Lesson 10: Separately Excited Dc Motors

ET 332a

Dc Motors, Generators and Energy Conversion Devices

1

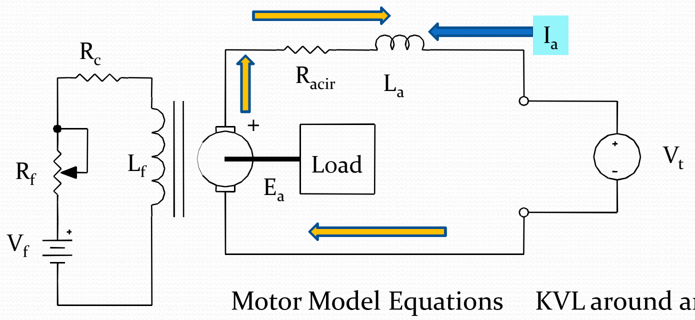
Learning Objectives

After this presentation you will be able to:

- Draw a circuit model of a separately excited dc motor.
- Identify and utilize equations that represent motor performance to solve separately excited dc motor problems
- Write a power balance for a separately excited motor and compute its efficiency
- Explain how changing motor load affects efficiency
- Interpret motor nameplate data

2

Separately Excited Dc Motor Model



Motor Model Equations

Inducted EMF Equation: $E_a = k_G \cdot n \cdot \Phi_p$

KVL around armature loop gives:

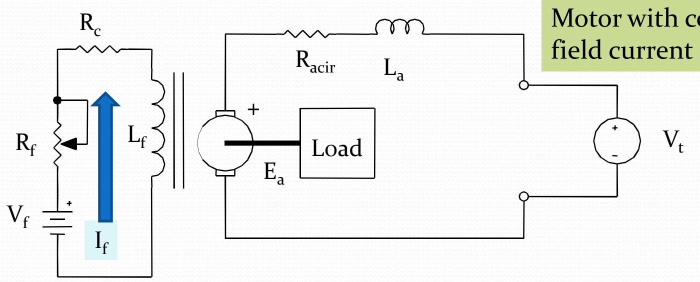
$$V_t = E_a + I_a \cdot R_{acir}$$

Solving for n gives: $n = \dfrac{E_a}{k_G \cdot \Phi_p}$

Solve for armature current $I_a = \dfrac{V_t - E_a}{R_{acir}}$

3

Separately Excited Dc Motor Model



Motor with constant field current

Assuming constant field current gives: $\Phi_p \cdot k_G = K_e$

Where K_e is the back EMF constant

Previous E_a equation simplifies to: $E_a = K_e \cdot n$

Solving for n gives: $n = \dfrac{E_a}{K_e}$

Back EMF, E_a, proportional to speed

4

Motor Torque Equations

Developed torque related to the field strength and the armature current.

$$T_D = k_m \cdot B_p \cdot I_a$$

Where: T_D = developed torque
B_p = flux density of field poles
I_a = armature current
k_m = motor design constant

k_m depends on number of turns, effective conductor length, # poles, units etc.

Relate pole flux density to the motor field current..... Remember

$B_p = \frac{\Phi_p}{A}$ and $\Phi_p = \frac{N \cdot I_f}{\mathfrak{R}}$ Combining gives $B_p = \frac{N \cdot I_f}{A \cdot \mathfrak{R}}$

5

Motor Torque Equations

Since N, A, are set by design and reluctance is assume constant in linear part of magnetization curve

Let $k_T = \frac{N}{A \cdot \mathfrak{R}}$ So now developed torque is given by

$$T_D = k_T \cdot I_f \cdot I_a$$

Developed torque is the product of I_f and I_a

For constant field current, I_f $K_T = k_T \cdot I_f$ So.....

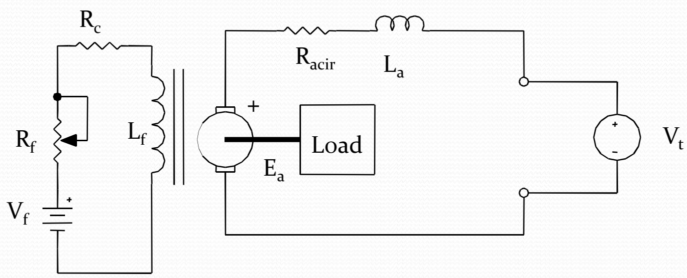
$$T_D = K_T \cdot I_a$$

Developed torque is proportional to armature current for constant field current

Note: K_T and K_e are numerically equal in SI units (N-m)

6

Example 10-1 Separately Excited Motor



A 240 V 20 HP 850 rpm separately excited motor draws 72A when operating at rated conditions. Determine the percent reduction of field flux necessary to obtain a speed of 1650 rpm if the motor draws 50.4 amps at that speed

$R_{acir} = 0.284\ \Omega$

7

Example 10-1 solution (1)

Example Solution

$V_T = 240\text{ V}$ $\quad R_{acir} = 0.284\ \Omega$

$n_1 = 850\text{ Rpm}$

$n_2 = 1650\text{ Rpm}$

Induced voltage is proportional to motor speed and pole flux

$$E_{a1} = n_1 \Phi_{p1} k_G \qquad E_{a2} = n_2 \Phi_{p2} k_G$$

$$E_a = V_T - I_a R_{acir}$$

8

Example 10-1 solution (2)

Find the induced EMF

$$E_{a1} = V_t - I_{a1} R_{acir}$$
$$E_{a2} = V_T - I_{a2} R_{acir}$$

$$I_{a1} = 72\text{A} \quad I_{a2} = 50.4\text{A}$$

$$E_{a1} = 240 - (72\text{A})(0.284\Omega) = 219.6\text{V}$$
$$E_{a2} = 240 - 50.4\text{A})(0.284\Omega) = 225.7\text{V}$$

Now use proportions to relate initial flux to final flux

9

Example 10-1 solution (3)

$$n_1 = \frac{E_{a1}}{\Phi_{p1} k_G} \qquad n_2 = \frac{E_{a2}}{\Phi_{p2} k_G}$$

$$\frac{n_1}{n_2} = \frac{\frac{E_{a1}}{\Phi_{p1} \cancel{k_G}}}{\frac{E_{a2}}{\Phi_{p2} \cancel{k_G}}} = \frac{\frac{E_{a1}}{\Phi_{p1}}}{\frac{E_{a2}}{\Phi_{p2}}}$$

Simplify proportions

$$\frac{n_1}{n_2} = \left[\frac{E_{a1}}{E_{a2}}\right]\left[\frac{\Phi_{p2}}{\Phi_{p1}}\right]$$

Must find Φ_{p2} in terms of Φ_{p1} using this equation

10

Example 10-1 solution (4)

$$\left[\frac{n_1}{n_2}\right]\left[\frac{E_{a2}}{E_{a1}}\right] = \frac{\Phi_{p2}}{\Phi_{p1}}$$

$$\left[\frac{n_1}{n_2}\right]\left[\frac{E_{a2}}{E_{a1}}\right]\Phi_{p1} = \Phi_{p2}$$

$$\left[\frac{850\ RPM}{1650\ RPM}\right]\left[\frac{225.63V}{219.6V}\right]\Phi_{p1} = \Phi_{p2}$$

$$0.529\,\Phi_{p1} = \Phi_{p2}$$

Use this equation to find the percent change in pole flux

$$\left[\frac{\Phi_{p1} - \Phi_{p2}}{\Phi_{p1}}\right]100\% = \Delta\%\,\Phi_p$$

11

Example 10-1 solution (5)

since $\Phi_{p2} = 0.529\,\Phi_{p1}$ substitute into above

$$\left[\frac{1.0\Phi_{p1} - 0.529\Phi_{p1}}{1.0\Phi_{p1}}\right]100\% = \Delta\%\,\Phi_p$$

$$\left[\frac{\Phi_{p1}}{\Phi_{p1}}\right]\left[\frac{1.0 - 0.529}{1.0}\right]100\% = \Delta\%\,\Phi_p$$

$$\boxed{47.05\% = \Delta\%\,\Phi_p}$$

Answer

12

Example 10-2 Separately Excited Dc Motor Solutions

A 20 HP, 240 V separately excited dc motor is operating a 600 rpm and drawing 30 A of load current. The total armature circuit resistance is 0.565 Ω.

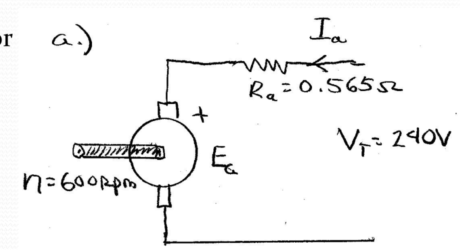
a.) Determine the emf constant K_e for this machine.

b.) If the operates at when it draws field excitation of the machine does not change determine the speed that the machine 22.3 A.

13

Example 10-2 Solution (1)

Part draw schematic of motor



$$E_a = V_T - I_a R_{acir}$$

$$I_a = 30\,A$$

$$E_a = 240 - 30A(0.565\Omega)$$

$$E_a = 223.05V$$

$$E_a = n \Phi_p K_G \Rightarrow \frac{E_a}{n} = \Phi_p K_G$$

$$\frac{223.05V}{600Rpm} = \Phi_p K_G = \boxed{0.37175\ V/Rpm}$$

14

Example 10-2 Solution (2)

b.) Speed a load of 22.3 A

Method 1 Speed proportional to induced emf

$$E_{a2} = V_T - I_{a2} R_{aoR}$$

$$E_{a2} = 240V - (22.3A)(0.565\Omega)$$

$$E_{a2} = 227.4V$$

Use proportionality

$$\frac{E_{a2}}{E_{a1}} = \frac{n_2}{n_1}$$

Solve for n_2

$$\left[\frac{E_{a2}}{E_{a1}}\right] n_1 = n_2$$

15

Example 10-2 Solution (3)

Compute the speed

$$\left[\frac{227.4V}{223.05V}\right] 600\,Rpm = n_2$$

$$\boxed{611.7\,Rpm = n_2}$$

METHOD 2: USE K_e

$$E_{a2} = K_e n_2$$

$$\frac{E_{a2}}{K_e} = n_2 \quad \frac{227.4V}{0.37175\,V/Rpm} = \boxed{611.7\,Rpm}$$

16

End Lesson 10

ET 332a

Dc Motors, Generators and Energy Conversion Devices

17