$$\mathbf{Z}_2 = j\frac{0.3\times 0.82}{0.35+0.82+0.3} = j0.1673 \text{ pu}$$

$$\mathbf{Z}_3 = j\frac{0.35\times 0.3}{0.35+0.3+0.82} = j0.0714 \text{ pu}$$

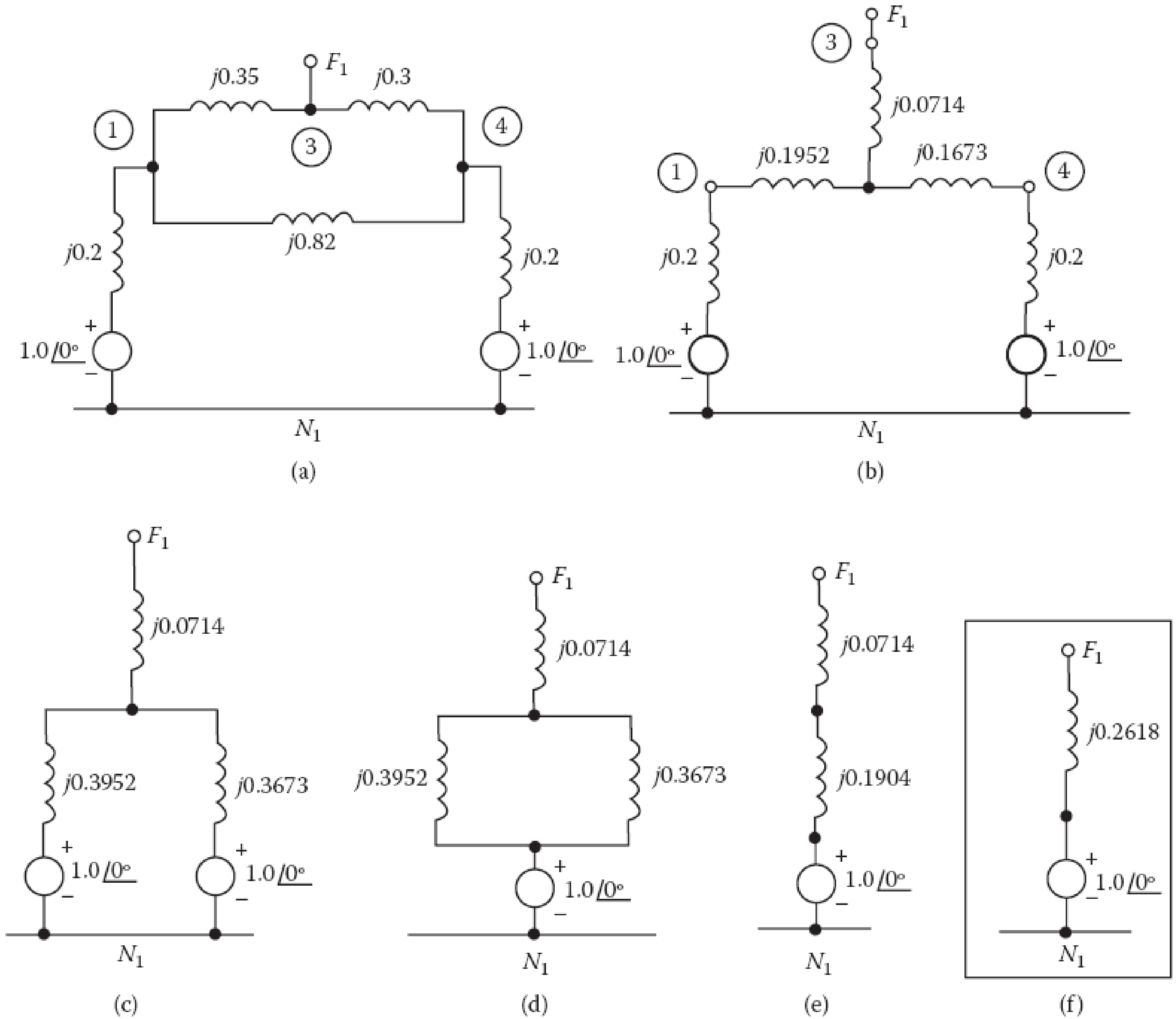


FIGURE 5.14 Reduction steps for positive-sequence network of Example 5.8.

(b) Figure 5.15 shows the steps of the negative-sequence network reduction. Note that, the delta that exits between nodes 1, 3, and 4, as shown in Figure 5.15a, must be replaced by its equivalent wye configuration, as shown in Figure 5.15b, by performing the calculations as in part (a) above.

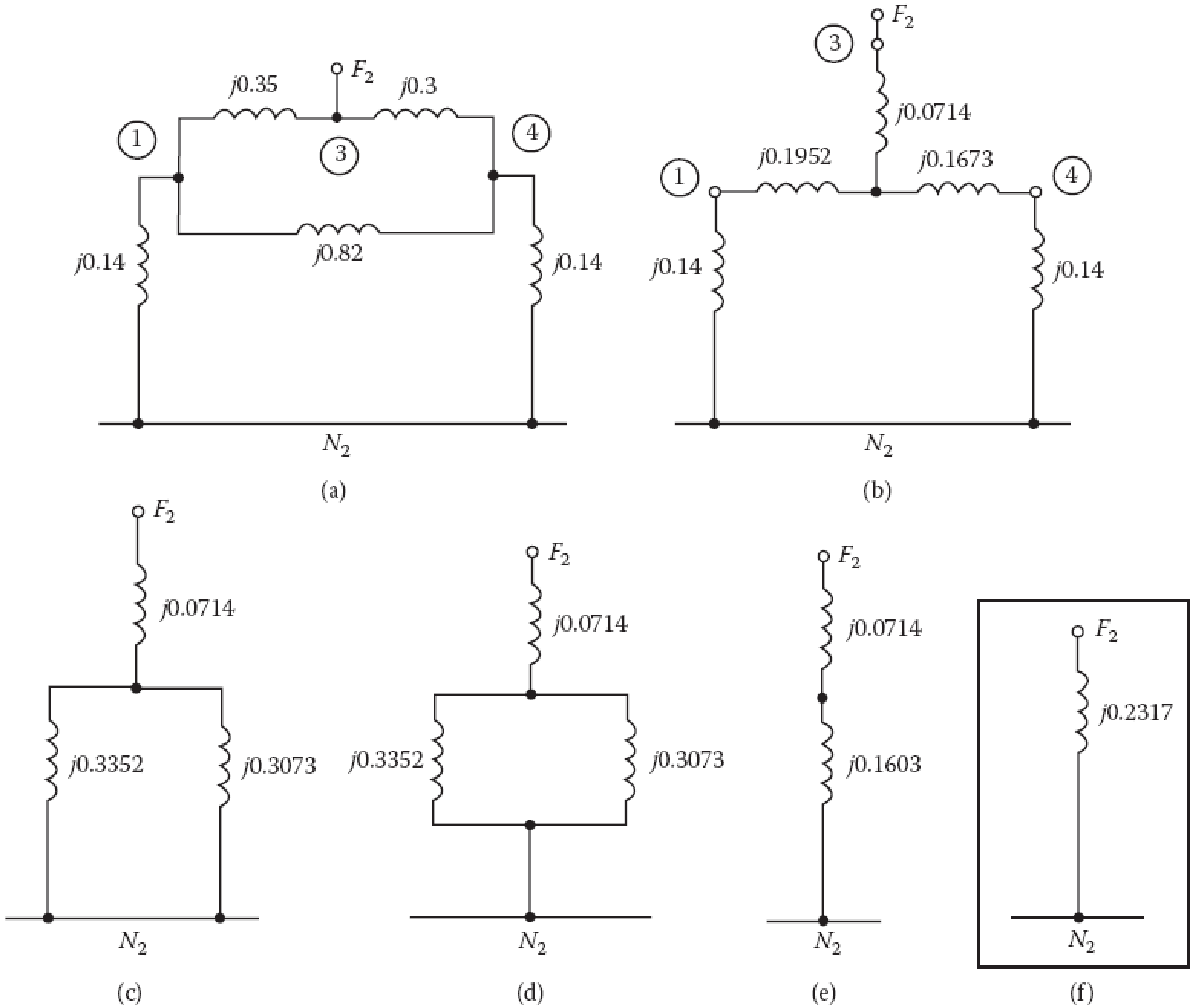


FIGURE 5.15 Reduction steps for negative-sequence network of Example 5.8.

(c) Figure 5.16 shows the steps of the zero-sequence network reduction.

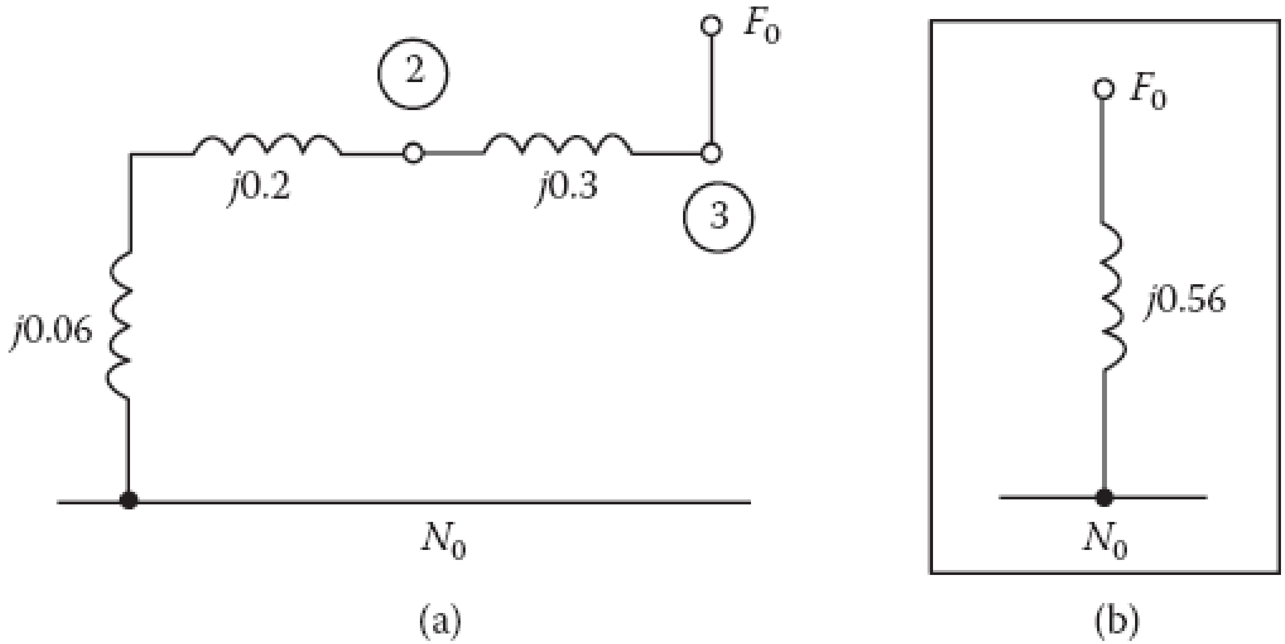


FIGURE 5.16 Reduction steps for zero-sequence network of Example 5.8.

TUGAS 7

Gambarkan rangkaian urutan positip, negatip dan nol dari rangkaian berikut

Generator 1:	20 MVA, 18 kV, $X_d'' = 20\%$
Generator 2:	20 MVA, 18 kV, $X_d'' = 20\%$
Synchronous motor 3:	30 MVA, 13.8 kV, $X_d'' = 20\%$
Three-phase Y-Y transformers:	20 MVA, 138Y/20Y kV, $X = 10\%$
Three-phase Y-Δ transformers:	15 MVA, 138Y/13.8Δ kV, $X = 10\%$

Choose a base of 50 MVA, 138 kV in the 40-Ω transmission line and mark all reactances in per unit. The negative-sequence reactance of each synchronous machine is equal to its subtransient reactance. The zero-sequence reactance of each machine is 8% based on its own rating. The neutrals of the machines are connected to ground through current-limiting reactors having a reactance of 5%, each on the base of the machine to which it is connected. Assume that the zero-sequence reactances of the transmission lines are 300% of their positive-sequence reactances.