Topics for Today:

- Startup
  - Web page: http://www.ee.mtu.edu/faculty/bamork/ee5220/
  - Book, references, syllabus, more are on web page.
  - Software - Matlab. ATP/EMTP [ License - www.emtp.org ]
    ATP tutorials posted on our course web page
  - EE5220-L@mtu.edu (participation = half letter grade, 5%)

- ATP Simulation pointers
- Cap Bank Switching (continued)
  - Circuit Breaker ratings - Capacitive Switching
  - Parameters
    - Cap Bank configurations
    - Current Limiting Reactors
- ATP - how it works internally
  - Conductance matrix formulation
  - Rs, Ls, Cs
  - Transmission lines
ATP Simulation Pointer for the day:

What are the best values of numerical damping resistances to add to small L's and large C's? This turns out to be a function of the integration timestep and the value of the L or C.

\[ R_p = \frac{2L}{0.15 \Delta t} \]

\[ R_s = \frac{0.15 \Delta t}{2C} \]
Key: Look at ATP Settings
Set Integer Parameter
"Plot Freq" = 1
(often set to larger odd number to reduce PL4 file size).

Be careful of aliasing errors! Use odd number, and not too large!

*.lis = text log    *.pl4 = binary plot
- always skip odd # pts.

- aliasing error odd # pts.
New Cap Installation -

\[ L_3 \quad R_s \quad \text{OUTRUSH} \]

OLD CB
ADD OUTRUSH REACT

\[ L_{bus} \]

NEW

\[ L_R \quad C_1 \quad C_2 \]

B/LB
Add current limiting reactors

\[ W_0 = \frac{1}{\sqrt{L_{bus} + 2L_R} \left( \frac{C_1 C_2}{C_1 + C_2} \right)} \]

\[ \therefore W_0 \text{ decreases.} \]

\[ Z_o = \sqrt{\frac{L_{bus} + 2L_R}{C_1 C_2}} \Rightarrow Z_o \text{ increase} \]

GREAT!
CB's are rated in terms of \( I_p \times f_0 \)
ADD OUTRUSH REACTOR

Common Approach for all RLC ckt's:
- Define operative L, C
- Find \( w_0 \), \( z_0 \)
- Find \( \Delta V = V(\infty) - V(0^+) \)
- Find \( I_p \)
- Sketch waveforms
- Check w/ ATP
\[
I_p \times f_0 \leq \frac{2 \times 10^7}{V_p \sqrt{\frac{L}{C}}}
\]

ADD

\[
I_p = \frac{V_p}{\sqrt{\frac{L}{C}} f_0^2}
\]

\[
\frac{1}{2\pi \sqrt{LC}}
\]

\[
\text{Lout\,brush} \rightarrow L_B \rightarrow \text{Fault}
\]

\[
\frac{V_p}{\sqrt{\frac{L}{C}}} \times \frac{1}{2\pi \sqrt{LC}} \leq 2 \times 10^7
\]

\[
\frac{V_p}{2\pi L} \leq 2 \times 10^7
\]
Solve for $L \leftarrow \text{Min require}$ \[ L = L_{\text{Bus}} + L_{\text{REACT}} \] \[ \tag{11} \]

If \[ L \leq L_{\text{Bus}} \Rightarrow \text{No Reactor Needed!} \]

If \[ L > L_{\text{Bus}} \]

\[ \Rightarrow L_{\text{REACTOR}} = L - L_{\text{Bus}} \]

For definite purpose:

a) $W_0 < W_{\text{rated}}$

b) $I_p < I_{\text{rated}}$

\[ I_p \quad \text{or} \quad W_0 < \text{rated.} \]
CAP BANK CONFIGURATIONS.
- Typically in WYE.

\[ \text{Fusing - External, Internal Fuseless} \]
External

Internal

Fuseless

\[ R \frac{A}{N} \frac{C}{T} \Rightarrow \tau = RC \]

entire "Can"

CAN
Look at series section 6 that loses one of its parallel cans.

\[ Z_{\text{section}} = \frac{Z_{\text{can}}}{(\text{No. Cans} - 1)} \]

Others - stay same

\[ Z_{\text{section}} = \frac{Z_{\text{can}}}{(\text{No. Cans})} \]

1. Section that loses can is exposed to overvoltage

A cascaded failure:

when add'l cans fail after first one (dominos).
Typical limit overvoltage to \( \leq 107\% \).

If system is at 1.05 \( p.u. \), not much room for increase.

\[
\text{Monitoring & Protection -}
\]

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A

\[\text{C} \quad \text{B} \quad \text{Desensitize to harmonics (60-Hz Only)}\]
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Monitor Voltage balance between the 3 VT Secondaries.
Other configs also possible.

Inrush & outrush current limiting calcs.