Topics for Today:

- Questions from last lectures?
- Questions/Comments on Homework #5? #6?
  - Jacobian Structure
  - Mismatch for converged data = ZERO!
- Homework #6 key points:
  - Convergence measures, ε = 0.001.
  - Output format: mismatches, circuit numbers, area efficiencies, branch flows, tap positions.
- Topics for Today:
  - various types of voltage-controlled bus
  - Fast Decoupled Newton Raphson
  - Data structures, LU factorization, reordering to avoid zero divides and/or speed up solution.
- Things coming along next:
  - Optimal Dispatch - Chapter 6.
  - Check out Aspen (manuals in lab)
E5200 - Advanced Methods in Power Systems

1) Create output file
2) Calculate line flows

Recalculate mismatch APS & AGS, check for convergence

\[ \begin{align*}
\Delta V + [\Delta P] & = [\Delta Q] \\
[\Delta G] & = [\Delta P] \\

\end{align*} \]

Update solution

Individually test if all are \( \leq \epsilon \)

Scan through all APS & AGS

2) Simpler method (more common)

\[ \| \Delta R \|, \| \Delta Q \|, \| \Delta V \| \leq \epsilon \]

1) Norm of mismatch vector:

Typical \( \epsilon = 0.001 \) or \( 0.0001 \) pu.

Convergence:

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EEE5200 - Advanced Methods in Power Systems

- Photovoltaic
- Wind
- Combined Heat and Power

Machine Capability:
- Curves

- Electric Power
- VAR
- Reactive Power
- Voltage

I - HoLi Wires within V limits:

1. HoLi Wires within V limits.
2. PV Bus (HoLi V | 1 Cons)
3. Swing Slack (only one)

Voltage - Controlled buses
$$\frac{\sqrt{\frac{R+6}{(V-V_1)}}}{\sqrt{\frac{\sqrt{2}}{V-V_1}}} \quad \frac{\sqrt{2}}{V-V_1} \quad \frac{\frac{1}{2}}{V-V_1}$$

Bus:

$$\text{Flows out of}$$

Diagram:

```
+---+---+---+---+---+
|   |   |   |   |   |
|   |   |   |   |   |
|   | R |   |   |   |
|   |   |   |   |   |
|   | G |   |   |   |
|   |   |   |   |   |
|   | X |   |   |   |
|   |   |   |   |   |
|   |   |   |   |   |
|   |   |   |   |   |
|   |   |   |   |   |
|   |   |   |   |   |
```

```
\underline{Calculating Branch Flow:}
```

```
\underline{Lines}
```
\[
\begin{align*}
Q_{\text{in}} &= \frac{1}{2}B_c \cos \theta_c + \frac{j}{2}B_c \sin \theta_c \\
\text{Bus} &\quad \text{Shunt} \\
0 &\quad \frac{V_1^2}{g} \\
\frac{V_2^2}{g} &\quad \frac{1}{\omega B} \\
\frac{1}{\omega B} &\quad \frac{V_2^2}{g} \\
\frac{V_2^2}{g} &\quad \frac{1}{\omega B} \\
\to \text{Bus} &\quad \text{Part} \quad Q_{\text{out}} \\
\to \text{Part} &\quad Q_{\text{out}} \\
\end{align*}
\]
- Do in-between iteration.
  - Put AC into [F].
  
  number.

In DC file: Voltage-controlled bus

- Load voltage bus.
- Also increase VAC flow.

Increase c to prop up \( V_1 \).

Voltage-controlled bus via LTC
LU Factorization (Crout’s Method)

There are two approaches: 
- "in situ" methods
- Sparse matrix storage.

- By rows (example shown here)
- By columns (your text’s approach)

Basic Procedure:

1. Copy Column one
2. Divide Row 1 off-diagonal entries by diagonal term of Row 1.
3. For each element $i,j$ where $i > 1$ and $j > 1$, subtract from it the product of $a_{i1} \cdot a_{ij}$
4. If the resulting sub-matrix is of order 2 or greater, go back to step 1 and perform the same operations on that sub-matrix.

Example:

\[
\begin{bmatrix}
A
\end{bmatrix}
\begin{bmatrix}
x
\end{bmatrix} = 
\begin{bmatrix}
y
\end{bmatrix}
\]

\[
\begin{bmatrix}
L
\end{bmatrix}
\begin{bmatrix}
U
\end{bmatrix}
\begin{bmatrix}
x
\end{bmatrix} = 
\begin{bmatrix}
y
\end{bmatrix}
\]

\[
\begin{bmatrix}
L
\end{bmatrix}
\begin{bmatrix}
z
\end{bmatrix} = 
\begin{bmatrix}
y
\end{bmatrix} \rightarrow \text{solve for } z
\]

\[
\begin{bmatrix}
U
\end{bmatrix}
\begin{bmatrix}
x
\end{bmatrix} = 
\begin{bmatrix}
z
\end{bmatrix} \rightarrow \text{solve for } [x].
\]
\[ \begin{bmatrix}
  4 & -6 & 19 & -9 \\
  9 & 0 & -5 & 0 \\
  2 & 0 & -5 & 0 \\
  0 & 0 & 0 & 0 \\
\end{bmatrix} = \mathbf{L} \]

\[ \mathbf{L} = \begin{bmatrix}
  3 & 1 & 2 & 1 \\
  2 & 0 & 0 & 0 \\
  0 & 0 & 0 & 0 \\
  2 & 0 & 0 & 0 \\
\end{bmatrix} \]

\[ \begin{bmatrix}
  3 & 1 & 2 & 1 \\
  2 & 0 & 0 & 0 \\
  0 & 0 & 0 & 0 \\
  2 & 0 & 0 & 0 \\
\end{bmatrix} \]

\[ \begin{bmatrix}
  4 & -6 & 19 & -9 \\
  9 & 0 & -5 & 0 \\
  2 & 0 & -5 & 0 \\
  0 & 0 & 0 & 0 \\
\end{bmatrix} \]

\[ \begin{bmatrix}
  3 & 1 & 2 & 1 \\
  2 & 0 & 0 & 0 \\
  0 & 0 & 0 & 0 \\
  2 & 0 & 0 & 0 \\
\end{bmatrix} \]

\[ \begin{bmatrix}
  1 & \text{Check!} \\
\end{bmatrix} \]

\[ \begin{bmatrix}
  4 & -6 & 19 & -9 \\
  9 & 0 & -5 & 0 \\
  2 & 0 & -5 & 0 \\
  0 & 0 & 0 & 0 \\
\end{bmatrix} \]

\[ \begin{bmatrix}
  3 & 1 & 2 & 1 \\
  2 & 0 & 0 & 0 \\
  0 & 0 & 0 & 0 \\
  2 & 0 & 0 & 0 \\
\end{bmatrix} \]

\[ \begin{bmatrix}
  4 & -6 & 19 & -9 \\
  9 & 0 & -5 & 0 \\
  2 & 0 & -5 & 0 \\
  0 & 0 & 0 & 0 \\
\end{bmatrix} \]

\[ \begin{bmatrix}
  3 & 1 & 2 & 1 \\
  2 & 0 & 0 & 0 \\
  0 & 0 & 0 & 0 \\
  2 & 0 & 0 & 0 \\
\end{bmatrix} \]
Key: Re-order the elements

"A Fill = Changing a zero to a non-zero"