Topics for Today:

- Announcements
  - Nov 2nd - 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]
I. Intro

II. Background
   A. Topic Area 1
      1) 
      2) 
   B. Topic Area 2
      1) 
      2) 
      3) 
   C. Topic Area 3
      1) 
      2) 
      3) 
      4) 

III. Proposed Approach
     ) Fill in details/work plan.
\[
[Y]' = [Z]
\]

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

\[
\begin{bmatrix}
  z_{11} & z_{12} & z_{1m} & \cdots & z_{1N} \\
  z_{21} & z_{22} & z_{2m} & \cdots & z_{2N} \\
  \vdots & \vdots & \ddots & \ddots & \vdots \\
  z_{m1} & z_{m2} & z_{mm} & \cdots & z_{mN} \\
  z_{N1} & z_{N2} & z_{Nm} & \cdots & z_{NN}
\end{bmatrix}
\]

If \([Z]\) is symmetric about the main diagonal \((\text{bilateral})\) then use either row or col.
\[ Z_{nn} = Z_{TH} \text{ at bus n.} \]

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

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

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

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

Grid System Diagram: 
- \( Z_{nn} \) connection at bus n.
- \( I_{ij} = -I_{sc} \) connections between buses.
- Reference voltage \( V_F \) at bus.
- Impedance \( Z_{nn} \) for bus n.
"Prefault" Situation

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

Lines, XfHrs, 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,

\[ V_{F,n} \sim \frac{V_F}{Z_{mn}} \]

\[ I_F = \frac{V_F}{Z_{nn}} \]

Often assume that \( V_F = 1.05/\mu \) p.u.
What happens at other buses during the fault? All bus voltages will dip. How much?

During Fault

\[ E_i = V_F \frac{\tilde{I}_F}{z_{nn}} \]

\[ = V_F - V_F \frac{z_{in}}{z_{nn}} = V_F - \frac{z_{in}}{z_{nn}} V_F \]
Fault Contributions (i.e. current)

Must Know

I_{Fault contrib}: Are CBS going to be able to interrupt?
- Relay engineers must know all current flows.
During Fault:
\[
\tilde{V}_g = V_F - I_F \tilde{Z}_{ng} \\
\tilde{V}_j = V_F - I_F \tilde{Z}_{nj} \\
\tilde{V}_k = V_F - I_F \tilde{Z}_{nk} \\
\tilde{I}_{gn} = \frac{\tilde{V}_g - \tilde{V}_n}{\tilde{Z}_{n-g}} \\
\]
Refering to Ybus, current contribs are

\[
\begin{bmatrix}
Z
\end{bmatrix}^{-1} = \begin{bmatrix}
\end{bmatrix}
\]

\[
y_{ng}
\]
\[
y_{nj}
\]
\[
y_{nk}
\]

\[
\begin{align*}
\bar{I}_{From}^g & = (V_g-V_n)(-y_{ng}) \\
\bar{I}_{From}^j & = (V_j-V_n)(-y_{nj}) \\
\bar{I}_{From}^k & = (V_K-V_n)(-y_{nk})
\end{align*}
\]
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
Begin with practical use of $[Z]$.

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

Useful to know $Z_{th}$ at bus:

\[ \frac{V}{I_{th}} = \frac{V_{th}}{I_{th}} = \frac{25k}{25k} \]
Objectives: Familiarization with most basic MatLab usage: entering complex numbers, matrix operations used to solve node equations, admittance and impedance matrices, plotting a simple waveform, etc.

Getting started: If you have not already, go thru the Matlab video tutorials posted on the EE5200 web page. From inside the Matlab program, you can also access tutorials by pressing F1 for Help, and then clicking on "Getting Started." Do this assignment with the goal of developing basic skills and making useful notes that you yourself will continue to refer back to. Hint to save a lot of time: make generous use of the e-mail forum to ask for and share ideas on even the most basic issue.

1) Referring to the circuit below, assume $E_1 = 120/0^\circ$ V, $E_2 = 100/-20^\circ$ V, and $E_3 = 120/30^\circ$ V.
   a) form $[Y]$ and enter the matrix into matlab (entries are complex numbers!),
   b) use MatLab to solve the matrix equation $[Y][V] = [I_{inj}]$ for the 3 node voltages.
   c) confirm your solution is correct - confirm KCL at node 2.
   d) invert $[Y_{bus}]$ to get $[Z_{bus}]$.

\[\text{Ex:}\]

\[\text{Thev. equiv of Gen}\]

\[\text{Gen} \quad \tilde{E}_1 \quad \tilde{E}_2 \quad \tilde{E}_3\]

\[\text{Convert to admittances u/Norton eqv}\]

\[\tilde{I}_1 \quad \tilde{I}_2 \quad \tilde{I}_3\]

2) A graphing (use Matlab "plot" function) exercise. In this case, save and execute your program as an .m file. Let's investigate the well-known Gibbs effect which occurs when the infinite series that defines a square wave is truncated (see http://en.wikipedia.org/wiki/Gibbs_phenomenon)

\[v_{square}(t) = V_p \sin(\omega t) + V_p/3 \sin(3\omega t) + V_p/5 \sin(5\omega t) + \ldots\]

Write a double for-loop which fills 2 storage vectors with the values of $v_{square}(0.005)$ and the corresponding time values for $\Delta t = 10\mu s$, for truncation after $m$ terms. Assume 60-Hz fundamental and $V_p = 10$ V. Plot the waveform.
$V_{Square}(t) = V_p \sin(\omega t)$

\[
\frac{m(2m-1)}{m} \rightarrow 1 + \frac{V_p}{3} \sin(3\omega t) \quad m = 1
\]

\[
\frac{3}{5} \rightarrow 3 + \frac{V_p}{5} \sin(5\omega t) \quad m = 2
\]

\[
+ \cdots \rightarrow \cdots + \frac{V_p}{8} \sin(8\omega t) \quad m = 3
\]

\[
\rightarrow \cdots + \frac{V_p}{\infty} \sin(\infty\omega t) \quad m = \infty
\]
$t = 0$

$0.055 s \quad f = 60$

$\Delta t = 10 \mu s$

$t_{end} = 0.055$

$N_{PTS} = t_{end}/\Delta t + 1$

$t = \text{zeros}(1, N_{PTS})$

$v = \text{zeros}(1, N_{PTS})$

$N_{TRMS} =$

$\Omega_{eq} = 2 + \pi f$
for \( n = 1: \text{NPTS} \)

\[
\tau(n) = (n-1) \Delta t
\]

end

for \( m = 1: \text{NTRMS} \)

\[
\tau'(n) = \tau(n) + \frac{V_p}{(2\pi m-1)} \sin((2\pi m-1)c_\text{mg} \Delta t)
\]

end

plot(\( \tau(n) \))

plot(\( x, y \))

i.e. \( (t, \tau) \)