Exam I Solutions Spring 1991

#1 (a) $|\bar{S}_{3\phi}| = \sqrt{3} \times 200 \times 10 = 2000\sqrt{3}$ VA

$\measuredangle \bar{S}_{3\phi} = +\cos^{-1}.8 = +36.87^\circ$ $\qquad \bar{S}_{3\phi} = P_{3\phi} + j\,Q_{3\phi}$

$Q_{3\phi} = 2000\sqrt{3} \sin 36.87^\circ = 1200\sqrt{3}$ $\qquad Q_{1\phi} = 400\sqrt{3}$

Each capacitor must supply $Q_{1\phi}$ so: $400\sqrt{3} = 200^2 \times 2\pi 60 C$

$\boxed{C = 45.9\ \mu F}$

(b) At unity power factor, $|\bar{S}_{3\phi}| = P_{3\phi} = 2000\sqrt{3} \times 0.8$

$\boxed{|\bar{I}| = \frac{1600\sqrt{3}}{\sqrt{3}\,200} = 8A}$

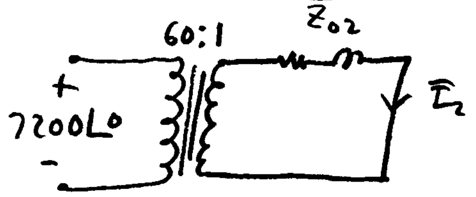
#2 (a) $|\bar{Z}_{02}| = \frac{5}{83.3} = .06\ \Omega$ $\qquad V_{2_{rated}} = 120v$ $\qquad I_{2_{rated}} = 83.3A$

$\%Z = \frac{.06}{120/83.3} \times 100$ $\qquad \boxed{\%Z = 4.165}$

(b) $I_{2_{rated}} = 83.3A$ $\qquad \frac{\%Z}{100} = .04165$

$\boxed{|\bar{I}_{2_{sc}}|_{\text{rated voltage}} = \frac{83.3}{.04165} = 2000A}$

OR



$|\bar{I}_2| = \frac{\frac{1}{60}7200}{.06}$

#3 Using rated hp. as full load,

$$T_{FL} = \frac{2 \times 746}{1180 \frac{2\pi}{60}} = 12.07 \text{ NM} \qquad s_{FL} = \frac{1200-1180}{1200} = .01667$$

Estimate using linear T vs slip $\quad T_{FL} \approx \dfrac{3 \times \left(\frac{230}{\sqrt{3}}\right)^2 .01667}{\frac{2\pi 60}{3} r_r'} \overset{\text{must}}{=} 12.07$

This gives $r_r' \approx .58\,\Omega \qquad \underset{\substack{\text{rotor}\\ \text{start}\\ (s=1)}}{P_{TO}} = 3 \times |\bar{I}_r'|^2 r_r'$

$$T_{start} = \frac{3 \times |\bar{I}_r'|^2 .58}{\frac{2\pi 60}{3}} \overset{\text{must}}{=} 8 \qquad |\bar{I}_r'| = 24A$$

$$\boxed{\text{Estimate } |\bar{I}_{as}| \approx |\bar{I}_r'| \approx 24A}$$

#4 when supply phase sequence is reversed $\quad s = \dfrac{1200-(-1200)}{1200} = 2$

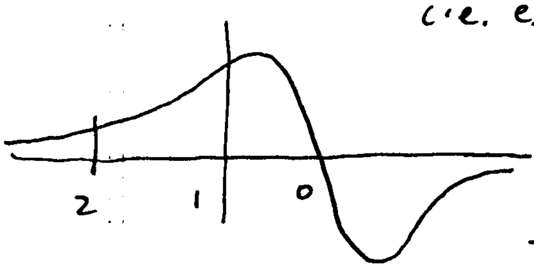
(a) A crude estimate would neglect everything except r_r'

$$\frac{230}{\sqrt{3}}\angle 0 \;\; \frac{0.7}{2} \Rightarrow \underset{\text{reversal}}{|\bar{I}_{as}|} = \frac{230/\sqrt{3}}{0.7/2} = 379 \text{ A}$$

$$\underset{\substack{\text{shaft}\\ \text{reversal}}}{T_{TO}} = \frac{3 \times \left(\frac{230}{\sqrt{3}}\right)^2 \times 2}{\left(\frac{2\pi 60}{3}\right) 0.7} = 1200 \text{ NM}$$

(b) These are both very high estimates. The actual current and torque would be limited by $r_s \; x_{ls} \; x_{lr}'$

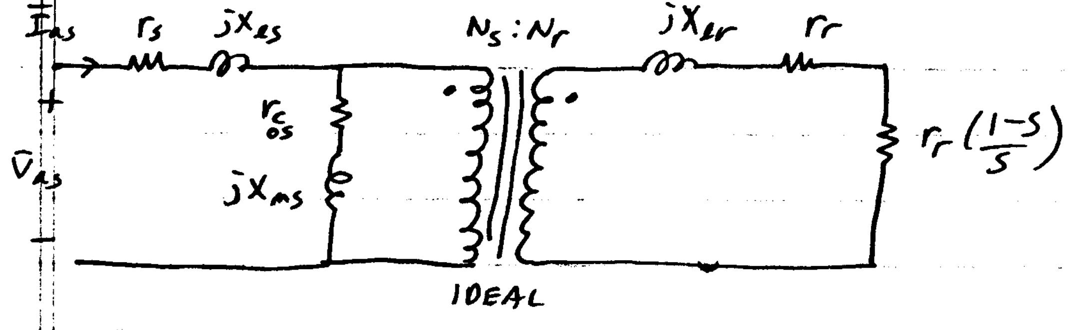
i.e. estimate $r_s \approx 0.7 \quad x_{ls} \approx x_{lr}' \approx 1\,\Omega$ (about same as r_r' at least)



$$|\bar{I}_{as}| = \frac{230/\sqrt{3}}{\sqrt{(0.7+\frac{0.7}{2})^2 + 2^2}} = 58 \text{ A}$$

(probably still too high)

$$\underset{\substack{\text{shaft}\\ \text{reversal}}}{T_{TO}} = \frac{3 \times 58^2}{\frac{2\pi 60}{3}} \left(\frac{0.7}{2}\right) = 28 \text{ NM}$$



$f_r = s f_s$ $\qquad$ $s = \dfrac{RPM_{sync} - RPM_{shaft}}{RPM_{sync}}$ $\qquad$ $P = \#\text{poles/phase}$

$$T_{\substack{TO\\shaft}} = \frac{P_{\substack{TO\\shaft}}}{\omega_{shaft}} = \frac{P_{\substack{TO\\rotor}}}{\omega_s} \approx \frac{3\,|\bar{V}_{as}|^2 r_r' s}{\underbrace{\omega_s}_{\text{m.r./s.}}\left[(s r_s + r_r')^2 + s^2(X_{ls} + X_{lr}')^2\right]} \quad \begin{pmatrix}\text{Neglects}\\ r_{cos} + jX_{ms}\end{pmatrix}$$

$$s_{\substack{max\\T}} \approx \frac{r_r'}{\sqrt{r_s^2 + (X_{ls} + X_{lr}')^2}} \qquad T_{max} \approx \frac{\frac{3}{2}\,|\bar{V}_{as}|^2}{\omega_s\left[r_s + \sqrt{r_s^2 + (X_{lr}' + X_{ls})^2}\right]} \quad \begin{pmatrix}\text{Neglects}\\ r_{cos} + jX_{ms}\end{pmatrix}$$

$$RPM_{\substack{\text{stator mmf}\\\text{w.r.t. stator}}} = \frac{120 f_s}{P} = RPM_{sync}$$

$$RPM_{\substack{\text{rotor mmf}\\\text{w.r.t. rotor}}} = \frac{120 f_r}{P}$$

$$\boxed{\begin{array}{l} \%Z = \dfrac{|\bar{Z}_{ol}|}{V_{rated}/I_{rated}} \times 100 \\[2ex] \%VR = \dfrac{|\bar{V}_{load_{NL}}| - |\bar{V}_{load_{FL}}|}{|\bar{V}_{load_{FL}}|} \times 100 \end{array}} \left.\right\} \text{with } |\bar{V}_{source}| \text{ fixed}$$

$$RPM_{\substack{\text{rotor mmf}\\\text{w.r.t. stator}}} = RPM_{\substack{\text{rotor mmf}\\\text{w.r.t. rotor}}} + RPM_{shaft} = \frac{120 f_r}{P} + RPM_{shaft}$$

$$= \frac{120 s f_s}{P} + RPM_{shaft} = \left(\frac{RPM_{sync} - \cancel{RPM_{shaft}}}{\cancel{RPM_{sync}}}\right)\cancel{RPM_{sync}} - \cancel{RPM_{shaft}}$$

$$= RPM_{sync.}$$