RUTGERS
School of Engineering
Department of Electrical and Computer Engineering

332:494:01/599:02 – Smart Grid – Spring 2021
Homework Assignment – Set 3

General guidelines for homework assignments: Homework should be submitted online (via Canvas)

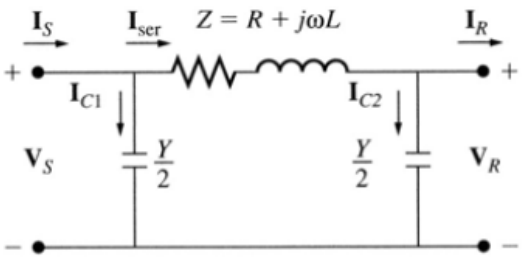
Question 1:

A three-phase overhead transmission line is designed to deliver 100 MVA at 220 kV line voltage over a distance of 100 km.
If the I^2R losses need to be kept to a maximum of 3% of the rated line MVA, given the resistivity of the conductor material to be $2.84 \times 10^{-8}\ \Omega \cdot m$, determine the required conductor diameter (in inches or mils) and the conductor size in circular mils.
Remark: neglect any other line losses (other than resistivity)

Question 2:

A $230kV$ three phase transmission line has a per phase series impedance of $z = 0.05 + j0.45\Omega$ per km and a per phase shunt admittance of $y = j3.4 \times 10^{-6}\ \Omega^{-1}\ per\ km$. The line is $80km$ long. Using the medium line π model:

(a) Determine the transmission line model: Z and $Y/2$



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

(b) Determine the constants A, B, C, and D for:

(c) Find the sending end (generating) voltage V_s, current I_s, and generated power S_{source} when the line delivers to a load of:

1. $200\ MVA$ with 0.8 lagging power factor at $220\ kV$
2. $306\ MVA$ with unity power factor at $220\ kV$

Question 3:

a. Given that the external diameter of a cable is 0.84" and the cables are located horizontally such that $D_{ab} = 10ft$, $D_{bc} = 10ft$ and $D_{ca} = 20ft$, what is the shunt capacitor per mile Y_C=_____[Ω^{-1} ·mile] or [$\Omega^{-1} \cdot$ m]

b. Given that the GMR of a cable is $0.16ft$ and the cables are located horizontally such that $D_{ab} = 10ft$, $D_{bc} = 10ft$ and $D_{ca} = 20ft$, what is the line inductive reactance per mile per phase X_L=_____[Ω /mile] or [Ω /m]

Remark: the grid frequency is assumed to be $f = 60Hz$.

Question 4:

Consider a 3-phase hydropower generator feeding power into the grid bus, which is held at line voltage of $26kV$. The internal reactance is $0.8pu$ for a rated power of $30MVA$.

(a) Choose as base value $S_{b,3\emptyset} = 30MVA$ and $V_{b,LL} = 26kV$ and calculate the per-unit values for the power and grid voltage.

(b) Assume the generator initially runs overexcited with $|E| = 1.3\ pu$ and a real power output of $P_e = 0.32pu$. Compute the reactive power and the apparent power output of the generator as measured at the grid bus.

(c) For the case in (b) find the power factor

(d) Assume the steam valve is opened to generate a 50% increase in power P_e, what are the new power angle, the reactive power, and the new power factor?

(e) What can be done to bring back the power factor to the previous value? Explain.

(f) Assume that from the original initial state we increase the field current such that the armature voltage amplitude is increased by 15%, what will be the resulting reactive power? What will be the resulting power factor?