Topics for Today:

- Introductions: course syllabus (being updated)
- Startup
  - Book
  - Software: Matlab, (Cyme, Aspen may be used for benchmarking)
- Access to EERC 134 (SGOC - Smart Grid Operations Center)
- Buy 3-ring binder, grid paper for homework submissions.
- Quick Review of Mesh and NODE equations
- Matrix formulations
- Possible Solution Methods
- Buy book, scan through Chapters 1 and 2 for Wed
- Matlab tutorials for beginners, posted on EE5200 web page.
- Pre-Req review notes and video, posted on EE5200 web page
"BIG DATA"

Traditional
- Data Structures
- Algorithms
- Applications

MATLAB
- Cyma
- Aspen

New
- Servers
- Dynamic Flow of data
- Dist Process Algorithms
Mesh 1: \( V_1 = z_1 \tilde{I}_1 + z_2 (\tilde{I}_1 - \tilde{I}_2) \)

Mesh 2: \( 0 = z_2 (\tilde{I}_2 - \tilde{I}_1) + z_3 (\tilde{I}_2 - \tilde{I}_3) + z_4 (\tilde{I}_2 - \tilde{I}_3) \)

Mesh 3: \( -\tilde{V}_3 = z_4 (\tilde{I}_3 - \tilde{I}_2) + z_5 (\tilde{I}_3) \)
In Matrix Form:

\[
\begin{bmatrix}
\frac{Z_1 + Z_2}{Z_2} & -Z_2 & 0 \\
-Z_2 & \frac{Z_2 + Z_3 + Z_4}{Z_4} & -Z_4 \\
0 & -Z_4 & \frac{Z_4 + Z_5}{Z_5}
\end{bmatrix}
\begin{bmatrix}
\vec{I}_1 \\
\vec{I}_2 \\
\vec{I}_3
\end{bmatrix}
= 
\begin{bmatrix}
\vec{V}_1 \\
0 \\
-\vec{V}_2
\end{bmatrix}
\]

\(Z_{\text{Loop or Mesh}}\)

\(Z_{NN} = \sum Z_s\) around mesh \(N\) (Self-impedance of mesh)

\(Z_{NK} = -\sum Z_s\) that are mutual to meshes \(N \& K\).

\(\vec{I}_s\) are mesh currents - not much use in power system analysis.

\(\vec{V}_s\) are usually node voltages, but at inner node of Gen.
Node Eqs.

\[ KCL: \sum I_{s(In)} = 0 \]

\[
\begin{align*}
\text{Node 1:} & \quad 2 + (V_2 - V_1)2 + (V_3 - V_1)5 + \left(-\frac{V_1}{1}\right)1 \\
\text{Node 2:} & \quad 8 + (V_1 - V_2)2 + (V_3 - V_2)4 + \left(-\frac{V_2}{3}\right)3 \\
\text{Node 3:} & \quad 0 + (V_2 - V_3)4 + (V_1 - V_3)5 + \left(-\frac{V_3}{6}\right)6
\end{align*}
\]
In Matrix Form:

$$\begin{bmatrix}
8 & -2 & -5 \\
-2 & 9 & -4 \\
-5 & -4 & 15
\end{bmatrix}
\begin{bmatrix}
V_1 \\
V_2 \\
V_3
\end{bmatrix}
= 
\begin{bmatrix}
2 \\
8 \\
0
\end{bmatrix}$$

Nodal Admittance Matrix
Node Voltages
Injected Currents

$[Y_n]$ or $[Y_{bus}]$

$Y_{nn} = + \sum$ Admittances "landing" on node $n$

$Y_{nk} = - \sum$ Admittances "spanning" between nodes $n \& k$.

Typical System: Lots of zeroes in off-diagonal elements

Exploit this by not store zero values.

Use SPARSE Matrix methods
Key Points:

\[ [Z_{\text{Mesh}}]^{-1} = [Y_{\text{Mesh}}] \]

\[ [Y_{\text{Bus}}]^{-1} = [Z_{\text{Bus}}] \]

SPARSE \quad \text{FULL}

From previous example:

\[ [Y_{\text{Bus}}][V_{\text{Bus}}] = [I_{\text{INJ}}] \]

Knowns (Generators)

How to solve?

- Brute force
- Gauss Elimination
- Gauss-Jordan
- LU Factorization

Preferred for large systems
Review -

Passive Voltage Drop Sign Convention
- Motors
- Loads (Impedances)

Active Sign Convention
- Generators (Sources)
Observations on topology of $[Y_{bus}]$

- Main diagonal is non-zero
- Most off-diagonal terms are zero
  (Sparse systems) most $y_{nk} = 0$
- Can $[Y_{bus}]$ always be inverted?
  (i.e. nonsingular). Singular matrices will produce "divide by zero overflow" and crash program.

Answer: Make sure you have at least one branch to ground/reference!

Example:

```
\[ \begin{array}{cccc}
2S & S & 4S & \\
\hline
V_1 & 0 & 2V_2 & 2V_3 \\
\end{array} \]
```
$[Y_{bus}] = \begin{bmatrix} +7 & -2 & -5 \\ -2 & +6 & -4 \\ -5 & -4 & +9 \end{bmatrix}$

Problem to look for:
If 2 of terms in a row is zero, then you're probably dealing with a singular matrix!

TRY TO INVERT WITH MATLAB!

- Symmetry about main diagonal

If no dependent sources, or phase-shifting xformrs, then it will be symmetric.