Topics for Today:

- Startup
  - Web page: [http://www.ee.mtu.edu/faculty/bamork/ee5220/](http://www.ee.mtu.edu/faculty/bamork/ee5220/)
  - Book, references, syllabus, more are on web page.
  - Software - Matlab. ATP/EMTP [License - www.emtp.org]
  - ATP tutorials posted on our course web page
- EE5220-L@mtu.edu (participation = half letter grade, 5%)

- HW#4 soon posted. Partnered exercise. Due Wed Feb 8th.
- ATP Simulation pointers
- Cap Bank Switching (continued)
  - Discussion - how to carry out HW#4
  - Parameters
    - Setup of this simple system simulation.
    - Cap Bank configurations
    - Transformer parameters
    - Rules of thumb for impedances
ATP Simulation Pointer for the day:

Always ground one point on your circuit. This avoids the problem of a "floating subnetwork." Essentially this is a situation where the admittance matrix that describes the circuit is singular. If the program would attempt to proceed with LU factorization there would be a divide by zero error and the program would crash.
\[
\begin{bmatrix}
y_a & -y_a & 0 \\
-y_a & y_a + y_b & -y_b \\
0 & -y_b & y_b \\
\end{bmatrix}
\begin{bmatrix}
V_1 \\
V_2 \\
V_3 \\
\end{bmatrix}
= 
\begin{bmatrix}
I_{\text{inj}} \\
0 \\
0 \\
\end{bmatrix}
\]

\[\approx 10^{15}, 10^{12}, \quad \Phi \approx 10^{12} \times 10^{15}\]
\[ X = \frac{\sqrt{3} V_{ll} (Isc)}{R} \]

\[ MVA_{sc} = \frac{2}{R} \times X \]

\[ Z_{TH} = \frac{V_{ln}}{Isc} \]
- Some parameters - vital
- " " - not important
- Some effects can be ignored.

Ex:

\[ L = (0.25)(100') = 25 \text{ mH} \]

\[ X_L = 2\pi f L \Omega \]
\[ = 377 L \Omega = 9.4 \text{ m}\Omega \text{ @ 60Hz} \]

\[ \Rightarrow \quad = \frac{78.5 \text{ m}\Omega}{500 \text{ Hz}} \]
\[ \Rightarrow \quad = \frac{785 \Omega}{5 \text{ kHz}} \]
115-kV
100 MVA

\[ Z_B = \frac{115^2}{100} = 132.2 \Omega \]

\[ Z_0 = \sqrt{\frac{1}{L C}} \]

\[ f_0 = \frac{1}{2\pi\sqrt{L C}} \]

"S.C. MVA"

\[ V_{TH} \quad V_{LN} \quad jX_{TH} \quad \frac{1}{2}I_{sc} \quad S.C. MVA = \sqrt{3} V_{LL} I_{sc} \]
Basic Series Impedances (Ohm/mi):

<table>
<thead>
<tr>
<th></th>
<th>Xo/Ro</th>
<th>Ro</th>
<th>Xo</th>
<th>R1</th>
<th>X1</th>
<th>X1/R1</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/0 Cu</td>
<td>4.721322</td>
<td>0.5867</td>
<td>2.77</td>
<td>0.303</td>
<td>0.6008</td>
<td>2.64</td>
</tr>
<tr>
<td>556.5 Al</td>
<td>5.76316</td>
<td>0.4704</td>
<td>2.711</td>
<td>0.1671</td>
<td>0.7421</td>
<td>3.97</td>
</tr>
<tr>
<td>1590 Al</td>
<td>7.415919</td>
<td>0.3568</td>
<td>2.846</td>
<td>0.07313</td>
<td>0.677</td>
<td>9.26</td>
</tr>
<tr>
<td>5&quot; Al</td>
<td>8.11904</td>
<td>0.3041</td>
<td>2.469</td>
<td>0.0209</td>
<td>0.5005</td>
<td>23.95</td>
</tr>
</tbody>
</table>

Note: Z0 values seem to be typically 3x bigger than Z1. This compares to T-Line sections that have no shield/ground wire.

\[ p = 1.8 \text{ m} \]

Strain Bus - Overhead Conductor for bus conductor.

Tube/Pipe Bus - Al tube or channel

Focus on \( X/R \) ratio and \( L/ft \).

Damping:

\[ E = \frac{1}{2} CV^2 \]

Assume \( Z_0 = Z_1 = Z_2 \)

(Ground Grid?)

1.8 m
See SK. ACP - Per Phase

OLD General Purpose
(I_{p1/2} = 2 \times 10^3)

\[ V_s = \frac{\sqrt{2} \times V_{\text{LL}, \text{RMS}}}{\sqrt{3}} = V_p \]

\[ Z_s = \text{From S.C. Study (CAPE, PSS/E)} \]
or assume 57\%, \( \frac{X}{R} = ? \) USE Judgement

Bus Sections - Go to Sr. Power Book

\[ L = K \log \frac{D}{r_1} \]

\[ R = \text{From Tables: } R_{AC@50°C} \]
Cap Bank Values

Equivalent L-N Cap of a \( \text{MVAR} \) Bank?

Typical Ratings: 100, 200, 400 kVAr
Low KV \( \rightarrow \) 24 KV
Losses: 0.05-0.3 W/kVAR

Each Cap: \( K_s \) \( \frac{R_{Diss}}{C} \)
CBi - Switches

Spreadsheet Calcs:

Outrush:

\[
\text{STEP \#2}
\]

\[
\frac{I_p f_o}{2 \times 10^7}
\]

\[
I_p = \frac{\Delta V}{Z_0} = \frac{V_p}{\sqrt{\frac{L_B + L_{CL}}{C_{EQ}}}}
\]

\[
\frac{1}{(L_B + L_{CL}) \times C_{EQ}}
\]
I_{out\text{trash}} \quad 2 \times I_p