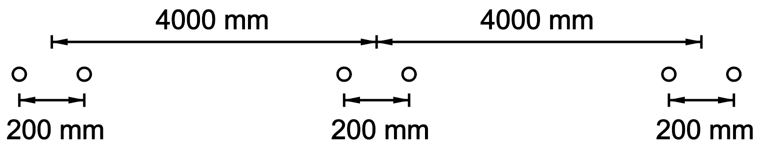
UNIVERSITY OF THE WITWATERSRAND
SCHOOL OF ELECTRICAL AND INFORMATION ENGINEERING
ELEN4018A/ELEN5008A: POWER SYSTEMS
TUTORIAL 1: TRANSMISSION LINES

Question 1

Determine the resistance, inductance and capacitance per unit length for the three-phase transmission line below. The subconductors, with a radius of 20 mm, are copper with a resistivity of $1,77 \times 10^{-8} \Omega m$. Skin effect correction factors must be included in the calculation.



Question 2

List the advantages of a three-phase transmission line with bundled conductors rather than single conductors. Amongst others, the issues of power flow and voltage drop should be considered.

Question 3

The outer radius of the inner conductor of a coaxial cable is r_1 and inner radius of the outer conductor is r_2. The insulating material between the two conductors has a conductivity of σ. Show that the resistance per unit length of the insulation between the conductors is

$$R' = \frac{ln\left(\frac{r_2}{r_1}\right)}{2\pi\sigma} \quad \text{in } \Omega/\text{m}$$

Question 4

A high voltage cable system consists of three coaxial cables laid in a horizontal formation in a trench. In the manufacturing process a triple extrusion is used to place a very thin semiconducting layer in electrical contact with the inner conductor, a thick layer of insulation over this semiconducting layer and finally another very thin semiconducting layer over the insulation.

The semiconducting layers are used to ensure the electric field in the insulation is strictly radial with minimal enhancement that could cause electrical treeing and hence reduced breakdown voltage.

The radius of the inner conductor and semiconducting layer is 15,5 mm and the insulation is 16 mm thick.

Determine the shunt conductance and shunt capacitance per unit length per phase if the relative permittivity of the insulation is 2,3 and the resistivity of the insulation is $10^{14}\ \Omega m$.

Question 5

If the transmission line in Question 1 is 300 km long, determine the nominal-pi and exact-pi models of the line for steady-state 50 Hz conditions. It may be assumed that the line has been perfectly transposed.

Question 6

A 500 km three-phase transmission line operates at a line voltage of 400 kV and a frequency of 50 Hz and has the following line constants

$$\begin{gathered} L' = 1,1\ \mu H\ /\ m \\ C' = 5,3\ pF\ /\ m \\ R' = 15\ \mu\Omega\ /\ m \\ G' = 0\ S\ /\ m \end{gathered}$$

The line supplies a load of 300 MW at a power factor of 0,9 lagging.

Determine the shunt capacitive compensation required at the receiving end if the voltage at both ends must remain at 400 kV.

Under these conditions, what is the receiving end power factor? The nominal-pi model can be used for the transmission line.

Question 7

For the 500 km transmission line in Question 6, determine the power limit and the magnitude of the series capacitance which should be installed at the mid-point of the line if the power limit is to be doubled.

Determine this capacitance using the hyperbolic equations and then the nominal-pi model of the line.

Question 8

A load of 600 MW is supplied from an infinite bus via two three-phase 132 kV transmission lines each having a series reactance of 15 Ω.

In the event of one of the lines being disconnected, show that the system remains stable.

If a three-phase short circuit occurs along one of the lines before it is disconnected, determine the critical clearing angle to which the system can accelerate without going unstable.

Dr JM Van Coller, 2018