Ongoing List of Topics:

- URL: http://www.ece.mtu.edu/faculty/bamork/EE5223/index.htm
- Term Project - proposed proj/teams being firmed up.
  - Begin working on projects next week, 8 weeks to complete
- Next Homework - directional overcurrent protection
  - Homework #8 - work on with project teams.
- Overview of many types of protection
  - Bus diff, xfmr diff, distance relaying for lines, synch check, capacitor banks, generators, motors, etc. (take a quick run through chapters of text).
- Symmetrical Components overview
  - Fault current is only first step of calc. Need fault contributions at relays!
  - transformer connections in zero seq, and phase shifts in pos/neg.
  - Sequence networks for 3-winding transformers.
Seg Networks

\[ \begin{align*}
\text{Pos ref.} & \quad \text{Neg ref.} \\
\text{Pos, Neg, Zero in series} & \quad \text{Pos, Neg in Parallel} \\
\text{Pos, Neg, Zero in Parallel} &
\end{align*} \]
Sequence Networks

i.e. \[ \begin{bmatrix} v_{a0} \\ v_{b0} \\ v_{c0} \end{bmatrix} \] = \[ \begin{bmatrix} -1/3 & 1 & -1/3 \\ 1 & -1 & 1 \\ -1/3 & -1/3 & 1/3 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} \]

Per Phase, 4th. P.U. 50 \%
\[ V_{TH} = \frac{V_{OC}}{2} \]
\[ Z_{TH} = \frac{V_{OC}}{I_{SC}} \]
\[ I_{SC} = I_{IN} \]
\[ I_{a1} = I_{a2} = I_{ao} \]

\[ \frac{I_F}{3} = I_{a1} = I_{a2} = I_{ao} \]

\[ [V_p] = [A] [V_s] \]
Pos: $\text{Bus 1: } V_{a1}, J_{a1} = V_{a1, fault} + I_{a1} \cdot Z_{L, 2F}$
$\text{Bus 2: } V_{a1}, J_{a2} = V_{a2, fault} + I_{a2} \cdot Z_{L, 2F}$
$V_{a2, 2F} = V_{a2, fault} + I_{a2} \cdot Z_{L, 2F}$
$V_{a, 2F} = V_{a, fault} + I_{a} \cdot Z_{L, 2F}$

Neg: $\text{Bus 1: } V_{a1}, J_{a1} = V_{a1, fault} + I_{a1} \cdot Z_{L, 2F}$
$\text{Bus 2: } V_{a1}, J_{a2} = V_{a2, fault} + I_{a2} \cdot Z_{L, 2F}$
$V_{a2, 2F} = V_{a2, fault} + I_{a2} \cdot Z_{L, 2F}$
$V_{a, 2F} = V_{a, fault} + I_{a} \cdot Z_{L, 2F}$

Zero: $\text{Bus 1: } V_{a1}, J_{a1} = V_{a1, fault} + I_{a1} \cdot Z_{L, 2F}$
$\text{Bus 2: } V_{a1}, J_{a2} = V_{a2, fault} + I_{a2} \cdot Z_{L, 2F}$
$V_{a2, 2F} = V_{a2, fault} + I_{a2} \cdot Z_{L, 2F}$
$V_{a, 2F} = V_{a, fault} + I_{a} \cdot Z_{L, 2F}$
Phase relays:

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} A \end{bmatrix} \begin{bmatrix} V_{ca} \\ V_{cb} \\ V_{ab} \end{bmatrix}$$

Then can apply relay:

i.e. do settings.

Then you'll have \([I_s] + [V_s]\)
at each bus.
\[ Z(\omega) = \frac{V(\omega)}{I(\omega)} \]

For Relays:

\[
\begin{align*}
Z_0 &= \frac{V_{ab}}{I_{ab}} \\
Z_1 &= \frac{V_{a1}}{I_{a1}} \\
Z_A &= \frac{V_{AN}}{I_a} \\
Z_{AB} &= \frac{V_{AB}}{I_{AB}} = \frac{V_a - V_b}{I_a - I_b}
\end{align*}
\]

Simplest case

If you use \( V_{ab} \):