EE493 Protection of Power Systems I

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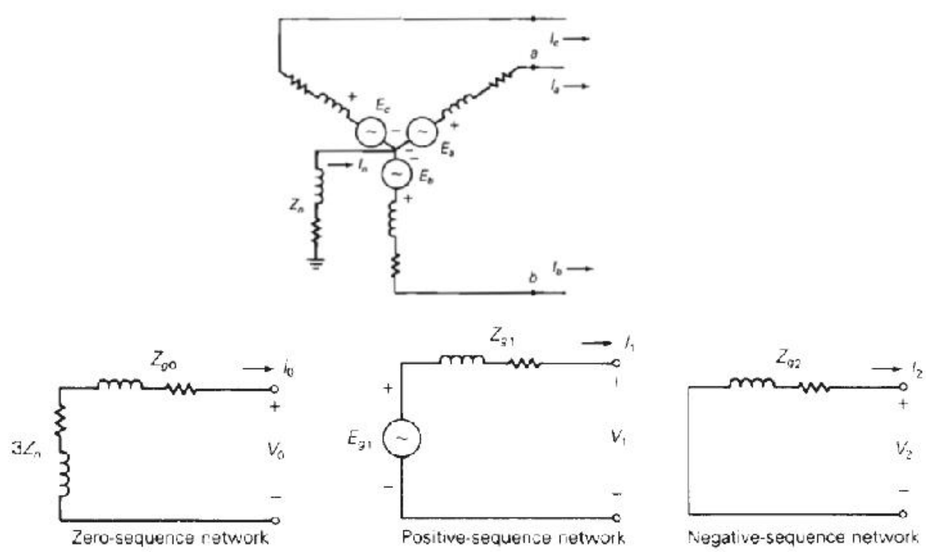
Chapter 8 of "Power System Analysis and Design", Fifth Edition, 2012, J. D. Glover, M. S. Saema, T. J. Overbye

SEQUENCE NETWORKS OF ROTATING MACHINES



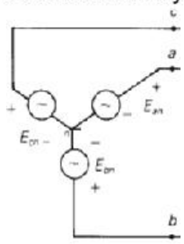
Sequence networks of a Y-connected synchronous generator

It is assumed generator is balanced and E_{g1} (positive sequence voltage). $=E_{an}$ (phase to neutral voltage). Therefore, if line-line voltage is give, you should calculate line-neutral voltage

$$E_{an} = \frac{E_{ab}\angle -30}{\sqrt{3}}$$

Reminder:

Always in balanced three-phase systems line to line voltages are $\sqrt{3}$
Times bigger than line to ground voltages and they lead the line to ground voltages by 30 degrees
It can be seen by looking at the following example



$$E_{an} = 10\angle 0^\circ$$
$$E_{bn} = 10\angle -120^\circ = 10\angle +240^\circ$$
$$E_{cn} = 10\angle +120^\circ = 10\angle -240^\circ \quad \text{volts}$$

Now if we calculate line to line voltage for phases a and b:

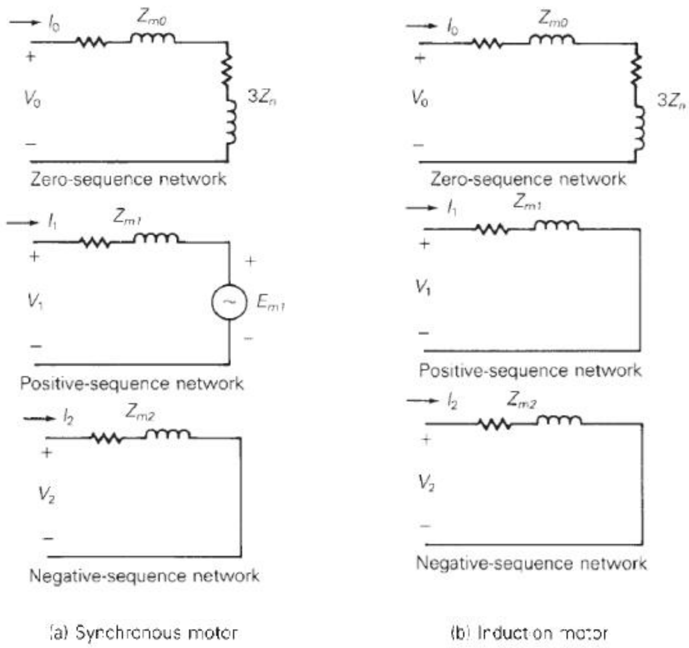
$$E_{ab} = E_{an} - E_{bn}$$
$$E_{ab} = 10\angle 0^\circ - 10\angle -120^\circ = 10 - 10\left[\frac{-1 - j\sqrt{3}}{2}\right]$$
$$E_{ab} = \sqrt{3}(10)\left(\frac{\sqrt{3} + j1}{2}\right) = \sqrt{3}(10\angle 30^\circ) \quad \text{volts}$$

It shows that Eab is $\sqrt{3}$ times bigger than Ean and leads Ean by 30 degrees

The voltage drop in the generator neutral impedance is $Z_n I_n$, which can be written as $(3Z_n)I_0$, since the neutral current is three times the zero-sequence current.

$$I_n = I_a + I_b + I_c$$
$$I_0 = \tfrac{1}{3}(I_a + I_b + I_c) \qquad I_n = 3I_0$$

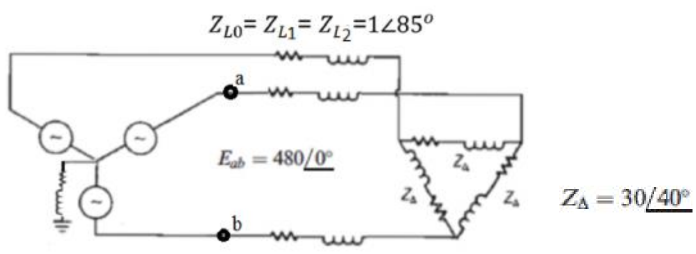
Since this voltage drop is due only to zero-sequence current, an impedance $(3Z_n)$ is placed in the zero-sequence network in series with the generator zero-sequence impedance Z_{g0}.



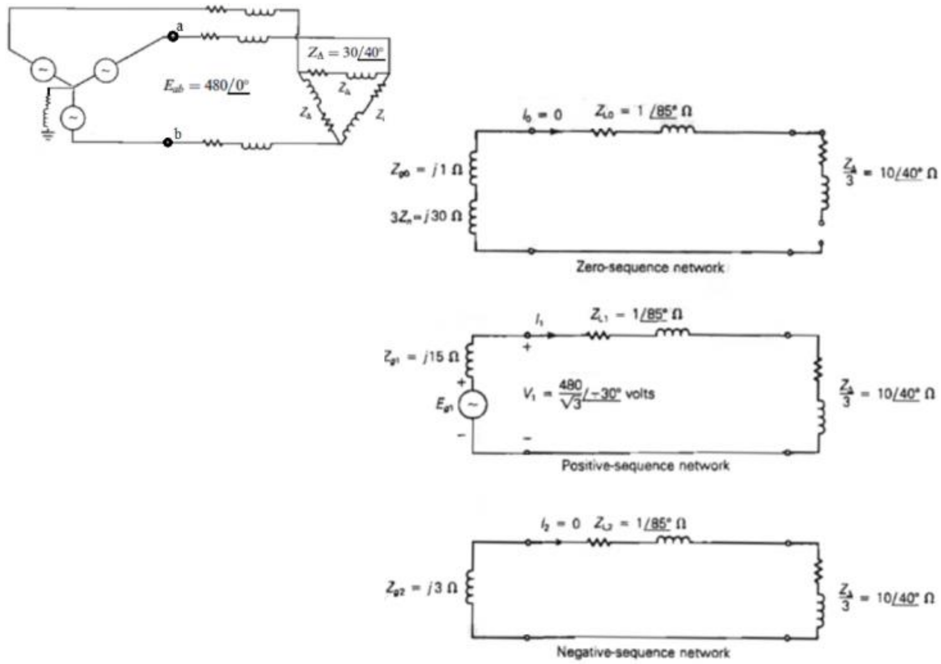
Sequence networks of three-phase motors

EXAMPLE

calculate the
sequence components of the line current. Assume that the generator neutral is grounded through an impedance $Z_n = j10\ \Omega$, and that the generator sequence impedances are $Z_{g0} = j1\ \Omega$, $Z_{g1} = j15\ \Omega$, and $Z_{g2} = j3\ \Omega$.



$Z_{L0} = Z_{L1} = Z_{L2} = 1\angle 85°$



It is clear that $I_0 = I_2 = 0$ since there are no sources in the zero- and negative-sequence networks. Also, the positive-sequence generator terminal voltage V_1 equals the generator line-to-neutral terminal voltage. Therefore, from the positive-sequence network

$$I_1 = \frac{V_1}{\left(Z_{L1} + \frac{1}{3}Z_\Delta\right)} = 25.83\underline{/-73.78°}\ \text{A} = I_a$$

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_0 \\ I_1 \\ I_2 \end{bmatrix}$$

I_1 equals the line current I_a, since $I_0 = I_2 = 0$.