

DC Generator

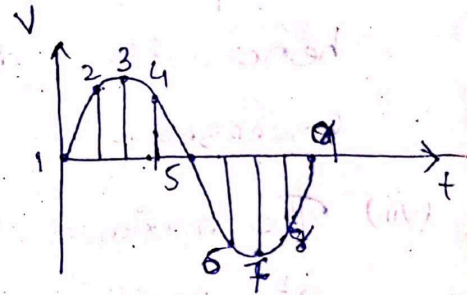
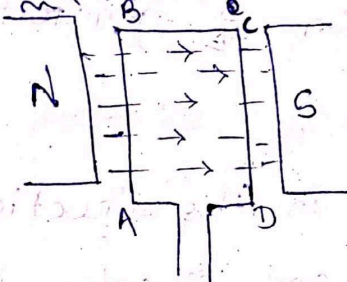
Definition:-

→ Electrical Generator is a machine that convert mechanical energy into electrical energy.

→ An electrical generator is based on the principle, that whenever a flux is cut by a moving conductor emf is induced at its two end.

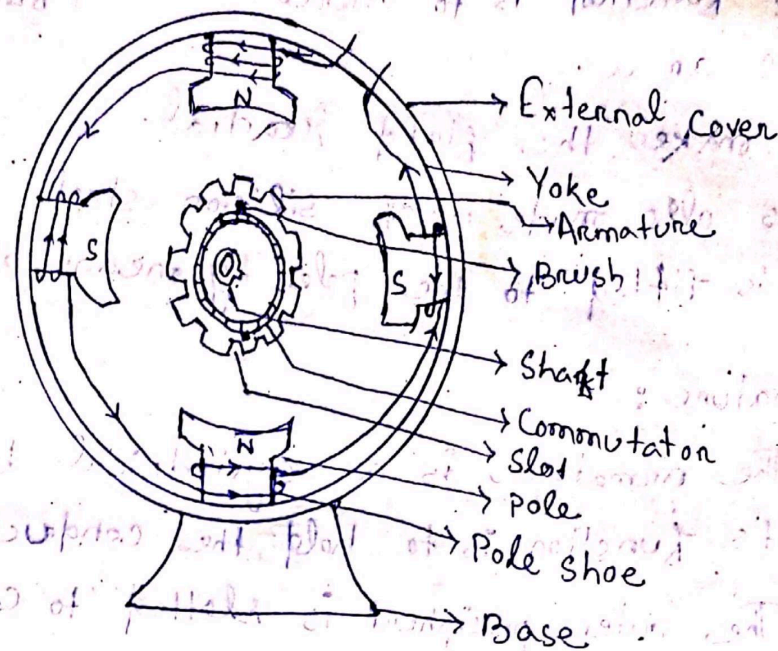
→ And the direction is of induced emf is given by Fleming's Right hand

Rule. DC Principle of Generator:-



- (i) When the loop is at position no. 1 the generated emf is 0V because the side ~~ABCD~~ coil ABCD is not cut any flux. The flux lines are parallel to the conductor. When the loop
- (ii) When the loop is at position no. 2 the coil sides are moving at an angle to the flux and therefore low emf is generated as indicated at point 2 in the figure.
- (iii) When the loop is at position no. 3 the coil sides ~~to~~ (AB and CD) are right angle to the flux lines. So, the flux

★ Parts of DC Generator



(i) External Cover :-

- It is made up of Cast iron.
- It protect the machine from dust and dirt.
- It is provided with radial ventilating duct to cool the machine.

(ii) Yoke :-

- The shape of the Yoke is hollow Cylinder.
- It is made up of silicon steel.
- It supports the magnetic poles.
- It provide a return path for magnetic flux.

(iii) Pole :-

- It is fitted with the Yoke by means of bolting.
- The pole is laminated in structure to reduce the eddy current loss.
- It is made up of silicon steel.
- It creates the magnetic flux when some current passes through it's winding.

(iv) Pole shoe :-

- It's function is to increase the effective pole area.
- It makes the field radial.
- It is also made up of silicon steel.
- It is fitted to the pole by means of bolting.

(v) Armature :-

- The armature is a cylindrical body.
- It's function is to hold the conductor.
- The outer periphery is slotted to carry the conductor.
- Armature is laminated to reduce the eddy current loss.
- It is made up of CRGO (Cold Rolled ^{Grain} oriented) material.

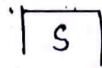
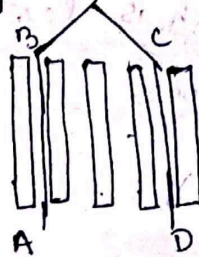
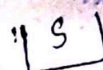
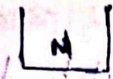
(vi) Commutator :-

- It is placed ^{on} at the front end of the armature.
- It is made up of copper.
- The total commutator is made up of different commutator segment.
- The shape of the commutator is circular.
- It convert AC to DC in case of generator and DC to AC in case of Motor.

(vii) Brush :-

- It is made up of copper or carbon.
- It's function is to collect the current.

* Pole Pitch :- distance between two adjacent slots



$$\text{Pole pitch} = \frac{Z}{P}$$

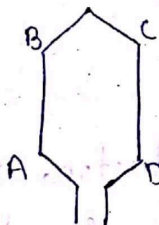
→ It is equal to no. of armature conductor on slot under one pole.

* Conductor :-

• It is a wire in which current is flowing i.e. AB or CD.

* Coil and winding element :-

→ The conductor AB and CD along with their end connection is called coil.



Single turned

Multiturned

→ The coil may be single turned and multiturned.

→ The sides of the coil is called winding elements.

* Coil Pitch or coil span :-

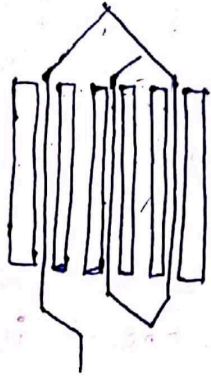
→ Coil pitch is the peripheral distance between 2 sides of a coil measured in terms of no. of armature slot.

→ If coil pitch is equal to the pole pitch then it is called the armature

winding is called full pitch and emf induced is maximum.

→ If coil pitch is less than pole pitch then the armature winding is called short pitch.

* Back pitch (Y_b):-



$$Y_b = \frac{Z}{P} + 1$$

The distance measured in terms of armature conductor which a coil advances in the back side of the armature is called back pitch. is denoted by Y_b .

* Front pitch:-

$$Y_f = \frac{Z}{P} - 1$$

The no. of armature conductor or element spanned by a coil on the front side is called front pitch and is denoted by y_f .

* Resultant pitch:-

It is distance between the beginning of one coil and the beginning of next coil. is known as β to which it is connected called as Resultant pitch.

* Commutator pitch:-

It is the distance measured in commutator bars or segment, ~~to~~ between the segment

to which ~~2~~ 2 ends of coil is connected is known as commutator pitch.

Q. Write down the winding table for 2 layer Simplex lap winding for 4 pole DC generator having 20 slots.

Ans. Given Data

$$\text{Pole} = P = 4$$

$$\text{Armature slots} = 20$$

$$\text{Total conductor} = 20 \times 2 = 40$$

$$Y_b = \frac{Z}{P} + 1 = \frac{40}{4} + 1 = 10 + 1 = 11$$

$$Y_f = \frac{Z}{P} - 1 = \frac{40}{4} - 1 = 10 - 1 = 9$$

Back Connection

$$Y_b = 11$$

$$1 + 11 = 12$$

$$3 + 11 = 14$$

$$5 + 11 = 16$$

$$7 + 11 = 18$$

$$9 + 11 = 20$$

$$11 + 11 = 22$$

$$13 + 11 = 24$$

$$15 + 11 = 26$$

$$17 + 11 = 28$$

$$19 + 11 = 30$$

$$21 + 11 = 32$$

$$23 + 11 = 34$$

$$25 + 11 = 36$$

$$27 + 11 = 38$$

$$29 + 11 = 40$$

$$31 + 11 = 42 - 40 = 2$$

$$33 + 11 = 44 - 40 = 4$$

Front Connection

$$Y_f = 9$$

$$12 - 9 = 3$$

$$14 - 9 = 5$$

$$16 - 9 = 7$$

$$18 - 9 = 9$$

$$20 - 9 = 11$$

$$22 - 9 = 13$$

$$24 - 9 = 15$$

$$26 - 9 = 17$$

$$28 - 9 = 19$$

$$30 - 9 = 21$$

$$32 - 9 = 23$$

$$34 - 9 = 25$$

$$36 - 9 = 27$$

$$38 - 9 = 29$$

$$40 - 9 = 31$$

$$42 - 9 = 33$$

$$44 - 9 = 35$$

Back Connection

$$35 + 11 = 46 - 40 = 6$$

$$37 + 11 = 48 - 40 = 8$$

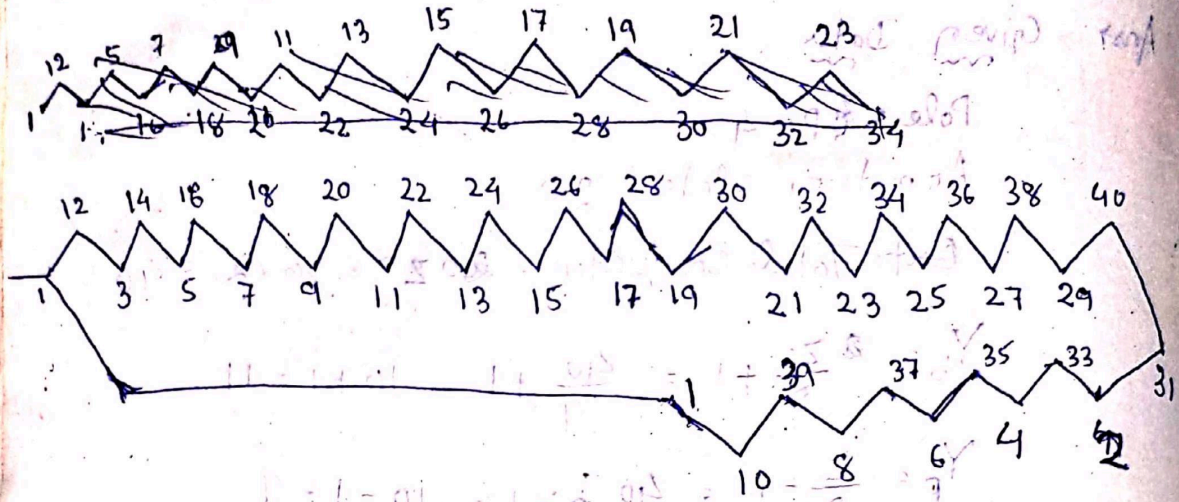
$$39 + 11 = 50 - 40 = 10$$

Front Connection

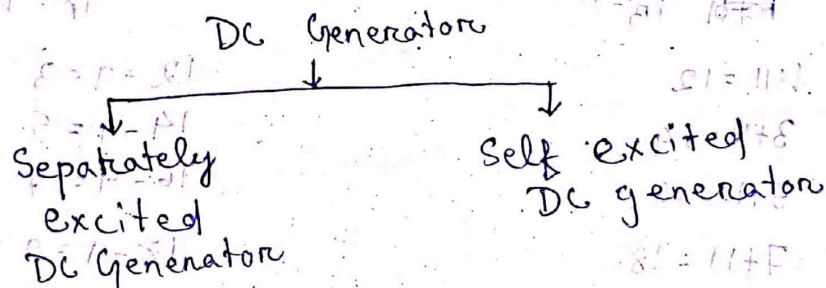
$$46 - 9 = 37$$

$$48 - 9 = 39$$

$$50 - 9 = 41 - 40 = 1$$

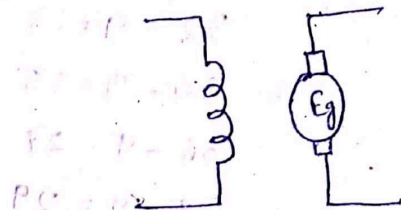


Types of DC Generator :-



(i) Separately excited DC Generator :-

→ In separately excited DC generator a separate DC supply is given to the field winding.

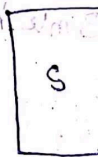
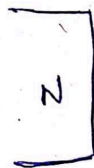


Armature Reaction :-

- The action of armature flux on + main flux is called armature reaction.
- The flux acting in a DC machine is that due to main pole is called main flux.
- The current through the armature conductors also creates a magnetic flux called armature flux.

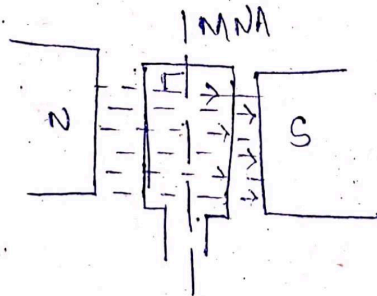
GNA (Geometric Neutral Axis) :-

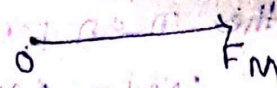
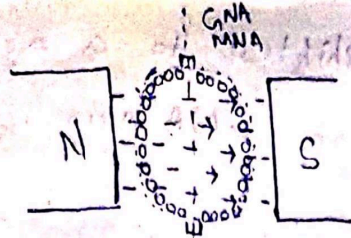
- The Geometric neutral axis is a axis that bisects the angle between the centre line of adjacent poles.



MNA (Magnetic Neutral Axis) :-

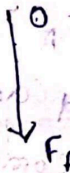
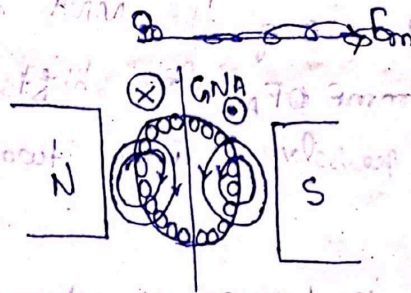
- It is the axis drawn perpendicular to the main direction of flux passing through the center of the armature.





→ The above figure shows the flux due to the main flux only.

→ The MMF produced during the main flux is OF_m

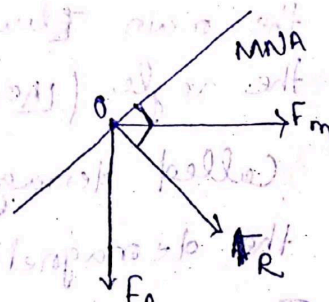
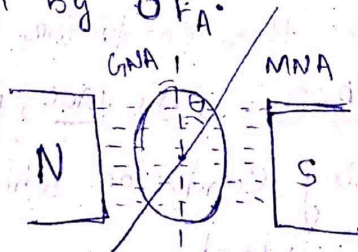


→ The above figure shows the flux due to the current flowing to the armature conductor only

→ The armature conductor left of GNA carry current in inward direction i.e. taken as (x) and those conductor right of the GNA carry current in outward direction i.e. taken as (o).

→ So, the direction of magnetic flux can be found out by ~~the~~ thumb rule.

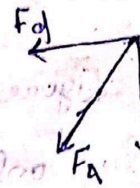
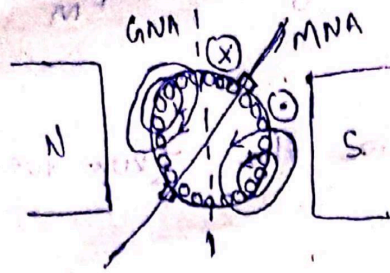
→ The mmf produced in the armature flux is given by OF_A .



→ The above figure shows the flux due to main pole and the armature conductor.

→ Resultant flux OF_R is the vector sum of

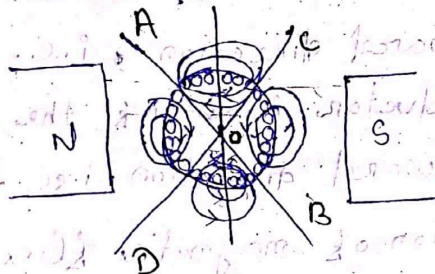
OFM and OFA. So, MNA shifted to an angle θ from the mean position on GNA axis.



→ In order to achieve sparkless commutation, the brushes must shift along the MNA due to the brush shift the mmf OFA also shifts same angle θ . So F_A can be resolved into two components, i.e. F_d and F_c .

→ The component F_d is known as demagnetising component and the component F_c is known as cross magnetising component.

Demagnetising and Cross magnetising conductors:-



→ The armature conductor on either side of GNA produces the flux in direct opposition to the main flux i.e. the conductor lying within the angle $(\angle AOC = \angle BOD = 2\theta)$. $\angle AOC$, $\angle BOD$ are called demagnetising conductor which produces the demagnetising effect.

→ The armature conductor lying between the angle $\angle AOD = \angle BOC$ produces cross magnetising effect. So, these conductors are called cross magnetising conductors.

Q. A separately excited DC generator has a
armature circuit resistance of 0.1Ω and total
Brush drop is $2V$. When running at 1000 rpm
it delivers a current of 100 Amp . at $250V$
to a load of constant resistance.
if the generator speed drops to 700 rpm with
field current constant. then find the
current to the load.

Ans → Given Data

$$R_a = 0.1\Omega$$

$$B.D. = 2V$$

$$N_1 = 1000\text{ rpm}$$

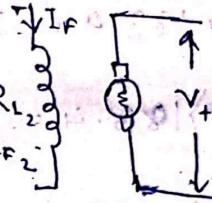
$$I_{a1} = I_{L1} = 100\text{ Amp}$$

$$V_t = 250V$$

$$N_2 = 700\text{ rpm}$$

$$R_L = \text{constant} = R_{L1} = R_{L2}$$

$$I_f = \text{constant} = I_{f1} = I_{f2}$$



$$R_L = \frac{V_t}{I_{L1}} = \frac{250}{100} = 2.5\Omega$$

$$\begin{aligned} E_{g1} &= I_{a1}R_a + V_t + B.D. \\ &= (100 \times 0.1) + 250 + 2 \\ &= 10 + 250 + 2 = 262V \end{aligned}$$

$$E_{g2} = V_t + I_{a2}R_a + B.D. \quad \text{Eq (1)}$$

$$I_{a2} = I_{L2}$$

$$E_g = \frac{P\phi ZN}{60A}$$

Here, P , Z and A constant

we know, $\phi \propto I_f = \text{constant}$

So, ϕ also a constant

$$\therefore E_g \propto N$$

$$\Rightarrow \frac{E_{g1}}{E_{g2}} = \frac{N_1}{N_2}$$

$$\Rightarrow \frac{262}{E_{g2}} = \frac{1000}{700}$$

$$\Rightarrow E_{g2} = \frac{262 \times 7}{10} = 183.4V$$

Putting E_{g2} in Eq (i)

$$E_{g2} = I_{a2} R_a + V_{t2} + B.D.$$

$$\Rightarrow 183.4 = (I_{a2} \times 0.1) + 250 + 2$$

$$\Rightarrow 183.4 - 252 = 0.1 I_{a2}$$

$$\Rightarrow -68.6 = 0.1 I_{a2}$$

$$\Rightarrow I_{a2} = -686$$

$$\Rightarrow E_{g2} = I_{a2} R_a + (I_{a2} \times R_L) + B.D. \quad (\because I_{a2} = I_{L2})$$

$$\Rightarrow 183.4 = I_{a2} (R_a + R_L) + 2$$

$$\Rightarrow 183.4 = I_{a2} (0.1 + 2.5) + 2$$

$$\Rightarrow 183.4 = 2.6 I_{a2} + 2$$

$$\Rightarrow 183.4 - 2 = 2.6 I_{a2}$$

$$\Rightarrow I_{a2} = \frac{181.4}{2.6} = 69.76 \text{ Amp}$$

$$\therefore I_{a2} = I_{L2} = 69.769 \text{ Amp}$$

Q2. A 4 pole DC shunt generator with a shunt field resistance of 100Ω and Armature resistance of 1Ω and has a 378 wave connected conductor in its armature. The flux per pole is 0.02 wb with a If the load resistance is 10Ω and ~~and~~ it is connected across the armature terminal and the generator driven at 1000 rpm calculate power absorbed by the load.

$$AT_{\text{pole}} = - \frac{1}{\frac{360}{40}} \times 1408 \times 30 = \frac{1408 \times 30}{40} = 1056 \text{ AT}$$

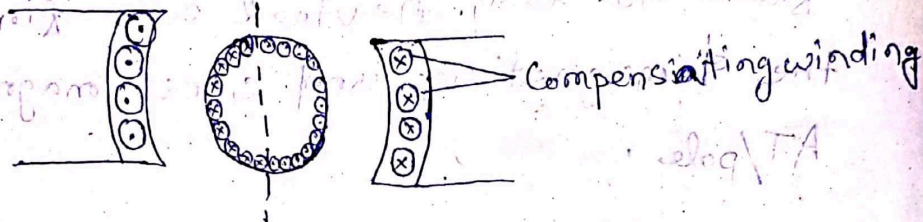
Cross magnetising $AT_{\text{pole}} = \frac{2}{\pi} Z I \left(\frac{1}{2p} - \frac{\theta_m}{360} \right)$

$$= 1408 \times 30 \left(\frac{1}{2 \times 8} - \frac{9}{360} \right)$$

$$= 1408 \times 30 \left(\frac{1}{16} - \frac{1}{40} \right)$$

$$= \cancel{1576.125} = 1584$$

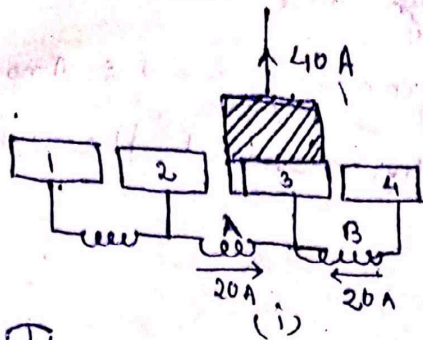
Compensating winding :-



→ The cross magnetising effect of Armature reaction can be neutralised by compensating winding.

→ A Compensating winding is a Auxiliary winding embeded in slots in pole face as shown in the figure. It is connected in series with the armature winding in manner, so that the direction current through the compensating conductor in any pole face will be opposite to the direction of current through the adjacent armature conductor.

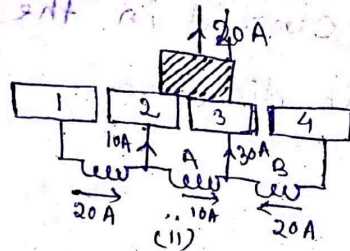
* Commutation :-



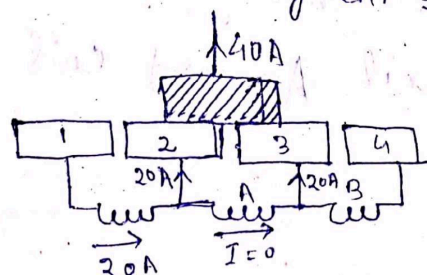
The process by which the current when passes through the brush axis

The reversal of current in a coil as the coil passes through the brush axis is called Commutation

→ In figure (i) the brush is contact with Segment 3, so the total current flows through the brush $I = 40 \text{ Amp}$. so, $I_A = 20 \text{ A}$ and $I_B = 20 \text{ A}$



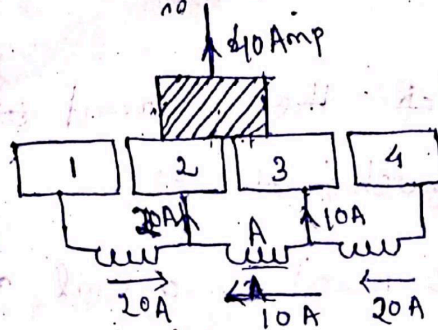
→ As the armature rotates the brush will make $\frac{1}{4}$ Contact with segment 2 and $\frac{3}{4}$ Contact with segment 3. Again the total current through the brush is 40Amp. i.e. 10Amp through Segment 2 and 30Amp through the segment 3.



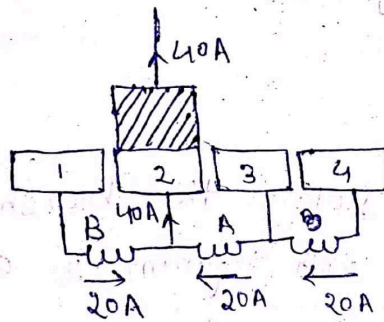
→ The above figure shows the instant when the brush is in $\frac{1}{2}$ contact with segment 2 and $\frac{1}{2}$

Contact with segment 3 and the total current will flow through the brush.

i.e. 20 Amp through segment 2 and 20 Amp through segment and the current through the coil A is 0 Amp.

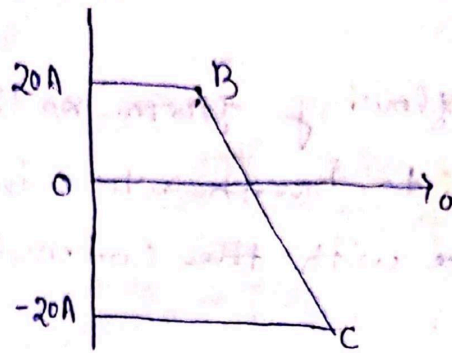


→ The above figure shows the instant when the brush is in $3/4$ contact with segment 2 and $1/4$ contact with segment 3 and the total current flow through the brush 40A i.e. 30A through segment 2 and 10A through segment 3 and the current in the coil is 10A but in reverse direction.

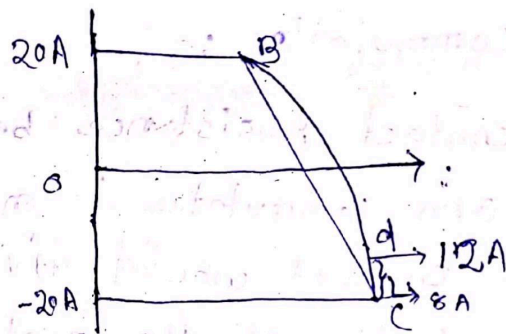


→ The above figure shows the instant when the brush is in contact with segment only. The total current through brush is 40A. i.e. 20A from coil A and coil B.

Improvement in Commutation :-



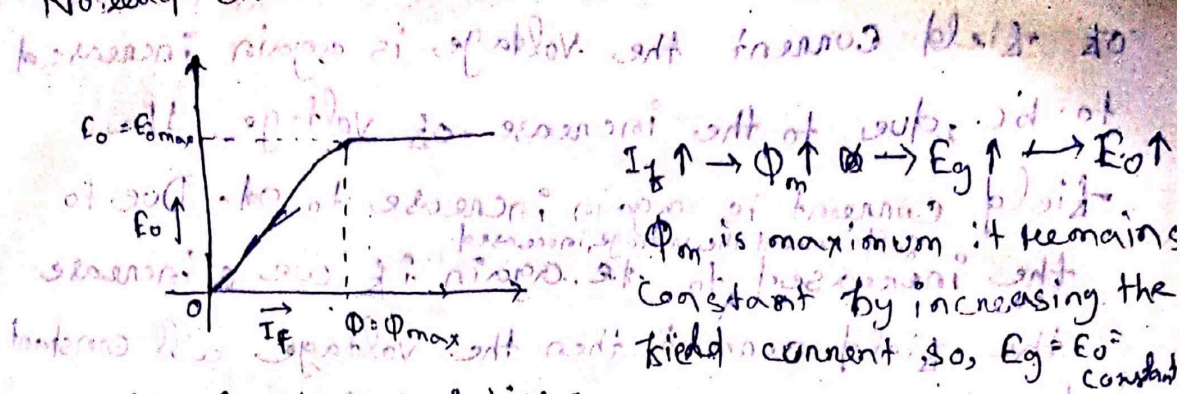
If the current changes at a uniform rate (i.e. BC is a straight line) then it is called ideal commutation. Under such condition no sparking will take place between brush and commutation.



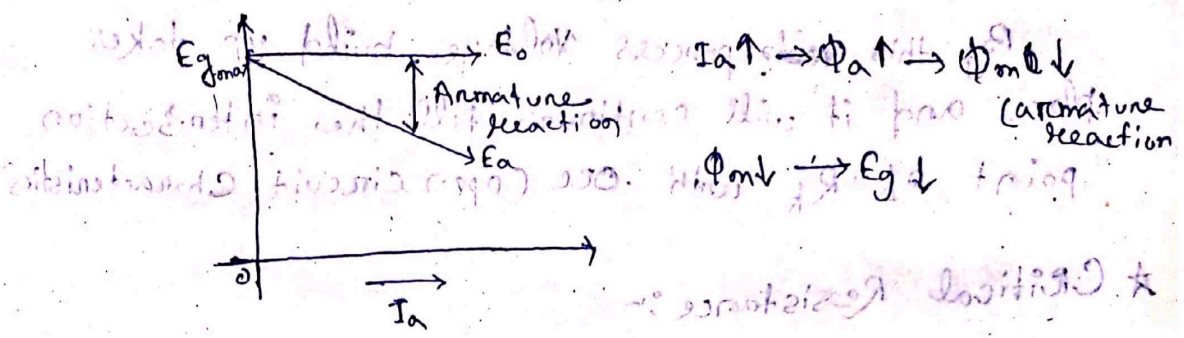
The ideal commutation can not be attained in practice because the armature coil has some inductance when the current changes in the coil so, a reactance voltage is induced in opposite direction to the current flowing through it.

This reactance voltage opposes the change of current so the commutation occurs more slowly than ideal commutation.

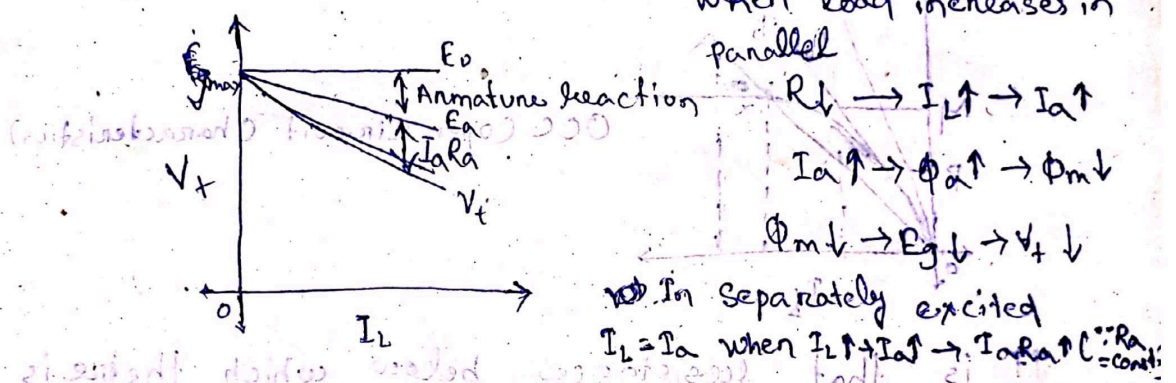
No Load Characteristics of a generator



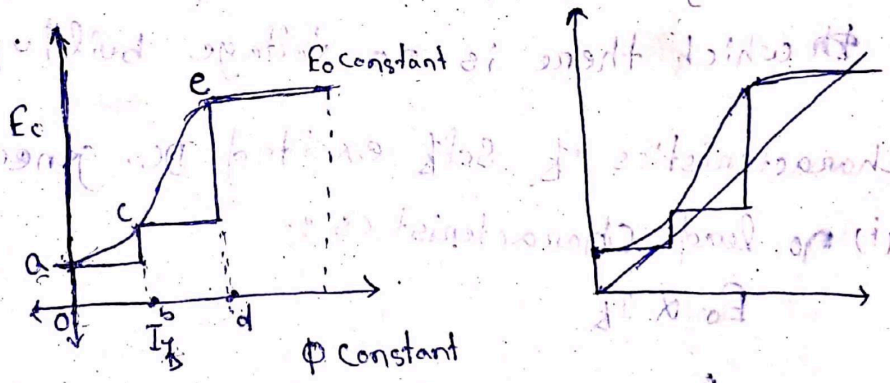
Internal Characteristics



External characteristics



Voltage build up in self excited DC Generator

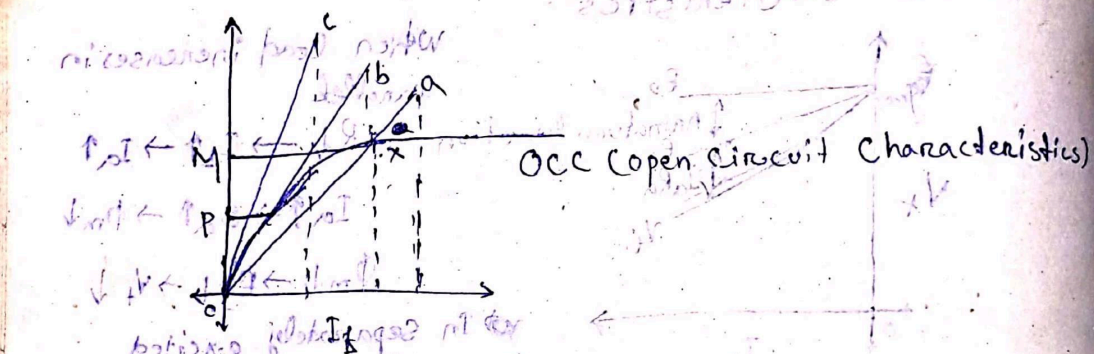


voltage build up phenomenon means the gradual generation voltage in a shunt generator. Due to the residual magnetism initially the voltage generated in a generator is 0V. Due to that voltage the

Field current increased to ob. Due to increase of field current the voltage is again increased to bc, due to the increase of voltage the field current is again increased to od. Due to the increased field current the voltage is increased to de. Again if we increase the field current then the voltage will constant due to the saturation of field current.

By this process voltage build up takes place and it will continue till the intersection point of R_k with OCC (Open circuit Characteristics).

* Critical Resistance :-

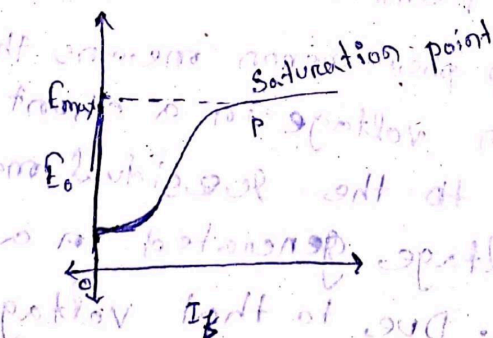


is that resistance below which there is a voltage build up takes place and above which there is no voltage build up.

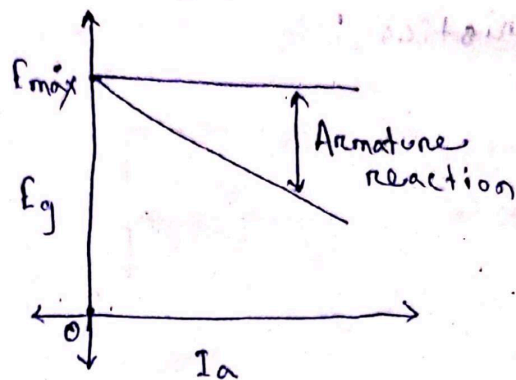
* Characteristics of Self excited DC generator :-

(i) no. load Characteristics :-

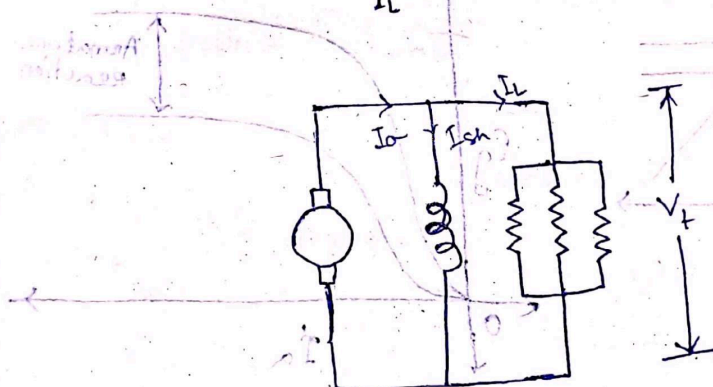
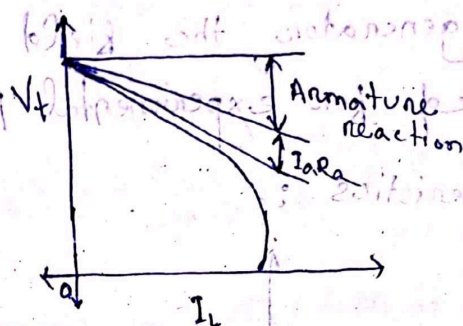
$$E_o \propto I_f$$



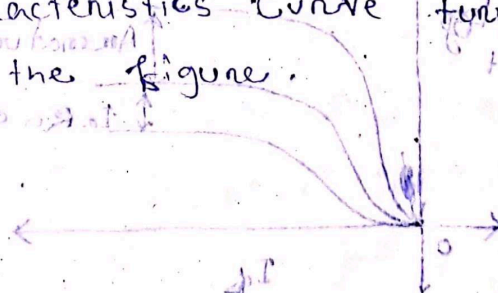
(ii) Internal Characteristics :-
 $E_g \propto I_a$



(iii) External Characteristics :-



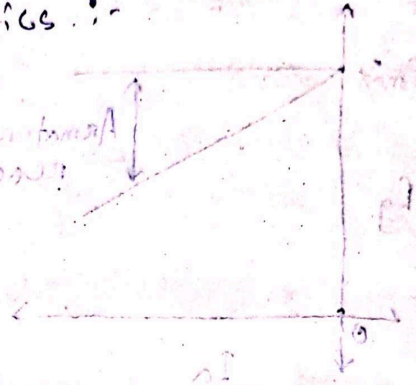
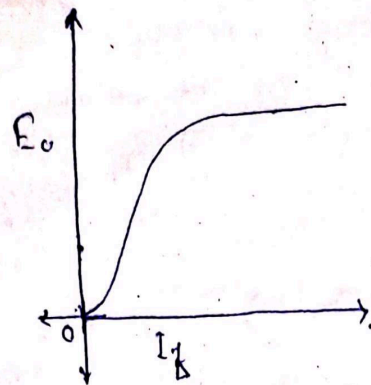
Any decrease of load resistance beyond a point instead of increasing the load current, decreases the load current and external characteristics curve turn back as shown in the figure.



$$V = E_g - I_a R_a = \phi$$

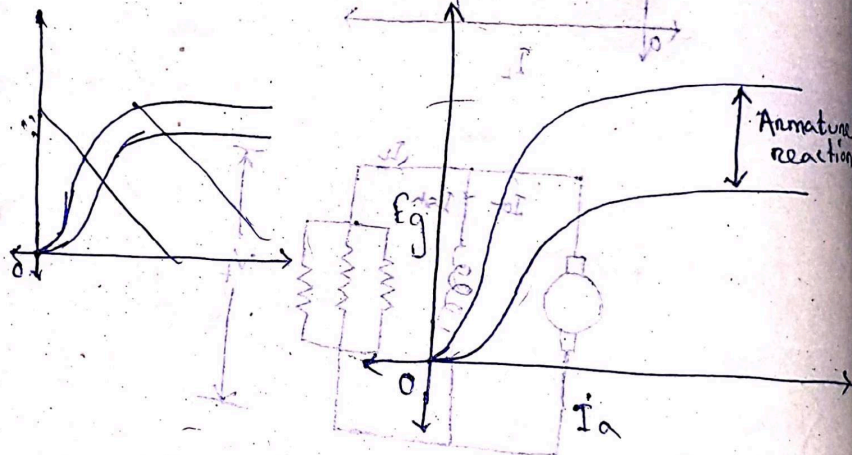
* Characteristics of self excited DC series generator.

(i) No load characteristics :-

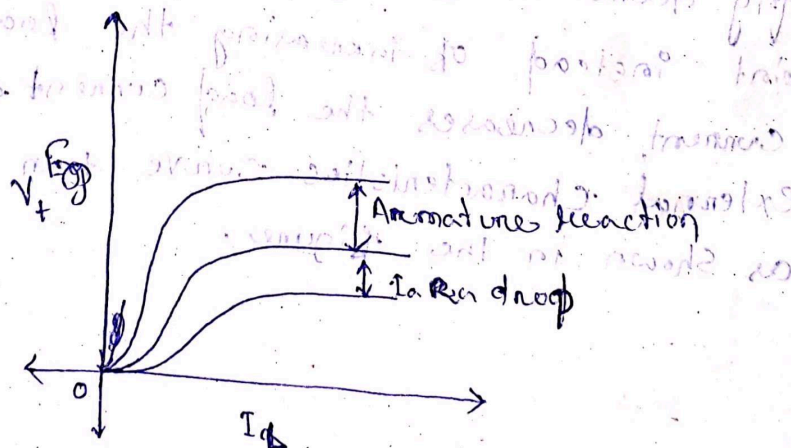


The ~~series~~ In series generator the field winding is separately excited for experimental purposes.

(ii) Internal characteristics :-



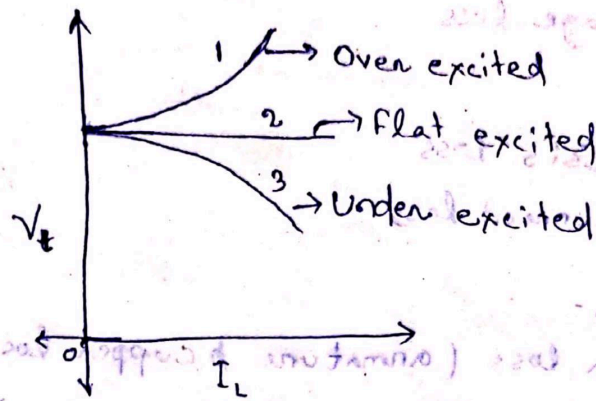
(iii) External Characteristics :-



$$E_g - I_a R_a = V_t$$

★ Characteristics of self excited DC compound generator:-

External characteristics:-



Curve - 1 (Over excited) :-

If the series winding turns are adjusted that with increase in load current the terminal voltage increases then it is called over excited compound generator.

Curve - 2 (Flat excited) :-

If the series winding turns are so adjusted that with increase in load current the voltage remains constant then it is called flat excited DC compound generator.

Curve - 3 (Under excited) :-

If the series winding turns are so adjusted that with increase in load current the terminal voltage decreases then it is called under excited DC compound generator.

Losses in D.C. machines :-

i) Friction & winding loss :-

- a) Friction loss
- b) windage loss

ii) Iron loss :-

- a) Hysteresis loss
- b) Eddy current loss

iii) Copper loss :-

- a) $I_a^2 R_a$ loss (armature copper loss)
- b) $I_{sh}^2 R_{sh}$ (shunt field cu. loss)

Friction loss :-

It occurs due to frictional part of D.C. machine.

Windage loss :-

It is also known as air friction loss.

It occurs due to replacement of air inside machine.

Eddy current loss :-

Whenever a magnetic flux passes through the rotating armature body, an emf is induced at the 2 ends of the armature due to Faraday's law of electromagnetic induction. This emf will circulate a current in a body of armature and this current is known as eddy current.

Due to eddy current, certain amount of loss occurs and that loss is known as eddy current loss.

Armature Cu. loss $\therefore (I_a^2 r_a)$

Shunt field Cu. loss $\therefore$

$I_{sh}^2 r_{sh}$

Total loss = Constant loss + Variable loss
 $= W_c + \text{Variable loss } (I_a^2 r_a)$

$W_c = \text{F \& W loss} + \text{Iron loss} + \text{shunt field Cu. loss}$

Efficiency (η) = $\frac{\text{O/p}}{\text{I/p}} = \frac{\text{O/p}}{\text{O/p} + \text{losses}}$

$P_{in} = P_{out} + \text{loss}$

$= \frac{P_{O/P}}{P_{O/P} + W_c + I_a^2 r_a}$

$P_{O/P} = V_t I_L$

$= \frac{V_t I_L}{V_t I_L + W_c + I_L^2 r_a}$

($\because I_a = I_L + I_{sh}$)
 R_{sh} is max^m
 $I_{sh} \approx 0$
 $I_a \approx I_L$

Condition for maximum efficiency $\frac{d\eta}{dI_L} = 0$
 η_{max} is occur when

$\frac{d\eta}{dI_L} = 0$ (for efficiency to be maximum the denominator should be minimum)

$\Rightarrow \frac{d}{dI_L} \left(\frac{V_t I_L}{V_t I_L + W_c + I_L^2 r_a} \right) = 0$
 $V_t \left[\frac{d}{dI_L} (V_t I_L + W_c + I_L^2 r_a) \right] = 0$

$$\frac{d}{dI_L} (V_t I_L + W_c + I_L^2 R_L) = 0$$

$$\Rightarrow \frac{d}{dI_L} (V_t I_L) + \frac{dW_c}{dI_L}$$

dividing $V_t I_L$ in both numerator and denominator

$$\frac{\frac{V_t I_L}{V_t I_L}}{\frac{V_t I_L + W_c + I_L^2 R_L}{V_t I_L}} = \frac{1}{1 + \frac{W_c}{V_t I_L} + \frac{I_L^2 R_L}{V_t I_L}}$$

$$= \frac{1}{1 + \frac{W_c}{V_t I_L} + \frac{I_L R_L}{V_t}}$$

$$\frac{d}{dI_L} \left[\frac{1}{1 + \frac{W_c}{V_t I_L} + \frac{I_L R_L}{V_t}} \right] = 0 \quad \text{or we can take}$$

$$\Rightarrow 0 + \frac{W_c}{V_t} (-I_L^{-2}) + \frac{R_L}{V_t} = 0 \quad \left(\because \frac{d}{dI_L} \left(\frac{1}{I_L} \right) = -I_L^{-2} \right)$$

$$\Rightarrow \frac{W_c}{V_t} = \frac{W_c I_L^{-2}}{V_t}$$

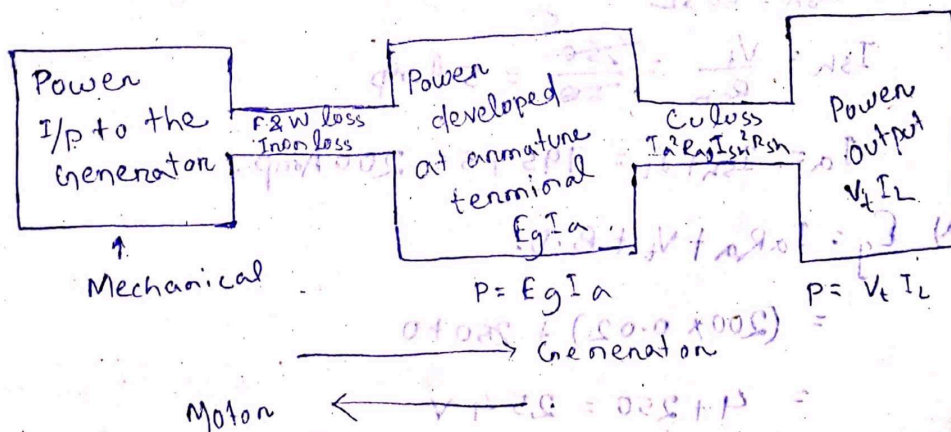
$$\Rightarrow R_L = \frac{W_c}{I_L^2}$$

$$\Rightarrow \boxed{W_c = I_L^2 R_L}$$

$\Rightarrow$ Constant loss = variable loss

When variable loss equal to constant loss the efficiency will be maximum.

Power stages of DC Machine :-



Efficiency:-

(i) Electrical efficiency :-

$$\eta_e = \frac{C}{B} \left(\frac{\text{electrical o/p}}{\text{electrical i/p}} = \eta_e \right)$$

(ii) Mechanical efficiency :-

$$\eta_m = \frac{B}{A} \left(\frac{\text{Total electrical o/p}}{\text{electrical i/p}} = \eta_m \right)$$

(iii) Overall Efficiency :-

$$\eta_o = \frac{C}{A} \left(\frac{\text{Total electrical o/p}}{\text{Mechanical i/p}} = \eta_o \right)$$

Q. A shunt generator delivers 195 Amp. at terminal voltage 250V. The armature resistance and shunt resistance 0.02 Ω and 50 Ω respectively.

The iron and friction loss is 950 watt. Find

(a) EMF generated

(b) Copper loss

(c) Output of prime mover

(d) Mechanical, electrical and overall efficiency.

Ans. Given Data

$$I_L = 195 \text{ Amp.}$$

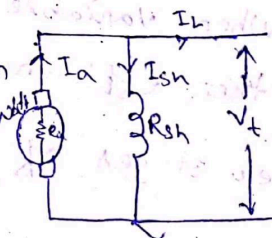
$$V_t = 250 \text{ V}$$

$$R_a = 0.02 \Omega$$

$$R_{sh} = 50 \Omega$$

Iron & Friction

$$\text{loss} = 950 \text{ watt}$$



$$I_{sh} = \frac{V_t}{R_{sh}} = \frac{250}{50} = 5 \text{ Amp}$$

$$I_a = I_{sh} + I_L = 195 + 5 = 200 \text{ Amp.}$$

1a) $E_g = I_a R_a + V_t + B.D.$

$$= (200 \times 0.02) + 250 + 0$$

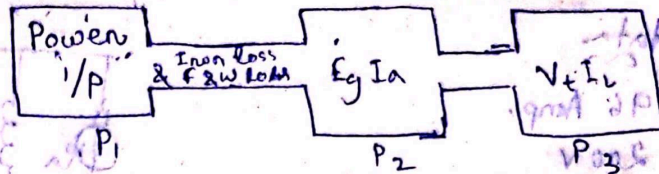
$$= 4 + 250 = 254 \text{ V}$$

(b) Copper loss :-

$$I_a^2 R_a = 200^2 \times 0.02 = 800 \text{ watt}$$

$$I_{sh}^2 R_{sh} = 5^2 \times 50 = 1250 \text{ watt}$$

$$I_a^2 R_a + I_{sh}^2 R_{sh} = 800 + 1250 = 2050 \text{ watt}$$



$$P_1 - \text{loss} = P_2$$

$$\Rightarrow P_1 = P_2 + \text{loss}$$

$$\Rightarrow P_1 = E_g I_a + 950$$

(c) Output of prime mover :-

$$= E_g I_a + (\text{Iron \& friction loss})$$

$$= (254 \times 200) + 950$$

$$= 50800 + 950 = 51750 \text{ watt} = A$$

$$C = \text{Output power} = V_t I_a = 250 \times 195 = 48750 \text{ watt}$$

(d) Mechanical efficiency :-

$$\eta_m = \frac{B}{A} = \frac{50800}{51750} \times 100 = 0.9816 \times 100 = 98.16\%$$

electrical efficiency :-

$$\eta_e = \frac{C}{B} = \frac{48750}{50800} \times 100 = 0.9596 \times 100 = 95.96\%$$

Overall efficiency :-

$$\eta_o = \frac{C}{A} = \frac{48750}{51750} \times 100 = 0.9420 \times 100 = 94.2\%$$

Q3. A shunt generator has a full load current of 196 Amp. at 220V. The stray losses are 720 watt. and shunt field resistance is 55Ω . If it has a full load efficiency of 88%. Find the armature resistance. also find the load current corresponding to maximum efficiency.

Ans: Given data:

$$I_L = 196 \text{ Amp.}$$

$$V_t = 220 \text{ V}$$

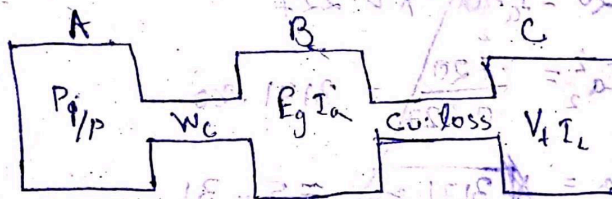
Stray losses (F&W loss + Iron loss)

$$= 720 \text{ Watt}$$

$$R_{sh} = 55\Omega$$

Full load efficiency (overall efficiency)

$$\frac{C}{A} = \eta_o = 88\%$$



$$I_{sh} = \frac{V_t}{R_{sh}} = \frac{220}{55} = 4 \text{ Amp.}$$

$$I_a = I_L + I_{sh} = 196 + 4 = 200 \text{ Amp.}$$

$$E_g = I_a R_a + V_t + B.D.$$

$$= 200 R_a + 220 + 0 =$$

$$\frac{C}{A} = 88\%$$

$$\Rightarrow \frac{V_t I_L}{A} = \frac{88}{100} \Rightarrow \frac{220 \times 196}{A} = \frac{88}{100}$$

$$\Rightarrow \frac{220 \times 196 \times 100}{88} = A$$

$$\Rightarrow A = 49000 \text{ watt.}$$

then, $5880 = (720 + 880) + I_a^2 r_a$

$\Rightarrow I_a^2 r_a = 5880 - 720 - 880 = 4280 \text{ watt}$

$\Rightarrow (200)^2 r_a = 4280$

$\Rightarrow r_a = \frac{4280}{(200)^2} = 0.107 \Omega$

At maximum efficiency:-

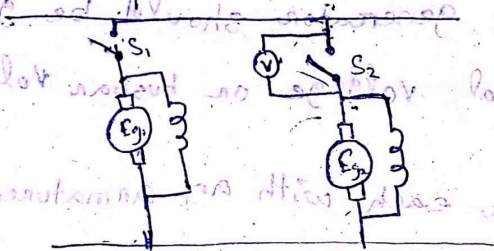
$W_c = I_L^2 r_a$

$\Rightarrow 720 + 880 = I_L^2 \times 0.107$

$\Rightarrow 1600 = I_L^2 \times 0.107$

$\Rightarrow I_L = \sqrt{\frac{1600}{0.107}} = 122.28 \text{ Amp}$

* Parallel operation of DC generation



Requirement of parallel operation:-

- (i) Continuity of service.
- (ii) Efficiency.
- (iii) Maintenance and repair purpose.
- (iv) Future use on additional plant.

→ Terminal voltage of 2 generator will remain same.

→ Proper polarity should be maintain.

→ Run the 1st generator at rated speed then connect the generator to busbar.

→ While connecting the 2nd generator the following procedure should be adopted

→ The armature of generator to speeded by the prime mover.

→ The excitation of generator is changed. The voltmeter leads to zero value. Then it means that the terminal voltage is same as busbar voltage. After that the switch is closed. So, the generator is parallel to the system. Under this condition the generator is not taking the load because the induced emf is same to the terminal voltage. So, the generator is called floating condition.

→ When there is a load requirement the induced emf of generator should be greater than the terminal voltage or busbar voltage.

Q. 2 Shunt generator each with an armature resistance of 0.01Ω and field resistance of 20Ω run parallelly to supply total load of 4000 Amp . the emf are respectively 210 V and 220 V . Calculate the busbar voltage and output of each machine.

Ans → Given Data

$$R_a = 0.01 \Omega$$

$$R_{sh} = 20 \Omega$$

$$I_L = 4000 \text{ Amp} = I_{L1} + I_{L2}$$

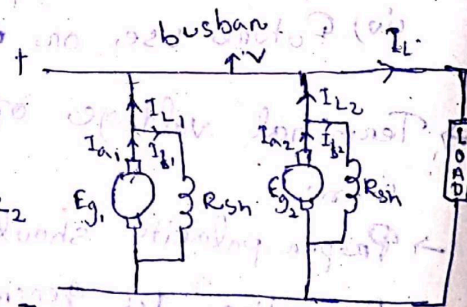
$$E_{g1} = 210 \text{ V}$$

$$E_{g2} = 220 \text{ V}$$

$$V = ?$$

$$I_{L1} = ?$$

$$I_{L2} = ?$$



Putting I_{L2} in Eq (ii)

$$220 - \left(I_{L2} + \frac{V}{20} \right) 0.01 = V$$

$$\Rightarrow 220 - 0.01 I_{L2} - \frac{V}{20} \times 0.01 = V$$

$$\Rightarrow 220 - 0.01 I_{L2} = V + \frac{V}{20} \times 0.01$$

$$\Rightarrow 220 - 0.01 I_{L2} = V + \frac{V}{2000}$$

$$\Rightarrow 220 - 0.01 I_{L2} = \frac{2001V}{2000}$$

$$\Rightarrow \frac{2001V}{2000} + 0.01 I_{L2} = 220$$

$$\Rightarrow 2001V + 20 I_{L2} = 220 \times 2000$$

$$\Rightarrow 2001V + 20 I_{L2} = 440000 \quad \text{Eq (iv)}$$

~~Solving~~

$$\text{Eq (iii)} - \text{Eq (iv)}$$

$$2001V + 20 I_{L1} = 420000$$

$$2001V + 20 I_{L2} = 440000$$

$$20 I_{L1} - 20 I_{L2} = 20000$$

$$\Rightarrow I_{L1} - I_{L2} = \frac{20000}{20} = 1000 \quad \text{Eq (v)}$$

$$\text{Solve } I_{L1} + I_{L2} = 4000 \quad \text{Eq (vi)}$$

$$I_{L1} + I_{L2} = 4000$$

$$I_{L1} - I_{L2} = 1000$$

$$2 I_{L1} = 5000 \Rightarrow I_{L1} = 2500 \text{ Amp.}$$

$$I_{L1} + I_{L2} = 4000$$

$$\Rightarrow 2500 + I_{L2} = 4000$$

$$\Rightarrow I_{L2} = 4000 - 2500 = 1500 \text{ Amp.}$$

~~Ans~~

~~$V = I_{L1} R_{L1}$~~ Putting I_{L2} in Eq (iii)

$$\Rightarrow 420000 = 20I_{L2} + 2001V$$

$$\Rightarrow 420000 - 20I_{L2} = 2001V$$

$$\Rightarrow 420000 - 20 \times 1500 = 2001V$$

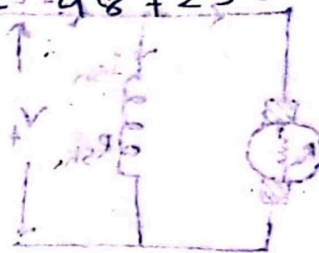
$$\Rightarrow 420000 - 30000 = 2001V$$

$$\Rightarrow V = \frac{390000}{2001} = 194.90 \text{ V}$$

$$P_L = V \times I_L = 194.90 \times 4000 = 779616.19 \text{ Watt}$$

$$P_{L1} = V \times I_{L1} = 194.90 \times 1500 = 292350 \text{ Watt}$$

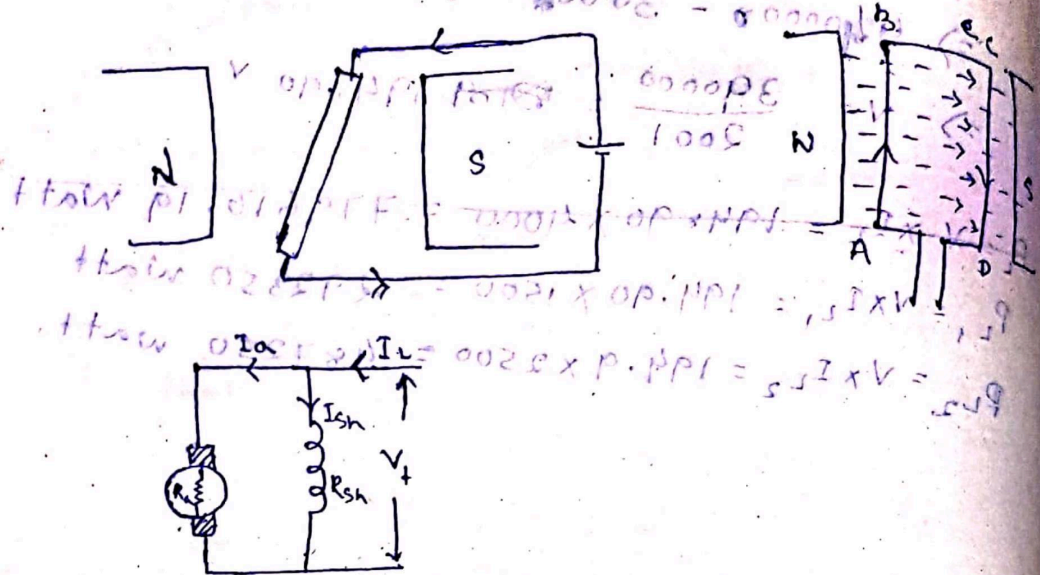
$$P_{L2} = V \times I_{L2} = 194.9 \times 2500 = 487250 \text{ watt}$$



DC Motor

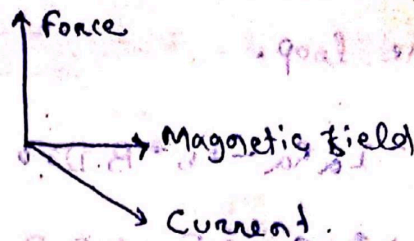
Working Principle of D.C. Motor :-

The ^{DC} machine which convert electrical energy to mechanical energy is called D.C. motor.

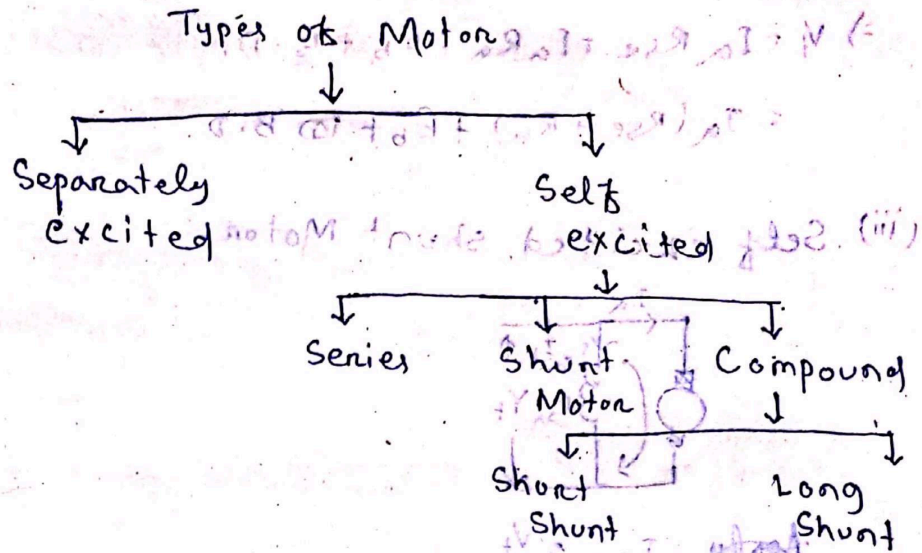


When some voltage is applied to the terminal of D.C. motor the current in the field winding is $I_{sh} = \frac{V_t}{R_{sh}}$. Due to this field current the magnetic pole will be excited and they will behave as magnet. Due to the terminal voltage V_t some current will flow in the armature winding. This is the case similar to a current carrying conductor placed inside the magnetic field.

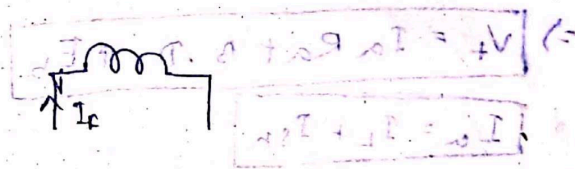
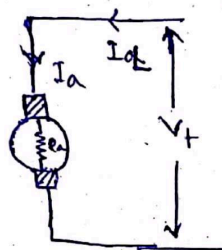
According to the basic principle of electromagnet whenever a current carrying conductor is placed in the magnetic field it experiences a torque and the direction of torque is given by Fleming's left hand rule.



Types of Motor :-



(i) Separately excited ^{D.C} Motor :-



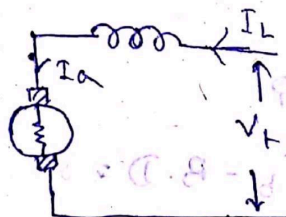
Apply KVL in the loop.

$$V_t - I_a R_a - B.D - E_b = 0$$

$$\Rightarrow V_t = E_b + I_a R_a + B.D.$$

$$I_a = I_L$$

(ii) Self excited Series motor.



Apply

Apply KVL in the loop.

$$V_t - I_{se} R_{se} - I_a R_a - E_b - B \cdot D = 0$$

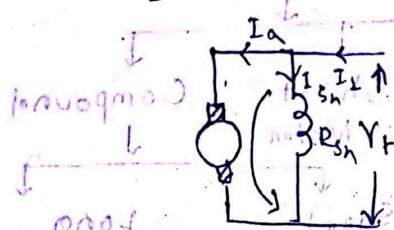
$$\Rightarrow V_t = I_{se} R_{se} + I_a R_a + E_b + B \cdot D$$

$$I_a = I_{se}$$

$$\Rightarrow V_t = I_a R_{se} + I_a R_a + E_b + B \cdot D$$

$$= I_a (R_{se} + R_a) + E_b + B \cdot D$$

(iii) Self excited shunt Motor:-



$$I_{sh} = \frac{V_t}{R_{sh}}$$

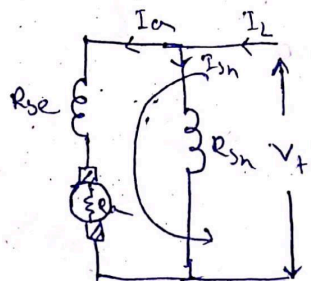
Apply KVL in the loop.

$$V_t - I_a R_a - B \cdot D - E_b = 0$$

$$\Rightarrow V_t = I_a R_a + B \cdot D + E_b$$

$$I_a = I_L + I_{sh}$$

(iv) Long shunt compound Motor:-



$$I_{sh} = \frac{V_t}{R_{sh}}$$

Apply KVL in the loop.

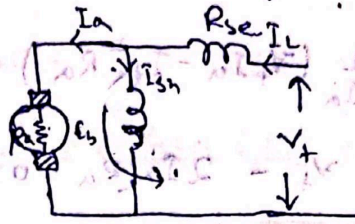
$$V_t - I_a R_{se} - I_a R_a - E_b - B \cdot D = 0$$

$$\Rightarrow V_t = I_a R_a + I_a R_{se} + E_b + B \cdot D$$

$$\Rightarrow V_t = I_a(R_{se} + R_a) + E_b + B.D.$$

$$I_a = I_L + I_{sh}$$

(V) Short Shunt Compound Motor :-



$$I_{sh} = \frac{V_t - I_L R_{se}}{R_{sh}}$$

Apply KVL in loop

$$V_t - I_L R_{se} - I_a R_a - B.D. - E_b = 0$$

$$\Rightarrow V_t = I_L R_{se} + I_a R_a + E_b + B.D.$$

$$I_a = I_L + I_{sh}$$

Significance of Back emf (E_b) :-

Since the generated emf in case of motor appears after all the process are completed. So, it is called back emf (E_b)

$$\text{In a motor } E_b = \frac{V_t - I_a R_a}{1}$$

At the time of starting $E_b = 0$, so,

$I_a = \frac{V_t}{R_a}$. Since, V_t is very terminal voltage has a high value and armature resistance has a small value. So a huge amount of armature current will flow through the armature winding, which will burnt the armature winding.

Condition for Maximum efficiency:-

$$E_b = V_t - I_a R_a \quad \text{--- Eq (i)}$$

$$\Rightarrow E_b I_a = V_t I_a - I_a^2 R_a$$

$$\frac{d}{dI_a} (E_b I_a) = 0$$

$$\frac{d}{dI_a} (V_t I_a - I_a^2 R_a) = 0$$

$$\Rightarrow V_t - 2I_a R_a = 0$$

$$\Rightarrow V_t = 2I_a R_a$$

$$\Rightarrow I_a R_a = \frac{V_t}{2} \quad \text{--- Eq (ii)}$$

Putting $I_a R_a$ in Eq (i)

$$E_b = V_t - \frac{V_t}{2}$$

$$\Rightarrow E_b = \frac{V_t}{2} \quad \text{Condition for maximum efficiency}$$

Hence when the back EMF is half of the applied voltage maximum power will be transferred.

Q. A 440 V DC shunt motor has a armature resistance of 0.8Ω and the field resistance of 200Ω . Determine the back emf giving an output of 7.46 kW and 85% efficiency.

Ans. Given Data

$$V_t = 440 \text{ V}$$

$$R_a = 0.8 \Omega$$

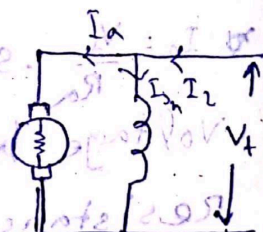
$$R_{sh} = 200 \Omega$$

$$P_{o/p} = 7.46 \text{ kW}$$

$$\text{Efficiency } (\eta) = 85\% = 0.85$$

we know

$$\eta = \frac{P_{o/p}}{P_{i/p}}$$



$$\Rightarrow 0.85 = \frac{7.46 \times 10^3 \text{ W}}{P_i/p}$$

$$\Rightarrow P_i/p = \frac{7.46 \times 10^3}{0.85} = 8776.47 \text{ Watt}$$

$$P_i/p = V_t \times I_L$$

$$\Rightarrow 8776.47 = 440 \times I_L$$

$$\Rightarrow I_L = \frac{8776.47}{440} = 19.94 \text{ Amp.}$$

$$I_L = I_a + I_{sh}$$

$$I_{sh} = \frac{V_t}{R_{sh}} = \frac{440}{200} = 2.2 \text{ Amp.}$$

$$I_L = I_a + I_{sh}$$

$$\Rightarrow I_a = I_L - I_{sh} = 19.94 - 2.2 = 17.74$$

Apply KVL in the loop

$$V_t = I_a R_a + E_b + B.D.$$

$$\Rightarrow 440 = 14.192 + E_b$$

$$\Rightarrow E_b = 440 - 14.192 = 425.808 \text{ V}$$

Q2. A 220V DC machine has a armature resistance of 0.5Ω . If Full load current is 20A. Find the induced emf when the machine act as generator
 (i) generator
 (ii) Motor.

Ans: Given Data

$$V_t = 220 \text{ V}$$

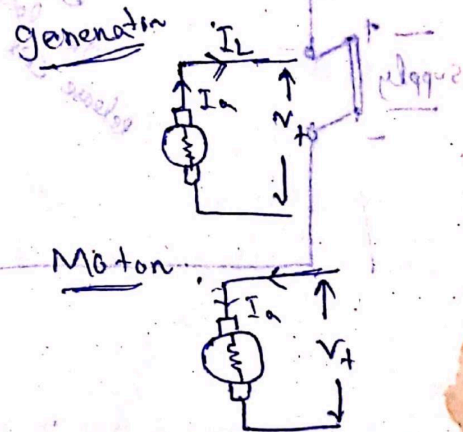
$$R_a = 0.5 \Omega$$

$$I_a = I_L = 20 \text{ A}$$

The generator case

$$E_g = V_t + I_a R_a + B.D.$$

$$= 220 + (20 \times 0.5) = 230 \text{ V}$$



$$\frac{W \cdot F_{01} \times 21.5 \cdot F}{21.9} = 28.0$$

$$\frac{F_{01} \times 21.5 \cdot F}{28.0} = 21.9$$

$$I \times V = \frac{E \times I \times V}{E \times I \times V} = \frac{E \times I \times V}{E \times I \times V}$$

$$I \times V = \frac{E \times I \times V}{E \times I \times V} = \frac{E \times I \times V}{E \times I \times V}$$

$$I \times V = \frac{E \times I \times V}{E \times I \times V} = \frac{E \times I \times V}{E \times I \times V}$$

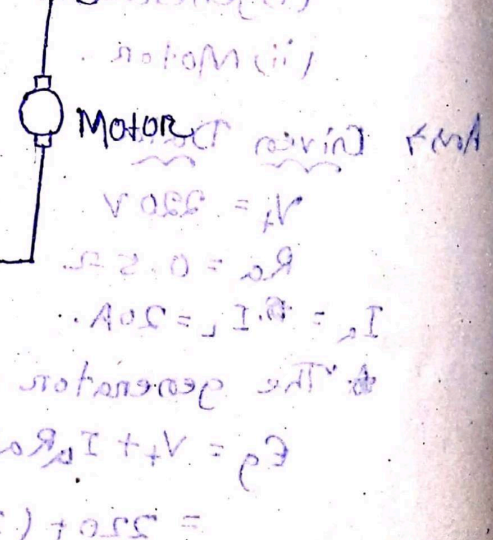
$$= \frac{0.143}{0.002} = \frac{143}{2} = 71.5$$

$$pI = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} = I - \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} = I - A$$

$$\Rightarrow \text{MIO} = 10 \cdot 10 \cdot 5 + 10 \cdot 10 \cdot 10 = 1500$$

Handwritten notes on a piece of paper, including the text "A" and "Voss".

Current is
out when the



Different types of starters used for D.C. shunt motors:

There are 2 types of starters used for starting the D.C. shunt and compound motors.

1. D.C. three point starter

D.C. four point starter.

D.C. Three point starter:

The starter has got only three terminals namely line (L), armature (A) and field (F or Z)

So, it is called a three point starter as shown in the figure.

Parts of a D.C. Three point Starter:-

The following are the main parts of a three point starter:

(i) Variable Resistance:-

It is made of an alloy. It is connected with the armature circuit in series. The resistance is designed for heavy current and low resistance values. It is wound in spiral shape and placed on the porcelain or asbestos sheet. A number of tapping are connected with the studs. When the motor starts, full resistance is connected in series with the armature and as the motor attains the speed, it is gradually decreased to zero value.

(ii) Handle:-

It is made of an iron and is insulated from the starter. A copper strip is placed under the handle to make contact with the

Studs. It has a soft iron piece which is attached by the no volt coil and the handle remains in ON position as long as the current flows through the no. volt coil.

(iii) Spring :-

It is wound on the handle of the starter. The function of a spring is to bring the handle in OFF position when the supply fails. Tension of the spring is placed in such a manner so that the handle comes at the OFF position immediately after the no volt coil is demagnetised.

(iv) No. volt coil :-

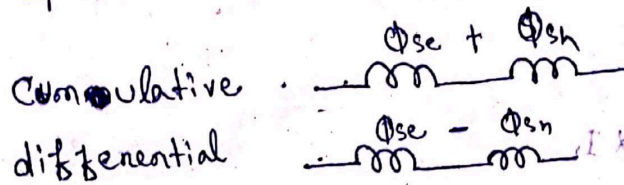
It is an electromagnet, consists of many turns of thin wire and is connected in series with the shunt field. The coil is magnetised by the current flowing in the shunt field and holds the starter handle in the ON position. In the event of supply failure, the no volt coil is demagnetised and the handle returns back to OFF position under the action of spring thereby disconnecting the motor from the main.

(v) Over load coil :-

It is also an electromagnet which is connected to the line and the handle. It consists of a few turns of thick wire. It is magnetised by the

Compound Motor :-

1. Torque $\propto$ armature current
2. speed $\propto$ armature current



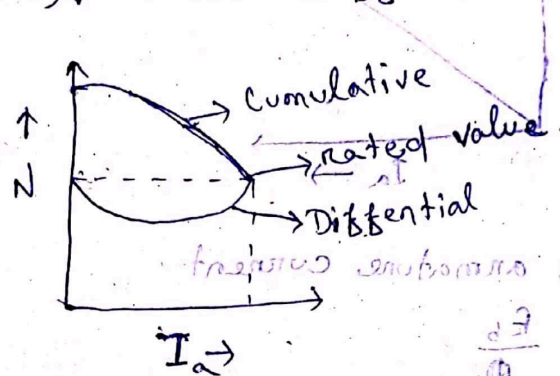
2. speed $\propto$ Torque armature current

$$\Phi_{sh} = \text{constant}$$

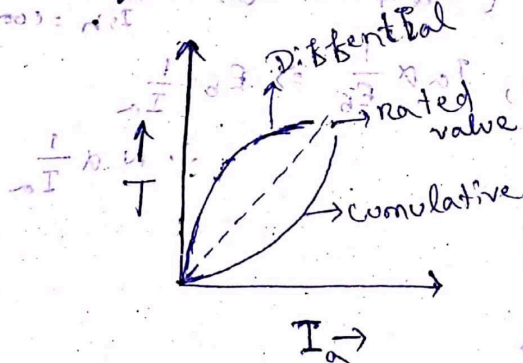
$$\Phi_{se} \propto I_a \uparrow$$

$$(\Phi_{sh} + \Phi_{se}) \uparrow \rightarrow N \downarrow \text{ (Cumulative)}$$

$$(\Phi_{sh} - \Phi_{se}) \downarrow \rightarrow N \uparrow \text{ (Differential)}$$



1. Torque $\propto$ armature current



$$T \propto \Phi I_a$$

$$\Phi = \Phi_{se} \pm \Phi_{sh}$$

$$\Phi_{sh} = \text{constant}$$

$$\Phi_{se} \propto I_a \propto \Phi_{se} \uparrow$$

$$\Phi = (\Phi_{sh} + \Phi_{se}) \uparrow$$

(Cumulative)

$$\Phi = (\Phi_{sh} - \Phi_{se}) \downarrow$$

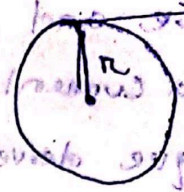
(Differential)

Torque developed in a motor

Torque is the turning and twisting force

$$T = F \times r$$

$$\begin{aligned} \text{Work done} &= F \times d \\ &= F \times 2\pi r \end{aligned}$$



Power developed = Work done $\times$ speed in rps

$$= F \times 2\pi r \times N$$



$$\begin{aligned} &= F \times r \times 2\pi N \\ &= T \times \omega \quad (\because \omega = \text{angular speed} = 2\pi N) \end{aligned}$$

$$\therefore \boxed{P_a = T_a \times \omega}$$

$$P_a = T_a \times \omega$$

$$\Rightarrow E_b I_a = T_a \times \omega \quad (\text{from power stages})$$

$$\Rightarrow \frac{P\phi Z N}{60 A} \times I_a = T_a \times 2\pi N$$

$$\Rightarrow \frac{P\phi Z N}{60 A} \times I_a = T_a \times \frac{2\pi N}{60} \text{ in r.p.s.}$$

$$\Rightarrow \frac{P\phi Z I_a}{A} = T_a \times 2\pi$$

$$\Rightarrow T_a = \frac{P\phi Z I_a}{2\pi A}$$

$$\Rightarrow \boxed{T_a = \frac{0.159 P\phi Z I_a}{A}}$$

$$E_b I_a = T_a \times \omega$$

$$\Rightarrow E_b I_a = T_a \times \frac{2\pi N}{60} \text{ in rpm.}$$

$$\Rightarrow T_a = \frac{60 E_b I_a}{2\pi N}$$

$$\Rightarrow \boxed{T_a = \frac{9.55 I_a E_b}{N}}$$

Q. A 250V, 4-pole wave-connected DC series motor has 752 conductors in its armature. It has a flux of 25 mwb and series resistance 0.75Ω . The motor takes a current 40 Amp. Estimate the speed & torque developed by it. It has a flux of

25 mwb.

Ans. Given Data
 $V_t = 250V$

$P = 4$

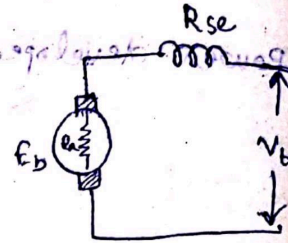
$A = 2$

$Z = 752$

$R_a + R_{se} = 0.75\Omega$

$I_a = I_L = 40 \text{ Amp.}$

$\phi = 25 \text{ mwb} = 25 \times 10^{-3} \text{ wb.}$



$$T_a = \frac{0.159 \text{ pph } I_a}{A}$$

$$= \frac{0.159 \times 4 \times 25 \times 10^{-3} \times 752 \times 40}{2}$$

$$= 239.136 \text{ Nm}$$

$$N = \frac{9.55 I_a}{T_a}$$

$$= \frac{9.55 \times 40}{239.136}$$

$$= 1.59 \text{ rpm}$$

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

$$E_b = V_t - I_a(R_a + R_{se}) + B.D.$$

$$= 250 - 40 \times 0.75 = 220 \text{ V}$$

$$220 = \frac{4 \times 25 \times 10^{-3} \times 752 \times N}{60 \times 2}$$

$$\Rightarrow \frac{220 \times 2 \times 60}{4 \times 25 \times 10^{-3} \times 752}$$

$$\Rightarrow N = 351.0638 \text{ rpm}$$

Q2 A 230V, DC shunt motor runs at 500 rpm. Calculate the armature current is 50 Amp. Calculate speed if the torque is doubled. given resistance is 0.2Ω .

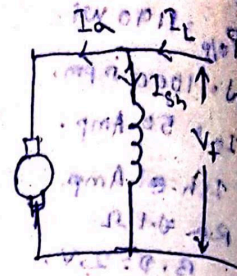
Ans → Given Data

$$V_t = 230V$$

$$N_1 = 500 \text{ rpm}$$

$$I_{a1} = 50 \text{ Amp}$$

$$R_a = 0.2 \Omega$$



$$E_b = V_t - I_a R_a - B.P.$$

$$= 230 - (50 \times 0.2) = 230 - 10 = 220 \text{ V}$$

$$T_1 = 9.55 \times \frac{E_b I_a}{N}$$

$$= 9.55 \times \frac{220 \times 50}{500} = 210.1 \text{ Nm}$$

$$T_2 = 2T_1 = 420.2 \text{ Nm}$$

$$T_2 = 9.55 \times \frac{E_b I_a}{N}$$

We know,

$T \propto I_a$ (in shunt motor)

$$\Rightarrow \frac{T_1}{T_2} = \frac{I_{a1}}{I_{a2}}$$

$$\Rightarrow \frac{T_1}{2T_1} = \frac{I_{a1}}{I_{a2}} \Rightarrow \frac{1}{2} = \frac{50}{I_{a2}}$$

$$\Rightarrow I_{a2} = 100 \text{ amp}$$

$$E_{b2} = V_t - (I_{a2} R_a - B.P.)$$

$$= 230 - (100 \times 0.2) = 230 - 20 = 210 \text{ V}$$

We know,

$$E_b \propto N \quad \left(\because E = \frac{\phi Z N}{60 A}, \phi = \text{constant} \right)$$

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

$$\Rightarrow \frac{220}{210} = \frac{500}{N_2}$$

$$\Rightarrow N_2 = \frac{500 \times 210}{220} = 477.27 \approx 477 \text{ rpm}$$

Q3. A shunt D.C. machine has a armature resistance of 0.12Ω and field resistance of 100Ω . The machine rated terminal voltage is 250 V . Find the ratio of speed as generator and motor. if the current is 50 Amp in each case.

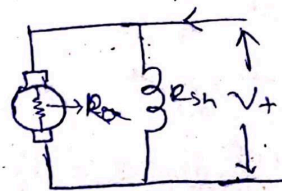
Ans: Given Data

$$R_a = 0.12 \Omega$$

$$R_{sh} = 100 \Omega$$

$$V_t = 250 \text{ V}$$

$$I_L = 50 \text{ Amp}$$



$$\frac{N_1}{N_2} = \frac{E_g}{E_b}$$

$$E_g = V_t + I_a R_a = 250 +$$

$$I_{sh} = \frac{V_t}{R_{sh}} = \frac{250}{100} = 2.5 \text{ Amp}$$

generator $I_{a1} = I_{sh} + I_L = 2.5 + 50 = 52.5 \text{ Amp}$

Motor $I_{a2} = I_L - I_{sh} = 50 - 2.5 = 47.5 \text{ Amp}$

$$E_g = V_t + I_{a1} R_a = 250 + (52.5 \times 0.12) = 256.3 \text{ V}$$

$$E_b = V_t - I_{a2} R_a = 250 - (47.5 \times 0.12) = 244.3 \text{ V}$$

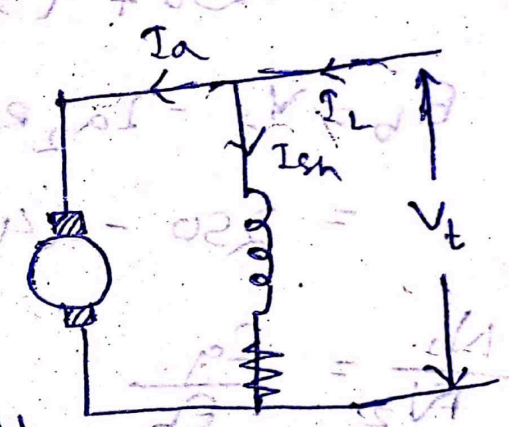
$$\frac{N_1}{N_2} = \frac{E_g}{E_b}$$

$$\Rightarrow \frac{N_1}{N_2} = \frac{256.3}{244.3} = 1.049$$

Speed Control of Shunt motor by flux control method

V_t = terminal voltage

I_{a1} = Armature current without external resistance added to the shunt field.



I_{a2} = Armature current with external resistance added to the shunt field.

N_1 = speed without external resistance is added to the shunt field.

N_2 = speed with external resistance added to the shunt field.

Φ_1 = Flux without external resistance added to the shunt field,

Φ_2 = Flux with external resistance added to the shunt field.

$$E_b = V_t - I_a R_a$$

$$\Rightarrow \frac{P \Phi Z N}{60 A} = V_t - I_a R_a$$

$$\Rightarrow K \Phi N = V_t - I_a R_a$$

$$\Rightarrow N \uparrow = \frac{V_t - I_a R_a}{K \Phi \downarrow} \quad \Rightarrow N = \frac{E_b}{K \Phi}$$

$$E_b = K N \Phi$$

$$E_{b1} = V_t - I_{a1} R_a$$

$$E_{b2} = V_t - I_{a2} R_a$$

$$K N_1 \Phi_1 = V_t - I_{a1} R_a$$

$$\frac{E_{b1}}{E_{b2}} = \frac{K N_1 \Phi_1}{K N_2 \Phi_2} = \frac{V_t - I_{a1} R_a}{V_t - I_{a2} R_a}$$

$$\Rightarrow \frac{N_1 \Phi_1}{N_2 \Phi_2} = \frac{V_t - I_{a1} R_a}{V_t - I_{a2} R_a}$$

Q1. A 250 V DC shunt motor has a armature resistance of 0.25Ω at no load. It takes an armature current of 50 Amp when runs at 750 rpm. If the flux of the motor reduced by 10% without changing the load torque, find the new speed of the motor.

Ans → Given Data

$$V_t = 250 \text{ V}$$

$$R_a = 0.25 \Omega$$

$$I_a = 50 \text{ Amp.}$$

$$N_1 = 750 \text{ rpm.}$$

$$\phi_1 = \phi$$

$$\phi_2 = 90\% \text{ of } \phi_1$$

$$= 0.9 \phi$$

Torque is constant

$$\text{i.e. } T_1 = T_2$$

$$\Rightarrow \phi_1 I_{a1} = \phi_2 I_{a2}$$

$$\Rightarrow I_{a2} = \frac{\phi_1 I_{a1}}{\phi_2}$$

$$\Rightarrow I_{a2} = \frac{50}{0.9} = 55.55 \text{ Amp.}$$

We know

$$\frac{N_1 \phi_1}{N_2 \phi_2} = \frac{V_t - I_{a1} R_a}{V_t - I_{a2} R_a}$$

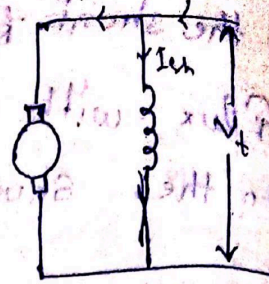
$$\Rightarrow \frac{750 \times \phi}{N_2 \times 0.9 \phi} = \frac{250 - (50 \times 0.25)}{250 - (55.55 \times 0.25)}$$

$$\Rightarrow \frac{750}{0.9 N_2} = \frac{237.5}{236.11}$$

$$\Rightarrow N_2 = \frac{1.005 \times 750}{0.9}$$

$$\Rightarrow N_2 = \frac{236.11 \times 750}{0.9 \times 237.5}$$

$$\Rightarrow N_2 = 828.45 \approx 828 \text{ rpm.}$$



if given reduce then $\phi_2 = 0.9 \phi_1$

$$\Rightarrow N_2 = 1582.5 \text{ rpm}$$

Q3. A 230 V shunt motor at 800 rpm. takes an armature current of 50 Amp. Find the resistance to be added in the shunt field circuit so, that the speed will be increased to 1000 rpm at an armature current of 80 Amp. Assume R_a & R_{sh} are 0.15 and 250 Ω respectively.

Ans Given Data

$$V_t = 230 \text{ V}$$

$$N_1 = 800 \text{ rpm}$$

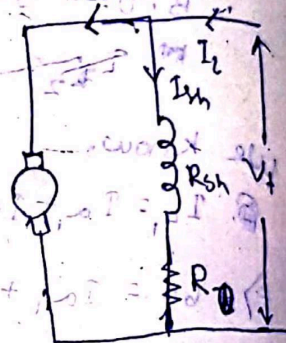
$$I_{a1} = 50 \text{ Amp}$$

$$N_2 = 1000 \text{ rpm}$$

$$I_{a2} = 80 \text{ Amp}$$

$$R_a = 0.15 \Omega$$

$$R_{sh} = 250 \Omega$$



We have

$$\frac{N_1 \Phi_1}{N_2 \Phi_2} = \frac{V_t - I_{a1} R_a}{V_t - I_{a2} R_a}$$

$$I_{sh1} = \frac{V_t}{R_{sh}} = \frac{230}{250} = 0.92 \text{ A}$$

$$I_{sh2} = \frac{V_t}{R_{sh} + R}$$

$$\Phi_1 \propto I_{sh1}$$

$$\Rightarrow \Phi_1 = \frac{V_t}{R_{sh}}$$

$$\Phi_2 \propto I_{sh2}$$

$$\Rightarrow \Phi_2 = \frac{V_t}{R_{sh} + R}$$

$$\Rightarrow \frac{N_1 \times \frac{V_t}{R_{sh}}}{N_2 \times \frac{V_t}{R_{sh} + R}} = \frac{V_t - I_{a1} R_a}{V_t - I_{a2} R_a}$$

$$\Rightarrow \frac{N_1 (R_{sh} + R)}{N_2 R_{sh}} = \frac{230 - (50 \times 0.15)}{230 - (80 \times 0.15)}$$

$$\Rightarrow \frac{800(250 + R)}{1000 \times 250} = \frac{230 - (50 \times 0.15)}{230 - (80 \times 0.15)}$$

$$\Rightarrow 800(250 + R) = 255166.55$$

$$\Rightarrow 250 + R = 318.95$$

$$\Rightarrow R = 68.95 \Omega$$

Speed control of shunt motor by armature control method:

I_{a1} = Armature current without added to the armature circuit.

V_t = terminal voltage.

I_{a2} = Armature

E_{b1} = Back emf with out external resistance added to the armature circuit.

E_{b2} = Back emf with external resistance added to the armature circuit.

I_{a2} = Armature current with external resistance added to the armature circuit.

R = external resistance added to the armature circuit.

$$E_{b1} = V_t - I_{a1} R_a$$

$$E_{b2} = V_t - I_{a2} R_a$$

$$\frac{K N_1 \Phi_1}{K N_2 \Phi_2} = \frac{V_t - I_{a1} R_a}{V_t - I_{a2} R_a}$$

