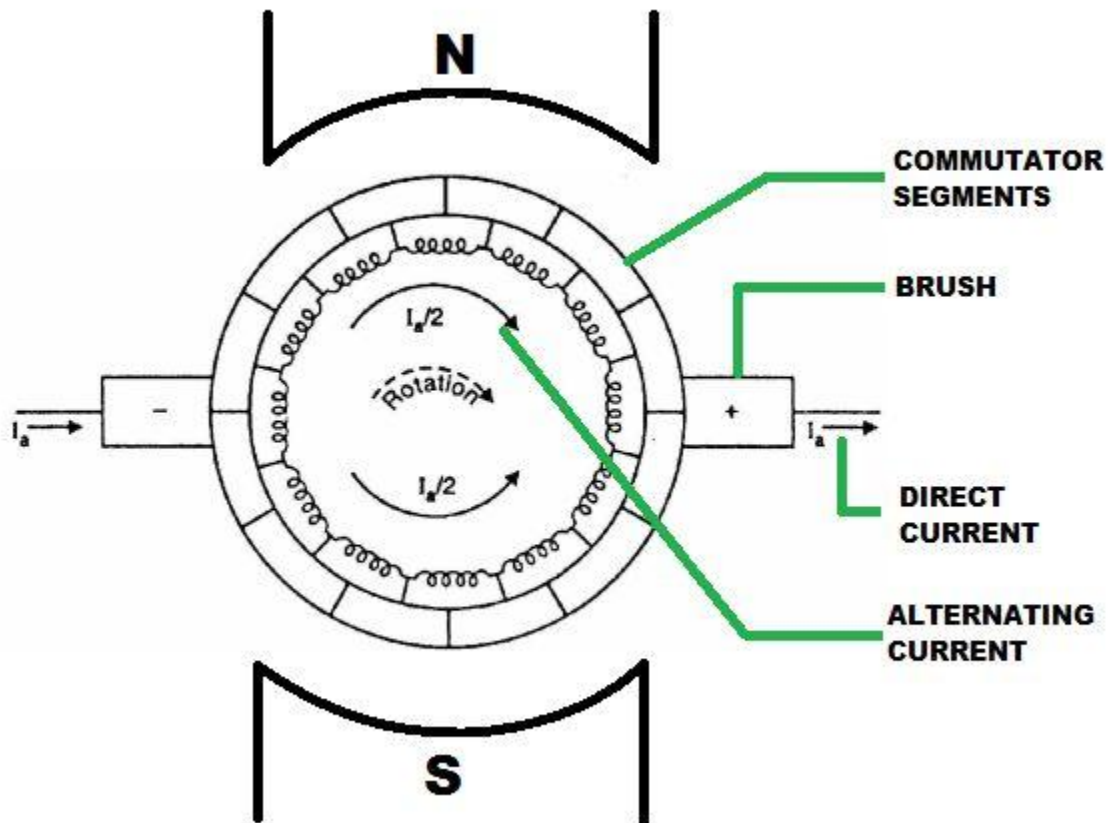
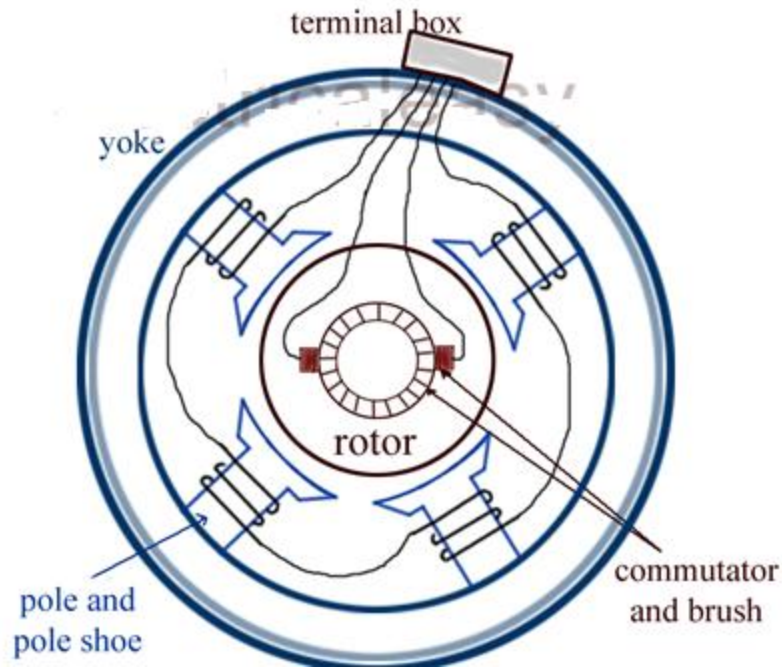


## DC GENERATOR

A dc generator is an electrical machine which converts mechanical energy into direct current electricity. This energy conversion is based on the principle of production of dynamically induced emf.

### CONSTRUCTION:





### Cross Sectional View of DC Generator

Above figure shows the constructional details of a simple 4-pole DC generator. A DC generator consists two basic parts,

stator and rotor.

Basic constructional parts of a DC generator are described below.

**Yoke:** The outer frame of a generator or motor is called as yoke. Yoke is made up of cast iron or steel. Yoke provides mechanical strength for whole assembly of the generator (or motor). It also carries the magnetic flux produced by the poles.

**Poles:** Poles are joined to the yoke with the help of screws or welding. Poles are to support field windings. Field winding is wound on poles and connected in series or parallel with armature winding or sometimes separately.

**Pole shoe:** Pole shoe is an extended part of the pole which serves two purposes, (i)to prevent field coils from slipping and (ii)to spread out the flux in air gap uniformly.



**Armature core (rotor)**

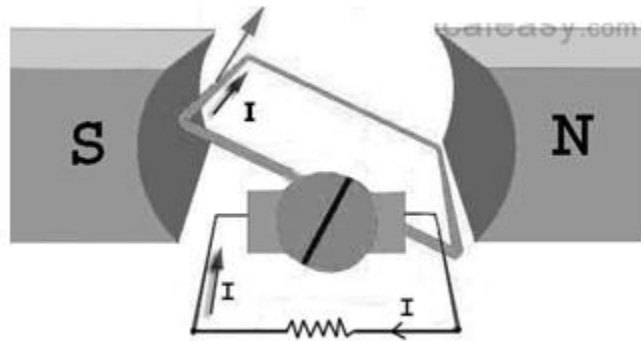
**Armature core:** Armature core is the rotor of a generator. Armature core is cylindrical in shape on which slots are provided to carry armature windings.

**Commutator and brushes:** As emf is generated in the armature conductors terminals must be taken out to make use of generated emf. But if we can't directly solder wires to commutator conductors as they rotates. Thus commutator is connected to the armature conductors and mounted on the same shaft as that of armature core. Conducting brushes rest on commutator and they slides over when rotor (hence commutator) rotates. Thus brushes are physically in contact with armature conductors hence wires can be connected to brushes.



**Commutator**

## WORKING PRINCIPLE OF A DC GENERATOR:



According to Faraday's law of electromagnetic induction, when a conductor moves in a magnetic field (thereby cutting the magnetic flux lines), a dynamically induced emf is produced in the conductor. The magnitude of generated emf can be given by emf equation of DC generator. If a closed path is provided to the moving conductor then generated emf causes a current to flow in the circuit.

Thus in DC generators, when armature is rotated with the help of a prime mover and field windings are excited (there may be permanent field magnets also), emf is induced in armature conductors. This induced emf is taken out via commutator-brush arrangement.

## EMF EQUATION OF A DC GENERATOR:

Let  $\Phi$  = flux/pole in Wb (weber)

Z = total no. of armature conductors

P = no. of generator poles

A = no. of parallel paths in armature

N = rotational speed of armature in revolutions per min. (rpm)

E = emf induced in any parallel path in armature

Now,

Avg. emf generated per conductor =  $\frac{d\phi}{dt}$  volts

and flux cut per conductor in one revolution =  $d\phi = \phi.P$  (Wb)

no. of revolutions per second (speed) =  $N/60$

∴ time for one revolution =  $dt = 60/N$

∴ emf generated / conductor =  $\frac{d\phi}{dt} = \frac{P\phi N}{60}$  volts

but generated emf ( $E_g$ ) will be equal to generated emf in any parallel path

∴ Generated emf ( $E_g$ ) =  $\frac{P\phi N}{60} \cdot \frac{Z}{A}$  volts

Now, for simplex wave wound generator

no. of parallel paths =  $A = 2$

∴  $E_g = \frac{P\phi N Z}{120}$  volts

and, for simplex lap wound generator

no. of parallel paths =  $A = \text{no. of poles} = P$

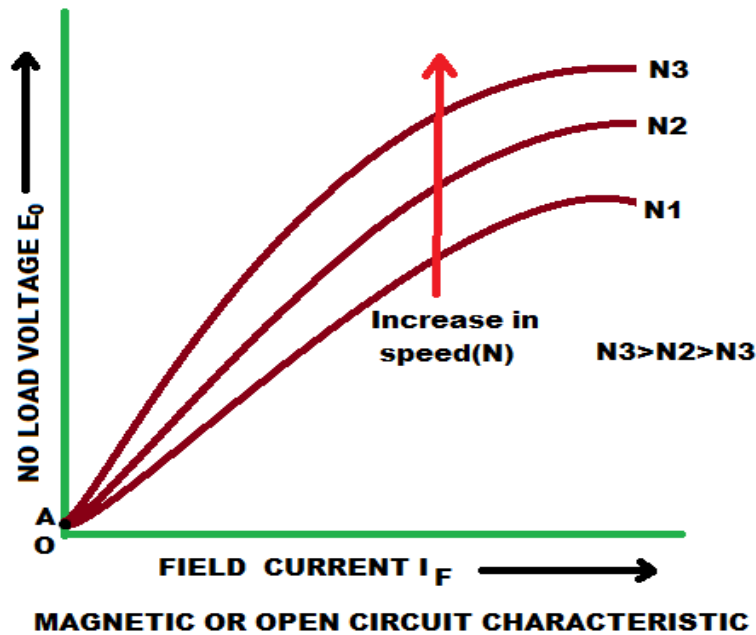
∴  $E_g = \frac{P\phi N}{60} \cdot \frac{Z}{P}$  volts

**CHARACTERISTICS OF DC GENERATOR:**

In a separately excited DC generator, the field winding is excited by an external independent source. There are generally three most important characteristics of DC generator:

### Magnetic or Open Circuit Characteristic of Separately Excited DC Generator

The curve which gives the relation between field current ( $I_f$ ) and the generated voltage ( $E_0$ ) in the armature on no load is called magnetic or open circuit characteristic of a DC generator. The plot of this curve is practically same for all types of generators, whether they are separately excited or self-excited. This curve is also known as no load saturation characteristic curve of DC generator. Here in this figure below we can see the variation of generated emf on no load with field current for different fixed speeds of the armature. For higher value of constant speed, the steepness of the curve is more. When the field current is zero, for the effect of residual magnetism in the poles, there will be a small initial emf (OA) as shown in the figure.



Let us consider a separately excited DC generator giving its no load voltage  $E_0$  for a constant field current. If there is no armature reaction and armature voltage drop in the machine then the voltage will remain constant. Therefore, if we plot the rated voltage on the Y axis and load current on the X axis then the curve will be a straight line and parallel to X-axis as shown in figure below. Here, AB line indicating the no load voltage ( $E_0$ ).

When the generator is loaded then the voltage drops due to two main reasons-

- 1) Due to armature reaction,

2) Due to ohmic drop (  $I_a R_a$  ).

### Internal or Total Characteristic of Separately Excited DC Generator

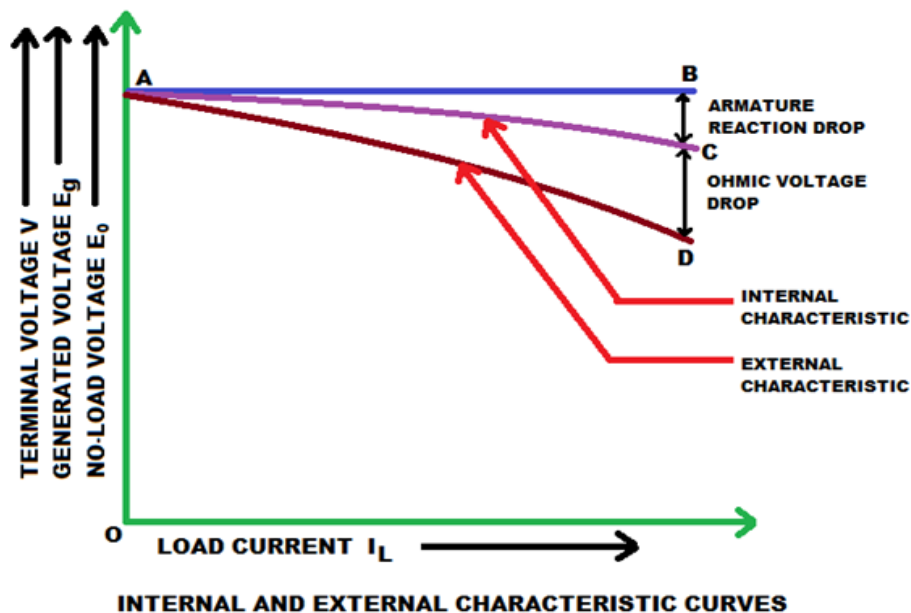
The internal characteristic of the separately excited DC generator is obtained by subtracting the drops due to armature reaction from no load voltage. This curve of actually generated voltage (  $E_g$  ) will be slightly dropping. Here, AC line in the diagram indicating the actually generated voltage (  $E_g$  ) with respect to load current. This curve is also called total characteristic of separately excited DC generator.

### External Characteristic of Separately Excited DC Generator

The external characteristic of the separately excited DC generator is obtained by subtracting the drops due to ohmic loss (  $I_a R_a$  ) in the armature from generated voltage (  $E_g$  ).

$$\text{Terminal voltage}(V) = E_g - I_a R_a.$$

This curve gives the relation between the terminal voltage (V) and load current. The external characteristic curve lies below the internal characteristic curve. Here, AD line in the diagram below is indicating the change in terminal voltage(V) with increasing load current. It can be seen from figure that when load current increases then the terminal voltage decreases slightly. This decrease in terminal voltage can be maintained easily by increasing the field current and thus increasing the generated voltage. Therefore, we can get constant terminal voltage.



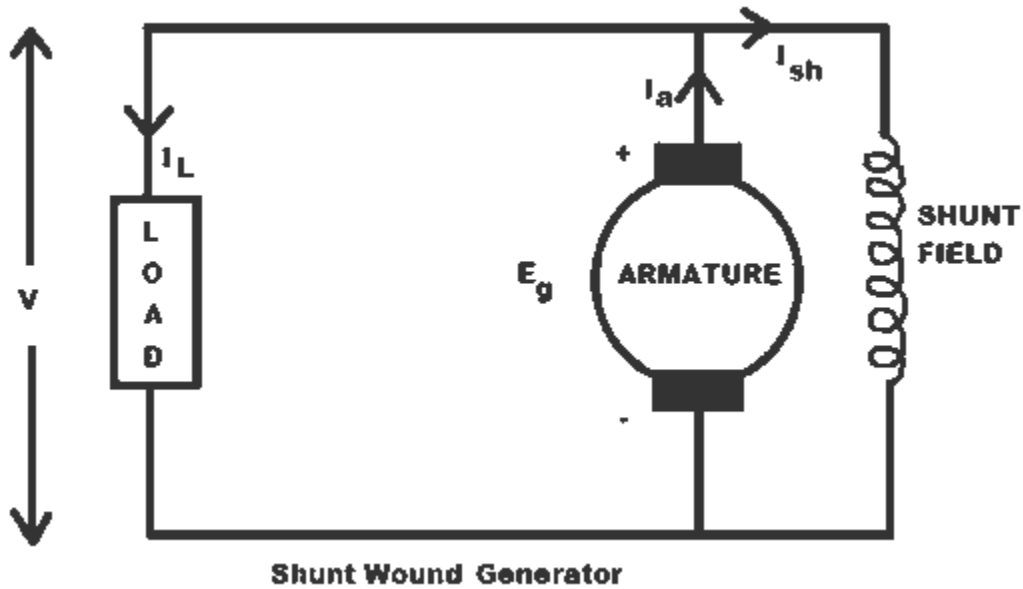
Separately excited DC generators have many advantages over self-excited DC generators. It can operate in stable condition with any field excitation and gives wide range of output voltage.

The main disadvantage of these kinds of generators is that it is very expensive of providing a separate excitation source.

**CHARACTERISTICS OF SELF EXCITED DC GENERATOR:**

In shunt wound DC generators the field windings are connected in parallel with armature conductors as shown in figure below. In these type of generators the armature current  $I_a$  divides in two parts. One part is the shunt field current  $I_{sh}$  flows through shunt field winding and the other part is the load current  $I_L$  goes through the external load.

$$\text{So, } I_a = I_{sh} + I_L$$



Three most important characteristic of shunt wound dc generators are discussed below:

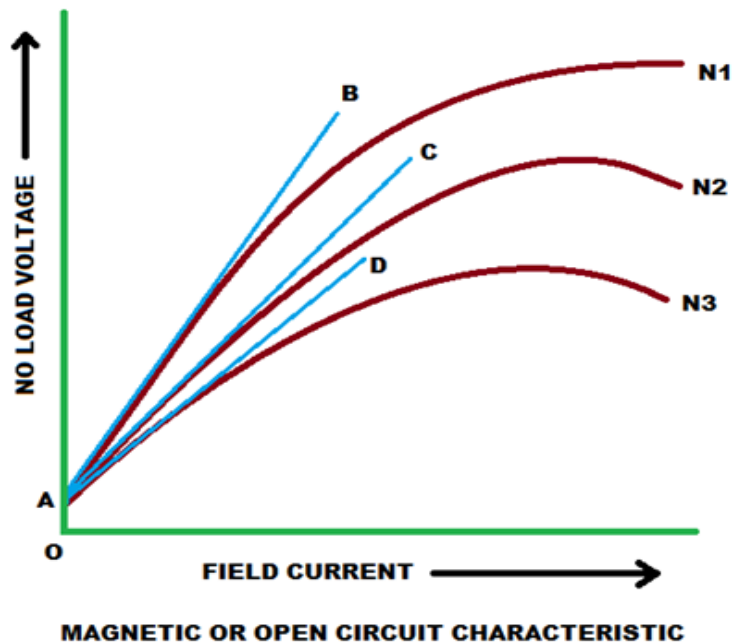
**Magnetic or Open Circuit Characteristic of Shunt Wound DC Generator**

This curve is drawn between shunt field current ( $I_{sh}$ ) and the no load voltage ( $E_0$ ). For a given excitation current or field current, the emf generated at no load  $E_0$  varies in proportionally with the rotational speed of the armature. Here in the diagram the magnetic characteristic curve for various speeds are drawn. Due to residual magnetism the curves start from a point A slightly up from the origin O. The upper portions of the curves are bend due to saturation. The external load resistance of the machine needs to be maintained greater than its critical value otherwise the machine will not excite or will stop running if it is already in motion. AB, AC and AD are the slopes which give critical resistances at speeds  $N_1$ ,  $N_2$  and  $N_3$ . Here,  $N_1 > N_2 > N_3$ .

**Critical Load Resistance of Shunt Wound DC Generator**



This is the minimum external load resistance which is required to excite the shunt wound generator.



### Internal Characteristic of Shunt Wound DC Generator

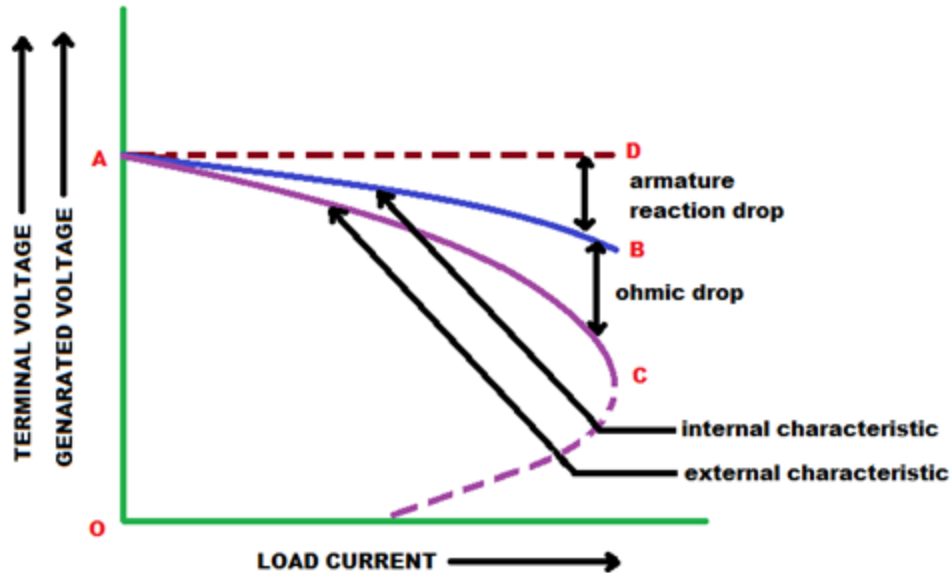
The internal characteristic curve represents the relation between the generated voltage  $E_g$  and the load current  $I_L$ . When the generator is loaded then the generated voltage is decreased due to armature reaction. So, generated voltage will be lower than the emf generated at no load. Here in the figure below AD curve is showing the no load voltage curve and AB is the internal characteristic curve.

### External Characteristic of Shunt Wound DC Generator

AC curve is showing the external characteristic of the shunt wound DC generator. It is showing the variation of terminal voltage with the load current. Ohmic drop due to armature resistance gives lesser terminal voltage the generated voltage. That is why the curve lies below the internal characteristic curve.

$$\text{Terminal voltage } V = (E_g - I_a R_a) = E_g - (I_{sh} + I_L) R_a$$

The terminal voltage can always be maintained constant by adjusting the of the load terminal.



When the load resistance of a shunt wound DC generator is decreased, then load current of the generator increased as shown in above figure. But the load current can be increased to a certain limit with (upto point C) the decrease of load resistance. Beyond this point, it shows a reversal in the characteristic. Any decrease of load resistance, results in current reduction and consequently, the external characteristic curve turns back as shown in the dotted line and ultimately the terminal voltage becomes zero. Though there is some voltage due to residual magnetism.

We know, Terminal voltage

Now, when  $I_L$  increased, then terminal voltage decreased. After a certain limit, due to heavy load current and increased ohmic drop, the terminal voltage is reduced drastically. This drastic reduction of terminal voltage across the load, results the drop in the load current although at that time load is high or load resistance is low.

That is why the load resistance of the machine must be maintained properly. The point in which the machine gives maximum current output is called breakdown point (point C in the picture).

## **CHARACTERISTICS OF DC SERIES GENERATOR:**

In these types of generators the field windings, armature windings and external load circuit all are connected in series as shown in figure below.

Therefore, the same current flows through armature winding, field winding and the load.

Let,  $I = I_a = I_{sc} = I_L$

Here,  $I_a$  = armature current

$I_{sc}$  = series field current

$I_L$  = load current

There are generally three most important characteristics of series wound DC generator which show the relation between various quantities such as series field current or excitation current, generated voltage, terminal voltage and load current.

### **Magnetic or Open Circuit Characteristic of Series Wound DC Generator**

The curve which shows the relation between no load voltage and the field excitation current is called magnetic or open circuit characteristic curve. As during no load, the load terminals are open circuited, there will be no field current in the field since, the armature, field and load are series connected and these three make a closed loop of circuit. So, this curve can be obtained practically by separating the field winding and exciting the DC generator by an external source. Here in the diagram below AB curve is showing the magnetic characteristic of series wound DC generator. The linearity of the curve will continue till the saturation of the poles. After that there will be no further significant change of terminal voltage of DC generator for increasing field current. Due to residual magnetism there will be a small initial voltage across the armature that is why the curve started from a point A which is a little way up to the origin O.

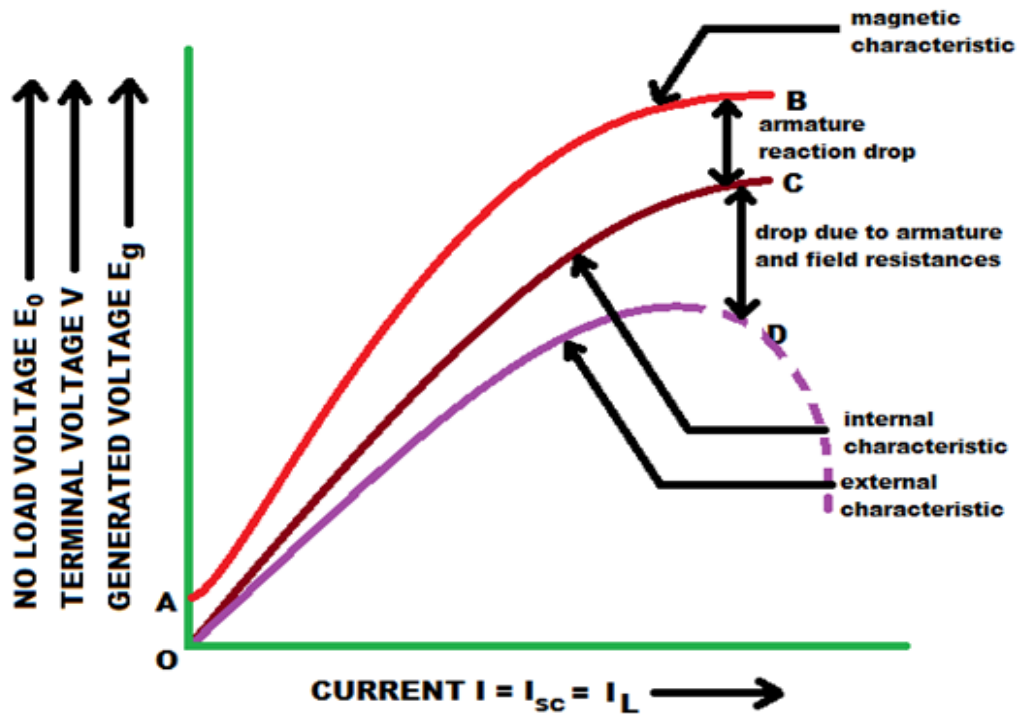
### **Internal Characteristic of Series Wound DC Generator**

The internal characteristic curve gives the relation between voltage generated in the armature and the load current. This curve is obtained by subtracting the drop due to the demagnetizing effect of armature reaction from the no load voltage. So, the actual generated voltage ( $E_g$ ) will be less than the no load voltage ( $E_0$ ). That is why the curve is slightly dropping from the open circuit characteristic curve. Here in the diagram below OC curve is showing the internal characteristic or total characteristic of the series wound DC generator.

## External Characteristic of Series Wound DC Generator

The external characteristic curve shows the variation of terminal voltage ( $V$ ) with the load current ( $I_L$ ). Terminal voltage of this type of generator is obtained by subtracting the ohmic drop due to armature resistance ( $R_a$ ) and series field resistance ( $R_{sc}$ ) from the actually generated voltage ( $E_g$ ).

$$\text{Terminal voltage } V = E_g - I(R_a + R_{sc})$$



**CHARACTERISTIC CURVES OF SERIES WOUND DC GENERATORS**

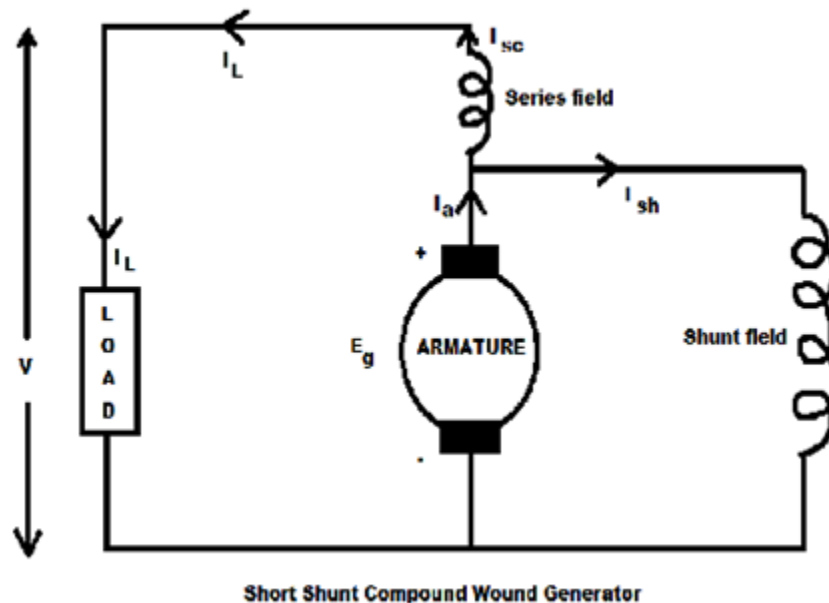
The external characteristic curve lies below the internal characteristic curve because the value of terminal voltage is less than the generated voltage. Here in the figure OD curve is showing the external characteristic of the series wound DC generator.

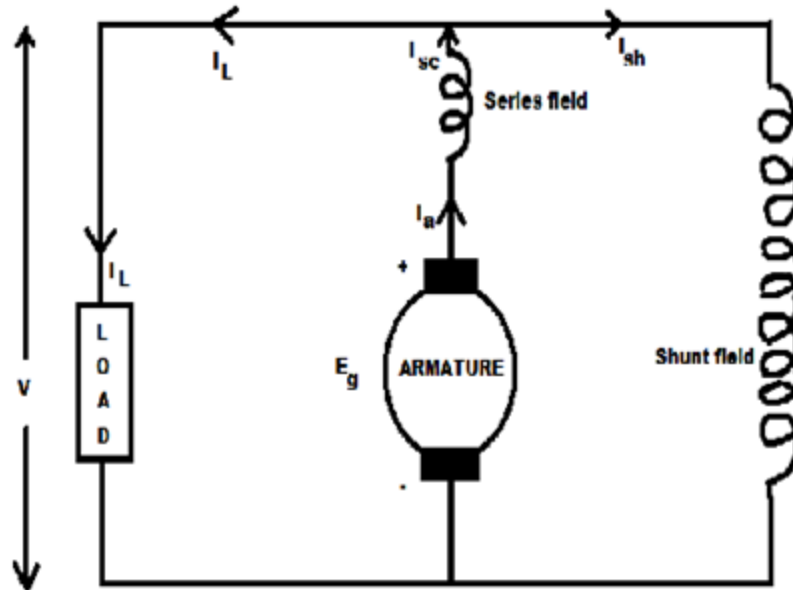
It can be observed from the characteristics of series wound DC generator, that with the increase in load (load is increased when load current increases) the terminal voltage of the machine increases. But after reaching its maximum value it starts to decrease due to excessive demagnetizing effect of armature reaction. This phenomenon is shown in the figure by the dotted line. Dotted portion of the characteristic gives approximately constant current irrespective of the external load resistance. This is because if load is increased, the field current is increased as field is series connected with load. Similarly if load is increased, armature current is increased as the armature is also series connected with load. But due to saturation, there will be no further significance raise of magnetic field strength hence any further increase in induced voltage. But due to increased armature current, the affect of armature reaction increases significantly which causes significant fall in load voltage. If load voltage falls, the load current is also decreased proportionally since current is

proportional to voltage as per Ohm's law. So, increasing load, tends to increase the load current, but decreasing load voltage, tends to decrease load current. Due these two simultaneous effects, there will be no significant change in load current in dotted portion of external characteristics of series wound DC generator. That is why **series DC generator is called constant current DC generator**.

### CHARACTERISTICS OF DC COMPOUND GENERATOR:

In compound wound DC generators both the field windings are combined (series and shunt). This type of generators can be used as either long shunt or short shunt compound wound generators as shown in the diagram below. In both the cases the external characteristic of the generator will be nearly same. The compound wound generators may be cumulatively compounded or differentially compounded (discussed earlier in the type of generators). Differentially compound wound generators are very rarely used. So, here we mainly concentrate upon the characteristic of cumulatively compound wound generators.





Long Shunt Compound Wound Generator

We all know that, in series wound DC generators, the output voltage is directly proportional with load current and in shunt wound DC generators, output voltage is inversely proportional with load current.

The electric current in the shunt field winding produces a flux which causes a fall in terminal voltage due to armature reaction and ohmic drop in the circuit. But the current in the series field also produces a flux which opposes the shunt field flux and compensate the drop in the terminal voltage and try to operate the machine at constant voltage.

**The combination of a series generator and a shunt generator gives the characteristic of a cumulative compound wound generator.**

At no load condition there is no current in the series field because the load terminals are open circuited. But the shunt field current helps to produce field flux and excite the machine. When the dc generator supplies load, the load current increases and current flows through the series field. Therefore, series field also provides some field flux and emf is also increased. The voltage drop in the shunt machine is therefore compensated by the voltage rise in the series machine.

Characteristics of DC Compound Generator

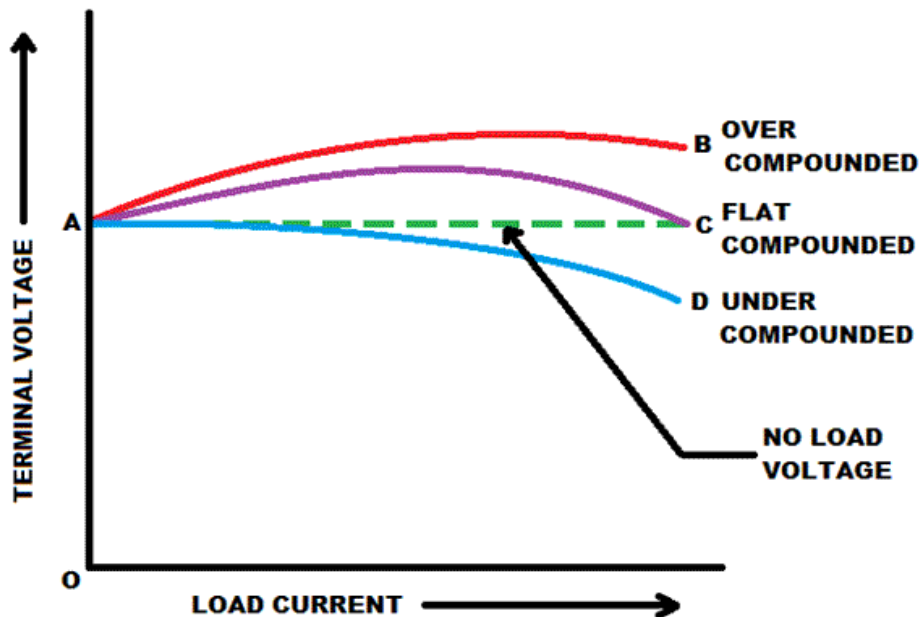
For small distance operation the flat compounded generators are generally used because the length of the feeder is negligible. But to maintain constant voltage over a long period, the over compounded generators are used. It works as a generator and a booster (boost the terminal voltage).

External characteristic of DC compound wound generator is drawn between the terminal voltage and the load current. By adjusting the no. of amp-turns in the series field winding we can get following external characteristics:

1. If the series turns are so adjusted that with the increase in load current the terminal voltage also increases, then the generator is called over compounded. The curve AB in the figure showing this characteristic. When the load current increases then the flux provides by the series field also increases. It gives the additional generated voltage. If the increase in generated voltage is greater than the voltage drops due to armature reaction and ohmic drop then, terminal voltage of the generator is increased.

2. If the series turns are so adjusted that with the increase in load current the terminal voltage remains constant, then the generator is called flat compounded. The curve AC in the figure showing this characteristic. When the load current increases then the flux provides by the series field also increases and gives the additional generated voltage. If the increase in generated voltage is equal to the voltage drops due to armature reaction and ohmic drop then, rated terminal voltage of the generator remains same as no load voltage.

3. If the series field winding has lesser no. of turns then the rated terminal voltage becomes less than the no load voltage, then the generator is called under compounded. Because, the increase in generated voltage is lesser than the voltage drops due to armature reaction and ohmic drop. Curve AD in the figure is showing this characteristic.



## **Starting Methods Of A DC Motor**

Basic operational voltage equation of a DC motor is given as

$$E = E_b + I_a R_a \quad \text{and hence} \quad I_a = (E - E_b) / R_a$$

Now, when the motor is at rest, obviously, there is no back emf  $E_b$ , hence armature current will be high at starting.

This excessive current will-

1. Blow out the fuses and may damage the armature winding and/or commutator brush arrangement.
2. Produce very high starting torque (as torque is directly proportional to armature current), and this high starting torque will produce huge centrifugal force which may throw off the armature windings.

Thus to avoid above two drawbacks, starters are used for **starting of DC machine**.

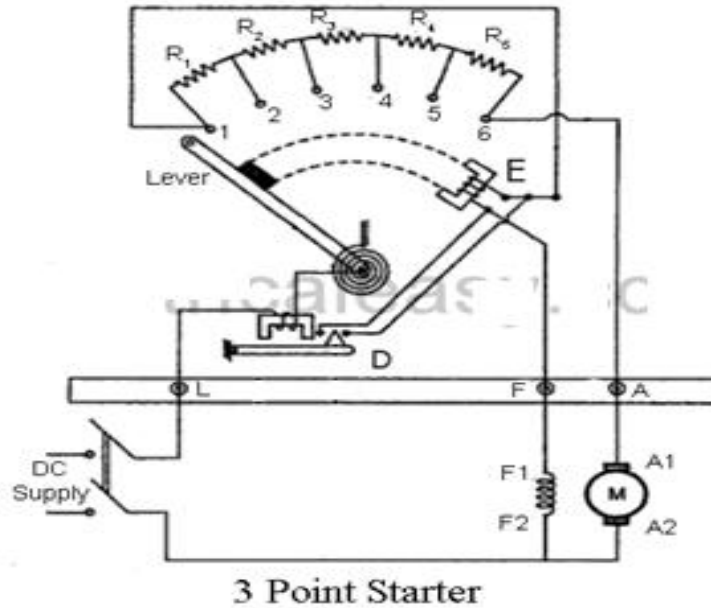
### **Starting Methods of a DC Motor**

Thus, to avoid the above dangers while **starting a DC motor**, it is necessary to limit the starting current. For that purpose, starters are used to start a DC motor. There are various starters like, 3 point starter, 4 point starter, No load release coil starter, thyristor starter etc. The main concept behind every **DC motor starter** is, adding external resistance to the armature winding at starting.



### 3 POINT STARTER:

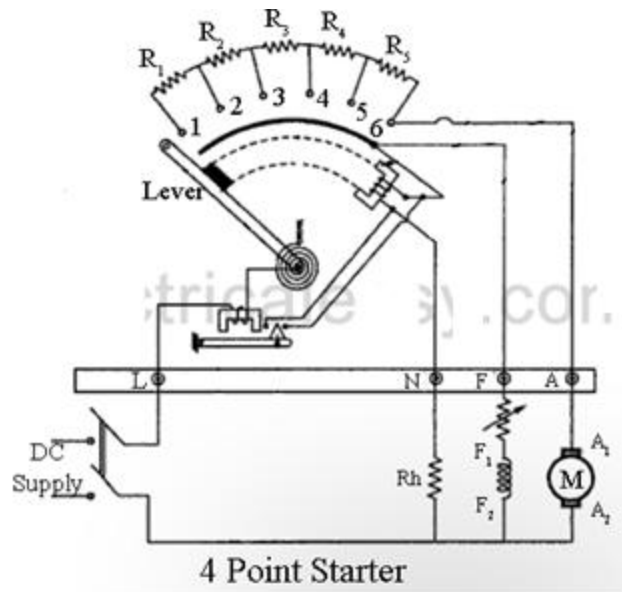
The internal wiring of a **3 point starter** is as shown in the figure.



When motor is to be started, the lever is turned gradually to the right. When lever touches point 1, the field winding gets directly connected across the supply, and the armature winding gets connected with resistances R1 to R5 in series. Hence at starting full resistance is added in series with armature. Then as the lever is moved further, the resistance is gradually is cut out from the armature circuit. Now, as the lever reaches to position 6, all the resistance is cut out from the armature circuit and armature gets directly connected across the supply. The electromagnet E (no voltage coil) holds the lever at this position. This electromagnet releases the lever when there is no (or low) supply voltage.

When the motor is overloaded beyond a predefined value, overcurrent release electromagnet D gets activated, which short circuits electromagnet E, and hence releases the lever and motor is turned off.

## 4 POINT STARTER:

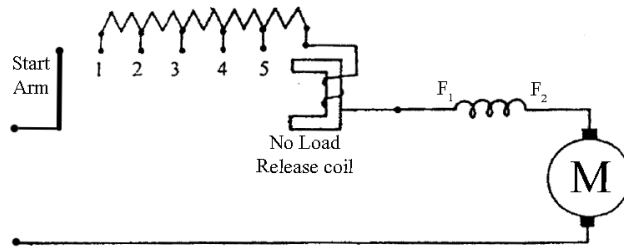


The main **difference between a 3 point starter and a 4 point starter** is that the no voltage coil is not connected in series with field coil. The field gets directly connected to the supply, as the lever moves touching the brass arc. The no voltage coil (or Hold on coil) is connected with a current limiting resistance  $R_h$ . This arrangement ensures that any change of current in the shunt field does not affect the current through hold on coil at all. This means that electromagnet pull of the hold-on coil will always be sufficient so that the spring does not unnecessarily restore the lever to the off position.

This starter is used where field current is to be adjusted by means of a field rheostat.

## DC series motor starter:

**Construction of DC series motor starters** is very basic as shown in the figure. A start arm is simply moved towards right to start the motor. Thus at first maximum resistance is connected in series with the armature and then gradually decreased as the start arm moves towards right. The no load release coil holds the start arm to the run position and leaves it at no load.



## SPEED CONTROL METHODS OF DC MOTOR:

We know, back emf of a DC motor  $E_b$  is the induced emf due to rotation of the armature in magnetic field. Thus value of the  $E_b$  can be given by the EMF equation of a DC generator.

$$E_b = \frac{P\Phi NZ}{60A}$$

(where,  $P$ = no. of poles,  $\Phi$ =flux/pole,  $N$ =speed in rpm,  $Z$ =no. of armature conductors,  $A$ =parallel paths)

$E_b$  can also be given as,

$$E_b = V - I_a R_a$$

thus from above equations

$$N = \frac{E_b \cdot 60A}{P\Phi Z}$$

but, for a DC motor  $A$ ,  $P$  and  $Z$  are constant

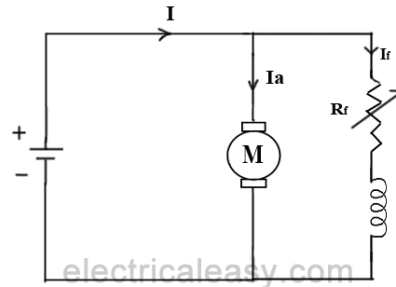
$$N \propto K \frac{E_b}{\Phi} \quad (\text{where, } K=\text{constant})$$

thus, it shows speed is directly proportional to back emf and inversely proportional to the flux per pole.

## SPEED CONTROL METHODS OF DC MOTOR

### Speed Control of Shunt Motor

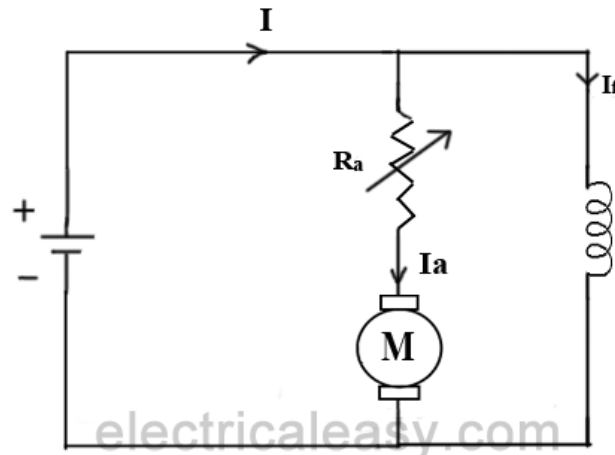
#### 1. Flux Control Method



It is seen that **speed of the motor** is inversely proportional to flux. Thus by decreasing flux speed can be increased and vice versa.

To control the flux, a rheostat is added in series with the field winding, as shown in the circuit diagram. Adding more resistance in series with field winding will increase the speed, as it will decrease the flux. Field current is relatively small and hence  $I^2R$  loss is small, hence this method is quiet efficient. Though speed can be increased by reducing flux with this method, it puts a limit to maximum speed as weakening of flux beyond the limit will adversely affect the commutation.

#### 2. Armature Control Method



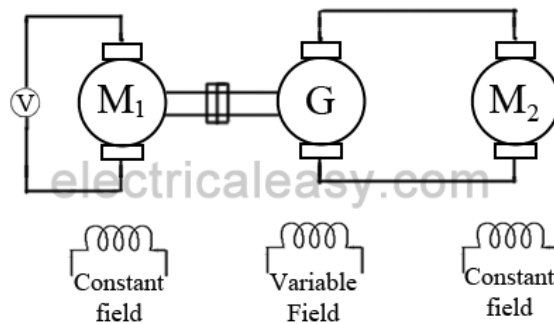
**Speed of the motor** is directly proportional to the back emf  $E_b$  and  $E_b = V - I_a R_a$ .

That is when supply voltage  $V$  and armature resistance  $R_a$  are kept constant, speed is directly proportional to armature current  $I_a$ . Thus if we add resistance in series with armature,  $I_a$  decreases and hence speed decreases. Greater the resistance in series with armature, greater the decrease in speed.

### 3. Voltage Control Method

A) Multiple voltage control: In this method the, shunt filed is connected to a fixed exciting voltage, and armature is supplied with different voltages. Voltage across armature is changed with the help of a suitable switchgear. The speed is approximately proportional to the voltage across the armature.

#### b) Ward-Leonard System:



This system is used where very sensitive **speed control of motor** is required (e.g electric excavators, elevators etc.) The arrangement of this system is as required in the figure beside.

M<sub>2</sub> is the motor whose speed control is required.

M<sub>1</sub> may be any AC motor or DC motor with constant speed.

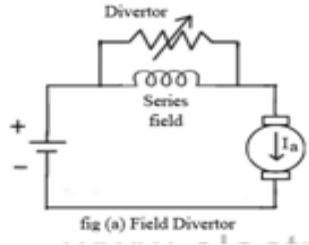
G is the generator directly coupled to M<sub>1</sub>.

In this method the output from the generator G is fed to the armature of the motor M<sub>2</sub> whose speed is to be controlled. The output voltage of the generator G can be varied from zero to its maximum value, and hence the armature voltage of the motor M<sub>2</sub> is varied very smoothly. Hence very smooth **speed control of motor** can be obtained by this method.

## Speed Control Of Series Motor

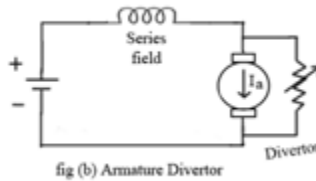
### 1. Flux Control Method

#### a) Field divertor :



A veritable resistance is connected parallel to the series field as shown in fig. This variable resistor is called as divertor, as desired amount of current can be diverted through this resistor and hence current through field coil can be decreased. Hence flux can be decreased to desired amount and speed can be increased.

#### b) Armature divertor:



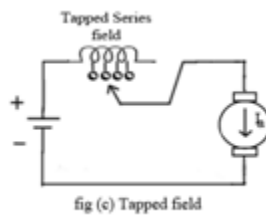
Divertor is connected across the armature as in fig .

For a given constant load torque, if armature current is reduced then flux must increase. As,

$$T_a \propto \Phi I_a$$

This will result in increase in current taken from the supply and hence flux  $\Phi$  will increase and subsequently **speed of the motor** will decrease.

#### c) Tapped field control:



As shown in fig field coil is tapped dividing number of turns. Thus we can select different value of  $\Phi$  by selecting different number of turns.

d) Paralleling field coils:

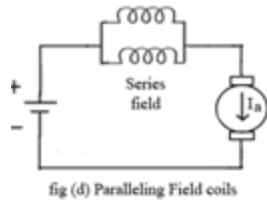


fig (d) Paralleling Field coils

In this method, several speeds can be obtained by regrouping coils as shown in fig .

## 2. Variable Resistance In Series With Armature

By introducing resistance in series with armature, voltage across the armature can be reduced. And hence, speed reduces in proportion with it.

## 3. Series-Parallel Control

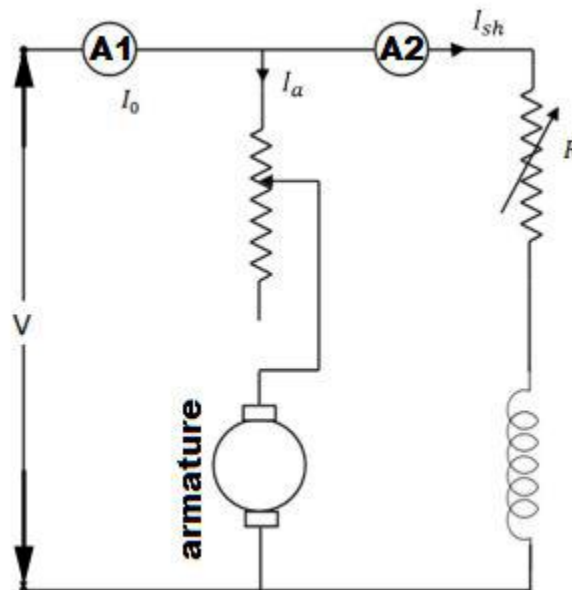
This system is widely used in electric traction, where two or more mechanically coupled series motors are employed. For low speeds, motors are joined in series, and for higher speeds motors are joined in parallel.

When in series, the motors have the same current passing through them, although voltage across each motor is divided. When in parallel, voltage across each motor is same although current gets divided.

## SWINBURNE'S TEST

This method is an indirect method of testing a dc machine. It is named after Sir James Swinburne. Swinburne's test is the most commonly used and simplest method of testing of shunt and compound wound dc machines which have constant flux. In this test the efficiency of the machine at any load is pre-determined. We can run the machine as a motor or as a generator. In this method of testing no load losses are measured separately and eventually we can determine the efficiency.

The circuit connection for Swinburne's test is shown in figure below. The speed of the machine is adjusted to the rated speed with the help of the shunt regulator R as shown in figure.



Connection Diagram of Swinburne's Test

### Calculation of Efficiency

Let,  $I_0$  is the no load current ( it can be measured by ammeter  $A_1$  )

$I_{sh}$  is the shunt field current ( it can be measured by ammeter  $A_2$  )

Then, no load armature current =  $(I_0 - I_{sh})$

Also let,  $V$  is the supply voltage. Therefore, No load power input =  $VI_0$  watts.



In Swinburne's test no load power input is only required to supply the losses. The losses occur in the machine mainly are:

Iron losses in the core

Friction and windings losses

Armature copper loss.

Since the no load mechanical output of the machine is zero in Swinburne's test, the no load input power is only used to supply the losses.

The value of armature copper loss =  $(I_0 - I_{sh})^2 R_a$

Here,  $R_a$  is the armature resistance.

Now, to get the constant losses we have to subtract the armature copper loss from the no load power input.

Then, Constant losses  $W_C = VI_0 - (I_0 - I_{sh})^2 R_a$

After calculating the no load constant losses now we can determine the efficiency at any load.

Let,  $I$  is the load current at which we have to calculate the efficiency of the machine.

Then, armature current ( $I_a$ ) will be  $(I - I_{sh})$ , when the machine is motoring.

And  $I_a = (I + I_{sh})$ , when the machine is generating.

Calculation of Efficiency When the Machine is Motoring on Load

Power input =  $VI$

Armature copper loss,  $P_{CU} = I^2 R_a = (I - I_{sh})^2 R_a$

Constant losses,  $W_C = VI_0 - (I_0 - I_{sh})^2 R_a$

Total losses =  $P_{CU} + W_C$

∴ Efficiency of the motor:

Calculation of Efficiency When the **Machine is Generating on Load**

Power input =  $VI$

Armature copper loss,  $P_{CU} = I^2 R_a = (I + I_{sh})^2 R_a$

Constant losses,  $W_C = VI_0 - (I_0 - I_{sh})^2 R_a$

Total losses =  $P_{CU} + W_C$

∴ Efficiency of the generator:

### **Advantages of Swinburne's Test**

The main advantages of this test are :

1. This test is very convenient and economical as it is required very less power from supply to perform the test.
2. Since constant losses are known, efficiency of Swinburne's test can be pre-determined at any load.

### **Disadvantages of Swinburne's Test**

The main disadvantages of this test are :

1. Iron loss is neglected though there is change in iron loss from no load to full load due to armature reaction.
2. We cannot be sure about the satisfactory commutation on loaded condition because the test is done on no-load.
3. We can't measure the temperature rise when the machine is loaded. Power losses can vary with the temperature.
4. In dc series motors, the Swinburne's test cannot be done to find its efficiency as it is a no load test.