

Name: Solutions

ECE 476

Exam #1

Tuesday , October 11, 2011

Closed book, closed notes
One note sheet allowed

1. _____ / 25

2. _____ / 20

3. _____ / 25

4. _____ / 30

Total _____ / 100

1. (25 points total)

A 3 ϕ , 300 mile, 345-kV line has series impedance of $z = 0.03 + j0.4 \Omega/\text{mile}$ and shunt admittance $y = j5.0 \times 10^{-6} \text{ mho/mile}$.

(9 pts) a. Calculate the line's characteristic impedance Z_c and the propagation constant γ .

(9 pts) b. Initially assume that the receiving end of the line is open-circuited and has a line to line voltage of 345 kV. Calculate the sending end line to line voltage magnitude.

(7 pts) c. Draw the long line π equivalent circuit for this line, showing the values of all parameters.

$$a) Z_c = \sqrt{\frac{z}{y}} = \sqrt{\frac{0.03 + j0.4}{j5 \times 10^{-6}}} = 283.2 \angle -2.14^\circ$$

$$\gamma = \sqrt{zy} = \sqrt{(0.03 + j0.4)(j5 \times 10^{-6})}$$

$$= 0.001416 \angle 87.86^\circ \text{ mi}^{-1}$$

$$b) T = \begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} \cosh \gamma l & Z_c \sinh \gamma l \\ \frac{1}{Z_c} \sinh \gamma l & \cosh \gamma l \end{bmatrix}$$

$$= \begin{bmatrix} 0.9114 \angle 0.412^\circ & 116.76 \angle 85.84^\circ \\ 0.001455 \angle 90.13^\circ & 0.9114 \angle 0.412^\circ \end{bmatrix}$$

$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

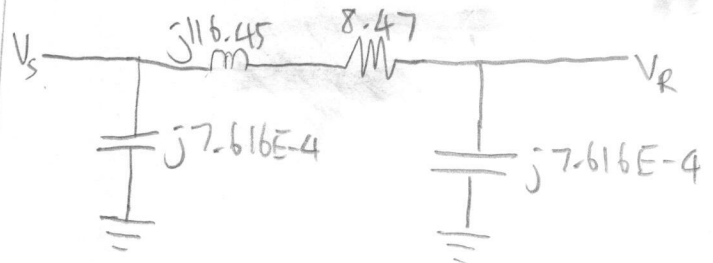
$$= \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} 345 \text{ E} 3 \\ 0 \end{bmatrix}$$

$$V_s = 314.42 \angle 0.412^\circ \text{ kV}$$

$$|V_s| = 314.42 \text{ kV}$$

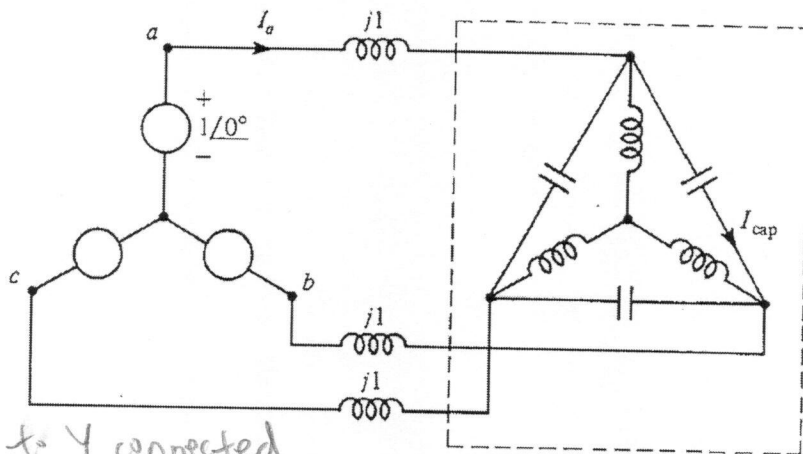
$$c) z' = Z_c \sinh \gamma l = B = 8.47 + j116.45$$

$$\frac{Y'}{2} = \frac{1}{Z_c} \tanh \frac{\gamma l}{2} = j7.616 \times 10^{-4}$$

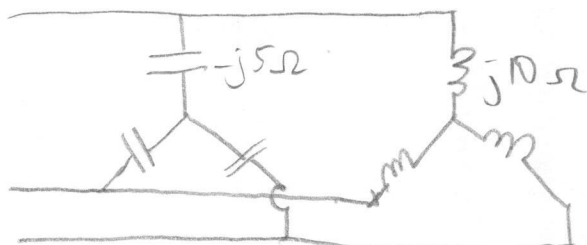


2. (20 points total)

The circuit shown below is a balanced three phase system with a wye-connected generator producing 1 volt (phase to neutral). Assume that each inductor has an impedance $Z_L = j10\Omega$ and each capacitor $Z_C = -j15\Omega$. Determine I_a , I_{cap} , and the total three phase complex power supplied by the y-connected voltage source.

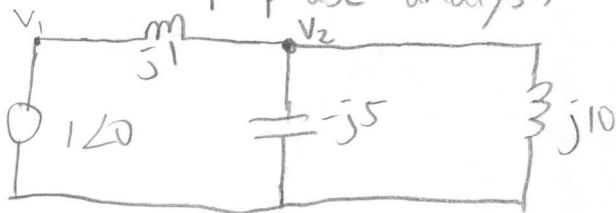


Convert load to Y connected



$$Z_{CY} = \frac{1}{3} Z_{CD} = -j5\Omega$$

Now use perphase analysis



$$Z_{total} = \frac{1}{\frac{1}{-j5} + \frac{1}{j10}} + j1 = -j9$$

$$I_a = \frac{V}{Z_{total}} = \frac{1\angle 0}{-j9} = j0.1111 \text{ A}$$

$$\begin{aligned} V_{ZY} &= V_1 - I_a \times j1 \\ &= 1\angle 0 - j0.1111 \times j1 \\ &= 1.111\angle 0 \end{aligned}$$

$$\begin{aligned} V_{Z\Delta} &= V_{ZY} \times \sqrt{3} \angle 30^\circ \\ &= 1.924 \angle 30^\circ \end{aligned}$$

$$I_{cap} = \frac{V_{Z\Delta}}{-j5} = 0.128 \angle 120^\circ$$

$$\begin{aligned} S_{source, 3\phi} &= 3 V_1 I_a^* \\ &= 3 \times 1\angle 0 \times (j0.1111)^* \\ &= 0.3333 \angle -90^\circ \end{aligned}$$

3. (25 points total)

A 3-phase, 60Hz, 50km long, completely transposed transmission line is built using Drake conductor. Drake conductor has an outside diameter of 1.108 inches; stranding of 26/7 (Al/St), which yields a GMR for the conductor of 0.0375 feet. Resistance at 60-Hz for this conductor is 0.117 Ω /mile. A horizontal tower configuration is used, with a phase spacing of 25 feet (25 feet between left and center phases, 25 feet between center and right, and hence 50 feet between left and right). Bundling is used, with 2 conductors per phase, spaced 1 foot apart. For reference $\mu_0 = 4\pi \times 10^{-7}$ H/m and $\epsilon_0 = 8.854 \times 10^{-12}$ F/m.

- Find the positive sequence inductance in H/m and inductive reactance in Ω /km.
- Find the capacitance to neutral in F/m and the admittance to neutral in S/km. Neglect the effect of the earth plane.
- Since the line is 50km, we can make the short line approximation. Draw the short line π equivalent circuit, labeling appropriate values.

For reference $\mu_0 = 4\pi \times 10^{-7}$ H/m and $\epsilon_0 = 8.854 \times 10^{-12}$ F/m. There are 1609 meters per mile.

$$\begin{aligned} \text{a) } GMR &= \sqrt[4]{0.0375^2 \times 1^2} = 0.1936 \text{ ft} \\ GMD &= \sqrt[3]{25 \times 25 \times 50} = 31.498 \text{ ft} \\ L &= 2 \times 10^{-7} \ln \left(\frac{GMD}{GMR} \right) = 1.018 \times 10^{-6} \frac{\text{H}}{\text{m}} \\ X &= 2\pi 60 \times L \\ &= 0.3839 \frac{\Omega}{\text{km}} \end{aligned}$$

$$\begin{aligned} \text{b) } \text{Outside diameter} &= 1.108 \text{ in} \\ &\rightarrow r = 0.0462 \text{ ft} \\ GMR &= \sqrt[2]{0.0462 \times 1} = 0.2149 \text{ ft} \\ GMD &= 31.498 \text{ ft} \\ C &= \frac{2\pi \epsilon_0}{\ln \left(\frac{GMD}{GMR} \right)} = 1.1154 \times 10^{-11} \frac{\text{F}}{\text{m}} \\ Y &= 2\pi 60 \times C \\ &= j4.2049 \times 10^{-6} \frac{\text{S}}{\text{km}} \end{aligned}$$

$$\begin{aligned} \text{c) } \text{Use } Z' &= Z, Y' = 0 \\ Z &= Zl = j \times l = j0.3839 \times 50 = j19.195 \Omega \\ Y &= 0 \quad R = \frac{0.117}{2} \times 50 \div 1.609 = 1.82 \Omega \\ \text{Pi model} & \quad \begin{array}{c} j19.195 \Omega \quad 1.82 \Omega \\ \text{---} \text{m} \quad \text{---} \text{m} \end{array} \end{aligned}$$

4. Multiple Choice. Circle the most correct answer. Ten problems, three points each for a total of 30 points.

Note this Problem Continues on the Next Page

- A. As discussed in class, the most common load model for the power flow is
- A. Constant impedance
 - B. Constant current
 - ☒ C. Constant power
- B. We can only use per phase analysis when:
- A. All loads and sources are Y connected
 - B. All loads and sources are delta connected
 - C. There is no mutual inductance between phases
 - ☒ D. A and C
 - E. B and C
- C. Which statement about phase and line voltages (V) and currents (I) in Wye and Delta connections is correct?
- ☒ A. Phase I = line I in Wye, and phase V = line V in Delta
 - B. Phase I = line I in Delta, and phase V = line V in Wye
 - C. Phase I = line I and phase V = line V in Wye
 - D. Phase I = line I and phase V = line V in Delta
- D. Using Newton's method to solve the equation $x^2 - \sin(x) - 2 = 0$, with an initial guess of $x=1$ (that is, its value at the zero iteration), select the value that is closest to the value of x after the second iteration:
- A. 1.6754
 - B. 1.7775
 - ☒ C. 1.8073
 - D. 2.3041
 - E. 2.3253
- E. The impedance of a 10 MVA, 22/220 kV transformer is 0.2 per unit. What is this impedance in per unit for a power base of 10 MVA, and a voltage base of 11 kV on the low voltage side of the transformer?
- A. 0.05 p.u.
 - B. 0.1 p.u.
 - C. 0.2 p.u.
 - D. 0.4 p.u.
 - ☒ E. 0.8 p.u.

- F. Transformer open circuit (OC) and short circuit (SC) tests allow us to calculate certain equivalent circuit values. Which parameters are calculated from the OC test and which are from the SC test?
- A. The OC test gives the resistances and the SC test gives the reactances
 - B. The OC test gives the series impedance and the SC test gives the shunt admittance
 - ☒ C. The OC test gives the shunt admittance and the SC test gives the series impedance
 - D. The OC test gives the voltages and the SC test gives currents
- G. In a long line Pi model, we use series impedance Z' and shunt admittance $Y'/2$. In the short line model, we use:
- A. Series impedance Z' and shunt admittance $Y'/2$
 - B. Series impedance Z' and shunt admittance $Y/2$
 - C. Series impedance Z and shunt admittance $Y/2$
 - ☒ D. Series impedance Z and shunt admittance 0
 - E. Series impedance 0 and shunt admittance 0
- H. In the power flow at the slack (swing) bus,
- A. P and V are fixed
 - B. P and Q are fixed
 - C. P and θ_v are fixed
 - D. V and Q are fixed
 - ☒ E. None of the above
- I. A solid conductor has a conductor area of 1113 kcmils. What is its outside diameter, in inches?
- ☒ A. 1.055"
 - B. 1.293"
 - C. 1113"
 - D. 1.044"
- J. If the diameter of a transmission line conductor is increased, then:
- A. Both the inductance and the capacitance increase
 - B. The inductance increases and the capacitance decreases
 - ☒ C. The inductance decreases and the capacitance increases
 - D. Both the inductance and the capacitance decrease
 - E. The inductance decreases and the capacitance remains unchanged