26-Shunt and Compound DC Motors

Text Chapter 6.6-6.9

ECEGR 450
Electromechanical Energy Conversion

Overview

- Introduction
- Shunt Motor
- Compound Motor

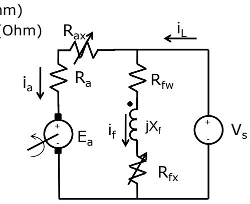
Shunt Motor

- Field winding and armature windings are connected in parallel
- An external variable resistance may be present to start or control the speed of the motor

Shunt Motor

Shunt Motor: field and armature windings are connected in parallel

- R_{fw}: field winding resistance (Ohm)
- R_{fx}: adjustable field winding resistance (Ohm)
- R_a: armature resistance (Ohm)
- X_f: field winding reactance (Ohm)

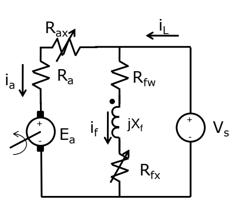


Shunt Motor Torque

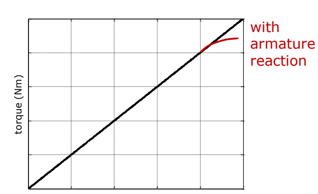
- For a fixed voltage source, the flux is constant
- Therefore

$$T_d = K_a \Phi_P i_a$$
$$K \triangleq K_a \Phi_P$$
$$T_d = K i_a$$

- Torque is proportional to armature current

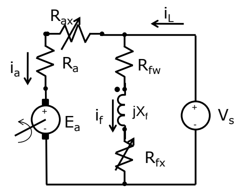


Shunt Motor



Shunt Motor Model

- Under a given load, circuit analysis yields
  $E_a = v_s - i_a R_a$ (assuming R_{ax} is 0 after starting)
- Recall that
  $E_a = K_a \Phi_P \omega_m$
- Therefore:
  $\omega_m = \frac{v_s - i_a R_a}{K_a \Phi_P}$



Shunt Motor

- Flux produced by the field winding in a shunt motor is constant
- As load on the motor increases:
  - Armature current increases
  - Due to voltage drop across R_a, the back emf decreases
  - Ignoring armature reaction, the speed decreases due to

$$\omega_m = \frac{v_s - i_a R_a}{K_a \Phi_P}$$

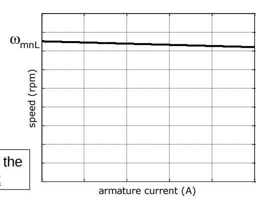
Shunt Motor

$$\omega_m = \frac{v_s - i_a R_a}{K_a \Phi_P}$$

$$\omega_{mnL} \triangleq \frac{v_s}{K_a \Phi_P}$$

$$\omega_m = \omega_{mnL} - \frac{i_a R_a}{K_a \Phi_P}$$

Since the armature resistance is low, the speed of the motor is nearly constant



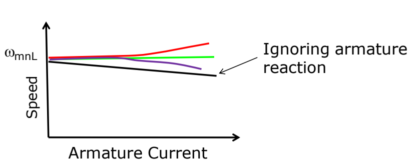
How does this compare to a series motor?

Shunt Motor

- Armature reaction increases with armature current
  - Flux is decreased
  - Speed is increased
- Increase in speed may be less than, greater than or equal to the drop in speed due to the increased armature current

Shunt Motor

- Including armature reaction



Shunt Motor

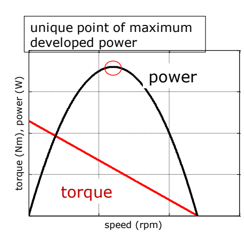
Torque-speed relationship is found from:

$$T_d = K_a \Phi_P i_a$$

$$\omega_m = \frac{v_s - i_a R_a}{K_a \Phi_P}$$

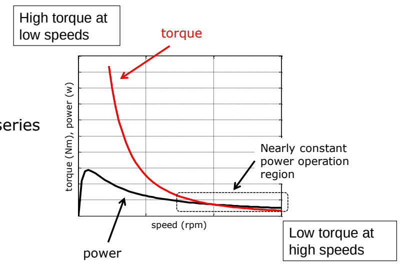
$$i_a = \frac{v_s}{R_a} - \frac{\omega_m K_a \Phi_P}{R_a}$$

$$T_d = \frac{v_s K_a \Phi_P}{R_a} - \frac{\omega_m K_a^2 \Phi_P^2}{R_a}$$



Series Motor

Recall for a series motor:



Shunt Motor

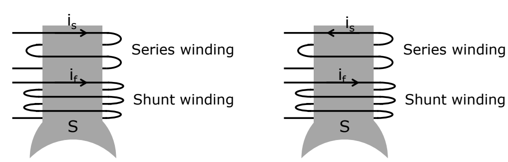
- Observations:
  - Torque decreases linearly with speed
  - Speed increases as the load decreases
  - Power developed is maximum when:

$$P_{d,max} = \frac{v_s^2}{4R_a}$$

Compound Motor

- A series winding may be added to a shunt motor to create a compound motor
- Hybrid of the characteristics of shunt and series motors
- Two types:
  - Cumulative
    - Flux set up by series winding is additive with flux set up by shunt winding $\phi_P = \phi_{sh} + k_f i_a$
  - Differential
    - Flux set up by series winding is subtractive with flux set up by shunt winding $\phi_P = \phi_{sh} - k_f i_a$

Compound Motor

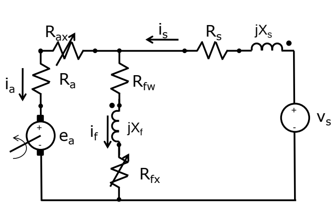


Cumulative (mmfs add)

Differential (mmfs subtract)

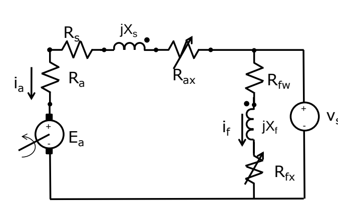
Compound Motor

Short-shunt compound motor: series winding is placed before shunt winding



Compound Motor

Long-shunt compound motor: shunt winding is placed directly across the voltage source



Compound Motor

As load increases for a long-shunt cumulative compound motor:

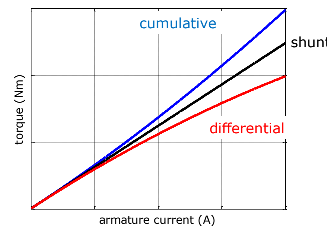
- Total flux increases due to increase in series winding current $\phi_P = \phi_{sh} + k_f i_a$
- Increase flux with the increased armature current increases the torque at a greater rate than in a shunt motor

$$T_d = K_a i_a \phi_{sh} + K_a k_f i_a^2$$

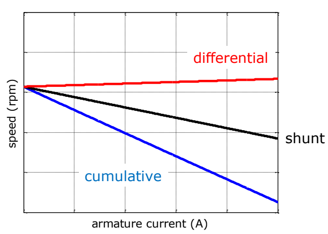
- Increased flux with increased voltage drops in the armature and field windings slows down the motor more rapidly than in a shunt motor

$$\omega_m = \frac{V_s - i_a(R_a + R_s)}{K_a(\phi_{sh} + k_f i_a)}$$

Torque vs Armature Current



Speed vs Armature Current



Compound Motor

- Observations:
  - Cumulative compound motor
    - Definite no-load speed (compare this with a series motor)
    - High starting torque if load is increased
    - Used in applications that require high torque and prone to sudden load changes (elevators, cranes, etc)
  - Differential compound motor
    - Possibility for damaging high speeds to be obtained if flux in series winding approaches that in shunt winding

Summary

- Shunt DC motors have field winding placed in shunt with voltage source
  - Near-constant speed operation
- Compound DC motors are hybrids of shunt and series motors, each with distinct characteristics