Solutions HW4
EE306 171

Solution Problem 1

a) Machine constant K_a

$\phi = 15\ \text{mWb} \quad Z = 330 \quad p = 4 \quad a = 2$

$$K_a = \frac{Zp}{2\pi a} = \frac{330 \times 4}{2\pi \times 2} = 105.04$$

b) Generated voltage E_a

$$E_a = K_a \phi \omega_m$$

$$= 105.04 \times 15 \times 10^{-3} \times \frac{1150 \times 2\pi}{60}$$

$$E_a = 189.74\ \text{V}$$

c) Conductor current I_c

Since, the armature is wave connected.

Conductor current $I_c = \dfrac{I_a}{a} = 125\ \text{A}$.

d) Electromagnetic torque T_e

$$T_e = K_a \phi I_a$$

$$= 105.04 \times 15 \times 10^{-3} \times 250$$

$$T_e = 393.99\ \text{N-m}$$

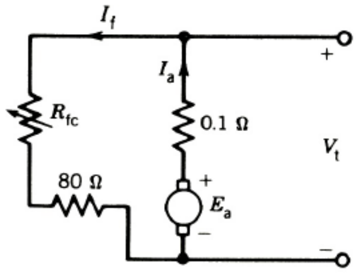
e) Power developed, P_{dev}, by the armature

$$P_{dev} = E_a I_a$$

$$= 189.74 \times 250$$

$$P_{dev} = 47.43\ \text{kW}$$

Solution Problem 2



(a) The maximum voltage will be generated at the lowest value of the field circuit resistance, $R_{fc} = 0$. Draw a field resistance line (see Fig. 3 provided) for $R_f = R_{fw} = 80\ \Omega$. The maximum generated voltage is

$$E_a = 111 \text{ volts}$$

(b)

$$\begin{aligned} V_t &= E_a - I_a R_a \\ &\simeq E_a \\ &= 100\text{ V} \end{aligned}$$

Draw a field resistance line that intersects the magnetization curve at 100 V (see Fig. 3 provided). For this case,

$$I_f = 1\text{ A}$$

$$R_f = \frac{100}{1} = 100\ \Omega = R_{fw} + R_{fc}$$

$$R_{fc} = 100 - 80 = 20\ \Omega$$

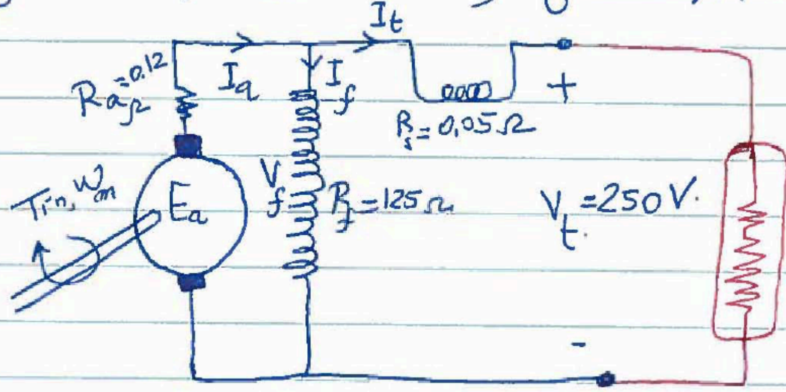
Solution Problem 3

$P = 6$, Short Shunt Compound generator

$\omega = 1200$ rpm, $R_f = 250$, $V_t = 250\,V$, $R_a = 0.12\,\Omega$,

$R_f = 125\,\Omega$, $R_s = 0.05\,\Omega$, $\eta = 82\%$, $P_{out} = 25\,kW$

a)



$P_{out} = 25\,kW$

$\omega_m = \frac{2\pi}{60} \times 1200 = 125.66$ rd/sec.

b)

$\eta = \frac{P_{out}}{P_{in}} \times 100\% \Rightarrow P_{in} = \frac{P_{out}}{\eta} = \frac{25}{0.82} = 30.488\,kW$

$P_{in} = T_{in} \times \omega \Rightarrow T_{in} = \frac{P_{in}}{\omega} = \frac{30.488 \times 10^3}{125.66} = 242.65\,N.m$

c) $P_{dev} = E_a I_a$, $I_t = P_{out}/V_t = \frac{25 \times 10^3}{250} = 100\,A$

$E_a = V_f + I_a R_a$, $V_f = V_t + I_t \times R_s = 250 + (100)(0.05)$

$V_f = 255\,V$

$I_f = V_f / R_f = 255/125 = 2.04\,A$, $I_a = I_f + I_t = 2.04 + 100 = 102.04\,A$

$I_a = 102.04\,A$, $E_a = 255 + (102.04)(0.12) = 267.2448\,V$

$P_{dev} = (267.2448)(102.04) = 27.26965\,kW$

$T_{dev} = P_{dev}/\omega = (27269.65/125.66) =$

$T_{dev} = 217.011\,N.m$

Solution Problem 4

DC Shunt motor

R_a=0.1 Ω
R_f=120 Ω
V_t= 120 V
I_L= 41 A
V_{brash}= 2 V
ω_m =200 ras/sec

a. $I_L = I_a + I_f$

$$I_f = \frac{V_t}{R_f} = \frac{120V}{120\Omega} = 1A$$

$$I_a = I_L - I_f = 41 - 1 = 40A$$

$$V_t = E_a + I_a R_a + 2V$$

b. $E_a = V_t - I_a R_a - 2V$

$$= 120 - 40 * 0.1 - 2 = 114\,V$$

$$P_{dev} = E_a * I_a$$

$$= 114 * 40 = 4.56\,kW$$

$$P_{dev} = T_{dev} * \omega_m$$

$$T_{dev} = \frac{P_{dev}}{\omega_m} = \frac{4.56\,kW}{200\,rad/\sec} = 22.8\,N - M$$

Solution Problem 5

(a)

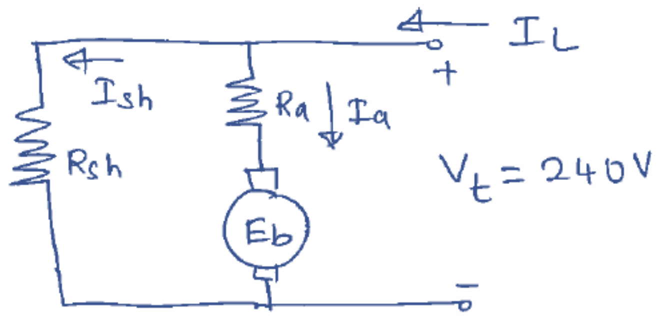
$$T = k_1 \times \emptyset \times i = k_2 \times i^2$$
$$\frac{T_1}{T_2} = 0.5 = \frac{i^2}{75^2}$$
$$i^2 = 0.5 \times 75^2 = 2812.5$$
$$i = 53.03\ A$$

(b)

$$E_{a1} = 600 - 75 \times 0.5 = 600 - 37.5 = 562.5\ V$$
$$E_{a2} = 600 - 53.03 \times 0.5 = 600 - 26.52 = 573.5\ V$$
$$\frac{n_2}{n_1} = \frac{573.5 \times 75}{562.5 \times 53.03} = 1.44$$
$$n_2 = 1.44 \times 500 = 720.97\ rpm$$

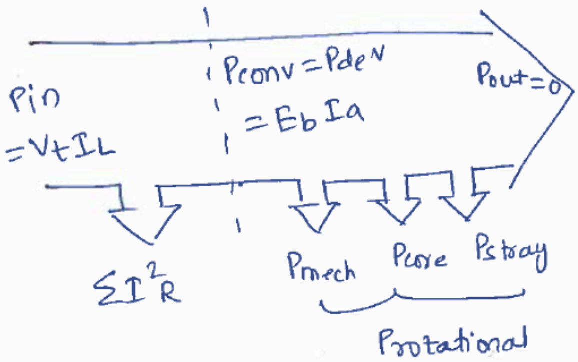
Solution Problem 6

(a)



(b)

No-Load operating condition:-



$P_{rot} = P_{in,NL} - \Sigma I^2R$ (OR)

$P_{rot} = P_{conv} = E_{b,NL} I_{a,NL}$

given $I_{L,NL} = 9A$

$$I_{sh,NL} = \frac{V_t}{R_{sh}} = \frac{240}{120} = 2A$$

$\Rightarrow$ $I_{a,NL} = I_{L,NL} - I_{sh,NL} = 9 - 2 = 7A$

By KVL,

$$E_{b,NL} = V_t - I_{a,NL}R_a - V_{BR}$$
$$= 240 - 7 \times 0.3 = 237.9V$$

Now $P_{rot} = E_{b,NL} \cdot I_{a,NL}$

$= 237.9 \times 7$

$$P_{rot} = 1665.3 \text{ W}$$

Full-load operating condition:-

$P_{in} = 12 \text{ KW}$

$P_{cu} = \Sigma I^2 R = I_a^2 R_a + I_{sh}^2 R_{sh}$

From, $V_t I_L = 12 \times 10^3$

$\Rightarrow I_L = \frac{12 \times 10^3}{240} = 50 \text{ A}$

$P_{cu} = (48)^2 \times 0.3 + 2^2 \times 120 =$

$$P_{cu} = 1171.2 \text{ W}$$

Now, Efficiency

$$\eta = \frac{P_{in} - P_{cu} - P_{rot}}{P_{in}} \times 100$$

$$= \frac{12000 - 1665.3 - 1171.2}{12000} \times 100$$

$$\eta = 76.36 \%$$

Solution Problem 7

(a)

SOLUTION At no-load conditions, $E_A = V_T = 240$ V. The field current is given by

$$I_F = \frac{V_T}{R_{\text{adj}} + R_F} = \frac{240\text{ V}}{175\ \Omega + 75\ \Omega} = \frac{240\text{ V}}{250\ \Omega} = 0.960\text{ A}$$

From Fig.5, this field current would produce an internal generated voltage E_{Ao} of 241 V at a speed n_o of 1200 r/min. Therefore, the speed n with a voltage E_A of 240 V would be

$$\frac{E_A}{E_{Ao}} = \frac{n}{n_o}$$

$$n = \left(\frac{E_A}{E_{Ao}}\right) n_o = \left(\frac{240\text{ V}}{241\text{ V}}\right)(1200\text{ r/min}) = 1195\text{ r/min}$$

(b)

SOLUTION At full load, the armature current is

$$I_A = I_L - I_F = I_L - \frac{V_T}{R_{\text{adj}} + R_F} = 110\text{ A} - \frac{240\text{ V}}{250\ \Omega} = 109\text{ A}$$

The internal generated voltage E_A is

$$E_A = V_T - I_A R_A = 240\text{ V} - (109\text{ A})(0.19\ \Omega) = 219.3\text{ V}$$

The field current is the same as before, and there is no armature reaction, so E_{Ao} is still 241 V at a speed n_o of 1200 r/min. Therefore,

$$n = \left(\frac{E_A}{E_{Ao}}\right) n_o = \left(\frac{219.3\text{ V}}{241\text{ V}}\right)(1200\text{ r/min}) = 1092\text{ r/min}$$

The speed regulation is

$$\text{SR} = \frac{n_{\text{nl}} - n_{\text{fl}}}{n_{\text{fl}}} \times 100\% = \frac{1195\text{ r/min} - 1092\text{ r/min}}{1092\text{ r/min}} \times 100\% = 9.4\%$$