Topics for Today:

- Announcements
  - Term Project: List of references (half a dozen) & outline are past due.
  - Software: Matlab, ATP/ATPDraw - Exercise on T-Lines
  - Office hrs: 2:00-3:00pm, Mon, Wed, Fri
  - Office: EERC 623. Phone: 906.487.2857
  - Recommended problems & all solutions thru Ch.11 will be posted.
  - Local Students: Alternate meeting times on Nov 4th, Nov 6th. 3:30-5:00

- Chapters 7 & 8 - Admittance Formulations, Network Calculations
  - Thevenin to Norton conversion
  - Ch 7-8: many of these topics will be covered in EE5240
  - Overview of $[Z]$ vs. $[Y]$ – tradeoffs in ease and usefulness
  - Short-circuit applications
  - Basic matrix operations that are of practical need in EE5200

- Intro to Load Flow
  - System parameters
  - Slack, PV, Load buses
  - Simulation output
\[ [Y]^\top = [Z] \]

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

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

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

$Z_{nn}$

$\frac{1}{2}$

$1$

Grid System

$[Z]$

$V_F = Voltage$ 

at bus (Voc) pre-fault

Reference

$I_{sc} = \frac{\bar{V}_F}{Z_{nn}}$
“Prefault” Situation

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

Reference

Lines, XFMRS, 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,

$$V_{F,B} \quad \bar{I}_F = \frac{\bar{V}_F}{Z_{nn}}$$

Often assume that

$$V_F = 1.05/\text{p.u.}$$
What happens at other buses during the fault? All bus voltages will dip. How much?

During Fault

\[ E_i = V_F - \frac{\bar{I}_F Z_{in}}{Z_{nn}} \]

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

Must Know

\[ I_{\text{FAULT contr}} \]: Are CBs going to be able to interrupt?

- Relay engineers must know all current flows.
Refering to Ybus, current contribs are

\[ \begin{bmatrix} \quad \end{bmatrix} \]

\[ y_{nn} \]

\[ y_{ng}, y_{nj}, y_{nk} \] only non-zero values in row n.

\[ \bar{I} \text{ From } \]

\[ \bar{I}_g = (V_g - V_n)(-y_{ng}) \]

\[ \bar{I}_j = (V_j - V_n)(-y_{nj}) \]

\[ \bar{I}_k = (V_k - V_n)(-y_{nk}) \]
P.6 method ok for Short-Line Connections.

- What about Pi-equiv Line
  - Shunt Load
  - Shunt Cap/React?

*must include effect of shunt caps unless $V_n = 0$.

More on this later, and in EE5240.

Not a contributor to 60-Hz Short-Circuit Current
Quick Intro to Load Flow

Click on NR -> Get printout, see p.1.

Explains system [Y], external injected

What does "Loadflow" do?

-3 Bus Types Known

<table>
<thead>
<tr>
<th></th>
<th>SLACK Bus (SWING Bus)</th>
<th>GEN Bus (PV Bus)</th>
<th>LOAD Bus (PQ Bus)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V = fixed</td>
<td>p, q</td>
<td>p is scheduled</td>
<td>p is fixed</td>
</tr>
<tr>
<td>s = 0</td>
<td>V is controlled</td>
<td>Q is fixed</td>
<td></td>
</tr>
<tr>
<td>only one!</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Determines p, q, s, v, s

Click on NR -> Get printout, see p.1.
shown in Figure 3.9 for a two-winding transformer, Figure 3.20 for a three-winding transformer, or Figure 3.25 for a tap-changing transformer.

Input data for each transmission line include the per-unit equivalent π circuit series impedance $Z'$ and shunt admittance $Y'$, the two buses to which the line is connected, and maximum MVA rating. Similarly, input data for each transformer include per-unit winding impedances $Z$, per-unit exciting branch admittance $Y$, the buses to which the windings are connected, and maximum MVA ratings. Input data for tap-changing transformers also include maximum tap settings.

The bus admittance matrix $Y_{bus}$ can be constructed from the line and transformer input data. From (2.4.3) and (2.4.4), the elements of $Y_{bus}$ are:

**Diagonal elements:** $Y_{kk} =$ sum of admittances connected to bus $k$

**Off-diagonal elements:** $Y_{kn} = -($sum of admittances connected between buses $k$ and $n$ $)_{k \neq n}$

\[ (6.4.2) \]

**EXAMPLE 6.9 Power-flow input data and $Y_{bus}$**

Figure 6.2 shows a single-line diagram of a five-bus power system. Input data are given in Tables 6.1, 6.2, and 6.3. As shown in Table 6.1, bus 1, to which a generator is connected, is the swing bus. Bus 3, to which a generator and a load are connected, is a voltage-controlled bus. Buses 2, 4, and 5 are load buses. Note that the loads at buses 2 and 3 are inductive since $Q_2 = -Q_{L2} = -0.7$ and $-Q_{L3} = -0.1$ are negative.

For each bus $k$, determine which of the variables $V_k$, $\delta_k$, $P_k$, and $Q_k$ are input data and which are unknowns. Also, compute the elements of the second row of $Y_{bus}$. 
The elements of $Y_{bus}$ are computed from (6.4.2). Since bus 3 is not directly connected to bus 2,

$$Y_{21} = Y_{23} = 0$$

Using (6.4.2),

$$Y_{24} = \frac{-1}{R_{24} + jX_{24}} = \frac{-1}{0.009 + j0.3} = -0.89276 + j9.91964 \quad \text{per unit}$$

$$Y_{25} = \frac{-1}{R_{25} + jX_{25}} = \frac{-1}{0.0045 + j0.05} = -1.78552 + j19.83932 \quad \text{per unit}$$

$$Y_{22} = \frac{1}{R_{24} + jX_{24} + R_{25} + jX_{25} + \frac{B_{24}^2}{2} + \frac{B_{25}^2}{2}}$$

$$= (0.89276 - j9.91964) + (1.78552 - j19.83932) + \frac{1.72}{2} + j\frac{0.88}{2}$$

$$= 2.67828 - j8.4590 = 28.5847 + 84.6244 \quad \text{per unit}$$

where half of the shunt admittance of each line connected to bus 2 is included in $Y_{22}$ (the other half is located at the other ends of these lines).

This five-bus power system is modeled in PowerWorld Simulator case Example 6.9. To view the input data, first click on the Edit Mode button to switch into the Edit mode (the Edit mode is used for modifying system parameters). Using the Case Information menu, you can view tabular displays showing the various parameters for the system. For example, Select Case Information, Buses... to view the parameters for each bus, and Case Information, Lines and Transformers... to view the parameters for the lines and transformer values. Fields shown in blue can be directly changed simply by typing over them, and those shown in green can be toggled by clicking on them.

The elements of the $Y_{bus}$ can also be displayed by selecting Case Information, Ybus. Since the $Y_{bus}$ entries are derived from other system parameters, they cannot be changed directly. Notice that several of the entries are blank, indicating that there is not line directly connecting these two buses (a blank entry is equivalent to zero). For larger networks, most of the elements of the $Y_{bus}$ are zero since any single bus usually has only a few incident lines. The elements of the $Y_{bus}$ can be saved in a Matlab format file by first right-clicking within the Ybus matrix to display the local menu, and then selecting “Save Ybus in Matlab Format” from the menu.

Finally, notice that no flows are shown on the one-line, because the nonlinear power-flow equations have not yet been solved. We cover the solution of these equations next.