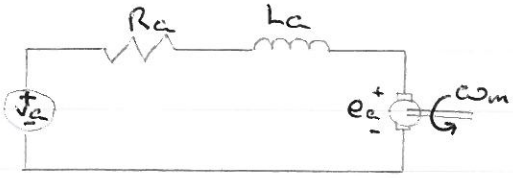
EE4001 Power Electronics, Drives, Energy Conversion DC Machines

4.



$R_a = 1.03\,\Omega$ $I_a = 1.25\,A$

$V_a = 50\,V$

$N = 2100\,rpm$

$\Rightarrow \omega = 219.9\,rad/s$

a) $K = \frac{e_a}{\omega_m}$

$e_a = V_a - I_a R_a$

$= 48.7125\,V$

$k = 0.222\,Nm/A$ (or $V s/rad$)

b) $P_{RL} = P_{NL} - I_a^2 R_a$, $P_{NL} = V_a I_a$

$= 60.89\,W$

c) $\omega = 178.02\,rad\,s^{-1}$

$e_a = 39.52\,V$

$I_a = \frac{V_a - e_a}{R_a} = 8.233\,A$

$P_{DEV} = e_a I_a = 325.4\,W$

$P_{OUT} = P_{DEV} - P_{RL}$

$= 264.5\,W = 0.36\,hp$

d) $I_{STALL} \Rightarrow \omega_m = 0 \Rightarrow e_a = 0$

$I_a = \frac{V_a}{R_a} = 46.6\,A$

$T = k I_a = 10.35\,Nm$

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9. $T_L = 5\,Nm$ @ 46.6π rads^{-1} $\qquad \omega_{NL} = 50\pi$ rads^{-1}

$T = \left(\frac{5}{46.6\pi}\right)\omega$ Nm

$T = 0.0341\omega$

$$\omega = \frac{V_a}{K\Phi} - \frac{R_a}{(k\Phi)^2}T$$

$$\omega_{NL} = \frac{V_a}{k\Phi} = 50\pi \text{ rads}^{-1}$$

$$\omega_{FL} = \frac{V_a}{k\Phi} - \frac{5R_a}{(k\Phi)^2} = 46.6\pi \text{ rads}^{-1}$$

$$\frac{R_a}{(k\Phi)^2} = \frac{3.\dot{3}\pi}{5} = \frac{2}{3}\pi$$

$$\omega_{WEAK} = \frac{50\pi}{0.8} - \frac{2\pi}{3\times 0.64}(0.0341)\omega_{WEAK}$$

$$\omega_{WEAK} = \frac{62.5\pi}{1 + 0.1116}$$

$$\omega_{WEAK} = 56.225\pi \text{ rads}^{-1}$$

$$= 1,687 \text{ rpm}$$

10. $T = \left(\frac{5}{46.6\pi^2}\right)\omega^2 = 0.0002333\,\omega^2$

$$\omega_{NL} = \frac{V_a}{k\Phi} = 50\pi \text{ rads}^{-1}$$

$\omega_{FL} = 46.6\pi$ rads^{-1} $\Rightarrow \frac{R_a}{(k\Phi)^2} = \frac{2\pi}{3}$

$$\omega_{WEAK} = 62.5\pi - \frac{(2\pi \times 0.000233)}{3\times 0.64}\omega_{WK}^2$$

$$0.000763\omega^2 + \omega + 62.5\pi = 0$$

$\omega = 55.2\pi$ rads^{-1}

$N = 1,656$ Rpm

18 $T = \left(\frac{5}{1400^2}\right)N^2 = (1.02\times10^{-6})N^2$

$N_{NL} = \frac{V_a}{k\phi} = 1500\text{rpm}$

$\Rightarrow \frac{TR_a}{(k\phi)^2} = 100$

$\Rightarrow \frac{R_a}{(k\phi)^2} = 20$

$N_{WEAK} = \frac{1500}{0.5} - \frac{20}{0.25}(1.02\times10^{-6})N^2$

$(8.16\times10^{-5})N_{WK}^2 + N_{WK} - 3000 = 0$

$N = 2,493\text{ rpm}$

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11. $V = 250V$
$R_a = 25m\Omega$
$N_{NL} = 1,100rpm$
$\omega_{NL} = 36.6\pi$ rad/s

i) @ NL, $T = 0 \Rightarrow I_a = 0$
$e_a = V_a = 250V$
$\Rightarrow k = \frac{e_a}{\omega} = 2.17$ Vs/rad

Equivalent e_a @ $N = 1200rpm$: $\frac{e_a}{\omega} = \frac{e'}{\omega'}$
$e' = 272.7V$
@ $E = 272.7$, $N = 1200rpm$, $I_a = 0$
$I_f = 5.9A$

ii) For $I_a = 600A$
$E_a = V - I_a R_a$
$= 235V$

@ $1200rpm$, $I_f = 5.9A$, $I_a = 600A$
$E = 252V$

$N = 1200 \frac{235}{252}$
$= 1,119rpm$

iii) $I_f' = I_f + \frac{1.5 I_a}{1000}$
$= 6.8A$

@ $1,200rpm$, $I_f = 6.8A$, $I_a = 600A$
$E = 272V$

$\frac{272}{1200} = \frac{235}{N}$
$N = 1,037rpm$

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12. $V = 250V$ $I_a = 400A$
$R_a = 25m\Omega$
3 series-field turns
1000 shunt-field turns
$N = 1,100$ rpm

$E = V + I_a R_a = 260V$
$E' = (\frac{1200}{1100})260$
$E' = 283.64\ V$
@ $I_a = 400A$, $E = 283V$, $N = 1,200$ rpm
$MMF = 7,125$ Aturn/pole
$MMF = N_{SH} I_{SHF} + N_{SRF} I_a$
$I_F = \frac{7,125 - 1,200}{1000} = 5.925A$

17. $V_{dc} = 48V$ $I_{NL} = 290mA$ $R_{ph-ph} = 1.04\Omega$
$N = 6,500$ rpm $T_{NL} = 20.6mNm$ $\eta = 0.85$
$K = 0.071$ T_L @ $\omega = 166.6\pi$ rads^{-1}
$= 306mNm$

$T_{EM} = T_{NL} + T_L$
$= 326.6mNm$
$P_o = \omega T_L = 160.22W$
$I_a = 4.6A$
$P_i = \frac{P_o}{\eta} = 188.5W$ → Theoretical
$V_{ph} = E + I_a R_a$
$V_{ph} = k\omega + I_a R$
$= 41.96V$
$P_{in} = V_{ph} I_a = 193W$
$\eta = 0.83$

$E_{ph} = \frac{E_{ph-ph}}{2} = 18.59V$
$I_{phrms} = \sqrt{\frac{2}{3}} I_a = 3.756A$

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PMAC Problems

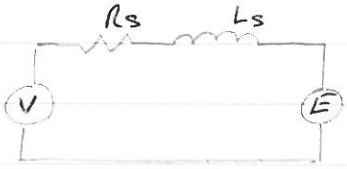
1

$pp = 2$ $\quad V_B = 300V$

$T = 100\ Nm$ $\quad \eta_{motor} = 90\%$

$N = 6000\ rpm$ $\quad \cos\phi = 0.9$

$\omega = 200\pi\ rad/s$



i) $V_{ph} = m\frac{V_B}{2\sqrt{2}} = 106.1\ V$

iii) $V_{ph} = V_{ph}\cos\phi + jV_{ph}\sin\phi$

$= (E_{ph} + I_{ph}R_s) + j\,I_{ph}X_{Ls}$

$= 95.49 + j\,46.25$

$P_{out} = T\omega = 62.832\ kW$

$P_{in} = \frac{P_{out}}{\eta} = 69.813\ kW = 3V_{ph}I_{ph}\cos\phi$

$I_{ph} = 243.7\ A$

ii) $E_{ph} = V_{ph}\cos\phi - I_{ph}R_s$

$= 88.18\ V$

iv) $I_{ph}X_{Ls} = 46.25\ V = I_{ph}\omega_e L_s$

$\omega_e = 2\omega_r$

$L_s = \frac{46.25}{400\pi I_{ph}} = 151\mu H$

v) $k = \frac{e}{\omega} = 0.14$

vi) $P_{cu} = 3I_{ph}^2 R_s$

$= 5.345\ kW$

vii) $P_{cfw} = (P_{in} - P_{out}) - P_{cu}$

$= 1.636\ kW$

EE4001 Power Electronics, Drives, Energy Conversion
PMAC Problems

2c) $pp = 2$ $\quad V_B = 42\,V$

$T = 20\,Nm$ $\quad \eta_{motor} = 90\%$

$N = 6000\,rpm$ $\quad \cos\phi = 0.9$

$\omega = 200\pi\ rad/s$

i) $V_{ph} = m\frac{V_B}{2\sqrt{2}} = 14.85\,V$

iii) $V_{ph} = V_{ph}\cos\phi + jV_{ph}\sin\phi$

$= 13.365 + j6.473$

$P_o = T\omega = 12.566kW$

$P_i = \frac{P_o}{\eta} = 13.962kW = 3V_{ph}I_{ph}\cos\phi$

$I_{ph} = 348.22\,A$

ii) $V_{ph}\cos\phi = E_{ph} + I_{ph}R_s$

$E_{ph} = 12.84\,V$

iv) $\omega_e I_{ph} L_s = 6.473\,V$

$\omega_e = 2\omega r$

$L_s = 14.8\,\mu H$

v) $k = \frac{e}{\omega} = 0.0204$

vi) $P_{cu} = 3I_{ph}^2 R_s$

$= 546W$

vii) $P_{CFW} = P_i - P_o - P_{cu}$

$= 850W$

EE4001 PMAC Machines

1. $T = 100\,Nm$, $\omega = 200\pi\ rads^{-1}$ } $P = 62.83\,kW$

$V_b = 300V$

$\eta_m = 0.9$

$\cos\phi = 0.9$

i) $V_{ph} = m\frac{V_b}{2\sqrt{2}} = 106.1\,V$

ii) $\bar{V}_{ph} = V_{ph}\cos\phi + jV_{ph}\sin\phi$

iii) $= (95.49 + j46.25)V$

$95.49 = E_{ph} + R_s I_{ph}$

$46.25 = I_{ph}(2\pi f_e L_s)$ $\qquad f_e = 2f = 200Hz$

$P_o = 62.83kW$

$P_i = 69.81kW = 3V_{ph}I_{ph}\cos\phi$

$I_{ph} = 243.7A$

$E_{ph} = 88.18V$

iv) $L_s = 151\mu H$

v) $E = k\omega \Rightarrow k = 0.14$

vi) $P_{cu} = 3I^2R$

$= 5.345\,kW$

vii) $P_{cfw} = P_i - P_o - P_{cu}$

$= 1.635\,kW$

EE4001 PMAC Machines

2. $T = 20 Nm$, $\omega = 200\pi$ rads^{-1} $\Big\}$ $P = 12.566 kW$

$V_b = 42V$ $\quad \eta_m = 0.9$ $\quad \cos\phi = 0.9$

i) $V_{ph} = m \frac{V_b}{2\sqrt{2}} = 14.85V$

iii) $P_o = 12566W$

$P_i = 13962W = 3 V_{ph} I_{ph} \cos\phi$

$I_{ph} = 348A$

ii) $V_{ph} = V_{ph}\cos\phi + j V_{ph}\sin\phi$

$= 13.365 + j6.47 = E_{ph} + I_{ph}R + j I_{ph}(2\pi f_e L_s)$

$E_{ph} = 12.843V$

iv) $f_e = 2f = 200Hz$

$L_s = 14.8\mu H$

v) $k = \frac{E}{\omega} = \frac{T}{3I} = 0.02$

vi) $P_{cu} = 3I^2R$

$= 544W$

vii) $P_{CFW} = P_i - P_o - P_{cu}$

$= 852W$

EE4001 PMAC

3. $P_o = 13.92\,kW$ $T = 80\,N_m$

$\omega = 173.99\,rads^{-1}$ $K_T = 3.05\ N_m/A$

$E_{ph} = 176.95\,V$ $K = 1.017\ V/rads^{-1}$

$I_{ph} = 26.23\,A$ $\eta = 0.88$

$R_{ph-ph} = 1.06\,\Omega$ $R_{ph} = 0.53\,\Omega$

$L_{ph-ph} = 6.58\,mH$ $L_{ph} = 3.29\,mH$

$f_e = 6f = 166.15\,Hz$

$V_{ph} = E_{ph} + 3I_{ph}(R_{ph} + j2\pi f_e L_{ph})$

$= 211\angle 25.27°\,V$

$\cos\phi = 0.904$

$P_i = 15.82\,kW$

$P_{Loss} = 1.9\,kW$

$P_{cu} = 3I^2R_{ph} = 1.094\,kW$

$P_{CFW} = 806\,W$