2.29 Speed Control of D.C. Series Motor

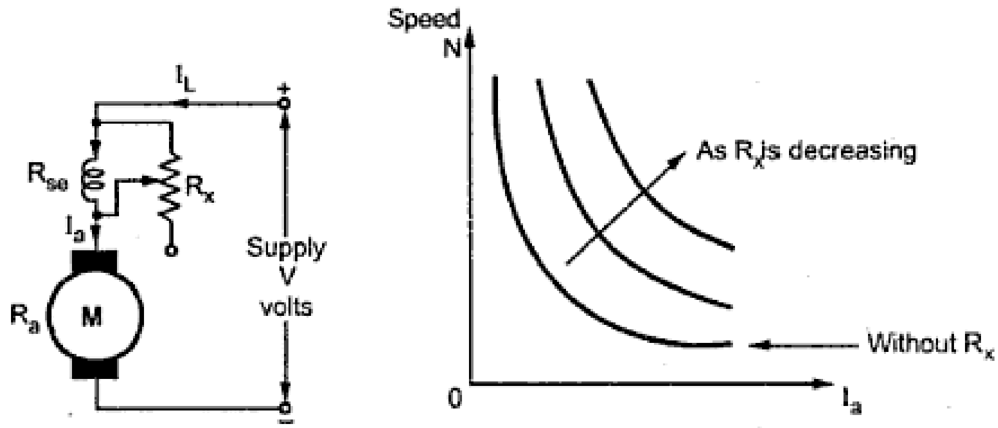
The flux produced by the winding depends on the m.m.f. i.e. magnetomotive force which is the product of current and the number of turns of the winding through which current is passing. So flux can be changed either by changing the current by adding a resistance or by changing the number of turns of the winding. Let us study the various methods based on this principle.

2.29.1 Flux Control

The various methods of flux control in a d.c. series motor are explained below :

2.29.1.1 Field Diverter Method

In this method the series field winding is shunted by a variable resistance (R_x) known as **field diverter**. The arrangement is shown in the Fig. 2.42 (a).



(a) Field diverter (b) Speed-current characteristics

Fig. 2.42

Due to the parallel path of R_x, by adjusting the value of R_x, any amount of current can be diverted through the diverter. Hence current through the field winding can be adjusted as per the requirement. Due to this, the flux gets controlled and hence the speed of the motor gets controlled.

By this method the speed of the motor can be controlled above rated value. The speed armature current characteristics with change in R_x is shown in the Fig. 2.42 (b).

2.29.1.2 Armature Diverter Method

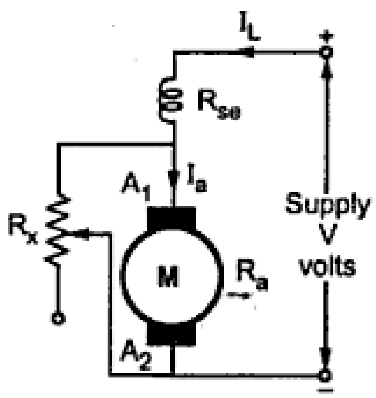


Fig. 2.43 Armature diverter

This method is used for the motor which require constant load torque. An armature of the motor is shunted with an external variable resistance (R_x) as shown in the Fig. 2.43. This resistance R_x is called **armature diverter.**

Any amount of armature current can be diverted through the diverter. Due to this, armature current reduces. But as $T \propto \phi I_a$ and load torque is constant, the flux is to be increased. So motor reacts by drawing more current from the supply. So current through field winding increases, so flux increases and speed of the motor reduces. The method is used to control the speed below the normal value.

2.29.1.3 Tapped Field Method

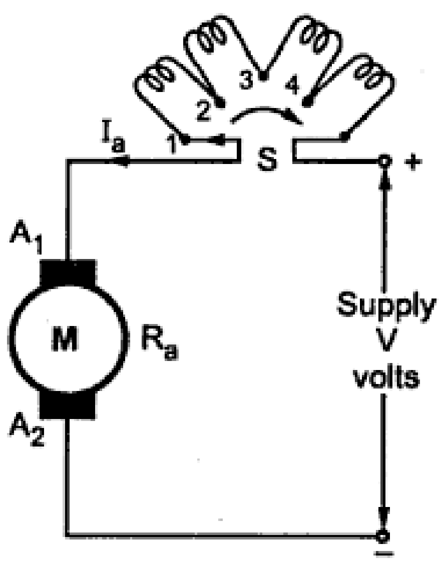


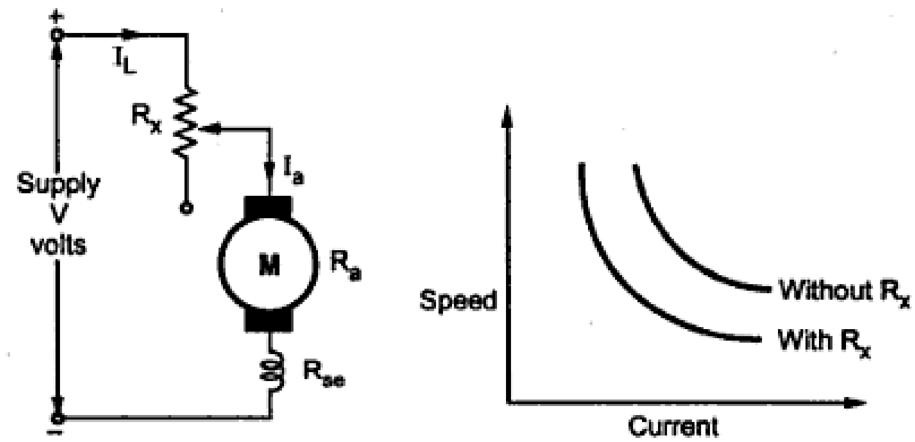
Fig. 2.44 Tapped field

In this method, flux change is achieved by changing the number of turns of the field winding. The field winding is provided with the taps as shown in the Fig. 2.44.

The selector switch 'S' is provided to select the number of turns (taps) as per the requirement. When the switch 'S' is in position 1 the entire field winding is in the circuit and motor runs with normal speed. As switch is moved from position 1 to 2 and onwards, the number of turns of the field winding in the circuit decreases. Due to this m.m.f. required to produce the flux, decreases. Due to this flux produced decreases, increasing the speed of the motor above rated value. The method is often used in electric traction.

2.29.2 Rheostatic Control

In this method, a variable resistance (R_x) is inserted in series with the motor circuit. As this resistance is inserted, the voltage drop across this resistance ($I_a R_x$) occurs. This reduces the voltage across the armature. As speed is directly proportional to the voltage across the armature, the speed reduces. The arrangement is shown in the Fig. 2.46 (a). As entire current passes through R_x, there is large power loss. The speed-armature current characteristics with change in R_x are shown in the Fig. 2.46 (b).



(a) **Fig. 2.46** (b)

2.29.3 Applied Voltage Control

In this method, a series motor is excited by the voltage obtained by a series generator as shown in the Fig. 2.47.

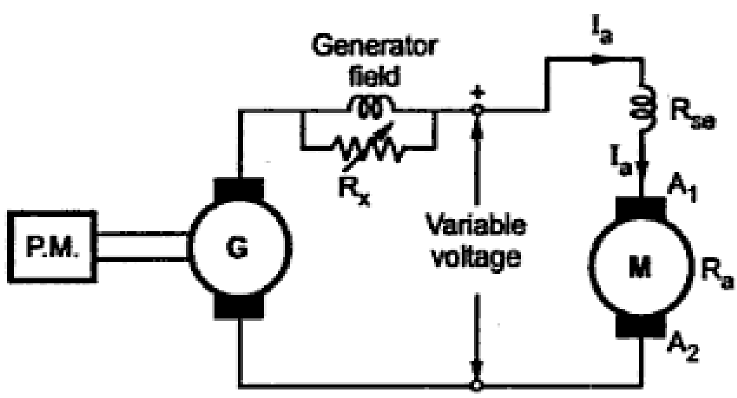


Fig. 2.47 Variable voltage control

The generator is driven by a suitable prime mover. The voltage obtained from the generator is controlled by a field divertor resistance connected across series field winding of the generator.

As $E_g \propto \phi$, the flux change is achieved, gives the variable voltage at the output terminals. Due to the change in the supply voltage, the various speeds of the d.c. series motor can be obtained.

Note : That all the advantages and disadvantages of various methods, discussed as applied to shunt motor are equally applicable to speed control of series motor.

Using speed equation $N \propto \frac{E_b}{\phi} \propto \frac{E_b}{I_{sh}}$

$$\frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}} \times \frac{I_{sh2}}{I_{sh1}}$$

$$\therefore \quad \frac{1500}{N_2} = \frac{243.775}{239.1062} \times \frac{0.7142}{0.125}$$

$$\therefore \quad N_2 = \mathbf{2575.03\ r.p.m.}$$

This shows that as flux ϕ decreases, the speed increases.

Example 2.13 : *A 250 V, d. c. series motor takes 30 A when running at 800 r.p.m., calculate the speed at which motor will run if field winding is shunted by a resistance equal to the field winding resistance and the load torque is increased by 50 %. Armature resistance is 0.15 Ω and series field resistance is 0.1 Ω. Assume the flux produced is proportional to the field current.*

Solution : The method is field diverter. The two conditions are shown in the Fig. 2.48 (a) and (b).

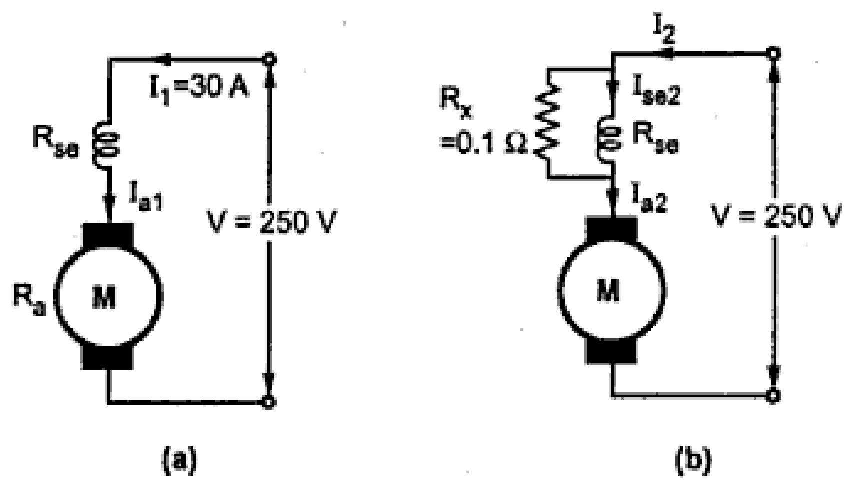


Fig. 2.48

$$V = 250\text{ V},\ R_a = 0.15\ \Omega,\ R_{se} = 0.1\ \Omega$$

In first case, $N_1 = 800$ r.p.m.

$$I_1 = I_{a1} = I_{se1} = 30\text{ A}$$

$$\phi \propto I_{se}$$

According to torque equation, $T \propto \phi I_a \propto I_{se} I_a$

$$\therefore \quad \frac{T_1}{T_2} = \frac{I_{se1}}{I_{se2}} \times \frac{I_{a1}}{I_{a2}}$$

Now $T_2 = T_1 + 0.5\ T_1$ ... (Increased by 50 %)

$\therefore$ $T_2 = 1.5\ T_1$ ... (1)

Let us see the current distribution in a parallel circuit. Consider two resistances R_1 and R_2 in parallel as shown in the Fig. 2.49.

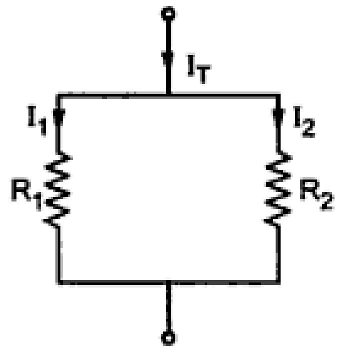


Fig. 2.49

Then $I_T = I_1 + I_2$

and $I_1 = I_T \times \dfrac{R_2}{R_1 + R_2}$

$I_2 = I_T \times \dfrac{R_1}{R_1 + R_2}$

Applying this to the Fig. 2.48 (b),

$$I_2 = I_{a2}$$

$$\therefore \quad I_{se2} = I_{a2} \times \frac{R_x}{R_x + R_{se}} = I_{a2} \times \frac{0.1}{0.1+0.1}$$

$$\therefore \quad I_{se2} = 0.5\ I_{a2} \qquad \text{... (2)}$$

Substituting equations (1) and (2) in torque equation,

$$\frac{T_1}{1.5 T_1} = \frac{30}{0.5\ I_{a2}} \times \frac{30}{I_{a2}}$$

$$(I_{a2})^2 = 2700$$

$$\therefore \quad I_{a2} = 51.9615\ A$$

and $I_{se2} = 0.5\ I_{a2} = 25.9807\ A$

Now $E_{b1} = V - I_{a1}\ R_a - I_{se1}\ R_{se} = 250 - 30 \times 0.15 - 30 \times 0.1$

$= 242.5\ V$

and $E_{b2} = V - I_{a2}\ R_a - I_{se2}\ R_{se} = 250 - 51.9615 \times 0.15 - 25.9807 \times 0.1$

$= 239.607\ V$

Use speed equation, $N \propto \dfrac{E_b}{\phi}$

$$\therefore \quad \frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}} \times \frac{I_{se2}}{I_{se1}}$$

$$\therefore \quad \frac{800}{N_2} = \frac{242.5}{239.607} \times \frac{25.9807}{30}$$

$\therefore$ N_2 = **912.744 r.p.m.**

➡ **Example 2.14 :** *A d.c. series motor runs at 500 r.p.m. on 220 V supply drawing a current of 50 A. The total resistance of the machine is 0.15 Ω, calculate the value of the extra resistance to be connected in series with the motor circuit that will reduce the speed to 300 r.p.m. The load torque being then half of the previous value. Assume flux proportional to the current.*

Solution : The method is rheostatic control. The two conditions are shown in the Fig. 2.50 (a), (b).

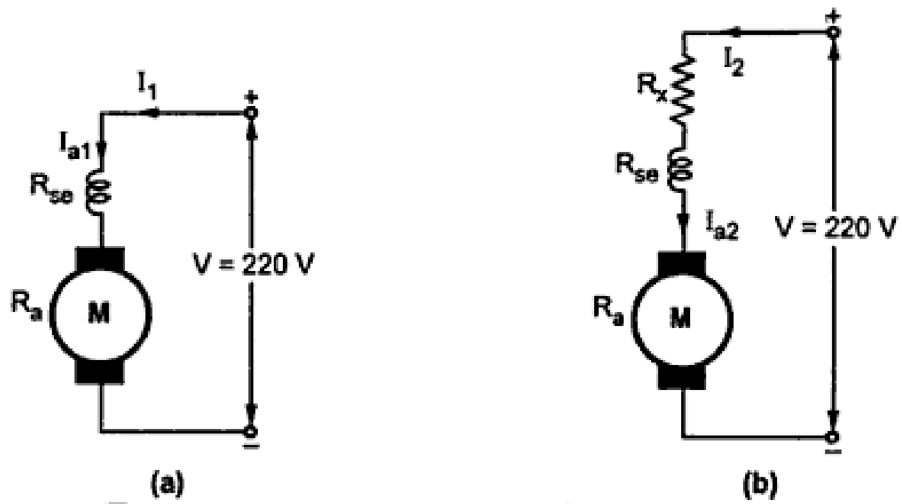


Fig. 2.50

V = 220 V, the total resistance i.e $R_e + R_{se} = 0.15\ \Omega$

In first case, $N_1 = 500$ r.p.m., $I_1 = I_{a1} = 50$ A and $T_2 = 0.5\ T_1$

In this case, the series field current is same as armature current,

$$\phi \propto I_{se} \propto I_a$$

$$\therefore \quad T \propto I_a^2$$

$$\therefore \quad \frac{T_1}{T_2} = \left(\frac{I_{a1}}{I_{a2}}\right)^2$$

$$\therefore \quad \frac{T_1}{0.5\ T_1} = \left(\frac{50}{I_{a2}}\right)^2$$

$$\therefore \quad I_{a2} = 35.355 \text{ A}$$

$$\therefore \quad E_{b1} = V - I_{a1}(R_a + R_{se}) = 220 - 50 \times 0.15 = 212.5 \text{ V}$$

and $$E_{b2} = V - I_{a2}(R_a + R_{se} + R_x) = 220 - 35.355\ (0.15 + R_x)$$

Use speed equation, $N \propto \frac{E_b}{\phi} \propto \frac{E_b}{I_a}$

$$\therefore \quad \frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}} \times \frac{I_{a2}}{I_{a1}}$$

$$\therefore \quad \frac{500}{300} = \frac{212.5}{[220 - 35.355(0.15 + R_x)]} \times \frac{35.355}{50}$$

$$\therefore \quad 220 - 35.355\,(0.15 + R_x) = 90.1552$$

$$\therefore \quad R_x = 3.5225\ \Omega$$