

example- Transformer Equivalent Circuit

Given: Transformer is rated $220 \text{ V}_{\text{rms}} : 440 \text{ V}_{\text{rms}}$ and 25 kVA at 60 Hz.

$\Rightarrow$ Calculate rated current on the $220 \text{ V}_{\text{rms}}$ side as $25,000/220 = \underline{113.636 \text{ A}_{\text{rms}}}$ and turns ratio $a = 220/440 = 0.5$.

With ohmmeter: $R_{w,P} = 0.05 \Omega$ and $R_{w,S} = 0.1 \Omega$.

Open circuit test ($220 \text{ V}_{\text{rms}}$ side): $V_{\text{oc}} = 220 \text{ V}_{\text{rms}}$, $I_{\text{oc}} = 10 \text{ A}_{\text{rms}}$, and $P_{\text{oc}} = 700 \text{ W}$.

Short circuit test ($220 \text{ V}_{\text{rms}}$ side): $V_{\text{sc}} = 19 \text{ V}_{\text{rms}}$, $I_{\text{sc}} = 113.64 \text{ A}_{\text{rms}}$, and $P_{\text{sc}} = 1 \text{ kW}$.

Find equivalent transformer circuits for both the primary and secondary sides.

Open circuit test

$$\text{Per (3-50), } Y_E = |Y_E| = \frac{I_{\text{oc}}}{V_{\text{oc}}} = \frac{10}{220} = 0.045 \text{ S.}$$

$$\text{Per (3-51), } \text{PF}_{\text{oc}} = \frac{P_{\text{oc}}}{V_{\text{oc}} I_{\text{oc}}} = \frac{700}{220(10)} = 0.318 \text{ lagging.}$$

$$\text{Per (3-52), } \theta = \theta_{ZE} = \cos^{-1} \left(\frac{P_{\text{oc}}}{V_{\text{oc}} I_{\text{oc}}} \right) = \cos^{-1} (0.318) = 71.447^\circ.$$

Per (3-53), put the magnitude and phase together to get

$$\underline{\bar{Y}_E = Y_E \angle -\theta_{ZE} = 0.045 \angle -71.447^\circ \text{ S} = 0.01446281 - j0.04309226 \text{ S.}}$$

$$\text{Per (3-49), } \bar{Y}_E = \frac{1}{R_C} - j \frac{1}{X_M} = 0.01446281 - j0.04309226 \text{ S. Calculate:}$$

$$\underline{R_C = \frac{1}{0.01446281} = 69.143 \Omega} \quad \text{and} \quad \underline{X_M = \frac{1}{0.04309226} = 23.206 \Omega}$$

$$\Rightarrow \underline{L_M = \frac{X_M}{\omega} = \frac{23.206}{2\pi(60)} = 61.56 \text{ mH.}}$$

Short circuit test

$$\text{Per (3-54), } Z_{SE} = |Z_{SE}| = \frac{V_{sc}}{I_{sc}} = \frac{19}{113.64} = 0.16719465 \, \Omega.$$

$$\text{Per (3-55), } PF_{sc} = \frac{P_{sc}}{V_{sc} I_{sc}} = \frac{1000}{19(113.64)} = 0.463 \text{ lagging.}$$

$$\text{Per (3-52), } \theta = \theta_{SE} = \cos^{-1} \left(\frac{P_{sc}}{V_{sc} I_{sc}} \right) = \cos^{-1} \left(\frac{1000}{19(113.64)} \right) = 62.4099^\circ.$$

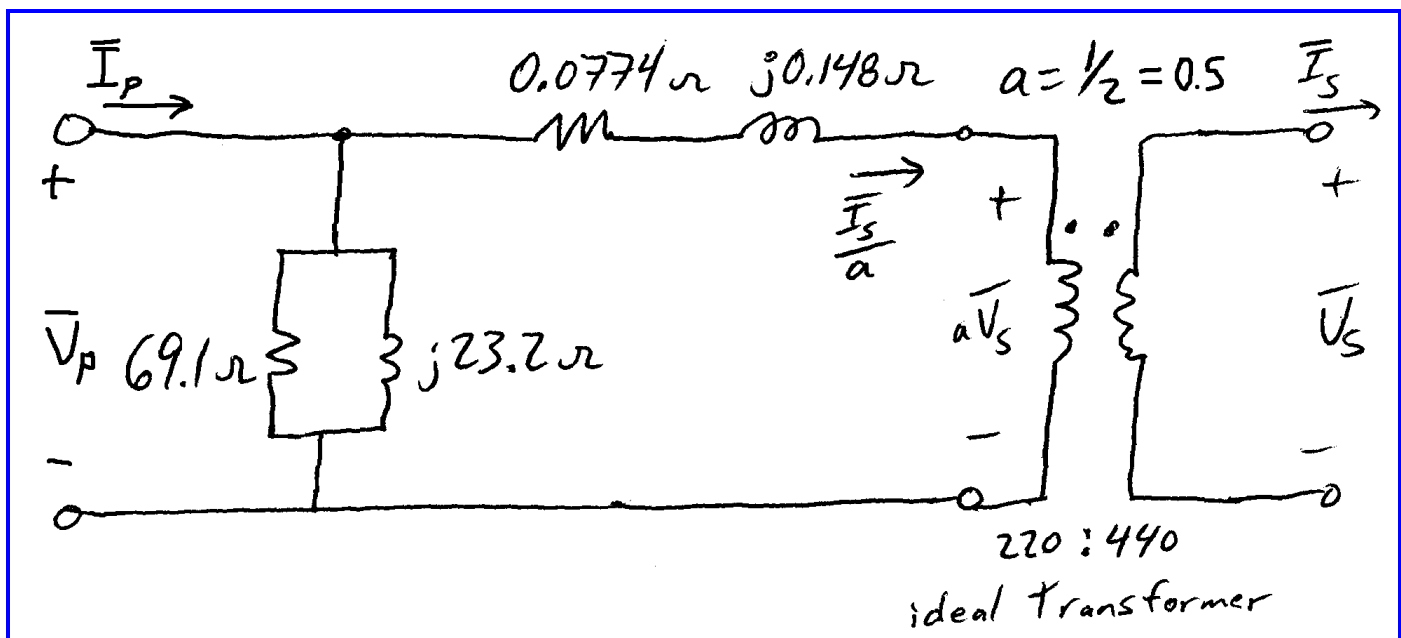
Per (3-57), put the magnitude and phase together to get

$$\bar{Z}_{SE} = Z_{SE} \angle \theta_{SE} = 0.16719465 \angle 62.4099^\circ \, \Omega = 0.077435 + j0.14818 \, \Omega.$$

$$\text{Per (3-58), } \bar{Z}_{SE} = 0.077435 + j0.14818 \, \Omega = R_{eq,p} + jX_{eq,p}.$$

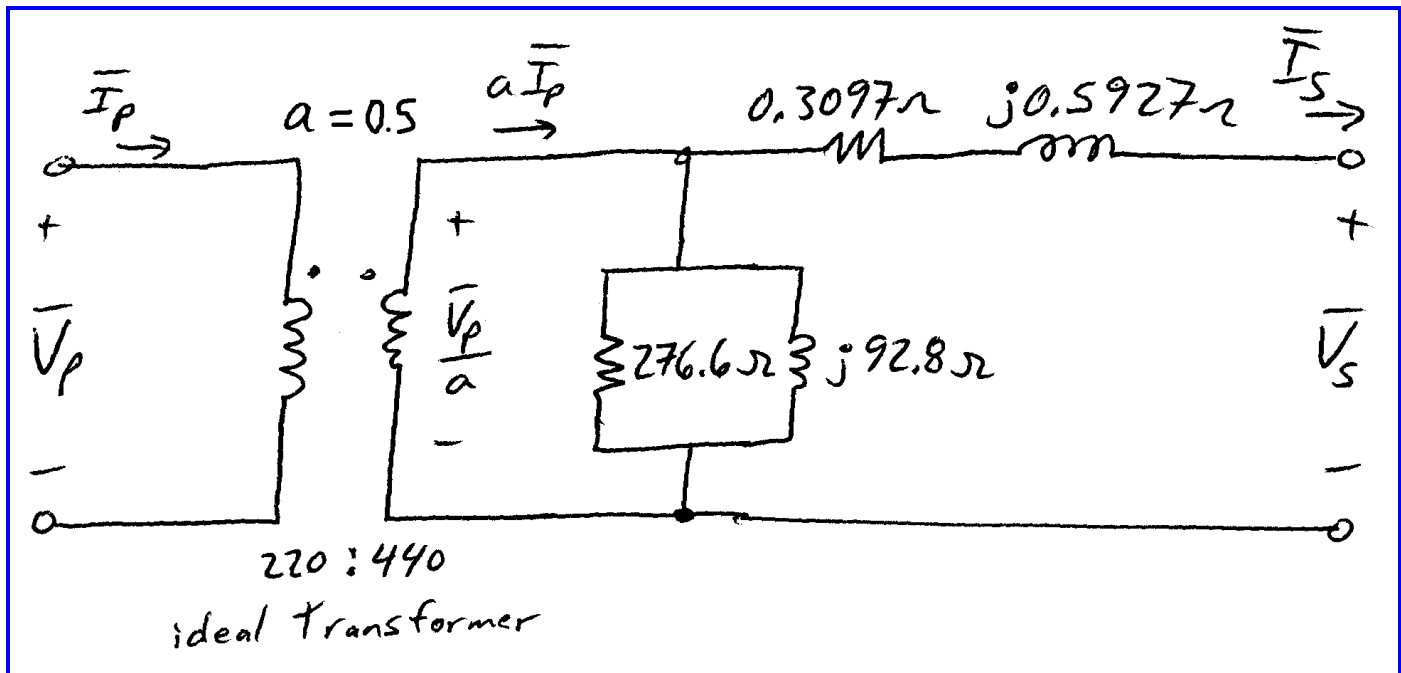
$$\Rightarrow \underline{R_{eq,p} = 0.077435 \, \Omega} \quad \text{and} \quad \underline{X_{eq,p} = 0.14818 \, \Omega}.$$

Approximate Primary Equivalent Circuit



To move/refer impedances to the secondary side of the transformer, use (3-17) $Z_L = Z_L' / a^2$. Here, $a^2 = (0.5)^2$, so $Z_L = 4 Z_L'$, i.e., multiply all impedances by 4.

Approximate Secondary Equivalent Circuit



Last, estimate R_p , X_p , R_s , and X_s as well as L_p and L_s by assuming that

$$\frac{R_p}{R_s} = \frac{R_{w,P}}{R_{w,S}} = \frac{0.05}{0.1} = 0.5 = k_w \text{ and } \frac{X_p}{X_s} = \frac{R_{w,P}}{R_{w,S}} = k_w = 0.5.$$

$$\text{Then, } R_{eq,P} = R_p + a^2 R_s = k_w R_s + a^2 R_s \Rightarrow 0.077435 = 0.5 R_s + 0.5^2 R_s.$$

$$\text{Solving, } \underline{R_s = 0.103247 \Omega} \text{ and } R_p = k_w R_s = 0.5(0.103247) \Rightarrow \underline{R_p = 0.051623 \Omega}.$$

$$\text{Similarly, } X_{eq,P} = X_p + a^2 X_s = k_w X_s + a^2 X_s \Rightarrow 0.14818 = 0.5 X_s + 0.5^2 X_s.$$

$$\text{Solving, } \underline{X_s = 0.19757 \Omega} \text{ and } X_p = k_w X_s = 0.5(0.19757) \Rightarrow \underline{X_p = 0.098787 \Omega}.$$

$$\Rightarrow \underline{L_s = \frac{X_s}{\omega} = \frac{0.19757}{2\pi(60)} = 0.524 \text{ mH}} \text{ and } \underline{L_p = \frac{X_p}{\omega} = \frac{0.098787}{2\pi(60)} = 0.262 \text{ mH}}.$$