

**Speed control methods of a DC motor and their applications**

**Objective:** At the end of this lesson you shall be able to  
 • explain the principle and the methods of controlling the speed of a DC motor.

**Principle of speed control in DC motors:** In certain industrial applications, the variation of speed is a necessity. In DC motors the speed can be changed to any specified value easily. This is the main reason for certain industries to prefer DC motors for drives rather than AC motors. The speed of a DC motor can be varied, based on the following simple relationship.

It is known that the applied voltage = back emf + armature resistance voltage drop

$$V = E_b + I_a R_a.$$

Hence  $E_b = V - I_a R_a$  and also

$$\text{the back emf } E_b = \frac{P\phi N}{60} \times \frac{Z}{A} = K\phi N$$

where K is a constant.

$$\text{Therefore } N = \frac{E_b}{k\phi} = \frac{V - I_a R_a}{k\phi} \dots\dots\dots \text{Eqn.1}$$

From the above expression, it is clear that the speed of a DC motor is directly proportional to the back emf  $E_b$ , and inversely proportional to flux ( $\phi$ ). Thus the speed of the DC motor can be varied by changing either the back emf  $E_b$  or the flux  $\phi$  or both. In fact, if the back emf is decreased across the armature, the speed decreases, and if the flux is decreased the speed increases. The following are the most common methods of controlling the speed of DC motors based on the above principle.

**Methods of speed control in DC shunt motors and compound motors**

**Armature control method:** This method works on the principle that the speed of the DC motor could be varied by varying the back emf. As the back emf =  $V - I_a R_a$ , by varying the armature resistance we can obtain various speeds. A variable resistance called controller is connected in series with the armature as shown in Fig 1. The controller should be selected to carry the armature current for a longer period.

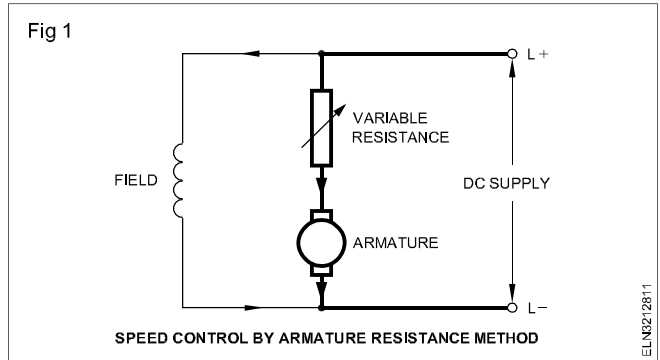
Let the initial and final speeds of the motor be  $N_1$  and  $N_2$ , and the back emf be  $E_{b1}$  and  $E_{b2}$  respectively,

$$\text{Then } N_1 = \frac{E_{b1}}{k} \dots\dots \text{Eqn.2.}$$

$$N_2 = \frac{E_{b2}}{k} \dots\dots \text{Eqn.3.}$$

By dividing Eqn.3 by Eqn.2 we have

$$N_2 = \frac{E_{b2} N_1}{E_{b1}}$$



By varying the controller resistance value in the armature circuit, the back emf can be varied from  $E_{b1}$  to  $E_{b2}$ , thereby, the speed can be varied from  $N_1$  to  $N_2$ .

**Advantages**

This method is suitable for constant load drives where speed variations from low speed up to normal speed are only required.

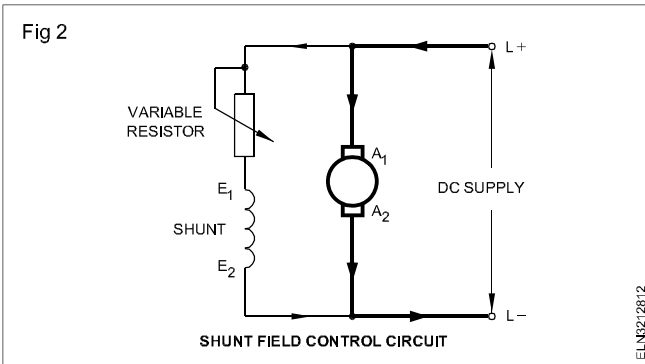
**Disadvantages**

- Speeds below normal can only be obtained.
- After setting the required speed, it changes with the change in the load because of speed variations not only due to control resistance but also due to load. Hence a stable speed cannot be maintained when the load changes.
- Power loss in the control resistance is high due to the higher current rating, leading to low efficiency of the motor.
- Cost of control resistance is high due to the fact it has to be designed to carry the armature current.
- Requires expensive arrangement to dissipate the heat developed in the control resistance.

**Application of the armature control method:** Suitable for DC shunt and compound motors used in printing machines, cranes and hoists where the duration of low speed operation is minimum.

**The shunt field control method:** This method works on the principle that the speed of the DC motor could be varied by varying the field flux. For this, a variable resistance

(rheostat) is connected in series with the shunt winding as shown in Fig 2.



When the resistance is increased in the field circuit, the field current and the flux are reduced. Due to the reduction of flux, the speed is increased.

### Advantages

- Higher speeds i.e. above normal speed only can be obtained which will be stable from no load to full load.
- As the magnitude of the field current is low, the power loss in the field rheostat is minimum.
- Control is easy, economical and efficient.

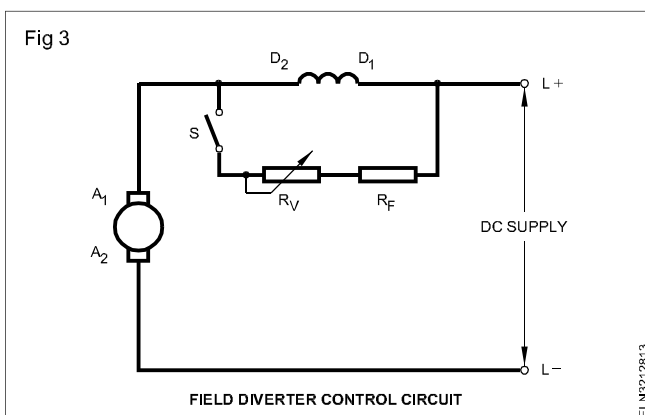
### Disadvantages

- Owing to the very weak field, a reduced torque is obtained at top speeds.
- The operation at high speeds with a weak field leads to commutation difficulties unless inter-poles are used.

**Application of shunt field control:** This method is the most widely used speed control method where speeds above normal are required, and at the same time, the load applied to the motor changes often.

### Method of speed control in DC series motors

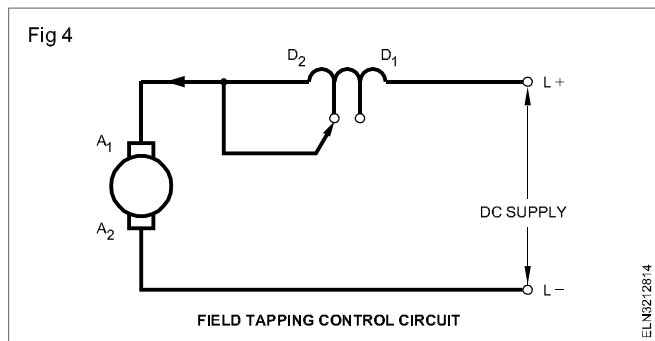
**Field diverter method:** A variable resistance, called a diverter, is connected in parallel with the field winding as in Fig 3.  $R_V$  represents the variable portion of the diverter and  $R_F$  the fixed portion. The function of  $R_F$  is to prevent the series winding being short-circuited, when the diverter is operated.



The smaller the value of  $R_V + R_F$ , the greater is the current diverted from the series winding, and, higher the speed of the motor. The minimum speed for a given input current is obtained by opening the switch 'S', thereby breaking the circuit through the diverter.

**Application of the series field diverter method:** This method is mainly used in the speed control of electric trains. By this method, speeds above normal only could be obtained, and the power loss in the diverter is quite considerable.

**Field tapping method:** A tap changing arrangement is made on the series field winding as shown in Fig 4. By varying the number of effective turns of the field winding, the speed can be controlled. The motor circuit should be started with all the winding included, and the speed can be changed then, by setting at a suitable tapping. This provision should be incorporated in the switch gear. Otherwise, if the tapping is kept at a lower setting and the motor is started, the motor races to a high speed at the time of starting itself, which is undesirable.



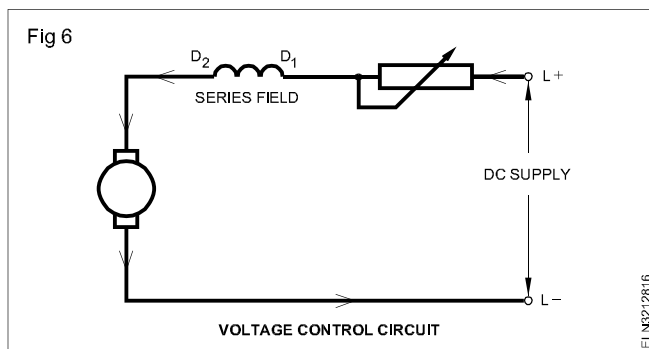
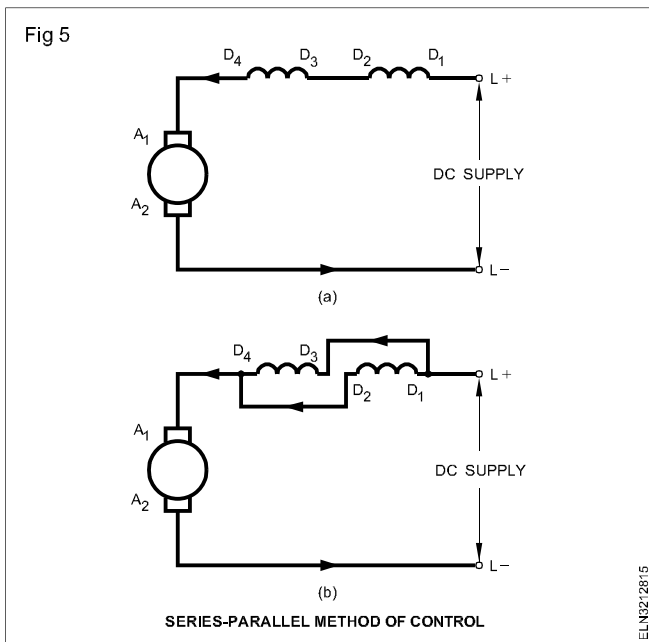
**Application of series field tapping method:** This method is used in small motors like food mixers, fans etc.

**Series parallel method:** Fig 5(a) shows a series motor with two halves of the field winding connected in series. If the two halves of the field winding are connected in parallel as in Fig 5(b), then for a given current 'I' taken from the supply, the current in each field coil is reduced to half and the flux is, therefore, reduced and the speed increased.

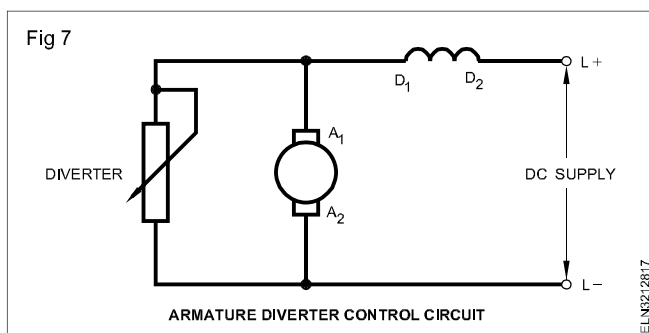
**Application of series parallel method:** This is the simplest method though only two speeds are possible. This method is often used for controlling the speed of fan motors.

**Supply voltage control method:** A controller (variable resistance) is connected in series with the motor as shown in Fig 6. This method can be used to control the speed from zero up to full normal speed.

The disadvantage in this method is that there is loss of energy in the control resistance in the form of heat. But with the introduction of SCR based control circuit, obtaining a variable supply voltage to motor is achieved with the least power loss. This method is widely used in larger modern machines where power loss is a major concern.



**Armature diverter method:** In this method, a variable resistor called a diverter is connected across the armature as shown in Fig 7. By this method, the armature current is controlled to vary the speed below the rated value for series motors.



For a motor running at constant load torque, if the armature current is reduced by the armature diverter, the line current increases to meet the torque, thereby, the series field current increases. This increased field current reduces the speed.

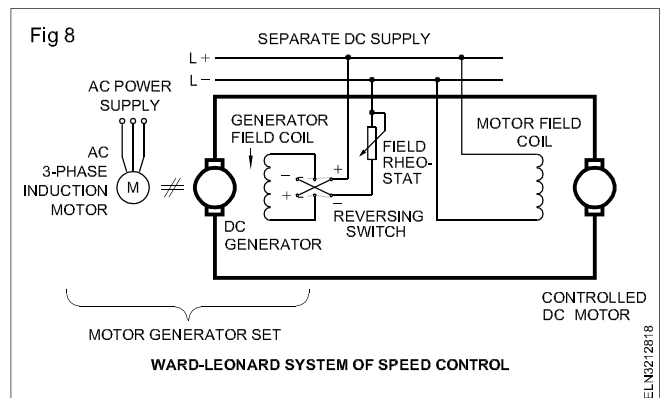
This method is wasteful, costly and unsuitable for changing loads.

The speed control methods illustrated for DC series motor cannot be used for compound motors as these adjustments would radically change the performance characteristics of the compound motor.

**Ward-Leonard system of speed control:** In all the methods explained so far, it is clear that the speed cannot be varied from zero to above normal by any one method and at least two methods are required to be combined to do so. Further, the efficiency of the above mentioned controls is much less, due to power loss and instability due to load variation.

A smooth variation of speed from zero to above normal with inherent stability of speed at all loads is achieved through an adjustable voltage system of speed control called Ward-Leonard system of speed control.

In this system, a DC generator is mechanically coupled to a constant speed DC motor or an AC 3-phase induction motor as shown in Fig 8. The generated supply from the DC generator is fed directly to the armature of the controlled DC motor. The fields of both the DC generator and the controlled DC motor are separately excited from a suitable DC supply. The field of the DC generator is controlled through a field rheostat and a change-over switch to vary the generated voltage and to change the polarity respectively. This enables the supply to the controlled DC motor to vary at a wide range and also makes it possible to reverse the supply voltage polarity. This, in turn, changes the speed of the controlled DC motor to vary from zero to above normal speed as well as change the direction of rotation, if necessary. The controlled DC motor speed can be brought down to zero by reducing the supply voltage of the generator to a suitable level.



### Advantages

- By this system, a speed as low as zero and as high as two times the normal speed could be achieved.
- The direction of rotation of the controlled DC motor can be changed simply by reversing the controller in the field circuit of the generator.
- As there is not much power loss in the field rheostat, the speed variations are achieved at higher efficiency.
- The speed of the controlled DC motor is independent of the load.

### Disadvantage

This method requires high initial cost and low overall efficiency due to three machines in operation.

**Application of the Ward-Leonard speed control method:** This system is used in steel rolling mills and paper mill drives, hoists, elevators etc. where a precise control of speed over a wide range is required. Even today DC motors are used in India as electrical drives in modern steel rolling mills, heavy industries like BHEL, HMT etc.

Due to modernization, these DC motors are incorporated with solid state control devices like transistors, diodes, thyristors and microprocessors to eliminate human errors of operation and to maintain trouble-free service though the basic principles for the speed control, remain, as already stated, valid.

## Method of calculation of control resistance and new speed

**Objective:** At the end of this lesson you shall be able to

- explain the method of calculating the value of control resistance when full load current of the motor, armature resistance and applied voltages are known.

We know from the earlier discussions that the speed of a DC motor.

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

where

V = rated voltage of motor

$I_a$  = armature current

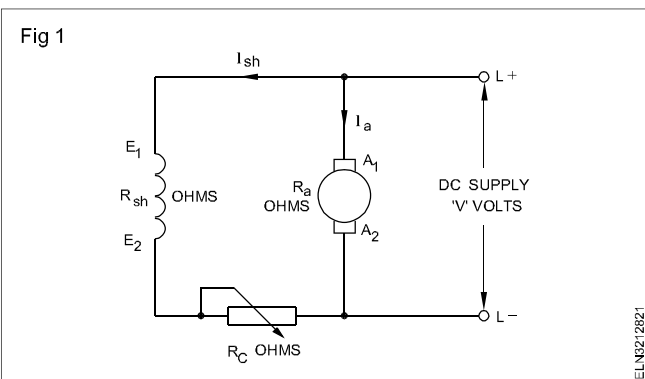
$R_a$  = armature circuit resistance

K is a constant for a particular motor

$\phi$  is the flux in webers per pole of the motor

N is the speed in r.p.m.

The various methods of speed control discussed in the earlier chapter were based on this formula. From these we know that the speed of the motor can be controlled by either changing the flux  $\phi$  or by changing the back emf  $E_b = (V - I_a R_a)$ . To obtain these, we found that control resistance is connected either in field or in armature circuits. When control resistance is added, the speed will change. An electrician should be in a position to determine the value of the control resistance to be connected in the circuit to obtain a designated speed. The value of control resistance to be used to obtain a new speed can be calculated based on the following information (Fig 1).



### Method of calculating control resistance in series with the shunt field

Let

$E_{b1}$  = back emf at speed N1

$E_{b2}$  = back emf at speed N2

$N_1$  = speed at which it is running

$N_2$  = new speed/speed to which it changes

$I_{F1}$  = field current at N1

$I_{F2}$  = field current at N2

$R_t$  = total shunt field circuit resistance

$R_{sh}$  = shunt field resistance

$R_c$  = value of control resistance in series with shunt field.

$$\text{Then } \frac{E_{b1}}{E_{b2}} = \frac{k\phi_1 N_1}{k\phi_2 N_2}$$

As  $\phi$  is proportional to the field current  $I_F$ .

$$\text{Therefore, we have } \frac{E_{b1}}{E_{b2}} = \frac{kI_{F1}N_1}{kI_{F2}N_2}$$

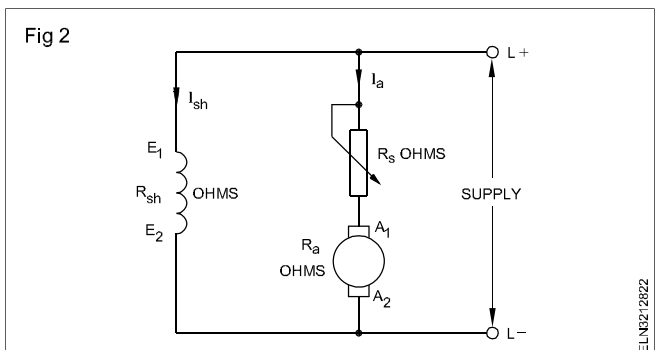
$$\text{Therefore the new speed } N_2 = \frac{E_{b2}I_{F1}N_1}{E_{b1}I_{F2}}$$

$$\text{Further } I_{F2} = \frac{\text{Applied voltage}}{\text{shunt field circuit resistance}} = \frac{V}{R_{sh} + R_c}$$

$$R_c = \frac{V}{I_{F2}} - R_{sh} \\ = R_t - R_{sh}$$

### Method of calculating the control resistance in series with the armature

Referring to Fig 2 we have



$I_{a1}$  = armature current at  $N_1$

$I_{a2}$  = armature current at  $N_2$

If  $I_{a1} = I_{a2}$ , then the load is of constant torque

$N_1$  = initial speed

$N_2$  = new or final speed

$V$  = supply voltage

$R_t$  = total armature circuit resistance

$R_s$  = control resistance

$R$  = control resistance in series with armatures

$$N_1 = \frac{E_{b1}}{k\phi} \text{ and } N_2 = \frac{E_{b2}}{k\phi}$$

$$N_2 = \frac{N_1 E_{b2}}{E_{b1}} = \frac{N_1 (V - I_{a1} R_t)}{(V - I_{a2} R_a)}$$

where  $R_t = R_s + R_a$ .

**Example 1 :** A 230 volts DC shunt motor runs at 1000 r.p.m. and takes an armature current of 20A. Find the resistance to be added to the field to increase speed to 1200 r.p.m. at an armature current of 30 amps, if  $R_a = 0.25$  ohms,  $R_{sh} = 230$  ohms.

As the armature current varies from 20 to 30 amps, we get two variables  $E_{b1}$  and  $E_{b2}$ . Further the speed has to be increased by adding resistance in the shunt field. As such the field current changes from  $I_{F1}$  to  $I_{F2}$ .

$$E_{b1} = V - I_{a1} R_a = 230 - (20 \times 0.25) = 230 - 5 = 225 \text{ V}$$

$$E_{b2} = V - I_{a2} R_a = 230 - (30 \times 0.25) = 230 - 7.5 = 222.5 \text{ volts}$$

$$I_{F1} = \frac{230}{230} = 1 \text{ amp.}$$

$$\frac{E_{b1}}{E_{b2}} = \frac{I_{F1} N_1}{I_{F2} N_2}$$

$$\begin{aligned} I_{F2} &= \frac{E_{b2} \times I_{F1} \times N_1}{E_{b1} N_2} \\ &= \frac{222.5 \times 1 \times 1000}{225 \times 1200} \\ &= 0.824 \text{ amp} \end{aligned}$$

$$R_t = \frac{230}{I_{F2}} = \frac{230}{0.824} = 279.12 \text{ ohms.}$$

Therefore,  $R_c = R_t - 230 = 279.12 - 230 = 49.12$  ohms.

**Example 2 :** A DC shunt motor operates on 230V takes an armature current of 20A at 1000 r.p.m.. Its armature resistance is 1 ohm. Calculate the value of resistance to be added to the series with armature to reduce its speed to 800 r.p.m..

$$E_{b1} = V - I_a R_a = 230 - (20 \times 1) = 230 - 20 = 210 \text{ volts}$$

$$\frac{E_{b1}}{E_{b2}} = \frac{N_1}{N_2}$$

$$\begin{aligned} \text{Therefore, } E_{b2} &= \frac{E_{b1} \times N_2}{N_1} \\ &= \frac{210 \times 800}{1000} = 168 \text{ volts.} \end{aligned}$$

$$E_{b2} = V - I_a R_t$$

$$\begin{aligned} \text{Therefore } I_a R_t &= V - E_{b2} \\ &= 230 - 168 = 62 \text{ volts.} \end{aligned}$$

$$\text{Therefore } R_t = 62/20 = 3.1 \text{ ohms}$$

$$\begin{aligned} R_s &= R_t - R_a \\ &= 3.1 - 1 = 2.1 \text{ ohms.} \end{aligned}$$

**Example 3 :** A 240 volts series motor takes 10 amps when giving its rated output at 2000 r.p.m.. Its resistance is 0.5 ohm. Find what resistance must be added to obtain the same torque at 1500 rpm. Calculate the power loss in control. (As torque is the same the current taken by the motor should be same.)

$$E_{b1} = V - I_a R_a = 240 - (10 \times 0.5) = 240 - 5 = 235 \text{ volts}$$

$$E_{b2} = \frac{E_{b1} N_2}{N_1} = \frac{235 \times 1500}{2000} = 176.3 \text{ volts.}$$

$$I_a R_t = V - E_{b2} = 240 - 176.3 = 63.7 \text{ volts}$$

$$\text{Therefore, } R_t = \frac{I_a R_t}{I_a} = \frac{63.7}{10} = 6.37 \text{ ohms.}$$

$$\text{Therefore, } R_s = R_t - R_a = 6.37 - 0.5$$

Series control resistance = 5.87 ohms

Power loss in control resistance  $I_a^2 R_s = 10^2 \times 5.87 = 587$  watts.

**Troubleshooting in DC machines**

**Objective:** At the end of this lesson you shall be able to  
 • use the trouble shooting chart to rectify defects in i) DC machines in general ii) DC motors iii) DC generators.

DC machines have electrical problems which are not normally found in AC machines. DC motors and generators have commutators and brushes, which cause special problems. If the commutator is properly maintained, it will give many years of useful service.

Troubleshooting in DC machines in general is discussed in Chart 1 where as Chart 2 deals with DC motors and Chart 3 is for DC generator.

Chart 1

**Troubleshooting chart for DC machines**

Symptoms	Cause	Remedies
Very rapid wearing out of the brushes  or over heating of pig tails  or heavy sparking at the commutator  or over heating of commutator.	a) Insufficient brush tension. b) Brushes not fully bedded. c) Incorrect size of grade of replaced brushes d) Overloading. e) Excessive brush pressure. f) Insufficient or unequal brush pressure due to brushes sticking in holder. g) Short circuit in commutator segment. h) Uneven commutator surface. i) Brushes may not be in magnetic neutral plane. j) Dirty oily or tarnished commutator surface. k) Incorrect direction of rotation.	a) Test brush tension. b) Inspect the brush faces and the brushes. c) Use correct grade of brush for replacement. d) Reduce the load. e) Adjust the brush tension to lower value f) Check the free movement of brushes in holder. g) Clean the commutator and test for shorts. Rectify the defect. Inspect the commutator surface. h) Under cut the mica and skin the commutator if necessary. i) Adjust the rocker arm to neutral plane. j) Clean and polish the commutator. k) Check the direction of rotation and rectify the defect.
Brush chatter or hissing noise	a) Excessive clearance of brush holders. b) Incorrect angle of brush. c) Incorrect brushes for the service. d) High mica. e) Incorrect brush spring pressure.	a) Adjust holders. b) Adjust to correct angle. c) Get manufacturer's recommendation. d) Undercut mica. e) Adjust to correct value.
Selective commutation (one brush takes more load than it should)	a) Insufficeint brush spring pressure. b) Unbalanced circuits in armature.	a) Adjust the correct pressure making sure brushes ride free in holders.

Symptoms	Cause	Remedies
Sparking at light loads	a) Paint spray, chemicals, oil or grease or other foreign material on commutator.	b) Eliminate high resistance in defective joints by checking armature or equalizer circuit or commutator risers. Check for poor contacts between bus and bus rings. a) Use motor designed for application. Clean commutator, and provide protection against foreign matter. Install an enclosed motor designed for the application.
Overheating of field coils	a) Short circuit between turns or layers	a) Replace defective coil or rewind the coil.
Overheating of armature	a) More voltage across the armature. may be high or in the case of motor the applied voltage. b) More current in armature. c) Armature winding shorted.	a) In the case of generator the speed may be high measure and reduce it. b) Reduce the overload. c) Check the commutator and remove any metallic particles in between segments. Test the machine for shorts and rectify the defect.
Machine operates but overheats	d) Insufficient air circulation around machine a) Overloading. b) Worn out bearing. c) Tight bearing. d) Shorted or earthed winding. e) Wrong alignment of pulley.	d) Allow good ventilation around the machine by providing fan etc. a) Reduce load. b) Replace bearing. c) Grease it. d) Test the winding. e) Align properly.
Vibration while running	a) Loose foundation bolts. b) Loose coupling pulleys. c) Wrong alignment. d) Loose internal parts. e) Bent shaft. f) Unbalanced armature. g) Damaged bearing.	a) Tighten them. b) Tighten them. c) Align properly d) Tighten them. e) True the shaft in a lathe f) Balance it. g) Inspect the bearing and replace it if necessary.
Mechanical noise	a) Foreign matter in air gap. b) Defective alignment. c) Defective bearing.	a) Clean the machine. b) Align the machine. c) Replace the bearing.
Bearing overheating	a) Incorrect grade or quantity of grease (roller type).	a) Remove incorrect grade or surplus grease and replenish with correct quantity of recommended grease

Chart 2

## Troubleshooting chart for DC motors

Symptoms	Cause	Remedies
Motor will not start	<ul style="list-style-type: none"> <li>a) Open circuit in starter.</li> <li>b) Low or no terminal voltage.</li> <li>c) Bearing frozen.</li> <li>d) Overload.</li> <li>e) Excessive friction.</li> </ul>	<ul style="list-style-type: none"> <li>a) Check for open starting resistor,</li> <li>b) Check the incoming voltage with name-plate rating and correct the supply voltage.</li> <li>c) Recondition the shaft and replace the bearing.</li> <li>d) Reduce the load.</li> <li>e) Check the bearing lubrication to make sure that the oil is sufficient quantity and of good quality. Disconnect motor from driven machine and turn motor by hand to see if trouble is in motor. Strip and reassemble motor; then check part by part for proper location and fit. Straighten or replace bent shaft.</li> </ul>
Motor stops after running short time	<ul style="list-style-type: none"> <li>a) Motor is not getting power.</li> <li>b) Motor is started with weak or no field.</li> <li>c) Motor torque insufficient to drive load.</li> </ul>	<ul style="list-style-type: none"> <li>a) Check voltage in the motor terminals: also fuses and overload relay. Rectify the defect.</li> <li>b) If adjustable-speed motor, check the rheostat for correct setting. If correct, check the condition of rheostat. Check the field coils for open winding. Check the wiring for loose or broken condition</li> <li>c) Check the line voltage with name plate rating. Use larger motor or one with suitable characteristic to match the load.</li> </ul>
Motor runs too slow under load.	<ul style="list-style-type: none"> <li>a) Line voltage too low.</li> <li>b) Brushes ahead of neutral plane.</li> <li>c) Overload.</li> </ul>	<ul style="list-style-type: none"> <li>a) Rectify the supply voltage or under load check and remove any excess resistance in supply line, connections or controller.</li> <li>b) Set brushes on neutral plane.</li> <li>c) Check to see that load does not exceed allowable load on motor.</li> </ul>
Motor runs too fast under load.	<ul style="list-style-type: none"> <li>a) Weak field.</li> <li>b) Line voltage too high.</li> <li>c) Brushes are out of neutral plane.</li> </ul>	<ul style="list-style-type: none"> <li>a) Check for resistance in shunt-under load field circuits. Check for grounds.</li> <li>b) Correct high voltage condition.</li> <li>c) Set brushes on neutral plane.</li> </ul>



Chart 3

Troubleshooting chart for DC Generators

Symptoms	Cause	Remedies
Generator fails to build up voltage	a) The direction of rotation must have been reversed. b) Brushes not resting on the commutator. c) Residual magnetism is completely lost.  d) Generator speed is too low.  e) Short circuit in the armature.  f) Open circuit in the armature. g) Short circuit in the field circuit.  h) Open circuit in field winding.	a) Change the direction of rotation  b) Brushes to be set over the commutator in correct position.  c) Run the generator as a DC motor or sometime (few seconds) or connect the field circuit to a battery or DC voltage to reestablish the residual magnetism.  d) Generator speed should be restored to normal speed by increasing the prime mover speed.  e) Rectify the short circuit in the armature.  f) Test and rectify the open circuit.  g) Test and rectify the short circuit which may be in the coil. Faulty coil will show much less resistance than a good coil.  h) Check the continuity of the circuit and rectify the defect.

## Maintenance procedure for DC machines

**Objectives:** At the end of this lesson you shall be able to

- state what is meant by preventive maintenance and its importance
- describe the recommended maintenance schedule for DC motors
- explain how to maintain the maintenance record.

**Preventive maintenance:** Preventive maintenance of electrical machines consists of routinely scheduled periodical inspections, tests, planned minor maintenance repairs and a system of maintaining inspection records for future reference. Preventive maintenance is a combination of routine and planned operations.

**Routine operations:** Routine operations are those which follow fixed schedules to maintain electrical motors at daily, weekly or at other fixed intervals.

**Planned operation:** By contrast, planned operation consists of additional work which is performed at irregular frequencies, and is determined by inspection and previous operating experience or the details of defects found in the maintenance records.

**Necessity of preventive maintenance:** By carrying out an effective preventive maintenance programme on electrical machines, we can eliminate major failures of the machines, accidents, heavy repair costs and loss of production time. Proper preventive maintenance will lead to economy of

operation, less down-time, dependable machine operation, longer machine life and lower overall cost of maintenance and repair.

**Scheduling of preventive maintenance:** Routine periodical inspection and tests may be scheduled to be carried out daily, weekly, monthly, half-yearly and annually depending upon the following factors.

- The importance of the motor/generator in the production
- The duty cycle of the machine
- The age of the machine
- The earlier history of the machine
- The environment in which the machine operates
- The recommendations of the manufacturer.

**Recommended maintenance schedule for machines:** While carrying out routine periodical maintenance, an electrician will make full use of his senses to diagnose and locate problems in electrical machines. The sense of smell directs attention to burning insulation: the sense of

feel detects excessive heating in winding or bearing; the sense of hearing detects excessive noise, speed or vibration and the sense of sight detects excessive sparking and many other mechanical faults.

Sensory impressions must also be supplemented by various testing procedures to localize the trouble. A thorough understanding of electrical principles and the efficient use of test equipment are important to an electrician during this phase of operation.

<b>Machine details</b>		<b>Page 1</b>
Manufacturer, Trade Mark _____		
Type, Model or List number _____		
Type of current _____		
Function _____ Generator/Motor		
Fabrication or serial number _____		
Type of connection _____ Sep/Shunt/Series/Compound		
Rated voltage _____ volts	Rated current _____ amps	
Rated power _____ K.W.	Rated speed _____ r.p.m.	
Rated exc. voltage _____ volts	Rated exc. current _____ amps	
Rating class _____	Directon of rotation _____	
Insulation class _____	Protection class _____	

The following maintenance schedule is recommended for DC machines.

### 1 Daily maintenance

- Examine visually earth connections and machine leads.
- Check the sparking at the commutator.
- Check the motor windings for overheating. (The permissible maximum temperature is near about that which can be comfortably felt by hand.)
- Examine the control equipment.
- In the case of oil-ring lubricated machines
  - a) examine the bearings to see that the oil rings are working
  - b) note the temperature of the bearings
  - c) add oil, if necessary
  - d) check end play.
- Check for unusual noise at the machine while running.

### 2 Weekly maintenance

- Examine the commutator and brushes.
- Check belt tension. In cases where this is excessive it should immediately be reduced. In the case of sleeve-bearing machines, the air gap between the rotor and stator should be checked.
- Blow out air through the windings of protected type machines situated in dusty locations.
- Examine the starting equipment for burnt contacts where machine is started and stopped frequently.

- Examine oil in the case of oil-ring lubricated bearings for contamination by dust, grit, etc. (This can be roughly judged from the colour of the oil.)
- Check foundation bolts and other fasteners.

### 3 Monthly maintenance

- Overhaul controllers.
- Inspect and clean the oil circuit breakers.
- Renew the oil in high-speed bearings which are in damp and dusty locations.
- Wipe the brush-holders and check the bedding of brushes of DC machines.
- Test the insulation of windings.

### 4 Half-yearly maintenance

- Check the brushes and replace, if necessary.
- Check the windings of machines subjected to corrosive and other elements. If necessary, bake the windings and varnish.
- Check the brush tension and adjust, if necessary.
- Check the grease in the ball and roller bearings, and make it up, where necessary, taking care to avoid overfilling.
- Check the current input to the motor or the output of the generator and compare it with normal values.
- Drain all the oil bearings, wash with petrol to which a few drops of oil have been added; flush with lubricating oil and refill with clean oil.

### 5 Annual maintenance

- Check all the high speed bearings, and renew, if necessary.

- Blow out all the machine winding thoroughly with clean dry air. Make sure that the pressure is not that high as to damage the insulation.
- Clean and varnish the oily windings.
- Overhaul the motors which have been subjected to severe operating conditions.
- Renew the switch and fuse contacts, if damaged.
- Check the oil in the starter and the grease/oil in the bearings.
- Renew the oil in the starters subjected to damp or corrosive elements.
- Check the switch conditions, resistance to earth between motor/generator windings, control gear and wiring.
- Check the resistance of earth connections.
- Check the air gaps in between the armature and field.

- Test the insulation of windings before and after overhauling the motors/generators.

## 6 Records

- Maintain a register giving one or more pages for each machine, and record therein all important inspections and maintenance works carried out from time to time. These records should show past performance, normal insulation level, air gap measurements, nature of repairs and interval between previous repairs and other important information which would be of help for good performance and maintenance.

While routine maintenance could be done either during the working of the machine or during short interval 'down' periods, the planned maintenance requires to be done during holidays or by taking shut-downs of small duration.

Planned maintenance schedule needs to be decided, based on the routine maintenance reports entered in the maintenance card.

Details of inner parts		Page 1
<p><b>Bearing</b></p> <p>Sleeve ball roller</p> <p>Front end No. _____</p> <p>Pulley end No. _____</p> <p>Grease type _____</p> <p>Coupling type _____</p> <p>Brush grade _____</p> <p>Brush No. as per manufacturer _____</p>	<p><b>Particulars of supply order</b></p> <p>Supply order No: _____</p> <p>Year of purchase _____</p> <p>Date of first inspection and test _____</p> <p>Date of installation _____</p> <p>Location _____</p>	

Initial test results	Page 1
Resistance value of shunt winding _____	
Resistance value of series winding _____	
Resistance value of armature _____	
Insulation resistance value between	
armature and shunt field _____	
armature and series field _____	
series field and shunt field _____	
armature and frame _____	
shunt field and frame _____	
series field and frame _____	

The 2<sup>nd</sup> page gives the record of maintenance carried out, and, in particular the defects noted therein.

### Maintenance record

Maintaining a system of inspection records is a must in preventive maintenance schedule. This system uses a register as stated above or cards as shown below which

are kept in the master file. By referring to these maintenance cards, the foreman can schedule the planned maintenance.

**Maintenance card:** The 1st page gives the details of name-plate, location, year of purchase, initial test results etc pertaining to the machine.

A careful study of the maintenance card helps the foreman to plan the shut-down date to facilitate early overhauling or planned maintenance schedule to prevent a major breakdown.

**Method of maintenance:** During the routine maintenance inspection, the investigations and adjustment to be carried out for the parts and accessories of the motors/generators are given below to improve the efficiency of preventive maintenance.

- Clean daily the motor/generator, switch gear and associated cables free from dirt, dust and grease. Use dry compressed air to drive away the dust from the machines.
- Check the bearing daily for excessive noise and temperature. If required, re-grease or re-oil the bearing with the same grade of grease/oil as in original. Do not mix different grades of grease together as it may result in forming sludge or acids, and spoil the bearings.
- Check the machine daily against strains of water or oil or grease which may leak from the surroundings. Take the necessary protective steps to prevent the leakage.
- Check daily the belts, gears and coupling for looseness, vibration and noise. Adjust/replace the parts, if found defective.
- Check weekly the brushes and the commutator for sparking and wear.

- Check weekly the bearing for proper lubrication.
- Check weekly the terminals and switch contacts.
- Inspect the brushes and the commutator once in a month for excessive wear, chatter and sparking. Worn-out brushes need to be replaced with the same grade brushes. Check spring tension on the brushes, and adjust, if necessary. Badly worn-out commutators need to be turned in a lathe or be replaced.
- Check monthly the brushes for proper seating. If necessary, reshape the brushes to proper curvature to suit the commutator surface.
- Check monthly the end plates and the shaft for excessive end play.
- Check monthly the main and auxiliary contact points of the switch gear for wear, pitting and burns. Badly worn out contact point needs replacement. Check the connection terminals for loose connection and scales or burning. Rectify the defects.
- Test monthly once the field windings and armature for insulation and ground faults. Low reading of insulation below 1 megohm indicates weak insulation. Dry out the winding, and re-varnish, if necessary.
- Check monthly once the foundation bolt and other fasteners for tightness.
- Once a year undercut the mica in between the commutator bars. Test the commutator and armature for shorts, open and ground faults.

**Maintenance card**

**Report on routine maintenance**

Date of maintenance	Scheduled maintenance carried out	Defects noted	Attended by (Signature)	Reported to (Signature)	Remarks

The 3rd page gives the details of the test carried out in the motor at intervals with corresponding readings

**Maintenance card**

**Report on test details**

Date of Test	Schedule	Test particulars	Test results	Tested by (Signature)	Reported to (Signature)	Remarks

From the above it is clear that atleast once in a year, the motor/generator needs a thorough overhauling in addition to frequent routine maintenance.

The 4th page gives the details of the defects, causes and repair carried out

**Motor service card**

Page 4

Date of repair	Repair and parts replaced	Cause	Repaired by (Signature)	Supervised by (Signature)	Remarks

## DC motor control system (drives) AC-DC and DC-AC control

**Objectives:** At the end of this lesson you shall be able to

- state the importance of AC to DC drive control
- list the advantages and applications of AC to DC drives
- explain the DC-DC drive control system (chopper)
- list the advantages and application of DC-DC drive.

### AC to DC drive control

AC/DC drive in an electronic device which converts a fixed frequency and voltage to an adjustable frequency and AC voltage source. It controls

- the speed
- the torque
- the horse power
- the directions of AC motor

These drives are also known as "Adjustable Speed Drives (ASD)" or "Variable Frequency Drives (VFD)"

It becomes more popularity due to energy saving.

The AC/DC converter is an SCR bridge, which receives AC power from the output wire and provides adjustable voltage DC power to DC bus, by using inverter.

The voltage regulator is required to preset the DC bus voltage level required for the output voltage amplitude to the motor

The frequency is adjusted by the frequency control device which is cause to control the speed of the motor.

Advances in technology have made the size, cost, reliability and performance of AC drives very appealing as Industrial "Variable Speed Applications"

#### Advantages

- Precise speed control
- Energy saving
- Simple operation
- No external control
- Good reliability
- Lighter and smaller in size

- It is preferable method of speed control

#### Application

Fans, Blowers, Compressors, Pumps, Lathes, Stamping presses, Etc.

### DC - DC drive control (Chopper)

DC - DC converter (chopper) drives are widely used in traction application all over the world. A DC - DC Converter is connected between a fixed voltage DC source and a DC motor to vary the armature voltage. In addition to armature voltage control a DC - DC converter can provide regenerative braking of the motors and can return energy back to the supply. It operates at high frequency.

DC-DC converter drives are also used in battery electric vehicle (BEVs). There are few control methods in DC-DC converter drive such as

- Power (or) acceleration control
- Regenerative brake control
- Rheostatic brake control
- Combined regenerative and rheostatic brake control

#### Advantages

It provides high starting torque. It is also possible to obtain speed control over a wide range. The methods of speed control are normally simpler and less expensive than those of AC drives.

#### Applications

- Servo applications
- Robotics