ex. Transformer Equivalent Circuit

ex. Given a transformer rated 220 V_{rms} : 440 V_{rms} and 25 KVA at 60Hz. An open circuit test on the 220 V_{rms} side yields: $V_{oc} = 220\,V_{rms}$, $10\,A_{rms} = I_{oc}$ and $P_{oc} = 700W$. The short circuit test on the 220 V_{rms} side yields: $I_{SC} = 113.64\,A_{rms}$, $V_{SC} = 19\,V_{rms}$, and $P_{sc} = 1000\,W$. Determine the equivalent transformer circuit on the primary side and secondary side.

Open ckt

$$Y_E = \frac{I_{oc}}{V_{oc}} = \frac{10}{220} = 0.0\overline{45}\ S$$

$$\theta_{Z_E} = \cos^{-1}\left(\frac{P_{oc}}{V_{oc} I_{oc}}\right) = \cos^{-1}\left(\frac{700}{220(10)}\right)$$

$$= \cos^{-1}(0.3\overline{18}) = \underline{71.447^\circ}$$

$$\underline{pf = 0.3182 \text{ lagging}}$$

$$\Downarrow$$

$$\bar{Y}_E = 0.0\overline{45}\angle{-71.447^\circ}\ S = 0.01446281 - j0.04309226\ S$$

$$R_c = \frac{1}{0.01446} = 69.143\,\Omega \qquad X_m = \frac{1}{0.0431} = 23.206\,\Omega$$

$$\Rightarrow L_m = \frac{X_m}{2\pi(60)} = 61.56\,mH$$

ex. cont.

Short ckt

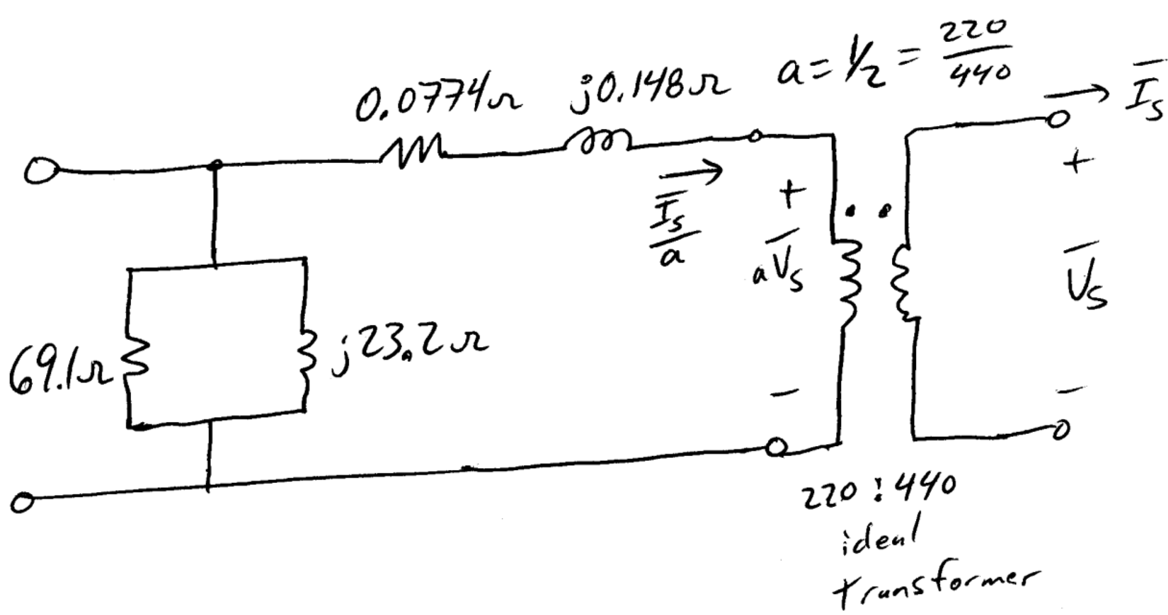
$$Z_{SE} = \frac{V_{sc}}{I_{sc}} = \frac{19}{113.64} = 0.16719465\ \Omega$$

$$\theta_{SE} = \cos^{-1}\left(\frac{P_{sc}}{V_{sc}I_{sc}}\right) = \cos^{-1}\left(\frac{1000}{19(113.64)}\right)$$

$$= \cos^{-1}(0.463143) = 62.4099^\circ$$

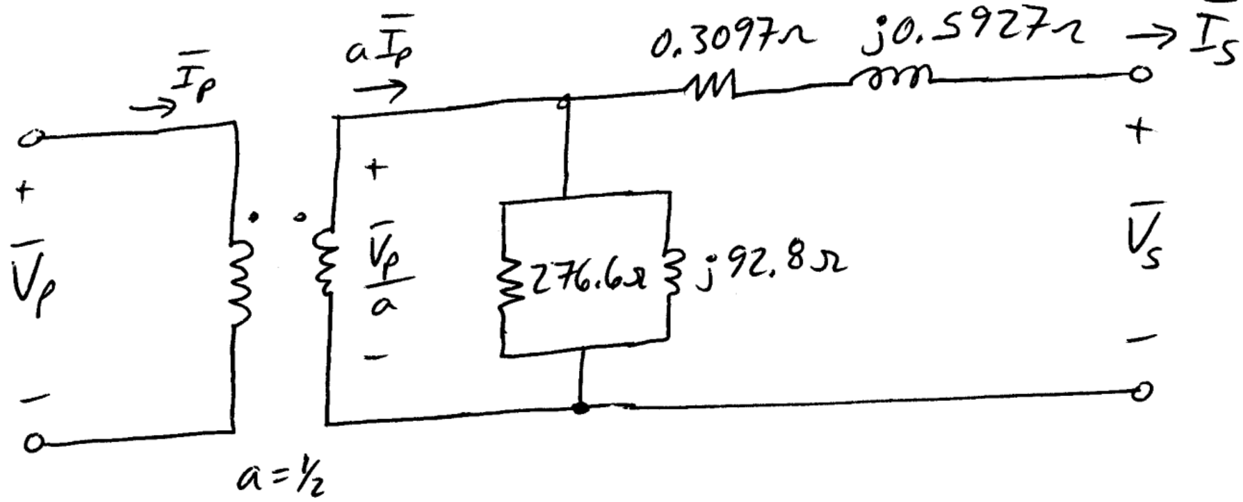
$$\bar{Z}_{SE} = 0.1672\angle 62.41^\circ\ \Omega = \underbrace{0.077435}_{R_{eq,P}} + j\underbrace{0.14818}_{X_{eq,P}}\ \Omega$$

Primary Approx. Equivalent Circuit



ex. cont.

To move/refer the impedances to the secondary side of the transformer, divide by a^2.
In this case, $a^2 = (1/2)^2 = 1/4$. So, dividing by a^2 is the same as multiplying by 4.



If the dc wire resistances are measured to be

$$R_{w,p} = 0.05\,\Omega \text{ and } R_{w,s} = 0.1\,\Omega.$$

Estimate R_p, R_s, X_p, and X_s as well as L_p and L_s.

Previously –

$$R_{eq,p} = 0.077435\,\Omega$$

$$X_{eq,p} = 0.14818\,\Omega$$

and $a = 1/2$

Assume that $\frac{R_p}{R_s} \simeq \frac{R_{w,p}}{R_{w,s}} = \frac{0.05}{0.1} = 1/2 = K_w$

Then $R_{eq,p} = R_p + a^2 R_s = K_w R_s + a^2 R_s$

$$0.077435 = 1/2\, R_s + (1/2)^2 R_s$$

$$\hookrightarrow \underline{\underline{R_s = 0.103247\ \Omega}}$$

$$R_p = K_w R_s = 1/2\, R_s = \underline{\underline{0.051623\ \Omega}}$$

Similarly, assume $\frac{X_p}{X_s} = K_w$

Then $X_{eq,p} = X_p + a^2 X_s = K_w X_s + a^2 X_s$

$$0.14818 = 1/2\, X_s + (1/2)^2 X_s$$

$$\hookrightarrow \underline{\underline{X_s = 0.19757\ \Omega}} \Rightarrow \underline{\underline{L_s = \frac{X_s}{2\pi(60)} = 0.524\,mH}}$$

$$X_p = K_w X_s = \underline{\underline{0.098787\ \Omega}} \Rightarrow \underline{\underline{L_p = 0.262\,mH}}$$