Speed Control of DC Motor (Shunt, Series, and Compound)

Often we want to control the speed of a DC motor on demand. This intentional change of drive speed is known as **speed control of a DC motor**.
Speed control of a DC motor is either done manually by the operator or by means of an automatic control device. This is different to speed regulation – where the speed is trying to be maintained (or 'regulated') against the natural change in speed due to a change in the load on the shaft.
The **speed of a DC motor** (N) is equal to:

$$N = \frac{V - I_a R_a}{k\phi}$$

Therefore speed of the 3 types of DC motors – shunt, series and compound – can be controlled by changing the quantities on the right-hand side of the equation above.

Hence the speed can be varied by changing:

1. The terminal voltage of the armature, V.
2. The external resistance in armature circuit, R_a.
3. The flux per pole, φ.

Terminal voltage and external resistance involve a change that affects the armature circuit, while flux involves a change in the magnetic field. Therefore **speed control of DC motor** can be classified into:

1. Armature Control Methods
2. Field Control Methods

We will discuss how both of these methods control the speed of **DC series motors** and **DC shunt motors**.

Speed Control of DC Series Motor

Speed control methods for a DC series motor can be classified as:

1. Armature Control Methods
2. Field Control Methods

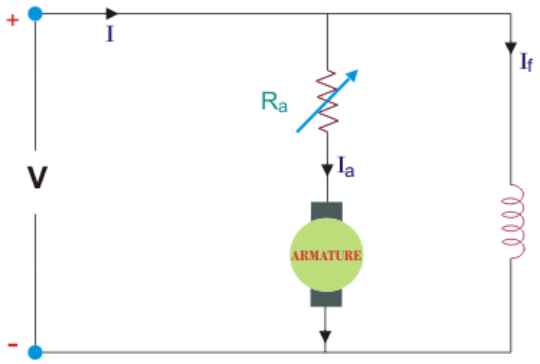
Armature Controlled DC Series Motor

Speed adjustment of a DC series motor by **armature control** may be done by:

1. Armature Resistance Control Method
2. Shunted Armature Control Method
3. Armature Terminal Voltage Control

Armature Resistance Control Method

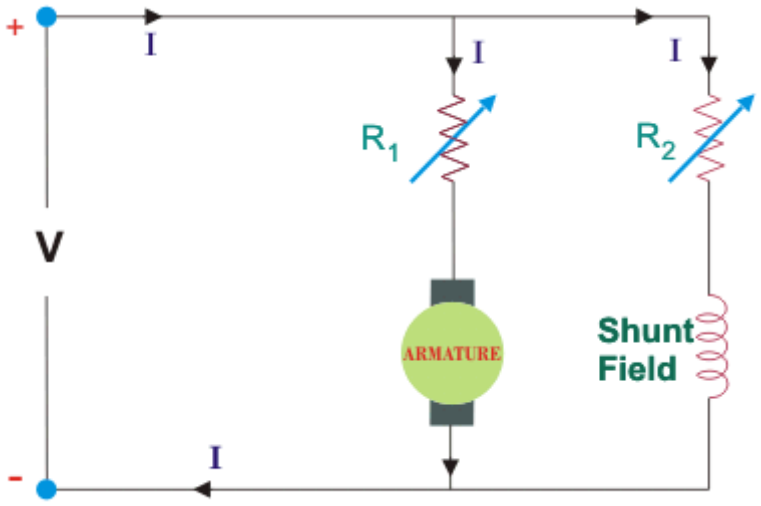
This is the most common method employed. Here the controlling resistance is connected directly in series with the supply of the motor as shown in the fig.



The power loss in the control resistance of DC series motor can be neglected because this control method is utilized for a large portion of time for reducing the speed under light load condition. This method of speed control is most economical for constant torque. This method of speed control is employed for DC series motor driving cranes, hoists, trains etc.

Shunted Armature Control

The combination of a rheostat shunting the armature and a rheostat in series with the armature is involved in this method of speed control. The voltage applied to the armature is varies by varying series rheostat R_1. The exciting current can be varied by varying the armature shunting resistance R_2. This method of speed control is not economical due to considerable power losses in speed controlling resistances. Here speed control is obtained over wide range but below normal speed.



Armature Terminal Voltage Control

The speed control of DC series motor can be accomplished by supplying the power to the motor from a separate variable voltage supply. This method involves high cost so it rarely used.

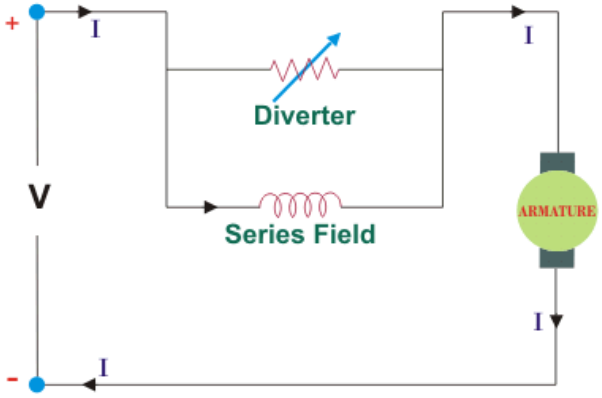
Field Controlled DC Series Motor

Speed adjustment of a DC series motor by **field control** may be done by:

1. Field Diverter Method
2. Tapped Field Control

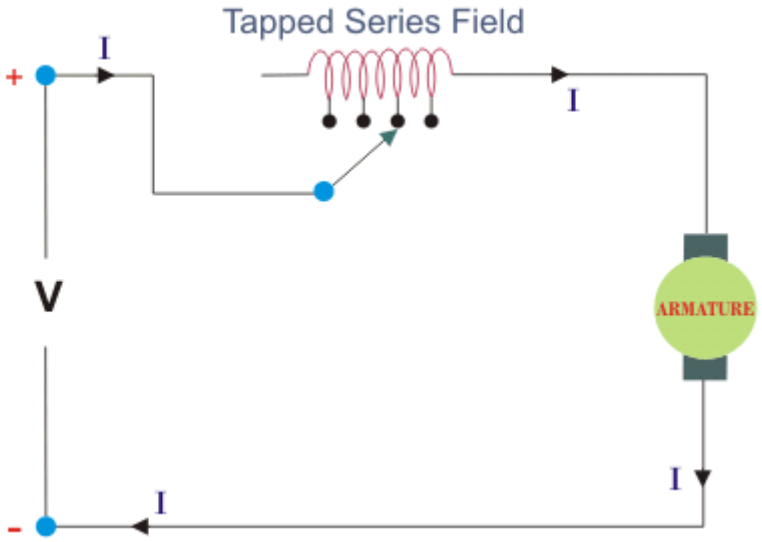
Field Diverter Method

This method uses a diverter. Here the field flux can be reduced by shunting a portion of motor current around the series field. Lesser the diverter resistance less is the field current, less flux therefore more speed. This method gives speed above normal and the method is used in electric drives in which speed should rise sharply as soon as load is decreased.



Tapped Field Control

This is another method of increasing the speed by reducing the flux and it is done by lowering number of turns of field winding through which current flows. In this method a number of tapping from field winding are brought outside. This method is employed in electric traction.



Speed Control of DC Shunt Motor

The classification of **speed control methods for a DC shunt motor** are similar to those of a DC series motor. These two methods are:

1. Armature Control Methods
2. Field Control Methods

Armature Controlled DC Shunt Motor

Armature controlled DC shunt motor can be performed in two ways:

1. Armature Resistance Control
2. Armature Voltage Control

Armature Resistance Control

In armature resistance control a variable resistance is added to the armature circuit. Field is directly connected across the supply so flux is not changed due to variation of series resistance. This is applied for DC shunt motor. This method is used in printing press, cranes, hoists where speeds lower than rated is used for a short period only.

Armature Voltage Control

This method of speed control needs a variable source of voltage separated from the source supplying the field current. This method avoids disadvantages of poor speed regulation and low efficiency of armature-resistance control methods.

The basic adjustable armature voltage control method of speed d control is accomplished by means of an adjustable voltage generator is called **Ward Leonard System**. This method involves using a motor-generator (M-G) set. This method is best suited for steel rolling mills, paper machines, elevators, mine hoists, etc. This method is known as Ward Leonard System.

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.

Field Controlled DC Shunt Motor

By this method a DC Shunt motor's speed is controlled through a field rheostat.

Field Rheostat Controlled DC Shunt Motor

In this method, speed variation is accomplished by means of a variable resistance inserted in series with the shunt field. An increase in controlling resistances reduces the field current with a reduction in flux and an increase in speed. This method of speed control is independent of load on the motor. Power wasted in controlling resistance is very less as field current is a small value. This method of speed control is also used in DC compound motor.

Disadvantages of Field Rheostat Controlled DC Shunt Motor

- Creeping speeds cannot be obtained.
- Top speeds only obtained at reduced torque.
- The speed is maximum at minimum value of flux, which is governed by the demagnetizing effect of armature reaction on the field.

Solid State Speed Control

Static Ward Leonard drives are being used these days because of the drawbacks of the classical method. Rotating M-G sets are replaced by solid state converters to control DC motor speed. The converters used are choppers (in case of DC supply) or controlled rectifiers (in case of AC supply). This method is not suitable for intermittent loads.

DC Motor Speed Control Theory

To derive the speed of a DC motor, we start with the equation for the DC motor's EMF (Electromagnetic Force). We know that the EMF equation of DC motor is equal to:

$$E = \frac{NP\phi Z}{60A}$$

Hence rearranging the equation:

- N = 60A E / PZØ

With k = PZ/60A, then:

- N = E / kØ

Hence with $E = V - I_aR_a$, we derive the speed of the DC motor (N):

$$N = \frac{V - I_aR_a}{k\phi}$$

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