Topics for Today:

- Announcements
  - Term Project: Keep cranking. Monday of finals week ok?
  - Software: Matlab, ASPEN
  - Office hrs: 2:00-3:00pm, Mon, Wed, Fri
  - Office: EERC 623. Phone: 906.487.2857
  - All solutions thru Ch.15 are posted.

Chapter 9 - Load Flow wrapup
- Corrective Actions for low or high bus voltage
- Line Loading concerns
- Contingencies
- System Security - Operation, Protection, Cyber-security

Chapter 13 - Power system operation, AGC, economic dispatch
- Paralleling of Generators, droop characteristics
- Optimization methods - LaGrange multipliers
Load Flow

- How set up, i.e. parameter input
- Parameter input?
- Typical Probs
- Bus voltage exceeded
- T-line loading overloaded
- Transformer concerns
- LOL concerns
- Limits of Gens exceeded

Load flow software:
- Change Bus to PQ
- Bus
Transformer Taps:

**HV:** No-Load taps: 5 taps ±5%

**LV:** LTC - Load Tap Changer ±10%, 5/8% steps

High Maintenance

100,000 - 500,000 operations.

- s +5%
- s +2.5%
- s Nominal
- s -2.5%
- s -5%

- Nominal
- 16.1
Bus voltage high/low.

Too high:

\[ Z_{kk} = j \cdot 2 \]

\[ V = 1.10 \text{ p.u. from converged loadflow} \]

Desired voltage:

\[ 1.0 \text{ p.u.} \]

\[ V_K = 1.0 = 1.1 \cdot \frac{j \cdot X_L}{j \cdot 2 + j \cdot X_L} \]

\[ 0.2 + X_L = 1.1 \cdot X_L \]

\[ 0.2 = 0.1 \cdot X_L \]

\[ X_L = 2 \text{ p.u.} \]

Note:
Choose \( X_L \) with smallest current draw.
Too Low:

\[ 2kk = j\cdot2 \]

Load flow: 0.91 p.u.

\[ 1.0 = 0.91 \frac{-jXc}{j\cdot2 - jXc} \]

Solving: \[ Xc = 2.22 \text{ p.u.} \]
What if \( z \in \mathbb{C} \) includes \( R \)?

\[
1.0 = 0.91 + jx_c
\]

Solve quadratic, square both sides, gives 2 solutions for \( x_c \).
Line Loading:

Short Line:
- usually no probes w/ voltage drop
- Ampacity of line
  \((I^2R\text{ heating})\)
  \(\Rightarrow\) higher \(R\)
  \(\Rightarrow\) more sag.
1. Ampacity
2. Voltage Drop: IR voltage drop results in low bus voltages.
3. Power Transfer Limits
   \[ V_{1Lx} = V_1 + \frac{1}{R} jX \left(-\frac{R}{X} + \frac{V_2}{V_1} \right) + \frac{V_2}{V_1} \sqrt{V_2^2 - L^2} \]
   \[ P_{1\to 2} = \frac{V_1 V_2}{X} \sin^2 \delta \]
   \[ = \frac{V_1 V_2}{X} \sin (\alpha - \beta) \]

For typical operation, 
\( \alpha - \beta \) should be limited below 35-40°.
4. Stability Limits
Contingencies –

Planning/design typically for "N-1" typical component. N-1 implies loss of most critical component. NERC, regional reliability councils, also To's need to be involved. N-1 implies loss of most critical component. N-1 implies loss of most critical component. N-1 implies loss of most critical component. System is very vulnerable in N-1 state, system must restore system ASAP.

Major "event" that impacts system ability to maintain operation.
Security: at least 3 uses/meanings:

1. "System Operation" - "secure operation"

2. Cyber-security - keep hackers from getting in, to servers.
   - Relays
   - Imbedded Processors.

Gen Paralleling

- Reference from Chapman.
- Refer to for gen'1 background.
- Good explanation for 1 or 2 gens.
- Does not give per unit treatment, refer to your text for that (Section 15.6).