Topics for Today:

• Course Info:
  • Web page:  http://www.ee.mtu.edu/faculty/bamork/ee5220/
  • Software - Matlab. ATP/EMTP [ License - www.emtp.org ] ATP tutorials posted on our course web page
  • EE5220-L@mtu.edu (participation = min of half letter grade, 5%)

• HW#5 will be posted. Partnered exercise. Due latest Tues Feb 25th 9am.
  • Section 12.4 - detailed derivation for capacitor
  • Prob 5.3 - first do ATP simulation, then Hand Calculations
  • Prob 5.6

• Term Project - proposed topic(s) by end of next week, via short e-mail.

• Circuit Breakers - Interruption issues
  • Restrike
  • Reignition

• Cap and Reactor application (projects similar to Hmwk4 are discouraged)
  • Dist system
  • Autotransformer tertiary
  • HV direct connection

• Transmission Lines - development of T-Line equations, traveling wave realays

• Transformers - hybrid model, inrush, GIC, ferroresonance
Cstp. Application

- LV on customer side of meter
  ⇒ Penalty for Low P.F. ⇒ P.F. Correction

Diagram with circuit representation.
Compensation, VR

Dist. VR

3 kV

Trans. Tie

L.V. Caps are cheaper to use.
Compensation

- Shunt
  - Voltage Support
  - Power Transfer
    \[ P_{1-2} = \frac{V_1 V_2}{X_{12}} \sin(\delta_1 - \delta_2) \]
- Stability

21% increase
(0.95 → 1.05 pu. V)
Series Comp: $C$
Switching -

Switching -

Order of

1.2 ms

500 kHz

0.5 m/s

Half period

F.25 0.5s
DISTRIBUTED PARAMETER T-LINES

- "LONG LINES" (>250 km @ 60 Hz)
- For lightning, even very short lines are modeled as dist-param.

For incremental length:

\[ I_S = I(x) \]
\[ V_S = V(x) \]
\[ Z = Z_L = R + jX \]
\[ Y = Y_L = G + jB \]
Making $\Delta X$ very small,

\[
\begin{align*}
\{ dV &= IZ dx \\
\{ dI &= Vy dx
\end{align*}
\]

Rearranging,

\[
\begin{align*}
\frac{dV}{dx} &= \frac{I^2}{dI/dx} \\
\frac{dI}{dx} &= Vy
\end{align*}
\]

(1)  

(2)

Taking derivative of (1),

\[
\frac{d^2V}{dx^2} = \frac{dI}{dx} z^2
\]
Substituting into (2)

\[ \frac{d^2 V}{dx^2} = V \frac{y}{z} \]

This implicit general solution:

\[ V = A_1 e^{\sqrt{y/z} x} + A_2 e^{-\sqrt{y/z} x} \]

Since \( I = \frac{dV}{dx} \)

\[ I = A_1 \sqrt{\frac{y}{z}} e^{\sqrt{y/z} x} - A_2 \sqrt{\frac{y}{z}} e^{-\sqrt{y/z} x} \]

At \( x = 0, \ V = V_R, \ I = IR \)

\[ V(0) = V_R = A_1 + A_2 \]

\[ I(0) = IR = \sqrt{\frac{y}{z}} A_1 - \sqrt{\frac{y}{z}} A_2 \]
Defining $Z_c = \sqrt{\frac{y}{y_j}} = \text{Char Imp.}$

$y = \sqrt{y_j Z_c} = \text{Propagation Const.}$

$V_R = A_1 + A_2$

$I_R = \frac{A_1 - A_2}{Z_c}$

$\Rightarrow A_1 = \frac{(V_R + Z_c I_R)}{2}$

$A_2 = \frac{V_R - Z_c I_R}{2}$
\[ \lambda (x) I = (x) I = I \]

\[ \lambda = \sqrt{x} \]

\[ \lambda (x) \]
In hyperbolic form,

From EQNS:

\[
\begin{bmatrix}
V_S \\
I_S
\end{bmatrix} = \begin{bmatrix}
A & B \\
C & D
\end{bmatrix} \begin{bmatrix}
V_R \\
I_R
\end{bmatrix}
\]

IF we match \([A B C D]\) with \(\pi\)-Eqn

\[
z' = z \left[\frac{\sinh (\gamma x)}{\gamma x}\right]
\]

\[
y' = y' \left[\frac{\tanh (\gamma x/2)}{\gamma x/2}\right]
\]

\[
\frac{y'}{2} = \frac{y'}{2} \left[\frac{\tanh (\gamma x/2)}{\gamma x/2}\right]
\]