DC MOTOR

An Electric DC motor is a machine which converts electric energy into mechanical energy. The working of DC motor is based on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force which is called Lorentz Force.

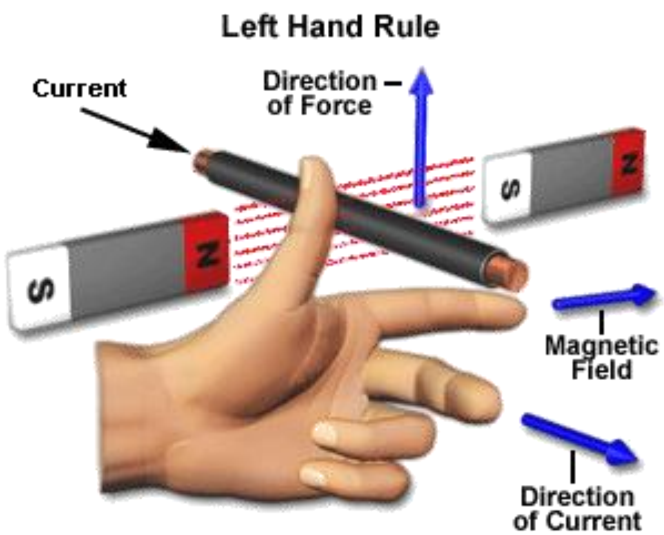
The direction of mechanical force is given by Fleming's Left-hand Rule and its magnitude is given by:

$$F = BIl \text{ Newton.}$$

Where, B = flux density of the field flux

I = current flowing through the conductor

l = effective length of the conductor



If a coil is placed in the field instead of a single conductor than a torque is produce and coil starts to rotate in the field. The torque can be express by the formula

$$\tau = BIl_w \cos\alpha$$

Where, α (alpha) is the angle between the plane of the armature turn and the plane of reference or the initial position of the armature which is here along the direction of magnetic field.

There is no basic difference in the construction of a DC generator and a DC motor. In fact, the same d.c. machine can be used interchangeably as a generator or as a motor. Like generators DC motors are also classified in to shunt-wound, series-wound and compound-wound.

DC motors are seldom used in ordinary applications because all electric supply companies furnish alternating current.

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However, for special applications such as in steel mills, mines and electric trains, it is advantageous to convert alternating current into direct current in order to use dc motors. The reason is that speed/torque characteristics of d.c. motors are much more superior to that of a.c. motors.

The speed of a DC motor to which armature rotates can be expressed by the following formula:

$$N = \frac{PZ}{60a} \emptyset I_a$$

Back EMF

When the armature of the motor is rotating, the conductors are also cutting the magnetic flux lines and hence according to the Faraday's law of electromagnetic induction, an emf induces in the armature conductors. The direction of this induced emf is such that it opposes the armature current (I_a) and for this reason it is called back emf or counter emf. Magnitude of Back emf can be given by the emf equation of DC generator.

Considering the back emf the speed equation can also be written as,

$$N = (V - I_a R_a)/ k\emptyset$$

Where, $V - I_a R_a = E_b$

The equation implies three things:

i. Speed of the motor is directly proportional to supply voltage.
ii. Speed of the motor is inversely proportional to armature voltage drop.
iii. Speed of the motor is inversely proportional to the flux due to the field findings

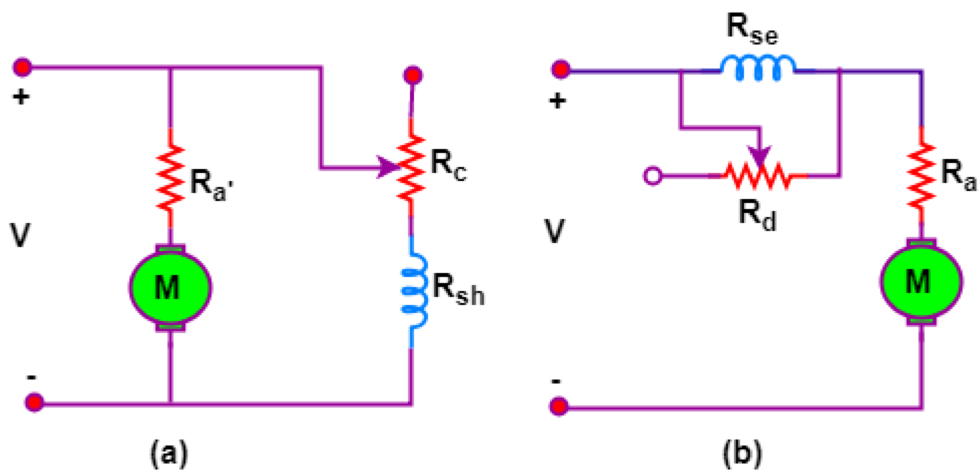
Thus, the speed of a DC motor can be controlled in three ways:

i. By varying the supply voltage
ii. By varying the flux, and by varying the current through field winding
iii. By varying the armature voltage, and by varying the armature resistance

Speed control of Shunt motor

i. Flux control method

It is already explained above that the speed of a dc motor is inversely proportional to the flux per pole. Thus by decreasing the flux, speed can be increased and vice versa.



To control the flux, a rheostat is added in series with the field winding, as shown in the circuit diagram. Adding more resistance in series with the field winding will increase the speed as it decreases the flux. In shunt motors, as field current is relatively very small, I_{sh}^2R loss is small. Therefore, this method is quite efficient. As speed can be increased above the rated value by reducing flux with this method, this method is used to control the speed above the base speed of the motor.

This method is applicable over only to a limited range because if the field is weakened too much, there is a loss of stability.

ii. Armature Voltage control

This method of speed control requires a variable source of voltage separate from the source supplying the field current. This method avoids the disadvantages of poor speed regulation and low efficiency which are characteristics of the armature-resistance control method but it is more expensive in initial cost. The adjustable voltage for the armature is obtained from an adjustable voltage generator or from an adjustable electronic rectifier. This method gives a large speed range with any desired number of speed points. It is essentially a constant-torque system, because the output delivered by the motor decreases with a decrease in applied voltage and a corresponding decrease in speed.

This particular system has a further advantage that can be employed to provide excellent starting characteristics by bringing the generator voltage gradually up from zero, starting and bringing the motor up to speed with a comparatively slowly increasing voltage. Because of the excellent starting characteristics, this system is used largely for modern high-speed elevators, and on account of the combination of excellent starting characteristics and the wide speed range available, it is used to some extent for reversing planer installations. This method is not applied to any great extent, generally on account of higher initial cost of the generating equipment.

Advantages of Armature Controlled DC Shunt Motor

1. Very fine speed control over whole range in both directions

2. Uniform acceleration is obtained

3. Good speed regulation

4. It has regenerative braking capacity

Disadvantages of Armature Controlled DC Shunt Motor

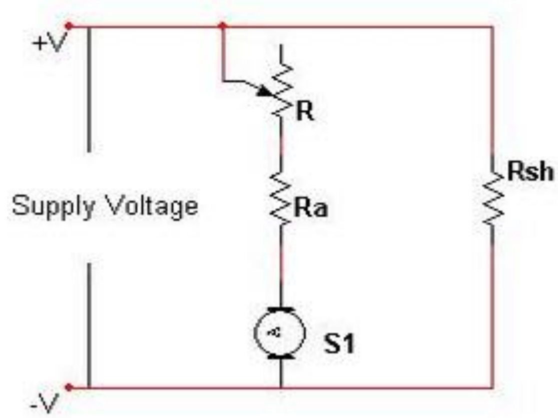
1. Costly arrangement is needed, floor space required is more

2. Low efficiency at light loads

3. Drive produced more noise.

iii. Armature Resistance Control Methods:

With this method, the speed of the DC motor can be controlled by controlling the armature resistance to control the voltage drop across the armature. This method also uses a variable resistor in series with the armature.



When the variable resistor reaches its minimum value, the armature resistance is at normal one, and therefore, the armature voltage drops. When the resistance value is gradually increased, the voltage across the armature decreases. This in turn leads to decrease in the speed of the motor.

This method achieves the speed of the motor below its normal range.

Starting Methods of A DC Motor

Basic operational voltage equation of a DC motor is given as,

$$V = E_b + I_aR_a \quad \text{and hence,} \quad I_a = (V - E_b) / R_a$$

Now, when the motor is at rest, obviously, the back emf$E_b = 0$. Hence, armature current at the moment of starting can be given as $I_a = V / R_a$. In practical DC machines, armature resistance is basically very low. Therefore, a large current flows through the armature during starting. This current is large enough to damage the armature circuit.To avoid this, a suitable DC motor starter must be used.

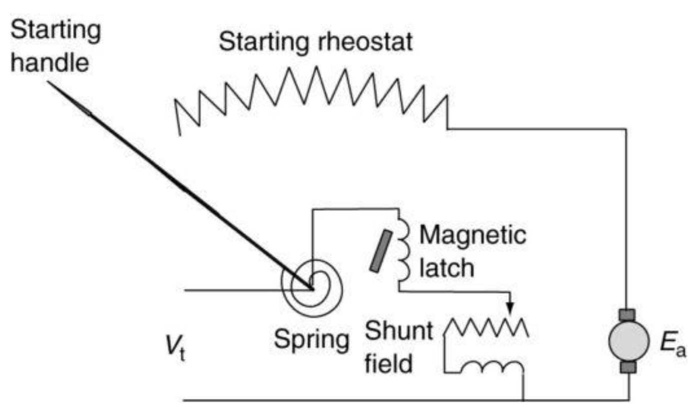
The main principal of the starter is the addition of external electrical resistance R_{ext} to the armature winding, so as to increase the effective resistance to $R_a + R_{ext}$, thus limiting the armature current to the rated value.

As the motor continues to run and gather speed, the back emf successively develops and increases, countering the supply voltage, resulting in the decrease of the net working voltage. At this moment to maintain the armature current to its rated value, R_{ext} is progressively decreased unless its made zero, when the motor is at rated speed and back emf produced is at its maximum. This regulation of the external electrical resistance in case of the starting of DC motor is facilitated by means of the a starter.

There are various types of dc motor starters, such as 3 point starter, 4 point starter, no-load release coil starter, thyristor controller starter etc. The basic concept behind every DC motor starter is adding external resistance to the armature winding during starting.

Following figure shows a manual starter circuit diagram. The arm is spring loaded and is rotated in the clockwise direction, gradually reducing the armature resistance as the motor accelerates. This starter is a so-called three-point starter.

The electromagnet that holds the starter in the run position is in the field circuit. This type of starter can be used for shunt and compound motors, and if the field is lost, the starter drops out, protecting the motor against runaway.



Three-point manual DC motor starter circuit diagram

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The disadvantage of this type of starter is that it may drop out if field resistance control is used to weaken the field for increased motor speed. This type of starter cannot be used for a series machine.