• Questions from last lecture?
• How are your matrix math skills?
• Questions on Hmwk #1 ? (Due 9am Wed).
• Everybody all set w/text, matlab, etc?
• Web page ok? Be sure to get 3-ring binder - lots of papers!

TODAY:
• Kron Reduction (network reduction) – refer to Lecture 2.
• Modifications to [Y] according to system changes
• Switching things in and out: lines, shunt reactors/caps, gens.
• Augmenting the admittance matrix
  • Ungrounded Voltage Source
  • Short Circuit
  • Two-winding Transformer
• Next: in situ methods to solve \([Y_{bus}] [V_{bus}] = [I_{inj}]\)
Admittance Equations

General Form:

\[
\begin{bmatrix}
Y_{\text{bus}}
\end{bmatrix}
\begin{bmatrix}
V_{\text{node}}
\end{bmatrix}
=
\begin{bmatrix}
I_{\text{inj}}
\end{bmatrix}
\]

We can add constraints:
- V Source Bus-Bus
- Short
- XFMR
- DEPENDENT SOURCES (OP-AMP)
SWITCHING LINES, ETC, in and out:

From Lecture 1:

$$[Y] = \begin{bmatrix}
8 & -2 & -5 \\
-2 & 9 & -4 \\
-5 & -4 & 15
\end{bmatrix}$$

Switch out Line 1-3:

$$\begin{bmatrix}
3 & -2 & 0 \\
-2 & 9 & -4 \\
0 & -4 & 10
\end{bmatrix}$$

\[\ddot{y}_{1-3} = 55\]
\[ Y_{kn} = \frac{1}{y_{nk} + y_{kn}} \]

\[ Y_{kk} = \frac{1}{y_{kk} - 4y_{kn} - y_{nn}} \]

Changing Sense:

Mode I, 5] Switch out:

Is it full-line:

How about a T-line?

\[ \frac{1}{y_{12}} = \frac{1}{y_{13} + y_{13}} = \frac{1}{y_{13} + y_{13}} \]

\[ y_{12} = \frac{y_{13}}{y_{13} + y_{13}} + \frac{y_{13}}{y_{13} + y_{13}} \]

\[ y_{12} = \frac{y_{13}}{y_{13} + y_{13}} - \frac{y_{13}}{y_{13} + y_{13}} \]

\[ y_{12} = \frac{y_{13}}{y_{13} + y_{13}} - \frac{y_{13}}{y_{13} + y_{13}} \]
AUGMENTING $[Y_{bus}]$

$[Y_{bus}]$

$[0.096800068000000]$

$x$

$[V_{bus}] = [I_{ns}]$

Coefficients of add'l eqns
New Constraints being added:

1. $\tilde{V}_S = \tilde{V}_L - \tilde{V}_K = \text{Known (forced voltage)}$
2. $\tilde{I}_L = + \tilde{I}_S$
3. $\tilde{I}_K = - \tilde{I}_S$
\[ \tilde{V}_s = \tilde{V}_k - \tilde{V}_K \]

**Note:**

This effect is on the left side of the equation.

If \( \tilde{V}_s = 0 \), the short circuit is removed.

\( \tilde{I}_e \) (INJ) is increased by \( +\tilde{I}_s \).

\( \tilde{I}_K \) (INJ) is "increased" by \( -\tilde{I}_s \).

Change sign when entering in column N+1 of \([\mathbf{N}]\)!
XFMR - IDEAL 2-WINDING

Polarity Marks: \[ I_P = I_S \\
\overline{V}_{mk} = \overline{V}_{ej} \]

The turns ratio "a" is in general, complex.
Aug Row → Voltage constraints
Aug Col → Current constraints

TYPICAL: INTRODUCE ZERO IN MAIN DIAG!
Constraints

Node Voltages

\[ \tilde{V}_m - \tilde{V}_k = a (\tilde{V}_e - \tilde{V}_j) \]
i.e. \[ \tilde{V}_{mk} = a \tilde{V}_e \]

\[ \tilde{V}_m - \tilde{V}_k + a \tilde{V}_j - a \tilde{V}_e = 0 \]

Injected Currents: (ADD'L)

\[
\begin{align*}
    l: & + \tilde{I}_s = a \tilde{I}_p \\
    j: & - \tilde{I}_s = - a \tilde{I}_p \\
    m: & - \tilde{I}_p \\
    k: & + \tilde{I}_p
\end{align*}
\]

Again: effect is on left side of eqn.; change signs in Column Nbr. of \[ V \].

General Reference for this is on next page.
(From Vlach - refer to syllabus reference list)

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<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>SYMBOL</th>
<th>MATRIX</th>
<th>EQUATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CURRENT SOURCE</td>
<td>![symbol]</td>
<td>( I \left[ \begin{array}{c} -J \ J \end{array} \right] )</td>
<td>( I_j = J \ I_j' = -J )</td>
</tr>
<tr>
<td>VOLTAGE SOURCE</td>
<td>![symbol]</td>
<td>( V \left[ \begin{array}{c} I \end{array} \right] )</td>
<td>( V_j - V_j' = E \ V_j' = 1 \ I_j' = -1 )</td>
</tr>
<tr>
<td>OPEN CIRCUIT</td>
<td>![symbol]</td>
<td>( \left[ \begin{array}{c} V_j \ V_j' \end{array} \right] )</td>
<td>( V = V_j - V_j' )</td>
</tr>
<tr>
<td>SHORT CIRCUIT</td>
<td>![symbol]</td>
<td>( \left[ \begin{array}{c} I \end{array} \right] )</td>
<td>( V_j - V_j' = 0 \ I_j = 1 \ I_j' = -1 )</td>
</tr>
<tr>
<td>ADMITTANCE</td>
<td>![symbol]</td>
<td>( \left[ \begin{array}{c} V_j \ V_j' \end{array} \right] )</td>
<td>( I_j = y(V_j - V_j') \ I_j' = y(V_j - V_j') )</td>
</tr>
<tr>
<td>IMPEDANCE</td>
<td>![symbol]</td>
<td>( \left[ \begin{array}{c} V_j \ V_j' \end{array} \right] )</td>
<td>( V_j - V_j' = I \ I_j = 1 \ I_j' = -1 )</td>
</tr>
<tr>
<td>NULLATOR</td>
<td>![symbol]</td>
<td>( \left[ \begin{array}{c} I \end{array} \right] )</td>
<td>( V_j - V_j' = 0 \ I_j = 0 \ I_j = 0 )</td>
</tr>
<tr>
<td>NORATOR</td>
<td>![symbol]</td>
<td>( I \left[ \begin{array}{c} 1 \ 1 \end{array} \right] )</td>
<td>( V, I ) are arbitrary</td>
</tr>
<tr>
<td>VCT</td>
<td>![symbol]</td>
<td>( \left[ \begin{array}{c} V_j \ V_j' \end{array} \right] )</td>
<td>( I_j = 0 \ I_j' = 0 \ I_k = g(V_j - V_j') \ I_k' = -g(V_j - V_j') )</td>
</tr>
</tbody>
</table>

**Fig. 4.4.1.** Ideal elements in the modified nodal formulation without graphs.