Topics for Today:

- Announcements
  - Your Term Project is a PROJECT (not a summary paper), so be sure there is some application/implementation of the concepts and theory.
  - Software: online students - apply for ATP/ATPDraw license, verify licensing when you receive it by e-mail, and we will mail you the install CD.
  - ASPEN software - run off of MTU server via internet, see e-mail instructions.
  - Office: EERC 614. Phone: 906.487.2857
  - Recommended problems & all solutions: Ch.9, 13 solns now posted.

- Chapter 9 - Load Flow wrapup
  - Implementation of Loadflow for Slack, Gen, and Load Bus
  - Input/translation/conversion of system data.
  - Aspen (PSS/E).
  - Corrective Actions for low or high bus voltage —
  - Line Loading concerns —
  - Contingencies —
  - System Security - Operation, Protection, Cyber-security
- Bus Types, Data (Also: Loads, and Shunt Devices)
- Lines
- Transformers
- Generators

- Slack/Swing/ V-S bus

\[ \sum P_{\text{area}} = 0 \]
\[ \sum Q_{\text{area}} = 0 \]

\( P, Q \) are "Slack" variables

or: [V-dependent P, Q]

"Scheduled" P, Q
Gen Bus (P-V Bus)

Solve for \( Q \) & \( S \) solved

\[ 2Q_{min} = 0 \]

\[ P, Q \]

"Slack Variable"

\[ |\tilde{V}| \text{ is fixed.} \]

If \( Q_{min} \) or \( Q_{max} \) are exceeded, change to PQ
P-Q or Load Buses: Solve for $\sqrt{V}$ and $S$

Scheduled $P, Q$

Grid Flows $[Y]$

VLS

Solve for bus voltage.

$\frac{Q}{V} = V^2 \cdot Bc$

$\alpha V: .95^2 \rightarrow 1.05^2$

$.9025 \rightarrow 1.102$
Voltage Collapse
"Possible"
"Voc" Depressed

Line
I_{Line}

Slack
P_{Slack}

\frac{\partial L}{\partial V^*}

\frac{\partial L}{\partial V'}
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 $Y_{bus}$.

*Careful: GIGO*

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**Figure 6.2**

Single-line diagram for Example 6.9

- **B1**: 400 MVA, 15 kV
- **B51**: 400 MVA, 15/345 kV
- **B52**:
- **B53**:
- **B41**: 345 kV, 50 mi
- **B42**: 345 kV, 200 mi
- **B21**: 345 kV, 100 mi
- **B22**: 345 kV, 50 mi
- **T1**: 800 MVA, 345/15 kV
- **T2**: 800 MVA, 345/15 kV
- **Line 1**: 800 MVA, 15 kV
- **Line 2**: 800 MVA, 15 kV
- **Line 3**: 800 MVA, 15 kV
- **Bus 1**: Slack
- **Bus 2**: PQ
- **Bus 3**: PV
- **Bus 4**: PQ
- **Bus 5**: PQ

Assumed constant $P_{Q_k}$, i.e., don't change w/ bus voltage.
The input data and unknowns are listed in Table 6.4. For bus 1, the swing bus, $P_1$ and $Q_1$ are unknowns. For bus 3, a voltage-controlled bus, $Q_3$ and $\delta_3$ are unknowns. For buses 2, 4, and 5, load buses, $V_2$, $V_4$, $V_5$ and $\delta_2$, $\delta_4$, $\delta_5$ are unknowns.
Transformers

*Zero unless LTC or PS, tap ratio ≠ 1.

Add effect into \([Y]\).
right click to enter params.

Alt - PrtScr → active window
Ctrl - PrtScr → whole screen
- Convergence Criteria:
  - Max iterations: [ ]
  - MW Tolerance: 0.05
  - MVAR Tolerance: 0.05

- Auto Adjustment Threshold:
  - MW: 20
  - MVAR: 20

- System slack bus: Slack 20 kV 0

- Misc. Options:
  - Start from last volt. solution
  - Solution Monitor
  - Start with LTC taps at nominal

- Enforce:
  - Generator VAR limits
  - Transformer taps
  - Area interchange
  - Gen remote volt control
  - Switched shunts
  - Phase shifters

- Solution Method:
  - Newton-Raphson
  - Fast Decoupled

- Buttons:
  - OK
  - Cancel
  - Help

- Handwritten notes:
  - Full Jacobian
  - Main-diag submatrices of Jacobian
  - }=
  - ?
Total generation = 6507.9 MW
Losses = 67.9 MW