Unit 3

Motor

When a machine converts electric energy into mechanical energy, it is called a **motor.** There is no fundamental difference in either the construction or the operation of the two machines. In fact, the same machine may be used as a motor or a generator.

Operation of a DC Motor

Since there is no difference in construction between a dc generator and a dc motor, the three types of dc generators discussed in Chapter 5 can also be used as dc motors. Therefore, there are three general types of dc motors shunt, series,and compound. The permanent-magnet (I'M) motor is a special case of a shunt

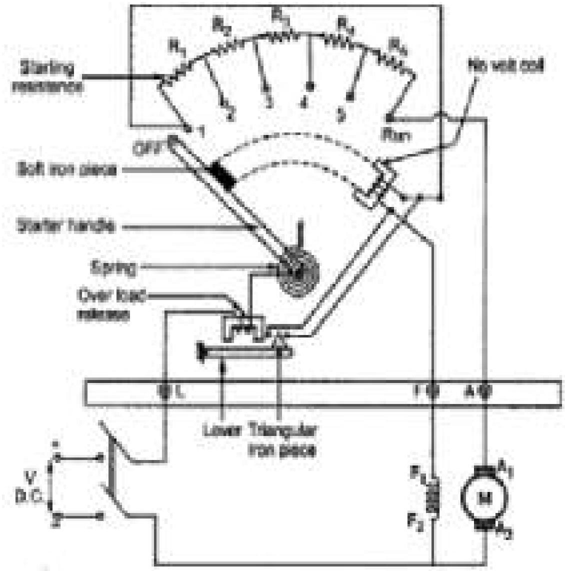
motor with uniform (constant) flux density. We can also have a separately excitedmotor if we use an auxiliary source for the field winding. Because it is notpractical to employ two power sources, one for the field winding and the other for the armature circuit, a separately excited motor is virtually nonexistent. However,a separately excited motor can also be treated as a special case of a shunt motor**..**A brief review is given here. In a dc motor, a uniform magnetic field is created by its poles. The armature conductors are forced to carry current by connecting them to a dc power source (supply) as shown in Figure 3.1. The current direction in the conductors under each pole is kept the same by the commutator. According to the Lorentz force equation, a current-carrying conductor when placed in a magnetic field experiences **a** force that tends to move it. This is essentially the principle ofoperation **of** a dc motor. **All** the conductors placed on the periphery **of** a dc motor are subjected to these forces, as shown in the figure. These forces cause the armature to rotate in the clockwise direction. Therefore, the armature **of *a*** dc motor rotates in the direction of the torque developed **by** the motor. For this reason, the torque developed by the motor is called the driving torque. Note that the torque developed by the conductors placed on the armature of a dc generator is in a direction opposite to its motion. Therefore, it can be labeled the retarding torque.

Starting a DC Motor

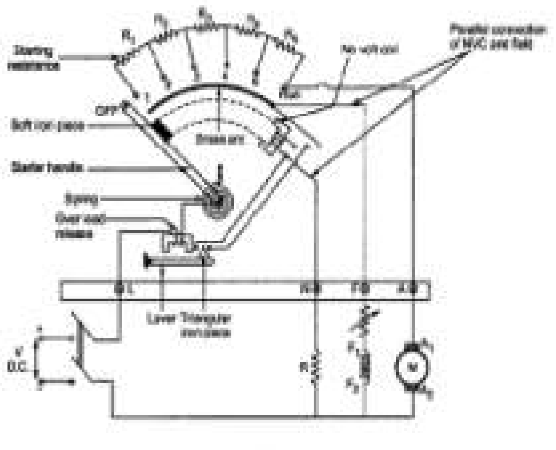
At the time of starting, the back emf in the motor is zero because the armature is not rotating. For a small value of the armature-circuit resistance R, the startingcurrent in the armature will be extremely high if the rated value of *V,* is impressed across the armature terminals. The excessive current can cause permanent damage to the armature windings. Thus, a dc motor should never be started at its rated voltage. In order to start a dc motor, an external resistance must be added in series with the armature circui .. The external resistance is gradually decreased as the armature comes up to speed. Finally, when the armature has attained its normal speed, the external resistance is "cut out" of the armature circuit..

It has been shown earlier that the speed of a motor is given by the relation

$$N = \frac{V - I_a R_a}{Z\Phi} \cdot \left(\frac{A}{P}\right) = K \frac{V - I_a R_a}{\Phi} \text{ r.p.s.}$$



3 point Starter



4 point Starter

Speed control of D.C. Motors:

Different ranges of speeds are required for different applications. A single motor can be used for different speeds for various works. Smooth speed control is possible in D.C. Shunt motor.

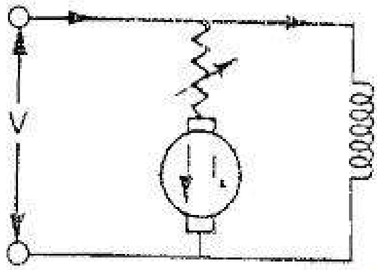
The speed of a D.C. motor can be expressed by the equation: Speed, $N \propto (v - IaRa)/\phi$. Neglecting the small voltage drop IaRa, the speed is directly proportional to the voltage impressed across the armature and inversely proportional to the flux. Hence the speed of a D.C. motor can be controlled by varying the voltage or flux. The above two methods are known as.

1. Armature control and 2. Field control.

These methods are applied to shunt, series and compound motors.

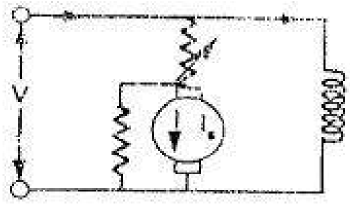
SPEED CONTROL OF D.C. SHUNT MOTOR

Armature Control Method:

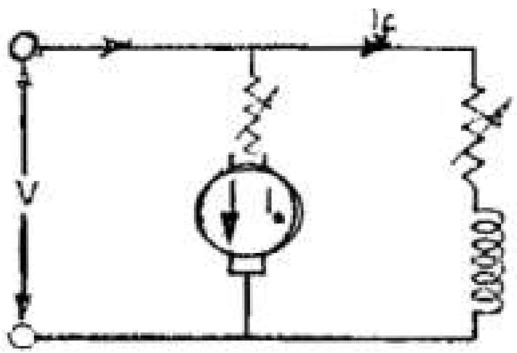


This method is used when spends below the no-load speed are required. As the supply voltage across the armature is varied by inserting a variable resistance in series with the armature. Circuit as shown in Fig.

As the controller resistance is increased, the Potential drop across the armature is decreased. So armature speed also decreases. In this method speed can be varied up to the rated speed.



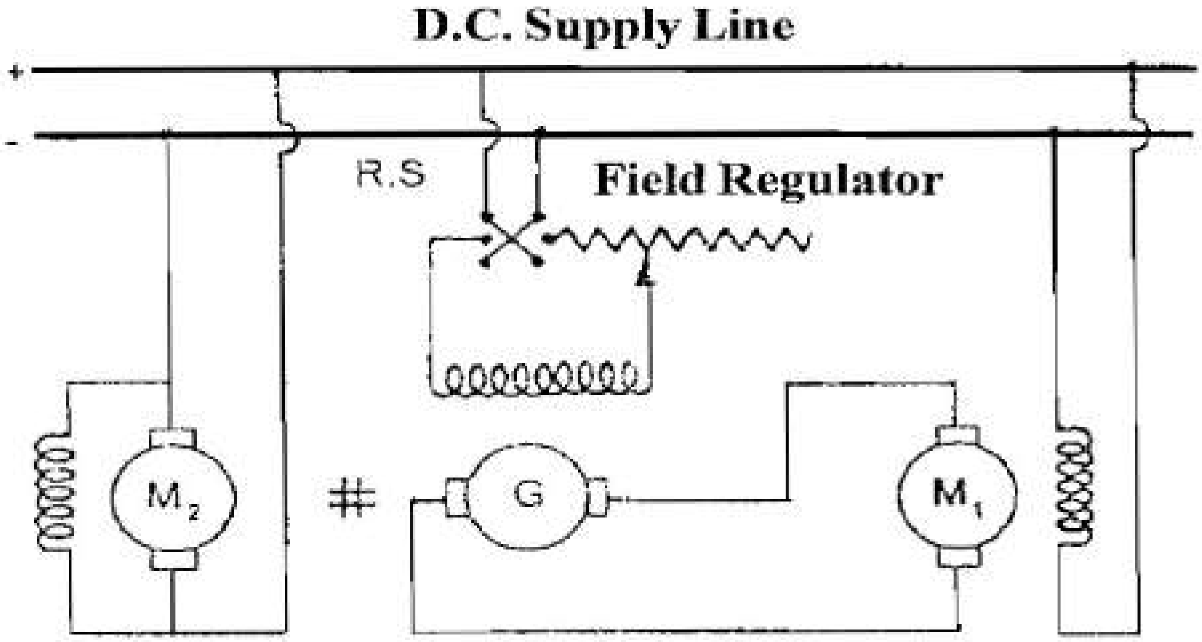
This method is very expensive because the power loss and not suitable for rapidly changing loads. A more suitable operation can be obtained by using a diverter across the armature in addition to armature control resistance as shown in Fig. . Now the changes in armature current (due to changes in load) will not be so effective in changing the P.D. across the armature.



By this method of speed control we can not have speeds below the rated speed. (Flux can not be increased). But the speed can be increased beyond the rated speed. By combining the field control and armature control methods, it is possible to get speed variations below or above normal speeds. The connection diagram for such a speed control is shown in fig. variable resistance are connected in the armature and field circuits.

Ward – Leonard System

This system is used where a very sensitive speed control is required.



M_1 is the main motor for which the speed control is required. The field of this motor is permanently connected across the D.C. supply lines. By applying a variable voltage across its armature, any desired speed can be obtained. This variable voltage is supplied by a motor-generator set which consists of either a D.C. or an A.C. motor M_2. The motor M_2 is directly coupled to the generator G.

The motor M_2 runs at an approximately constant speed. The output voltage of "G" is directly fed to the main motor M_1. The voltage of the generator can be varied from zero to its maximum value by means o its field regulator. The field current of the generator can be reversed by the reversing switch Rs. Therefore the generated voltage can be reversed and hence the direction of rotation of M_1 is also reversed.

It should be remembered that motor-generator set always runs in the same direction.

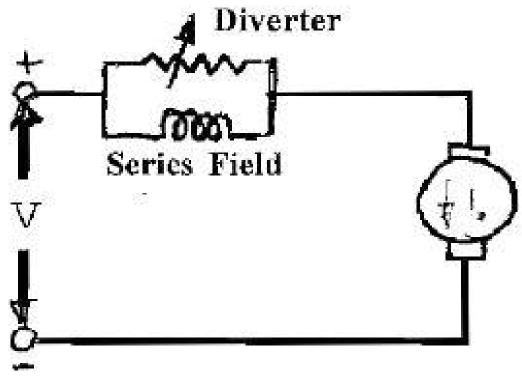
The capital cost of such a system is high, since three machines are employed. But this method is very effective and the speed control obtained is very smooth.

If a vasiable resisance is connected in series with the field circuit of motor M_1. The speed above the rated value can be obtained. The direction of rotation of a D.C. motor can be reversed either by

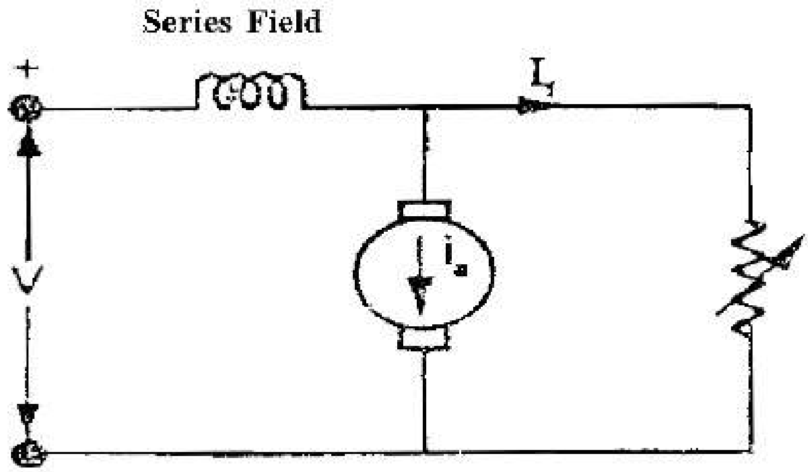
SPEED CONTROL OF D.C. SERIES MOTOR:-

Speed of a D.C. series motor can be controlled by the following methods

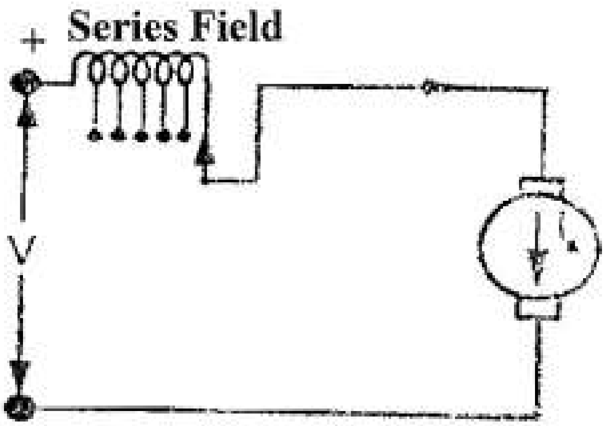
(1) Field Diverter Method:-



(2) Armature Diverter Method:



(3) Tapped Field Control



Losses and efficiency

The output of a generator or motor is always less than the input because some of the energy supplied is lost as heat. These losses raise the temperatures of the machine parts above that of surrounding air until such temperatures are reached that the heat losses are radiated as fast as they are generated. Certain of the losses depend upon the load. The temperature rise therefore depends upon the load also, and the maximum allowable temperature rise determines the maximum permissible load that the machine may carry. The limit of output occurs at the load for which the temperature rise becomes high enough to endanger the insulation of the windings.

Thus the consideration of machine losses is important for the following three reasons:

1. Losses appreciably influence the operating cost of the machine.
2. Losses determine the heating of the machine and hence the rating or power output that can be obtained without undue deterioration of the insulation.
3. The voltage drops or current components associated with supplying the losses must be properly accounted for in a machine representation.

Machine efficiency is given by

$$\text{Efficiency} = \frac{\text{output}}{\text{input}}$$

which can also be expressed as

$$\text{Efficiency} = \frac{\text{input} - \text{losses}}{\text{input}} = 1 - \frac{\text{losses}}{\text{input}}$$

$$\text{Efficiency} = \frac{\text{output}}{\text{output} + \text{losses}}$$

Testing of D.C machines

The following important performance tests are conducted on D.C. machines:

1. The magnetization or open circuit test.
2. The load characteristics
3. The determination of efficiency curve.
4. The temperature rise test.

The procedure to conduct the *magnetization* or *open circuit test* and *load characteristic* (external characteristic) *tests* has already been discussed.

The methods for determining efficiency can be divided into following three methods:

(i) Direct method (ii) Indirect method

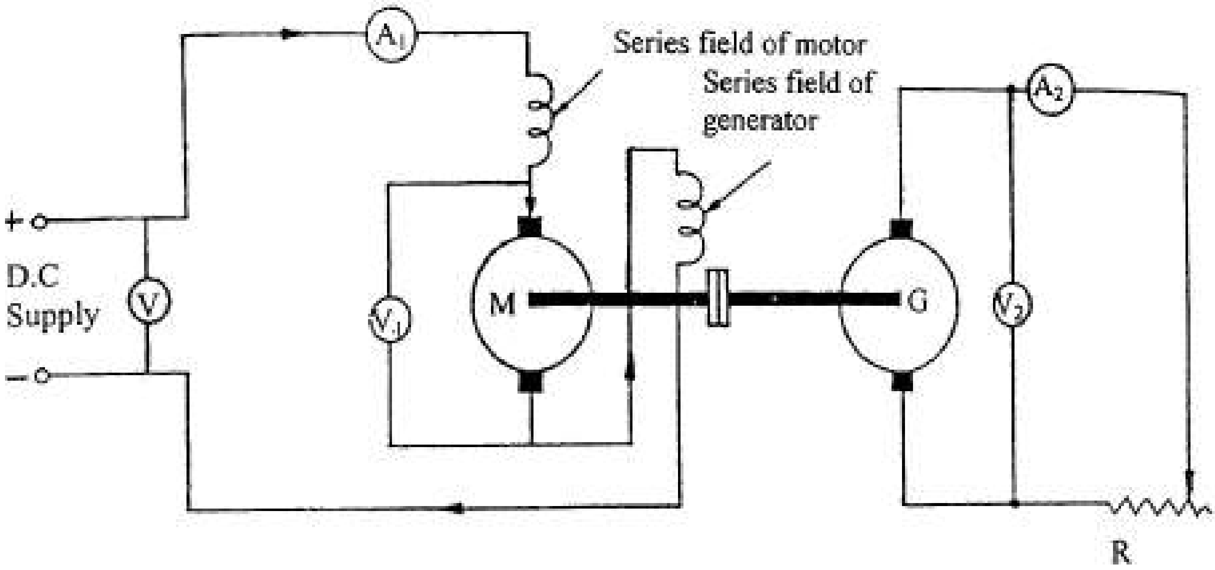
(iii) Regenerative method.

Regenerative method. This method requires two identical machines, one of them works a motor and drives the other, which is mechanically coupled to it. The other machine works as a generator and feed back power into the supply. Thus the *total power drawn from the supply is only for supplying internal losses of the two machines*. Thus even *very large machines may be tested as the power required is small.*

Hopkinson test is a regenerative test for determining efficiency of D.C. machines.

For a d.c shunt motor change of speed from no load to full load is quite small. Therefore, mechanical loss can be assumed to remain same from no load to full load. Also if field current is held constant during loading, the core loss too can be assumed to remain same.

In this test, the motor is run at rated speed under no load condition at rated voltage. Since the motor is operating under no load condition, net mechanical output power is zero. Hence the gross power developed by the armature must supply the core loss and friction & windage losses of the motor.



Let V = supply voltage (reading of voltmeter V)

I_1 = motor input current (reading of ammeter A_1)

V_2 = terminal voltage of generator (reading of voltmeter V_2)

I_2 = load current of generator (reading of ammeter A_2)

R_a = armature resistance of each machine

R_{se} = series field resistance of each machine.

Input to the whole set $= VI_1$

Output $= V_2 I_2$

Total losses of the set, $P_t = VI_1 - V_2 I_2$

Armature and field copper loss of motor $= I_1^2 (R_a + R_{se})$

Armature and field copper loss of generator $= I_2^2 R_a + I_1^2 R_{se}$

Total copper loss of the set, $P_c = I_1^2 (R_a + R_{se}) + I_2^2 R_a + I_1^2 R$

$= I_1^2 (R_a + 2R_{se}) + I_2^2 R_a$

Stray losses for the set $= P_t - P_c$

Stray losses per machine, $P_s = \dfrac{P_t - P_c}{2}$.

Motor Efficiency:

Motor input $= V_1 I_1$

Motor losses $= I_1^2 (R_a + R_{se}) + P_s$

Motor output $= V_1 I_1 - [I_1^2 (R_a + R_{se}) + P_s]$

∴ Motor efficiency, $$\eta_m = \frac{V_1 I_1 - [I_1^2 (R_a + R_{se}) + P_s}{V_1 I_1}$$

Generator Efficiency:

Generator output $= V_2 I_2$

Generator losses $= I_2^2 R_a + I_1^2 R_{se} + P_s$

Generator input $= V_2 I_2 + I_2^2 R_a + I_1^2 R_{se} + P_s$

∴ Generator efficiency, $$\eta_e = \frac{V_2 I_2}{V_2 I_2 + I_2^2 R_a + I_1^2 R_{se} + P_s}$$