

example- Transformer Per-Unit Equivalent Circuit

Take equivalent transformer circuit from previous example and express on a per-unit basis.

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

$\Rightarrow$ Calculate turns ratio $a = 220/440 = 0.5$.

From prior example:

Primary Side:

$$R_{C,P} = 69.143 \, \Omega, X_{M,P} = 23.206 \, \Omega, R_{eq,P} = 0.077435 \, \Omega, \& X_{eq,P} = 0.14818 \, \Omega.$$

Secondary Side:

$$R_{C,S} = 276.572 \, \Omega, X_{M,S} = 92.824 \, \Omega, R_{eq,S} = 0.30974 \, \Omega, \& X_{eq,S} = 0.59272 \, \Omega.$$

Choose: $S_{\text{base}} = 25 \text{ kVA}$ and $V_{\text{base}} = 440 \text{ V}_{\text{rms}}$ (secondary side).

Then: $I_{\text{base}} = S_{\text{base}} / V_{\text{base}} = 2500 / 440 \text{ V}_{\text{rms}} \Rightarrow I_{\text{base}} = 56.8181 \text{ A}_{\text{rms}}$.

Per (3-61), $Z_{\text{base}} = V_{\text{base}} / I_{\text{base}} = 440 / 56.81 \Rightarrow Z_{\text{base}} = 7.744 \, \Omega$.

The per-unit **secondary** equivalent circuit values are:

$$R_{C,S,pu} = R_{C,S} / Z_{\text{base}} = 276.572 / 7.744 \quad \Rightarrow \quad R_{C,S,pu} = 35.71 \text{ (low),}$$

$$X_{M,S,pu} = X_{M,S} / Z_{\text{base}} = 92.824 / 7.744 \quad \Rightarrow \quad X_{M,S,pu} = 11.98,$$

$$R_{eq,S,pu} = R_{eq,S} / Z_{\text{base}} = 0.30974 / 7.744 \quad \Rightarrow \quad R_{eq,S,pu} = 0.0400 \text{ (high),}$$

$$\text{and } X_{eq,S,pu} = X_{eq,S} / Z_{\text{base}} = 0.59272 / 7.744 \quad \Rightarrow \quad X_{eq,S,pu} = 0.07654.$$

How about using the **primary side**?

Choose: $S_{\text{base}} = 25 \text{ kVA}$ and $V_{\text{base}} = 220 \text{ V}_{\text{rms}}$ (primary side).

Then: $I_{\text{base}} = S_{\text{base}} / V_{\text{base}} = 2500 / 220 \text{ V}_{\text{rms}} \Rightarrow I_{\text{base}} = 113.6363 \text{ A}_{\text{rms}}$.

Per (3-61), $Z_{\text{base}} = V_{\text{base}} / I_{\text{base}} = 220 / 113.6363 \Rightarrow Z_{\text{base}} = 1.936 \, \Omega$.

The per-unit primary equivalent circuit values are:

$$R_{C,P,pu} = R_{C,P} / Z_{base} = 69.143 / 1.936 \Rightarrow \underline{R_{C,P,pu} = 35.71},$$

$$X_{M,P,pu} = X_{M,P} / Z_{base} = 23.206 / 1.936 \Rightarrow \underline{X_{M,P,pu} = 11.98},$$

$$R_{eq,P,pu} = R_{eq,P} / Z_{base} = 0.077435 / 1.936 \Rightarrow \underline{R_{C,P,pu} = 0.0400},$$

$$\text{and } X_{eq,P,pu} = X_{eq,P} / Z_{base} = 0.14818 / 1.936 \Rightarrow \underline{X_{eq,P,pu} = 0.07654}.$$

Note that we got the same per-unit equivalent circuit!

Per-Unit Primary/Secondary Equivalent Circuit

