Topics for Today:

- Announcements
  - Nov 5th - Chance to perfect Detailed Term Project outline (3-level) in format of report Table of Contents + complete list of references.
  - Software: online students - apply for ATP/ATPDraw license, verify licensing when you receive it by e-mail, and we will mail you the install CD.
  - ASPEN software - arranging to run off of MTU server via internet.
  - Office: EERC 614. Phone: 906.487.2857
  - Recommended problems & all solutions: Ch.7, 8 solns now posted.

- Chapter 7, 10 - Network Equations, Basic Fault applications
  - Fault current - dc offset. Section 10.1
  - Importance of X/R ratio
  - Circuit breaker ratings
  - Three-Phase fault calcs using [Zbus]. Section 10.3
  - Fault current contributions using [Zbus]. Eqn. (10.21)
  - Admittance approach using [Ybus]
\[ [Y]^{-1} = [Z] \left( [Y_{bus}]^{-1} = [Z_{bus}] \right) \]

Look at \([Z]\) in regards to S.C. calcs.

If \([Z]\) is symmetric about the main diagonal (bilateral) then use either row or col.
Begin with practical use of $[L2]$ 7c

Thevenin Impedance: Main diagonal element of $[Z]$.

Useful to know $Z_{in}$ of bus $f$.

\[
\frac{V_{in}}{I_{f}} = \frac{V_{f}}{I_{f}} = \frac{Z_{in}}{Z_{in}}
\]
\[ Z_{nn} = Z_{TH} \text{ at bus n.} \]

\[ \text{off-diagonal } Z\text{s represent the mutual impedences between bus } n \text{ & all other buses.} \]

\[ Z \]

\[ V_F = \text{Voltage at bus (Voc) pre-fault} \]

\[ I_{sc} = \frac{V_F}{Z_{nn}} \]
"Fault" Situation

$\begin{bmatrix} \tilde{Z} \end{bmatrix} = \begin{bmatrix} \tilde{Y} \end{bmatrix}$

Lines, XFMRS, LOADS, SHUNT CAP/REACTORS

(for this case, also the Gen Impedances)

Ex: Fig 7.5

IF there is a fault at bus $n$ in system,

$V_{F,Bn}$

$\tilde{I}_F = \frac{\tilde{V}_F}{\tilde{Z}_{nn}}$

Often assume that $V_F = 1.05/10^6$ p.u.
\[ V_i = V_F - I_F Z_{In} \]

In = -I_F, injected into bus n

\[ \begin{bmatrix} \vdots & \vdots & \vdots \\ Z \end{bmatrix} \begin{bmatrix} \cdots & \cdots \end{bmatrix} = \begin{bmatrix} \text{In} & \text{In} \\ \text{In} & \text{In} \\ \text{In} & \text{In} \end{bmatrix} \]

\[ \text{In} \times \text{In} = V_F \]

V_drops due to -I_F
What happens at other buses during the fault? All bus voltages will dip. How much?

During Fault

\[ E_t = V_F - \frac{\bar{I}_F}{Z_{mm}} Z_{lm} \]

\[ = V_F - \frac{\bar{V}_F}{Z_{mm}} Z_{lm} = V_F - \frac{Z_{lm}}{Z_{mm}} V_F = \bar{V}_F \left( 1 - \frac{Z_{lm}}{Z_{mm}} \right) \]

\[ \bar{I}_F = \frac{\bar{V}_F}{Z_{mm}} \]
Fault Contributions (i.e. current)

Must Know

If fault contribution: Are CBS going to be able to interrupt?

- Relay engineers must know all current flows.
Refering to Ybus, current contribs are

\[ [Z]^* = \begin{bmatrix}
  -y_{mg} \\
  y_{nj}
\end{bmatrix} \]

\[ I_{\text{From}} = (V_g - V_n)(-y_{mg}) \]
\[ I_j = (V_j - V_n)(-y_{nj}) \]
\[ I_K = (V_K - V_n)(-y_{nk}) \]
P.6 method ok for Short-Line Connections.

- What about \( \pi \)-equiv Line
- Shunt Load
- Shunt Cap/React?

*must include effect of Shunt Cap, unless \( V_n = 0 \).

More on this later, and in EE5240.

Not a contributor to 60-Hz Short-Circuit Current
\[ y_{sc} = \infty \]

\[ \infty = 10^{15} - 10^{18} \text{ (max for computer)} \]

\[ \therefore y_{nn} = y_{nn} + y_{sc} = y_{nn} + 10^{15} \approx \infty \]
\[
\begin{bmatrix}
Y
\end{bmatrix}
\Rightarrow
\begin{bmatrix}
Y_1 & \cdots & Y_n
\end{bmatrix}
= \begin{bmatrix}
0 \\
I_2 \\
\vdots \\
I_n
\end{bmatrix}
\uparrow
\text{unknowns}
\uparrow
\text{knowns}
\Rightarrow
\text{Same as}
V_f = -\Delta V
\]
Admittance Method to Calculate \( I_{sc} \)

\[
[y_{bus}] = \left[ \begin{array}{c}
     \text{Fault} \\
     \text{Bus}
\end{array} \right] [y_{bus}]
\]

When building \[ y_{bus} \],

\[
-\frac{1}{R_{ij}x} + j \frac{1}{s_{ij} + R_{ij}x} = 0
\]

\[
D = \frac{3}{2}
\]

\[
0 = \frac{2}{3} - 10 + \frac{1}{2}
\]

\[
y_{mn} = \frac{1}{R_{ij}x}
\]

Fault Location

Load Location