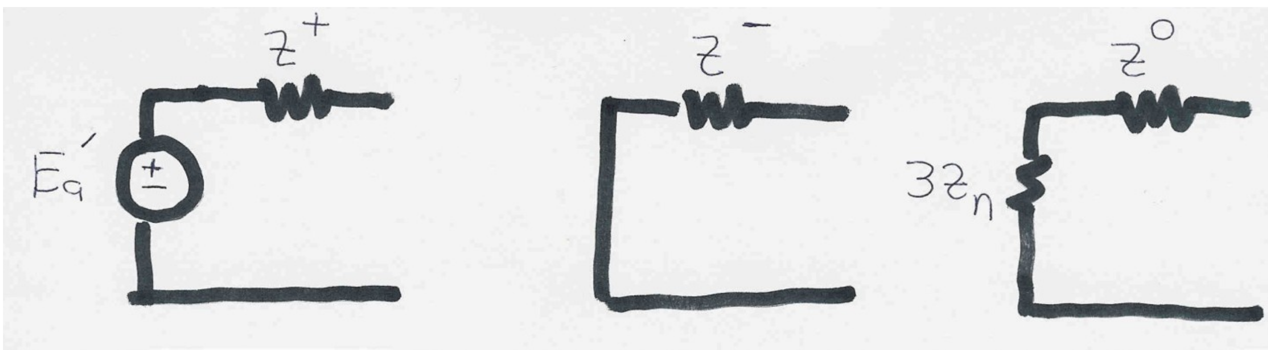
EEE- 601
POWER SYSTEM ANALYSIS
Unit-1

Sequence diagrams for generators

- Key point: generators only produce positive sequence voltages; therefore only the positive sequence has a voltage source



During a fault $Z^+ \approx Z^- \approx X_d''$. The zero sequence impedance is usually substantially smaller. The value of Z_n depends on whether the generator is grounded

SEQUENCE IMPEDANCE

- Impedances offered by power system components to positive, negative and zero sequence currents.
- Positive sequence impedance

The impedance of a component when positive sequence currents alone are flowing.

- Negative sequence impedance

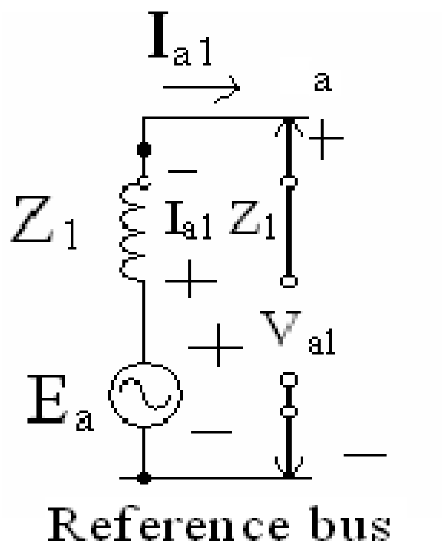
The impedance of a component when negative sequence currents alone are flowing.

- Zero sequence impedance

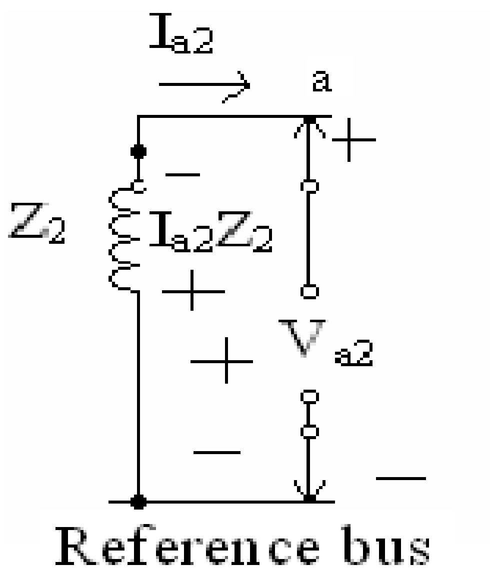
The impedance of a component when zero sequence currents alone are flowing.

SEQUENCE NETWORK

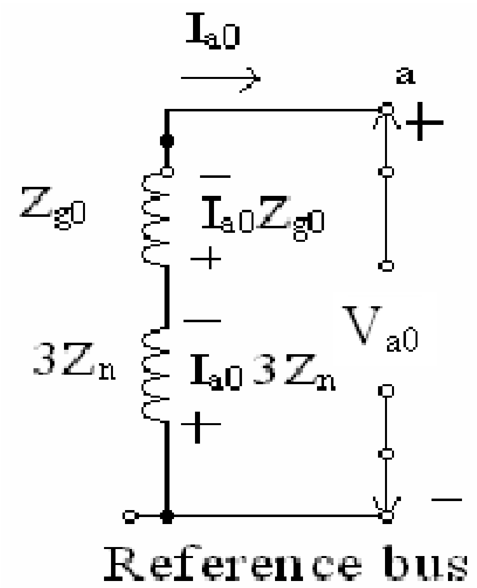
SEQUENCE NETWORK FOR GENERATOR



positive sequence network



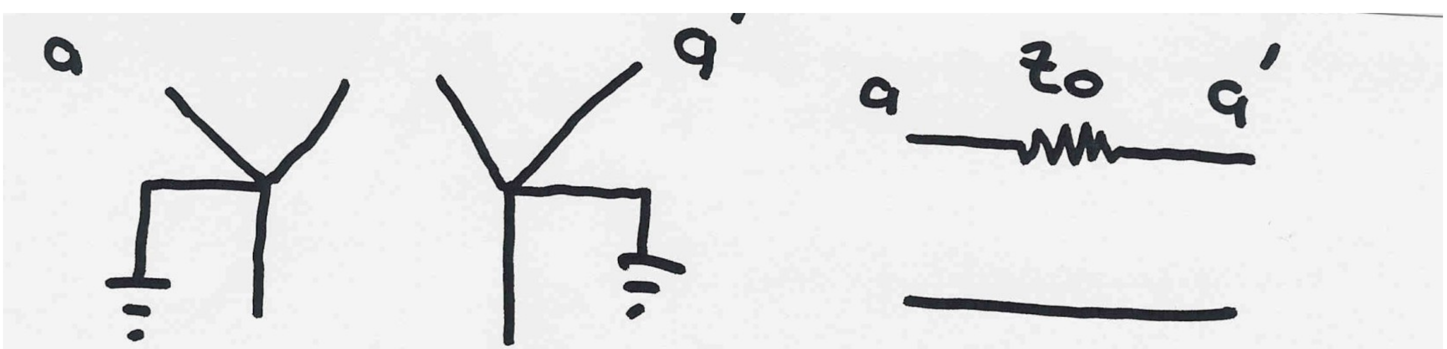
negative sequence network



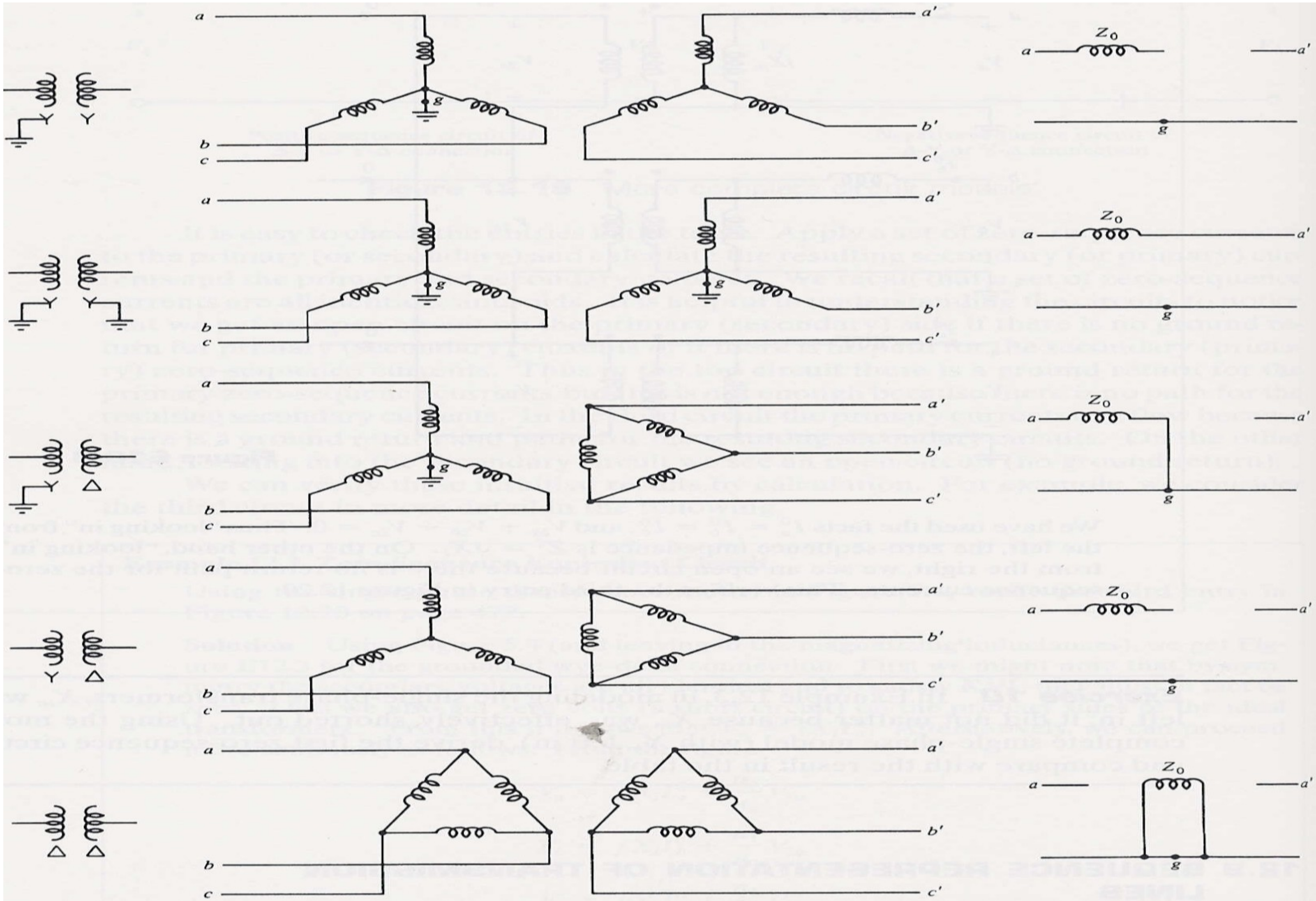
Zero sequence network

Sequence diagrams for Transformers

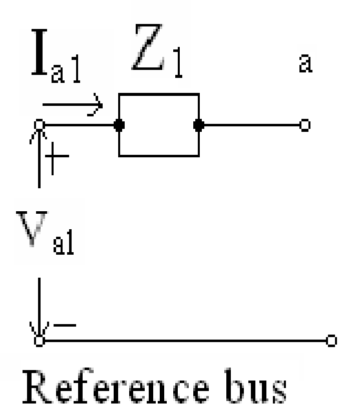
- The positive and negative sequence diagrams for transformers are similar to those for transmission lines.
- The zero sequence network depends upon both how the transformer is grounded and its type of connection. The easiest to understand is a double grounded wye-wye



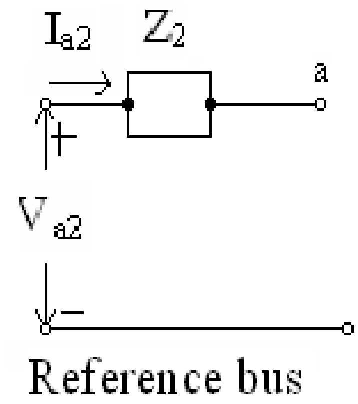
Transformer Sequence Diagrams



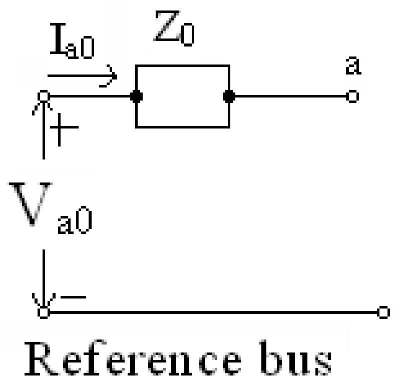
SEQUENCE NETWORK FOR TRANSMISSION LINE



positive sequence network

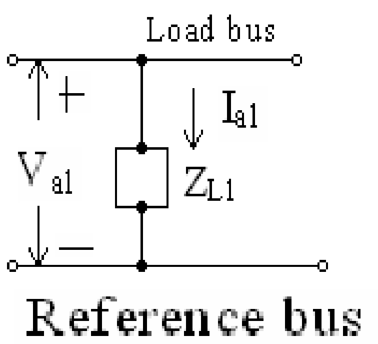


negative sequence network

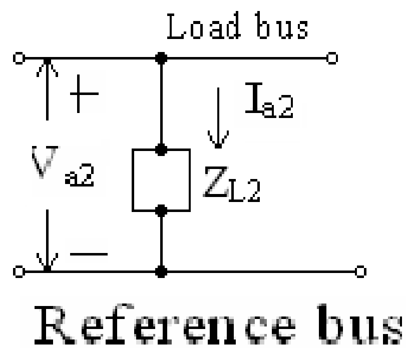


Zero sequence network

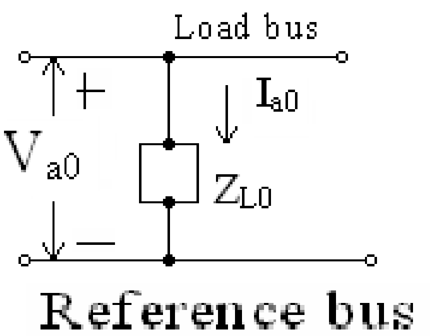
SEQUENCE NETWORK FOR LOAD



positive sequence network



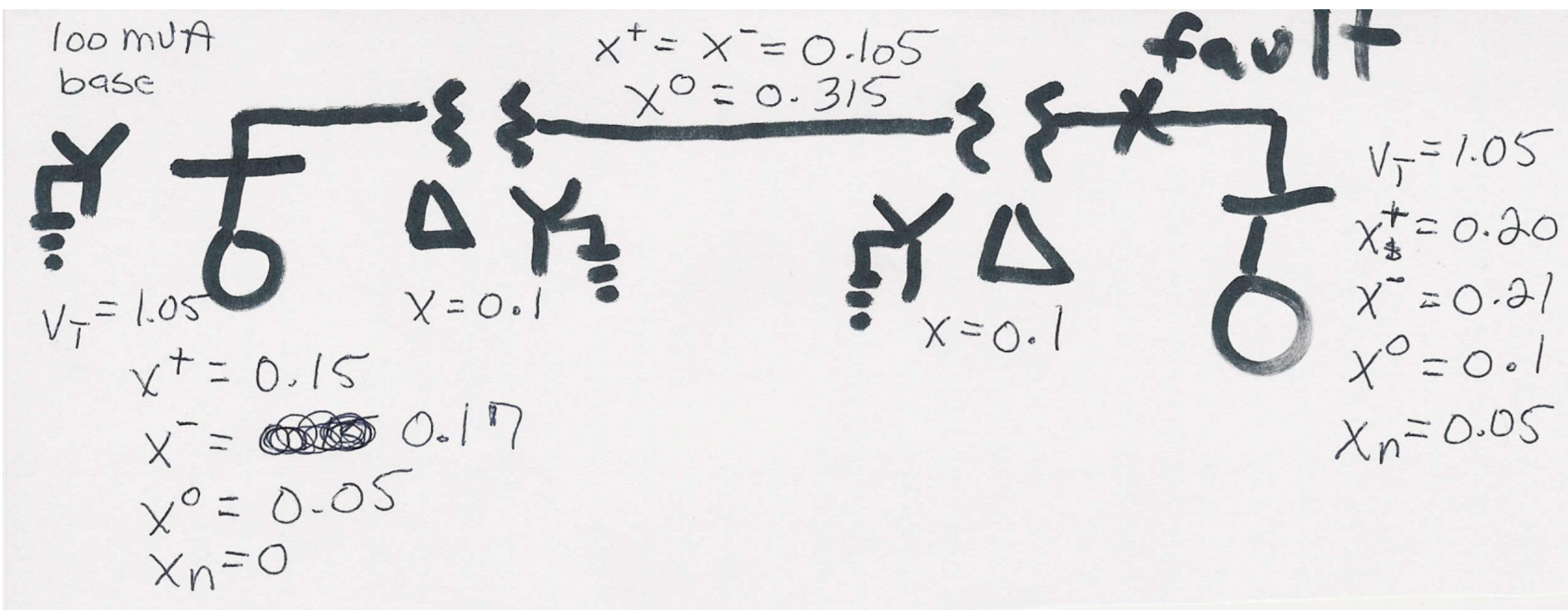
negative sequence network



Zero sequence network

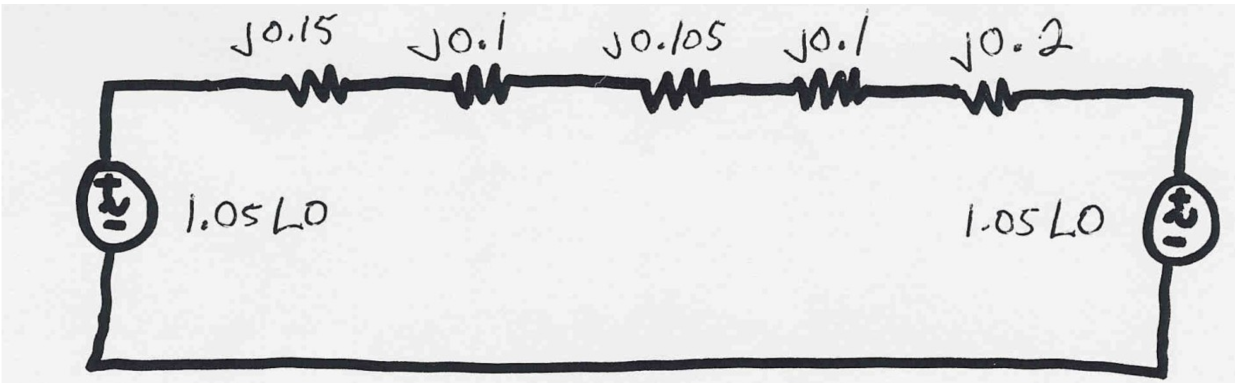
Unbalanced Fault Analysis

- The first step in the analysis of unbalanced faults is to assemble the three sequence networks. For example, for the earlier single generator, single motor example let's develop the sequence networks

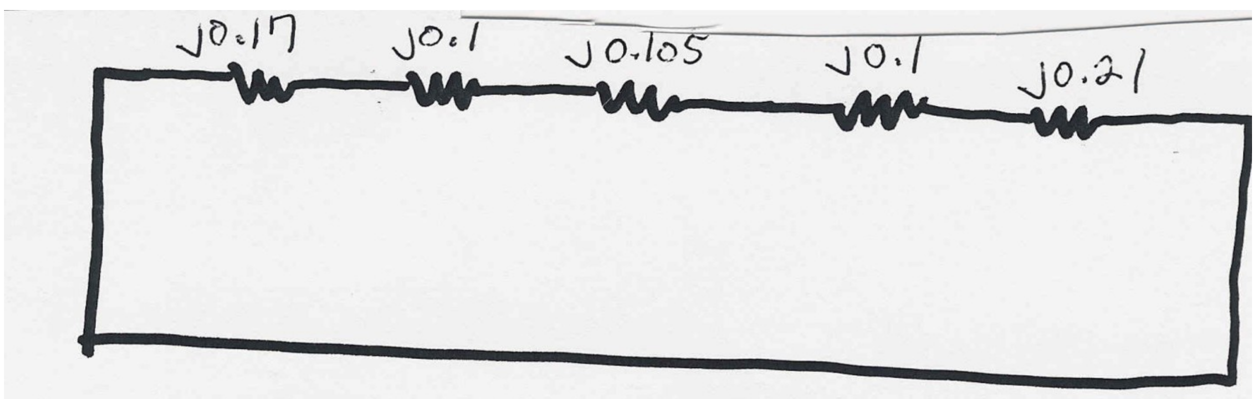


Sequence Diagrams for Example

Positive Sequence Network

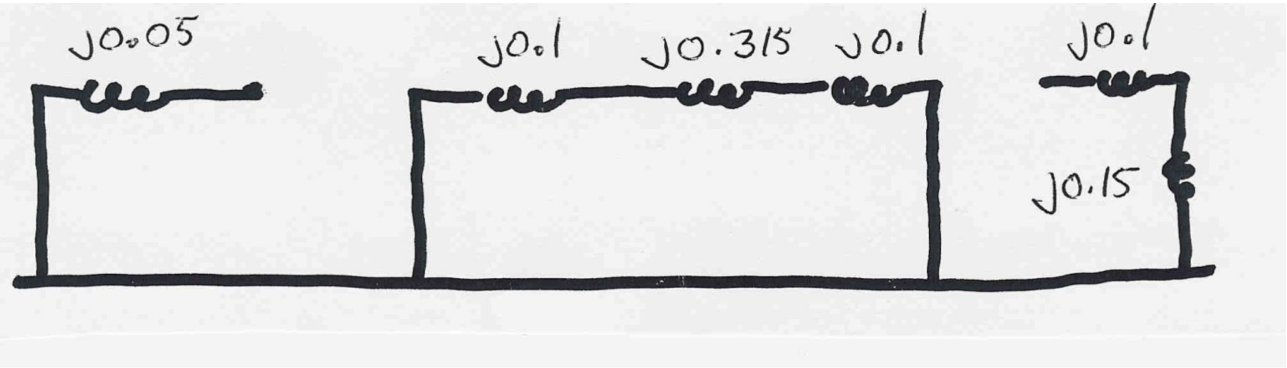


Negative Sequence Network



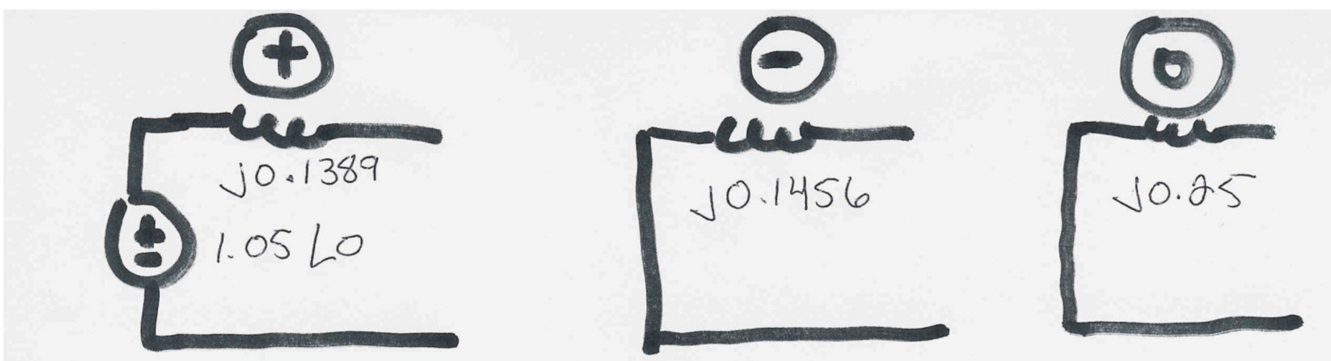
Sequence Diagrams for Example

Zero Sequence Network



Create Thevenin Equivalents

- To do further analysis we first need to calculate the thevenin equivalents as seen from the fault location. In this example the fault is at the terminal of the right machine so the thevenin equivalents are:



$$Z_{th}^{+} = j0.2 \text{ in parallel with j0.455}$$

$$Z_{th}^{-} = j0.21 \text{ in parallel with j0.475}$$

Three phase power in symmetrical components

- $S = V_p^T I_p^* \quad = \quad [A\, V_s]^T [A\, I_s]^*$

  $= V_s^T A^T A^* I_s^* \quad = \quad 3\, V_s^T I_s^*$

  $= 3V_{a0}\, I_{a0}^* + 3V_{a1}\, I_{a1}^* + 3V_{a2}\, I_{a2}^*$

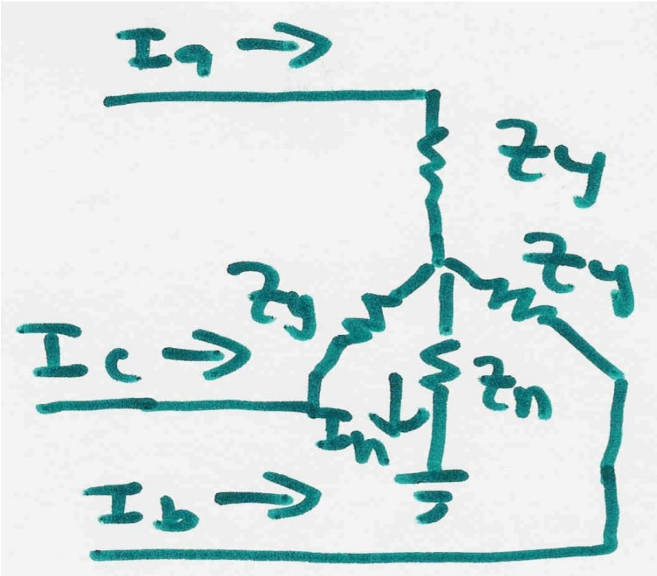
  note that $A^T = A$

$$A^* = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}$$

$$A^T A^* = 3 * \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Use of Symmetrical Components

- Consider the following wye-connected load:



$$I_n = I_a + I_b + I_c$$

$$V_{ag} = I_a Z_y + I_n Z_n$$

$$V_{ag} = (Z_Y + Z_n) I_a + Z_n I_b + Z_n I_c$$

$$V_{bg} = Z_n I_a + (Z_Y + Z_n) I_b + Z_n I_c$$

$$V_{cg} = Z_n I_a + Z_n I_b + (Z_Y + Z_n) I_c$$

$$\begin{bmatrix} V_{ag} \\ V_{bg} \\ V_{cg} \end{bmatrix} = \begin{bmatrix} Z_y + Z_n & Z_n & Z_n \\ Z_n & Z_y + Z_n & Z_n \\ Z_n & Z_n & Z_y + Z_n \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

Use of Symmetrical Components

$$\begin{bmatrix} V_{ag} \\ V_{bg} \\ V_{cg} \end{bmatrix} = \begin{bmatrix} Z_y + Z_n & Z_n & Z_n \\ Z_n & Z_y + Z_n & Z_n \\ Z_n & Z_n & Z_y + Z_n \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

$$\mathbf{V} = \mathbf{Z}\,\mathbf{I} \qquad \mathbf{V} = \mathbf{A}\,\mathbf{V}_s \qquad \mathbf{I} = \mathbf{A}\,\mathbf{I}_s$$

$$\mathbf{A}\,\mathbf{V}_s = \mathbf{Z}\,\mathbf{A}\,\mathbf{I}_s \quad \rightarrow \quad \mathbf{V}_s = \mathbf{A}^{-1}\,\mathbf{Z}\,\mathbf{A}\,\mathbf{I}_s$$

$$\mathbf{A}^{-1}\,\mathbf{Z}\,\mathbf{A} = \begin{bmatrix} Z_y + 3Z_n & 0 & 0 \\ 0 & Z_y & 0 \\ 0 & 0 & Z_y \end{bmatrix}$$

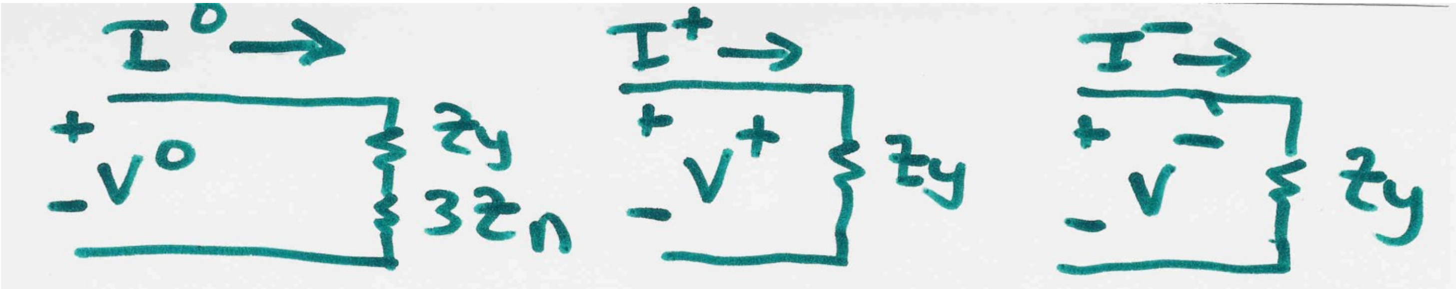
Networks are Now Decoupled

$$\begin{bmatrix} V^0 \\ V^+ \\ V^- \end{bmatrix} = \begin{bmatrix} Z_y + 3Z_n & 0 & 0 \\ 0 & Z_y & 0 \\ 0 & 0 & Z_y \end{bmatrix} \begin{bmatrix} I^0 \\ I^+ \\ I^- \end{bmatrix}$$

Systems are decoupled

$V^0 = (Z_y + 3Z_n)\, I^0 \qquad V^+ = Z_y\, I^+$

$V^- = Z_y\, I^-$



Thank you