National University of Singapore

Department of Electrical & Computer Engineering

EE1002:Circuits and Systems

Tutorial - 8 Solution (Transformers and Rectifiers)

Year 2013-14

Q.1 The parameters given are:

$$N_{HV} = N_1 = 800, N_{LV} = N_2 = 100, V_1 = 240\,V, Z_L = 3\,\Omega$$

(a) $V_2 = \left(\frac{N_2}{N_1}\right) \times V_1 = \left(\frac{100}{800}\right) \times 240 = 30\,V, I_2 = \frac{V_2}{Z_L} = \frac{30\,V}{3\,\Omega} = 10\,A$

(b) $I_1 = \left(\frac{N_2}{N_1}\right) \times I_2 = \left(\frac{100}{800}\right) \times 10\,A = 1.25\,A$

(c) $Z_1 = \frac{V_1}{I_1} = \frac{240\,V}{1.25\,A} = 192\,\Omega$

(d) $Z_{L'} = \left(\frac{N_1}{N_2}\right)^2 \times Z_L = \left(\frac{800}{100}\right)^2 \times 3 = 192\,\Omega$

Q.2 The parameters given are:

$$V_1 = 100\angle 0^0\,V, \left(\frac{N_2}{N_1}\right) = 1/over2, \left(\frac{N_3}{N_1}\right) = 1, Z_2 = 5\,\Omega, Z_3 = 10\,\Omega$$

(a) The dots are placed at top ends of coils 2 and 3 so that they would be opposing the MMF produced by coil 1.

(b) $V_2 = \left(\frac{N_2}{N_1}\right) \times V_1 = \left(\frac{1}{2}\right) \times 100\angle 0^0\,V = 50\angle 0^0\,V, V_3 = \left(\frac{N_3}{N_1}\right) \times V_1 = \left(\frac{1}{1}\right) \times 100\angle 0^0\,V = 100\angle 0^0\,V, I_2 = \frac{V_2}{Z_L} = \frac{50\angle 0^0\,V}{5\,\Omega} = 10\angle 0^0\,A, I_3 = \frac{V_3}{Z_L} = \frac{100\angle 0^0\,V}{10\,\Omega} = 10\angle 0^0\,A,$

(c) $N_1 \times I_1 = N_2 \times I_2 + N_3 \times I_3 \Rightarrow I_1 = \frac{N_2 \times I_2 + N_3 \times I_3}{N_1} = \frac{\frac{1}{2} \times N_1 \times I_2 + N_1 \times I_3}{N_1} = \frac{1}{2} \times 10\angle 0^0 + 10\angle 0^0 = 15\angle 0^0$

Q.3 The induced voltages are given by:

$$v_1 = N_1 \frac{d\phi}{dt} \text{ and } v_2 = N_2 \frac{d\phi}{dt} \Rightarrow \frac{v_1}{v_2} = \frac{N_1}{N_2} \Rightarrow v_2 = \frac{N_2}{N_1} v_1 = \frac{100}{1000} 120\angle 0 = 12\angle 0\,V$$

From the circuit we have

$$I_1 = I_2 + I_3$$

As the net MMF required to set-up the flux is zero we have

$$(N_1 - N_2)I_1 + N_2 I_3 = (N_1 - N_2)I_1 + N_2(I_1 - I_2) = 0 \Rightarrow \frac{I_1}{I_2} = \frac{N_2}{N_1}$$

We have

$$I_2 = \frac{V_2}{Z_2} = \frac{12\angle 0\,V}{6\angle 0} = 2\angle 0\,A \Rightarrow I_1 = \frac{N_2}{N_1} I_2 = \frac{100}{1000} 2\angle 0\,A = 0.2\angle 0\,A$$

$$I_3 = I_1 - I_2 = 0.2\angle 0\,A - 2.0\angle 0\,A = -1.8\angle 0\,A$$

Q.4 Assume that the primary side series-resistance is referred to the secondary side and let the combined resistances in the secondary side be R_{eq} and the corresponding output voltage and current on the secondary side be V_2, I_2 and let the power-factor of the load $\cos\phi$ is maintained constant.

When the output power increases normally, V_2 is maintained constant and it is I_2 increases with increase in P_{out}. Then we have

$$P_{out} = V_2 \times I_2 \times \cos\phi, R_{eq} = a^2 R_1 + R_2, P_{cu-loss} = I_2^2 R_{eq}, P_{const-loss} = \frac{{V_1}^2}{R_c}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{P_{out} + P_{loss}} = \frac{P_{out}}{P_{out} + P_{cu-loss} + P_{const-loss}} = \frac{V_2 \times I_2 \times \cos\phi}{V_2 \times I_2 \times \cos\phi + I^2 R_{eq} + P_{const-loss}}$$

Variable load means that it is I_2 that is changing as a function of load.

$$\frac{d\eta}{dI_2} = \frac{d}{dI_2}\left(\frac{V_2 \times I_2 \times \cos\phi}{V_2 \times I_2 \times \cos\phi + I^2 R_{eq} + P_{const-loss}}\right) = 0 \Rightarrow P_{cu-loss} = P_{const-loss}$$

Q.5 The parameters given are:

$$V_{rms} = 230\,V, f_s = 50\,Hz, R_L = 200\,\Omega$$

The average output voltage is given by

$$V_{o,avg.} = \frac{2V_m}{\pi} = \frac{2 \times 230\sqrt{2}}{\pi} = 207.1\,V$$

The capacitance needed to reduce the peal-to-peak ripple voltage to 1% of the output voltage is given by

$$C = \frac{I_L}{2f_s V_{pk-to-pk}} = \frac{V_{o,avg}}{2f_s R_L V_{pk-to-pk}} = \frac{1}{2f_s R_L\left(\frac{V_{pk-to-pk}}{V_{o,avg}}\right)} = \frac{1}{2 \times 200 \times 50\,Hz \times 0.01} = 5000\,\mu F$$

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