KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
ELECTRICAL ENGINEERING DEPARTMENT
EE 306 – Term 181
HW # 4: DC Machines
Due Date: (Nov 8th, 2018)

Problem # 1:

A four-pole DC machine has a wave winding of 300 turns. The flux per pole is 0.025 Wb. The DC machine rotates at 1000 rpm.

(a) Determine the machine constant,
(b) Determine the generated voltage,
(c) Determine the kW rating if the rated current through the turn is 25 A.

$N = 300, \quad P = 4, \quad a = 2, \quad \phi = 0.025\ Wb$

(a) $$K_a = \frac{NP}{\pi a} = \frac{300 \times 4}{\pi \times 2} = 190.99$$

(b) $$E_a = 190.99 \times 0.025 \times \frac{1000}{60} \times 2\pi$$

$$E_a = 500\ V$$

$$I_a = 2 \times 25 = 50\ A$$

(c) $$P = 500 \times 50 = 25\ kW$$

Problem # 2:

The following information is taken from the nameplate of a separately-excited dc generator.

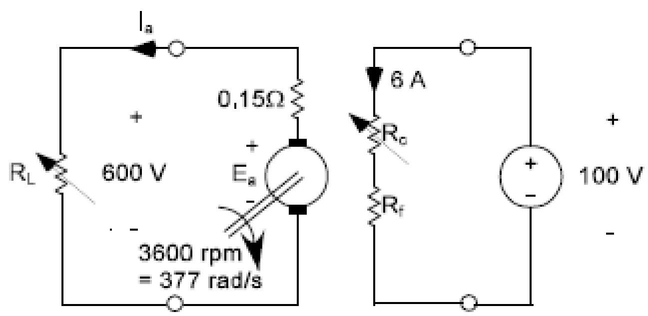
Armature: 120 kW, 600 V, 0.15 Ω.

Field: 100 V, 6.0 A

At its rated speed of 3600 rpm the no-load torque is measured at 16 Nm. Ignore armature reaction and magnetic saturation.

a) For rated load conditions determine:
i) Rated Shaft Horsepower
ii) Rated Efficiency
iii) Load Impedance

b) Determine the terminal voltage, kW output and the efficiency if the field current is reduced to 4.5 A, and the speed is reduced to 3000 rpm, causing the rotational losses to become 4 kW. The load impedance is unchanged.



$$I_a = \frac{P_{out}}{V} = \frac{120 \times 10^3}{600} = 200A$$

$$E_a = 600 + 0{,}15 \times 200 = 630 \text{ V}$$

$$P_D = E_a I_a = 630 \times 200 = 126 \text{ kW}$$

$$\omega_m = 2\pi \times 3600/60 = 377 \text{ rad/s}$$

$P_{rot} = 16 \times 377 = 6032$ W $\qquad P_{shaft} = P_D + P_{rot} = 126 + 6.032 = 132 \text{ kW} = \boxed{177 \text{ hp}}$

ii) $P_{in} = P_{shaft} = 132 \times 10^3 = 132$ kW

$$\eta = \frac{P_{out}}{P_{in}} = \frac{120 \times 10^3}{132 \times 10^3} \times 100\% = \boxed{91\%}$$

ii) $$R_L = \frac{V}{I_a} = \frac{600}{200} = \boxed{3\ \Omega}$$

b) $E_a = K_a\Phi\omega_m$ or $630 = K_a\Phi \times 377$ $\quad\therefore\ K_a\Phi = 1.6711$

$$(K_a\Phi)' = 1.6711 \times \frac{4.5}{6} = 1.2533 \qquad \text{and} \quad \omega_m' = 2\pi \times 3000/60 = 314.2 \text{ rad/s}$$

$\therefore\ E_a' = 1.2533 \times 314.2 = 393.7$ V

$$I_a = \frac{E_a}{R_a + R_L} = \frac{393.7}{0.15 + 3} = 125\ A \qquad \text{and} \quad V' = I_a' R_L = \boxed{375 \text{ V}}$$

$P'_{out} = V'I'_a = 375 \times 125 = \boxed{46.87 \text{ kW}}$

$P_D' = 393.7 \times 125 = 49.22$ kW $\therefore\ P'_{shaft} = 49.22 + 4 = 53.22$ kW

$\therefore\ P'_{in} = 53.22 \times 10^3$ kW

$$\therefore\ \eta = \frac{46.87}{53.22} \times 100\% = \boxed{88.1\%}$$

Problem # 3:

A 240 V DC shunt motor has an armature resistance of 0.05. When the motor is connected to its supply, the armature current is 20 A, the field current is 12 A, and the speed is 1200 rpm. Now, a load is applied to the shaft, and the armature current increases to 300 A, and the speed drops to 1150 rpm. Determine the following for the loaded condition,

(a) Rotational loss,
(b) Field circuit loss,
(c) Efficiency at the loaded condition.

(a) From no-load Condition, rotational loss is :

$$P_{rot} = E_a I_a = (240 - 20 * 0.05) * 20$$

$$= 4780 \text{ W}$$

* This Can be assumed constant if the speed variation is small.

(b) $P_f = 240 * 12 = 2880 \text{ W}$

(c) $P_a = E_a I_a = (240 - 300 * 0.05) * 300$

$$= 67500 \text{ W}$$

$P_{out} = 67500 - 4780 = 62720 \text{ W}$

$P_a = 240 * 300 = 72000 \text{ W}$

$P_{in} = P_a + P_f = 74880 \text{ W}$

$$\eta = \frac{62720}{74880} * 100$$

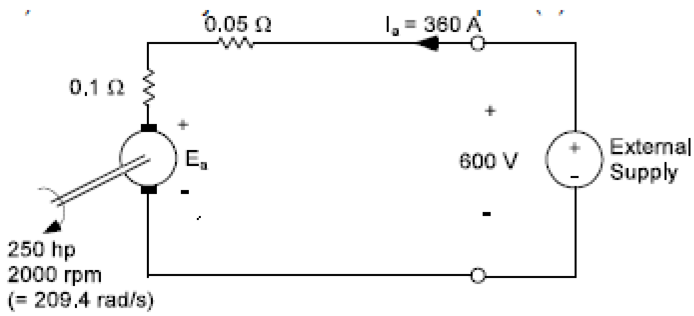
$$\boxed{\eta = 83.8\%}$$

d) $Speed\ regulation = \frac{1200-1150}{1150} * 100\% = 4.35\%$

Problem # 4:

A 600 V dc series motor is rated at 250 hp, 2000 rpm. It has an armature resistance of 0.1 Ω and a field resistance of 0.05 Ω. It draws a current of 360 A from the supply when delivering rated load. Ignore magnetic saturation and determine:

a) Rated output torque.
b) Rated developed torque.
c) Rated efficiency.
d) Rotational losses at rated speed.
e) Speed when the load is changed, causing the line current to drop to 90 A.
f) Developed torque for the conditions in part (e).
g) Horsepower output for the conditions in (e) if the rotational losses are proportional to speed (not speed2).
h) Efficiency for the conditions in part (e).



$P_{out} = 250 \times 746 = 186.5$ kW

$$T_{out} = \frac{186.5 \times 10^3}{209.4} \boxed{= 890.5 \text{ Nm}}$$

To get developed torque we need the developed power, $P_D = E_a I_a$

$E_a = 600 - 0.15 \times 360 = 546$ V

$P_D = 546 \times 360 = 196.56$ kW

b) $$\therefore\ T_D = \frac{196.56 \times 10^3}{209.4} = \boxed{938.5 \text{ Nm}}$$

c) $$P_{in} = 600 \times 360 = 216 \text{ kW} \quad \therefore\ \eta = \frac{186.5}{216} \times 100\% = \boxed{86.3\ \%}$$

d) $$P_{rot} = P_D - P_{out} = \boxed{10.06 \text{ kW}}$$

e) For rated conditions: $$(K_a\Phi) = \frac{E_a}{\omega_m} = \frac{546}{209.4} = 2.607$$

$$\therefore\ (K_a\Phi)' = 2.607 \times \frac{90}{360} = 0.6517$$

and $E'_a = 600 - 0.15 \times 90 = 586.5$ V $\quad \therefore \quad \omega'_m = \dfrac{E'_a}{(K_a\Phi)'} = \dfrac{586.5}{0.6517} = 900$ rad/s

$\therefore$ $\boxed{n' = 8593 \text{ rpm}}$ notice that the speed has increased with reduced load.

f) $$T_D' = (K_a\Phi)'I_a' = 0.6517 \times 90 = \boxed{58.66 \text{ Nm}}$$

g) $P_D' = 586.5 \times 90 = 52.79$ kW and $P'_{rot} = 10.06 \times 10^3 \times \left(\dfrac{8593}{2000}\right) = 43.25$ kW

$$P'_{out} = P'_D - P'_{rot} = 9.56 \text{ kW} = \boxed{12.82 \text{ hp}}$$

h) $$P_{in} = 600 \times 90 = 54 \text{ kW} \quad \therefore\ \eta = \frac{9.56}{54} \times 100\% = \boxed{17.7\ \%}$$