Topics for Today:

• Announcements
  • 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%)

• HW#5 will be posted. Partnered exercise. Due approx Mon Feb 20th 9am.
• ATP Simulation pointers 3-phase connections
• Cap Bank Switching
• ATP - how it works internally
  • History of program development, versions available
  • Rs, Ls, Cs
  • Transmission lines
• Circuit Breakers - Interruption issues
  • Restrike
  • Reignition
3-PHASE ELEMENTS

SPLITTER - 3ph → 1 ph

CONNECTING: Draw from 1 → 2

Ground - Connect at 1Ø element
Notes

EMTP - BPA, 1970 → '85

1985 EPRI ↓ DCG

EPRI EMTP or DCG EMTP

- TACS

EMTP/RV

ATP

OTHERS:
- EMTDC/Pscad
- Micro-Tran
- ABB/Siemens
- EDF - MORGAT

Different:
- TACS
- MODELS

controls
Side Note:
Mathematical Structure is
\[ [Y] [Y] = [I] \]
Sparse
\[ \uparrow \text{node } V_S \quad \uparrow \text{injected currents} \]
Injected Currents!

\[ V_s \rightarrow \text{Network} \rightarrow Y_{bus} \]

Thevenin - Bad: Extra Node \( V \) = Fixed

Instead, convert to Norton:

\[ \frac{V_s}{Z_s} \rightarrow Y_s = \frac{1}{Z_s} \rightarrow \text{Network} \rightarrow Y_{bus} \]
\[ \frac{L}{v_{k,m} - v_{m}} - \frac{G}{\Delta t} = \frac{2L}{G} \]

\[ v_{k} - v_{m} = L \frac{di_{k,m}(t)}{dt} \]

\[ di_{k,m}(t) = \left\{ i_{k,m}(t) - i_{k,m}(t-\Delta t) \right\} \]

\[ dt \equiv \Delta t \]

Trapezoidal Integration
\[ i = \int \frac{dv}{L} = \frac{1}{L} \int v \, dt \]

\[ v \, dt = L \, di \]

\[ di = \frac{1}{L} v \, dt \]

\[ i = \frac{1}{L} \int v \, dt \]

\[ i \approx \frac{1}{L} \]

\( \Delta t \) in EMTP cannot be as small as \( dt \), \( \Delta t \) is finite.
Look at trapezoidal implementation of eqn:

\[ V_K(t) - V_m(t) = L \frac{d i_{k,m}(t)}{dt} \]

\[ d i_{k,m}(t) = \frac{1}{L} \int_{t-\Delta t}^{t} [V_K(t) - V_m(t)] dt \]
The integral can then be approximated as the area of the trapezoid:

\[ \frac{1}{L} \int_{t-\Delta t}^{t} \left[ u_k(t) - u_m(t) \right] dt \]

\[ \approx \frac{\Delta t}{L} \left[ \frac{u_k(t) - u_m(t) + u_k(t-\Delta t) - u_m(t-\Delta t)}{2} \right] \]

(i.e. area of trapezoid = \( \Delta t \times \) average height of sides)
\[ \text{dr}_k(t) = \frac{1}{L} \int_{t-\Delta t}^{t} [v_k(t) - v_m(t)] \, dt \]

\[ \text{dr}_m(t) - \text{dr}_m(t-\Delta t) \]
Integral is:

\[
\frac{1}{L} \left[ U_k(t) - U_m(t) + U_k(t-\Delta t) \right] \frac{\Delta t}{2} - \Delta U_m(t-\Delta t)
\]

putting pieces together,

\[ i_{k,m}(t) \equiv i_{k,m}(t-\Delta t) \quad \text{OK} \]

\[ + \frac{\Delta t}{2L} \left[ U_k(t) - U_m(t) + U_k(t-\Delta t) \right] - U_m(t-\Delta t) \]

Separating \((t)\) & \((t-\Delta t)\) terms,
\[ i_{m,k}(t) = \frac{\Delta t}{2L} \left[ v_k(t) - v_m(t) \right] \]

Current at time = \( t \) for present voltage drop

\[ + i_{k,m}(t-\Delta t) + \frac{\Delta t}{2L} \left[ v_k(t-\Delta t) - v_m(t-\Delta t) \right] \]

\[ I_{\text{hist}} = I_{k,m} = \text{Summation of all currents at past time steps, i.e. } t-\Delta t, \ t-2\Delta t, \ t-3\Delta t, \ldots. \]

Initial condition: \( I_{\text{hist}}(0) = i(0) \).
$\text{[Ybus]}$ is augmented according to system elements needed.

\[ R = \frac{1}{G} \]\(\rightarrow\) into $\text{[Ybus]}$

\[ R = \frac{\Delta t}{2C} \]

$[Y][V] = [I]$
\[
L_i
\]
\[
R = \frac{2L}{\Delta t}
\]
\[
\text{"HISTORY CURRENT"}
\]