# KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
# ELECTRICAL ENGINEERING DEPARTMENT
# EE 306 – Term 192
## HW # 4: DC Machines
### Due Date: (UT-Classes, March 22, 2020; MW-Classes, March 23, 2020)

**Problem # 1:**

A 220 V shunt motor has armature and field resistance of 0.2 Ω and 220 Ω respectively. The motor is running at 1000 rpm and drawing 10 A current from the supply to drive a constant load torque. Calculate the new speed and armature current if an external armature resistance of value 5 Ω is placed in the armature circuit. Neglect armature reaction and saturation.

For initial operating point: $I_{L1} = 10$ A, $r_a = 0.2$ Ω and supply voltage $V = 220$ V.

$$\begin{aligned} \text{Field current } I_{f1} &= 220/220 \text{ A} = 1\text{A} \\ \text{Armature current } I_{a1} &= 10\text{A} - 1\text{A} = 9\text{A} \end{aligned}$$

Now we write down the expressions for the torque and back emf.

$$\begin{aligned} T_{e1} = k_t I_{f1} I_{a1} &= k_t \times 1 \times 9 = T_L \\ E_{b1} = k_g I_{f1} n = k_g \times 1 \times 1000 = V - I_{a1} r_a &= 220 - 9 \times 0.2 = 218.2\text{V} \\ k_g \times 1 \times 1000 &= 218.2\text{V} \end{aligned}$$

Since field resistance remains unchanged $I_{f2} = I_{f1} = 1$ A. Let the new steady armature current be $I_{a2}$ and the new speed be $n_2$. In this new condition the torque and back emf equations are

$$\begin{aligned} T_{e2} &= k_t \times 1 \times I_{a2} = T_L \\ E_{b2} &= k_g \times 1 \times n_2 \\ &= V - I_{a2}(r_a + R_{ext}) \\ \therefore k_g \times 1 \times n_2 &= 220 - I_{a2} \times 5.2 \text{ V} \end{aligned}$$

Taking the ratios of $T_{e2}$ and $T_{e1}$ we get,

$$\begin{aligned} \frac{T_{e2}}{T_{e1}} &= \frac{k_t \times 1 \times I_{a2}}{k_t \times 1 \times 9} \\ \text{Thus, } I_{a2} &= 9 \text{ A} \end{aligned}$$

Now taking the ratio emfs $\frac{E_{b2}}{E_{b1}}$, we get,

$$\frac{k_g \times 1 \times n_2}{k_g \times 1 \times 1000} = \frac{220 - I_{a2} \times 5.2}{218}$$

$$\begin{aligned} \frac{n_2}{1000} &= \frac{220 - 9 \times 5.2}{218.2} \\ \text{or, } \frac{n_2}{1000} &= \frac{173.2}{218.2} \\ \text{or, } n_2 &= \frac{173.2 \times 1000}{218.2} \\ \therefore n_2 &= 793.76 \text{ rpm} \end{aligned}$$

**Problem # 2:**

Separately excited dc generator is rated for a load voltage of 150 V for a full load current of 20 A at 1500 rpm. With the load disconnected, the output voltage is 160 V.
a. Determine the voltage regulation, the load resistance, the armature resistance, and the developed torque at full load.
b. The speed of the generator is decreased to 1200 rpm, and the load resistance is unchanged. Determine the load current, the load voltage, and the developed power.

$$\text{(a) voltage regulation} = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\% = \frac{160 - 150}{150} \times 100\% = 6.667\%$$

$$R_L = \frac{V_L}{I_L} = \frac{150}{20} = 7.5\,\Omega \qquad R_A = \frac{V_{NL} - V_{FL}}{I_{FL}} = \frac{160 - 150}{20} = 0.5\,\Omega$$

$$\omega_m = n_m \frac{2\pi}{60} = 157.1 \text{ rad/s} \qquad T_{dev} = \frac{P_{dev}}{\omega_m} = \frac{E_A I_A}{\omega_m} = \frac{160 \times 20}{157.1} = 20.37 \text{ Nm}$$

(b)

$$V_{NL} = E_A = 160\frac{1200}{1500} = 128 \text{ V} \qquad I_L = \frac{E_A}{R_A + R_L} = \frac{128}{0.5 + 7.5} = 16 \text{ A}$$

$$V_L = R_L I_L = 120 \text{ V} \qquad P_{dev} = E_A I_A = 2048 \text{ W}$$

**Problem # 3:**

A shunt-connected 5-hp dc motor is rated for operation at VT=200 V, IL=23.3 A, and nm=1500 rpm. Furthermore, IF= and RA=0.4 Ω. Under rated conditions find:

A. the input power;
B. the power supplied to the field circuit;
C. the power lost in the armature resistance;
D. the rotational loss;
E. the efficiency

(a) $P_{in} = V_T I_L = 4660 \text{ W}$

(b) $P_F = V_T I_F = 300 \text{ W}$

(c) $I_A = I_L - I_F = 21.8 \text{ A}$

$P_{R_A} = R_A I_A^2 = 190.1 \text{ W}$

(d) $P_{rot} = P_{in} - P_F - P_{R_A} - P_{out}$

$= 440 \text{ W}$

(e) $\eta = \dfrac{P_{out}}{P_{in}} \times 100\% = 80.0\%$

**Problem # 4:**

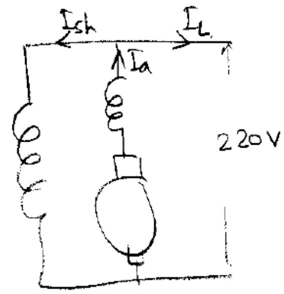
A 240V series motor. The armature resistance is 0.42Ω and a series field resistance is 0.18Ω. The speed is 500rev/min when the current is 36A. What is the motor speed when the load reduces the line current to 21A. Assume 3V brush drop and the flux is proportional to the current.

$$500 = \frac{240-3-36(0.6)}{K_a\phi} \Rightarrow K_a\phi = 0.431$$
$$n = \frac{240-3-21(0.6)}{(\frac{21}{36})(0.431)} = 893\,rpm$$

**Problem # 5:**

A long-shunt DC generator running at 1000 rpm supplies 22 kW at a terminal voltage of 220 V. The armature, shunt, and series resistances are 0.05, 110, and 0.06 Ω respectively. The efficiency of the generator is 88%. Find: -
(a) Copper loss
(b) Rotational loss
(c) Input torque

Solution




$$I_L = \frac{22000}{220} = 100\ A$$
$$I_{sh} = \frac{220}{110} = 2\ A$$
$$I_a = 102\ A$$

(a) $P_{cu} = I_a^2(R_a+R_s) + I_{sh}^2 R_{sh} = 1584.5\ W$

(b) $\eta = \frac{P_{o/p}}{P_{o/p}+P_{rot}+P_{cu}}$ $\quad 0.88 = \frac{22000}{22000+P_{rot}+1584.5}$

$P_{rot} = 1415.5\ W$

(c) $P_{i/p} = \frac{P_{o/p}}{\eta} = 25000\ W = T\omega$

$$25000 = T * \frac{2\pi * 1000}{60}$$