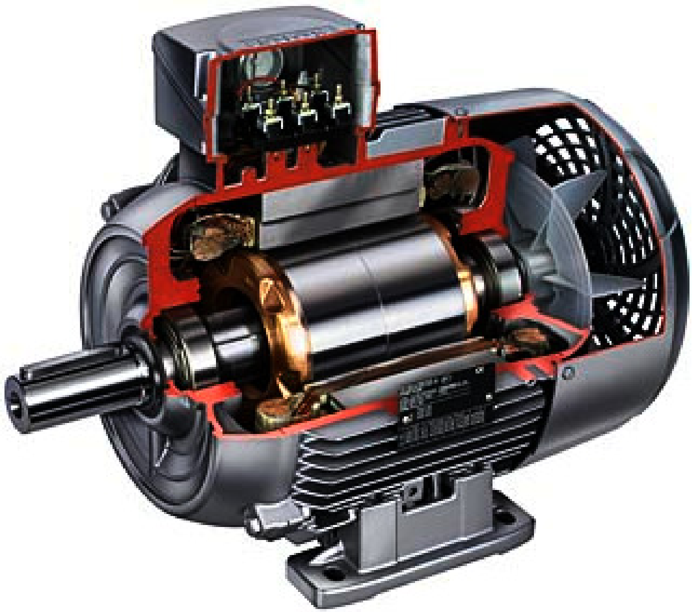
EEE 3352

Electromechanics & Electrical Machines



Lecture 4: Examples

Dr A Zulu

Example 4.1:

- A 220/100-V transformer has a total resistance of 2 Ω and a total leakage reactance of 3 Ω both referred to the primary.
- The secondary current is 10 A.

$$V_{1rated} = 100 \text{ V},\ V_{2rated} = 220 \text{ V},\ R_T = 2\ \Omega,\ X_T = 3\ \Omega,\ I_2 = 10 \text{ A}$$

$$I_2^{'} = I_2 \frac{N_1}{N_2} = 10 \times \frac{100}{220} = 4.5 \text{ A}$$

$$Z_T = \sqrt{R_T^{'2} + X_T^{'2}} = \sqrt{2^2 + 3^2} = 3.6\ \Omega$$

$$\phi_T = \tan^{-1}\frac{X_T}{R_T} = \tan^{-1}\frac{3}{2} = 56.3^\circ$$

$$\text{Reg} = \frac{I'_2 Z_T}{V_1}\cos(\phi_T - \phi_L)$$

- Find the regulation at zero power factor lag

$$\phi_L = 90^\circ$$

$$\text{Reg} = \frac{I'_2 Z_T}{V_1}\cos(\phi_T - \phi_L)$$

$$\text{Reg} = \frac{4.5\times3.6}{220}\cos\left(56.3^\circ - 90^\circ\right) = \underline{\underline{0.061}}$$

- Find the regulation at unity power factor

$$\phi_L = 0^\circ$$

$$\text{Reg} = \frac{I'_2 Z_T}{V_1} \cos(\phi_T - \phi_L)$$

$$\text{Reg} = \frac{4.5 \times 3.6}{220} \cos\left(56.3^\circ - 0^\circ\right) = \underline{\underline{0.041}}$$

- Find the regulation at zero power factor lead

$$\phi_L = -90^\circ$$

$$\text{Reg} = \frac{I'_2 Z_T}{V_1}\cos\left(\phi_T - \phi_L\right)$$

$$\text{Reg} = \frac{4.5\times 3.6}{220}\cos\left(56.3^\circ - (-90^\circ)\right) = -\underline{\underline{0.061}}$$

- Find the power factor which gives maximum regulation

$$\phi_L = \phi_T = 56.3^\circ$$

$$\text{p.f.} = \cos\phi_L = \cos 56.3^\circ = \underline{\underline{0.56 \text{ lag}}}$$

- Find the maximum regulation

$$\text{Reg}_{\max} = \frac{I'_2 \, Z_T}{V_1}$$

$$\text{Reg}_{\max} = \frac{4.5 \times 3.6}{220} = \underline{\underline{0.0736}}$$

- Find the power factor which gives zero regulation

$$\phi_L - \phi_T = 90^\circ$$

$$\phi_L = 90^\circ + \phi_T = 90^\circ + 56.3^\circ$$

$$\text{p.f.} = \cos\phi_L = \cos 146.3^\circ = -\underline{\underline{0.832}} \ \text{ or } \ \underline{\underline{0.832 \text{ lead}}}$$

Example 4.2

- A single-phase transformer is rated at 10 kVA, 240/100 V
- When the secondary terminals are open-circuited and the primary winding is supplied at normal voltage, the input current is 2.6 A at a power factor of 0.3 lag

$$V_{1rated} = 240 \text{ V},\ V_{2rated} = 100 \text{ V},\ S_{rated} = 10 \text{ kVA}$$

$$V_1 = 240\angle 0^\circ \text{ V}$$

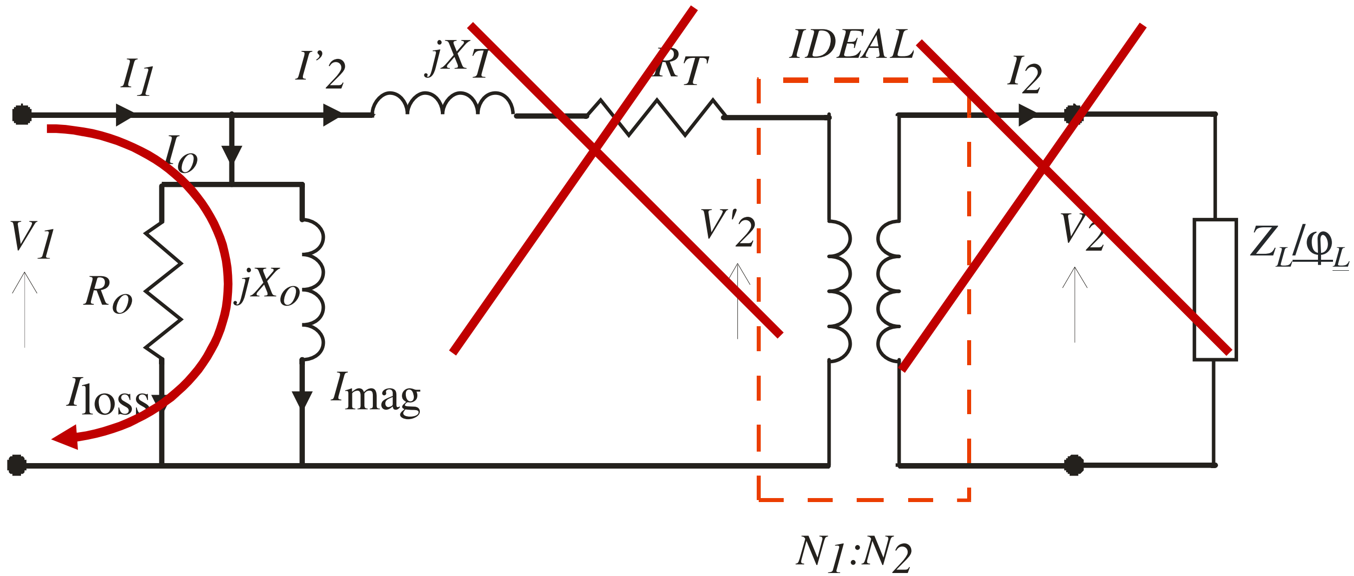
$$\theta_o = \cos^{-1} 0.3 = 72.5^\circ$$

Open circuit

$$I_2 = 0 = I_2^{'}$$

$$|I_1| = |I_o| = 2.6 \text{ A}$$

$$I_o = 2.6\angle -72.5^\circ \text{ A} = 0.78 - j2.48 \text{ A} = \left|I_{Loss}\right| + j\left|\text{I}_{\text{mag}}\right|$$



$$R_o = \frac{V_1}{I_{Loss}} = \frac{240}{0.78} = 308\ \Omega$$

$$X_o = \frac{V_1}{I_{mag}} = \frac{240}{2.48} = 97\ \Omega$$

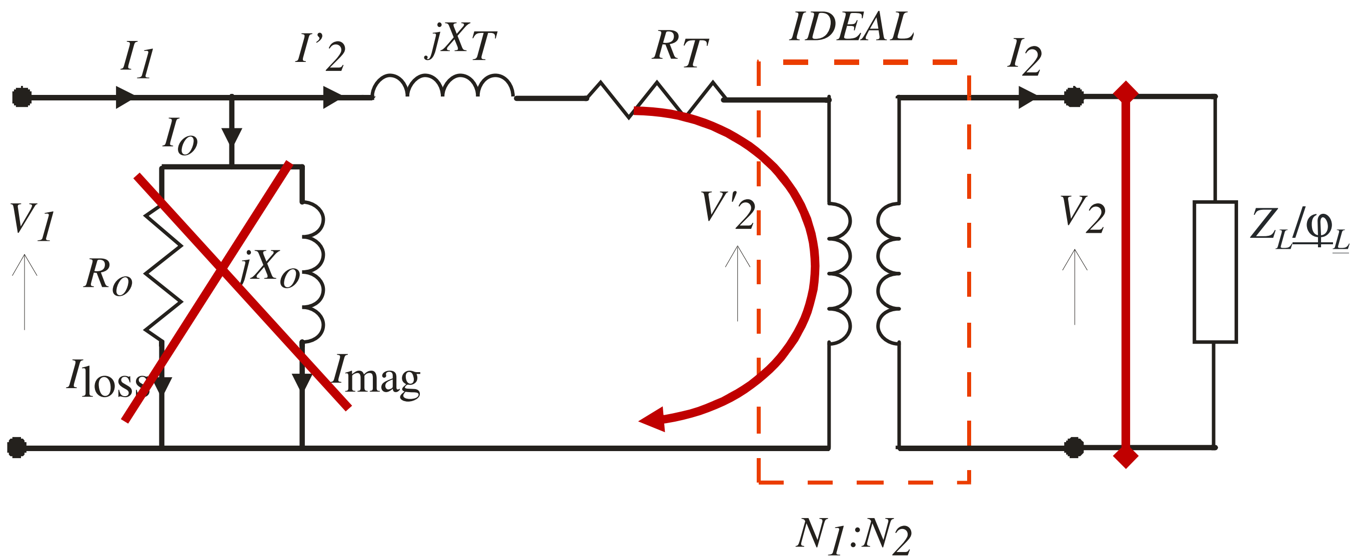
- When the secondary terminals are short-circuited, a voltage of 18 V applied to the primary causes the full-load current to flow in the secondary, the power input to the primary being 240 W.

$$V_1 = 18\angle 0^\circ \text{ V}$$

$$P_1 = 240 \text{ W}$$

$$I_1 = I_{FL} = \frac{S_r}{V_{1rated}} = \frac{10\times 10^3}{240} = 41.7 \text{ A}$$

Short circuit



$$I_1^2 R_T = P \rightarrow R_T = \frac{P}{I_1^2} = \frac{240}{41.7^2} = 0.14\ \Omega$$

$$Z_T = \frac{V_1}{I_1} = \frac{18}{41.7} = 0.43\ \Omega$$

$$Z_T^2 = R_T^2 + X_T^2 \rightarrow X_T = \sqrt{Z_T^2 - R_T^2} = \sqrt{0.43^2 - 0.14^2} = 0.41\ \Omega$$

- Calculate, at full load unity power factor, the:
  - regulation

$$\text{Reg}=\frac{I'_2 Z_T}{V_1}\cos(\phi_T-\phi_L)$$

$$I_{2FL}=I_{2rated}=\frac{S_r}{V_{2r}}=\frac{10\times10^3}{100}=100\ \text{A}$$

$$I_2^{'}=\frac{N2}{N1}I_2=\frac{100}{240}\times100=41.7\ \text{A}$$

$$Z_T=0.43\ \Omega \quad \Bigg| \quad \phi_T=\tan^{-1}\frac{X_T}{R_T}=\tan^{-1}\frac{0.41}{0.14}=71.1^\circ\ \Omega \quad \Bigg| \quad \phi_L=0^\circ$$

$$\text{Re}\,g = \frac{I'_2 Z_T}{V_1}\cos\left(\phi_T - \phi_L\right)$$

$$= \frac{41.7 \times 0.43}{240}\cos\left(71.1^\circ - 0^\circ\right)$$

$$= 0.024$$

$$\underline{\underline{= 2.4\%}}$$

- Calculate, at full load unity power factor, the:
  - efficiency

$$\eta = \frac{xS_r \cos\phi_L}{xS_r \cos\phi_L + P_{Fe} + x^2 P_{CuFL}}$$

$$x = 1$$

$$P_{\mathrm{CuFL}} = \text{ power at full-load short circuit power } = 240 \text{ W}$$

$$\text{or } P_{\mathrm{CuFL}} = I_{\mathrm{2FL}}^{'2} R_T = 41.7^2 \times 0.14 = 243 \text{ W (round off error in } R_T\text{)}$$

$$P_{Fe} = \text{ power at no-load with open circuit voltage}$$

$$= V_1 I_o \times \text{p.f.} = 240 \times 2.6 \times 0.3 = 187.2 \text{ W}$$

$$\eta = \frac{xS_r \cos\phi_L}{xS_r \cos\phi_L + P_{Fe} + x^2 P_{CuFL}}$$

$$= \frac{1\times(10\times10^3)\times1}{1\times(10\times10^3)\times1+187.2+1^2\times240}$$

$$= 0.959$$

$$\underline{\underline{= 95.9\%}}$$