6

Speed Control of D.C. Motors

INTRODUCTION

Although a far greater percentage of electric motors in service are a.c. motors, the d.c. motor is of considerable industrial importance. The principal advantage of a d.c. motor is that its speed can be changed over a wide range by a variety of simple methods. Such a fine speed control is generally not possible with a.c. motors. In fact, fine speed control is one of the reasons for the strong competitive position of d.c. motors in the modern industrial applications. In this chapter, we shall discuss the various methods of speed control of d.c. motors.

6.1 SPEED CONTROL OF D.C. MOTORS

The speed of a d.c. motor is given by :

$$N \propto \frac{E_b}{\phi}$$

or

$$N = K\frac{(V - I_a R)}{\phi} \text{ r.p.m.} \qquad ...(i)$$

where

$$R = R_a \qquad ...\textit{for shunt motor}$$

$$= R_a + R_{se} \qquad ...\textit{for series motor}$$

From exp. (*i*), it is clear that there are three main methods of controlling the speed of a d.c. motor, namely :

(*i*) By varying the flux per pole (ϕ). This is known as *flux control method.*

(*ii*) By varying the resistance in the armature circuit. This is known as *armature control method.*

(*iii*) By varying the applied voltage V. This is known as *voltage control method.*

6.2 SPEED CONTROL OF D.C. SHUNT MOTORS

The speed of a shunt motor can be changed by (*i*) flux control method (*ii*) armature control method (*iii*) voltage control method. The first method (*i.e.* flux control method) is frequently used because it is simple and inexpensive.

1. Flux control method. It is based on the fact that by varying the flux ϕ, the motor speed ($N \propto 1/\phi$) can be changed and hence the name flux control method. In this method, a variable resistance (known as *shunt field rheostat*) is placed in series with shunt field winding as shown in Fig. 6.1.

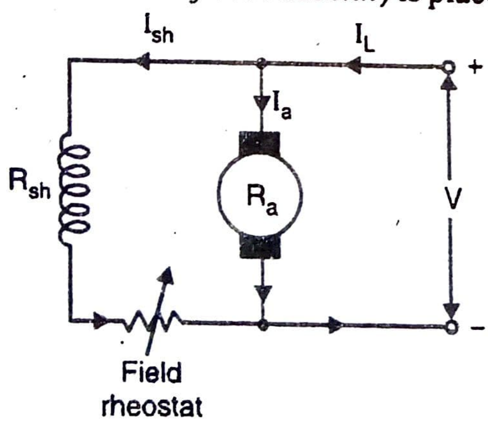

Fig. 6.1

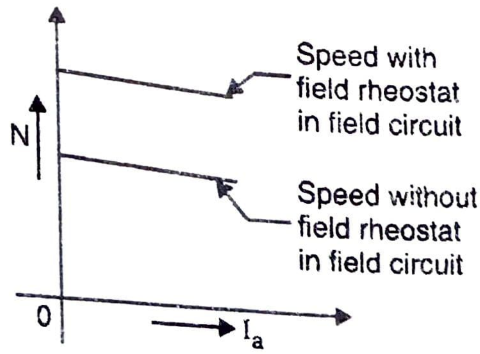

Fig. 6.2

The shunt field rheostat reduces the shunt field current I_{sh} and hence the flux ϕ. Therefore, we can only *raise the speed of the motor above the normal speed (See Fig. 6.2). Generally, this method permits to increase the speed in the ratio 3 : 1. Wider speed ranges tend to produce instability and poor commutation.

Advantages

(*i*) This is an easy and convenient method.

(*ii*) It is an inexpensive method since very little power is wasted in the shunt field rheostat due to relatively small value of I_{sh}.

(*iii*) The speed control exercised by this method is independent of load on the machine.

Disadvantages

(*i*) Only speeds higher than the normal speed can be obtained since the total field circuit resistance cannot be reduced below R_{sh} – the shunt field winding resistance.

(*ii*) There is a limit to the maximum speed obtainable by this method. It is because if the flux is too much weakened, commutation becomes poorer.

Note. *The field of a shunt motor in operation should never be opened because its speed will increase to an extremely high value.*

2. Armature control method. This method is based on the fact that by varying the voltage available across the armature, the back e.m.f. and hence the speed of the motor can be changed. This is done by inserting a variable resistance R_C (known as *controller resistance*) in series with the armature as shown in Fig. 6.3.

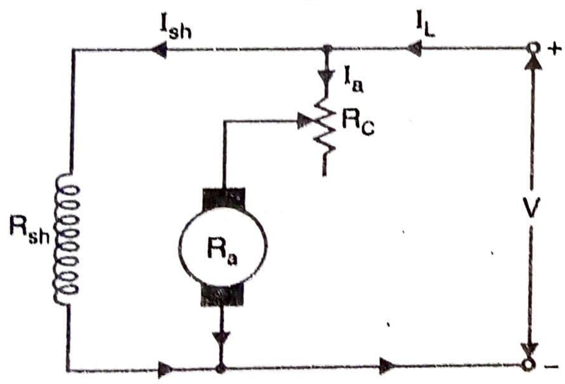

Fig. 6.3

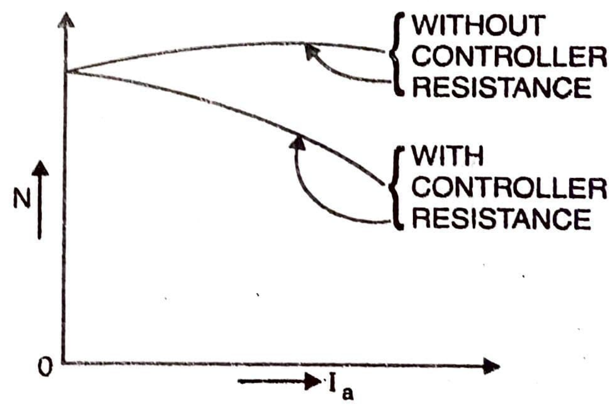

Fig. 6.4

$$N \propto V - I_a (R_a + R_C)$$

where R_C = controller resistance

Due to voltage drop in the controller resistance, the back e.m.f. (E_b) is †decreased. Since $N \propto E_b$, the speed of the motor is reduced. The highest speed obtainable is that corresponding to $R_C = 0$ *i.e.*, normal speed. Hence, this method can only provide speeds below the normal speed (See Fig. 6.4).

Disadvantages

(*i*) A large amount of power is wasted in the controller resistance since it carries full armature current I_a.

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* When resistance in the field circuit is increased, the current (I_{sh}) in the field circuit decreases. This causes reduction in the field flux. Thus fewer magnetic lines are cut by the armature and, therefore, less back e.m.f. (E_b) is generated. As a result, more current (I_a) flows through the armature. The increase in armature current is greater than the decrease is flux. Therefore, the torque ($T \propto \phi I_a$) is greater and the armature speed increases. In doing so, the back e.m.f. increases and reduces the armature current. The speed increases until the developed torque becomes equal to load torque and then the motor again runs at a constant speed. Therefore, peculiar as it may seem, the speed of a shunt motor is increased by increasing the resistance of the field circuit.

† $E_b = V - I_a (R_a + R_C)$. Since V is constant, E_b will decrease.

(*ii*) The speed varies *widely with load since the speed depends upon the voltage drop in the controller resistance and hence on the armature current demanded by the load.

(*iii*) The output and efficiency of the motor are reduced.

(*iv*) This method results in poor speed regulation.

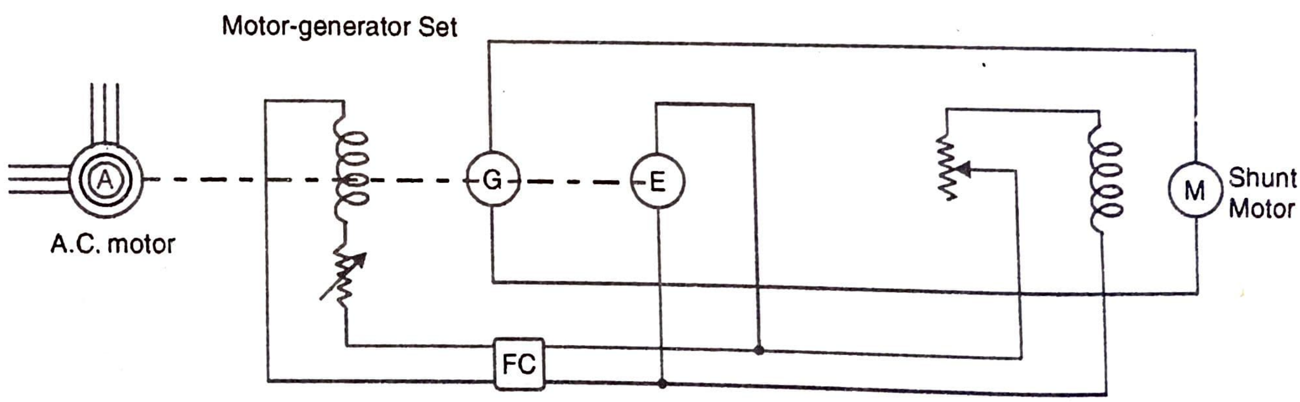
Due to above disadvantages, this method is seldom used to control the speed of shunt motors.

Note. The armature control method is a very common method for the speed control of d.c. series motor. The disadvantage of poor speed regulation is not important in a series motor which is used only where varying speed service is required.

3. Voltage control method. In this method, the voltage source supplying the field current is different from that which supplies the armature. This method avoids the disadvantages of poor speed regulation and low efficiency as in armature control method. However, it is quite expensive. Therefore, this method of speed control is employed for large size motors where efficiency is of great importance.

(*i*) **Multiple voltage control.** In this method, the shunt field of the motor is connected permanently across a fixed voltage source. The armature can be connected across several different voltages through a suitable switchgear. In this way, voltage applied across the armature can be changed. The speed will be approximately proportional to the voltage applied across the armature. Intermediate speeds can be obtained by means of a shunt field regulator.

(*ii*) **Ward-Leonard system.** In this method, the adjustable voltage for the armature is obtained from an adjustable-voltage generator while the field circuit is supplied from a separate source. This is illustrated in Fig. 6.5. The armature of the shunt motor M (whose speed is to be controlled) is connected directly to a d.c. generator G driven by a constant-speed a.c. motor A. The field of the shunt motor is supplied from a constant-voltage exciter E. The field of the generator G is also supplied from the exciter E. The voltage of the generator G can be varied by means of its field regulator. By reversing the field current of generator G by controller FC, the voltage applied to the motor may be reversed. Sometimes, a field regulator is included in the field circuit of shunt motor M for additional speed adjustment. With this method, the motor may be operated at **any speed upto its maximum speed.



Ward-Leonard speed-control system

Fig. 6.5

Advantages

(*a*) The speed of the motor can be adjusted through a wide range without resistance losses which results in high efficiency.

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* A more stable operation can be obtained by placing a diverter across the armature in addition to the controller resistance. A change in armature current (due to change in load torque) will not now be so effective in changing the voltage drop across the armature (See Example 6.28).

** Since we can vary the voltage of the generator G applied to motor M. Note that field circuit of the motor is supplied form a separate source. Therefore, the field circuit current is not affected by the variation of generator voltage.