EE2029 Test (113 Marks, 15%) 19 October 2020 ID Number: Solutions

Question 1 (33%)

Circle T if statement is true, F if statement is false. Each problem is worth 3%.

1	T	F	Insulation disks are used to allow the current to flow from the transmission line to the ground.
2	T	F	Heat dissipation in line conductors is due to the line reactance.
3	T	F	The di-electric effect within the conductors is modelled as admittance.
4	T	F	Underground cable and overhead line have similar inductance per km under the same voltage and power ratings.
5	T	F	Receiving-end voltage of a transmission line under full load is the same as the sending-end voltage at full load for the medium transmission line model.
6	T	F	Transformer is designed to step-up or step-down the power between the primary and secondary sides.
7	T	F	An ideal transformer assumes no magnetizing current flows into the core.
8	T	F	Short-circuit test is used to find the magnetizing impedance of a transformer core.
9	T	F	Circulating current decreases within a transformer core when using laminated core than single solid core.
10	T	F	The voltage ratings of three-phase transformer are given in line-to-line values.
11	T	F	A transformer is inductive in nature.

Question 2 (20%)

A three-phase transformer rated at 10MVA 66kV/22kV (Wye-Wye connection) is connected to a three-phase load of 10.0Ω at the low-voltage side. Compute the per unit load referred to the high-voltage side. The base values of the transformer are 100MVA, 66kV for the high-voltage side, and 22kV for the low-voltage side.

$$Z_{LV,base} = \frac{(22k)^2}{100M} = 4.84\ \Omega$$

$$R_L = \frac{10}{4.84} = 2.066\ p.u.$$

The per unit values are the same when referred to LV and HV sides using the base ratings.

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Question 3 (30%)

Suppose the equivalent circuit for a 20MVA, 22kV/33kV transformer has the following equivalent circuit parameters: $X_1 = 0.1\,\Omega$, $X_2 = 0.05\,\Omega$, $X_M = 100\,\Omega$, $R_1 = 0.01\Omega$, and $R_2 = 0.01\,\Omega$. Note that the magnetising inductance X_M is referred to the high-voltage side of the equivalent circuit. Taking the transformer rating as the base quantities, compute the equivalent circuit parameters in per unit. Also draw the equivalent circuit and label all the transformer parameters.

$$Z_{LV,base} = \frac{(22k)^2}{20M} = 24.2\,\Omega \quad \& \quad Z_{HV,base} = \frac{33k^2}{20M} = 54.45\,\Omega$$

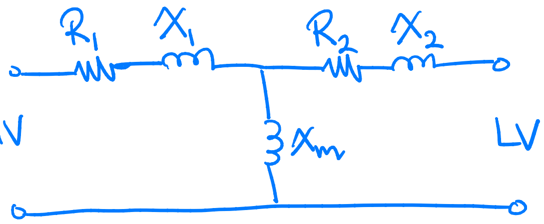
$$\Rightarrow X_1 = \frac{0.1}{54.45} = 0.00184 \text{ p.u.}$$

$$R_1 = \frac{0.01}{54.45} = 0.000184 \text{ p.u.}$$

$$X_m = \frac{100}{54.45} = 1.84 \text{ p.u.}$$

$$X_2 = \frac{0.05}{24.2} = 0.00207 \text{ p.u.}$$

$$R_2 = \frac{0.01}{24.2} = 0.000413 \text{ p.u.}$$



Per unit equivalent circuit

Question 4 (30%)

A three-phase underground cable connects a local substation to nearby HDBs. The 10 km cable is rated at 22 kV, 50 Hz. XLPE cables are commonly used in Singapore, and have a series resistance of 0.01 Ω/km and inductance of 0.2 mH/km. The shunt capacitance of the cable is 0.02 μF/km, and the conductance is zero. The receiving-end of the line is connected to a three-phase load delivering 10 MVA at a lagging power factor of 0.9. Given the receiving-end voltage is 20∠0° kV, calculate voltage regulation and transmission line efficiency using the medium line model. Also, draw the nominal equivalent circuit diagram and label it with the calculated transmission line parameters, i.e. Z, Y, V_S, V_R, I_S, I_R.

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} \frac{ZY}{2}+1 & Z \\ Y\left(1+\frac{ZY}{4}\right) & \frac{ZY}{2}+1 \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$Z = 10 \times (0.01 + 2\pi \times 50 \times 0.2 \times 10^{-3}) = 0.1 + j0.628\,\Omega$$

$$Y = 10 \times j2\pi \times 50 \times 0.02 \times 10^{-6} = j6.283 \times 10^{-5}\,S$$

$$A = D = \frac{ZY}{2} + 1 = 1.00 + j3.142 \times 10^{-6}$$

$$B = Z = 0.1 + j0.628$$

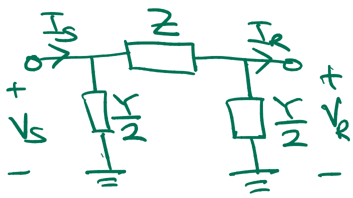
$$C = \left(\frac{ZY}{4}+1\right)Y = -9.87 \times 10^{-11} + j6.283 \times 10^{-5}$$

$$|I_R| = \frac{10\,MVA}{\sqrt{3} \times 20k} = 288.68\,A \quad \& \quad \theta = \cos^{-1}0.9 = 25.8° \text{ (lagging)}$$

$$\Rightarrow \hat{I}_R = 288.68 \angle -25.8°\,A$$

$$V_S = AV_R + BI_R = 11.65 \angle 0.74° \text{ kV (per phase)}$$

$$I_S = CV_R + DI_R = 288.36 \angle -25.7°\,A$$



$$\%\text{ regulation} = \frac{|V_S|/|A| - |V_R|}{|V_R|} \times 100\% = 0.89\%$$

$$\eta = \frac{10 \times 0.9}{Re\{V_S I_S^*\} \times 3} \times 100 = \frac{9}{9.024} \times 100 = 99.73\%$$