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 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:

HV: No-Load taps: 5 taps  
\[ \pm 5\% \]

LV: LTC - Load Tap Changer  
\[ \pm 10\%, \ 5/8\% \text{ steps} \]

High Maintenance
100,000 - 500,000 operations.

- Nominal
- +5%
- +8.5%
- -2.5%
- -5%

- Nominal
- 16k
Bus voltage high/low.

Too high:
\[ E_{kk} = j \cdot 2 \]

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

Desired voltage:
\[ V = 1.0 \text{ p.u.} \]

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

\[ 0.2 + X_L = 1.1 X_L \]

\[ 0.2 = 0.1 X_L \]

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

\[ x_c = \frac{1}{3c} \]

Solving:

\[ x_c = \frac{2.22}{0.91} \]

\[ B_c = \omega c \]

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

\[ Q = v^2 \frac{Bc}{x_c} \]
What if \( Z_{kk} \) includes \( R \)?

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

Square both sides,

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

2 solns for \( X_c \).

\( X_c = \frac{1}{\omega C} \)

Which \( X_c \) is "correct" to spec.

Case 1: \( X_c_1 \) is pos, \( X_c_2 \) is neg. (Redact.)

Case 2: \( X_c_1 \) is pos, \( X_c_2 \) is pos.
\( X_c_1 > X_c_2. \)
\[ Z(\omega) \Rightarrow R - C \Rightarrow Z = \frac{1}{j\omega C} \]

\[ Z(\omega) \Rightarrow R - C \Rightarrow \]

EE5220
-Freq Scan
Line Loading:

Short Line:
- usually no prob w/ Voltage drop
- Ampacity of line
  \(I^2R\) heating
  \(\Rightarrow\) higher R
  \(\Rightarrow\) more segs.
  - NESC.

- ACSR
- Composite - 3M.
1. Ampacity
2. Voltage Drop: \( \mathbf{I} \times (R+jX) \) results in low bus voltages.
3. Power Transfer Limits
   \[ V_1LX = V_1 \times \frac{R \cdot jX}{\sqrt{R^2 + jX^2}} \]
4. For typical operation,
   \( \alpha - \beta \) should be limited below 35-40°.
5. Stability Limits
   \[ P_{\text{max}} = \frac{V_1V_2}{X} \sin (\alpha - \beta) \]
   \[ P_{\text{max}} = \frac{V_1V_2}{X} \sin (\alpha - \beta) \]
Contingencies— Major "event" that impacts & system ability to maintain operation within limits.

Planning/design typically for "N-1"

N-1's 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.
1. Security: system operation
   - Secure at least 3 uses/mappings

2. Cyber-security - keep hackers
   - Cyber
   - Relays
   - Imbedded Processors
   - Getting in to servers

3. Security: power system protection