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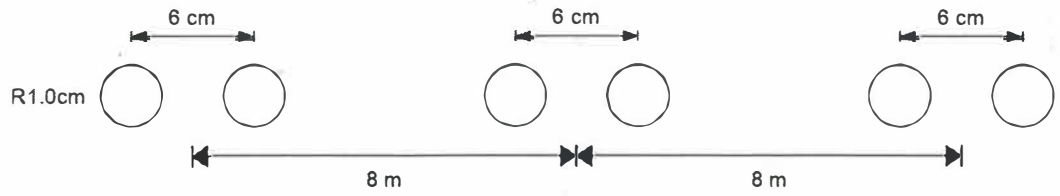
1) The figure below shows the conductor configuration of three-phase overhead transmission line with each phase bundle consisting of two solid conductors. All conductors have a radius of 1 cm with 6 cm bundle spacing. The bundles are equally spaced at 8 m from each other. Assume the GMR for one conductor is r′



a) Find the phase inductance of the line in mH/km. [4 marks]

(1) $D_{eq} = \sqrt[3]{8 \times 8 \times 16} = 10.08\ m$

(1) $D_{SL} = \sqrt{(0.7788)(0.01) \times 0.06} = 0.0216\ m$ (1)

(1) $L = 2 \times 10^{-7} \ln\left(\frac{D_{eq}}{D_{SL}}\right) = 1.23\ mH/km$

b) Find the capacitance to neutral of the line in nF/km. [3 marks]

(1) $D_{eq} = \sqrt[3]{8 \times 8 \times 16} = 10.08\ m$

(1) $D_{SC} = \sqrt{0.01 \times 0.06} = 0.0245\ m$

(1) $C = \frac{2\pi\varepsilon_0}{\ln\left(\frac{D_{eq}}{D_{SC}}\right)} = 9.24\ nF/km$

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2) The specification of a three phase high voltage transmission line is provided below:

- Rated voltage: 260 kV
- Phase line resistance: 0.06 Ω/km
- Phase line reactance: 0.5 Ω/km
- Phase to neutral admittance: $j4 \times 10^{-6}$ S/km

For the following line segments:

- Determine the ABCD parameters
- Sketch the equivalent line circuit and label the line parameters, voltages and currents (No numerical values needed for the labels)

a) Line segment is 150 km. [8 marks]

(1) $Z = z \cdot \ell = (0.06 + j0.5)(150) = 9 + j75 = 75.54 \angle 83.16\ \Omega$

(1) $Y = y \cdot \ell = (j4 \times 10^{-6})(150) = j6 \times 10^{-4}$ S

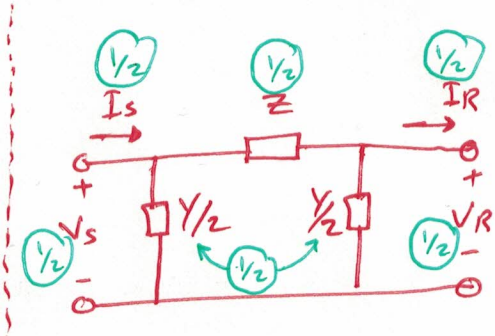
(1) $A = D = 1 + \frac{YZ}{2} = 0.978 + j0.0027$

$= 0.978 \angle 0.158$

(1) $B = Z$

(1) $C = Y\left(1 + \frac{YZ}{4}\right) = -8.1 \times 10^{-7} + j5.93 \times 10^{-4}$

$= 5.93 \angle 90.08$



b) Line segment is 50 km [6 marks]

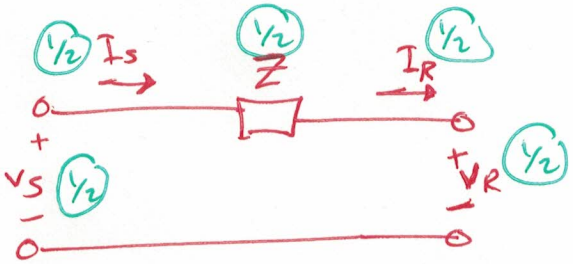
(1) $Z = z \cdot \ell = (0.06 + j0.5)(50) = 3 + j25 = 25.18 \angle 83.16\ \Omega$

(1/2) $A = 1$

(1) $B = Z$

(1/2) $C = 0$

(1/2) $D = 1$



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3) A 60 km three phase transmission line is rated at 260 kV (Line to line). The sending bus is delivering 100 MW and 40 MVAr at the rated voltage. Calculate line-to-line voltage and current at the receiving bus. [5 marks]

Hint: The ABCD parameters for this line are $\begin{bmatrix} 1 & 3.6+j30 \\ 0 & 1 \end{bmatrix}$

(1) $I_R = I_S = \frac{S}{\sqrt{3}V_{LL}} \angle \theta_I$

(1) ; $\theta_I = -\tan\frac{Q}{P}$

$= -21.8$

→ $I_R = \frac{\sqrt{(100\times10^6)^2+(40\times10^6)^2}}{\sqrt{3}\times 260\times10^3} \angle -21.8$

$= 239.16 \angle -21.8$ A

* Alternative method for I_R :-

(1) $I_R = I_S = \frac{S^*}{\sqrt{3}V_{LL}}$ ← (1)

$= \frac{(100\times10^6 - j40\times10^6)}{\sqrt{3}\times 260\times10^3}$

$= 239.16 \angle -21.8$ A

In the online version of this quiz, the current values were provided. For a short line, Is = Ir

* From ABCD matrix → $Z = B = 3.6+j30 = 30.22\angle 83.15$

(1) $V_{R_{LN}} = V_{S_{LN}} - IZ$

$= \frac{260\times10^3}{\sqrt{3}} \angle 0 - (239.16\angle -21.8)(30.22\angle 83.15)$ (1)

$= 146.64 - j6.34 = 146.78 \angle -2.48$ kV

(1/2) (1/2)

→ $V_{R_{LL}} = \sqrt{3}\, V_{R_{LN}} (1\angle 30) = 254.22 \angle 27.52$ k