Topics for Today:

- Announcements
  - Nov 6th - Detailed Term Project outline (3-level) in format of report Table of Contents + complete list of references.
  - Software: can apply for ATP/ATPDraw license, verify licensing when you receive it by e-mail, and we will mail you the install CD.
  - **ASPEN OneLiner** - runs off of MTU server via internet: remote.mtu.edu
  - 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 \([Z_{bus}]\). Section 10.3
  - Fault current contributions using \([Z_{bus}]\). Eqn. (10.21)
  - Admittance approach using \([Y_{bus}]\)
\[ [Y]^{-1} = [Z] \quad ( [Y_{mv}]^{-1} = [Z_{bus}] ) \]

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 $[Z]$.

Thevenin Impedance: Main diagonal element of $[Z_{bus}]$. 

Useful to know $Z_{TH}$ at bus.

Prefault Voltage $\vec{V}_{TH}$. 

Fault $\vec{I}_F = \frac{\vec{V}_{TH}}{Z_{FF}}$.
\[ Z_{nn} = Z_{TH} \text{ at bus } n. \]

* Off-diagonal Z's represent the mutual impedances between bus n and all other buses.

\[ Z_{mn} \rightarrow n \]

\[ I_{inj} = -I_{sc} \]

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

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

Grid System

Reference
"Prefault" Situation

\[
[Z] = [Y]^{-1}
\]

Lines, XFMRS, LOADS, SHUNT CAP/REACTORS 3
(for this case, also the Gen Impedances) *
Ex: Fig 7.5

Reference

IF there is a fault at bus n in system,

\[
V_F, B1 \sim \tilde{I}_F = \frac{\tilde{V}_F}{Z_{nn}}
\]

Often assume that \( V_F = 1.05 / \angle 0 \) p.u.
\[ V_i = V_F - I_F Z_{ln} \]

\[ I_n = -I_F, \text{ injected into bus n} \]

\[ V_{drops} \text{ due to } -I_F \]

\[ I_{Zm} = V_F \]

\[ \begin{bmatrix}
    \cdots & Z_{mn} & \cdots \\
    Z_{mn} & \ddots & Z_{nn} \\
    Z_{mn} & & \ddots & \ddots \\
    & & & & \ddots \\
\end{bmatrix}
\]
What happens at other buses during the fault? All bus voltages will dip. How much?

During Fault

\[ E = V_F - \frac{\overline{I}_F Z_{im}}{Z_{nn}} \]

\[ = V_F - \frac{V_F}{Z_{nn}} Z_{im} = V_F - \frac{Z_{im}}{Z_{nn}} V_F = \overline{V}_F \left(1 - \frac{Z_{im}}{Z_{nn}}\right) \]
Fault Contributions (i.e. current)

Must Know

\[ I_{\text{Fault contr.}} : \text{Are CBS going to be able to interrupt?} \]
- Relay engineers must know all current flows.
Refering to Yous, current contribs are

\[ [Z]^{-1} = \begin{bmatrix} \ldots & -y_{mn} & \ldots \end{bmatrix} \]

Only non-zero values in row n.

\[ \bar{I}_{\text{From}} = (V_g - V_n)(-y_{ng}) \]

\[ g \quad I = \frac{(V_g - V_n)(-y_{ng})}{y_{ng}} \]

\[ j \quad I = (V_j - V_n)(-y_{nj}) \]

\[ k \quad I = (V_K - V_n)(-y_{nk}) \]
\[ y_{kn} = -\sum \text{Spanning admittances} \]

\[ y_{kn} = -y_{k-n,1} - y_{k-n,2} \]
P.4 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.
\[ y = 10^{15} - 10^{18} \text{ (max for computer)} \]

\[ 8 = y_m + y_n + y_{usc} \]

\[ y_m = y_{usc} + 10^{15} \]

\[ y_n = 8 \]

\[ y_{usc} = 8 \cdot 10^{15} \]
\[
\begin{bmatrix}
Y
\end{bmatrix}
\xrightarrow{\text{knowns}}
\begin{bmatrix}
\cdots & \cdots & \cdots & \vdots \\hline
\end{bmatrix}
\xrightarrow{\text{unknowns}}
\begin{bmatrix}
\cdots & \cdots & \cdots & \cdots & \cdots \\hline
\end{bmatrix}
\xrightarrow{\text{knowns}}
\begin{bmatrix}
0 \\
I_{2} \\
I_{2} \\
I_{2} \\
0 \\
\end{bmatrix}
\]

Same as
\[V_{f} = \Delta V\]
Admittance Method to Calculate Isc

\[
\begin{bmatrix}
  Y \\
  V_m \\
  V_n
\end{bmatrix} =
\begin{bmatrix}
  I_{inj}
\end{bmatrix}
\]

When building \([Y_{bus}]\),

\[
\tilde{Y}_{nn} = \frac{1}{R + jX} + jB_c + \frac{1}{R_t + jX_t} + \frac{1}{Z_L} + 10^{15} \quad Y_F \equiv \infty
\]