EE 5220 - Lecture 12

Wednesday Feb 13, 2008

Topics for Today:

• **Startup**
  • Web page:  [http://www.ee.mtu.edu/faculty/bamork/ee5220/](http://www.ee.mtu.edu/faculty/bamork/ee5220/)
  • Book, references, syllabus, more are on web page.
  • Software - Matlab. ATP/EMTP [ License - [www.emtp.org](http://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 Mon Feb 25th 9am.
• ATP Simulation pointers 3-phase connections
• Cap Bank Switching — recap.
• ATP - how it works internally
  • History of program development, versions available
  • Rs, Ls, Cs
  • Transmission lines
• Circuit Breakers - Interruption issues
  • Restrike
  • Reignition
ATP Simulation Pointer for the day:

When building 3-phase circuits, you are actually drawing a one-line which represents the L-G per-phase equivalent of the system. Node names have a base name 5 characters long, with the 6th character A, B, C automatically added. Click on the 3-phase end of the splitter if you want to define the base node name.

If you need to make single-phase connection(s) to individual phases, use the splitter. When drawing a connecting line to a splitter, start at the node of the single-phase element and connect to the splitter. The uppermost connection on the splitter, when it faces to the right, is phase A at the top, then B, C as you go downward. If you need to ground one phase, you can do that at the single phase element, but not at the splitter.
3-PHASE ELEMENTS

SPLITTER - 3ph → 1 ph

CONNECTING: Draw from 1 → 2

Ground - Connect at 1Ø element
Rs, Ls & Cs in EMTP

Notes

EMTP - BPA, 1970 → '85

1985 EPRI ↓ DCG

EPRI EMTP
or DCG EMTP

- TACS ↓

EMTP/RV

F.O.I. 1987

ATP -

OTHERS:

- EMTDC/PSCAD
- Micro-Tran
- ABB/Siemens
- EDF - MORGAT

Different:

- TACS
- Models

(Controls)
Side Note:

Mathematical Structure is

\([Y][V] = [I]\)

Sparse \(\uparrow\) \(\uparrow\) \(\uparrow\)
node \(V_i\) \(I_{injected}\) \(currents\)
Injected Currents!

\[ \begin{align*}
\text{Thevenin = Bad: Extra Node} \\
V &= \text{Fixed}
\end{align*} \]

Instead, convert to Norton:

\[ \begin{align*}
\text{NORTON} \\
Y_s &= \frac{1}{Z_s}
\end{align*} \]
\[ V_{K,m} - V_m = L \frac{di_{K,m}(t)}{dt} \]

\[ di_{K,m}(t) ≈ \{i_{K,m}(t) - i_{K,m}(t-\Delta t)\} \]

\[ dt = \Delta t \]

Trapezoidal Integration

\[ \int_{t-\Delta t}^{t} f(t) \, dt \]
$$\nu \, dt = L \, di$$

$$\nu = \frac{1}{2} \nu \, dt$$

$$i = \frac{1}{L} (2.5 \, \text{A})$$

At cannot be as small as dt.

At is finite.
Look at trapezoidal implementation of eqn:

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

\[ d i_{k,m}(t) = \frac{1}{L} \int_{t-\Delta t}^{t} [U_K(t) - U_m(t)] dt \]

\[ \int_{U_m}^{U_K(t)} N(t) \]

\[ U_K(t-\Delta t) - U_m(t-\Delta t) \]
The integral can then be approximated as the area of the trapezoid:

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

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

(i.e. area of trapezoid = \( \Delta t \times \text{average height of sides} \))
\[ \frac{d}{dt} \left[ \frac{1}{i \kappa_m(t)} \right] = \frac{1}{\Delta t} \left\{ \kappa_m(t) - \kappa_m(t - \Delta t) \right\} \]
Integral is:

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

putting pieces together,

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

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

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

Current at time = t for present voltage drop

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

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

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

\[ R = \frac{1}{G} \rightarrow \text{into } [Y_{bus}] \]

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

\[ \begin{align*}
K & \quad \downarrow \quad i_{km}(t) \\
& \quad \downarrow \\
m & \quad i_{km}(t-\Delta t)
\end{align*} \]

\[ [Y][V] = [I] \]
\[ R = \frac{2L}{\Delta t} \]

\[ V(t) = V_{km} \]

\[ i_{km}(t - \Delta t) \]

\[ K_0 \theta \]

\[ m \]

\[ \text{"HISTORY CURRENT"} \]