Topics for Today:

• Announcements
  • Term Project outline (i.e. Table of Contents + List of references due in?
  • 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.
  • Office: EERC 614. Phone: 906.487.2857
  • Recommended problems & all solutions: Ch.7 solns posted.

• Chapter 6 - Recap, a few last items...
  • Case Study of Series Compensation - 500-kV Forbes Line
  • Propagation Constant $\gamma = \alpha + j\beta$
  • Reflection Coefficients, Use of bounce diagrams
  • ATP Tutorial video; ATP travel wave simulation video

Chapter 7 - Network Equations, Admittance Approaches
• $[Y]$ for Transformer Representation, 2-winding, 3-winding
• $[Y]$ for lines and loads
• How’s your linear algebra? Time to make use of it...
• Basic strategy for building up $[Y]$ for whole network
\[
Y_{\text{bus}} = [I_{\text{inj}}] = [E_{\text{inj}}]
\]
2-Winding Xfmr

Y1 Y2 (0° phase shift)

(Bus 5) A A' (Bus 7)

\[
\begin{bmatrix}
Y1
\end{bmatrix} =
\begin{bmatrix}
555 + \frac{1}{2 E_{sc}} & 1 & 7
5 & 5
7 & 7 & 7
\end{bmatrix}
\begin{bmatrix}
y57
\end{bmatrix} - \frac{1}{2 E_{sc}}
\begin{bmatrix}
y77
\end{bmatrix} + \frac{1}{2 E_{sc}}
\]
\[ [Z] \text{ vs. } [Y]? \text{ Which is better?} \]

\[ [Z_{bus}] = [Y_{bus}] \]

\( Z \) is better:
- \( Z_{mm} = Z_{TH} \)
- Good for Fault Studies, hand calcs.

\( Y \) is better
- Sparse, large systems, easy storage.
- Large systems, better throughout...

10,000 x 10,000

100,000,000

800 MB

800 MB
\[ R_{0.08 \text{pu}} \quad X_{0.105 \text{pu}} \quad \frac{B_c}{?} \]

\[ Q = \frac{V^2}{X_c} = \frac{V^2 B_c}{(1.0)^2 B_c} = 0.04 \text{pu} \]

\[ \Rightarrow B_c = 0.04 \text{pu} \]
500-kV Line - May be fun to model...
Hydro

SSR is very unlikely.

Not'l Frog. is usually out of SSR range.
From: "Tom Ernst (MP)" <TERNST@mnpower.com>
To: "MTU EE5200 Class Dist List (E-mail)" <EE5200-L@mtu.edu>
Subject: 500 kV Transmission Line Series Compensation
Date: Wed, 8 Oct 2003 11:18:06 -0500
X-Mailer: Internet Mail Service (5.5.2653.19)
Sender: owner-ee5200-l@mtu.edu
Reply-To: "Tom Ernst (MP)" <TERNST@mnpower.com>
X-Spam-Status: No, hits=-5.8 required=5.0
    tests=BAYES_10
    version=2.53
X-Spam-Level: 

Good Morning,

The 500 kV transmission line that goes from Duluth (Forbes Substation) to
Winnipeg (Dorsey Substation) is series compensated for about 25% of the Xl.
The series capacitors are located near the line's mid-point at Roscoe, MN. We
also have shunt reactors on the Duluth end to help control the Ferranti
rise.

The next 500 kV line to the south from Duluth (Forbes substation) to
Minneapolis (Chisago County substation) is series compensated at the Chisago
Co end. I'm not sure how much compensation that is, but it is probably in
the same range. The also have shunt reactors at Chisago County.

Both of these series capacitors were added as part of a project that nearly
doubled the line's transfer capacity. In this case, the transfer capacity is
not limited solely by the line impedance, but by the steady state export
limit from Manitoba to the US which is based on over-all transfer capability
of the 500 kV system plus the 230 kV tie lines that operate in parallel with
the 500 kV.

One of the biggest issues with series compensated lines is the voltage rise
across the capacitors during short circuits and the associated high fault
currents that are created by the low X series impedance. To help with this,
the series caps have flash-over gaps or non-linear resistors (varistors)
across them to quickly remove (short) them during faults. This produces an
interesting short circuit analysis problem since the solution is time
variant as the varistor or gap conducts. Programs like ASPEN OneLiner
develop steady state short circuit calculations and are not suited for time
variant solutions (you have to pick which machine characteristic to use -
transient or sub transient). To solve the series cap problem, ASPEN does an
iterative solution where it solves the case with zero conduction in the gap
and then uses the voltage rise across the cap to calculate a gap conduction.
It then recalculate a new short circuit value based on that gap conduction
and then repeats the process until it sees minimal change in the solution.

Tom

Printed for Bruce Mork <bamork@mtu.edu>
Close look at $x = \alpha + j\beta$


g = \sqrt{2y} = \sqrt{(0.2+j0.6) \text{sq/mi}} \times 7.3 \text{ m/s/mi}

Very high $\gamma$

$\Rightarrow$ may assume lossless?

\[
= 0.00034/\text{mi} + j0.00212 \text{ rad/mi}
\]

\[
= 0.00034 \text{ neper/mi} + j0.00212 \text{ rad/mi}
\]

Tells us how much attenuation/mi the wave will experience.

For 250 mi:  \[\text{Attenu} = (0.00034 \text{ neper/mi})(250 \text{ mi})\]

\[= 0.085 \text{ or } 8.5\%\]
Reflections

Voltage Reflection Coefficient:
\[ \frac{V_R^-}{V_R^+} = \frac{Z_a - Z_c}{Z_a + Z_c} = \rho \quad \frac{Z_s - Z_c}{Z_s + Z_c} = \rho_s \]

Current Reflection Coefficient
\[ \frac{I_R^-}{I_R^+} = -\frac{V_R^-}{V_I^+} = -\rho \]

\[ I_R = \frac{V_R^+}{Z_c} \quad I_R = -\frac{V_R^-}{Z_c} \]
"Bounce Diagrams"

Refer to end of Lecture 1 notes...

\[ S \]

10kV \[ \rightarrow +10kV (8.31) \]

10kV \[ \rightarrow -10kV (-3.97) \]

10kV \[ \rightarrow 10kV (+7.00) \]

\[ R \]

20kV \[ \rightarrow 20kV (18.8) \]

0V \[ \rightarrow 0V (12.98) \]

20kV \[ \rightarrow 20kV (15.8) \]

\[ \psi_s = -1 \]

\[ \psi_r = +1 \]

Beware