Department of Electrical Engineering
EE 313.3 Electrical machines I
Solution to the Midterm Examination (Numerical part)

Instructor: N. Chowdhury — October 1999

Marks

1. The open-circuit characteristic data of a dc generator taken at 1200 r.p.m. are shown below:

Field current (A)	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0
Term. voltage (V)	92	165	237	303	349	382	415	438	456	469

4 (a) The generator is connected in self-excited mode with an external rheostat connected in series with the field coil. Determine the no-load terminal voltage of the dc generator at 1200 r.p.m. if the field circuit resistance is adjusted to 180 ohms.

4 (b) Determine the no-load terminal voltage of the generator if the speed drops to 1100 r.p.m. All other conditions remain same as mentioned in (a).

Solution:

(a) At no-load the voltage drop, $I_a R_a$, is very small. Therefore, for all practical purposes $V_t \approx E_a$.
Draw the OCC curve at 1200 rpm. Also draw the field circuit resistance line on the same graph.

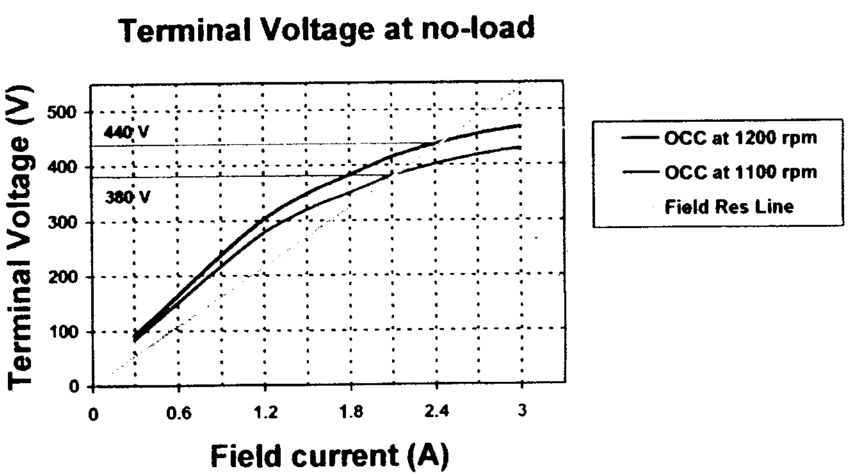

Figure 1. Generated voltage at no-load

The field circuit resistance line intersects the 1200 rpm OCC curve at 440 V (Figure 1). Therefore, the no-load terminal voltage at 1200 rpm is 440 V. Ans.

(b) Draw a new OCC curve at 1100 rpm. Use the data for 1200 rpm OCC to generate the 1100 rpm OCC data in the following way.

For a given field current, the generated voltage is proportional to the speed. Therefore,

$$E_a^{1100} = E_a^{1200} * \left(\frac{1100}{1200}\right)$$

The field circuit resistance line intersects the 1100 rpm OCC curve at 380 V (Figure 1). Therefore, the no-load terminal voltage at 1100 rpm is 380 V. Ans.

6 2. A dc shunt generator is driven at 900 r.p.m. with its output terminals connected to an electroplating process. The generator is delivering 180 A at a terminal voltage of 240 V. The field circuit resistance and the armature resistance of the generator are 60 Ω and 0.08 Ω respectively. Determine the output power of the generator. Determine the total electrical power generated by the dc machine.

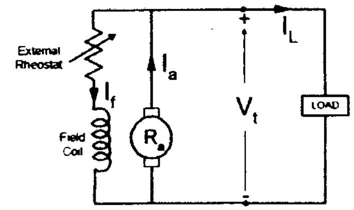

Figure 2. A dc shunt generator.

Solution:

I_L = 180 A and V_t = 240 V. Field current, $I_f = V_t / R_f$. I_f = 240 / 60 = 4 A

Armature current, $I_a = I_L + I_f$ = 180 + 4 = 184 A

The output power of this generator is: $P_{out} = V_t \times I_L$ = 240 X 180 = 43.2 kW Ans.

The total power generated is given by: $P_{total} = P_{out} + P_{loss}$ where P_{loss} is the power lost in the field and the armature circuit.

$$P_{total} = P_{out} + I_a^2 R_a + I_f^2 R_f$$
$$P_{total} = 43.2\ \text{kW} + (184)^2(0.08) + (4)^2(60)$$
$$P_{total} = 46868.5\ \text{W}$$

Total electrical power generated is 46868.5 W Ans.

8 3. A 80-hp, 440-V, 500-rpm dc shunt motor has been purchased to drive a grinding machine at a cement factory. The motor is supplied from a 400 V dc supply and is drawing a line current of 120 A while driving the grinding machine at 470 r.p.m. The field circuit resistance and the armature resistance of the motor are

130 Ω and 0.05 Ω respectively. Determine the efficiency of the dc motor if the combined mechanical loss at 470 r.p.m. is 4 kW

Solution:

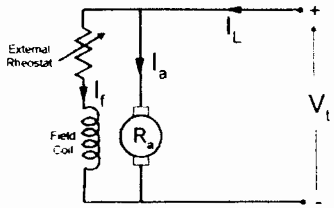

Figure 3. A dc shunt motor

Field current, $I_f = V_t / R_f$. $V_t = 400$ V and $R_f = 130\ \Omega$. Therefore, $I_f = 400 / 130 = 3.08$ A
Armature current, $I_a = I_L - I_f = 120 - 3.08 = 116.92$ A

$$E_a = V_t - I_aR_a = 400 - (116.92)(0.05) = 394.2 \text{ V}$$

$$P_{out} = P_c - \text{Rotational losses} = E_aI_a - 4 \text{ kW} = (394.2)(116.92) - 4 \text{ kW} = 42077 \text{ W}$$

$P_{in} = V_tI_L = (400)(120) = 48000$ W

Efficiency $= P_{out} / P_{in} = 42077 / 48000 = 0.88$ Ans.

6 4. A dc series motor draws a line current of 160 A and runs at 500 r.p.m. at rated output when connected to a 480-V dc supply. The total resistance of the armature and the series field winding is 0.12 ohm. Determine the speed of the motor when the load changes so that it draws a line current of 120 A. Neglect saturation and armature reaction.

Solution:

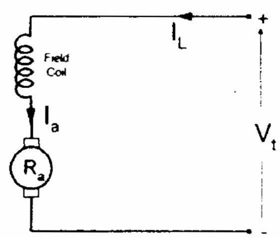

Figure 4. A dc series motor

Calculate the counter emf at 500 rpm.
$E_{a1} = V_t - I_L(R_a + R_f) = 480 - (160)(0.12) = 460.8$ V

Calculate the counter emf for the second case.
$E_{a2} = V_t - I_L(R_a + R_f) = 480 - (120)(0.12) = 465.6$ V

Neglecting saturation and armature reaction, $E_a = KI_a\omega_m = KI_f\omega_m$

$$\frac{E_{a1}}{E_{a2}} = \frac{KI_{a1}\omega_{m1}}{KI_{a2}\omega_{m2}} = \frac{I_{a1}n_1}{I_{a2}n_2}$$

$$\frac{460.8}{465.6} = \frac{(160)(500)}{(120)n_2}$$

$$n_2 = \left(\frac{465.6}{460.8}\right)\left(\frac{160}{120}\right)500$$

$n_2 = 673.6$ rpm Ans.

THE END