Topics for Today:

- Announcements
  - Detailed Term Project outline (in format of report Table of Contents) + complete list of references.
  - 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 623.  Phone: 906.487.2857
  - Recommended problems & all solutions: Ch.9, 13 solns now posted.

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

Next: 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. ✓

- What to do w/ output? Typical Probs:
  - Bus voltage too high/low
  - T-line loading exceeded.
  - Transformers overloaded.
    - LoL concerns
    - Age concerns
  - Q limits of Gens exceeded.

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

High Maintenance

100,000 - 500,000 operations.

HV: No-Load taps: 5 taps ±5%

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

- Nominal
- +2.5%
- -2.5%
- +5%
- -5%
Bus voltage high/low.

Too high:

\[ E_{KK} = j \cdot 0.2 \]

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

Desired voltage:

1.0 p.u.

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

\[ 0.2 + X_L = 1.1X_L \]

\[ 0.1X_L = 2 \text{ p.u.} \]
Load flow: 0.91 p.u.

\[
X_c = \frac{1}{jX_c}
\]

\[
x_c = 2.22 \text{ p.u.}
\]

Solving:

\[
X_c = \frac{0.91}{j2.22 - jX_c}
\]

\[
x_c = \frac{1}{0.91}
\]

\[
Q = \frac{V_i^2}{x_c}
\]

\[
B_c = \omega C
\]
What if $Z_kk$ includes $R$?

\[
1.0 = 0.91 \left| \frac{-jX_c}{(0.05 + j\omega)} - jX_c \right|
\]

\[
\Rightarrow \text{take abs. value.}
\]

Square both sides,

\[
\Rightarrow \text{gives quadratic,}
\]

\[
2 \text{ solns for } X_c.
\]

Which $X_c$ is "correct" to spec.

\[
X_c = \frac{1}{\omega C}
\]

**Case 1:**

$X_{c1}$ is pos, $X_{c2}$ is neg. (React.)

**Case 2:**

$X_{c1}$ is pos, $X_{c2}$ is pos. $X_{c1} > X_{c2}$. 
Line Loading:

Short Line:
- usually no probes w/ voltage drop

- Ampacity of line
  \( I^2R \) heating

  \[ \Rightarrow \] higher \( R \)

  \[ \Rightarrow \] more sag.

- ACSR
- Composite - 3M.

\[ \text{I} \rightarrow \text{Vdrop small} \]
1. Ampacity
2. Voltage Drop: \( I \times (R+jX) \) results in low bus voltages.
3. Power Transfer Limits
   \[ V_{1L} = V + \frac{1}{R} \left( \frac{X}{\sqrt{V_1^2 + V_2^2}} \right) \]
   \[ P = \frac{V_1V_2}{X} \sin^2 \delta \]
   \[ P_{max} = \frac{V_1V_2}{X} \sin (\alpha-B) \]

For typical operation,
\( \alpha-B \) should be limited below \( 35-40^\circ \).

4. Stability Limits
Contingencies — Major "event" that impacts system ability to maintain operation within limits.

Planning/design typically for "N-1"

- N-1 implies loss of most critical component.

NERC, regional reliability councils, also TO's need to be involved.

- Survive N-1, but not N-2.
- System is very vulnerable in N-1 state, must restore system to secure state of operation ASAP.
Security: at least 3 uses/meanings:

1. "System Operation" - "secured 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).