ET 332a
Dc Motors, Generators and Energy Conversion Devices

LESSON 12 SHUNT CONNECTED DC MOTORS

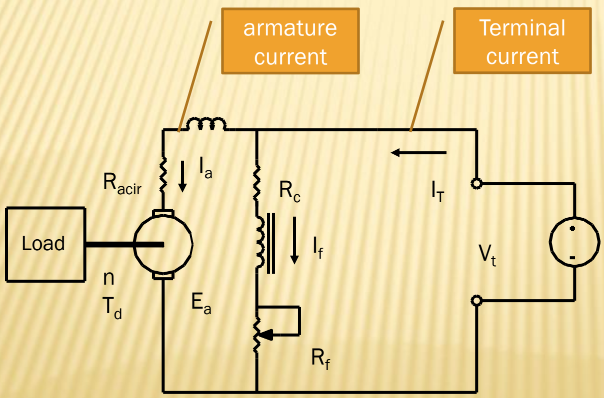
LEARNING OBJECTIVES

After this presentation you will be able to:

- Draw the circuit model of a shunt motor and label all parts correctly
- Use the shunt motor equations to perform calculations on shunt dc motor operation
- Draw and explain how the shunt motor torque speed characteristic affects its operation.

SHUNT CONNECTED DC MOTORS

Field current supplied from the same source as armature. Field current constant if not modified by rheostat.



Motor circuit model schematic

Motor Model Equations

$$I_a = I_T - I_f$$

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

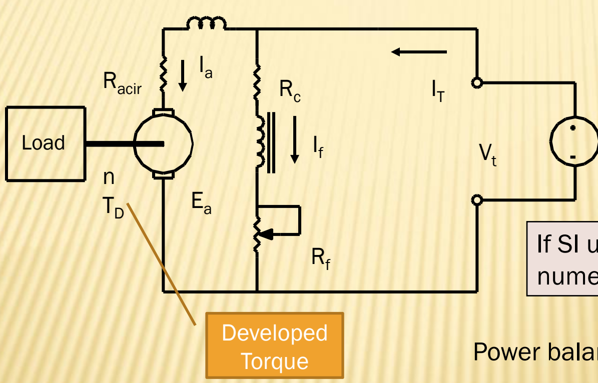
Motor Speed

$$n = \frac{E_a}{\Phi_p \cdot k_G} \qquad \Phi_p \cdot k_G = K_e$$

$$n = \frac{V_T - I_a \cdot R_{acir}}{\Phi_p \cdot k_G}$$

Speed proportional to E_a

SHUNT CONNECTED DC MOTORS



Developed Torque

$$T_D = K_T \cdot I_a$$

Torque proportional to armature current

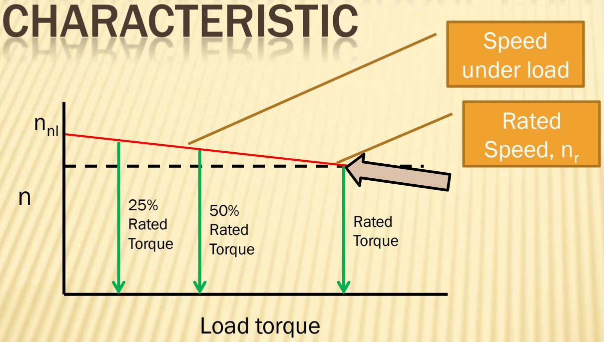
If SI units are used, $K_e = K_T$ numerically

Power balance in the armature

$$P_e = P_{em}$$

$$E_a \cdot I_a = T_D \cdot \omega$$

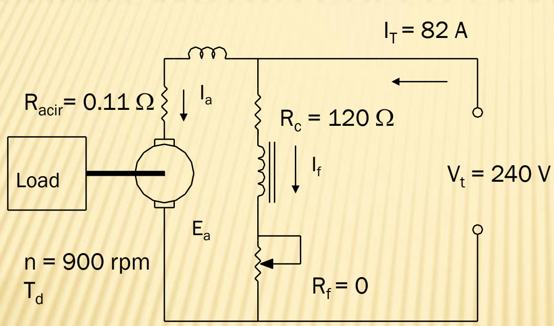
SHUNT MOTOR TORQUE-SPEED CHARACTERISTIC



Difference between no-load speed and rated is small.

Shunt motor gives almost constant speed for over wide range of mechanical load torques.

SHUNT MOTOR SPEED EXAMPLE 12-1



Find the motor terminal current and the motor speed when the developed torque load is increased by 50% from the initial conditions given.

Calculate the speed regulation for the change in load conditions given above

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EXAMPLE 12-1 SOLUTION (1)

Find I_a from the terminal current and the field current

$$I_T = 82\,A$$

$$I_a = I_T - I_f \qquad I_f = \frac{V_T}{R_f} = \frac{240V}{120\Omega} = 2A$$

$$I_a = 82 - 2A = 80A$$

Find E_a

$$E_a = V_T - I_a R_{acir} \qquad R_{acir} = 0.11\Omega$$

$$E_a = 240V - (80A)(0.11\Omega)$$

$$E_a = 231.2V$$

Electric power developed

$$P_e = E_a I_a = (231.2V)(80A) = 18{,}496W$$

7

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EXAMPLE 12-1 SOLUTION (2)

Electric power equals electromechanical power in the armature

$$P_{em} = P_e \Rightarrow T_d \omega = E_a I_a$$

$$T_d = \frac{E_a I_a}{\omega} = \frac{P_e}{\omega}$$

ω = speed in rad/sec $\quad n = 900$ RPM

$$\omega = \left[\frac{2\pi}{60}\right] n \qquad \omega = \left[\frac{2\pi}{60}\right] 900\text{ RPM}$$

$$\omega = 94.25\text{ rad/s}$$

$$T_d = \frac{18{,}496W}{94.25\text{ rad/s}}$$

$$\boxed{T_d = 196.24\text{ rad/s}}$$

Torque at initial operating point

Compute 50% Torque Increase

$$T_{d50} = T_d + T_d\left[\frac{50\%}{100\%}\right]$$

$$T_{d50} = 196.24 + 196.24\left[\frac{50\%}{100\%}\right]$$

$$T_{d50} = 294.4\text{ N-m}$$

8

EXAMPLE 12-1 SOLUTION (3)

Compute the torque constant to find the new armature current

$$K_T = \frac{196.24\ N\text{-}m}{80A} = 2.452\ N\text{-}m/A$$

$T_d = K_T I_{ad}$ K_T is CONSTANT as T_d increases

$T_{d50} = K_T I_{a50}$

$$\frac{T_{d50}}{K_T} = I_{a50}$$

Compute I_{a50} using K_T and T_{d50}

$$\frac{T_{d50}}{K_T} = I_{a50} \Rightarrow \frac{294.4\ N\text{-}m}{2.453\ N\text{-}m/A} = 120\ A$$

Terminal current, add I_f to I_{a50}

$$I_T = I_a + I_f = 120A + 2A = \boxed{122A}$$

EXAMPLE 12-1 SOLUTION (4)

Find new speed

$$\omega = \frac{V_T - I_a R_{acir}}{K_e}$$

Remember $K_e = K_T$ numerically in SI unit. Constant I_f means K_e is constant from load 1 to load 2

New load motor speed

$I_{a50} = 120\ A$ omit I_f

$K_e = K_T = 2.453\ V/rad/s$

use different units

$$\omega_{50} = \frac{V_T - I_{a50} R_{acir}}{K_e}$$

$$\omega_{50} = \frac{240 - (120A)(0.115\Omega)}{2.453\ V/rad/s}$$

$\omega_{50} = 92.458\ rad/s$

Convert to RPM

EXAMPLE 12-1 SOLUTION (5)

Convert radians/second to rpm to compare with initial speed of 900 rpm

$$n_{50} = \omega_{50}\left(\frac{60}{2\pi}\right)$$

$$92.458\left[\frac{60}{2\pi}\right] = n_{50}$$

$$882.91 \text{ Rpm} = n_{50}$$

Calculate percentage speed change for a 50% increase in load developed torque. Take 900 rpm as the base speed, n_b.

$$\%\Delta n = \frac{n_b - n_{50}}{n_b} \times 100\% = \frac{900 - 882.91}{900} \times 100\%$$

$\%n = 1.9\%$ speed change for 50% Torque increase

Almost constant speed over wide load torque range. Shunt motor considered constant speed motor

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END LESSON 12