ELEC 342: Electromechanical Energy Conversion and Transmission

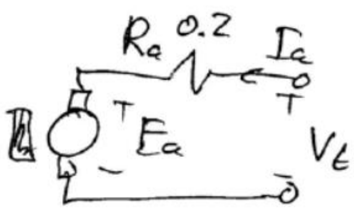
Homework 4, Chapter 4

Solution of the Assignments

P 4.30):

A permanent magnet dc motor drives a mechanical load requiring a constant torque of 25 N · m. The motor produces 10 N · m with an armature current of 10 A. The resistance of the armature circuit is 0.2 Ω. A 200 V dc supply is applied to the armature terminals. Determine the speed of the motor.

Solution:



$R_a = 0.2\,\Omega$

$V_t = 200\,V$

$T_{Load} = 25\,Nm$, ω_{Load}? n_{Load} - ?

$I_a = 10\,A$ at $T_e = 10\,N\cdot m$.

$T_e = K_t \cdot I_a \Rightarrow K_t = T_e / I_a = 1$

$$I_{a,Load} = \frac{T_{e,Load}}{K_t} = 25\,A$$

$V_t = E_a + R_a I_a \Rightarrow E_a = V_t - R_a I_a$

$E_a = 200 - 0.2 \cdot 25 = 195\,V$

$$E_a = K_t \cdot \omega \Rightarrow \omega = \frac{E_a}{K_t} = 195\ r/s$$

$\boxed{\omega_{Load} = 195\ r/s}$

$$n_{Load} = \frac{30}{\pi} \cdot \omega_{Load} = \boxed{1862.1\ rpm}$$

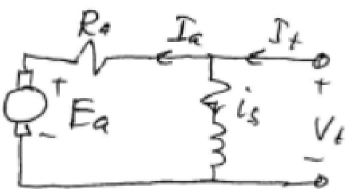
P 4.31):

A dc shunt motor drives an elevator load which requires a constant torque of 300 N · m. The motor is connected to a 600 V dc supply and the motor rotates at 1500 rpm. The armature resistance is 0.5 Ω.

(a) Determine the armature current.

(b) If the shunt field flux is reduced by 10%, determine the armature current and the speed of the motor.

Solution:



$T = 300\,Nm$; $V_t = 600V$;
$n = 1500\,rpm$
$R_a = 0.5\,\Omega$

$\omega = n \cdot \frac{\pi}{30} = 157.08\ r/s$

a) $I_a - ?$

$P_m = \omega T$

$\omega T = P_m = P_e = I_a \cdot E_a = I_a (V_t - R_a I_a)$

$\omega T = V_t \cdot I_a - R_a I_a^2$

$\underset{a}{R_a} I_a^2 \underbrace{- V_t}_{b} I_a + \underbrace{\omega T}_{c} = 0$

$ax^2 + bx + c = 0$

$x_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$I_{a1,2} = \frac{V_t \pm \sqrt{V_t^2 - 4 R_a \cdot \omega \cdot T}}{2 R_a}$

$I_{a1} = 1115.5\,A$ $\Rightarrow$ $P_m = \omega T \approx 47,124\,W$

$P_{in} = V_t \cdot I_a = 6.69 \times 10^5$

$\boxed{I_{a2} = 84,49\,A}$ $= \underline{50,693\,W}$

b) $V_t = R_a I_a + E_a$; $E_a = V_t - R_a I_a = 557.76\,V$

$E_a = K_a \Phi \omega \Rightarrow K_a \Phi = K = \frac{E_a}{\omega} = 3.5508$

$K' = 0.9K = 0.9 K_a \Phi = 3.1957$

$T = \underbrace{K_a \Phi}_{\downarrow 10\%} I_a^{\uparrow}$; $I_a' = \frac{T}{K'} = \frac{300}{3.1957} = 93.8781\,A$

$E_a' = V_t - R_a I_a' = 600 - 0.5 \cdot 93.88 = 553.06\,V$

$\omega' = \frac{E_a'}{K'}$, $n' = \frac{30}{\pi} \cdot \frac{553.06}{3.1957} \approx 1652.7\,\underline{rpm}$

P 4.32):

A dc shunt motor is connected to a 230 V supply and delivers power to a load drawing an armature current of 200 amperes and running at a speed of 1200 rpm. $R_a = 0.2\ \Omega$.

(a) Determine the value of the generated voltage at this load condition.

(b) Determine the value of the load torque. The rotational losses are 500 watts.

(c) Determine the efficiency of the motor if the field circuit resistance is 115 Ω.

Solution:

(a) $E_a = 230 - (0.2)(200) = 190\ V$

(b) $E_a I_a = 190 \times 200 = 38,000\ W$

$P_{load} = 38,000 - 500 = 37,500$

$$T_L = \frac{37500}{2\pi\ 1200/60} = 298.4\ Nm$$

(c) $$I_f = \frac{230}{115} = 2\ A$$

$I_t = I_a + I_f = 200 + 2 = 202A$

$P_{in} = V_t I_t = 230 \times 202 = 46,460\ W$

$$\eta = \frac{37500}{46460} \times 100\% = 80.71\%$$

P 4.38):

A dc motor is mechanically connected to a constant-torque load. When the armature is connected to a 120 V dc supply, it draws an armature current of value 8 A and runs at 1800 rpm. The armature resistance is $R_a = 0.08\ \Omega$. Accidentally, the field circuit breaks and the flux drops to the residual flux, which is only 5% of the original flux.

(a) Determine the value of the armature current immediately after the field circuit breaks (i.e., before the speed has had time to change from 1800 rpm).

(b) Determine the theoretical final speed of the motor after the field circuit breaks.

Solution:

a) $E_a = V_t - i_a R_a = 120V - 8A \cdot 0.08\Omega = 119.36V$

$E_a' = 5\% \cdot E_a = 0.05 \cdot 119.36V = 5.968V$

$$I_a' = \frac{V_t - E_a'}{R_a} = \frac{120V - 5.968V}{0.08\Omega} = 1425.4A$$

b) $$I_a^{new} = \frac{I_a}{5\%} = \frac{8A}{0.05} = 160A$$

$E_a^{new} = V_t - I_a^{new} \cdot R_a = 120V - 160A \cdot 0.08\Omega = 107.2V$

$$N^{new} = \frac{N}{5\%} \cdot \frac{E_a^{new}}{E_a} = \frac{1800\ RPM}{0.05} \cdot \frac{107.2V}{119.36V} = 32332\ RPM$$

P 4.39):

A 600 V dc series motor has armature and field winding resistance of 0.5 Ω. When connected to a 600 V supply, it operates at 500 rpm and takes 75 A. If the load torque is reduced to half, determine

(a) The armature current.

(b) The speed at which it will operate.

Assume that the flux is proportional to current and neglect armature reaction.

Solution:

(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)

$$E_{a1} = 600 - 75 \times 0.5 = 600 - 37.5 = 562.5\ V$$

$$E_{a2} = 600 - 53.03 \times 0.5 = 600 - 26.52 = 573.5\ V$$

$$\frac{n_2}{n_1} = \frac{573.5 \times 75}{562.5 \times 53.03} = 1.44$$

$$n_2 = 1.44 \times 500 = 720.97\ rpm$$