# Problem 1

① $V_{a,r} = R_a I_{a,r} + E_{a,r} = R_a I_{a,r} + K' \omega_{m,r}$

$$K' = \frac{V_{a,r} - R_a I_{a,r}}{\omega_{m,r}} = \frac{220 - 2(11.6)}{1500\left(\frac{\pi}{30}\right)}$$

$$K' = 1.25 \left[\frac{V}{r/s}\right]$$

$$\frac{2V_m}{\pi}\cos\alpha = R_a I_{a,r} + K' \omega_m$$

$$\frac{2(230\sqrt{2})}{\pi}\cos\alpha = 2(11.6) + 1.25(1000)$$

solve for $\alpha$

$$\alpha = 41.8^\circ$$

② $\frac{2V_m}{\pi}\cos\alpha = R_a I_{a,r} + K' \omega_m$

$$\frac{2(230\sqrt{2})}{\pi}\cos\alpha = 2(11.6) + 1.25(-1500)$$

$$\alpha = 147^\circ$$

③ $\frac{2V_m}{\pi}\cos\alpha = R_a I_{a,r} + K' \omega_m$ "assume constant flux"

$$\frac{2(230\sqrt{2})}{\pi}\cos(145^\circ) = 2(11.6) + 1.25\,\omega_m$$

solve for $\omega_m$

$$\omega_m = -154.3 \text{ r/sec}$$

## Problem 2

$$V_{a,r} = R_a I_{a,r} + K' \omega_{m,r}$$

$$I_{a,r} = \frac{V_{a,r} - K'\omega_{m,r}}{R_a} = \frac{230 - 2\left(1000 \frac{\pi}{30}\right)}{0.4217} = 48.76\ A.$$

"$\alpha = 0^\circ$"

$$V_a = \frac{2V_m}{\pi} \cos\alpha = \frac{2(240\sqrt{2})}{\pi} \cos(0^\circ) = 216.1\ V = R_a I_{a,r} + K'\omega_m$$

$$\omega_m = \frac{216.1 - 0.4217(48.76)}{2}$$

$$\omega_m = 97.77\ r/sec \quad or \quad n_m = 937.62\ rpm$$

$$\eta = \frac{P_a}{P_{in}} = \frac{E_a I_{a,r}}{V_a I_{a,r}} = \frac{K'\omega_m}{V_a} = \frac{2(97.77)}{216.1} =$$

$$\eta = 90.44\ \%$$

"$\alpha = 20^\circ$"

$$V_a = \frac{2V_m}{\pi} \cos\alpha = \frac{2(240\sqrt{2})}{\pi} \cos 20^\circ = 202\ V = R_a I_{a,r} + K'\omega_m$$

$$\omega_m = \frac{202 - 0.4217(48.76)}{2} =$$

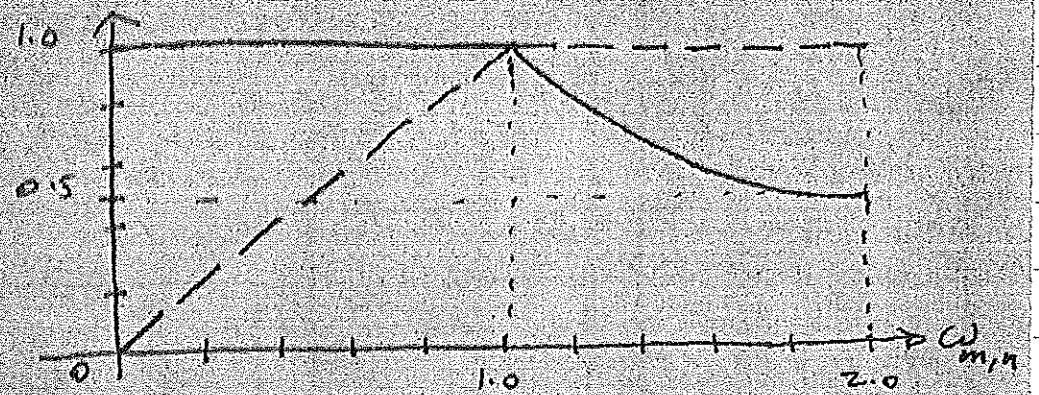
$$\omega_m = 91.22\ r/sec \quad or \quad n_m = 871.08\ rpm$$

$$\eta = \frac{P_a}{P_{in}} = \frac{K'\omega_m}{V_a} = \frac{2(91.22)}{202}$$

$$\eta = 89.88\ \%$$

# Problem 3

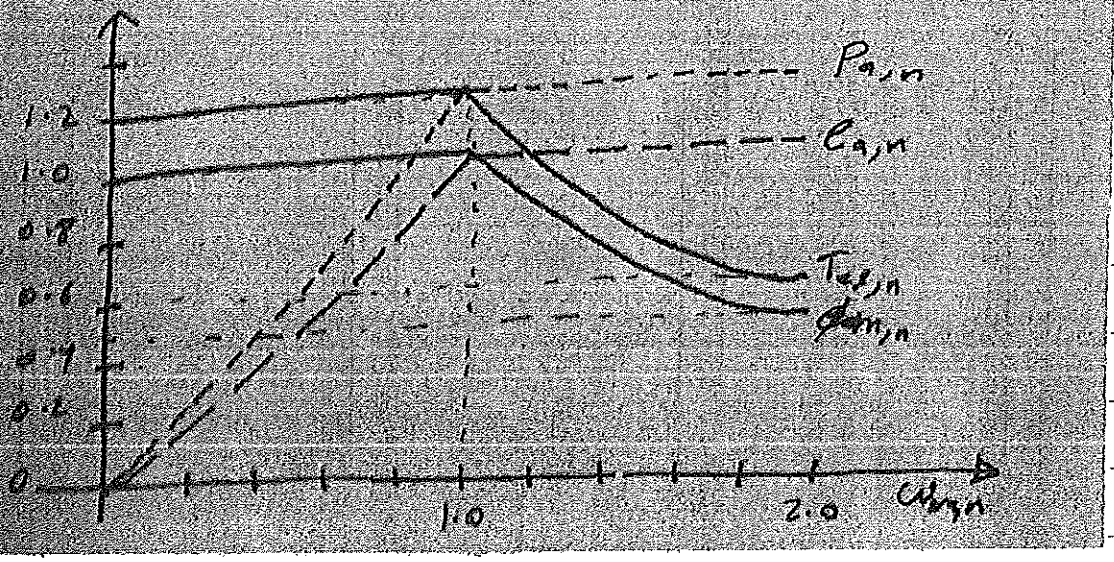
$C_a' = 1.0\ \mu F$




——— $T_{a4,n} + \Phi_{2,n}$

— · — · — $P_{a,n} + C_{4,n}$

$C_a' = 1.2\ \mu F$



# Problem 4

① $V_{a,r} = R_a I_{a,r} + K' \omega_{m,r}$

$500 = 0.052\, I_{a,r} + K'\left(1250 \frac{\pi}{30}\right)$

$500 = 0.052\, I_{a,r} + 130.9\, K' \quad \cdots ①$

$T_{ele,r} = K' I_{a,r} = \frac{P_{a,r}}{\omega_{m,r}} = \frac{250(746)}{130.9}$

$K' I_{a,r} = 1424.8 \quad \cdots ②$

Solve ① + ② $\Rightarrow$ $K' = 3.6653$ V/(rad/sec)

$I_{a,r} = 388.73$ A

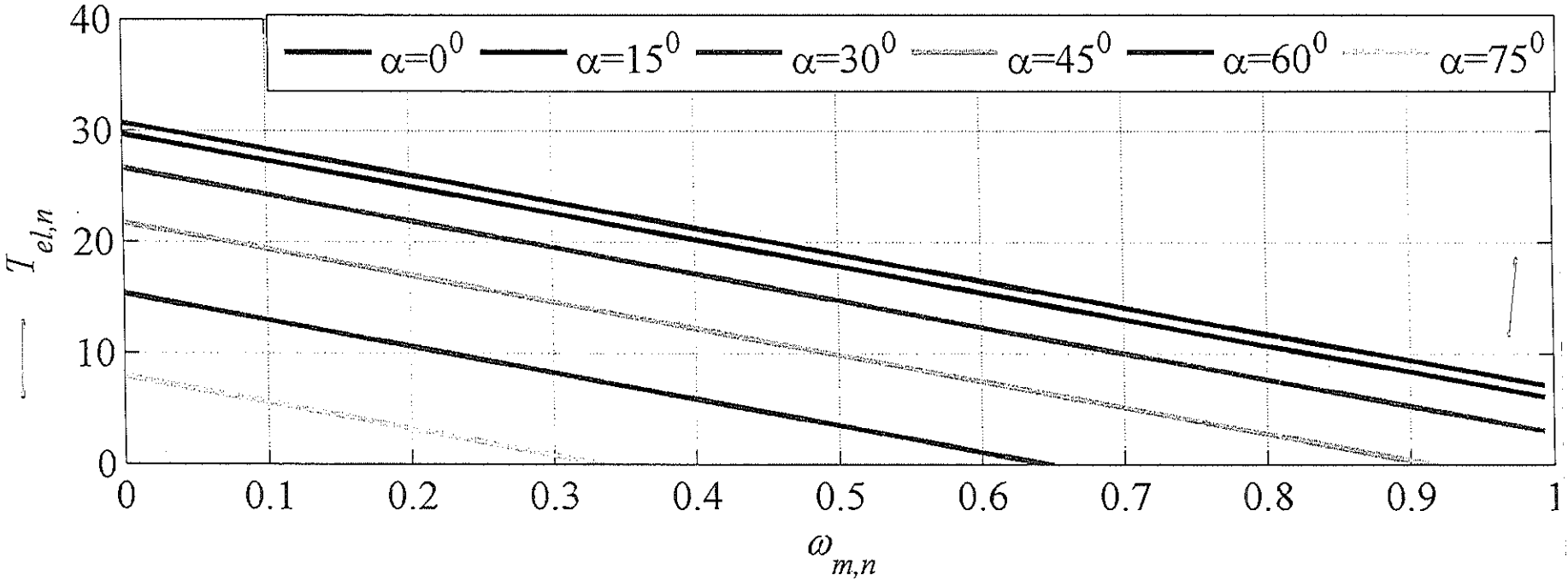
② $T_{ele} = K' I_a$

$I_a = \frac{V_a - K' \omega_m}{R_a}$

$V_a = \frac{3\sqrt{3} V_m}{\pi} \cos\alpha$

$T_{ele} = \frac{K'}{R_a}\left[V_a - K' \omega_m\right]$

$T_{ele} = 4378.8 \cos\alpha - 258.35\, \omega_m$


α=0⁰
α=15⁰
α=30⁰
α=45⁰
α=60⁰
α=75⁰
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
$T_{el,n}$
$\omega_{m,n}$

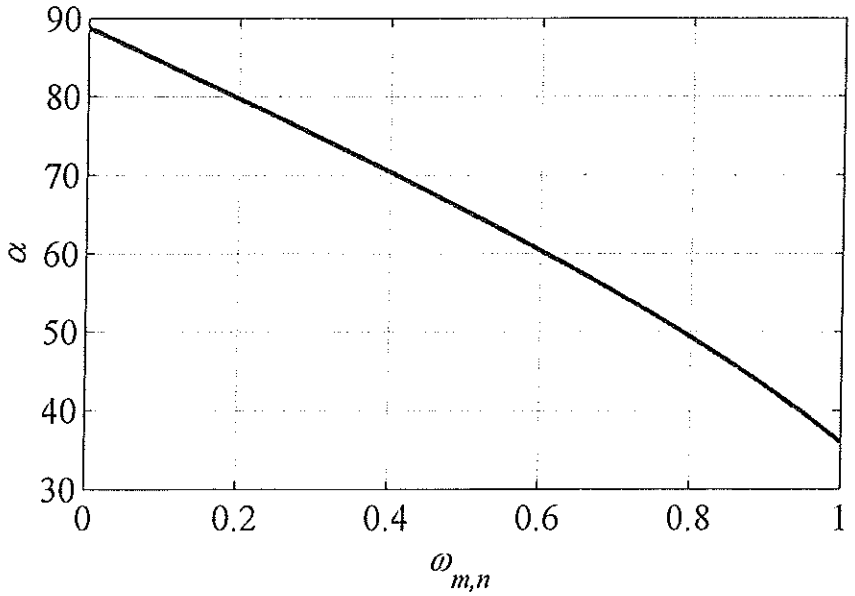
(2.) $\frac{3\sqrt{3}\,V_{m}}{\pi}\cos\alpha = V_{a,r}$

$\frac{3\sqrt{3}\left(N\sqrt{\frac{2}{3}}\,460\right)}{\pi}\cos\alpha = 500$

$\alpha = 36.4°$

(3.) $V_a = \frac{3\sqrt{2}\left(N\sqrt{\frac{2}{3}}\,460\right)}{\pi}\cos\alpha = 0.088(153.71) + 7.646\omega_m$

$\alpha = \cos^{-1}\left[0.0218 + 0.0043\,\omega_m\right]$



# problem 5

## speed controller

$K_1 = 2\zeta\omega_n J - B$

$K_2 = J\omega_n^2$

let $\zeta = 1/\sqrt{2}$

$J = 0.0607$, $B = 0.0869$, $\omega_n = 2\pi(500\text{rad})$

$K_1 = 269.6$, $K_2 = 5.99 \times 10^5$

## current controller

$K_1 = 2\zeta\omega_n L_a - R_a$

$K_2 = \omega_n^2 L_a$

let $\zeta = 1/\sqrt{2}$

$R_a = 4\Omega$, $L_a = 72\text{ mH}$, $\omega_n = 2\pi(1000)$

$K_1 = 635.8$, $K_2 = 2.84 \times 10^4$

## flux controller

$K_1 = 2\zeta\omega_n L_f$

$K_2 = \omega_n^2 L_f$

let $\zeta = 1/\sqrt{2}$

$L_f = 78\text{ mH}$, $\omega_n = 2\pi(2000)$

$K_1 = 1386.2$, $K_2 = 1.23 \times 10^7$.

# problem 6

$$V_{a1} = R_a I_a + \cancel{E_{a1}}^{0} = 0.3(25) = 7.5 \angle$$

$$\omega_{m_1} = 0$$

$$V_{a2} = R_a I_a + E_{a2} = 0.3(25) + 60(2000)(0.00167) = 207.9 \angle$$

$$\omega_{m_2} = 2000\left(\frac{\pi}{30}\right)$$

$$\delta_1 = \frac{7.5}{220} = 0.0341$$

$$\delta_2 = \frac{207.9}{220} = 0.943$$

## problem 7

$$\eta = \frac{P_{out}}{P_{in}} = 0.785$$

$$\frac{746 \times 1}{P_{in}} = 0.785$$

$$P_{in} = V_{a,r} I_{a,r} = 950.32$$

$$I_{ar} = \frac{950.32}{10} = 95.032\ A$$

$$V_a| = (1.5 I_{a,r}) R_a = 1.5(95.032)(0.053) = 7.56\ V$$

$\omega_m = 0$

$$V_a| = (1.5 I_{a,r}) R_a + K'\omega_m = 1.5(95.032)\frac{0.053}{4} + 0.0191(0.4)\left(1500\frac{\pi}{30}\right)$$

$\omega_m = 0.4$

$$= 9.56\ V$$

$$\delta| = \frac{7.56}{23} = 0.33$$

$\omega_m = 0.0\ p.u$

$$\delta| = \frac{9.56}{23} = 0.41$$

$\omega_m = 0.4\ p.u$