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](http://www.emtp.org) ]
    ATP tutorials posted on our course web page
  • [EE5220-L@mtu.edu](mailto:EE5220-L@mtu.edu) (participation = min half letter grade)

• HW#4 soon posted. Partnered exercise. Due Mon Feb 12th.
• 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 of the Day:

Always ground one point on your circuit. This avoids the problem of “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.

**Note:** In ATP, there is an undesirable and somewhat random automatic “correction” of this situation, where one node is grounded to fix the situation, but the user may not be aware that this has been done or which node has been grounded. **Better:** you control the situation by grounding the node that needs to be grounded.
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.
\[
\begin{bmatrix}
y_a & -y_a & 0 \\
y_a & y_a + y_b - y_b & -y_b \\
0 & -y_b & y_b
\end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} I_{\text{inj}} \\ 0 \\ 0 \end{bmatrix}
\]
- Some parameters - vital
- " " - not important
- Some effects can be ignored.

Ex:

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

\[ X_L = 2\pi f L \Omega \]
\[ = 377 L \Omega = 9.4 \text{ m}\Omega \text{ @ } 60\text{Hz} \]
\[ = 78.5 \text{ m}\Omega \text{ @ 500Hz} \]
\[ = 785 \text{ \mu}\Omega \text{ @ 5kHz} \]
$Z_B = \frac{115^2}{100} = 1322 \Omega$

$\begin{align*}
\text{S.C. MVA} &= \sqrt{3} V_{LL} I_{SC} \\
\text{S.C. MVA} &= \sqrt{3} \cdot 115 \cdot 100 = 1322 \text{ MVA}
\end{align*}$

$f_0 = \frac{1}{2\pi \sqrt{LC}}$

$Z_0 = \sqrt{\frac{L}{C}}$
### Basic Series Impedances (Ohm/mi):

<table>
<thead>
<tr>
<th>Material</th>
<th>( X_o/\varepsilon_0 )</th>
<th>( \varepsilon_0 )</th>
<th>( X_0 )</th>
<th>( R_1 )</th>
<th>( X_1 )</th>
<th>( X_1/R_1 )</th>
<th>(uH/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/0 Cu</td>
<td>4.721323</td>
<td>0.5867</td>
<td>2.77</td>
<td>0.303</td>
<td>0.6008</td>
<td>2.64</td>
<td>0.402</td>
</tr>
<tr>
<td>556.5 Al</td>
<td>5.76318</td>
<td>0.4704</td>
<td>2.711</td>
<td>0.1671</td>
<td>0.7421</td>
<td>3.97</td>
<td>0.373</td>
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<tr>
<td>1590 Al</td>
<td>7.415819</td>
<td>0.3568</td>
<td>2.848</td>
<td>0.07313</td>
<td>0.877</td>
<td>9.26</td>
<td>0.340</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>
<td>0.251</td>
</tr>
</tbody>
</table>

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

\[ \varepsilon = 1\text{ in} \]

**Strain Bus - Overhead Conductor** for bus conductor.

**Tube/ Pipe Bus - Al tube or channel**

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

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

Damping:

Assume \( \varepsilon_0 = \varepsilon_1 = \varepsilon_2 \)

(Ground Grid?)

152-m
See SK. ACP - Per Phase

OLD General Purpose
(I_p x f = 2 x 10^3)

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

\[ Z_s = \text{From S.C. Study (CAPE, PSS/E)} \]
or assume 5%, \( x/R = ? \) USE Judgement

Bus Sections - Go to Sr. Power Book

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

\[ R = \text{From Tables: } \frac{\text{mmHg}}{\text{ft}} \]

\[ R_{ac@50^\circ C} \]
Cap Bank Values

Equiv L-N Cap of a _ MVAR Bank?

Typical Ratings: 100, 200, 400 KVAR
Low KV → 24 KV
Losses: 0.05 - 0.3 W/KVAR

Each Can:

Ks

R_{Diss}
CBs - Switches

Spreadsheet Calcs:

Outrush:

\[ \text{STEP #2} \]

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

\[ I_p \times f_0 = 2 \times 10^7 \]

\[ IP* f_0 < 2 \times 10^7 \]