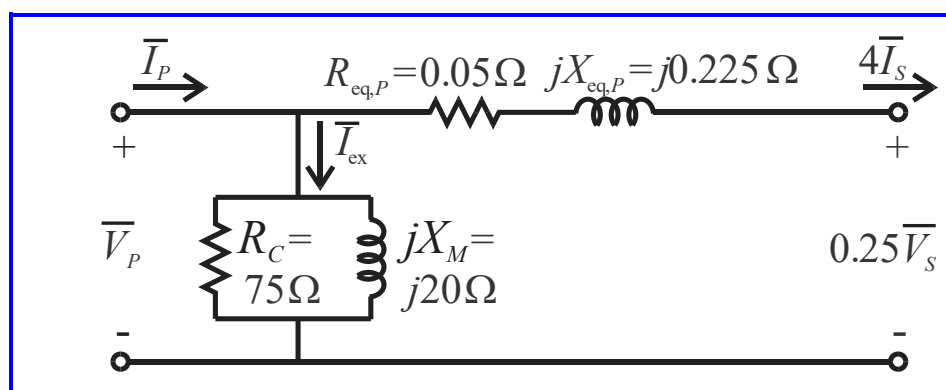


3-1 The secondary winding of a transformer has a terminal voltage of $v_s(t) = 282.8 \sin 377t$ V. The turns ratio of the transformer is 50:200 ($a = 0.25$). If the secondary current of the transformer is $i_s(t) = 7.07 \sin (377t - 36.87^\circ)$ A, what is the primary current of this transformer? What are its voltage regulation and efficiency? The impedances of this transformer referred to the primary side are

$$\begin{array}{ll} R_{eq} = 0.05 \, \Omega & R_C = 75 \, \Omega \\ X_{eq} = 0.225 \, \Omega & X_M = 20 \, \Omega \end{array}$$

- First, draw approximate phasor equivalent circuit. Then, find RMS phasor secondary current and voltage. In addition to the primary current (RMS phasor & time-domain), find the primary voltage (RMS phasor & time-domain).

Per Figure3-18a, the approximate primary-side phasor equivalent circuit is



In cos() form, $v_S(t) = 282.6 \cos(377t - 90^\circ)$ V. Expressing as an RMS phasor-

$$\bar{V}_s = \frac{282.6}{\sqrt{2}} \angle -90^\circ \Rightarrow \underline{\bar{V}_s = 199.8284 \angle -90^\circ \text{ (V}_{\text{rms}})}.$$

In cos() form, $i_S(t) = 7.07 \cos(377t - 126.87^\circ)$ V. Expressing as an RMS phasor-

$$\bar{I}_s = \frac{7.07}{\sqrt{2}} \angle -126.87^\circ \Rightarrow \underline{\bar{I}_s = 4.9992 \angle -126.87^\circ (\text{A}_{\text{rms}})}.$$

$$\bar{V}_p = 4\bar{I}_s(0.05 + j0.225) + 0.25\bar{V}_s$$

By KVL,

$$\Rightarrow \bar{V}_p = 53.54066 \angle -86.7884^\circ \text{ (V}_{\text{rms}}).$$

$$v_P(t) = \sqrt{2}(53.54) \cos(377t - 86.7884^\circ) \text{ V} \quad \Rightarrow \quad \mathbf{v_P(t) = 75.718 \cos(377t - 86.7884^\circ) \text{ V.}}$$

By Ohm's Law,
$$\bar{I}_{\text{ex}} = \bar{V}_P \left[\frac{1}{R_C} + \frac{1}{jX_M} \right] = (53.54066 \angle -86.7884^\circ) \left[\frac{1}{75} + \frac{1}{j20} \right].$$
$$= 2.770582 \angle -161.857^\circ \text{ (A}_{\text{rms}})$$

By KCL,
$$\bar{I}_P = \bar{I}_{\text{ex}} + 4\bar{I}_S$$
$$= (2.770582 \angle -161.857^\circ) + 4 \left(\frac{7.07}{\sqrt{2}} \angle -126.87^\circ \right)$$
$$\Rightarrow \underline{\bar{I}_P = 22.3235 \angle -130.951^\circ \text{ (A}_{\text{rms}})}.$$
$$i_P(t) = \sqrt{2}(22.3235) \cos(377t - 130.951^\circ) \text{ V} \quad \Rightarrow \underline{i_P(t) = 31.57 \cos(377t - 130.95^\circ) \text{ A}}.$$

Per (3-68), the voltage regulation is

$$\text{VR} = \frac{V_P / a - V_{S,\text{fl}}}{V_{S,\text{fl}}} \times 100\% = \frac{53.54 / 0.25 - 199.8284}{199.8284} \times 100\% \Rightarrow \underline{\text{VR} = 7.17\%}.$$

To get the efficiency, first find input and output powers-

$$P_{\text{in}} = V_P I_P \cos(\theta_{VP} - \theta_{IP}) = 53.54 (22.3235) \cos(-86.7884^\circ + 130.951^\circ) = 857.406 \text{ W}$$

$$P_{\text{out}} = V_S I_S \cos(\theta_{VS} - \theta_{IS}) = 199.8284 (4.9992) \cos(-90^\circ + 126.87^\circ) = 799.185 \text{ W}$$

Per (3-71), the efficiency is
$$\eta = \frac{P_{\text{out}}}{P_{\text{in}}} \times 100\% = \frac{799.185}{857.406} \times 100\% \Rightarrow \underline{\eta = 93.21\%}.$$