UNIT-III

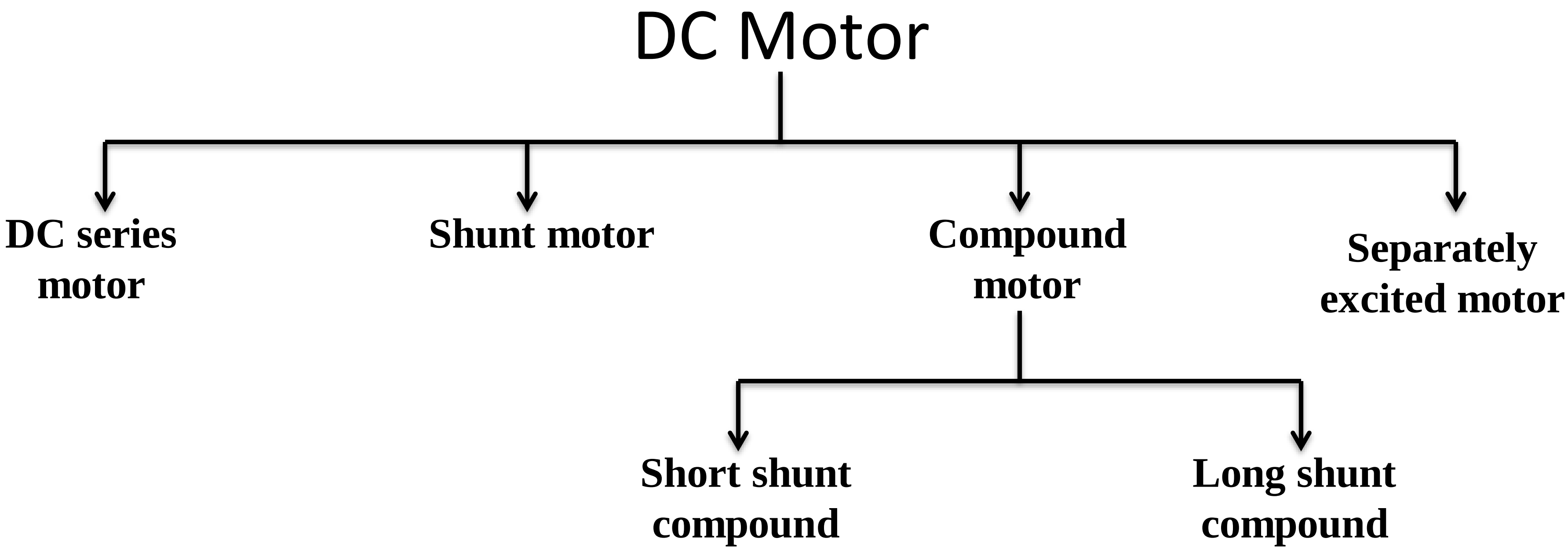
Fundamentals of Electrical Machines

Lecture 19

Prepared By:
Krishan Arora
Assistant Professor and Head

Types of DC Motors

- Depending on the way of connecting the armature and field windings of a d.c. motors are classified as follows:



Important Equations

Voltage Equation

$$V = E_b + I_a R_a + V_b \qquad \text{.......(1)}$$

- But voltage drop across brushes is negligible.

$$\therefore V = E_b + I_a R_a \qquad \text{......(2)}$$

Torque equation of DC shunt motor:

- $\therefore T \propto I_a$ ....(3)

Torque equation DC series motor:

- $T \propto I_a I_a = T \propto I_a^2$ ....(4)

Revision Quiz (Poll 1)

- Which part will surely tell that given motor is DC motor and not an AC type?

  a) Winding
  b) Shaft
  c) Commutator
  d) Stator

Speed Equations

- We know that the expression for the back emf is, $E_b = \frac{NP\varphi Z}{60\ A}$
- But P, Z and 60A are constants. Therefore we can write that,

$$E_b \propto ø\ N \qquad \text{......(1)}$$

- Therefore the speed can be expressed as,

$$N \propto E_b / ø \qquad \text{.......(2)}$$

$$N = k\ E_b / ø \qquad \text{.........(3)}$$

- But $V = E_b + I_a\ R_a$

$$\therefore E_b = V - I_a\ R_a \qquad \text{...........(4)}$$

- Substituting eq.(4) into eq.(2) we get,

$$N \propto (V - I_a\ R_a) / ø \qquad \text{.......(5)}$$

- Since $ø \propto I_{field}$, we can write,

$$N \propto (V - I_a\ R_a) / I_{field} \qquad \text{.......(6)}$$

Speed Control of DC Motor:

- The speed equation of dc motor is

$$N \propto \frac{Eb}{\emptyset} \propto \frac{(V - IaRa)}{\emptyset}$$

- But the resistance of armature winding or series field winding in dc series motor are small.
- Therefore the voltage drop $IaRa$ or $Ia(Ra + R_s)$ across them will be negligible as compare to the external supply voltage V in above equation.
- Therefore $N \propto \frac{V}{\emptyset}$, since V>>>> $IaRa$
- Thus we can say

1. Speed is inversely proportional to flux Ø.
2. Speed is directly proportional to armature voltage.
3. Speed is directly proportional to applied voltage V.

So by varying one of these parameters, it is possible to change the speed of a dc motor

Thus speed can be controlled by:

- <u>Flux control method:</u> By Changing the flux by controlling the current through the field winding.

- <u>Armature control method:</u> By Changing the armature resistance which in turn changes the voltage applied across the armature

Flux Control Method

Advantages:

- It provides relatively smooth and easy control
- Speed control above rated speed is possible
- As the field winding resistance is high the field current is small. Power loss in the external resistance is small . Hence this method is economical

Disadvantages:

- Flux can be increased only upto its rated value
- High speed affects the commutation, motor operation becomes unstable

Armature Voltage Control Method

- The speed is directly proportional to the voltage applied across the armature .
- Voltage across armature can be controlled by adding a variable resistance in series with the armature

Potential Divider Control

If the speed control from zero to the rated speed is required , by rheostatic method then the voltage across the armature can be varied by connecting rheostat in a potential divider

Need of Starter:

We know that, $V = E_b + I_a R_a$............for a dc shunt motor

and $V = E_b + I_a(R_a + R_s)$....for a dc series motor

Hence the expression for I_a are as follows:

$$I_a = \frac{V - E_b}{R_a} \text{....................... for dc shunt motor}$$

$$I_a = \frac{V - E_b}{(R_a + R_s)} \text{..................for dc series motor}$$

At the time of starting the motor, speed N=0 and hence the back emf E_b=0. Hence the armature current at the time of starting is given by,

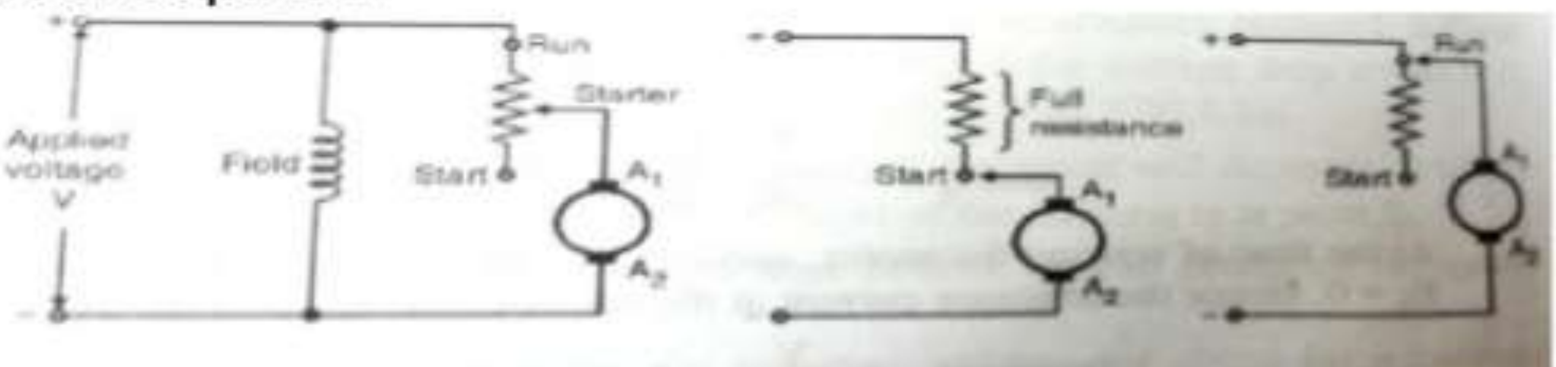
$$I_{a(starting)} = \frac{V}{R_a} \text{............for dc shunt motor}$$

$$I_{a(starting)} = \frac{V}{(R_a + R_s)} \text{......for dc series motor}$$

- Since the the values of R_a and $R_s$are small, the starting currents will be tremendously large if the rated voltage is applied at the time of starting.
- The starting current of the motor can be 15 to 20 times higher than the full load current.
- Due to high starting current the supply voltage will fluctuate.
- Due to excessive current, the insulation of the armature winding may burn.
- The fuses will blow and circuit breakers will trip.
- For dc series motors the torque $\mathrm{T} \propto {I_a}^2$. So an excessive large starting torque is produced. This can put a heavy mechanical stress on the winding and shaft of the motor resulting in the mechanical damage to the motor.
- So to avoid all these effects we have to keep the starting current of motor below safe limit. This is achieved by using starter.

Principle of starter:

- Starter is basically a resistance which is connected in series with the armature winding only at the time of starting the motor to limit the starting current.
- The starter of starter resistance will remain in the circuit only at the time of starting and will go out of the circuit or become ineffective when the motor speed upto a desire speed.



(a) Principle of starter (b) At the time of starting (c) Under normal operating condition

- At the time of starting, the starter is in the start position as shown in fig. so the full starter resistance appears in series with the armature. This will reduce the starting current.
- The starter resistance is then gradually cut off. The motor will speed up, back emf will be developed and it will regulate the armature current. The starter is not necessary then.
- Thus starter is pushed to the Run position as shown in fig under the normal operating condition. The value of starter resistance is zero in this position and it does not affect the normal operation.

Types of starter:

1. Three point starter
2. Four point starter

Applications of DC Motor

1. Shunt motor applications:

i. Various machine tools such as lathe machines, drilling machines, milling machines etc.

ii. Printing machines

iii. Paper machines

iv. Centrifugal and reciprocating pumps

v. Blowers and fans etc.

2. Series motor applications:

i. Electric trains
ii. Diesel-electric locomotives
iii. Cranes
iv. Hoists
v. Trolley cars and trolley buses
vi. Rapid transit systems
vii. Conveyers etc.

3. Cumulative compound motor applications:

i. Elevators
ii. Rolling mills
iii. Planers
iv. Punches
v. Shears

4. Differentials compound motors applications:

- The speed of these motors will increase with increase in the load, which leads to an unstable operation.
- Therefore we can not use this motor for any practical applications

Quick Quiz (Poll 2)

No-load speed of which of the following motor is highest?

a) Differentially compound motor
b) Cumulative compound motor
c) Series Motor
d) Shunt Motor

Quick Quiz (Poll 3)

In which of the following application DC series motor is used?

a) Centrifugal Pump
b) Motor Operation in DC and AC
c) Water pump drive
d) Starter for car