EE306 Energy Conversion

HW4 Due UT Classes March 12th 2019; MW Classes March 13th 2019

Key Solutions

Problem 1:

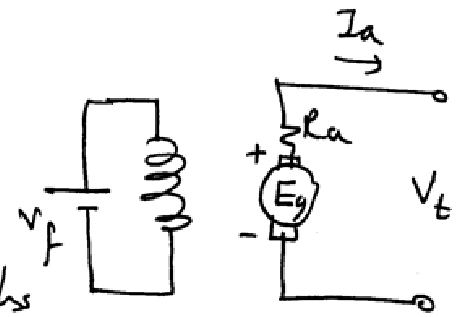
An 8-pole separately excited DC generator is lap wound with 480 conductors. The magnetic flux and the speed are such that the average EMF generated in each conductor is 2.2 V, and each conductor is capable of carrying a full-load current of 100A . Calculate:

(a) the terminal voltage on no load,

(b) the output current on full load,

(c) the power developed by the armature on full load.

Solution:

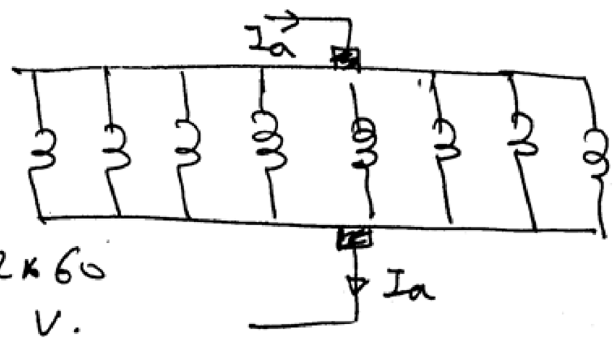


$P = 8$, $Z = 480$, $E_g = 2.2\,V/\text{Cond.}$

$I_{\text{Cond}} = 100A$

(a) $P = a = 8 =$ # of parallel paths

$$\#\ \text{cond/path} = \frac{Z}{a} = \frac{480}{8} = 60$$



induced emf/path $= 2.2 \times 60 = 132\ V.$

$E_g = 132 =$ noload terminal voltage

(b) $I_{a_{F.L}} = a \ast \text{current/path} = 8 \ast 100 = 800\ A.$

(c) $P_d = E_g \ast I_a = 132 \times 800 = \underline{\underline{105.6}}\ kW$

Problem 2:

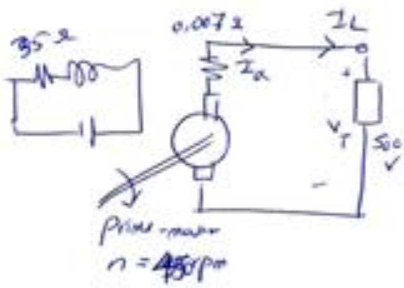
A4-pole, 500V DC separately excited generator is running at a speed of 450 rpm. Its field and armature resistances are 35 and 0.007 ohms respectively. If the generator is supplying a 750 kW load and the rotational power loss is 12180 W, find:

a) The armature induced voltage,

b) The input power

Solution:

Load = 750 kW



$$E_a = V_T + I_a(R_a)$$

$$I_a = I_L = \frac{P_{load}}{V_T} = \frac{750\times10^3}{500}$$

$$I_a = \underline{1500A}$$

(a)

$$\Rightarrow E_a = 500 + 1500(0.007)$$

$$\boxed{E_a = 510.5\ V}$$

(b)

$$P_{in} = P_{out} + P_{losses}$$

$$= 750\times10^3 + (1500)^2(0.007) + 12180$$

$$\boxed{P_{in} = 777.93\ KW}$$

(This is neglecting the field winding losses)

Problem 3:

A 500 V, 450 rpm, 750 kW, separately excited DC generator operates at rated conditions with a rotational losses of 12180 W. The armature resistance $R_a = 0.007\ \Omega$ and the field resistance $R_f = 35\ \Omega$. Assume that the armature reaction is negligible, then find at rated conditions:

(a) the generated EMF,
(b) the input mechanical power,
(c) the input shaft torque,
(d) the efficiency if the field resistance draws a current of 15A.
(e) if the speed is changed to half rated value without adjustment of field current, find the maximum electrical power output possible without overheating armature winding, i.e., with the same full load armature current.

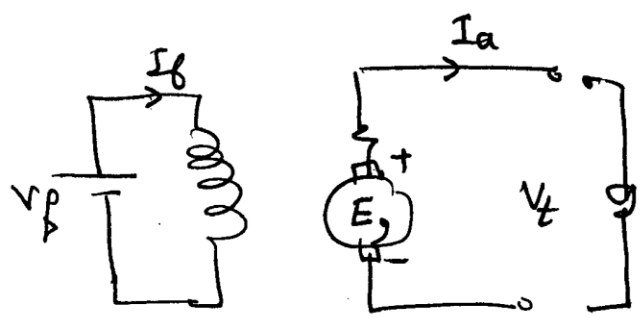
Solution:

500 V, 450 r.pm, 750 KW

$P_{rotational} = 12.18$ KW

$R_a = 0.007\ \Omega$

$R_f = 35\ \Omega$.



(a) $E_g = V_t + I_a R_a$

$I_{a_{F.L}} = \dfrac{750 * 10^3}{500} = 1500$ A

$\rightarrow E_g = 500 + 1500 * 0.007 = 510.5$ V

(b) $P_{i/p_m} = P_o + P_{cu} + P_{rotational}$.

$P_{cu} = I_a^2 R_a = (1500)^2 * 0.007 = 15.75$ KW .

$\rightarrow P_{i/p_m} = 750 + 15.75 + 12.18 = 777.93$ KW
= mechanical input Power

(c) $T_{i/p} = \dfrac{P_{i/p}}{\omega_m} = \dfrac{777.93 * 10^3}{2\pi * \frac{450}{60}} = 16.51$ K N.m.

(d) $\eta = \dfrac{P_o}{P_{i/p}} = \dfrac{P_o}{P_{i/p_m} + P_{cu\ field}}$

$$P_{cu\,field} = I_f^2 R_f = (15)^2 * 35 = 6.86 \text{ KW}$$

$$\eta = \frac{750}{\cancel{777}\,\cancel{.}93 + 6.86} * 100$$

$$= 95.57\,\%$$

(e) $N_2 = \frac{450}{2} = 225$ r.p.m

$$\frac{E_{g1}}{E_{g2}} = \frac{N_1}{N_2} \quad (\phi = \text{Const}) \rightarrow E_{g_2} = \frac{E_{g_1}}{2} = \frac{510.5}{2}$$

$$\rightarrow P_{d_{max.}} = E_{g_2} * I_{a_{f.L}} = \frac{510.5}{2} * 1500 = 382.875$$

$$P_{o_{max.}} = P_d - I_a^2 R_a = 382.875 - 15.75$$

$$= 367.125 \text{ KW}$$

Problem 4:

A 5-hp 120-V 41-A 1800 r/min shunt dc motor is operating at full load. Its armature resistance is 0.30 ohm, and its field resistance is 120 ohm.

a) What is the efficiency of this motor? What is its total rotational loss?

b) Assuming constant rotational losses and a linear magnetization curve, what will the machine's speed be after a 1 percent increase in field resistance?

Solution:

(a) The input power to this motor is

$$P_{IN} = V_T I_L = (120\ \text{V})(41\ \text{A}) = 4920\ \text{W}$$

The output power of the motor is

$$P_{OUT} = (5\ \text{hp})(746\ \text{W/hp}) = 3730\ \text{W}$$

Therefore, the efficiency of the motor is

$$\eta = \frac{P_{OUT}}{P_{IN}} \times 100\% = \frac{3730\ \text{W}}{4920\ \text{W}} \times 100\% = 76\%$$

The machine's total rotational loss will be the difference between the power converted from electrical to mechanical form inside it and the power out of its shaft. The power converted in this machine is $E_A I_A$, and I_A is

$$I_A = I_L - I_F = 41\ \text{A} - \frac{120\ \text{V}}{120\ \Omega} = 40\ \text{A}$$

E_A is given by

$$E_A = V_T - I_A R_A = 120\ \text{V} - (40\ \text{A})(0.30\Omega) = 108\ \text{V}$$

Therefore, the power converted from electrical to mechanical form is

$$P_{conv} = E_A I_A = (108\ \text{V})(40\ \text{A}) = 4320\ \text{W}$$

and the rotational losses are

$$P_{rot\ loss} = P_{conv} - P_{OUT} = 4320\ \text{W} - 3730\ \text{W} = 590\ \text{W}$$

(b) If the field resistance increases by 1%, then the field current becomes

$$I_{F,2} = \frac{120\ \text{V}}{121.2\ \Omega} = 0.9901\ \text{A}$$

We must now make some assumption about the nature of the load on the machine to finish the problem. Since no special type of load was specified, we will make the simplifying assumption that E_A is constant, since this gives the simplest answer.

If the value of E_A before the change is equal to the value of E_A after the change, then the speed of the motor can be found from the equation

$$\frac{E_{A2}}{E_{A1}} = \frac{K\phi_2\omega_2}{K\phi_1\omega_1} = \frac{I_{F2}\ n_2}{I_{F1}\ n_1} = 1$$

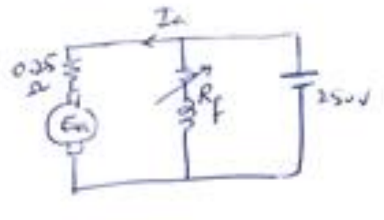
Therefore,

$$n_2 = \frac{1.0\ \text{A}}{0.9901\ \text{A}}\ (1800\ \text{rev/min}) = 1818\ \text{rev/min}$$

Problem 5:

A 250 V DC shunt motor has an armature resistance of 0.25 ohms and a variable field resistance. At a certain loading condition, the motor's generated (induced) voltage is 245 V. Find what will be the motor's new armature current when there is 1% decrease in the flux value?

Solution:



$E_a = 245\,V$

$E_a = K\phi\omega$

cond. 1 $\rightarrow E_a = 245\,V$

cond 2 $\rightarrow E_a = ?$

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

$$I_{a_1} = \frac{250 - 245}{0.25} = 20\,A$$

$$\frac{E_{a_1}}{E_{a_2}} = \frac{K\phi_1\omega_1}{K\phi_2\omega_2} \Rightarrow \left(\begin{array}{c}\omega_1 = \omega_2 \\ K \text{ const}\end{array}\right).$$

$$\frac{E_{a_1}}{E_{a_2}} = \frac{\cancel{K}\,\cancel{\phi_1}\,\cancel{\omega_1}}{\cancel{K}\; 0.99\,\cancel{\phi_1}\,\cancel{\omega_2}} \Rightarrow E_{a_2} = 0.99\,E_{a_1}$$

$$\boxed{E_{a_2} = 242.55\,V}$$

$$\Rightarrow I_{a_2} = \frac{V_T - E_{a_2}}{0.25} = \frac{250 - 242.55}{0.25} = 29.8\,A$$