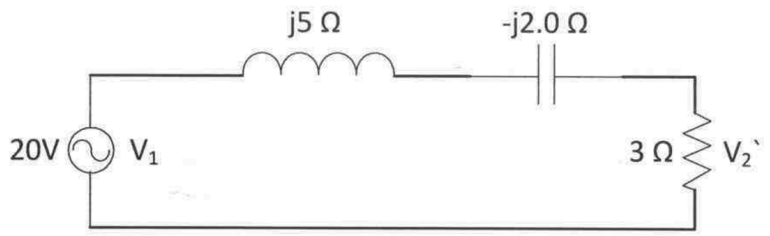
Solution HW3 EE306 Term 171

Solution Problem 1

The equivalent circuit referred to the primary side is:



Impedance of the circuit,

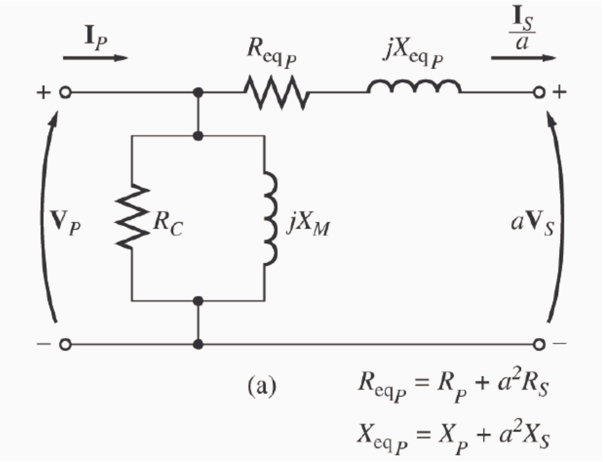
$Z = 3 + j5 - j20 = 3 + j3 = 4.24\ \Omega$

$I_1 = \frac{20}{4.24} = 4.72$ A

$V_2' = 4.72 \text{ x } 3 = 14.15$ V

Actual load voltage $V_2 = 100 \text{ x } 14.15 = 1415$ V

Solution Problem 2



The secondary voltage and current are

$$\mathbf{V}_S = \frac{282.8}{\sqrt{2}}\angle 0^\circ \text{ V} \;=\; 200\angle 0^\circ \text{ V}$$

$$\mathbf{I}_S = \frac{7.07}{\sqrt{2}}\angle -36.87^\circ \text{ A} \;=\; 5\angle\text{-}36.87^\circ \text{ A}$$

The secondary voltage referred to the primary side is

$$\mathbf{V}_S{}' = a\mathbf{V}_S = 100\angle 0^\circ \text{ V}$$

The secondary current referred to the primary side is

$$\mathbf{I}_S{}' = \frac{\mathbf{I}_S}{a} = 10\angle -36.87^\circ \text{ A}$$

The primary circuit voltage is given by

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

$$\mathbf{V}_P = 100\angle 0^\circ \text{ V} + \left(10\angle -36.87^\circ \text{ A}\right)\left(0.20\ \Omega + j0.750\ \Omega\right) = 106.2\angle 2.6^\circ \text{ V}$$

The excitation current of this transformer is

$$\mathbf{I}_{\text{EX}} = \mathbf{I}_C + \mathbf{I}_M = \frac{106.2\angle 2.6^\circ \text{ V}}{300\ \Omega} + \frac{106.2\angle 2.6^\circ \text{ V}}{j80\ \Omega} = 0.354\angle 2.6^\circ + 1.328\angle -87.4^\circ$$

$$\mathbf{I}_{\text{EX}} = 1.37\angle -72.5^\circ \text{ A}$$

Therefore, the total primary current of this transformer is

$$\mathbf{I}_P = \mathbf{I}_S{}' + \mathbf{I}_{\text{EX}} = 10\angle -36.87^\circ + 1.37\angle -72.5^\circ = 11.1\angle -41.0^\circ \text{ A}$$

Solution Problem 3

OPEN CIRCUIT TEST:

$$|Y_{EX}| = |G_C - jB_M| = \frac{0.45\text{ A}}{230\text{ V}} = 0.001957$$

$$\theta = \cos^{-1}\frac{P_{OC}}{V_{OC}I_{OC}} = \cos^{-1}\frac{30\text{ W}}{(230\text{ V})(0.45\text{ A})} = 73.15°$$

$$Y_{EX} = G_C - jB_M = 0.001957\angle -73.15°\text{ mho} = 0.000567 - j0.001873\text{mho}$$

$$R_C = \frac{1}{G_C} = 1763\,\Omega$$

$$X_M = \frac{1}{B_M} = 534\,\Omega$$

Transformer ratio = a = 2

Hence

***$R_{C,s}$* = *R_C/a^2* = 1763/4 = 440.75 ohm**

***$X_{M,s}$* = *X_M/a^2* = 534/4 = j133.5 ohm**

SHORT CIRCUIT TEST:

$$|Z_{EQ}| = |R_{EQ} + jX_{EQ}| = \frac{19.1\text{ V}}{8.7\text{ A}} = 2.2\,\Omega$$

$$\theta = \cos^{-1}\frac{P_{SC}}{V_{SC}I_{SC}} = \cos^{-1}\frac{42.3\text{ W}}{(19.1\text{ V})(8.7\text{ A})} = 75.3°$$

$$Z_{EQ} = R_{EQ} + jX_{EQ} = 2.20\angle 75.3°\,\Omega = 0.558 + j2.128\,\Omega$$

$$R_{EQ} = 0.558\,\Omega$$

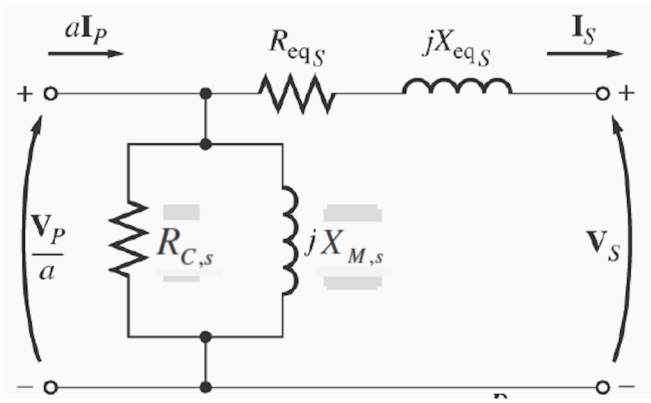
$$X_{EQ} = j2.128\,\Omega$$

Here

***R_{eqS}* = *R_{EQ}* = 0.588 ohm**

***X_{eqS}* = *X_{EQ}* = j2.128 ohm**

(b) The resulting equivalent circuit is shown below:



Solution Problem 4

(a)

(i) $I_{HV}\big|_{NL} = \frac{11000}{57600} + \frac{11000}{j16.34} = 0.7\angle{-74.2^\circ}\ A$

$I_{HV\,(rated)} = \frac{300 \times 10^3}{11 \times 10^3} = 27.27\ A.$

$I_{\frac{NL}{FL(rated)}}$ in % $= \frac{0.7}{27.27} \times 100 = 2.57\ \%$

(ii) $P_{NL} = P_{core} = \frac{11000^2}{57600} = 2100\ W$

(iii) $PF\big|_{NL} = \cos 74.2^\circ = 0.27$ lagging

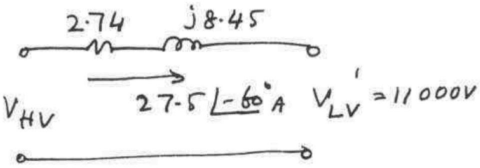
(iv) $P_{cu,FL} = 27.27^2 \times 2.784 = 2070\ W.$

(b) $I_{LV} = \frac{2200}{16\angle 60^\circ} = 137.5\angle{-60^\circ}\ A.$

Referred to HV side, $\left(a = \frac{11000}{2.2} = 5\right)$

$I'_{LV} = \frac{137.5}{5} = 27.50\angle{-60^\circ}\ A.$

$V_{HV} = 11000\angle 0^\circ + 27.5\angle{-60^\circ} \times (2.74 + j8.45)$



$= 11{,}239\angle 0.3^\circ\ V.$

$VR = \frac{11239 - 11000}{11000} \times 100\ \% = 2.17\ \%$

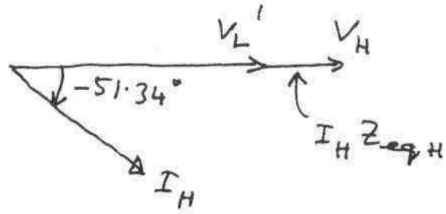
Solution Problem 5

(a)

$\theta_{eq} = \tan^{-1}\frac{5}{4} = 51.34^\circ$

For worst case VR $\rightarrow$ $\theta_2 = -51.34^\circ$

and V_L' and V_H are in phase.



$I_H = \frac{25000}{2300} = 10.87A$

$Z_{eq\,H} = \sqrt{4^2+5^2} = 6.4\,\Omega$

$I_H Z_{eq\,H} = 10.87 \times 6.4 = 69.6\,V$

$VR = \frac{69.6}{2300} \times 100\,\% = 3.03\,\%$

(b)

$P_{out} = 25 \times 0.85 = 21.25\,kW$

$P_{cu} = I_H^2 R_{eq\,H} = 10.87^2 \times 4 = 472.63\,W$

$P_{core} = \frac{230^2}{450} = 117.56\,W$

$Eff = \frac{21{,}250}{21{,}250 + 472.63 + 117.56} \times 100\% = 97.3\%$

(c)

$X = \sqrt{\frac{117.56}{472.63}} = 0.499$

$P_{cu} = P_{core} = 117.56\,W$

$P_{out} = 25 \times 0.499 = 12.475\,kW$

$Eff = \frac{12475}{12475 + 117.56 + 117.56} \times 100\% = 98.15\,\%$

Solution Problem 6

$$P_{out} = 10 \times 0.8 = 8\,KW$$

$$P_{core} = 100\,W, \quad P_{cu,FL} = 60 \times 2^2 = 240\,W$$

$$Eff = \frac{8000}{8000 + 100 + 240} \times 100\% = 95.92\%$$