UNIT – II

TYPES OF DC GENERATORS:

Characteristics of different types of generators – critical field resistance and critical speed – applications – numerical problems - commutation - methods of improving commutation - Compensating windings.

TYPES OF D.C. GENERATORS

The magnetic field in a d.c. generator is normally produced by electromagnets rather than permanent magnets. Generators are generally classified according to their **methods of field excitation**. On this basis, d.c. generators are divided into the following two classes:

(i) Separately excited d.c. generators

(ii) Self-excited d.c. generators

The behaviour of a d.c. generator on load depends upon the method of field excitation adopted.

SEPARATELY EXCITED D.C. GENERATORS

A d.c. generator whose field magnet winding is supplied from an independent external d.c. source (e.g., a battery etc.) is called a separately excited generator. Fig. (2.1) shows the connections of a separately excited generator. The voltage output depends upon the speed of rotation of armature and the field current
($E_g = P \varphi Z N/60 A$).

The greater the speed and field current, greater is the generated e.m.f. It may be noted that separately excited d.c. generators are rarely used in practice. The d.c. generators are normally of self-excited type.

Armature current, $\mathbf{I_a = I_L}$

Terminal voltage, **V=** $E_g - I_a R_a$

Electric power developed = $E_g I_a$

Power delivered to load =

$$E_g I_a - I_a^2 R_a = I_a (E_g - I_a R_a) = V I_a$$

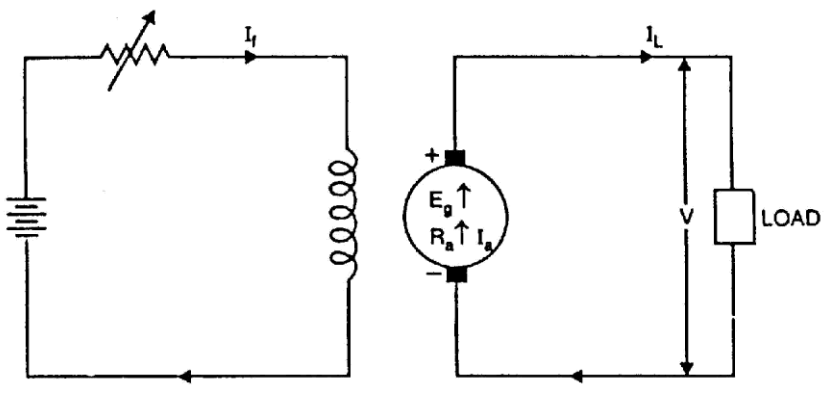


Fig 2.1

SELF-EXCITED D.C. GENERATORS

A d.c. generator whose field magnet winding is supplied current from the output of the generator itself is called a self-excited generator.

There are three types of self-excited generators depending upon the manner in which the field winding is connected to the armature, namely;

(i) Series generator; (ii) Shunt generator; (iii) Compound generator

(i) Series generator

In a series wound generator, the field winding is connected in series with armature winding so that whole armature current flows through the field winding as well as the load.

Fig. (2.2) shows the connections of a series wound generator. Since the field winding carries the whole of load current, it has a **few turns of thick wire having low resistance.** Series generators are rarely used except for special purposes e.g., as **boosters.**

Armature current, $I_a = I_{se} = I_L = I$ (say)

Terminal voltage $V = E_g - I(R_a + R_{se})$

Electric power developed in armature = $E_g I_a$

Power delivered to load $= E_g I_a - I_a^2(R_a + R_{se}) = I_a[E_g - I_a(R_a + R_{se})] = VI_a or VI_L$

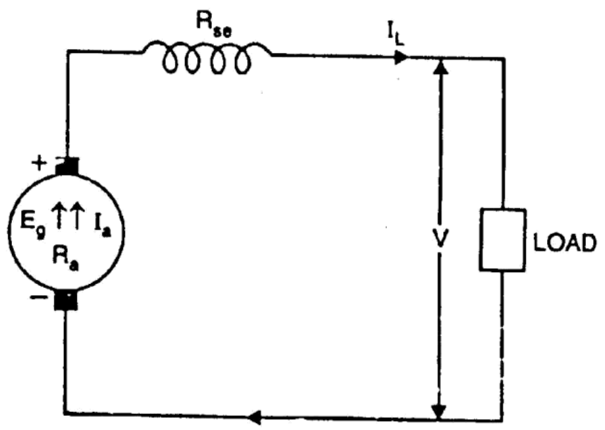


Fig 2.2

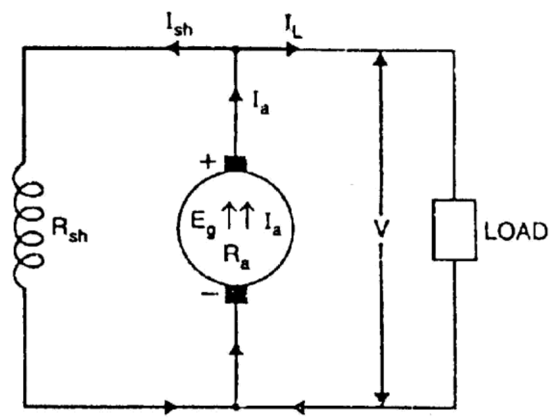


Fig 2.3

(ii) Shunt generator

In a shunt generator, **the field winding is connected in parallel with the armature winding** so that terminal voltage of the generator is applied across it.

The shunt field winding has many turns of fine wire having high resistance. Therefore, only a part of armature current flows through shunt field winding and the rest flows through the load.

Fig. (2.3) shows the connections of a shunt-wound generator.

Shunt field current, $I_{sh} = V/R_{sh}$

Armature current, $I_a = I_L + I_{sh}$

Terminal voltage, V = $E_g - I_a R_a$

Power developed in armature = $E_g I_a$

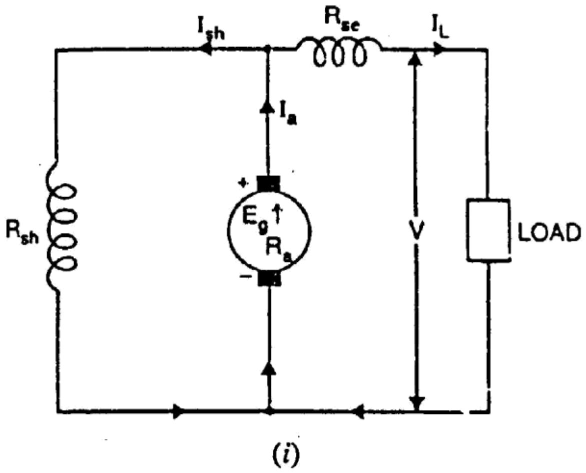
Power delivered to load = VI_L

(iii) Compound generator

In a compound-wound generator, there are two sets of field windings on each pole—one is in series and the other in parallel with the armature. A compound wound generator may be:

(a) **Short Shunt** in which only shunt field winding is in parallel with the armature winding [See Fig. 2.4 (i)].

(b) **Long Shunt** in which shunt field winding is in parallel with both series field and armature winding [See Fig. 2.5 (ii)].



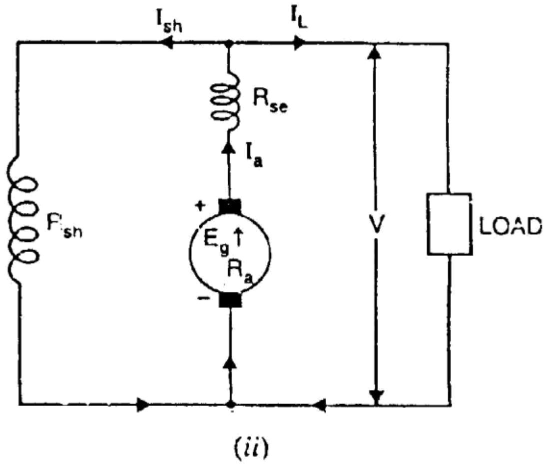


Fig 2.4 Fig 2.5

Short shunt compound generator

Series field current. $I_{se} = I_L$

Shunt field current, $I_{sh} = \frac{V + I_{se} R_{se}}{R_{ssh}}$

Terminal voltage, $V = E_g - I_a R_a - I_{se} R_{se}$

Power developed
in armature= $E_g I_a$

Power delivered to load= VI_L

Long shunt compound generator

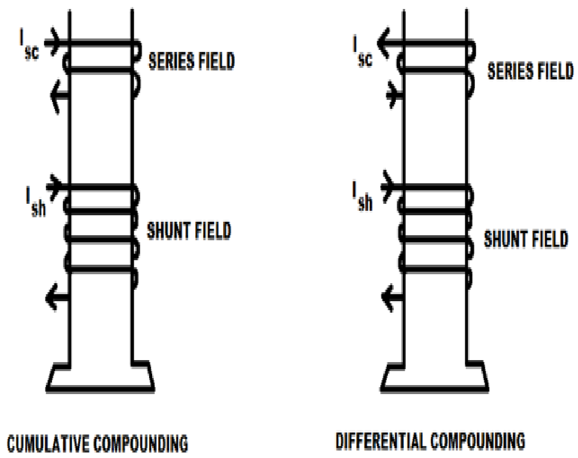
Series field current, $I_{se} = I_a = I_L + I_{sh}$

Shunt field current, $I_{sh} = V / R_{sh}$

Terminal voltage, $V = E_g - I_a (R_a + R_{se})$

Power developed in armature= $E_g I_a$

Power delivered to load= VI_L



In a compound wound generator, the shunt field is stronger than the series field. **When the series field assists the shunt field, generator is said to be commutatively compound wound.** On the other hand if **series field opposes the shunt field, the generator is said to be differentially compound wound.**

ARMATURE RESISTANCE (R_A)

The resistance offered by the armature circuit is known as armature resistance (R_a) . It includes:

(i) resistance of armature winding
(ii) resistance of brushes

The armature resistance depends upon the construction of machine. Except for small machines, R_a value is generally less than 1 Ω.

D.C. GENERATOR CHARACTERISTICS

INTRODUCTION

The speed of a d.c. machine operated as a generator is fixed by the prime mover. For general-purpose operation, the prime mover is equipped with a speed governor so that the **speed of the generator is practically constant.** Under such condition, the generator performance deals primarily with the relation between **excitation, terminal voltage and load.** These relations can be best exhibited graphically by means of curves known as generator characteristics. These characteristics show at a glance the behaviour of the generator under different load conditions.

The following are the three most important characteristics of a d.c. generator:

1.Open Circuit Characteristic (O.C.C.)

This curve shows the **relation between the generated e.m.f. at no-load (E_0) and the field current (I_f) at constant speed.** It is also known as magnetic characteristic or no-load saturation curve.

Its shape is practically the same for all generators whether separately or self-excited. The data for O.C.C. curve are obtained experimentally by operating the **generator at no load and constant speed and recording the change in generated voltage as the field current is varied.**

2.Internal or Total characteristic (E/I_a)

This curve shows the **relation between the generated e.m.f. on load (E) and the armature current (I_a). The e.m.f. E is less than E_0 due to the demagnetizing effect of armature reaction.** Therefore, this curve will lie below the open circuit characteristic (O.C.C.).

The internal characteristic is of interest chiefly to the designer. It cannot be obtained directly by experiment. It is because a voltmeter cannot read the e.m.f. generated due to the voltage drop in armature resistance. **The internal characteristic can be obtained from external characteristic if winding resistances are known because armature reaction effect is included in both characteristics.**

3.External characteristic (V/I_L)

This curve shows the **relation between the terminal voltage (V) and load current (I_L). The terminal voltage V will be less than E due to voltage drop in the armature circuit**.

Therefore, this curve will lie below the internal characteristic. This characteristic is very important in determining the suitability of a generator for a given purpose. It can be obtained by making simultaneous measurements of terminal voltage and load current (with voltmeter and ammeter) of a loaded generator.

OPEN CIRCUIT CHARACTERISTIC OF A D.C. GENERATOR

The O.C.C. for a d.c. generator is determined as follows. The field winding of the d.c. generator (series or shunt) is disconnected from the machine and is separately excited from an external d.c. source as shown in Fig.2.6 (ii). The generator is run at fixed speed (i.e., normal speed). The field current (I_f) is increased from zero in steps and the corresponding values of generated e.m.f. (E_0) read off on a voltmeter connected across the armature terminals. On plotting the relation between E_0 and I_f, we get the open circuit characteristic as shown in Fig. 2.6 (i).

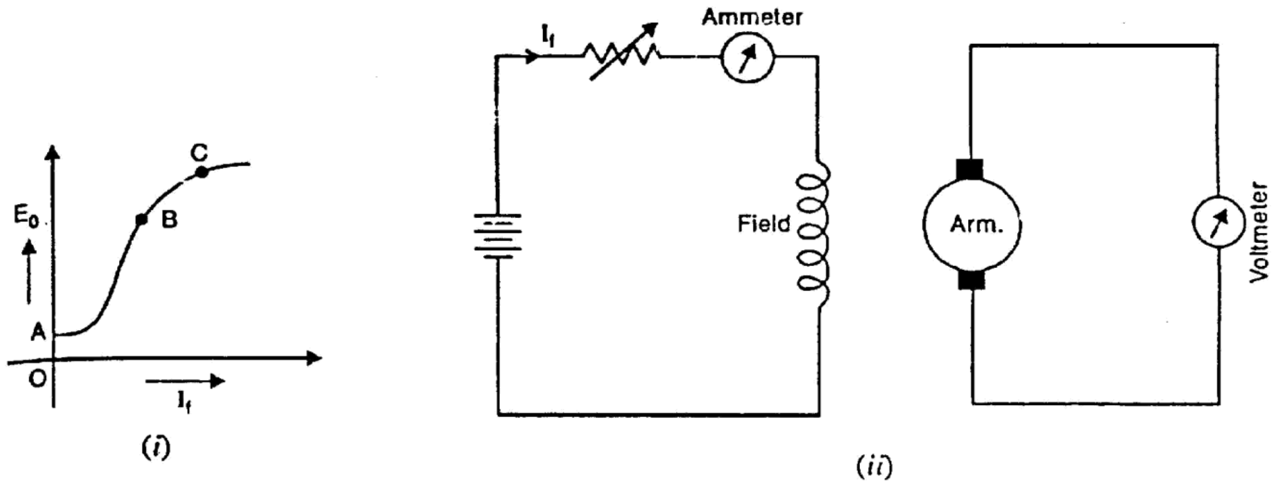


Fig 2.6

The following points may be noted from O.C.C.:
(i) When the field current is zero, there is some generated e.m.f. OA. This is due to the residual magnetism in the field poles.
(ii) Over a fairly wide range of field current (upto point B in the curve), the curve is linear. It is because in this range, reluctance of iron is negligible as compared with that of air gap. The air gap reluctance is constant and hence linear relationship.
(iii) After point B on the curve, the reluctance of iron also comes into picture. It is because at higher flux densities, μ_r for iron decreases and reluctance of iron is no longer negligible. Consequently, the curve deviates from linear relationship
(iv) After point C on the curve, the magnetic saturation of poles begins and E_0 tends to level off.
The reader may note that the O.C.C. of even self-excited generator is obtained by running it as a separately excited generator.

CHARACTERISTICS OF A SEPARATELY EXCITED D.C.GENERATOR

The obvious disadvantage of a separately excited d.c. generator is that we require an external d.c. source for excitation. But since the output voltage may be controlled more easily and over a wide range (from zero to a maximum), this type of excitation finds many applications.

(i) Open circuit characteristic.

The O.C.C. of a separately excited generator is determined in a manner described in Previous Section. Fig. (2.7) shows the variation of generated e.m f. on no load with field current for various fixed speeds. Note that if the value of constant speed is increased, the steepness of the curve also increases. When the field current is zero, the residual magnetism in the poles will give rise to the small initial e.m.f. as shown.

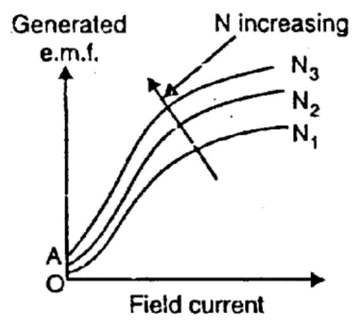


Fig 2.7

(ii) Internal and External Characteristics

The external characteristic of a separately excited generator is the curve between the terminal voltage (V) and the load current I_L (which is the same as armature current in this case). In order to determine the external characteristic, the circuit set up is as shown in Fig. (2.8) (i). As the load current increases, the terminal voltage falls due to two reasons: (a)The armature reaction weakens the main flux so that actual e.m.f. generated E on load is less than that generated (E_0) on no load.

(b) There is voltage drop across armature resistance (= $I_L R_a$ = $I_a R_a$).

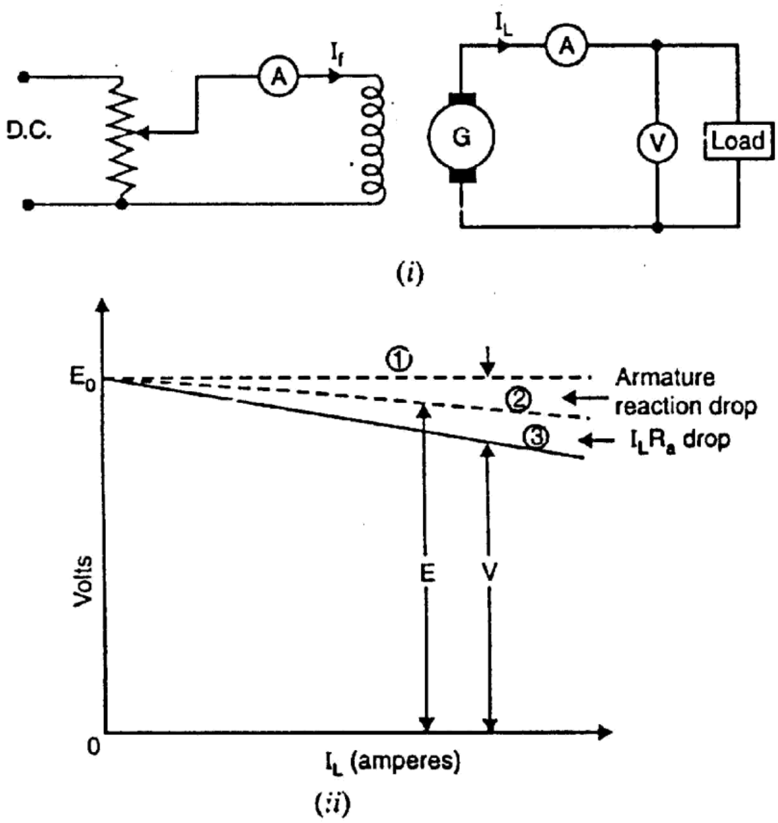


Fig 2.8

Due to these reasons, the external characteristic is a drooping curve [curve 3 in Fig. 2.8 (ii)]. Note that in the absence of armature reaction and armature drop, the generated e.m.f. would have been E_0 (curve 1).

The internal characteristic can be determined from external characteristic by adding $I_L R_a$ drop to the external characteristic. It is because armature reaction drop is included in the external characteristic. Curve 2 is the internal characteristic of the generator and should obviously lie above the external characteristic.

CHARACTERISTICS OF SERIES GENERATOR

Fig. 2.9 (i) shows the connections of a series wound generator. Since there is only one current (that which flows through the whole machine), the load current is the same as the exciting current.

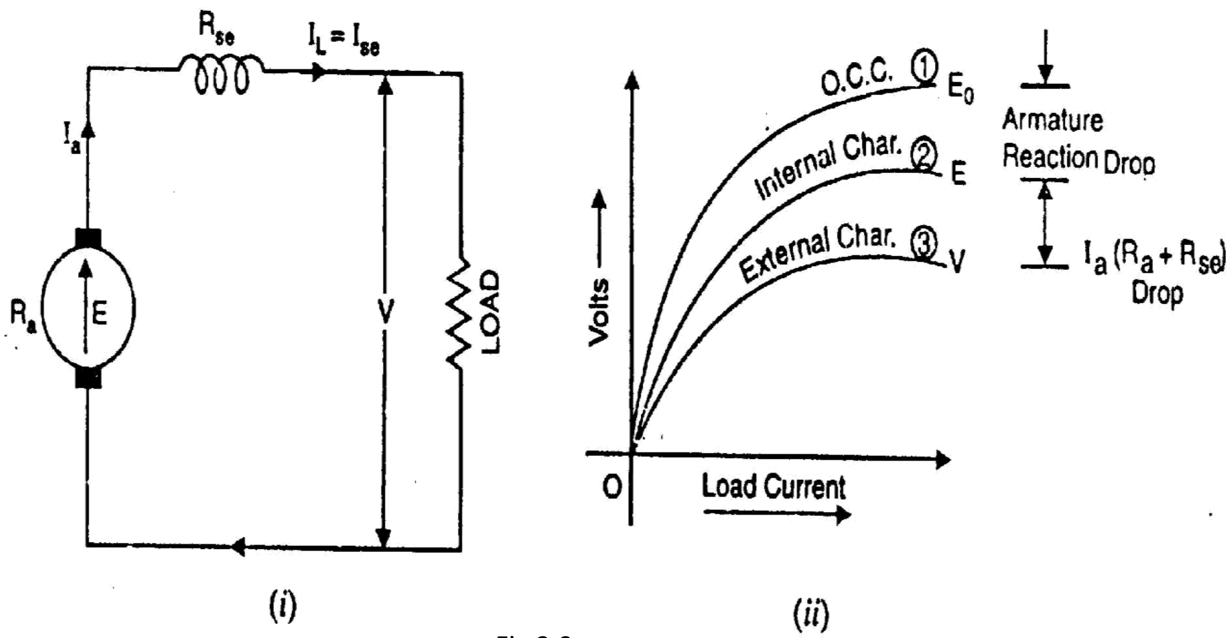


Fig 2.9

(i) O.C.C.

Curve 1 shows the open circuit characteristic (O.C.C.) of a series generator. It can be obtained experimentally by disconnecting the field winding from the machine and exciting it from a separate d.c. source as discussed in earlier section.

(ii) Internal characteristic

Curve 2 shows the total or internal characteristic of a series generator. It gives the relation between the generated e.m.f. E. on load and armature current. Due to armature reaction, the flux in the machine will be less than the flux at no load. Hence, e.m.f. E generated under load conditions will be less than the e.m.f. E_0 generated under no load conditions. Consequently, internal characteristic curve lies below the O.C.C. curve; the difference between them representing the effect of armature reaction [See Fig. 2.9(ii)].

(iii) External characteristic

Curve 3 shows the external characteristic of a series generator. It gives the relation between terminal voltage V and load current I_L:· $V = E - I_a(R_a + R_{se})$

Therefore, external characteristic curve will lie below internal characteristic curve by an amount equal to ohmic drop [i.e., $I_a(R_a + R_{se})$] in the machine as shown in Fig. The internal and external characteristics of a d.c. series generator can be plotted from one another .

CHARACTERISTICS OF A SHUNT GENERATOR

Fig 2.11(i) shows the connections of a shunt wound generator. The armature current I_a splits up into two parts; a small fraction I_{sh} flowing through shunt field winding while the major part I_L goes to the external load.

(i) O.C.C.

The O.C.C. of a shunt generator is similar in shape to that of a series generator as shown in Fig. 2.11 (ii). The line OA represents the shunt field circuit resistance. When the generator is run at normal speed, it will build up a voltage OM. At no-load, the terminal voltage of the generator will be constant (= OM) represented by the horizontal dotted line MC.

ii) Internal characteristic

When the generator is loaded, flux per pole is reduced due to armature reaction. Therefore, e.m.f. E generated on load is less than the e.m.f. generated at no load. As a result, the internal characteristic (E/I_a) drops down slightly as shown in Fig. 2.11 (ii).

(iii) External characteristic

Curve 2 shows the external characteristic of a shunt generator. It gives the relation between terminal voltage V and load current I_L.

$$V = E - I_a R_a$$

$$= E - (I_L + I_{sh})R_a$$

Therefore, external characteristic curve will lie below the internal characteristic curve by an amount equal to drop in the armature circuit [i.e., $(I_L + I_{sh})R_a$] as shown in Fig. 2.11(ii).

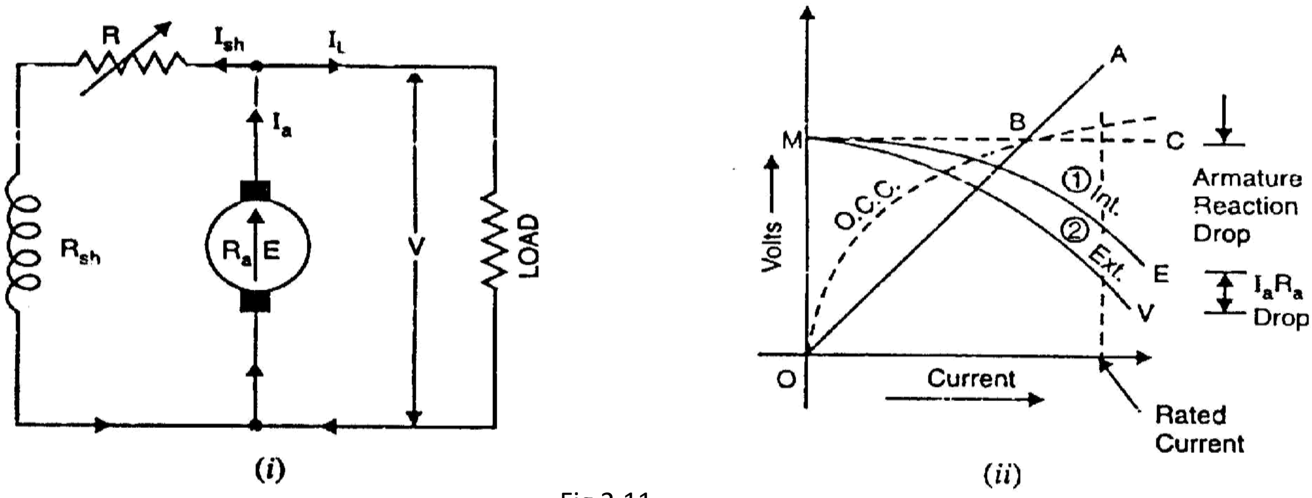


Fig 2.11

Note. It may be seen from the external characteristic that change in terminal voltage from no-load to full load is small. The terminal voltage can always be maintained constant by adjusting the field rheostat R automatically.

COMPOUND GENERATOR CHARACTERISTICS

In a compound generator, both series and shunt excitation are combined as shown in Fig. (2.12). The shunt winding can be connected either across the armature only (short-shunt connection S) or across armature plus series field (long-shunt connection G). The compound generator can be cumulatively compounded or differentially compounded generator. The latter is rarely used in practice. Therefore, we shall discuss the characteristics of cumulatively- compounded generator. It may be noted that external characteristics of long and short shunt compound generators are almost identical.

External characteristic

Fig. (2.13) shows the external characteristics of a cumulatively compounded generator. The series excitation aids the shunt excitation. The degree of compounding

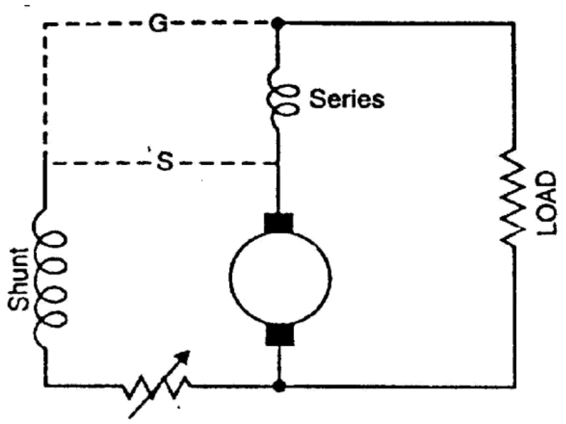


Fig 2.12

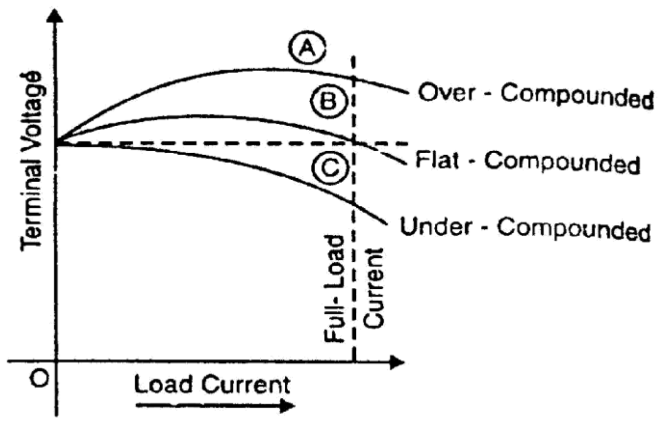


Fig 2.13

depends upon the increase in series excitation with the increase in load current.

(i) If series winding turns are so adjusted that with the increase in load current the terminal voltage increases, it is called over-compounded generator. In such a case, as the load current increases, the series field m.m.f. increases and tends to increase the flux and hence the generated voltage. The increase in generated voltage is greater than the I_aR_a drop so that instead of decreasing, the terminal voltage increases as shown by curve A in Fig. (2.13).

(ii) If series winding turns are so adjusted that with the increase in load current, the terminal voltage substantially remains constant, it is called flat-compounded generator. The series winding of such a machine has lesser number of turns than the one in over-compounded machine and, therefore, does not increase the flux as much for a given load current. Consequently, the full-load voltage is nearly equal to the no-load voltage as indicated by curve B in Fig (2.13).

(iii) If series field winding has lesser number of turns than for a flat- compounded machine, the terminal voltage falls with increase in load current as indicated by curve C m Fig. (2.13). Such a machine is called under-compounded generator.

COMMUTATION:

The e.m.f. induced in each coil of armature is alternating in nature. If load is connected, the current flowing will also be alternating. But the flow of current in a d.c. generator must be undirectional. This can be achieved by the use of commutator. When the armature conductors are under the influence of one pole they carry current in one direction whereas the current is reversed when the conductors are under the influence of other pole. **This reversal of current takes place along the magnetic neutral axis.**

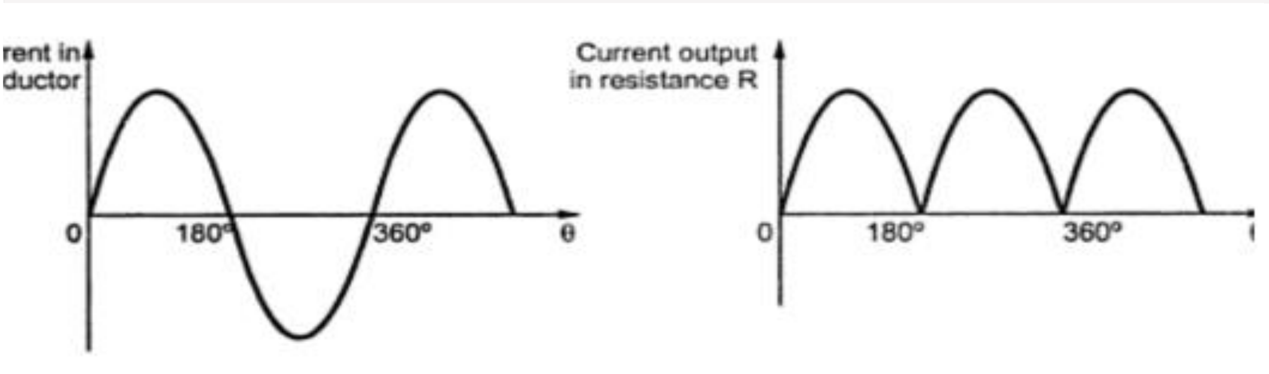


fig. 2.14(current in conductor)

Note : **The reversal of current is likely to take place in short interval when a coil is short circuited by a brush so that transfer of current from one direction to other is carried out without any sparking. This process is called commutation.**

Thus a process by which current in the short circuited coil is reversed while it crosses the MNA is called commutation. The time during which the coil remains short circuited is known as commutation period. This period is generally of the order of **0.0005 to 0.002 sec.**

The commutation is said to **be ideal when current changes from +I to zero and zero to -I within the commutation period**. The sparking is produced between the commutator and brush if current is not reversed by that time. This **will lead to damage of commutator as well as brush.** Hence for satisfactory operation of d.c. machine proper commutation is required i.e. transfer of current must be without sparking and losses and heating of brushes and the commutator.

Now we will see the process of commutation in detail with the help of the figures. Let us assume that the armature winding is ring type and the **width of brush is equal to the width of one commutator segment and one mica insulation**. In this case only one coil is short circuited at a time at each of these brushes whereas in actual practice width of brush is more than that of commutator so that more than two coils are simultaneously short circuited at each brush.

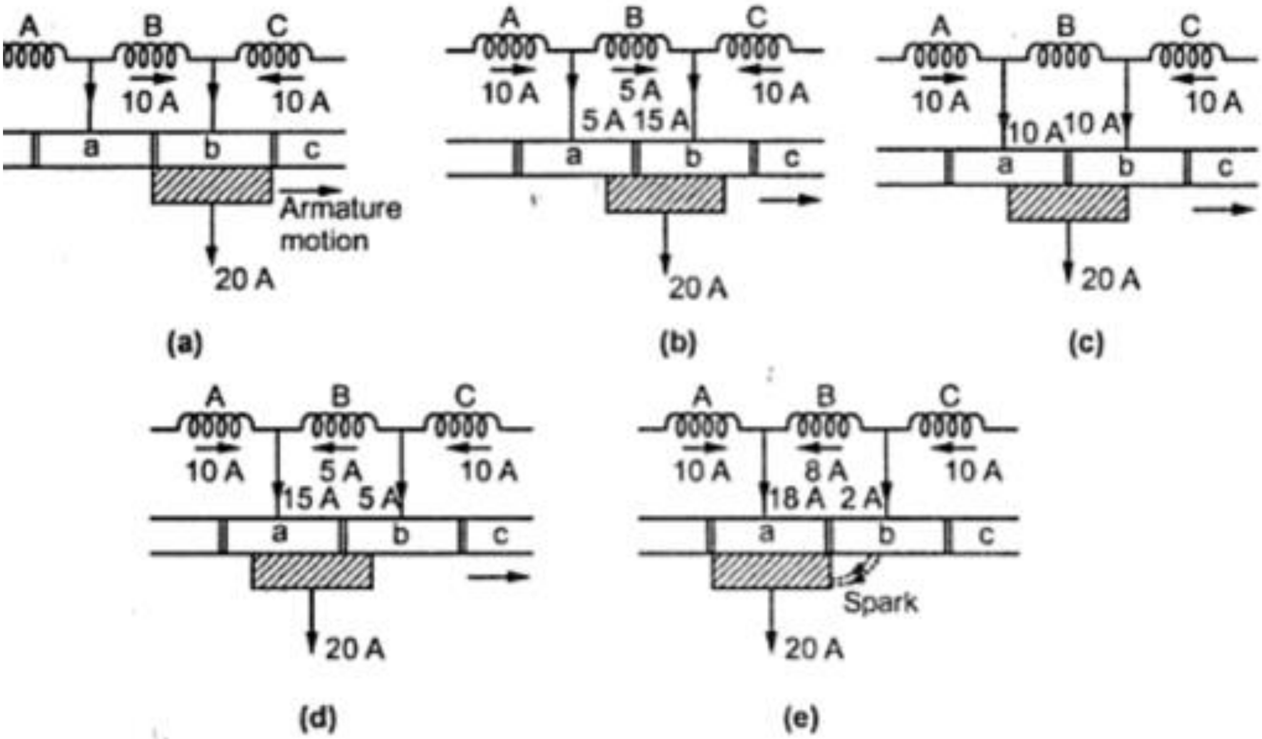


fig. 2 .15 Practical commutation

As shown in the Fig. 2.15(a), **coil B is about to be short circuited**. The brush is about to come in contact with commutator segment 'a'. Suppose that each coil is carrying current of 10 A so that total brush current is 20 A as every coil meeting at the brush supplies half the brush current independently of lap or wave wound armature.

Before coil B is short circuited, it is belonging to the group of coils lying left of the brush. It is carrying current 10 A from left to right.

As seen from the Fig. 2.15(b), **coil B is entering short circuit period.** The current in coil B has reduced from 10 A to 5 A as the other 5 A flows via segment 'a'. The total current is remaining same at 20 A. But area of contact of the brush is more with segment 'b' than with segment 'a'. Hence current of 15 A is from segment 'b' whereas 5 A from segment 'a'.

The coil B is in the middle of its short circuit period as shown in the Fig. 2(c). The current in coil B is reduced to zero. The current 10 A and 10 A pass to the brush directly from coils A and C. The total current is again20 A and the contact area of brush with the segments 'a' and 'b' are equal.

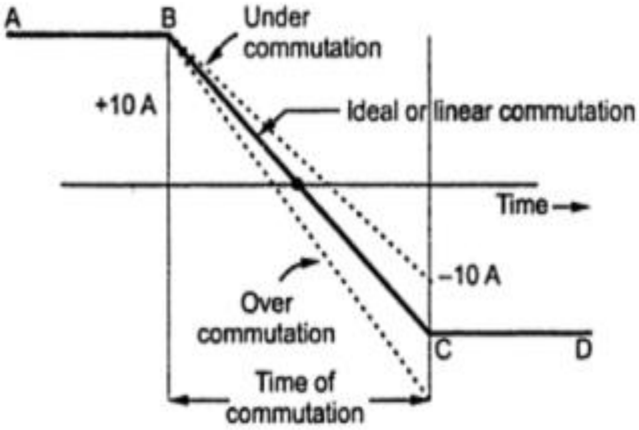
As shown in the Fig. 2(d), the coil B is now under group of coils to the right of brush. The contact area of brush with segment 'b' is decreasing whereas with segment 'a' is increasing. Coil B is now carrying 5 A in other direction. Thus current of 15 A is passed via. segment 'a' to the brush while the other 5 A is supplied by coil C and passes from segment 'b' to brush. Again the total current is 20 A.

If case of ideal commutation is assumed then current through coil B will reverse at the end of commutation or short circuit period. But as shown in Fig. 2(e) current flowing through coil B is only 8 A instead of 10 A. So the difference in coil currents i.e. 10 - 8 = 2 A jumps directly from segment 'b' to the brush through air and produces spark.

The variation in current during the process of commutation can be plotted with respect to time as shown in the Fig. 2.16.

The current in the coil B is 10 A till commutation begins represented by horizontal line AB. After finishing commutation the current is again 10 A but in reverse direction represented by horizontal line CD. Thus current changes from +10 A to 0 and then to -10 A. The way in which this current changes is important. If current varies uniformly represented by straight line BC the commutation is said to be linear commutation.

But it is observed that the **self induced e.m.f. in the coil will try to maintain the current in the same direction and will cause delay for commutation.** The commutation in this case is said to be retarded or under commutation. This is shown by the dotted part in the Fig. 2.16. **.**



2.16 Linear commutation

If reversal of current in the coil is faster than ideal or linear commutation then also sparking may occur. The commutation in this case is said to be over commutation or accelerated commutation.

Thus it can be seen that if reversal of current is retarded or accelerated then value of current in the short circuited coil after the commutation period is over is different than that when linear commutation occurs. This will cause sparking at the brushes. This will lead to excessive wear and tear of commutator and ultimately lead to burning of commutator. Hence it is desired that the commutation must be as sparkless as possible.

Now let us see that why there is delayed or accelerated commutation. **The main reason for non-linear commutation is the production of self induced e.m.f. in the coil undergoing commutation as the coil has significant amount of self inductan**ce because it is embedded in the armature which is made up of high permeability material. This self induced e.m.f. though small in magnitude produces a large current through the coil whose resistance is small due to short circuit.

METHODS OF IMPROVING COMMUTATION

To make the commutation satisfactory we have to make sure that the current flowing through the coil completely reversed during the commutation period attains its full value.

There are three main **methods of improving commutation**. These are

1. Resistance commutation
2. E.M.F. commutation
3. Compensating windings

1. Resistance Commutation

In this method of commutation we use high electrical resistance brushes for getting spark less commutation. This can be obtained by replacing low resistance copper brushes with high resistance carbon brushes.

We can clearly see from the picture that the current I_C from the coil C may reach to the brush in two ways in the commutation period. One path is direct through the commutator segment b and to the brush and the 2nd path is first through the short-circuit coil B and then through the commutator segment a and to the brush. When the brush resistance is low, then the current I_C from coil C will follow the shortest path, i.e. the 1st path as its electrical resistance is comparatively low because it is shorter than the 2nd path as shown in fig 2.17.

When high resistance brushes are used, then as the brush moves towards the commutator segments, the contact area of the brush and the segment b decreases and contact area with the segment a increases.

Now, as the electrical resistance is inversely proportional to the contact area of the resistance ,R_b will increase and R_a will decrease as the brush moves. Then the current will prefer the 2nd path to reach to the brush. Thus by this **method of improving commutation**, the quick reversal of current will occur in the desired direction.

$$Resistance: \quad R = \rho\frac{l}{A}$$

ρ is the resistivity of the conductor. l is the length of the conductor. A is the cross-section of the conductor (here is this description it is used as contact area).

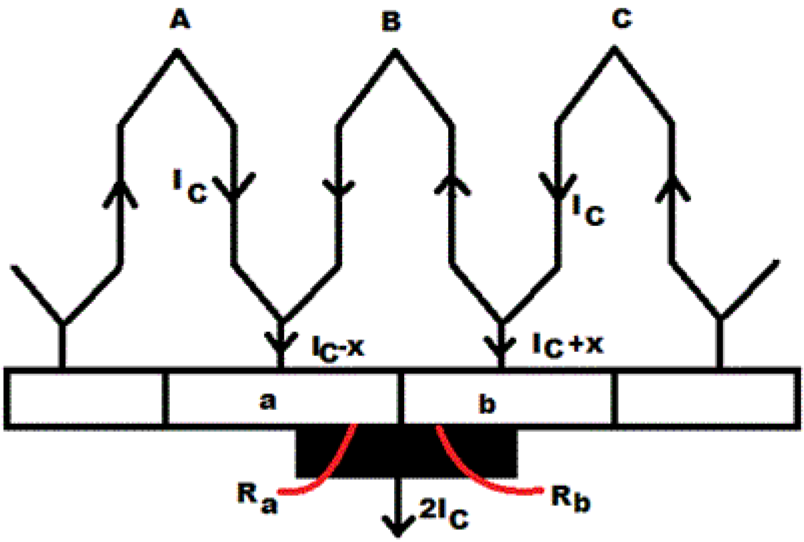


Fig.2.17

2. *E.M.F. Commutation*

The main reason of the delay of the current reversing time in the short circuit coil during commutation period is the inductive property of the coil.

In this type of commutation, the reactance voltage produced by the coil due to its inductive property, is neutralized by producing a reversing emf in the short circuit coil during commutation period.

Reactancevoltage:

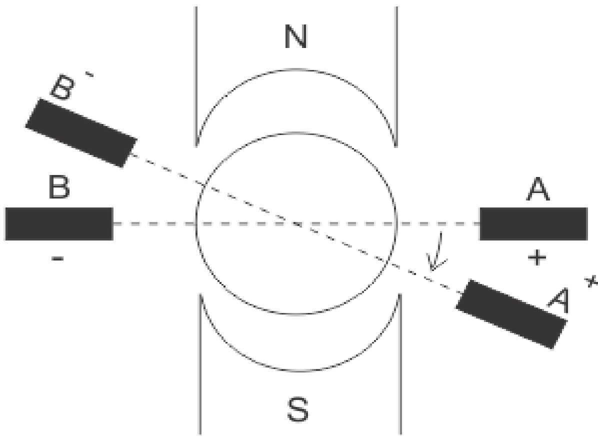
The voltage rise in the short circuit coil due to inductive property of the coil, which opposes the current reversal in it during the commutation period, is called the reactance voltage.
We can produce reversing emf in two ways

1. By brush shifting.
2. By using inter-poles or commutating poles.

1. **Brush Shifting Method of Commutation**

In this method of improving commutation the brushes are shifted forward direction for the DC generator and in backward direction for the motor for producing the sufficient reversing emf for eliminating the reactance voltage.

When the brushes are given the forward or backward lead then it brings the short circuit coil under the influence of the next pole which is of the opposite polarity. Then the sides of the coil will cut the necessary flux form the main poles of opposite polarity for producing the sufficient reversing emf.



Generator Brush Shift

This method is rarely used because for best result,

with every variation of load, the brushes have to be shifted.

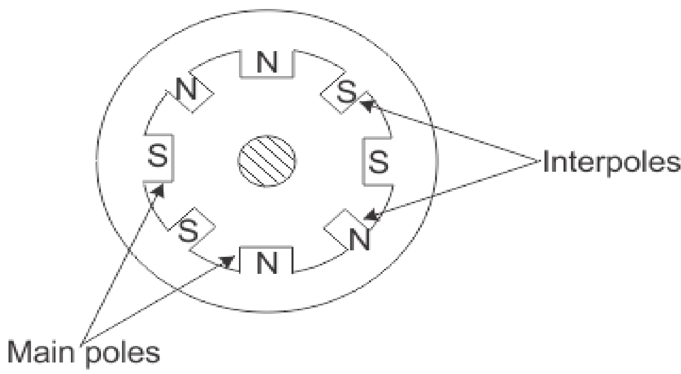
Fig. 2.18

2.Method Of Using Inter-Pole

In this method of commutation some small poles are fixed to the yoke and placed between the main poles. These poles are called inter-poles.

Their polarity is same as the main poles situated next to it for the generator and for the motor the polarity is same as the main pole situated before it.

The inter-poles induce an emf in the short circuit coil during the commutation period which opposes reactance voltage and give spark-less commutation.



Interpole Commutation

Fig.2.19

3.Compensating Windings

This is the most effective mean of eliminating the problem of armature reaction and flash over by balancing the armature mmf. **Compensating windings are placed in slots provided in pole faces parallel to the rotor (armature) conductors.** The major drawback with the compensating windings is that they very costly. Their use is mainly for large machines subject to heavy overloads or plugging and in small motors subject to sudden reversal and high acceleration.

APPLICATIONS OF D.C GENERATORS:

1.Applications of Separately Excited DC Generators

This type of DC generators are generally more expensive than self-excited DC generators because of their requirement of separate excitation source. Because of that their applications are restricted. They are generally used where the use of self-excited generators are unsatisfactory.

1. Because of their ability of giving wide range of voltage output, they are generally used **for testing purpose in the laboratories.**

2. Separately excited generators operate in a stable condition with any variation in field excitation. Because of this property they are used as **supply source of DC motors**, whose speeds are to be controlled for various applications. **Example- Ward Leonard Systems of speed control.**

2.Applications of Shunt Wound DC Generators

These type of DC generators generally **give constant terminal voltage** for small distance operation with the help of field regulators from no load to full load.

1. They are used **for general lighting.**
2. They are used to **charge battery** because they can be made to give constant output voltage.
3. They are used for **giving the excitation to the alternators.**
4. They are also used **for small power supply** (such as a portable generator).

3. Applications of Series Wound DC Generators

These types of generators are restricted for the use of power supply because of their increasing terminal Voltage characteristic with the increase in load current from no load to full load. For this property they can be used as **constant current source** and employed for various applications.

1. They are used for **supplying field excitation current in DC locomotives for regenerative breaking.**
2. This types of generators are used as **boosters** to compensate the voltage drop in the feeder in various types of distribution systems such as railway service.
3. In **series arc lightening** this type of generators are mainly used.

4.Applications of Compound Wound DC Generators

Among various types of DC generators, the compound wound DC generators are most widely used because of its compensating property. **Depending upon number of series field turns, the cumulatively compounded generators may be over compounded, flat compounded and under compounded.**

1. **Cumulative compound wound generators** are also **used for driving a motor.**

2.For small distance operation, such as **power supply for hotels, offices, homes and lodges, the flat compounded generators are generally used.**

3.The **differential compound wound generators**, because of their large demagnetization armature reaction, are used for **arc welding** where huge voltage drop and constant current is required.

Residual Magnetism

In ferromagnetic materials, the magnetic power and the generated voltage increase with the increase of the current flow through the coils. When current is reduced to zero, there is still magnetic power left in those coils core. This phenomenon is called residual magnetism. The core of a DC machine is made of **ferromagnetic material.**

BUILDING UP OF VOLTAGE OF A SHUNT GENERATOR AT NO LOAD

The curve plotted between the generated emf and shunt field current will be similar to that shown in Fig. 2.20. **The generator excites itself due to residual magnetism and develops the voltage** as described below:

Line OP represents the shunt field resistance. When the generator is started a small emf (represented by OA in the Fig.) is induced due to residual magnetism. This induced emf causes a flow of current oa' in the field circuit. This is obtained by drawing a horizontal line from point A meeting the field resistance line at point **a** and then from point **a** drawing perpendicular line meeting current axis at a'.

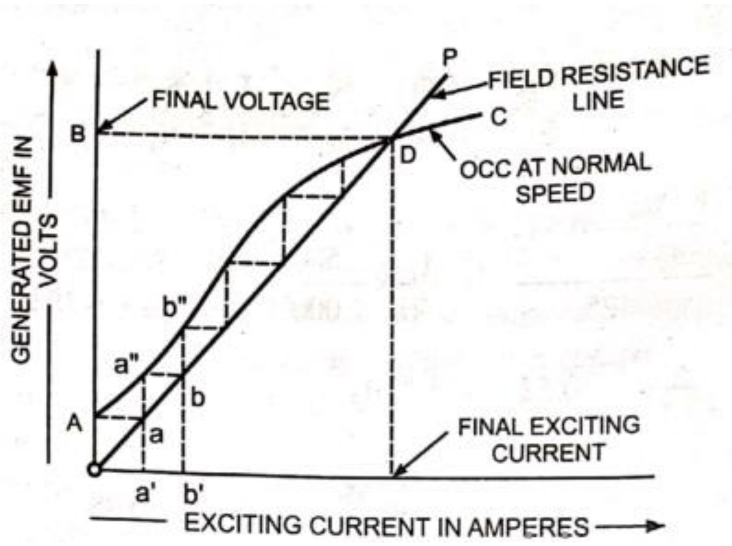


Fig.2.20 Building Up of Voltage of a Shunt Generator At No Load

When field current is Oa', the generated emf. is a'a" which produces a field current Ob', which in turn produces a high voltage b'b". Thus it is observed that effect is cumulative and value of induced emf and field current increases until these reach point D, the point of intersection of the shunt field resistance line and magnetic characteristic obtained. In Fig. 2.20 instantaneous increases in induced emf and field current are shown but in practice flux increases gradually. OB is the maximum value of emf that can be generated and generator cannot generate more than this voltage.

CRITICAL FIELD RESISTANCE

It is that **value of the field resistance at which the D.C. shunt generator will fail to excite.**

The critical field resistance is defined as the maximum field circuit resistance (for a given speed) with which the shunt generator would excite. **The shunt generator will build up voltage only if field circuit resistance is less than critical field resistance.**

It is a Tangent to the Open Circuit Characteristics of the Generator(at a given speed).

CRITICAL FIELD RESISTANCE

It has been already stated that the maximum voltage which a generator can generate is given by the point of intersection of field resistance line with the open circuit characteristic. If the line OA represents the field resistance, then the maximum emf generated is Oa1, if the field resistance is increased to the value represented by line OB, the generated voltage will be Ob1 and if it is further increased so that the line representing the field resistance becomes tangent to the curve, as line OC, then emf generated is Oc1 and the **value of resistance given by this line is called the critical resistance (Fig 2.21).**

If field resistance is further increased beyond critical resistance, as represented by line OD the generator will not excite because the line OD has got no point of intersection with the magnetic characteristic (ignoring initial portion of the curve).

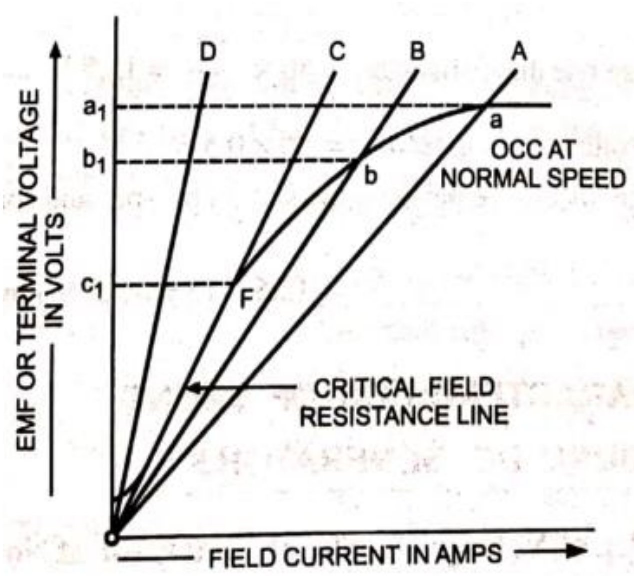


Fig.2.21

CRITICAL SPEED:

It is that speed for which the given shunt field resistance becomes the critical field resistance.

DETERMINATION OF CRITICAL SPEED

Critical Speed of a shunt wound generator is that speed for which the given shunt field resistance will represent critical field resistance.

In Fig. 2.22, curve I is the OCC at given speed N, OB is the tangent line to the OCC and line OP is the line drawn to represent the given shunt field resistance.

Let curve II be OCC drawn at the critical speed Nc, to be determined.

By definition of critical speed line OP will be tangent to the new OCC.

If any ordinate AB is drawn intersecting line OP at C then

$$\frac{AC}{AB} = \frac{NC}{N}$$

$$Nc = \frac{AC}{AB} X\ N$$

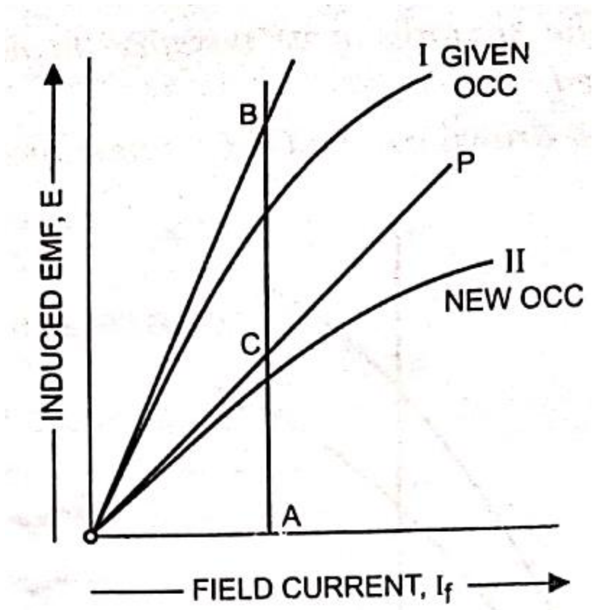


Fig.2.22

Hence to determine critical speed,

(i) draw given OCC, a line tangent to given OCC and line representing the given shunt field resistance,

(ii) draw any ordinate intersecting the field resistance line and tangent line to given OCC and

(iii) multiply the given speed by the ratio of the intercepts of ordinate drawn between field resistance line and abscissa and between tangent line to given OCC and abscissa.

Speed thus obtained will be critical speed.

CONDITIONS FOR SELF EXCITATION

The conditions required to be fulfilled before a series or a shunt generator excites itself are given below:

There must be **some residual magnetism in the field system.**

The residual magnetism must be in proper direction. The field coils should be connected with the armature in such a way that current flowing through them should increase the emf induced by the residual magnetism.

For a **series wound generator, the resistance of the external circuit should be less than the critical resistance.**

For a **shunt wound generator, resistance in the field circuit must be less than critical resistance for field circuit** and resistance in the load circuit, must be greater than critical resistance for the load circuit.

CAUSES OF FAILURE TO BUILD UP VOLTAGE

There may be one or more of the following reasons due to which a self excited generator may fail to build up voltage.

1. No residual magnetism. The start of the build up process needs some residual magnetism in the magnetic circuit of the generator. If there is little or no residual magnetism, because of inactivity , no voltage will be induced that can produce field current.

2. Reversal of Field Connections. The voltage induced owing to residual magnetism acts across the field and results in flow of current in the field coils in such a direction as to produce magnetic flux in the same direction as the residual flux. Reversal of connections of the field winding destroys the residual magnetism which causes the generator failure to build up voltage.

3. In case of **dc series wound generators, the resistance in the load circuit may be more than its critical resistance,** which may be due to

(i) open-circuit

(ii) high resistance of load circuit

(iii) faulty contact between brushes and commutator and

(iv) commutator surface dirty or greasy.

4. In case of **shunt wound generator:**

(a) the resistance of the shunt field circuit may be greater than the critical resistance,

(b) the resistance in the load circuit may be lower than the critical resistance;

(c) the speed of rotation may not be equal to rated one.

Remedy. In case the generator is started up for the first time, it may be that no voltage will be built up either because the poles have no residual magnetism or the poles have retained some residual magnetism but the field winding connections are reversed so that the magnetism developed by the field winding on start has destroyed the residual magnetism and the machine can not "build up". In both the cases, the field coils must be connected to a de source (a storage battery) for a short while to magnetise the poles. The application of external source of direct current to the field is called flashing of the field.