(1)

A 100-kVA 8000/277-V distribution transformer has the following resistances and reactances:

$R_P = 5\ \Omega \qquad R_S = 0.005\ \Omega$

$X_P = 6\ \Omega \qquad X_S = 0.006\ \Omega$

$R_C = 50\ \text{k}\Omega \qquad X_M = 10\ \text{k}\Omega$

The excitation branch impedances are given referred to the high-voltage side of the transformer.

(The values on the nameplate are rated line voltage and line current)

(a) Find the equivalent circuit of this transformer referred to the low-voltage side.

***(b)* Find the per-unit equivalent circuit of this transformer.**

(c) Assume that this transformer is supplying rated load at 277 V and 0.85 PF lagging. What is this transformer's input voltage? What is its voltage regulation?

(d) What are the copper losses and core losses in this transformer under the conditions of part *(c)*?

(e) What is the transformer's efficiency under the conditions of part *(c)*?

(a) The turns ratio of this transformer is a = 8000/277 = 28.88. Therefore, the primary impedances referred to the low voltage (secondary) side are

$$R_P' = \frac{R_P}{a^2} = \frac{5\ \Omega}{(28.88)^2} = 0.006\ \Omega$$

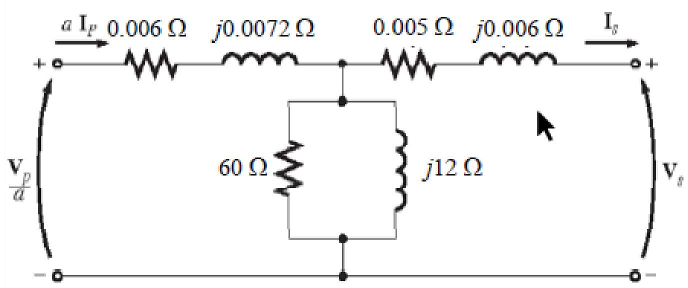
$$X_P' = \frac{R_P}{a^2} = \frac{6\ \Omega}{(28.88)^2} = 0.0072\ \Omega$$

and the excitation branch elements referred to the secondary side are

$$R_C' = \frac{R_C}{a^2} = \frac{50\ \text{k}\Omega}{(28.88)^2} = 60\ \Omega$$

$$X_M' = \frac{X_M}{a^2} = \frac{10\ \text{k}\Omega}{(28.88)^2} = 12\ \Omega$$

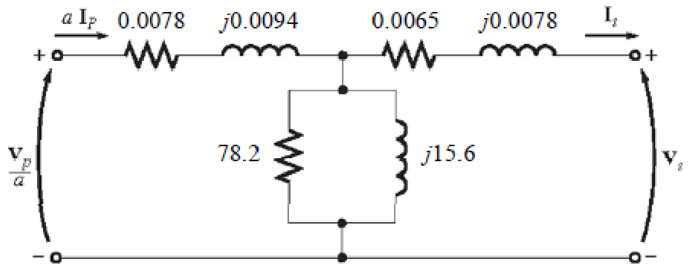
The resulting equivalent circuit is



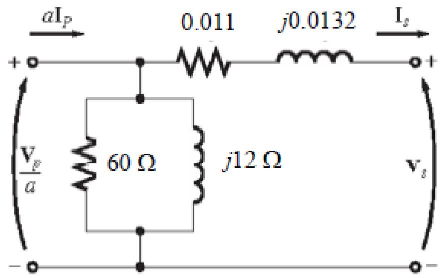
(b) The rated kVA of the transformer is 100 kVA, and the rated voltage on the secondary side is 277 V, so the rated current in the secondary side is 100 kVA/277 V = 361 A. Therefore, the base impedance on the primary side is

$$Z_{\text{base}} = \frac{V_{\text{base}}}{I_{\text{base}}} = \frac{277 \text{ V}}{361 \text{ A}} = 0.767\ \Omega$$

Since $Z_{\text{pu}} = Z_{\text{actual}} / Z_{\text{base}}$, the resulting per-unit equivalent circuit is as shown below:



(c) To simplify the calculations, use the simplified equivalent circuit referred to the secondary side of the transformer:



The secondary current in this transformer is

$$\mathbf{I}_S = \frac{100 \text{ kVA}}{277 \text{ V}} \angle -31.8° \text{ A} = 361\angle -31.8° \text{ A}$$

Therefore, the primary voltage on this transformer (referred to the secondary side) is

$$\mathbf{V}_P' = \mathbf{V}_S + \left(R_{\text{EQ}} + jX_{\text{EQ}}\right) \mathbf{I}_S$$

$$\mathbf{V}_P' = 277\angle 0° \text{ V} + (0.011 + j0.0132)(361\angle -31.8° \text{ A}) = 283\angle 0.4° \text{ V}$$

The voltage regulation of the transformer under these conditions is

$$\text{VR} = \frac{283 - 277}{277} \times 100\% = 2.2\%$$

(d) Under the conditions of part *(c)*, the transformer's output power copper losses and core losses are:

$$P_{\text{OUT}} = S \cos\theta = (100 \text{ kVA})(0.85) = 85 \text{ kW}$$

$$P_{\text{CU}} = (I_S)^2 R_{\text{EQ}} = (361)^2 (0.11) = 1430 \text{ W}$$

$$P_{core} = \frac{V_p'^2}{R_C} = 283^2 / 60 = 1335$$

(e) The efficiency of this transformer is

$$\eta = \frac{P_{OUT}}{P_{OUT} + P_{CU} + P_{CORE}} \times 100\% = \frac{85000}{85000 + 1430 + 1335} = 96.8\%$$

2)

Part (a):

$$|Z_{\mathrm{eq,H}}| = \frac{V_{\mathrm{sc,H}}}{I_{\mathrm{sc,H}}} = 14.1\ \Omega$$

$$R_{\mathrm{eq,H}} = \frac{P_{\mathrm{sc,H}}}{I^2_{\mathrm{sc,H}}} = 752\ \mathrm{m}\Omega$$

$$X_{\mathrm{eq,H}} = \sqrt{|Z_{\mathrm{eq,H}}|^2 - R^2_{\mathrm{eq,H}}} = 14.1\ \Omega$$

and thus

$$Z_{\mathrm{eq,H}} = 0.75 + j14.1\ \Omega$$

Part (b): With $N = 78/8 = 9.75$

$$R_{\mathrm{eq,L}} = \frac{R_{\mathrm{eq,H}}}{N^2} = 7.91\ \mathrm{m}\Omega$$

$$X_{\mathrm{eq,L}} = \frac{X_{\mathrm{eq,H}}}{N^2} = 148\ \mathrm{m}\Omega$$

and thus

$$Z_{\mathrm{eq,L}} = 7.9 + j148\ \mathrm{m}\Omega$$