8-5

(a) $n_s = \frac{n}{1-s} = \frac{855}{(1-0.05)} = 900$ rpm

(b) $p = \frac{120f}{n_s} = \frac{(120)(60)}{900} = 8$ poles

(c) $f_r = sf = (0.05)(60) = 3$ Hz

8-11 Refer to Fig. 8-8

(a) $n_s = \frac{120f}{P} = \frac{(120)(60)}{4} = 1800$ rpm

$n = (1-s)n_s = (1-0.05)(1800) = 1710$ rpm

(b) $V_1 = \frac{220}{\sqrt{3}} \angle 0^\circ = 127 \angle 0^\circ$

$I_2 = \frac{V_1}{(R_1 + \frac{R_2}{s}) + j(X_1 + X_2)} = \frac{127 \angle 0^\circ}{(0.3 + \frac{0.2}{0.05}) + j(0.5+0.5)} = 28.77 \angle -13.1^\circ$ A

$I_m = \frac{V_1}{jX_m} = \frac{127 \angle 0^\circ}{j15} = 8.47 \angle -90^\circ$ A

$I_1 = I_2 + I_m = 28.77 \angle -13.1^\circ + 8.47 \angle -90^\circ = 31.78 \angle -28.1^\circ$ A

(c) $PF_1 = \cos\theta = \cos 28.1^\circ = 0.882$ lagging

(d) $P_{in} = 3V_1 I_1 \cos\theta = (3)(127)(31.78)\cos 28.1^\circ = 10,680$ W

$P_{ag} = 3I_2^2 \frac{R_2}{s} = (3)(28.77)^2\left(\frac{0.2}{0.05}\right) = 9932.6$ W

$P_{dev} = (1-s)P_{ag} = (1-0.05)(9932.6) = 9435.9$ W

$P_{out} = P_{dev} - P_{rot} = 9435.9 - 500 = 8935.9$ W

$\omega_m = \frac{2\pi n}{60} = \frac{2\pi(1710)}{60} = 179.1$ rad/s

$T_{out} = T_{shaft} = \frac{P_{out}}{\omega_m} = \frac{8935.9}{179.1} = 49.9$ N-m

(e) $\eta = \frac{P_{out}}{P_{in}} = \frac{8935.9}{10,680} 100\% = 83.7\%$

8-17

$$R_1 = \frac{1}{2}\left(\frac{V_{DC}}{I_{DC}}\right) = \frac{1}{2}\left(\frac{8}{50}\right) = 0.08\ \Omega$$

$$R_{nl} = \frac{P_{nl}}{3I_{nl}^2} = \frac{3800}{(3)(38)^2} = 0.877\ \Omega$$

$$Z_{nL} = \frac{V_{nL}}{\sqrt{3}\,I_{nl}} = \frac{440}{\sqrt{3}\,(38)} = 6.685\ \Omega$$

$$X_{nl} = \sqrt{Z_{nl}^2 - R_{nl}^2} = \sqrt{(6.685)^2 - (0.877)^2} = 6.627\ \Omega$$

$$R_{bl} = \frac{P_{bl}}{3I_{bl}^2} = \frac{4800}{(3)(110)^2} = 0.132\ \Omega$$

$$Z_{bl} = \frac{V_{bl}}{\sqrt{3}\,I_{bl}} = \frac{80}{\sqrt{3}\,(110)} = 0.42\ \Omega$$

$$X_{bl,test} = \sqrt{Z_{bl}^2 - R_{bl}^2} = \sqrt{(0.42)^2 - (0.132)^2} = 0.40\ \Omega$$

$$X_{bl} = \left(\frac{f_{rated}}{f_{test}}\right) X_{bl,test} = \left(\frac{60}{15}\right)(0.40) = 1.60\ \Omega$$

$$X_1 = X_2 = \frac{1}{2} X_{bl} = \frac{1}{2}(1.60) = 0.80\ \Omega$$

$$X_m = X_{nL} - X_1 = 6.627 - 0.80 = 5.827\ \Omega$$

$$R_2 = R_{bl} - R_1 = 0.132 - 0.08 = 0.052\ \Omega$$

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8-20

$$R_1 = \frac{1}{2}\left(\frac{V_{DC}}{I_{DC}}\right) = \frac{1}{2}\left(\frac{6}{12}\right) = 0,25\ \Omega$$

$$R_{nl} = \frac{P_{nl}}{3I_{nl}^2} = \frac{1200}{(3)(6)^2} = 11,11\ \Omega$$

$$Z_{nl} = \frac{V_{nl}}{\sqrt{3}\,I_{nl}} = \frac{440}{\sqrt{3}\,(6)} = 42,34\ \Omega$$

$$X_{nl} = \sqrt{Z_{nl}^2 - R_{nl}^2} = \sqrt{(42,34)^2 - (11,11)^2} = 40,86\ \Omega$$

$$R_{bl} = \frac{P_{bl}}{3I_{bl}^2} = \frac{750}{(3)(16)^2} = 0,976\ \Omega$$

$$Z_{bl} = \frac{V_{bl}}{\sqrt{3}\,I_{bl}} = \frac{35}{\sqrt{3}\,(16)} = 1,263\ \Omega$$

$$X_{bl} = \sqrt{Z_{bl}^2 - R_{bl}^2} = \sqrt{(1,263)^2 - (0,976)^2} = 0,8\ \Omega$$

$$X_1 = X_2 = \frac{1}{2}X_{bl} = \frac{1}{2}(0,8) = 0,4\ \Omega$$

$$X_m = X_{nl} - X_1 = 40,86 - 0,4 = 40,46\ \Omega$$

$$R_2 = R_{bl} - R_1 = 0,976 - 0,25 = 0,726\ \Omega$$

8-23 Refer to Fig. 8-8 : $V_1 = \frac{440}{\sqrt{3}} \angle 0^\circ = 254 \angle 0^\circ$ V

(a) $I_2 = \frac{V_1}{R_1 + \frac{R_2}{s} + j(X_1 + X_2)} = \frac{254 \angle 0^\circ}{0.12 + \frac{0.10}{0.035} + j(0.25 + 0.2)} = 84.36 \angle -8.6^\circ$ A

$I_m = \frac{V_1}{jX_m} = \frac{254 \angle 0^\circ}{j15} = 16.93 \angle -90^\circ$

$I_1 = I_2 + I_m = 84.36 \angle -8.6^\circ + 16.93 \angle -90^\circ = 88.5 \angle -19.5^\circ$ A

$PF_1 = \cos 19.5^\circ = 0.943$ lagging

(b) $P_{ag} = 3 I_2^2 \frac{R_2}{s} = (3)(84.36)^2 \left(\frac{0.10}{0.035}\right) = 61{,}000$ W

(c) $P_{conv} = P_{dev} = (1 - s) P_{ag} = (1 - 0.035)(61{,}000) = 58{,}865$ W

8-29

(a) $P_{out} = 20\ kW$

$$P_{dev} = P_{out} + P_{rotational} = 20 + 1.5 = 21.5\ kW$$

$$P_{ag} = \frac{P_{dev}}{1-s} = \frac{21.5}{1-0.045} = 22.5\ kW$$

(b) $$n_s = \frac{120f}{p} = \frac{(120)(60)}{6} = 1200\ rpm$$

$$n = (1-s)n_s = (1-0.045)(1200) = 1146\ rpm$$

$$\omega_m = \frac{2\pi n}{60} = \frac{2\pi(1146)}{60} = 120\ rad/s$$

$$T_{out} = \frac{P_{out}}{\omega_m} = \frac{20{,}000}{120} = 166.7\ N\text{-}m$$

(c) $$T_{dev} = \frac{P_{dev}}{\omega_m} = \frac{21{,}500}{120} = 179.2\ N\text{-}m$$

8-33 Refer to Fig. 8-8.

$$V_1 = \frac{230}{\sqrt{3}} \angle 0^\circ = 132.8 \angle 0^\circ$$

$$n_s = \frac{120f}{P} = \frac{(120)(60)}{4} = 1800 \text{ rpm}$$

$$\omega_s = \frac{2\pi n_s}{60} = \frac{(2\pi)(1800)}{60} = 188.5 \text{ rad/sec}$$

$$n_{FL} = (1-s)n_s = (1-0.035)(1800) = 1737 \text{ rpm}$$

$$\omega_{FL} = \frac{2\pi n_{FL}}{60} = \frac{(2\pi)(1737)}{60} = 182 \text{ rad/sec}$$

(a)

$$P_{out} = (10)(746) = 7460 \text{ W}$$

$$P_{rotational} = 0$$

$$P_{dev} = P_{out} + P_{rotational} = 7460 \text{ W}$$

$$P_{ag} = \frac{P_{dev}}{1-s} = \frac{7460}{1-0.035} = 7730.6 \text{ W}$$

$$RCL = 3I_2^2 R_2 = sP_{ag} = (0.035)(7730.6) = 270.6 \text{ W}$$

$$\therefore \quad I_2^2 = \frac{270.6}{3R_2}$$

$$|I_2| = \frac{|V_1|}{\sqrt{\left(R_1 + \frac{R_2}{s}\right)^2 + (X_1 + X_2)^2}} = \frac{132.8}{\sqrt{\left(0.25 + \frac{R_2}{0.035}\right)^2 + (0.35 + 0.45)^2}}$$

$$I_2^2 = \frac{(132.8)^2}{\left(0.25 + \frac{R_2}{0.035}\right)^2 + (0.8)^2} = \frac{270.6}{3R_2}$$

Solving, $R_2 = 0.218$

8-35

(a) $V_1 = \frac{440}{\sqrt{3}} \angle 0^\circ = 254 \angle 0^\circ \text{ V}$

Assume a 4-pole machine: $n_s = \frac{120f}{p} = \frac{(120)(60)}{4} = 1800 \text{ rpm}$

$$\omega_s = \frac{2\pi n_s}{60} = \frac{(2\pi)(1800)}{60} = 188.5 \text{ rad/sec}$$

$$|I_{start}| = \frac{|V_1|}{\sqrt{(R_1+R_2)^2+(X_1+X_2)^2}} = \frac{254}{\sqrt{(0.2+0.15)^2+(1.0+0.8)^2}} = 138.5 \text{ A}$$

$$T_{start} = \frac{3 I_{1start}^2 R_2}{\omega_s} = \frac{(3)(138.5)^2(0.15)}{188.5} = 45.8 \text{ N-m}$$

(b) $$\frac{R_2'}{s_{max}} = \sqrt{R_1^2+(X_1+X_2)^2} = \sqrt{(0.2)^2+(1.0+0.8)^2} = 1.81$$

$$R_2' = 1.81\, s_{max} = (1.81)(1.0) = 1.81 \ \Omega$$

$$R_{ckt} = R_2' - R_2 = 1.81 - 0.15 = 1.66 \ \Omega$$