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 614. 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 if output too high/low?
- Bus voltage overloaded?
- Transformer overloaded?
- LOL concerns?
- A limits of Gen's 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%
- ±57%

**LV**: LTC - Load Tap Changer

- ±10%
- 5/8% steps

- KHN Nominal
- 16h
Bus voltage high/low.

Too high:

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

Desired voltage:

1.0 p.u.

\[ V_K = 1.0 = 1.1 \frac{jX_L}{j2+jX_L} \]

\[ 0.2 + X_L = 1.1 X_L \]

\[ 0.2 = 0.1 X_L \]

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

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

\[ 1.0 = \frac{0.91}{\omega C} \]

Solving:

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

\[ Q = \frac{V^2}{x_c}, \quad \frac{V^2}{x_c} = \frac{\omega C}{2} \]

\[ B_c = \omega C \]
What if \( Z_{kk} \) includes \( R \)?

\[
1.0 = 0.91 \left| \frac{-jX_c}{(0.05+j2)-jX_c} \right| \quad \Rightarrow \text{must take abs. value.}
\]

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:** \( X_c_1 \) is pos, \( X_c_2 \) is neg. (React.)

**Case 2:** \( X_c_1 \) is pos, \( X_c_2 \) is pos. \( X_c_1 > X_c_2. \)
Line Loading:

Short Line:
- usually no prob. w/ voltage drop
- Ampacity of line
  (I^2R heating)
  => higher R
  => more seg.
  - NESC.

- ACSR
- Composite - 3M.
1. Ampacity
2. Voltage Drop: \[ I \times (R + jX) \]
   results in low bus voltages.
3. Power Transfer Limits
   \[ V_1L_2 = V_2 \]
   \[ P = \frac{V_1V_2}{X} \sin^8 \theta \]
   \[ = \frac{V_1V_2}{X} \sin (\alpha - \beta) \]

For typical operation,

\[ \alpha - \beta \] should be limited below \[ 35-40^\circ \].

4. Stability Limits
Contingencies - Major "event" that impacts 8 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.