ASN6

Sunday, February 18, 2024 10:06 AM

1) $B = 0.2\,T$, $R = 0.26\,\Omega$, $\ell = 1.6\,m$, $V_T = 94V$

a) $I_{start} = \frac{V_t}{R} = 335.7143\,A$

$F_{start} = B I_{start} \ell = 107.4286\,N$

b) $v_{noload} = \frac{V_t}{B\ell} = 293.75\,m/s$

c) $F_{load} = 25N$ (Given)

$v_{25N} = \frac{V_T}{B\ell} - \frac{F_{load} \cdot R}{(B\ell)^2} = 225.3906\,m/s$

$F_{new} = F_{start} - F_{load} = 82.4286\,N$

$P_{out} = V_{bar} \cdot I_{bar} = 18578.6272\,W$

$P_{in} = V_T \cdot I_{new} = 24713.3929\,W$

$\eta = \frac{P_{out}}{P_{in}} \times 100\% = 75.1989\%$

$I_{bar} = \frac{F_{new}}{B\ell} = 257.5893\,A$

$F_{bar} = B I_{bar} \ell = 82.4286\,N$

$V_{bar} = I_{bar} \cdot R = 72.125\,V$

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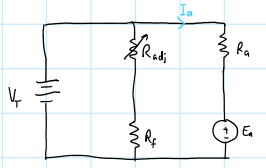
2)



$V_T = 238V$ $P = 41\,hp$

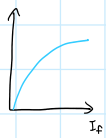
$R_F = 167\,\Omega$ $E_a = f(I_f)$

$R_a = 0.29\,\Omega$

$R_{adj} = 198\,\Omega$

a) $I_{a,start} = \frac{V_T}{R_a} = 820.6897\,A$

b)



$\omega = 1200\,\frac{rad}{min}\left(\frac{1}{2\pi}\right) = 20(2\pi)\,\frac{rad}{s}$

$k\phi = \frac{E_a}{\omega}$

$I_f = \frac{V_T}{R_{adj} + R_f} = 0.6521\,A$

Linear Interpolation: $E_a = 240.5536\,V$

$\tau = \frac{E_a}{\omega} I_a$

$= 1591.02\,N_m$

$I_a = \frac{238}{0.29} = \dots$

$\tau = k\phi I_a$

$I_f = \frac{238}{167+198} \rightarrow E_a = \dots$

$k\phi\,\omega = E_a$

$k\phi = \frac{E_a}{\omega \cdot 2\pi}$

$\tau = k\phi I_a$

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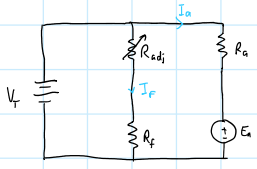
3) Shunt DC motor

239V, $R_f = 199\,\Omega$, $R_a = 0.17\,\Omega$, $R_{adj} = 354\,\Omega$, $loss_r$ @ full load $= 2000\,W$, $\omega = \frac{1200}{60} 2\pi\,rad/s = 40\pi$



$I_f = \frac{V_T}{R_{adj} + R_f} = 0.4484\,A$

LIPb

$E_a = 186.7903\,V$

$k\phi = \frac{E_a}{\omega} = 1.4864$

Idle $\rightarrow P = P_{loss}$

System:

$P_{loss} = E_{a,idle} \cdot I_a$

$I_a = \frac{V_T - E_{a,idle}}{R_a} = 8.4186\,A$

$E_{a,idle} = 237.5488\,V = k\phi\,\omega_{idle}$

$\omega_{idle} = 159.8251\,rad/s \xrightarrow{\times \frac{60}{2\pi}} 1526.2195\,rpm$

$I_a = \frac{V_t - E_a}{R_a} = 307.1160\,A$

$= k\phi\,\omega_{idle} \cdot I_a$

$\omega_{idle} = 4.3811\,rad/s \xrightarrow{\times \frac{60}{2\pi}} 41.8364\,rpm$

$I_{a,idle} = \frac{V_t - E_a}{R_a} = \frac{V_t - k\phi\,\omega_{idle}}{R_a} = 1367.5753\,A$

239V

$P_{out} = P_{loss} = 2000W$

$I_f = \frac{239}{179+354} = \dots$

$E_a = \dots$

$k\phi = \frac{E_a}{2\pi n}$

$P_{loss} = E_a I_a$

$I_a = \frac{239}{199} \dots$

$V_t - E_a = I_a$

$W_{idle} = 159.9251$ rad/s $\xrightarrow{\times \frac{60}{2\pi}}$ 1526.2195 rpm

$I_T = I_f + I_a = 8.8670$ A

$I_{a_{idle}} = \frac{V_t - E_a}{R_a} = \frac{V_t - k\phi W_{idle}}{R_a} = 1367.5753$ A

$I_a = \frac{239}{199} \ldots$

$\frac{V_t - E_a}{R_a} = I_a$

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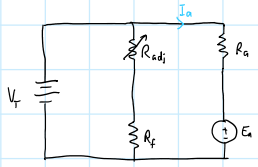
4)



233 V, $R_f = 124$, $R_a = 0.17$, $R_{adj} = 200$, P = 29 hp

P_{loss} @ full load = 1100 W, $W = \frac{1200}{60} \cdot 2\pi$

$I_f = \frac{V_T}{R_f + R_{adj}} = 0.7191$

↓ LIP

$E_a = 252.5631$ V

$k\phi = \frac{E_a}{W} = 2.0098$

$P_{tot} = P_{loss} = E_{a_{idle}} I_{a_{idle}}$

$I_{a_{idle}} = \frac{V_t - E_{a\,idle}}{R_a} = 4.7334$ V

$E_{a\,idle} = 232.1946$ V

$W_{idle} = \frac{E_{a\,idle}}{k\phi} = 115.5293$ rad/s

system →

$P_{tot} = P_{loss} + P_{rated} = E_a I_a$

$E_{a_{FL}} = k\phi\, W_{FL} = 215.0265$ V

$I_a = \frac{V_t - E_{a_{FL}}}{R_a} = 105.9265$ A

$W_{FL} = 106.9872$ rad/s $\xrightarrow{\times \frac{60}{2\pi}}$ 1021.6528 RPM

$I_s = I_f + I_a = 106.4456$ A

Regulation:

$\frac{W_{idle} - W_{FL}}{W_{FL}} \times 100\% = 7.98\%$

$\tau = \frac{P_{motor}}{W_{FL}} = \frac{P_{rated}}{W_{FL}} = 202.2110$ N·m

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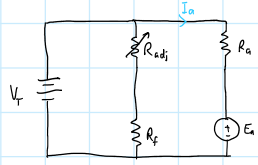
5)



$V_t = 283$ V, $R_f = 131\,\Omega$, $R_a = 0.11\,\Omega$, $R_{adj} = 157\,\Omega$, $P_{rated} = 21$ hp = 15666 W

P_{loss} @ FL = 750 W, $W = 40\pi$ rad/s

$I_f = \frac{V_T}{R_{adj} + R_f} = 1$ A

$E_a = 280.5412$ V → $k\phi = \frac{E_a}{W} = 2.2315$

$P_{TOT} = P_{loss} + P_{rated} = E_{a_{FL}} I_{a_{FL}}$

$I_{a_{FL}} = \frac{V_t - E_{a_{FL}}}{R_a} = 59.3975$ V

$E_{a_{FL}} = 276.4685$ V

$W_{FL} = \frac{E_{a_{FL}}}{k\phi} = 123.8394$ rad/s $\xrightarrow{\times \frac{60}{2\pi}}$ 1182.5791 rpm

Relation: ↓ R_{adj}, ↓ I_f, ↓ E_a, ↑ W

Adjustable R_{adj} b/w 80 Ω, 480 Ω:

MIN: $I_f = \frac{V_T}{80 + R_f} = 1.3412$ A

(labelled MAX in HP Prime) $E_a = 290.9653$

$k\phi_{MIN} = \frac{E_a}{W} = 2.3154$

⋮

$E_{a_{FL}} = 276.4685$ V

$I_{a_{FL}} = 59.3975$ V

$W_{FL} = 119.4027$ rad/s $\xrightarrow{\times \frac{60}{2\pi}}$ 1140.2121 rpm

ω_{FL} = 117. [illegible] 1110.2121 rpm

MAX $I_f = \frac{V_T}{480 + R_F} = 0.4632$ A

(labelled MIN in HP Prime) $E_a = 191.1510$ V

$k\phi_{MAX} = \frac{E_a}{\omega} = 1.5267$

⋮

$E_{a_{FL}} = 276.4685$ V

$I_{a_{FL}} = 59.3775$ V

$\omega_{FL} = 181.0848$ rad/s $\xrightarrow{\times \frac{60}{2\pi}}$ 1729.2902 rpm

IDLING SPEED: $P_{out} = P_{Loss}$

Solve $P_{Loss} = E_a I_a$

$I_a = \frac{V_T - E_a}{R_a} = 2.6529$ A

$E_a = 282.7082$ V

$\omega_{min/max} = \frac{E_{a_{min/max}}}{k\phi_{min/max}} = 122.0976 / 185.1758$ (from previously)

1165.9459 rpm 1768.7987 rpm

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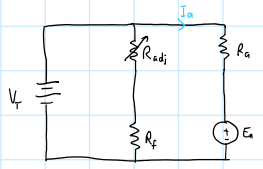
6)



$V_T = 244$ V

$R_f = 222\ \Omega$

$R_a = 0.23\ \Omega$

$R_{adj} = 173\ \Omega$

$N_f = 2400$

$\omega = 40\pi$

$P_{rated} = 18$ hp

$P_{loss} = 850$ W

Deactivated Compensation Winding:
$R_{eaction_a} = 530\ A = K_f$
$I_A^* = 105A$

W/ compensation

$I_f = \frac{V_T}{R_{adj} + R_f} = 0.6177$ A

$E_a = 233.8861$ V

$k\phi = \frac{E_a}{\omega} = 1.8612$

$P_{loss} + P_{rated} = E_{a_{FL}}\left(\frac{V_T - E_{a_{FL}}}{R_a}\right)$

$E_{a_{FL}} = 229.7036$ V $\quad I_{a_{FL}} = \frac{V_T - E_{a_{FL}}}{R_a} = 62.1584$

$\omega_{FL} = 123.4165$ rad/s $\xrightarrow{\times \frac{60}{2\pi}}$ 1178.5809 rpm

($\frac{E_{a_{FL}}}{k\phi}$)

w/o compensation

$I_f^* = I_f - \frac{K_f I_{a_{FL}}}{N_f} = 0.4895$ A

$E_a^* = 200.8565$

$k\phi^* = \frac{E_a^*}{\omega} = 1.5984$

⋮

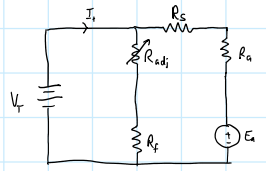
$\omega_{FL}^* = \frac{E_a^*}{k\phi^*}$ 107.9174 rad/s $\xrightarrow{\times \frac{60}{2\pi}}$ 1030.5352 rpm

$P_{loss} + P_{rated} = E_a^*\left(\frac{V_t - k\phi^*\omega^*}{R_a}\right)$

$E_{a_{FL}}^* = \frac{P_{loss} + P_{rated}}{I_a^*} = 135.9810$ V

$\omega_{FL}^* = 100.1831$ rad/s $\xrightarrow{\times \frac{60}{2\pi}}$ 956.6985 rpm

7)



$V_T = 248V$, $I_t = 34A$

$R_F = 222\Omega$, $R_A = 0.12\Omega$, $R_{adj} = 104\Omega$

$P_{rated} = 21 h_p = 15666 W$

$P_{loss} = 850 W$

$N_p = 2050$, $N_s = 27$

$R_s = 0.05$

a) $I_t = I_F + I_A$

$I_T = \frac{V_t}{R_F + R_{adj}} + I_A \longrightarrow I_F = 0.7607 A$

$\rightarrow I_A = 33.2393 A \longrightarrow E_A = 242.3493 V$

$I_F^* = I_f + \frac{N_S}{N_F} I_A = 1.1915 A \xrightarrow{LIP} E_A^* = 287.9817 V$

$\omega_{new} = 1200 \cdot \frac{E_A}{E_A^*} = 1009.8579$ rpm

b) $P_{Tot} = P_{loss} + P_{rated}$

$E_a I_a = T \omega_{new} + P_{loss}$ ($\omega_{new} \times \frac{2\pi}{60}$)

$\rightarrow T = 68.1362 Nm$

c) $E_a I_a = P_{loss} + P_{rated}$; $I_a = \frac{V_T - E_a}{R_s + R_a}$

$\rightarrow E_a = 236.1083V \longrightarrow E_{a_{FL}}$

$\rightarrow I_a = 69.9509 A$

$I_f = \frac{V_T}{R_{adj} + R_f} = 0.7607 A$

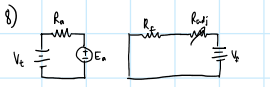
$I_T = I_f + I_a = 70.7117 A$

d) $I_{fd} = \frac{\overset{a}{N_F I_f} + \overset{c}{N_S I_{as}}}{N_p} = 1.6870$

$E_{afd} = 296.8671 V$

$\omega_{FL} = \frac{E_{aFL}}{E_{afd}} \times 1200 = 954.4001$ rpm

8)



$V_t = 233 V$
$R_{adj} = 177\Omega$
$R_f = 176\Omega$
$R_a = 0.035\Omega$
$P_{rat} = 1300 W$

$I_f = \frac{V_t}{R_{adj} + R_f} = 0.6601 A \xrightarrow{LIP} E_a = 242.1076$

a) $V_t = 280V$

$P_{rat} = E_{ai}\left(\frac{V_t - E_{ai}}{R_a}\right) \rightarrow E_{ai} = 279.1374V$

$\omega = 1387.0067$ RPM

b) $V_t = 292V \rightarrow E_{ai} = 291.8441V$

$\omega = 1446.5175$ RPM

c) $V_t = 223V \rightarrow E_{ai} = 222.7958$

$\omega = 1104.2813$ RPM

9) $130 < V_t < 250$ $\quad R_a = 0.29\Omega$

$V_t = 210\,V$ $\quad P_{rot} = 240\,W$

$97 < R_{adj} < 277$

$R_f = 228$

a) Max RPM: $V_t = 250$, $R_{adj} = 277\Omega$

$I_f = \frac{V_f}{R_f + R_{adj}} = 0.4158\,A \xrightarrow{LIP} E_a = 175.6328\,V$

$P_{rot} = E_{ai}\left(\frac{V_t - E_{ai}}{R_a}\right) \rightarrow E_{ai} = 249.7213$

$W_{max} = f \cdot \frac{E_{ai}}{E_a} = 1706.2049\ RPM$

b) Min RPM: $V_t = 130$, $R_{adj} = 97\Omega$

$I_f = \frac{V_f}{R_f + R_{adj}} = 0.6162\,A \xrightarrow{LIP} E_a = 239.4077\,V$

$P_{rot} = E_{ai}\left(\frac{V_t - E_{ai}}{R_a}\right) \rightarrow E_{ai} = 129.4624\,V$

$W_{min} = f \cdot \frac{E_{ai}}{E_a} = 648.9135\ RPM$

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10) $V_t = 276V$, $I_t = 43A$, $N = 31$, $R_s = 0.04\Omega$, $R_a = 0.04\Omega$, $f = 900$ RPM

$E_a = V_t - I_a(R_a + R_s)$

$I_a = \frac{I_t}{2}$ $\quad \phi = \frac{E_a}{\omega} = \frac{E_a}{f\frac{2\pi}{60}}$

$MMF = NI_a \ldots \rightarrow E_{af}$

$\omega = f\left(\frac{E_{af}}{E_a}\right)$

$\tau = k\phi I_a$

a, b)

$V_t = E_a + I_a(R_s + R_a) \rightarrow E_a = 274.28\,V$

$I_a = \frac{I_t}{2} = 21.5A$

$mmf_a = N \cdot I_a = 666.5 \xrightarrow{LIP} E_{af} = 113.315 = k\phi\omega$

$k\phi = \frac{E_{af}}{\omega} = E_{af} \cdot \frac{60}{2\pi f} = 1.2023$

$\tau_{50\%} = k\phi I_a = 25.8497\ Nm$

$W_{50\%} = f \cdot \frac{E_a}{E_{af}} = 2178.4583\ RPM$

c, d) $I_a = I_t$

$V_t = E_a + I_a(R_s + R_a) \rightarrow E_a = 272.56\,V$

$mmf_b = N \cdot I_a = 1333 \xrightarrow{LIP} E_{af_b} = 175.308\,V$

$k\phi = \frac{E_{af_b}}{\omega} = 1.8601$

$\tau_{100\%} = k\phi I_a = 79.9833\ Nm$

$W_{100\%} = f \cdot \frac{E_a}{E_{af_b}} = 1399.2744\ rpm$

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11) $V_t = 265V$, $P = 7hp =$, $W = 1200$ rpm, $R_a = 0.36\Omega$, $I_f = 1.4A$, $I_L = 11.25A$

$I_{f\,new} = 1.1A$

$I_a = I_t - I_f = 9.85A$

$E_a = V_t - I_a R_a = 261.454V$

$I_{a_2} = \frac{V_t}{\sqrt{\left(\frac{I_{f\,new}}{I_f}\right)^2\left(\frac{E_a}{I_a}\right)} + R_a} = 15.8241A$

$E_{a_2} = V_t - I_{a_2} R_a = 259.3033\,V$

$W_2 = W\left(\frac{E_{a_2}}{E_a}\right)\left(\frac{I_f}{I_{f\,new}}\right) = 1514.7096\ RPM$

$I_{L2} = I_{a_2} + I_{f\,new} = 16.9241A$

$P_{mech} = E_{a_2} I_{a_2} = 4103.2481\,W$

$\eta = \frac{P_{mech}}{V_t I_{L2}} \times 100\% = 91.4904\%$

12) $\tau = 275\ Nm$, $V_T = 570V$, $w = 1260\ rpm$, $r_a = 0.35\Omega$

a) $P = \frac{2\pi w}{60}\tau$

$= 11550\pi$

$V_t = \frac{P}{I_a} + I_a R_a \rightarrow I_{a1} = 66.3678\ A$

b) $\tau_2 = \tau_1$

$\phi_1 I_{a1} = \phi_2 I_{a2}$

$\phi_2 = (1-0.29)\phi_1 = 0.71\phi_1$

$I_{a2} = \frac{\phi_1}{0.71\phi_1} I_{a1} = 93.4888\ A$

$\frac{E_{a1}}{E_{a2}} = \frac{\phi_1 w}{\phi_2 w_2}$

$E_{a2} = V_t - I_{a_2} R_a = 537.2859V$

$E_{a1} = \frac{P}{I_{a_1}} = 546.7730\ V$

$\rightarrow \frac{E_{a1}}{E_{a2}} = \frac{\phi_1}{0.71\phi_1}\frac{w}{w_2} \rightarrow w_2 = 1743.8559\ rad/s$

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13) $V_t = 180V$, $P = 5.8\ kW$, $w = 2100\ rpm$, $E_a = 13V$

a) $I_{a_{FL}} = \frac{P}{V_t - E_a} = 34.7305\ A$

$R_a = \frac{E_a}{I_{a_{FL}}} = 0.3743\ \Omega$

$I_a^* = \frac{V_t}{R_a} = 480.8844\ A$

b) Limit $I_{a_{start}}$ to 1.5 times $I_{a_{FL}}$

$R_s = \frac{V_t}{1.5\ I_{a_{FL}}} - R_a = 3.0809\ \Omega$

c) $k\phi = \frac{V_t - E_a}{w \cdot \frac{2\pi}{60}} = 0.7594$

$w_2 = \frac{V_t}{\left(\frac{k\phi}{1-0.19}\right)} = 191.1946\ rad/s \xrightarrow{\times \frac{60}{2\pi}} 1833.4132\ rpm$

(1-0.19 given)

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14) $V_t = 150V$, $I_{a1} = 15A$, $w = 2100\ rpm$ (N), $R_a = 0.22\Omega$, $\phi_2 = 0.075\phi_1$

$\rightarrow I_f = 0$

$E_{b1} = V_t - I_{a_1} R_a = 146.7\ V$

$\frac{E_{b2}}{E_{b1}} = \frac{\phi_2}{\phi_1}$ from $E_b = k\phi w$

$\rightarrow E_{b2} = 11.0025V$

$I_{a2} = \frac{V_t - E_{b2}}{R_a} = 631.8068A$

$\frac{E_{b2}}{E_{b1}} = \frac{\phi_2}{\phi_1}\frac{N_2}{N_1}$ (speed)

$N_2 = 2100$ rpm

$k\phi = \frac{E_{a1}}{w \times \frac{2\pi}{60}} = 0.6671$

$k\phi^* = k\phi \times 0.075 = 0.0500$

$\tau = k\phi\, i_a = 10.0063\ Nm$

$\tau = k\phi^*\left(\frac{V_t - k\phi^* w_2}{R_a}\right) \rightarrow w_2 = 2118.6655\ rad/s$

$\xrightarrow{\times \frac{60}{2\pi}} 20231.7655\ rpm$

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15) $V_t = 640V$, $R_a = 0.34\Omega$, $R_f^* = R_f + R_{adj} = 435\Omega$

$I_m = 100A$, $w_1 = 1750\ rpm$, $w_2 = 1050\ rpm$

$I_{f1} = \frac{V_T}{R_f^*} = 1.4713\ A$

$I_{a_1} = I_T - I_{f_1} = 98.5287\ A$

$$I_{f1} = \frac{V_T}{R_f + R_{adj}} = 1.4713\ A$$

$$I_{a1} = I_m - I_{f1} = 98.5787\ A$$

$$E_{a1} = V_T - I_{a1} R_a = 606.5002\ V$$

$$I_{f2} = I_{f1}$$

$$I_{a2} = I_{a1} \cdot \frac{W_2}{W_1} = 82.7641$$

$$R_{add} = \left(\left(\frac{W_2}{W_1}\right) E_{a1} - V_t\right)\left(-\frac{1}{I_{a2}}\right) - R_a = 1.2373\ \Omega$$