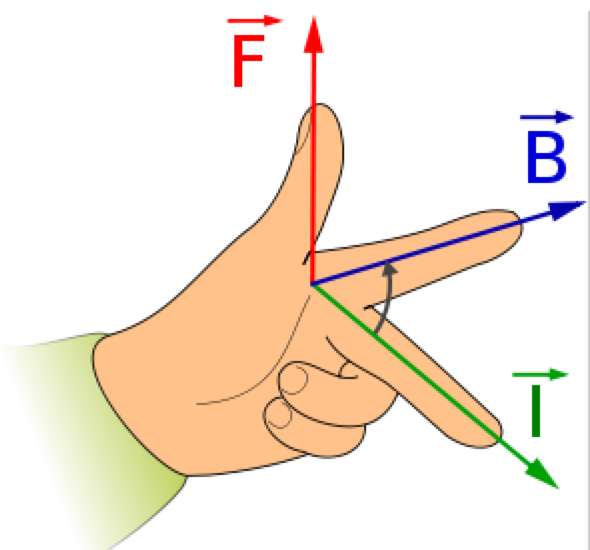
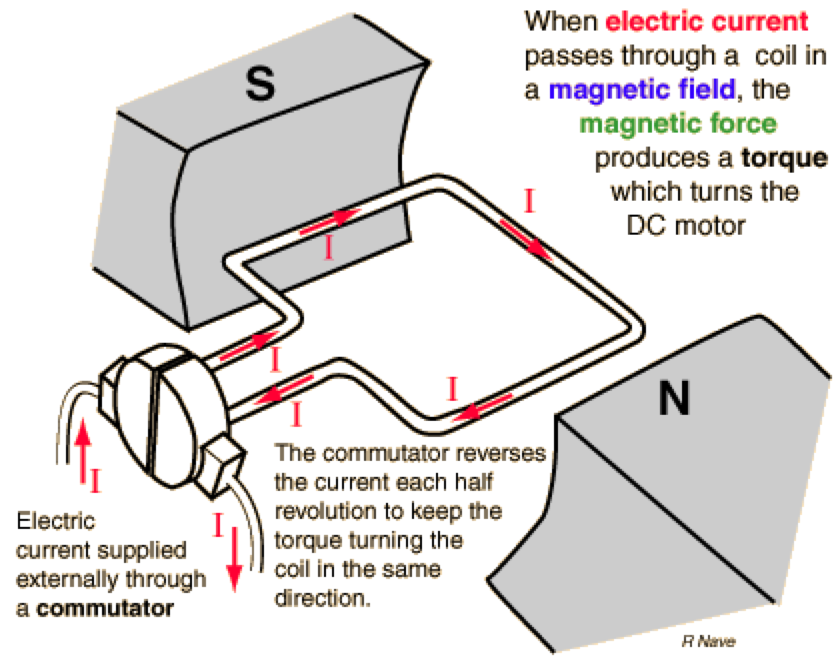
DC MOTORS

Principle Of Operation

- If a conductor carrying current is placed in a magnetic field force acts on the conductor ie. F=Bi/ Newton.

- Motors works on Fleming's left hand rule.





- When the field winding is excited and its armature conductors are supplied with current, they experience a force tending to rotate the armature.

- By applying Fleming's left hand rule, the direction of the force on each conductors can be found out.

- It will be seen that each conductor experience a force which tends to rotate the armature in anticlockwise direction.

- These forces collectively produce a driving torque which sets the armature rotating.

Principle of Energy conversion

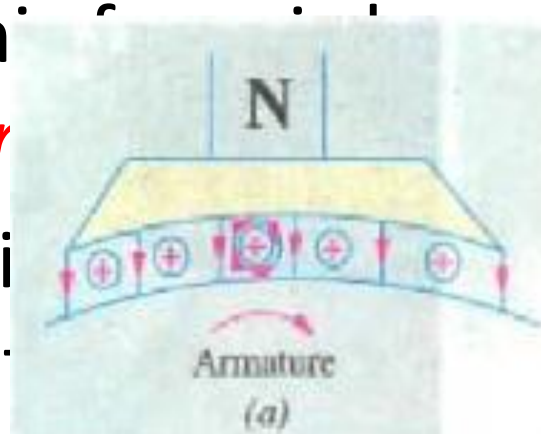
- *"Energy can neither be created nor it can be destroyed it can only be converted from one form to another."*

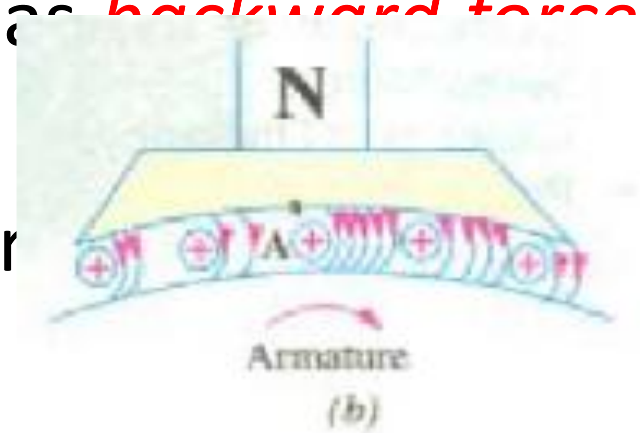
AND

- *" Energy conversion is possible only if there is some opposition whose overcoming provides the necessary means for such conversion".*

Back EMF & Its Significance:

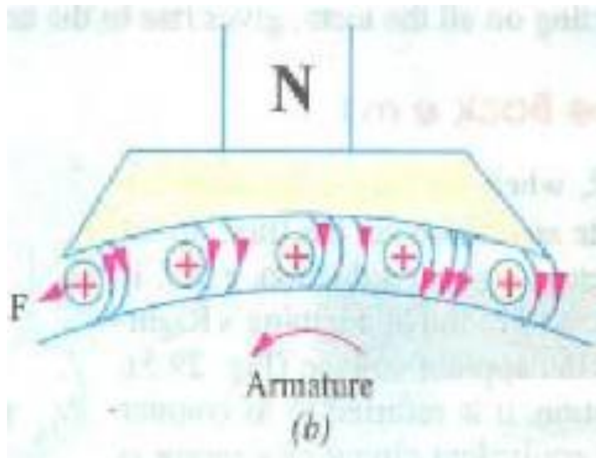
- Fig (a) represents the field setup independently by the main poles and the armature conductors like 'A' in the fig.
- These magnetic flux lines will produce a force in the direction opposite to that of armature conductors, thi n a *backward force or magnetic dr*





- It is against thi pr work in case o

- Now let us take the case of Motor:-
- Let us suppose that the prime mover is uncoupled from DC machine and current is sent through the armature as shown.



- The conductors will again experience a force in the anticlockwise direction (Fleming's left hand rule).
- Hence the machine will start rotating anticlockwise.

- As said above, energy conversion is not possible unless there is some opposition whose overcoming provides the necessary means for such conversion.

- In generator that opposing force was the magnetic drag, but whats the equivalent of that drag in motors???

It's the "BACK EMF"

- As soon as the armature starts rotating, dynamically induced emf is produced in the armature.
- The direction of this induced emf is in direct opposition to the applied voltage, that is why it is known as *Back Emf* and is denoted by

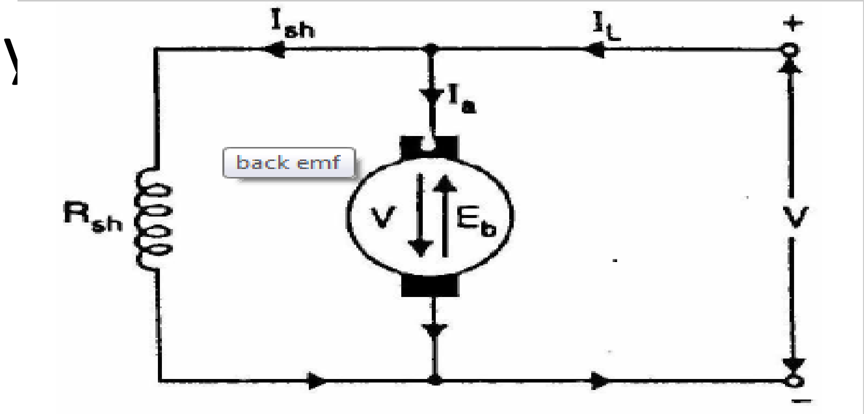


Fig. (4.2)

- The applied voltage 'V' has to force current through the armature against this back emf E_b.
- The electric work done in overcoming this opposition is converted into mechanical energy developed in the armature.

CHARACTERISTICS OF DC MOTORS

What does Characteristics means?

- The characteristic curves of a motor are those curves which shows relationships between the following quantities:-

1) Torque & armature current (Electrical Characteristics)

2) Speed & armature current.

3) Speed & Torque (Mechanical Characteristics)

Characteristics of Series Motor:-

- **Ta/Ia Characteristics:-**

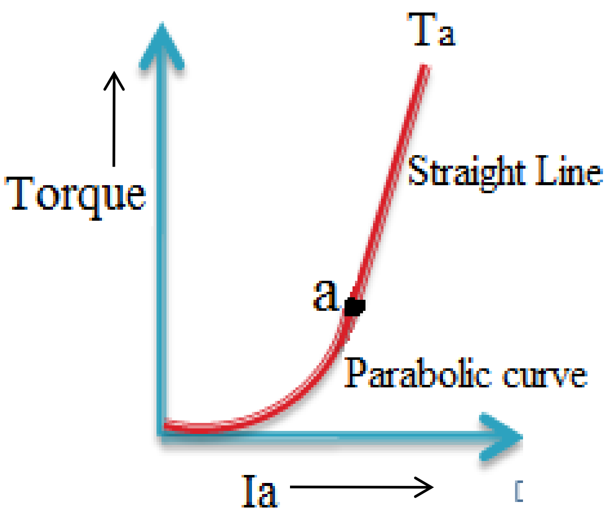
We know that for a series motor

$T_a \alpha \Phi.I_a$; and $\Phi \alpha I_a$ up to the point

Of magnetic saturation. Hence before

Magnetic saturation-

$$T_a \alpha \Phi.I_a \Rightarrow T \alpha (I_a)^2$$

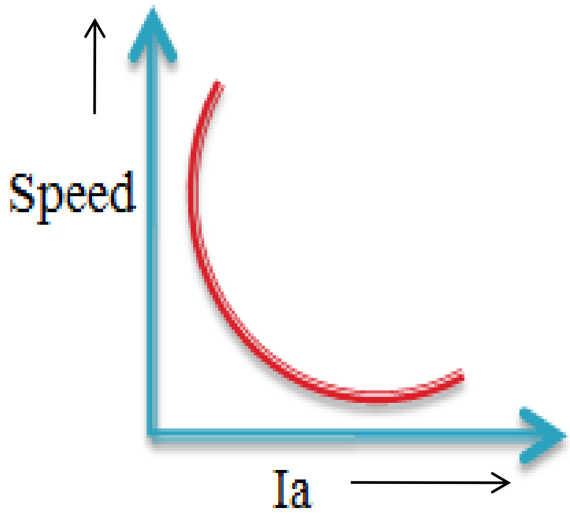


Hence torque varies as the square of the current. After saturation, Φ is almost constant, therefore it becames independent of I_a. Hence $T \alpha (I_a)$ only, so the characteristics is a straight line after point 'a'.

- **N/I_a Characteristics:-**

Variation of speed can be deduced from the formula-

$$N \alpha \frac{E_b}{\phi}$$

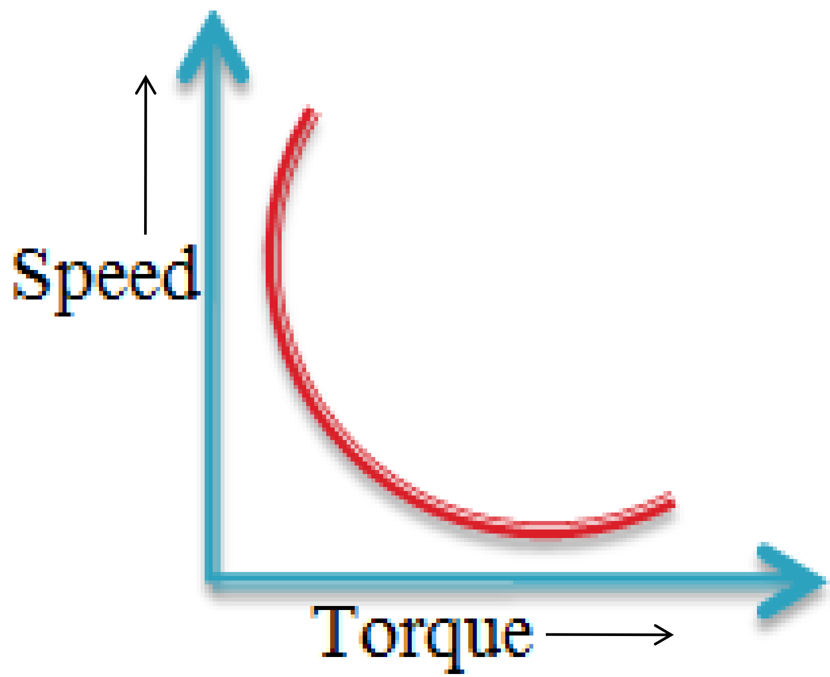


Change in 'E_b for various load currents is small and hence may be neglected. With increased I_a , 'Φ' also increases. Hence speed varies inversely as armature current as shown in fig. When load is heavy 'I_a' is large. Hence speed is low . But when load current and hence 'I_a' falls to a small value, speed becomes dangerously high.

- **N/T_a (Mechanical Characteristics):-**

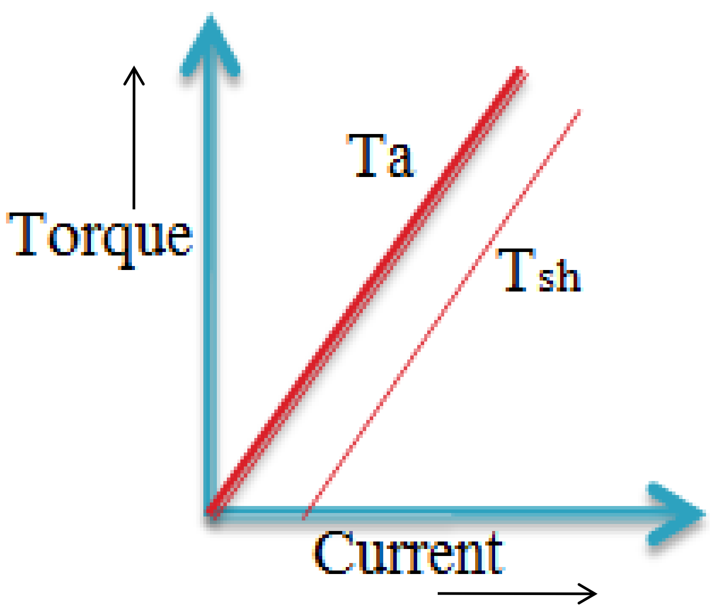
It is found from the above two curves that when Speed is high, torque is low and vice-versa. The relation

between the two is as shown.



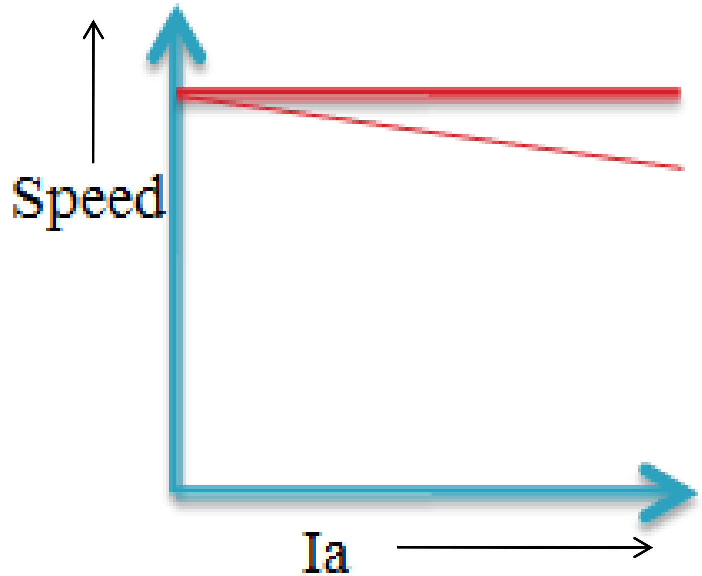
Characteristics of DC Shunt Motor:

- **Ta/Ia Characteristics:-**
- As in the case of shunt motor 'Φ' remains constant. Hence Assuming 'Φ' to be practically constant we find that T α (Ia). Hence the Characteristics is as shown.



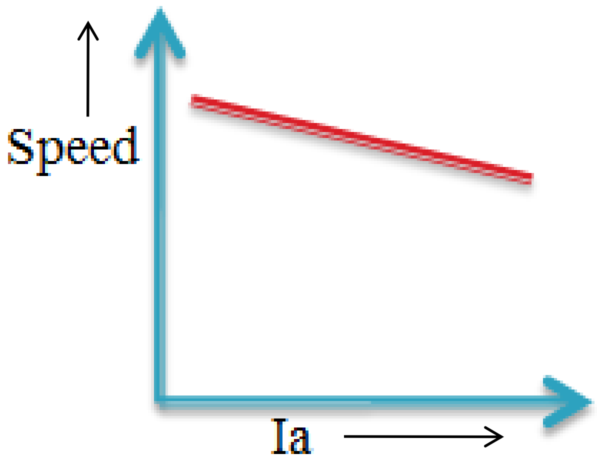
- **N/Ia Characteristics:-**

- If 'Φ' is assumed to be constant, then N α Eb. As 'Eb' is also practically constant, speed is for most purpose remains constant. But strictly speaking both 'Eb' and 'Φ' decreases with increasing load.



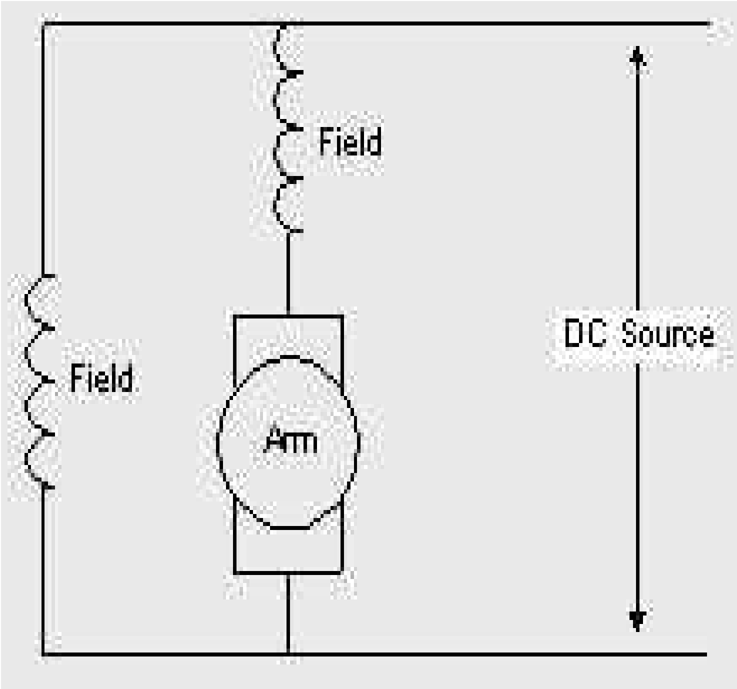
- **N/T_a Characteristics:-**

- The above characteristics can be deduced from (1) and (2) drawn above and is shown in fig below.

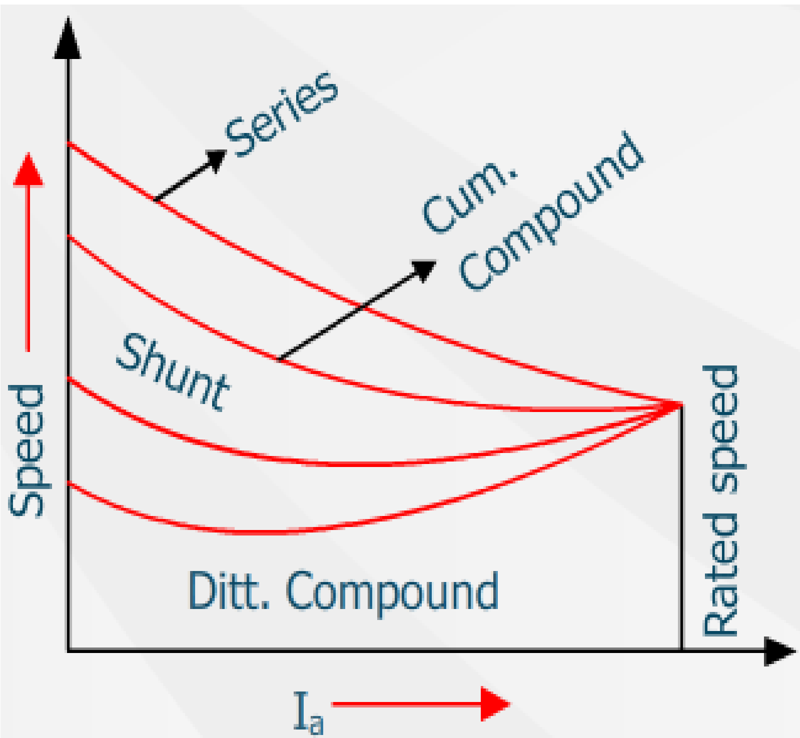


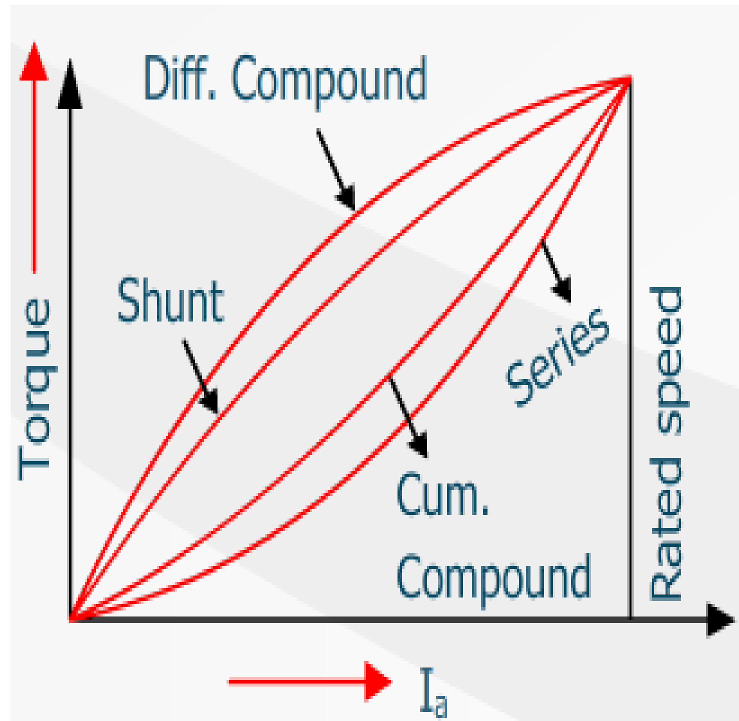
• Compound Motors:-

• These motors have both Series and shunt wdgs. If Series excitation helps the Shunt excitation ie. Fluxes is In the same direction then the Motor is said to be cumulative Compound. And if on the other Hand, series field opposes the Shunt field, then the motor is Said to be differentially compounded.



- The characteristics of such motors lie in between those of shunt and series motor as shown





Cumulative Compound Differential Compound

THANKS!!!

STARTING METHODS OF DC MOTOR

WHY DO WE NEED A STARTER??

- We know that the voltage equation of a DC motor is:-
- $$V = E_b + I_a.R_a$$
- If the above eqn. is rearranged in terms of current we have:-
- $$I_a = (V - E_b)/R_a$$
- At the time of starting the motor speed is zero as E_b is zero. (=ΦZNP/60A)
- With the rated applied voltage the starting armature current is therefore $$\frac{V_t}{R_a}$$

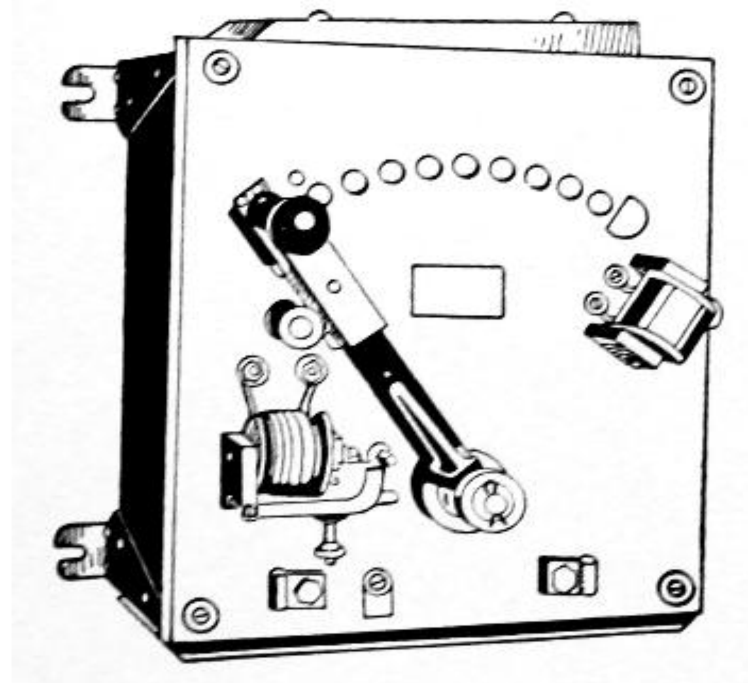
- Since the resistance R_a is much smaller the motor draws large starting armature current from the supply mains.

- Such a heavy inrush of starting current taken by the motor may result in:-

1) Detrimental sparking at the commutators.
2) Damage to the armature winding.
3) Deterioration of the insulation due to overheating.
4) Large dips in the supply voltage.

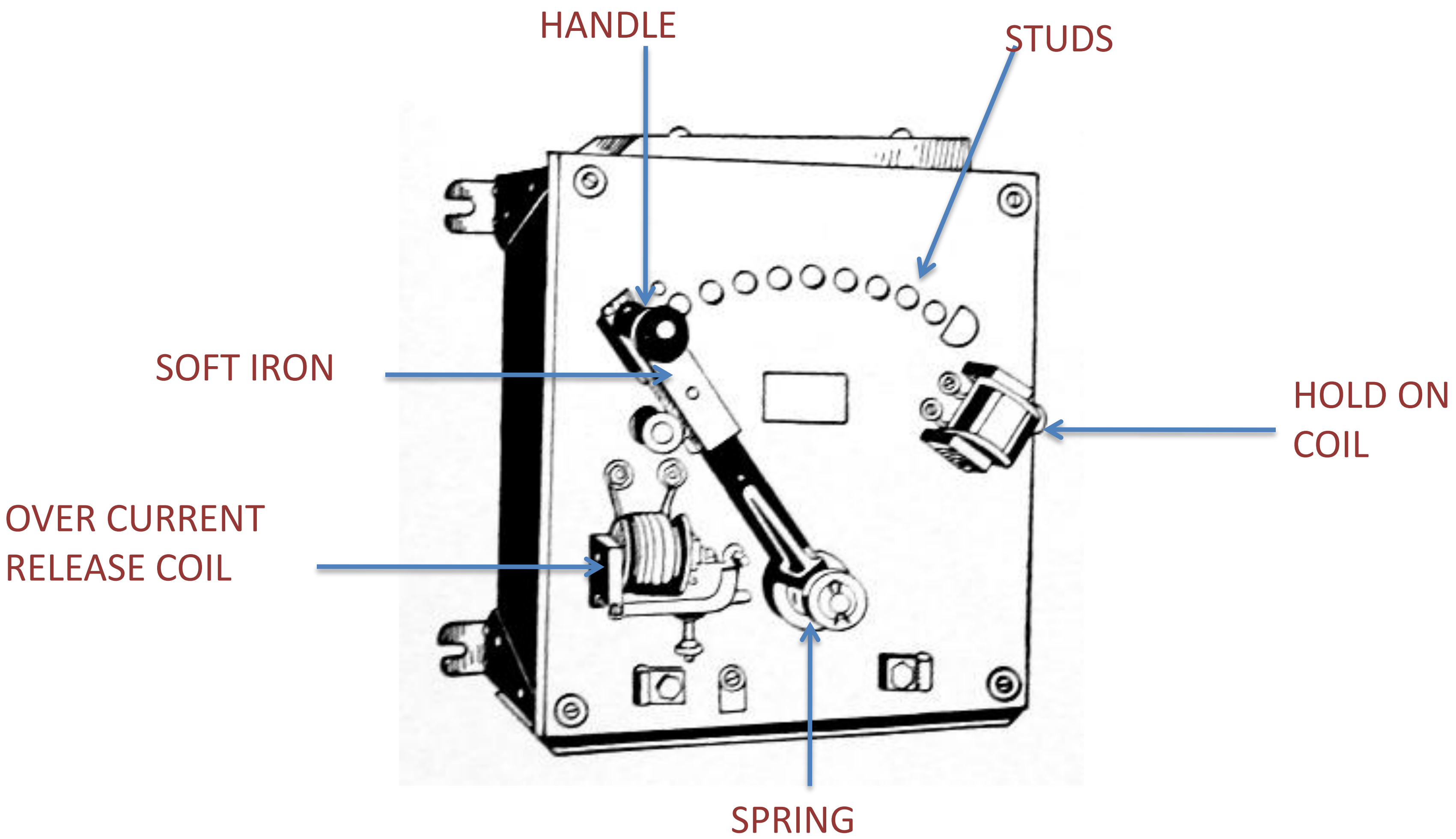
3Point Starters:-

- This is How the starter looks like:-



- OUTER VIEW INNER VIEW

- <u>Various Parts of a Starter:-</u>

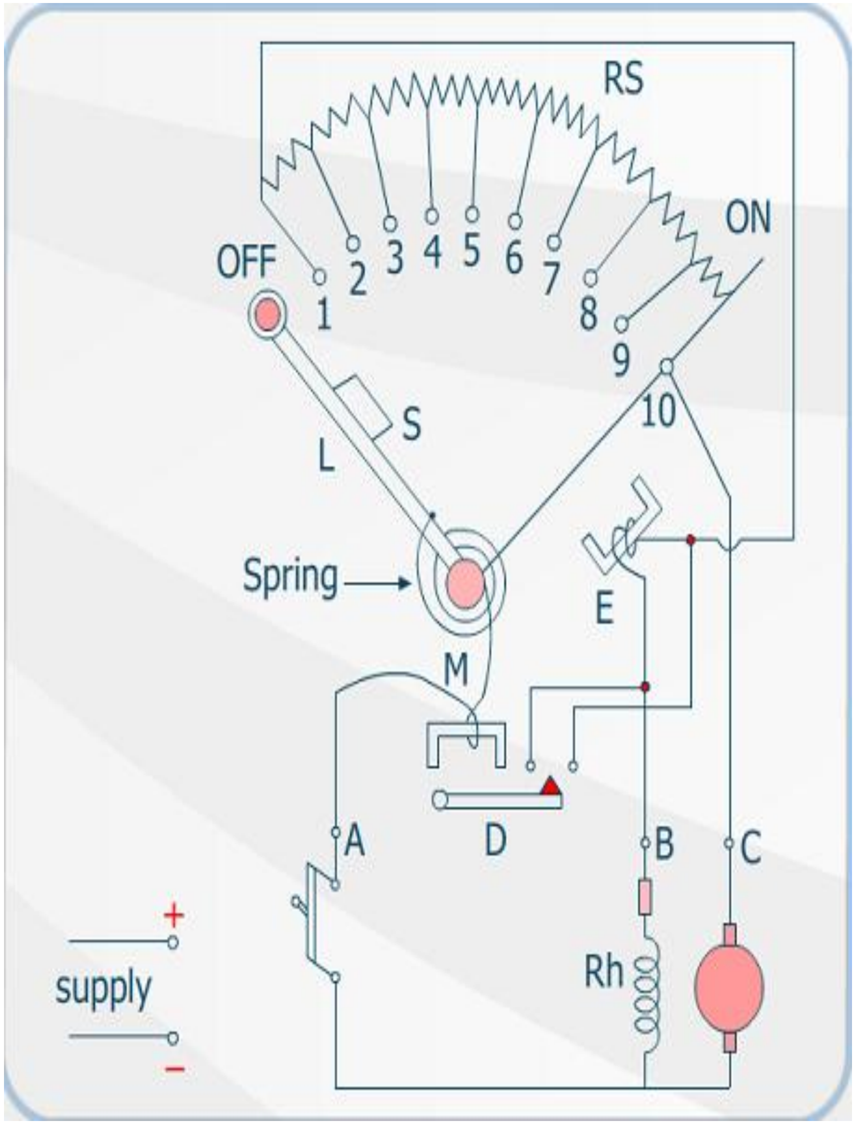


3 Point Starter:-

Fig shown is of 3point starter. The three terminals marked A,B,C.

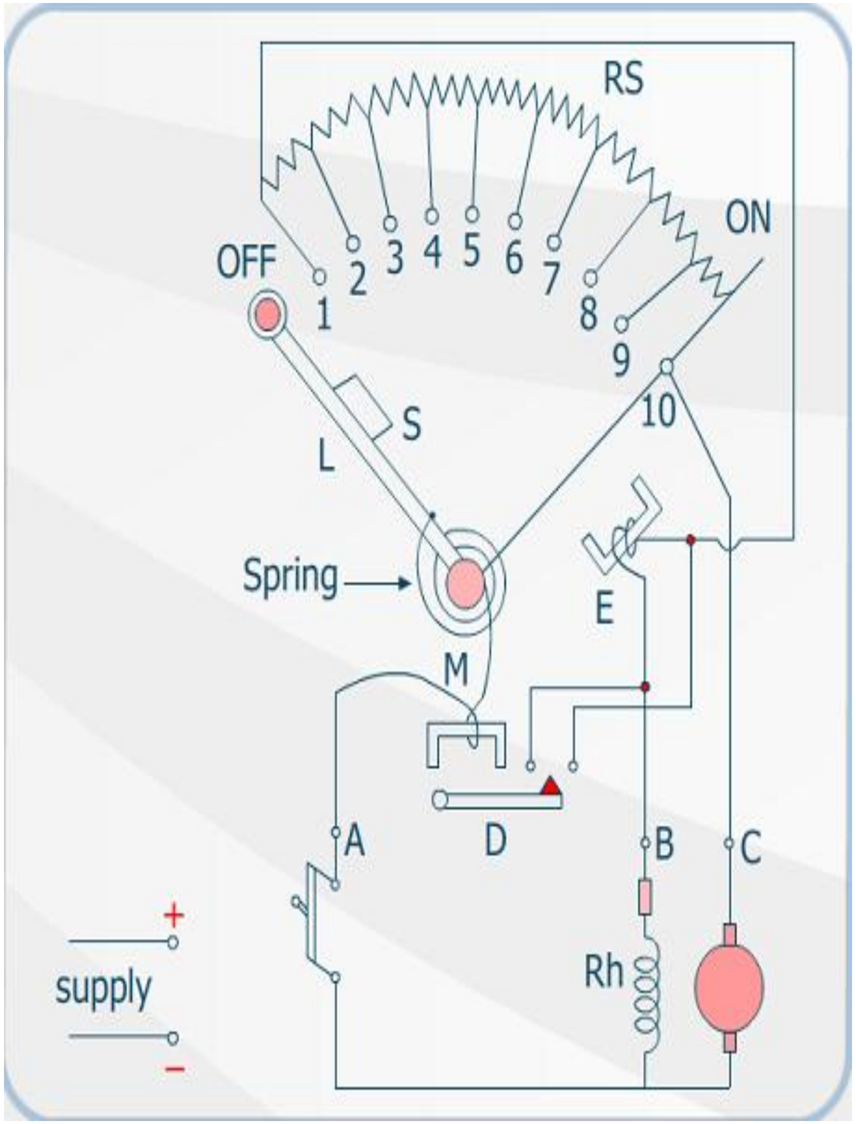
- One line is directly connected to one armature terminal & one field terminal which are tied together.

- The other line is connected to point A which is further connected to the starting arm 'L' through the over current release 'M'



- To start the motor the main switch is first closed and starting arm is slowly moved to the right.

- As soon as the arm make contact with stud 1, the field circuit is directly connected across the line and at the same time full starting resistance R is placed in series with the armature.



- The starting current drawn by the armature is

$$I=V/(Ra + Rs)$$

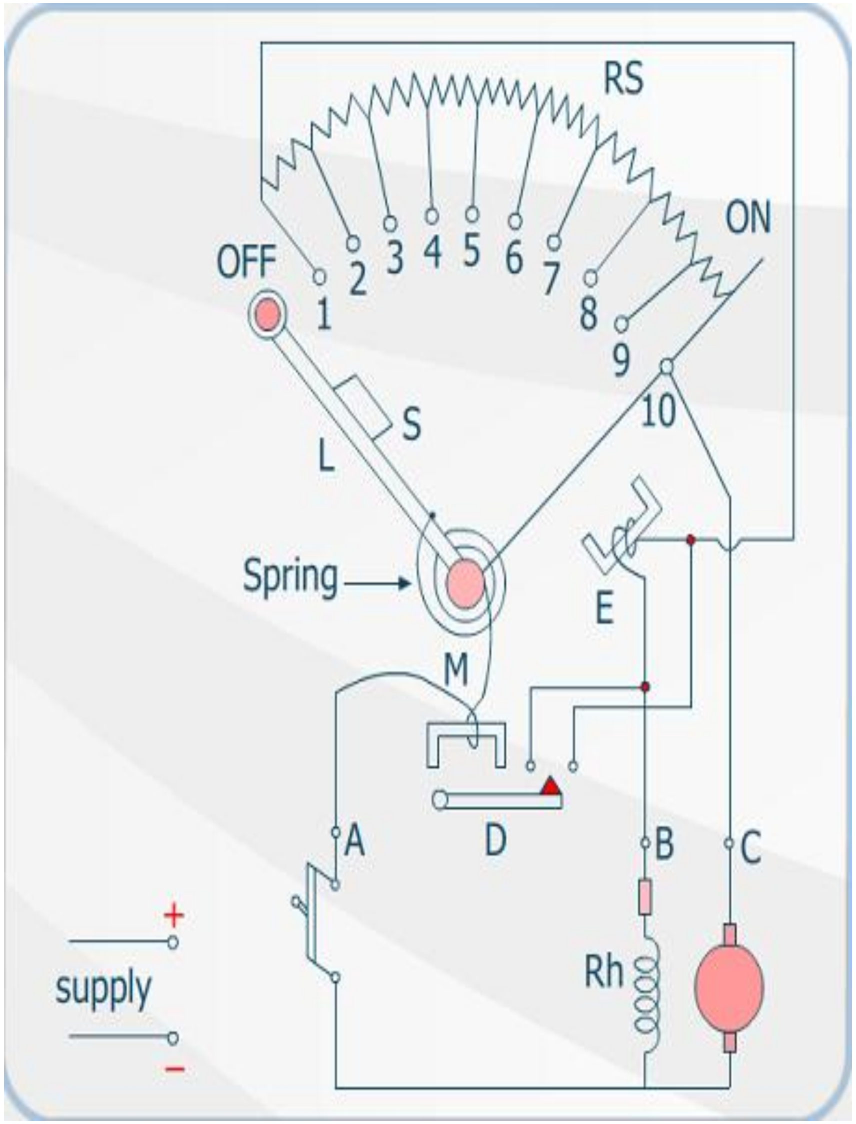
Where Rs is the starting resistance.

- As the arm is further moved, the starting resistance is gradually cut out till, when the arm reaches the running position, the resistance is all cut out.

- There is a soft iron piece *'S'* attached to the arm which in the full 'ON' or running position is attracted and held by an electromagnet *'E'* energised by the shunt current. It is variously known as **'HOLD ON'** coil, **'LOW VOLTAGE'** release.

- Now we will discuss the action of the two protective devices:-

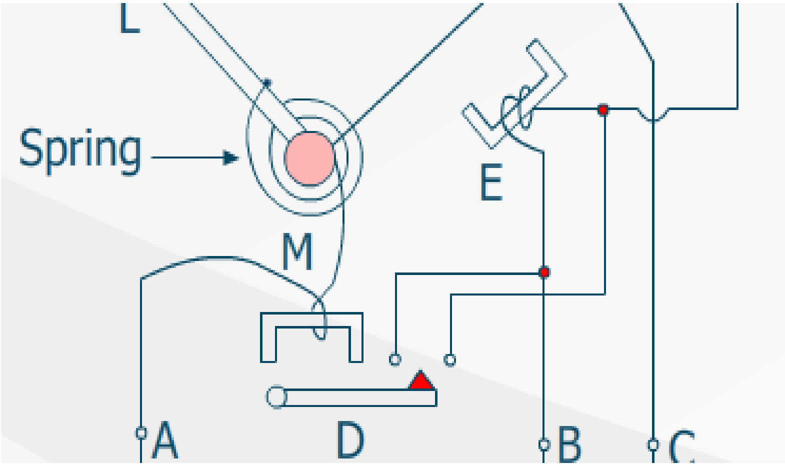
- **Hold ON :-** The normal action of this coil is to hold on the arm in the full running position. But in the case of failure of the supply, it is de-energised, thereby releasing the arm which pulled back by the spring to the 'OFF' position.



- One great advantage of connecting the Hold on coil in series with the shunt field is that, should the field circuit became open, the starting arm immediately springs back to the OFF position thereby preventing the motor from running away.

- **Over current release:-**

This consist of an electromagnet connected in the supply line. If the motor becomes overloaded beyond a predetermined value, then arm D is lifted & short circuits the electromagnet. Hence the arm is released back to OFF position.



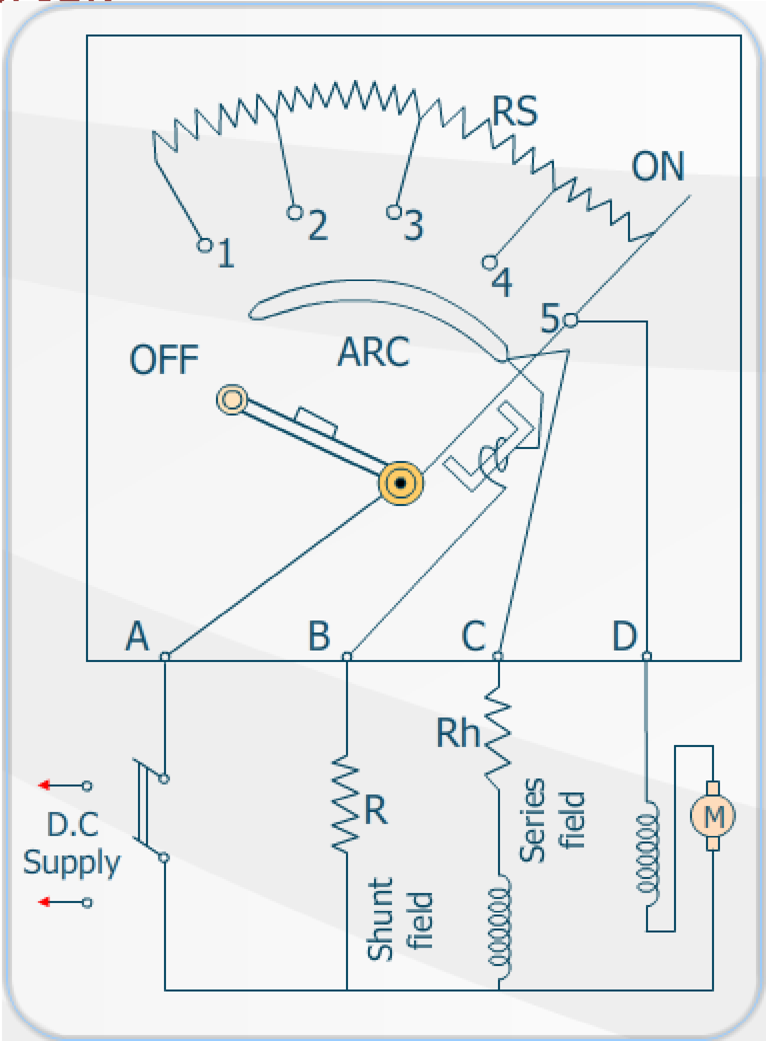
DISADVANTAGE:-

- In case of 3 point starter the field coil and the holding coil are in series.
- If the speed above the normal are to obtained the field current must be reduced .
- At certain value of reduced field current, the electromagnetic pull of the holding coil may became less than the spring force.
- In such case the starter handle returns to the OFF position and the motor stops working
- Thus a 3 point starter can’t be used where wide range of speed control by shunt field control is required.

4 POINT STARTER:-

- As the name suggests, it has four terminals (L,L,F,A).
- Working is same as that of the 3 point starter.

- When compared to the 3 point starter, it will be noticed that one important change has been made ie. The hold On coil has been taken out of shunt field and has been connected directly across the line through a protecting resistance as shown.



- When the armature touches Stud 1,the line current divides into three parts:
- (i) one part goes to the starting resistance Rs.
- (ii) The second part passes through the shunt field and its field resistance.
- (iii) Third part goes through the Hold-On coil and current protecting resistance R.

- With this arrangement any change of current in the shunt field circuit does not at all affect the current passing through Hold-On coil.

- Hence the desirable speed control can be easily attained.

SPEED CONTROL

- The term ‘*speed control*’ stands for intentional speed variation, carried out manually or automatically.

- The speed of a DC motor is given by:-

$$\omega_{m1} = \frac{V_t - I_a R_a}{K_a \Phi}$$

($E_b = K_a.\Phi.\omega_{m1}$)

- From the above eqn. we can make out that there are basically three methods of speed control and these are:-

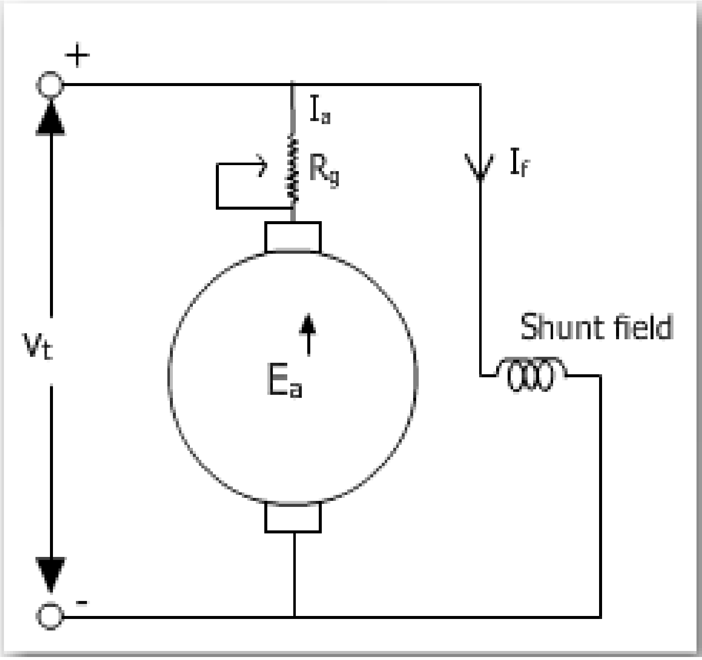
- The various methods for controlling the speed of DC motor are:-

a) Speed control by varying armature circuit resistance.

b) Speed control by varying the field flux.

c) Speed control by varying the terminal voltage (“*Ward-Leonard Method*”).

- <u>Speed control by varying armature ckt resistance:-</u>
- The scheme for the connection o



shunt motor is illustrated in the fig shown, where ‘R_g’ is the controlling resistance and is connected in serie with the armature circuit.

- When ‘R_g’ is not present then the Armature current Ia is given by:-

$$Ia_1 = \frac{V_t - K_a \phi \omega_{m1}}{R_a}$$

-----Eqn (1)

($E_b = K_a \Phi \omega_{m1}$)

- When Rg is inserted in the armature circuit and if it is assumed that there is no change in speed for the time being, then:-
- $$Ia_2 = \frac{V_t - K_a \phi \omega_{m1}}{R_a + R_g} = Ia_1 \frac{R_a}{R_a + R_g}$$ ----- Eqn(2)

- In shunt motor field flux Φ remains unchanged therefore with the reduction in armature current, torque T(α Φ .Ia) decreases and hence the back emf also decreases.

$$\omega_{m1} = \frac{V_t - Ia_1 Ra}{K_a \phi} = \frac{E_{a1}}{K_a \phi}$$

- From the above eqn(1).

- When new steady state condition is reached, with Rg in the armature circuit then from Eqn(2):-

$$\omega_{m2} = \frac{V_t - Ia_1(R_a + R_g)}{K_a\phi} = \frac{E_{a2}}{K_a\phi}$$

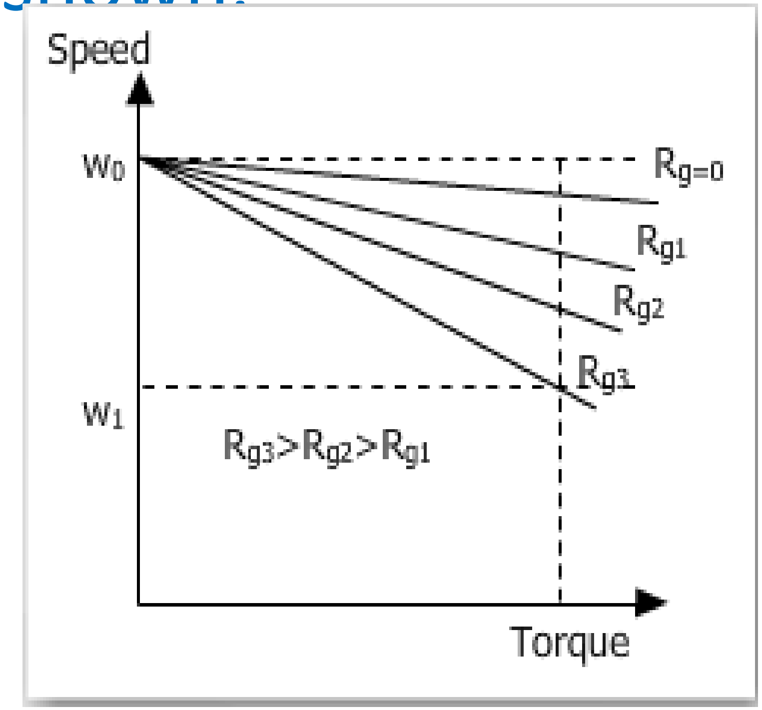
- Therefore

Eqn(a)

$$\frac{\omega_{m2}}{\omega_{m1}} = \frac{N_1}{N_2} = \frac{E_{a2}}{E_{a1}} = \frac{V_t - I_{a1}(R_a + R_g)}{V_t - I_{a1}R_a}$$ --

From the above equation (a) we can easily make out that the speed has decreased from its previous value.

- Hence we find that as we go on increasing the external resistance the speed-torque curve will vary as shown.

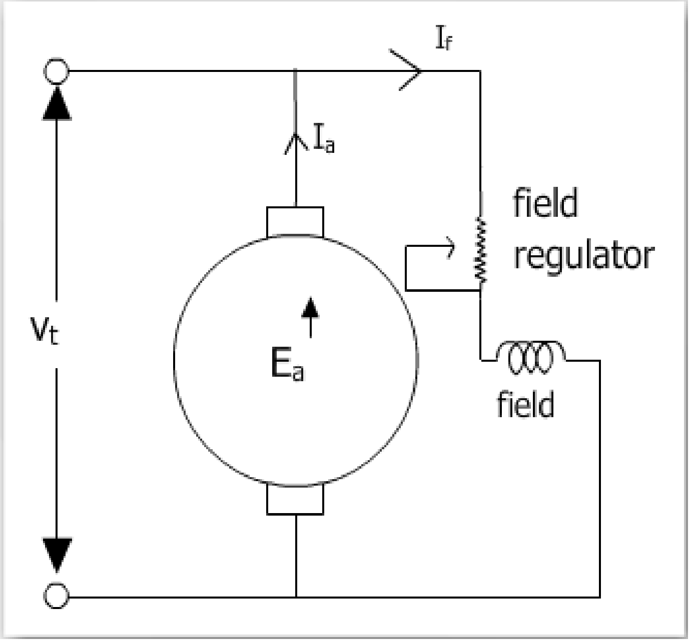


- <u>**Advantages:-**</u>
- The principal advantage of this method is that speed below base speed down to the creeping speed are easily obtainable.
- <u>**Disadvantages:-**</u>
- Lower Efficiency and higher operational cost at reduced speeds.
- Poor speed regulation with fixed controller resistance 'Rg' in the armature circuit.

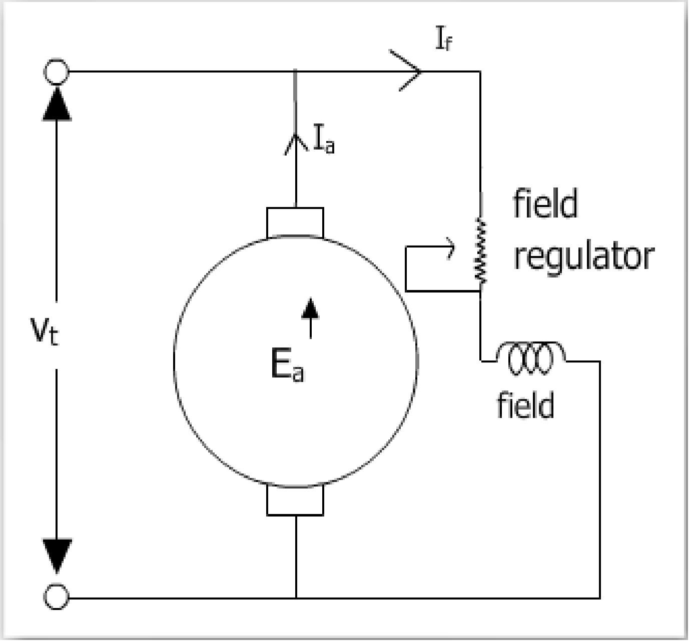
• Speed Control by Varying the field flux:-

- The field flux and hence the speed can be controlled easily by varying the field regulating resistance.

- This is one of the simplest and economical methods and is used extensively in modern electric drives.



- Under steady running conditions, if field circuit resistance is increased, the field current I_f & the field flux Φ are reduced.

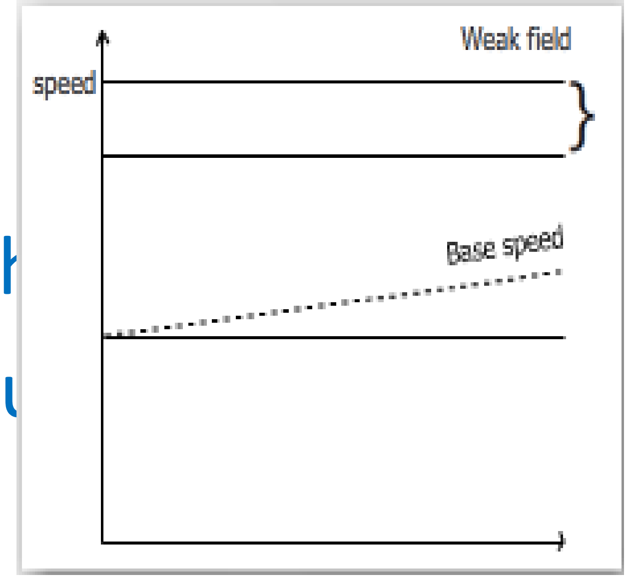


- Decrease in the field flux causes a reduction of counter emf. As a result more current flows through the armature. In view of this the electromagnetic torque is increased & became more then the load torque hence the motor gets accelerated.

- If armature current is Ia1 for flux Φ1 and Ia2 for flux Φ2, then for a constant load torque:-

$$Ia_1 = \frac{T_e(=T_L)}{K_a\phi_1} \Rightarrow \omega_1 = \frac{V_t - I_{a1}R_a}{K_a\phi_1}$$

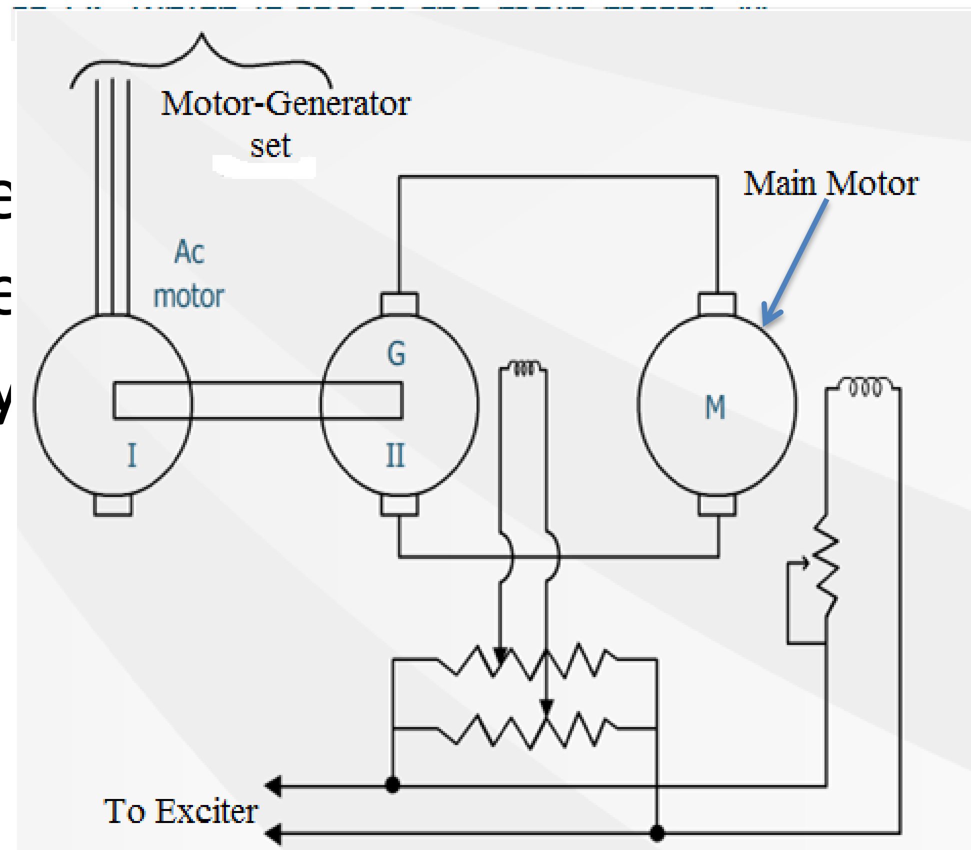
$$Ia_2 = \frac{T_e(=T_L)}{K_a\phi_2} \Rightarrow \omega_2 = \frac{V_t - I_{a2}R_a}{K_a\phi_2}$$



- The above two eqn's describe th change in speed and armature cu as the field flux is varied.

WARD-LEONARD SYSTEM

- In the fig. shown, ‘M’ is a separately excited DC Motor whose speed is to be controlled and G is separate excited generator driven by 3-phase (Induction Motor).

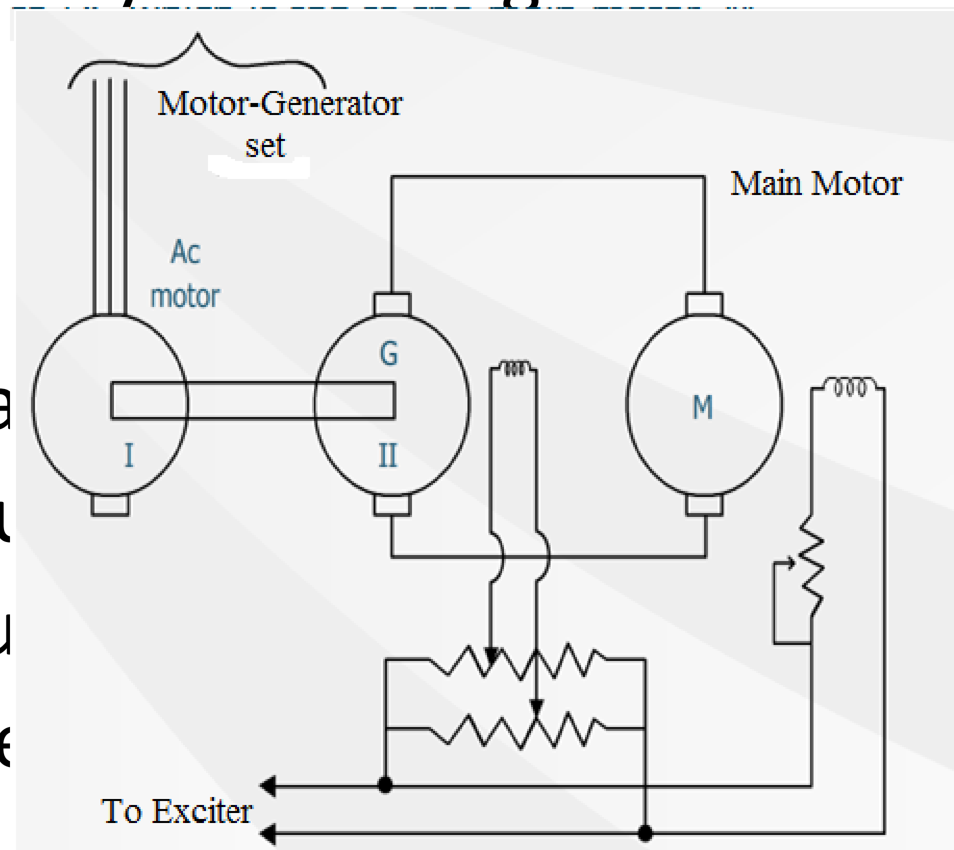


- The combination of AC motor & DC generator is called Motor-Generator set

It converts AC to DC which is fed to main motor ‘M’.

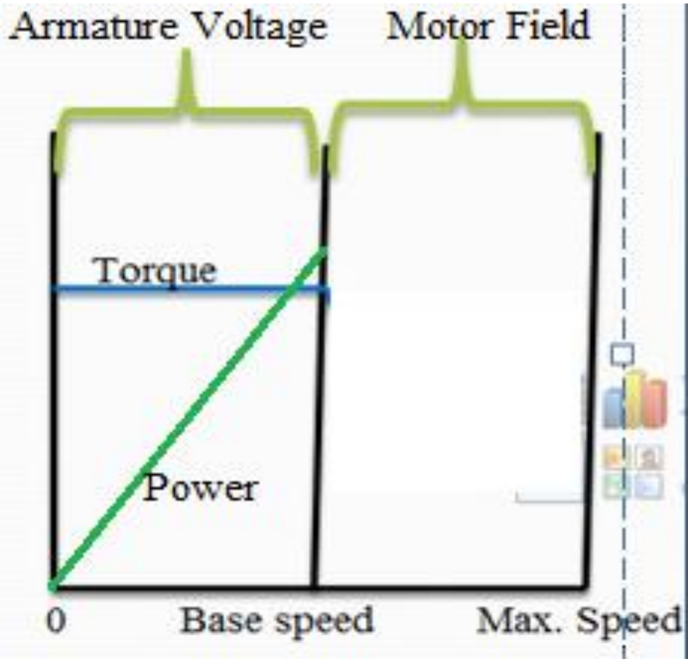
- For starting the motor 'M', its field winding is first energized and then the generator output voltage is adjusted to a low value by decreasing its field excitation.

- This is done in order to l
the starting current to a sa
value but it should be ensu
that enough starting torqu
produced to accelerate the
Motor & load.



- In view of this, no starting rheostats are necessary and therefore, considerable amount of energy is saved during starting.
- A change in the generator field current varies the voltage applied to the motor armature and therefore the motor speed is changed.
- Thus the motor speed control is obtained merely by changing the generator field current.

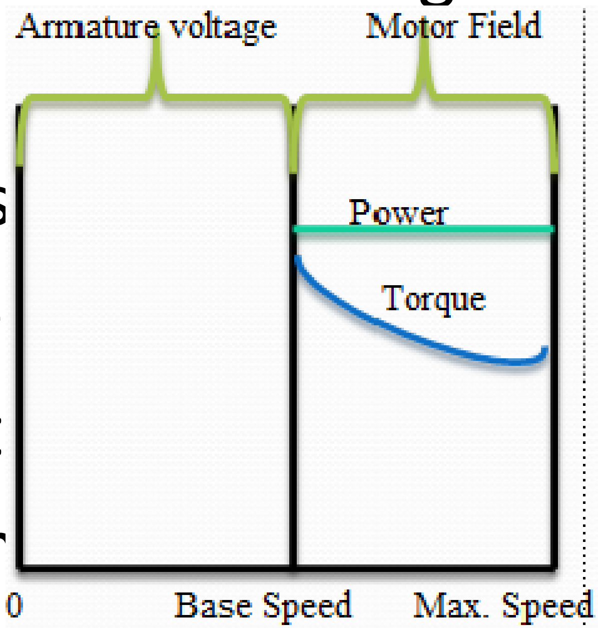
- Speed from the lowest possible speed up to the base speed are obtained by increasing the generator output voltage with constant motor flux.



- Since speed control is carried out at rated current ‘Ia’ and with constant motor field flux ‘Φ’, a constant torque (Φ. Ia) up to the base speed is obtained.

- Power(Torque*Speed) increases in proportion to speed. Thus a constant torque and variable power drive is obtained up to the base speed with “armature voltage control method”.

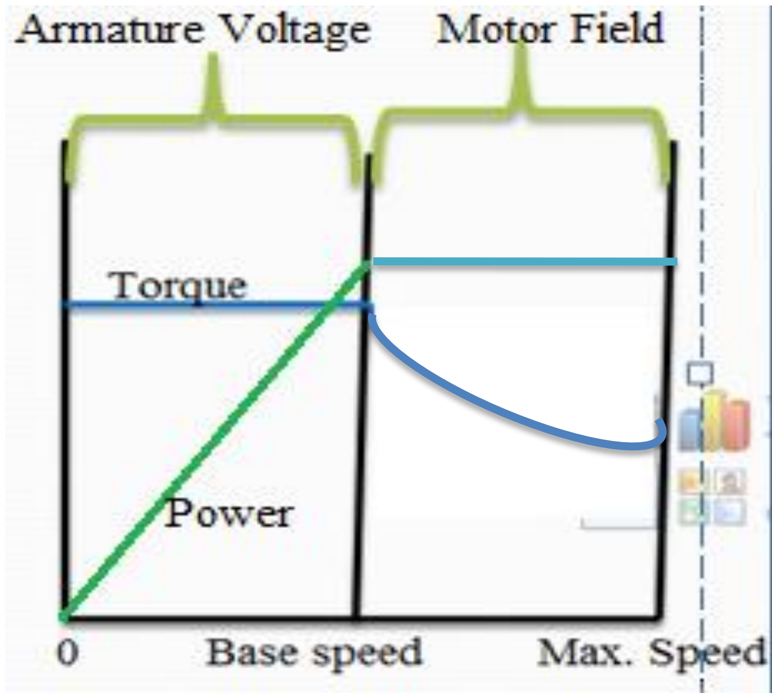
- Speed above base speed are obtained by decreasing the motor field flux with constant generator voltage.



- As before the armature current 'Ia' is kept equal to its rated value, under the conditions, Vt.Ia or Ea.Ia remains const and electromagnetic torque proportior to (Φ. Ia) decreases as the flux is decreased

- Thus weakening of the motor field flux results in constant power.

- The combined graph of both the methods of speed control is shown as below:-



- ***Advantages:-***
- It provides wide range and smooth speed control.
- The direction of main motor rotation can be changed merely by reversing the generator field current.
- The efficiency at low speeds is higher than that obtained by other methods of speed control.
- ***Disadvantage:-***
- The only disadvantage of this method is its higher initial cost, because 3 machines of equal ratings are required.