7-3

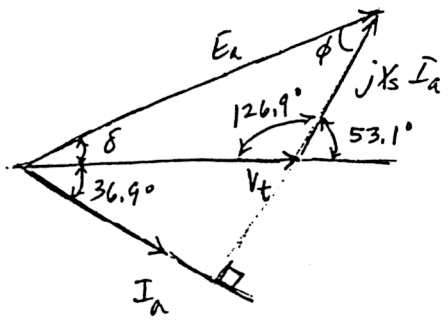
$$P = \frac{120f}{n} = \frac{(120)(60)}{900} = 8 \text{ poles}$$

7-8

$$V_t = \frac{2300}{\sqrt{3}} \angle 0^\circ = 1327.9 \angle 0^\circ \text{ V}$$

$$I_a = \frac{150{,}000}{\sqrt{3}\,(2300)} \angle -\cos^{-1} 0.8 = 37.65 \angle -36.9^\circ \text{ A}$$

$$|E_a| = \frac{3500}{\sqrt{3}} = 2020.7 \text{ V}$$



$$\frac{\sin\phi}{|V_t|} = \frac{\sin 126.9^\circ}{|E_a|} = \frac{\sin\delta}{|X_s I_a|}$$

$$\sin\phi = \frac{|V_t|}{|E_a|}\sin 126.9^\circ = \frac{1327.9}{2020.7}\sin 126.9^\circ = 0.5255$$

$$\phi = 31.7^\circ$$

$$\delta = 180^\circ - 126.9^\circ - 31.7^\circ = 21.4^\circ$$

$$X_s = \frac{|V_t|}{|I_a|}\frac{\sin\delta}{\sin\phi} = \frac{1327.9}{37.65}\frac{\sin 21.4^\circ}{\sin 31.7^\circ} = 24.5\ \Omega$$

7-10

(a) $$V_t = \frac{230}{\sqrt{3}} \angle 0^\circ = 132.8 \angle 0^\circ \text{ V}$$

$$I_a = \frac{80{,}000}{\sqrt{3}\,(230)} \angle -\cos^{-1} 0.866 = 200.8 \angle -30^\circ \text{ A}$$

(b) $$E_a = V_t + (R_a + jX_s) I_a = 132.8 \angle 0^\circ + (0.1 + j0.5)(200.8 \angle -30^\circ)$$

$$= 214.64 \angle 21^\circ$$

7.10 (Contd.)

© $\delta = 21°$

(d) $\omega_m = \frac{2}{p}(2\pi f) = \left(\frac{2}{6}\right)(2\pi)(60) = 125.66 \text{ rad/sec}$

$$P = \frac{3E_a V_t}{X_s}\sin\delta = \frac{(3)(214.64)(132.8)}{0.5}\sin 21° = 61.29 \text{ kW}$$

$$T = \frac{P}{\omega_m} = \frac{61,290}{125.66} = 487.7 \text{ N-m}$$

7-12

$S_b = 10 \text{ MVA}$

$V_b = 12 \text{ kV}$

$$Z_b = \frac{V_b^2}{S_b} = \frac{(12)^2}{10} = 14.4 \,\Omega$$

(a) $$X_{s,unsat} = \frac{15000/\sqrt{3}}{480} = 18.042 \,\Omega = 1.253 \text{ pu}$$

(b) $$X_{s,sat} = \frac{12000/\sqrt{3}}{480} = 14.43 \,\Omega = 1.0 \text{ pu}$$

7-25

$$\cos\theta = \frac{P}{\sqrt{3}\,V_t I_a} = \frac{850,000}{\sqrt{3}\,(12,000)(48)} = 0.852$$

$$\theta = \cos^{-1} 0.852 = 31.6°$$

$$E_a = V_t - jX_s I_a = \frac{12000}{\sqrt{3}}\angle 0° - (j38)(48\angle -31.6°) = 6171\angle -14.6° \text{ V}_{LN}$$

for lagging PF

or $$E_a = \frac{12000}{\sqrt{3}}\angle 0° - (j38)(48\angle 31.6°) = 8036\angle -11° \text{ V}_{LN}$$

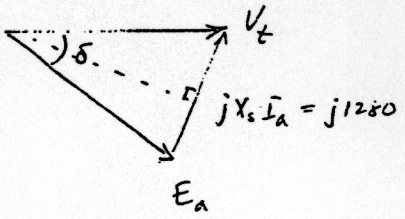
for leading PF

-26

$$V_t = \frac{2400}{\sqrt{3}} \angle 0^\circ = 1385.6 \angle 0^\circ \text{ V}$$

$$E_a = \frac{2400}{\sqrt{3}} \angle -\delta = 1385.6 \angle -\delta \text{ V}$$

$$X_s I_a = (16)(80) = 1280$$



$$V_t \sin\left(\frac{\delta}{2}\right) = \frac{1280}{2}$$

$$\sin\left(\frac{\delta}{2}\right) = \frac{1280/2}{1385.6} = 0.462$$

$$\frac{\delta}{2} = 27.5^\circ$$

$$\delta = 55^\circ$$

$$I_a = \frac{V_t - E_a}{jX_s} = \frac{1385.6 \angle 0^\circ - 1385.6 \angle -55^\circ}{j16} = 80 \angle -27.5^\circ \text{ A}$$

$$P = \sqrt{3} V_t I_a \cos\theta = \sqrt{3}(2400)(80)\cos 27.5^\circ = 295 \text{ kW}$$

$$P = 3\frac{E_a V_t}{X_s} \sin\delta = \frac{3(1385.6)(1385.6)}{16} \sin 55^\circ = 295 \text{ kW}$$

$$\omega_m = \left(\frac{2}{p}\right)(2\pi f) = \left(\frac{2}{4}\right)(2\pi)(60) = 188.5 \text{ rad/sec}$$

$$T = \frac{P}{\omega_m} = \frac{295 \times 10^3}{188.5} = 1564 \text{ N-m}$$

7-33

$$I_a = \frac{20{,}000}{\sqrt{3}(480)} = 24.06 \text{ A}$$

$$P_{cu} = 3 I_a^2 R_a = (3)(24.06)^2(2.5) = 4340 \text{ W} = 4.34 \text{ kW}$$

$$P_{in} = \sqrt{3} V_t I_a \cos\theta = \sqrt{3}(480)(24.06)(0.8) = 16 \text{ kW}$$

$$P_{out} = P_{in} - P_{ca} - P_{rotational} = 16 - 4.34 - 1.5 = 10.16 \text{ kW}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{10.16}{16} 100\% = 63.5\%$$