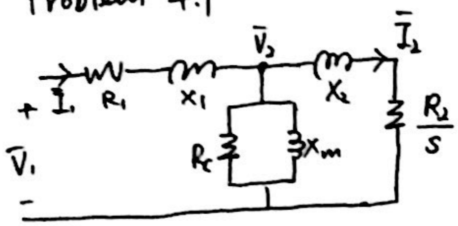
ECE 431.   HW 4.   SP 2020.

Problem 4.1



a) : $Z_{in} = R_1 + jx_1 + [R_c \,//\, jx_m \,//\, (\frac{R_2}{s} + jx_2)]$

$= 0.2 + j1 + [300 \,//\, j80 \,//\, (\frac{0.24}{0.035} + j0.8)]$

$= 6.73 + j2.3 \ \Omega$

$\bar{I}_1 = \frac{460/\sqrt{3}}{Z_{in}} = \underline{37.3 \angle -18.87^\circ \ A}.$

$S = 3\bar{V}_1 \bar{I}_1^* = 3 \left(\frac{460}{\sqrt{3}}\right)(37.3 \angle 18.87^\circ) = 29719 \angle 18.87^\circ \ VA.$

$\underline{P = 28.1 \text{ kW.} \quad Q = 9.61 \text{ kVAR.}}$

b). $\bar{V}_2 = \bar{V}_1 - \bar{I}_1 (R_1 + jx_1) = \frac{460}{\sqrt{3}} - (37.3 \angle -18.87^\circ)(0.2 + j1) = 248.6 \angle -7.60^\circ \ V.$

$\bar{I}_2 = \frac{\bar{V}_2}{\frac{R_2}{s} + jX_2} = \frac{248.6 \angle -7.60^\circ}{\frac{0.24}{0.035} + j0.8} = 36.02 \angle -14.25^\circ \ A.$

$P_{out} = 3\,|I_2|^2 R_2 \left(\frac{1-s}{s}\right) - P_{fw} = 3\,(36.02)^2\, 0.24 \left(\frac{1-0.035}{0.035}\right) - 300 = 25.46 \text{ kW.}$

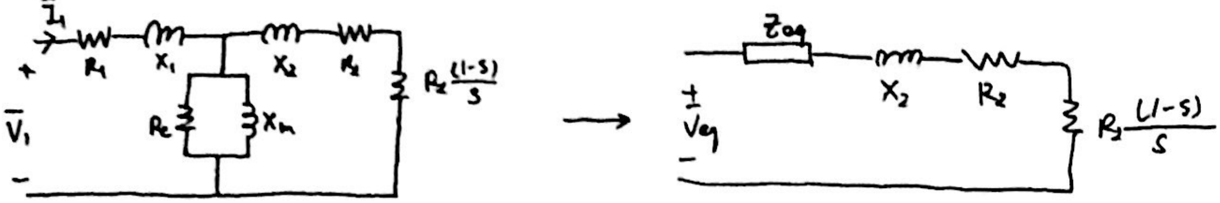
$P_{rotor} = 3\,|I_2|^2 R_2 = 3\,(36.02)^2\, 0.24 = 934 \ W.$

c) $P_{core} = 3\frac{|V_2|^2}{R_c} = 3\,\frac{(248.6)^2}{300} = 618.02 \ W.$

$\eta = \frac{P_{out}}{P_{in}} \times 100\% = \frac{25.46}{28.1} \times 100\% = 90.6\ \%$

Scanned by CamScanner

Problem 4.2.



$N_{op} = 1170\text{ rpm} \Rightarrow N_s = 1200\text{ rpm},\ P = 6.$

$$\bar{V}_{eq} = \bar{V}_1 \left(\frac{R_c /\!/ jX_m}{R_1 + jX_1 + R_c /\!/ jX_m}\right) = \frac{480}{\sqrt{3}}\left(\frac{300 /\!/ j100}{0.5 + j + 300/\!/j100}\right) = 273.93 \angle 0.94^\circ\ V.$$

$$Z_{eq} = R_c /\!/ jX_m /\!/ (R_1 + jX_1) = 300 /\!/ j100 /\!/ (0.5 + j) = 0.493 + j0.989\ \Omega.$$

a) $$T_{em} = \frac{3P}{2W_e}\ \frac{V_{eq}^2\,(R_2/s)}{(R_{eq} + \frac{R_2}{s})^2 + (X_{eq} + X_2)^2}$$

$$T_{start} = T_{em}\big|_{s=1} = \frac{3\times 6}{2\cdot 120\pi}\ \frac{273.93^2\,(0.5)}{(0.493+0.5)^2 + (0.989+1)^2} = \underline{181.24\ Nm.}$$

$$T_{load}\big|_{W_m=0} = 150\ Nm$$

$\because T_{start} > T_{load}$ $\therefore$ the motor will start.

b) $$\bar{I}_1 = \frac{\bar{V}_1}{R_1 + jX_1 + R_c /\!/ jX_m /\!/ (\frac{R_2}{s} + jX_2)}$$

$$\bar{I}_{start} = \bar{I}_1\big|_{s=1} = \frac{480/\sqrt{3}}{0.5 + j + 300/\!/j100/\!/(0.5+j)} = \underline{124.65 \angle -63.4^\circ A.}$$

c) $$T_{load} = 150 + 0.5\,W_m = 150 + 0.5\left(\frac{2W_e(1-s)}{P}\right)$$

$$T_{em} = \frac{3\times 6}{2\times 120\pi}\ \frac{273.93^2\,(0.5/s)}{(0.493 + \frac{0.5}{s})^2 + (0.989+1)^2} = 150 + 0.5\left(\frac{2\times 120\pi}{6}(1-s)\right) = T_{load}$$

$\Rightarrow \underline{s = 7.1\%}$

$n = n_s(1-s) = 1200\,(1 - 0.071) = \underline{1114.8\ \text{rpm}}.$

d) $$T_{em} = T_{load} = 150 + 0.5\left(\frac{2\times 120\pi}{6}(1 - 0.071)\right) = 208.37\ Nm.$$

$$W_m = \frac{2W_e(1-s)}{P} = \frac{2\times 120\pi(1-0.071)}{6} = 116.74\ \text{rad/s}.$$

$P_{out} = T_{em} W_m = 24.3\ kW.$

$$\bar{I}_1 = \bar{I}_1\big|_{s=0.071} = \frac{480/\sqrt{3}}{0.5 + j + 300/\!/j100/\!/(0.5/0.071 + j)} = 36.42 \angle -18.39^\circ A.$$

$\bar{S}_{3\phi} = 3\bar{V}_1\bar{I}_1^* = 28.73 + j9.55\ kVA.$

$\eta = \frac{P_{out}}{P_{in}} = \frac{24.3}{28.73} = \underline{84.6\%}$

e) : P.F. $= \cos(18.39^\circ) = 0.949$ lagging.