UNIT – I

D.C Generators & D.C Motors

Introduction :-

Direct current (D.C) Machines are Electromechanical Energy Conversion devices which can operate as generators converting mechanical energy to electrical energy. They can also operate as motors, taking electrical energy from a dc system and converting it into mechanical energy of rotation and driving a mechanical loop.

Principle of operation of a D.C Generator :-

All the generators work on a principle of dynamically induced emf. This principle is nothing but "the Faraday's Laws of electromagnetic induction". It states that, "whenever the flux linking with a conductor changes, an electromotive force (emf) is setup in that conductor". The change in flux associated with the conductor can exist only when there exists a relative motion between a conductor and the flux.

The relative motion can be acheived by rotating conductor with respect to flux or by rotating flux with respect to a conductor. So voltage gets generated in a conductor, as long as there exists a relative motion between the conductor and the flux.

Dynamically induced emf :-

An induced emf which is due to physical movement of conductor with respect to flux or movement of flux with respect to conductor is called dynamically induced emf.

A generating action requires following basic components to (i) The conductor (ii) the flux (iii) The relative motion between the conductor & flux.

In D.C generator, the conductors are rotated to cut the magnetic flux, keeping the flux stationary. To have the rotation of conductors, the conductors are placed on the armature rotated with help of external device called a prime mover. The necessary magnetic flux is produced by current carrying winding which is called field winding. The direction of induced emf can be obtained by using Fleming's right hand rule.

Fleming's Right Hand Rule :-

If three fingers of a right hand, namely thumb, index finger and middle finger are outstretched so that everyone of them is at right angles with the remaining two. If forefinger or index finger represents the direction of the lines of flux, thumb points in the direction of motion of the conductor, then middle finger gives the direction of emf induced in the conductor.

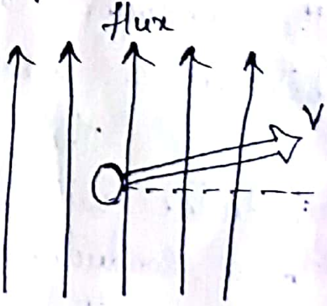
The magnitude of the induced emf is given by

$$E = Blv \sin\theta$$

where B = magnetic flux density

l = Active length of conductor

v = Relative velocity of conductor



Single loop DC generator :-

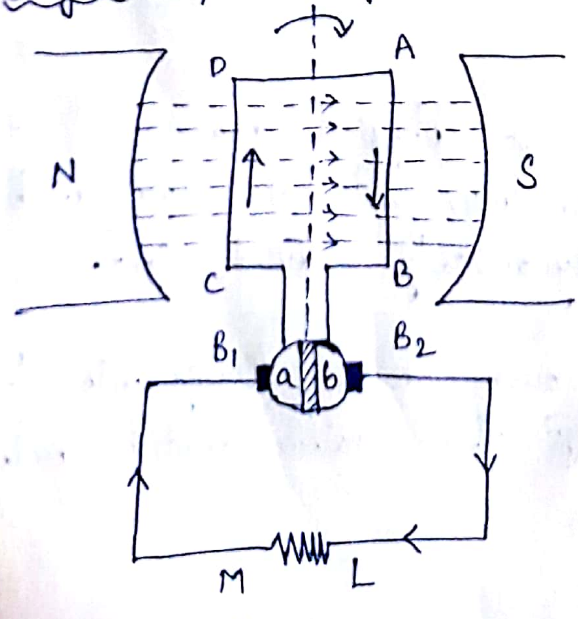
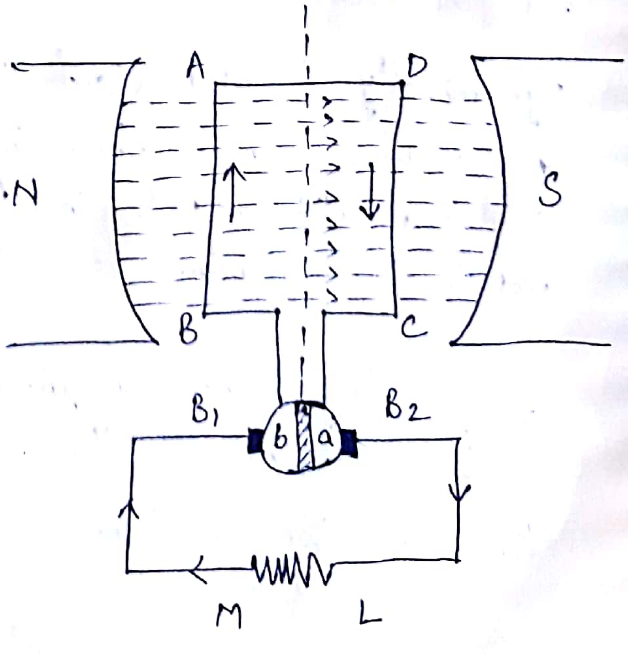
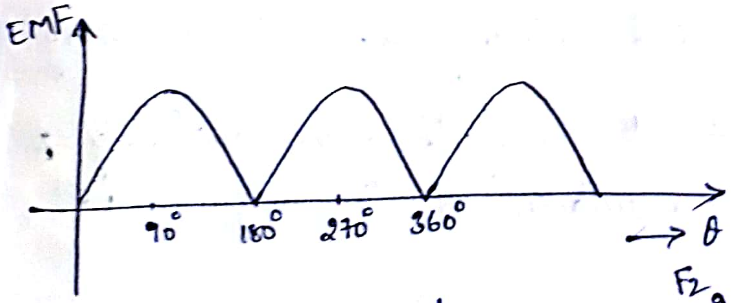


fig (a)

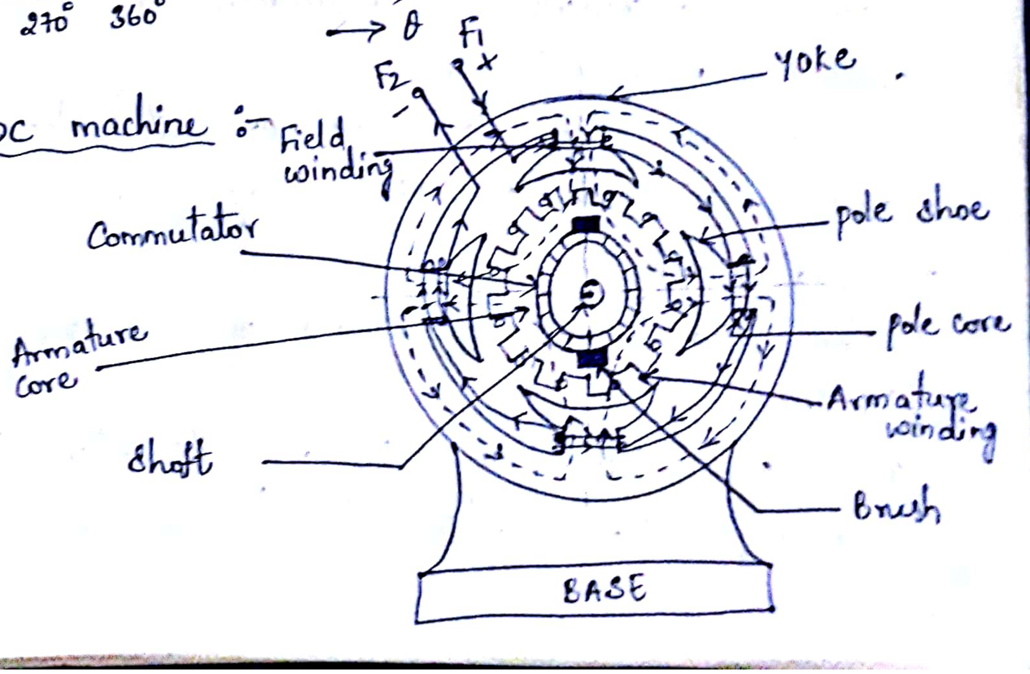


In the figure above, a single loop of conductor of rectangular shape is placed between two opposite poles of magnet.
Let us consider, the rectangular loop of a conductor ABCD which rotates inside the magnetic field about its own axis ab. when the loop rotates, it cuts the flux lines of the field. At this instant shown in fig(a) emf is induced in the both the sides AB & BC of the loop.

As the loop is closed there will be a current circulating through the loop. It is seen that in the first half of the revolution current flows along ABLMCD i.e. Brush 1 in contact with segment a. In the next half revolution, the direction of the induced current in the coil is reversed as shown in fig(b). But at the same time the position of the segments a and b also reversed which results in brush 1 comes in touch with segment b. Hence the current in the load resistance again flows from L to M. The waveform of the current through the load circuit is unidirectional.



<u>Construction of DC machine :-</u>



A DC generator has the following parts

1. yoke
2. poles
3. Field winding
4. Armature
5. Commutator
6. Brushes
7. Bearing.

① yoke :- It is outer frame of DC Generator.

Functions :-

→ It provides mechanical support to the poles.
→ It provides a path of low reluctance for magnetic flux.
→ It serves of outermost cover of d.c machine.

choice of material :
It is made up of cast iron for small machines. For large machines it is made up of cast steel.

② poles :-
Each pole is divided into two parts (i) pole core (ii) pole shoe.

Functions :-

→ pole core carries a field winding which is necessary to produce flux.
→ pole shoes spread out the magnetic flux uniformly in the airgap and reduce the reluctance of the magnetic path.

choice of material :
It is made up of cast iron or cast steel. The pole shoe is always laminated to avoid Eddy current loss.

③ Field winding :-
The field winding is wound on the pole core.

Functions :-
It helps in producing the magnetic flux i.e. Exciting the pole as an Electromagnet. It is also called as Exciting winding.

Choice of material : Copper or Aluminium.

④ Armature :-

It is further divided into two parts (i) Armature core (ii) Armature winding.

(i) Armature core :-

Armature core is cylindrical in shape mounted on the shaft. It is build up of circular laminated sheet. It consists of slots on its periphery.

Functions :-

→ The purpose of armature core is to hold the armature winding.

→ provides low reluctance path to magnetic flux.

(reluctance: obstruction offered by a mag. ckt to the mag. flux)

Choice of Material :-

It is assembled from steel laminations having a in order to reduce eddy current losses, the laminations are insulated from each other.

(ii) Armature winding :-

Armature winding is nothing but the interconnection of armature conductors, placed in the slots provided on the armature core.

Functions :-

→ Generation of emf takes place in the armature winding in case of generators.

→ To carry the current supplied in case of d.c motors.

Choice of material :-

It is made up of conducting material, which is copper.

⑤ Commutator :-

The nature of emf induced in the armature conductors is alternating. The function of the commutator is to convert the ac voltages induced in the armature conductors to dc voltage in the external circuit in generator operation, whereas in dc motors it produces unidirectional torque.

Choice of material :-

As it collects current from armature, it is also made up of copper segments. It is made up of high conductivity hard drawn copper.

⑥ Brushes :-

The rotating armature and external circuit are connected through brushes.

Function :

Brushes are employed to collect current from the commutator and deliver it to the load.

Choice of material :-

These are rectangular and are made of carbon, carbon graphite.

⑦ Bearings :-

Ball - Bearings are usually used as they are more reliable. For heavy duty machines, roller bearings are preferred.

EMF Equation of a D.C Generator :-

Let ϕ = magnetic flux / pole in wb

Z = total no. of armature conductors

P = no. of poles

A = no. of parallel paths = 2 ---- for wave winding

$A = P$ --- for lap winding.

N = speed of armature in r.p.m

E_g = emf of the generator = emf / parallel path

Magnetic flux cut by one conductor in one revolution of the armature,

$$d\phi = P\phi \text{ webers}$$

Time taken to complete one revolution,

$$dt = \frac{60}{N} \text{ sec.}$$

Emf generated / Conductor $= \frac{d\phi}{dt} = \frac{P\phi}{60/N} = \frac{P\phi N}{60}$ volts.

Emf of generator, E_g = Emf per parallel path

= (Emf / Conductor) × no. of conductors in series per parallel path

$= \frac{P\phi N}{60} \times \frac{Z}{A}$

$$\therefore \boxed{E_g = \frac{P\phi Z N}{60A}}$$

where $A = 2$ for wave winding

$= P$ for Lap winding.

Problem:- Calculate the Emf generated by 4-pole wave-wound generator having 65 slots with 12 conductors per slot when driven at 1200 r.p.m. The flux per pole is 0.02 wb.

Sol:- $E_g = \frac{P\phi Z N}{60A}$.

Here $P = 4$; $\phi = 0.02$ wb; $N = 1200$ r.p.m; $Z = 12 \times 65 = 780$; $A = 2$

$$E_g = \frac{4 \times 0.02 \times 780 \times 1200}{60 \times 2} = 624 \text{ volts.}$$

Problem:- A 6-pole Lap-wound d.c generator has 600 conductors on its armature. The flux per pole is 0.02 Wb. Calculate (i) the speed at which the generator must be run to generate 300V (ii) what would be the speed if the generator were wave-wound?

Sol:- (i) Lap wound, $E_g = \frac{P\phi Z N}{60A}$.

$$N = \frac{E_g \times 60A}{P\phi Z} = \frac{300 \times 60 \times 6}{6 \times 0.02 \times 600} = 1500 \text{ r.p.m}$$

(ii) Wave wound, $N = \frac{E_g \times 60A}{P\phi Z} = \frac{300 \times 60 \times 2}{6 \times 0.02 \times 600} = 500$ rpm.

Problem :- An 8-pole, lap-wound armature rotated at 350 rpm is required to generate 260 V. The useful magnetic flux per pole is 0.05 wb. If the armature has 120 slots, calculate the no. of conductors per slot.

Sol :-

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$$E_g = \frac{P \phi Z N}{60 A}$$

$$\therefore Z = \frac{E_g \times 60A}{P \phi N} = \frac{260 \times 60 \times 8}{8 \times 0.05 \times 350} = 890.$$

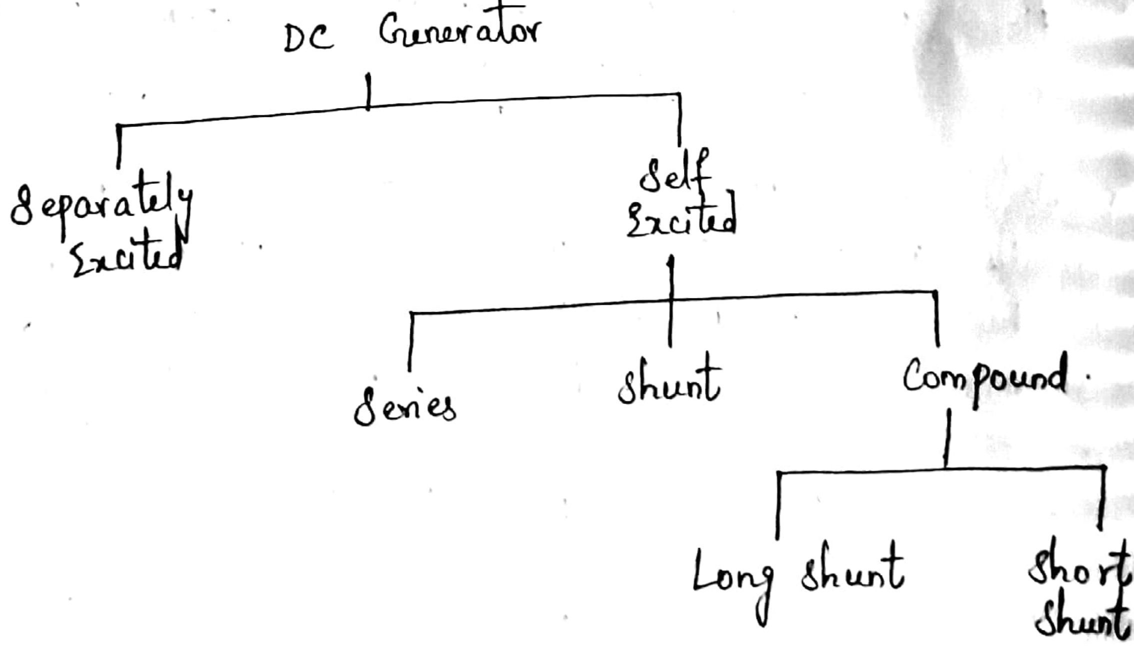
$\therefore$ No. of conductors / slot = 890/120 = 7.14.

This value must be an even number.

Hence, Conductors / slot = 8.

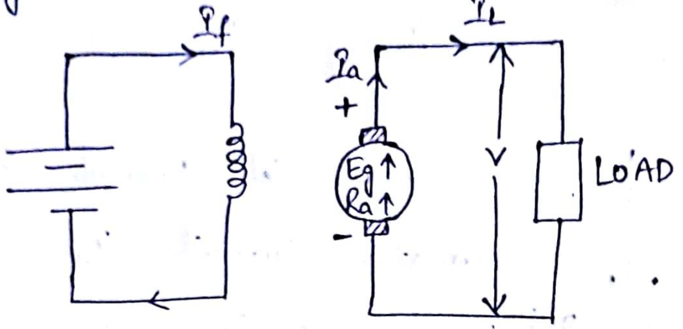
Classification of DC Generators :-

DC Generators are classified based on the type of excitation employed to produce the required flux in the field circuit. This classification is given as,



Seperately Excited DC Generators :-

A dc generator whose field magnet winding is supplied from an independent external d.c source is called a separately excited generator.



Armature current, $I_a = I_L$

Terminal voltage, $V = E_g - I_a R_a$

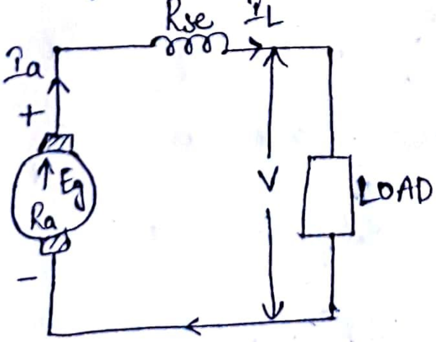
Electric power developed, $= E_g I_a$

power delivered to load $= E_g I_a - I_a^2 R_a = I_a(E_g - I_a R_a) = V I_a$

Self-Excited D.C Generators :-

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



Arm. current, $I_a = I_{se} = I_L = I$ (Say)

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

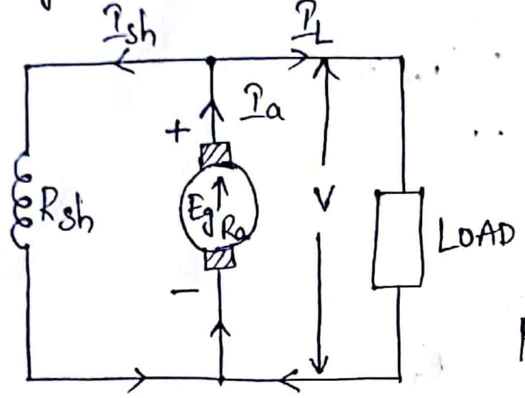
Power developed in armature $= E_g I_a$

power delivered to load $= E_g I_a - I_a^2 (R_a + R_{se})$

$= I_a [E_g - I_a (R_a + R_{se})]$

$= V I_a$ or $V I_L$

(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. Therefore, only a part of armature current flows through shunt field winding and the rest flows through the load.



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

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

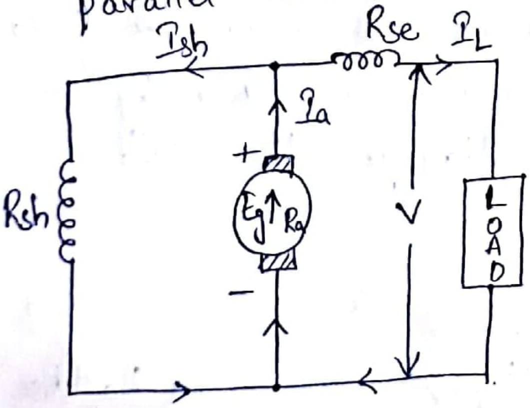
Terminal voltage, $V = E_g - I_a R_a$

power developed in armature $= E_g I_a$.

power delivered to load $= V I_L$.

(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.



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

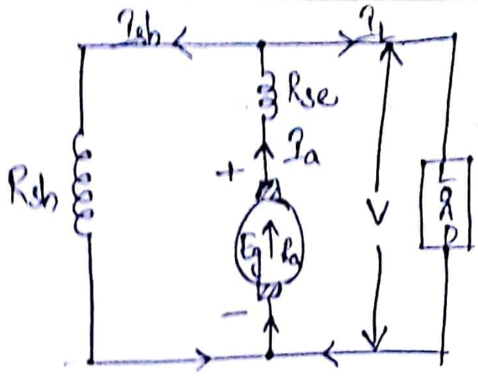
Shunt field current, $I_{sh} = \dfrac{V + I_{se} R_{se}}{R_{sh}}$

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

power developed in armature $= E_g I_a$.

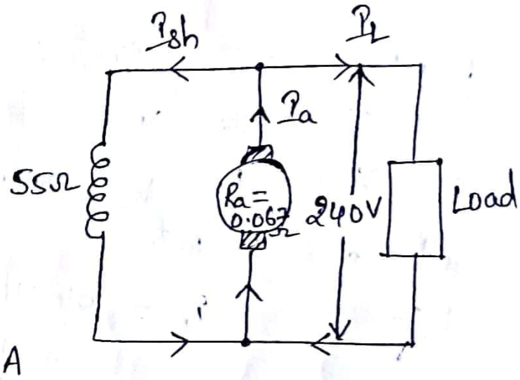
power delivered to load $= V I_L$.

(b) **Long shunt** :- in which shunt field winding is in parallel with both series field and armature winding.



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 $= V I_L$

Problem:- A 100 kW, 240V shunt generator has a field resistance of 55 Ω and armature resistance of 0.067 Ω. Find the full-load generated voltage.



Sol:-

$$I_L = \frac{100 \times 10^3}{240} = 416.7\,A$$

$$I_{sh} = 240/55 = 4.36\,A$$

$$I_a = I_L + I_{sh}$$
$$= 416.7 + 4.36 = 421.1\,A$$

$$E_g = V + I_a R_a$$
$$= 240 + 421.1 \times 0.067 = 268.2\,V.$$

Problem:- A 4-pole d.c shunt generator with a wave-wound armature has to supply a load of 500 lamps each of 100 W at 250V. Allowing 10V for the voltage drop in the connecting leads between the generator and the load and drop of 1V per brush, calculate the speed at which the generator should be driven. The magnetic flux per pole is 30 mWb and the armature and shunt field resistances are respectively 0.05 Ω & 65 Ω. The no. of armature conductors is 390.

Sol:- Load current, $I_L = \frac{500 \times 100}{250} = 200\,A.$

voltage across shunt $= 250 + 10 = 260\,V$

$$I_{sh} = 260/65 = 4\,A.$$

$$I_a = I_L + I_{sh} = 200 + 4 = 204\,A.$$

Brush drop = 2×1 = 2V.

E_g = voltage across shunt + 2 + $I_a R_a$.

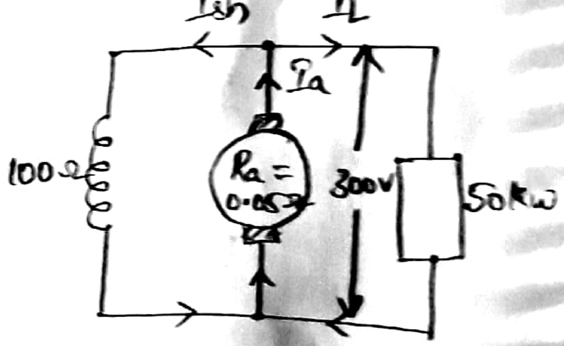
= 260 + 2 + 204 × 0.05

= 272.2 V.

Now, $E_g = \frac{P \phi Z N}{60 A}$

$\therefore N = \frac{E_g \times 60 A}{P \phi Z} = \frac{272.2 \times 60 \times 2}{4 \times 30 \times 10^{-3} \times 390} = 698$ rpm.

problem :- A 30 kW, 300V d.c shunt generator has armature and field resistances of 0.05Ω and 100Ω respectively. Calculate the total power developed by the armature when it delivers full load output.



Sol :-

$I_L = \frac{30 \times 10^3}{300} = 100A.$

$I_{sh} = 300/100 = 3A.$

$I_a = I_L + I_{sh} = 100 + 3 = 103A.$

$E_g = V + I_a R_a$

= 300 + 103 × 0.05 = 305.15V

power developed by armature = $E_g I_a$

= 305.15 × 103 = 31.43×10^3 W

= 31.43 kW.

problem :- A 4-pole Lap-wound d.c shunt generator has a useful flux per pole of 0.07 wb. The armature winding consists of 220 turns, Each of 0.004Ω resistance. Calculate the terminal voltage when running at 900 rpm. If the armature current is 50A.

Sol :-

$E_g = \frac{P \phi Z N}{60 A}$

Z = 220 × 2 = 440 ; φ = 0.07 wb ; N = 900 rpm ; A = P = 4

$$\therefore E_g = \frac{4 \times 0.07 \times 440 \times 900}{60 \times 4} = 462V$$

No. of turns per parallel path = $220/4 = 55$

Resistance per parallel path = $0.004 \times 55 = 0.22\Omega$

$$E_g = V + I_a R_a$$

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$$462 = V + 50 \times 0.055$$

$$\therefore V = 459.25 \text{ V}.$$

Losses in a DC Machine :-

- Losses in a d.c. machine
  - Copper losses
    - Armature cu loss
    - shunt field cu loss
    - Series field cu loss
  - Iron Losses
    - Hysteresis loss
    - Eddy current loss
  - Mechanical Losses
    - Friction loss
    - Windage loss.

① Copper losses :- These losses occur due to currents in the various windings of the machine.

(i) Armature cu loss = $I_a^2 R_a$.

(ii) shunt field cu loss = $I_{sh}^2 R_{sh}$.

(iii) Series field cu loss = $I_{se}^2 R_{se}$.

② Iron or Core losses :- These losses occur in the armature of the d.c machine and are due to the rotation of armature in the magnetic field of the poles. They are of two types,

(i) Hysteresis loss :- Hysteresis loss occurs in the armature of the d.c machine since any given part of the armature is subjected to magnetic field reversals as it passes under successive poles.

Hysteresis loss, $P_h = \eta B_{max}^{1.6} f V$ watts

where B_{max} = Maximum magnetic flux density in armature

f = Frequency of magnetic reversals

$= \frac{NP}{120}$ where N is in rpm. 14

V = Volume of armature in m^3.

η = Steinmetz hysteresis Co-efficient.

In order to reduce this loss in a d.c machine, armature Core is made of such materials which have a low value of steinmetz hysteresis Co-efficient e.g. Silicon steel.

(ii) Eddy Current loss :- When armature rotates in the magnetic field of the poles, an emf is induced in it which circulates eddy currents in the armature core. The power loss due to these eddy currents is called eddy current loss. In order to reduce this loss, the armature core is built up of thin laminations insulated from each other by a thin layer of varnish.

Eddy current loss, $P_e = K_e B_{max}^2 f^2 t^2 V$ watts.

where K_e = Constant

B_{max} = Maximum magnetic flux density in the Core

f = frequency of magnetic reversals

t = Thickness of lamination.

V = Volume of Core in m^3.

(3) Mechanical losses :- These losses are due to friction & windage

(i) friction loss e.g. bearing friction, brush friction etc.

(ii) Windage loss i.e. air friction of rotating armature.

These losses depend upon the speed of the machine.

Iron losses + Mechanical losses = Stray losses.

Constant and Variable Losses :-

The losses in a d.c. generator (or d.c motor) may be sub-divided into (i) constant losses (ii) Variable losses.

(i) **Constant losses :-** Those losses in a d.c generator which remain constant at all loads are known as constant losses. The constant losses are :

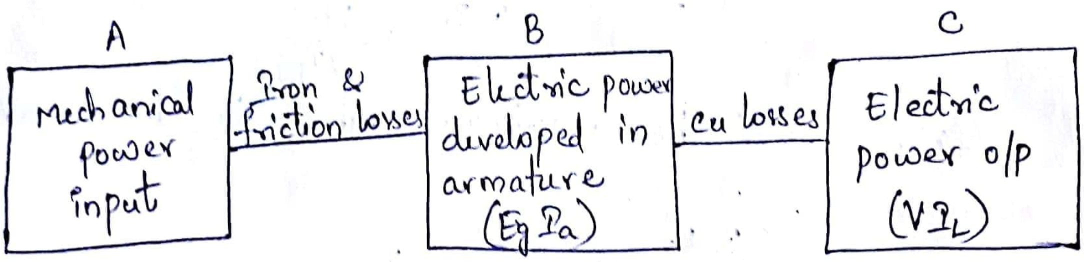
(a) iron losses
(b) mechanical losses
(c) shunt field losses.

(ii) **Variable losses :-** Those losses in a d.c generator which vary with load are called variable losses. The variable losses are :

(a) cu loss in armature winding ($I_a^2 R_a$).
(b) cu loss in series field winding ($I_{se}^2 R_{se}$).

Total losses = Constant losses + Variable losses.

Power stages of d.c Generator :-



(i) Mechanical efficiency : $\eta_m = \frac{B}{A} = \frac{E_g I_a}{\text{Mech. power i/p}}$.

(ii) Electrical efficiency : $\eta_e = \frac{C}{B} = \frac{V I_L}{E_g I_a}$.

(iii) Commercial or overall efficiency :

$$\eta_c = \frac{C}{A} = \frac{V I_L}{\text{Mech. power i/p}}.$$

$$\eta_c = \eta_m \times \eta_e$$

overall efficiency, $\eta_c = \frac{C}{A} = \frac{o/p}{i/p} = \frac{i/p - \text{losses}}{i/p}$.

Condition for maximum efficiency :-

The efficiency of a d.c generator is not constant but varies with load. Consider a shunt generator delivering a load current I_L at a terminal voltage V.

Generator o/p = VI_L

Generator i/p = o/p + Losses.

= VI_L + Variable losses + Constant losses

$= VI_L + I_a^2 R_a + W_c$.

$= VI_L + (I_L + I_{sh})^2 R_a + W_c$ $\quad \because I_a = I_L + I_{sh}$

The shunt field current I_{sh} is generally small as compared to I_L and, therefore, can be neglected.

$\therefore$ Generator i/p $= VI_L + I_L^2 R_a + W_c$.

$$\therefore \eta = \frac{o/p}{i/p} = \frac{VI_L}{VI_L + I_L^2 R_a + W_c}.$$

$$= \frac{1}{1 + \left(\frac{I_L R_a}{V} + \frac{W_c}{VI_L}\right)} \quad \text{———} (1).$$

The efficiency will be maximum when the denominator of eq. (1) is minimum i.e.

$$\frac{d}{dI_L}\left(\frac{I_L R_a}{V} + \frac{W_c}{VI_L}\right) = 0$$

$$\frac{R_a}{V} - \frac{W_c}{VI_L^2} = 0$$

$$\frac{R_a}{V} = \frac{W_c}{VI_L^2}.$$

$$I_L^2 R_a = W_c$$

i.e, **Variable loss = Constant loss** $\quad \because I_L \approx I_a$

Problems :- A shunt generator supplies 96A at a terminal voltage of 200 volts. The armature and shunt field resistances are 0.1 Ω and 50 Ω respectively. The iron and frictional losses are 2500 W. Find (i) Emf generated (ii) cu losses (iii) Commercial η.

Sol :- (i) $I_{sh} = 200/50 = 4A$.

$I_a = I_L + I_{sh} = 96 + 4 = 100A$.

$E_g = V + I_a R_a = 200 + 100 \times 0.1 = 210V$.

(ii) Armature cu loss $= I_a^2 R_a$

$= (100)^2 \times 0.1 = 1000 W$.

Shunt cu loss $= I_{sh}^2 R_{sh}$

$= (4)^2 \times 50 = 800 W$.

Total cu loss $= 1000 + 800 = 1800 W$.

(iii) Total losses = stray losses + cu losses

$= 2500 + 1800 = 4300 W$.

o/p power $= 96 \times 200 = 19200 W$

i/p power $= 19200 + 4300 = 23500 W$.

$\therefore \eta = \frac{19200}{23500} \times 100\% = 81.7\%$

Problem :- The shunt generator delivers full load current of 200A at 240V. The shunt field resistance is 60 Ω and full-load efficiency is 90%. The stray losses are 800 W. Find (i) armature resistance (ii) current at which maximum efficiency occurs.

Sol :- Generator o/p $= 240 \times 200 = 48000 W$.

" i/p $= 48000/0.9 = 53333 W$.

Total losses $= 53333 - 48000 = 5333 W$.

Shunt field current, $I_{sh} = 240/60 = 4 A$.

Armature Current, $I_a = 200 + 4 = 204 A$.

Shunt cu loss = $I_{sh}^2 R_{sh} = (4)^2 \times 60 = 960\,W$

Constant losses = stray losses + shunt cu loss

= ~~5333 - 1760~~

= 800 + 960 18

= 1760 W.

∴ Arm. cu loss = Total losses − Constant losses

= 5333 − 1760 = 3573 W.

i.e. $I_a^2 R_a = 3573$.

$R_a = 3573/(204)^2 = 0.0858\,\Omega$

(ii) For max. efficiency, the condition is :

Variable losses = Constant losses.

$I_L^2 R_a = 1760$

$\therefore I_L = \sqrt{\frac{1760}{0.0858}} = 143.22\,A.$

Problem :- A 75 KW shunt generator is operated at 230V. The stray losses are 1810 W and shunt field circuit draws 5.35 A. The armature circuit has a resistance of 0.035 Ω and brush drop is 2.2V. Calculate (i) total losses (ii) i/p of prime mover (iii) efficiency at rated load.

Sol :- (i) load current, $I_L = 75 \times 10^3/230 = 326.1\,A.$

Arm. current, $I_a = I_L + I_{sh} = 326.1 + 5.35 = 331.5\,A$

Arm. cu loss = $I_a^2 R_a = (331.5)^2 \times 0.035 = 3846\,W.$

Shunt cu loss = $V I_{sh} = 230 \times 5.35 = 1230\,W.$

Brush power loss = Brush drop × I_a = 2.2 × 331.5 = 729 W.

∴ Total losses = 1810 + 3846 + 1230 + 729

= 7615 W.

(ii) o/p power = 75 KW = 75000 W

i/p of prime mover = 75000 + 7615 = 82615 W

(iii) $\eta = \frac{75000}{82615} \times 100 = 90.8\%$

D.C. Generator characteristics :-

There are three important characteristics of any dc generator.
They are :

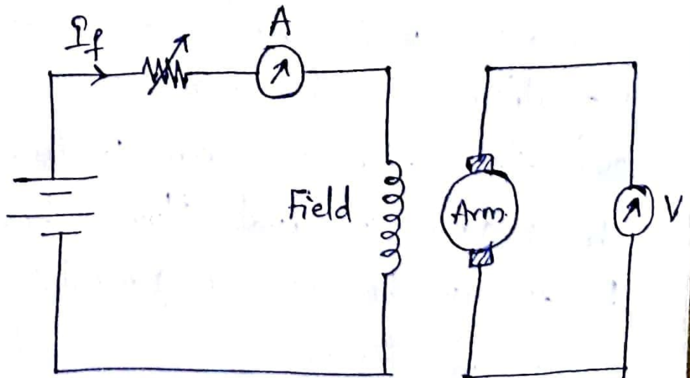
① **The open circuit characteristic (O.C.C) :-**
Sometimes OCC is also known as the no-load magnetisation characteristic. It gives the relation between the generated emf on no-load and the field current when the machine is driven at its rated speed.

② **The external characteristic or the load characteristic :-**
It gives the relation between the terminal voltage across the armature and the load current when the machine is driven at its rated speed.

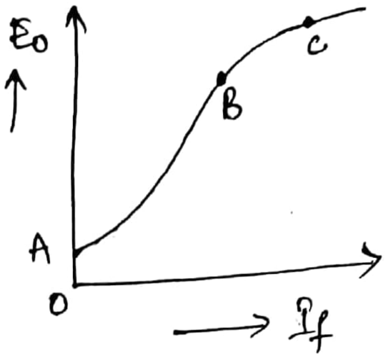
③ **The internal characteristic :-**
It gives the relation between the generated emf with load and the load current when the machine is run at its rated speed.

Characteristics of a seperately Excited Generator :-

The field winding of the d.c generator is disconnected from the machine and is seperately excited from an external d.c. source as shown.



The generator is run at fixed speed. The field current (I_f) is increased from zero in steps & the corresponding values of generated emf (E_o) read off on a voltmeter connected across the armature terminals. On plotting the relation between E_o & I_f, we get OCC as shown,



The following points may be noted from O.C.C:

(i) When the field current is zero, there is some generated emf OA. This is due to the residual magnetism in the field poles.

(ii) Over a wide range of field current (upto point B), 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 has 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.

Generator Build-up :-

Consider a shunt generator. If the generator is run at a constant speed, some emf will be generated due to residual magnetism in the main poles. This small emf circulates a field current which in turn produces additional flux to that of the original residual flux. This process continues and the generator builds up the normal generated voltage following the OCC as shown in fig.(i).

The field resistance R_f can be represented by a straight line passing through the origin as shown in fig (ii). The two curves can be shown on the same diagram as they have the same ordinates in fig. (iii).

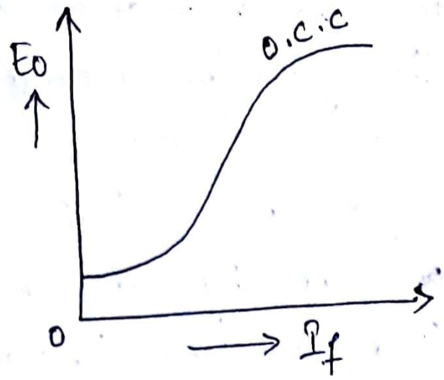


fig: (i)

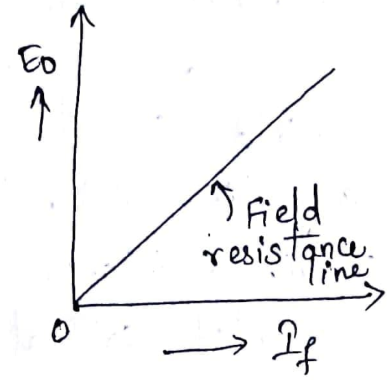
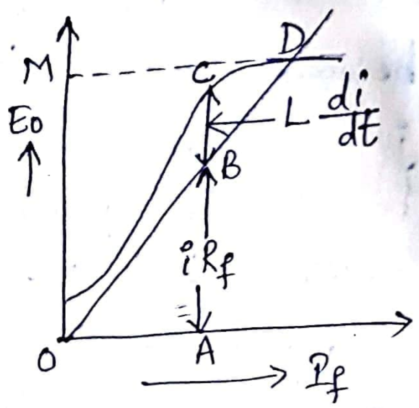


fig: (ii)



Since the field current is inductive, there is a delay in the increase in current upon closing the field circuit switch. At any instant, the field current is i (= OA) and is increasing at the rate di/dt.

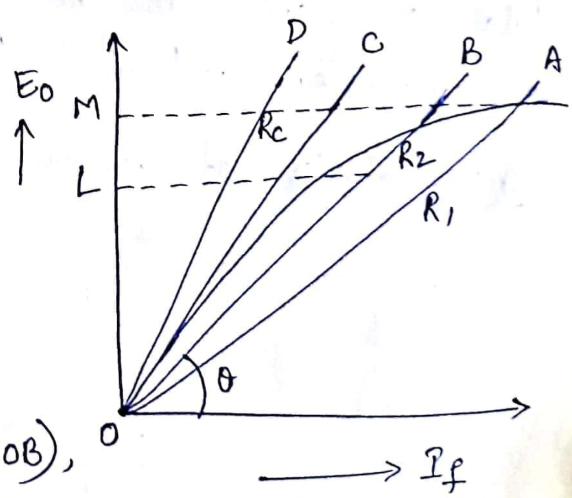
Then, $E_0 = iR_f + L\frac{di}{dt}$ where R_f = total field circuit resistance

L = inductance of field circuit.

The voltage build up of the generator is given by the point of intersection of o.c.c and field resistance line. Thus, D is point of intersection of the two curves. Hence, the generator will build up a voltage OM.

Critical field resistance for a shunt Generator :-

The voltage build up in a shunt generator depends upon field circuit resistance. If the field circuit resistance R_1 (line OA), then generator will build up a voltage OM as shown. If the field circuit resistance is increased to R_2 (line OB), the generator will build up a voltage OL, sligtly less than OM. As the field circuit resistance is increased, the slope of

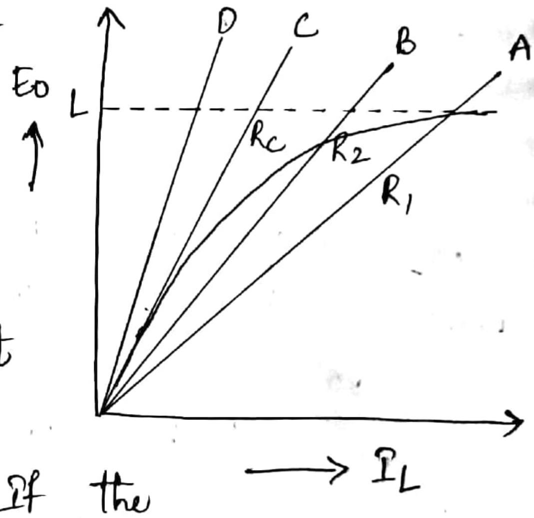


resistance line also increases. When the field resistance line becomes tangent (line OC) to O.C.C., the generator would just excite. If the field circuit resistance is increased beyond this point (say line OD), the generator will fail to excite. The field circuit resistance represented by line OC (tangent to O.C.C) is called critical field resistance R_c for the shunt generator. 22

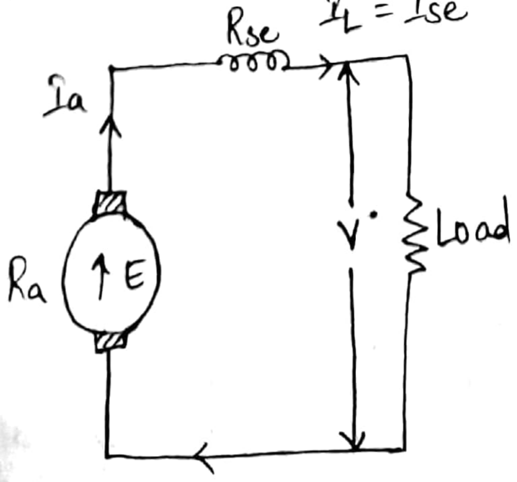
The maximum field circuit resistance (for a given speed) with which the shunt generator would just excite is known as its critical field resistances.

Critical Resistance for a Series Generator :-

Fig. shows the voltage build up in a series generator. Here R_1, R_2, etc. represent the total circuit resistance. If the total circuit resistance is R_1, then series generator will build up a voltage OL. The line OC is tangent to O.C.C and represents the critical resistance R_c for a series generator. If the total resistance of the circuit is more than R_c, (line OD), the generator will fail to buildup voltage.



Characteristics of Series Generator :-



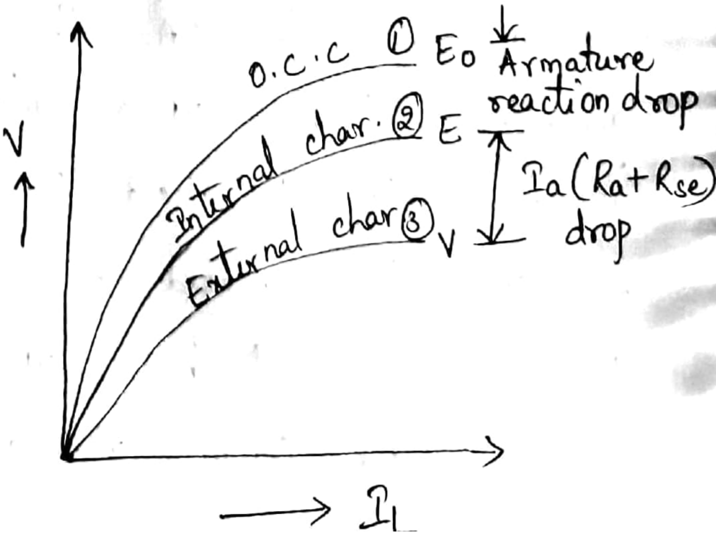


Figure shows the connections of a series wound generator. Since there is only one current, the load current is the same as the exciting current.

(i) <u>O.C.C:</u> Curve ① shows the open circuit characteristics of a series generator. It can be obtained experimentally by disconnecting the field winding from the machine and exciting it from a seperate d.c source.

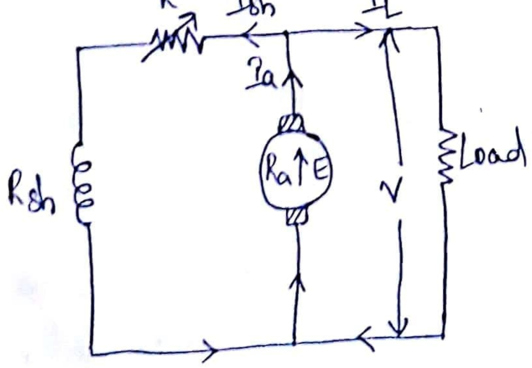
(ii) <u>Internal characteristic:-</u> curve ② shows the total or internal characteristic of a series generator. It gives the relation between the generated emf E on load and armature current. Due to armature reaction, the flux in the machine will be less than the flux at no load. Hence, emf E generated under load conditions will be less than the emf 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.

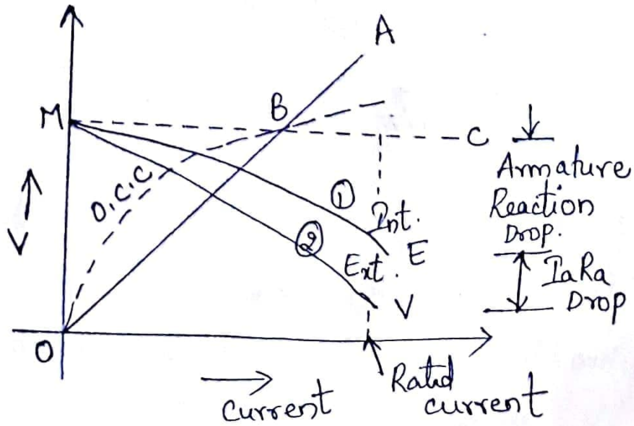
(iii) <u>External characteristic:</u> Curve ③ shows the external characteristic of a series generator. It gives the relation between terminal voltage V and load current I_L.

$$V = E - I_a(R_a + R_{se}).$$

Therefore, external characteristic curve will lie below internal characteristic curve by an amount equal to ohmic drop.

<u>Characteristics of a Shunt Generator:-</u>





(i) O.C.C :- The O.C.C of a shunt generator is similar in shape to that of a series generator. 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.

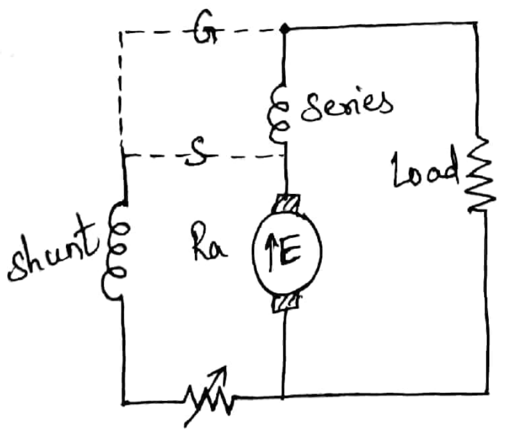
(ii) Internal characteristic :- When the generator is loaded, flux per pole is reduced due to armature reaction. Therefore, emf E generated on load is less than the emf generated at no load.

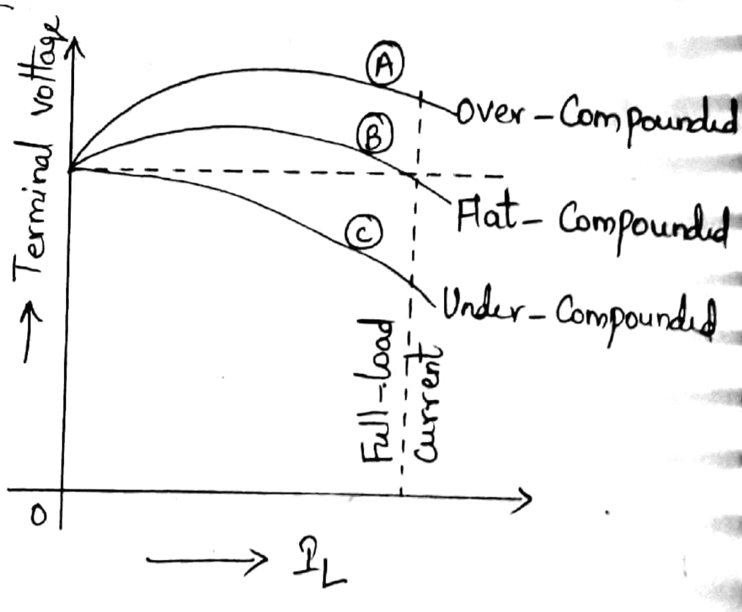
(iii) External characteristic :- Curve ② shows the external characteristic of a shunt generator. It gives the relation between terminal voltage V and load current I_L.

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

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

Compound Generator characteristics :-





In a compound generator, both series and shunt excitations are combined as shown. The shunt winding can be connected either

Figure shows the connections of a series wound generator. Since there is only one current, the load current is the same as the exciting current.

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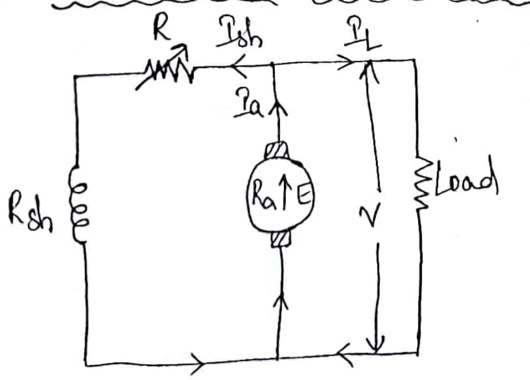
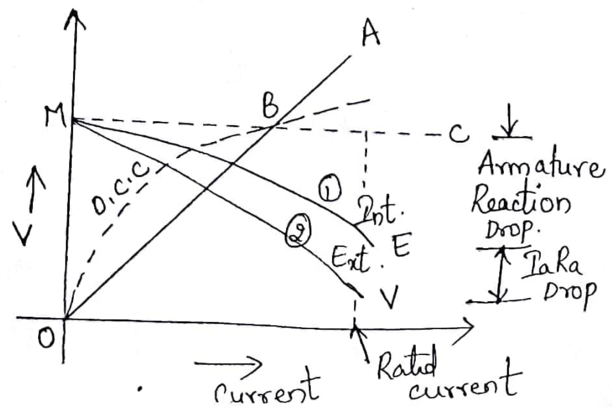
Characteristics of a Shunt Generator :-





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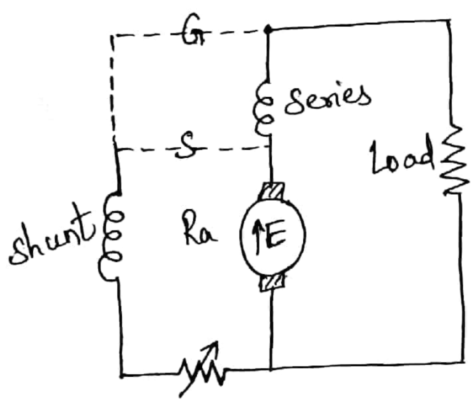

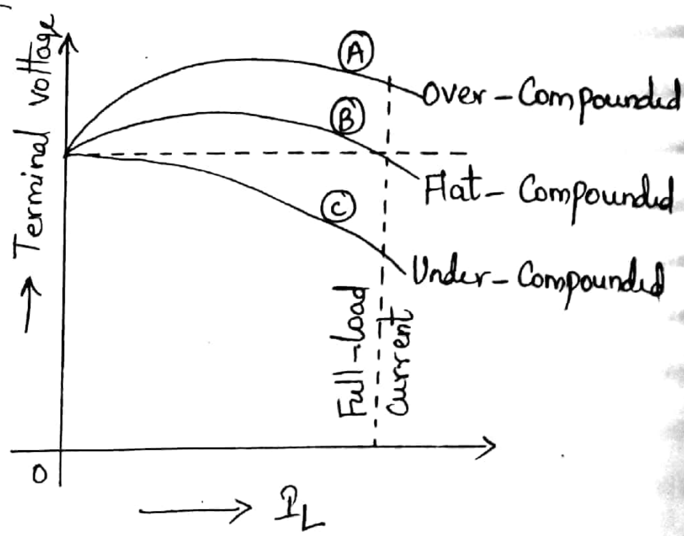

In a compound generator, both series and shunt excitations are combined as shown. The shunt winding can be connected either across the armature only (short - shunt Connection S) or across armature plus series field (long - shunt connection G). The External characteristics of long & short shunt generators are almost identical.

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<u>External characteristic</u> : The series Excitation aids the shunt excitation. The degree of compounding 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 <u>over - compounded generator</u>. The increase in generated voltage is greater than the $I_a R_a$ drop so that instead of decreasing, the terminal voltage increases as shown by curve A.

(ii) If series winding turns are so adjusted that with the increase in load current, the terminal voltage remains constant, it is called <u>flat - compounded generator</u>. The full-load voltage is nearly equal to the no- load voltage as indicated by curve B.

(iii) If series winding has lesser no. of turns than that for a flat - compounded machine, the terminal voltage falls with increase in load current as indicated by curve C. Such a machine is called <u>under - Compounded generator</u>.