Energy Conversion-1

Prepared by

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DC Machines :-

→ It is an electrical equipment which operates or generates dc power.

→ In terms of Industrial applications dc Machines having advantages over AC Machines.

→ The Primary Adv. of dc Machines is easy way of speed control.

DC Motor :-

It is an electrical machines which converts electrical energy into mechanical energy.

DC Generators :-

It is an electrical machine which converts Mechanical energy into electrical energy.

Principle of DC Generator :-

It is based on the principle that when a conductor cuts the magnetic flux emf will ~~not~~ induced on it which makes a flow of current in the conductor provided the conductor path is closed. The direction of induced emf in based on fleming's Right hand rule.

fleming right hand Rule :-

If the fore fingere, middle finger & thumb are straights perpendicular to each other, if thumb represents the motion of the conductor, & fore finger represents direction of flux then the middle finger represents the direction of induced emf.

having influence of south pole. in this position the total conductor placed horizontal to magnetic field flux. therefore e.m.f induced in the coil is zero.

→ At position no. 2 the conductor starts rotates weaks or min angles, which results emf induced in the conductor.

→ At the position no. 3 a conductor is placed perpendicular to the magnetic field so that maxᵐ flux can be linkage. which results maxᵐ emf induced across the conductor.

→ with the same revolution / rotation value of emf becomes zero at position 5 as the conductor is again horizontal to magnetic field.

→ During the position no. 5 the influence of magnetic pole to the individual conductor reverse, therefore from position no. 5 to 1 the direction of induced emf will be in the reversed direction.

→ The waveform represents the total emf induced in a complete rotation.

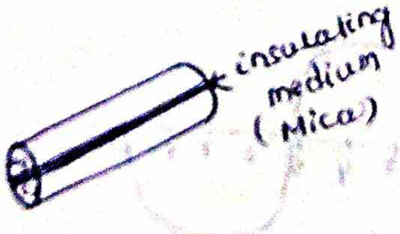
→ From the waveform we can easily identified the induced emf or the current is alternating, therefore to change the alternating emf into dc emf one diff mechanism has be added to the machine, which is called commutator.

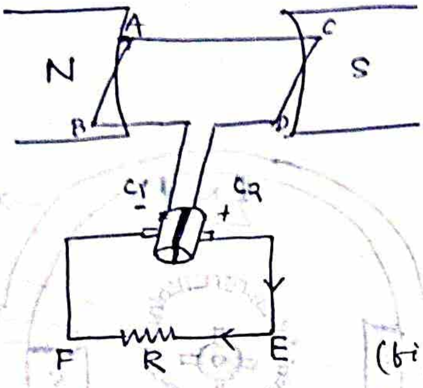
Commutator

it is a mechanical converter which converts generated Ac into fixed dc.

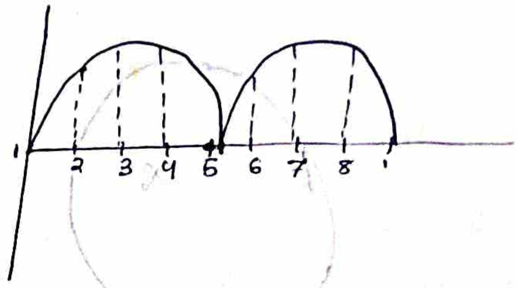
→ it is a combination of two carbon plates separated by insulating medium.

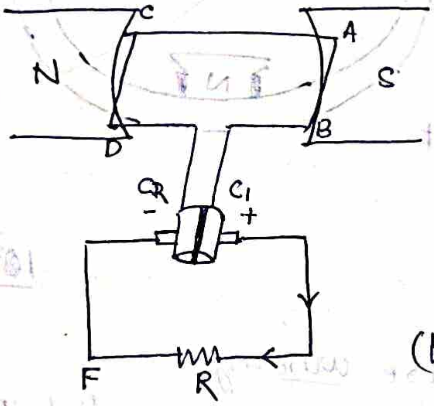
→ Commutators are placed in the shaft of the armature without electrical coupling.





(fig-1)





(fig-2)

In the (fig-1) conductor AB & CD having the influence of north & south pole respectively due to that the direction of current across the load from E to F.

→ In the (fig-2) the conductor AB & CD changes their position & influence with south & north pole respectively.

→ During this position commutator also change its position w.r.t conductor position. which results the direction of current will be reverse which is from E to F.

→ with the help of commutator what the output we are achiving is not fix one it is complete pulsating one.

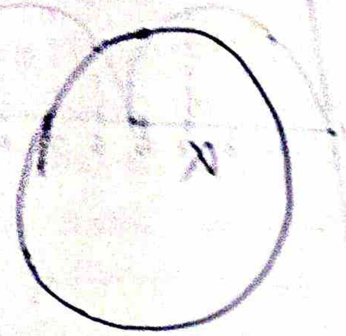
→ To avoid such situation we have to increase no. of conductors in the armature.

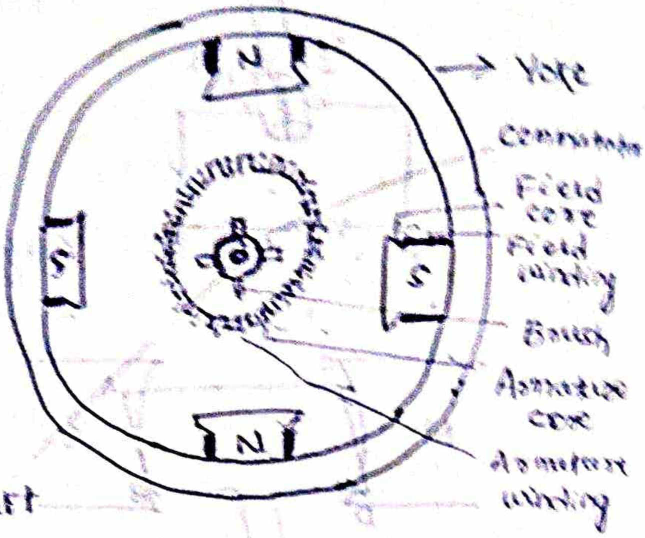
<u>Construction of DC Generator</u> :-

In the point of construction both dc generator & motor are similar i.e. we can utilize a dc generator as motor or vice versa.

the main component of the dc generator are ~~to~~.

→ field system
→ Armature ~~pole~~ Core
→ Armature winding
→ Commutor
→ Brush
→ Yoke





onstruction-

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General features of DC Armature winding :-

A dc machine generally employes windings distributed n each slots over the circumference of armature core. he position of the conductor is so arranged that it lies ight angle to the magnetic flux and to the direction of notion of the conductor. therefore induced emf in the conductor given by,

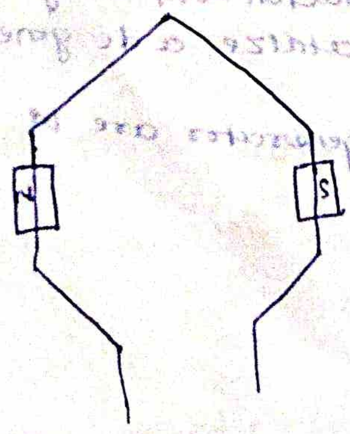
$e = BLV$

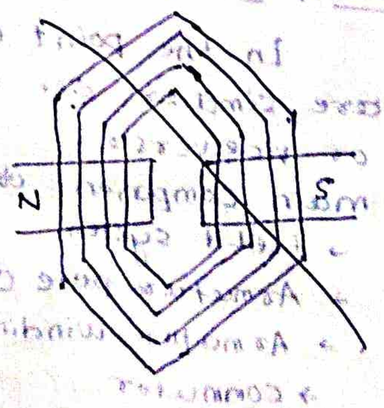
B = magnetic flux density wb/m^2

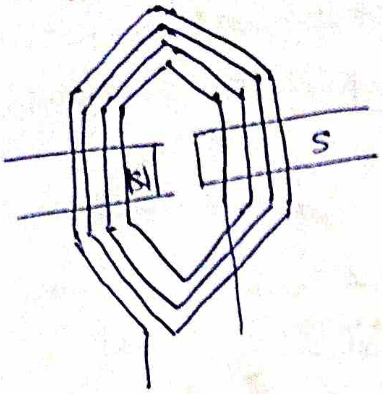
L = length of the conductor (M)

V = velocity of the " M/sec

the armature conductors are connected to form coils, he basic component of all types of armature winding is the armature coil.







In single term coil two coil sides connected at the back of the armature, But in 4 term coil 8 coil sides are essemble at the armature, the coil sides of conductor is desigeing such a way that each side of the coil influence to diff poles.

→ the emf of the coil sides added together because as the armature rotates the induced emf in the conductor always in opposite direction.

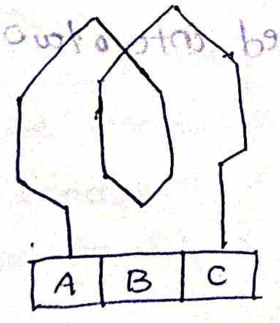
→ Most of the dc armature winding in each slot of the armature core two conductors are placed.

→ While arranging the double condcuctor in a single slot we have to make sure that one coil side of a coil lies top of the slot and another coil side lies bottom of the another slot.

→ the coil ends which such arrangement will lie side by side

→ In 2 layer winding it is desirable 2 number the coil side rather than slots.

→ The coil sides connected through commutator segment in such a way that to form a series parallel connection because to get better control over voltage & current.



Commutator pitch :- (Yc)

It is defined as no. of commutor segment spand by each coil of the winding.

Pole pitch :- (Y_P)

The distance betn two adjacent poles; It is equal to the number of armature conductors.

if there are 400 conductors and 4 poles, then pole pitch is $400/4 = 100$ conductor

coil span or coil pitch :-

It is the distance, measured in terms of armature slots between two sides of a coil.

Ex :- If the coil span 9 slots, its means one side of the coil is in slot 1 and the other one is in slot 10.

It is devided in two Pitch

(i) Full pitch

In case of full pitch coil pitch = pole pitch

so that maxm amount of emf can be induced

(ii) Short pitch

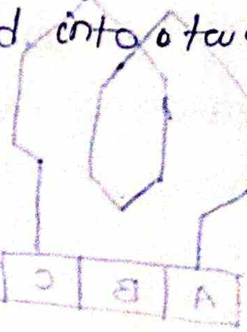
In this case coil pitch is always less then Pole pitch

Types of winding

The armature winding is classified into two types-

→ Lap winding

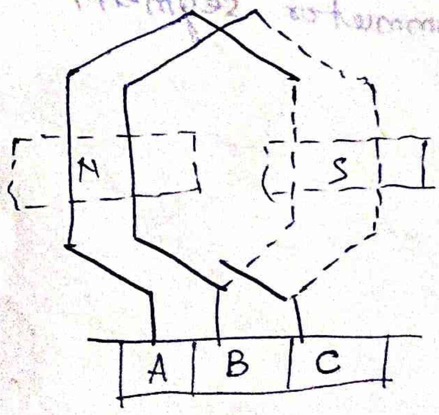
→ wave winding



Lap winding

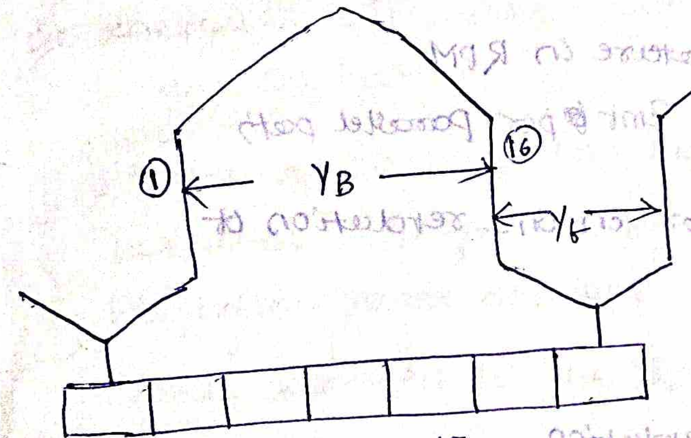
Low voltage & high current machines

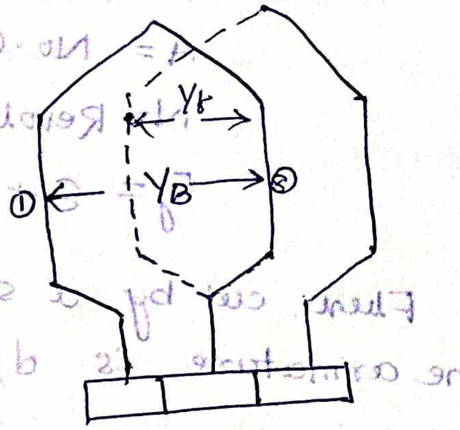
no of parallel path $a = p$



Back pitch - (Y_B)

It is the distance measure in terms of armature conductor betn the two sides of the coil at the back of the armature.

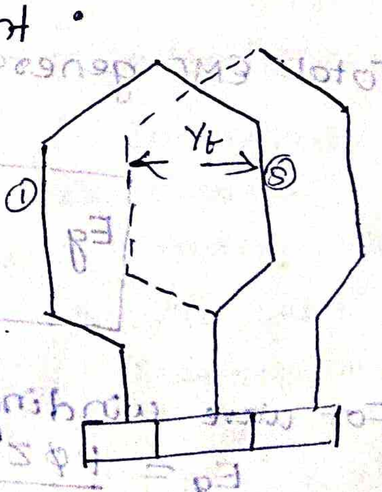




$Y_B = 16 - 1 = 15$

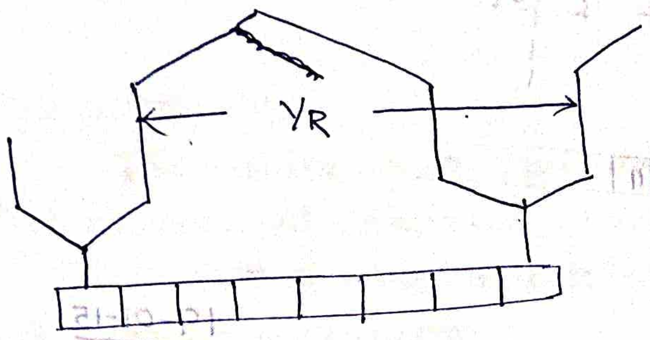
Front Pitch (Y_f) =

It may be defined as the distance in terms of armature conductor between 2nd conductor of 1 coil & First conductor of next coil which ~~are~~ ~~cas~~ are connected together to a single commutator segment.



Resultant pitch(Y_R):-

It can be defined as resultant of Front pitch & back pitch otherwise it can also be defined as distance in terms of armature winding in betn 1st conductor of 1 coil to the first conductor of next coil which are connected together.



EMF equation of DC Generator:-

Let ϕ = Flux per pole in wb

Z = total no. of conductor in armature

= total no. of slots × no of conductor in each slot

P = No. of poles

A = No. of parallel path

N = Revolution of armature in RPM

E_g = Emf generated or Emf per parallel path

Flux cut by a single conductor in one revolution of the armature is $d\phi = \frac{P\phi}{Z} = P\phi$

Time taken to complete one revolution

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

EMF generated per conductor $= \frac{d\phi}{dt} = \frac{P\phi}{60/N} = \frac{P\phi N}{60}$

Total EMF generated = Emf generated per parallel path

= emf generated/conductor × no. of conductor/parallel path

$$\boxed{E_g = \frac{P\phi N}{60} \times \frac{Z}{A} = \frac{P\phi ZN}{60A}} \quad \text{——— (1)}$$

For wave winding

$$E_g = \frac{P\phi ZN}{60 \times 2} = \frac{P\phi ZN}{120} \quad (A=2)$$

For Lap winding:-

$$E_g = \frac{P\phi Z N}{60 \times P} = \frac{\phi Z N}{60} \therefore (A = P)$$

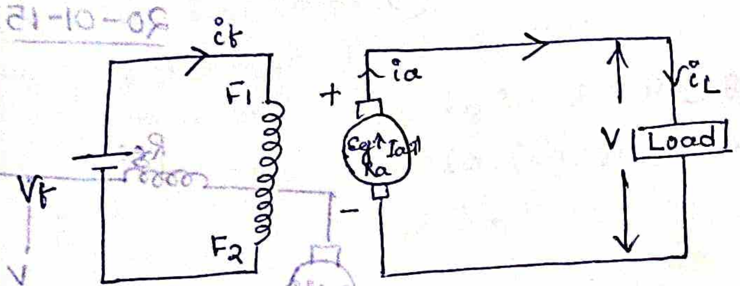
Classification of DC Generator :-

The DC generators are broughtly clasified into 2 categories as for the excilation system.

(i) separately excited DC generator

(ii) Self excited DC generator

Separately excited DC generator :-



Ra = Armature resistance

It is a kind of DC generator whose field is being excited or energises with some external DC source.
ex- DC batteres

Armature current $I_a = I_L$

Terminal voltage $V = E_g - I_a R_a$

Electrical Power develope $P_g = E_g I_a$

Power delevered to the Load $P_d = E_g I_a - I_a^2 R_a = I_a(E_g - I_a R_a)$

$= I_a V$

$= I_L V$

Self excited dc generator :-

→ It advance version of dc generator in which no external source is being utilize to energize the field core because it utilize it's own power.

→ what are the Power is being developed it being fed back to the field winding to make it energized.

→ But during the initial condition this Process may not work therefore to avoid that situation we are preferring the poles which are having self magnetic property which is Residual magnetism.

Losses in the DC Machine :-

~~Broughtly~~ the Broadly the losses of the DC machine can be devided into 3 categories :
- core loss
- copper loss
- Mechanical loss

Core losses :-

Lossing of Lower at core is known as core losses. As the core's are made ~~by~~ ~~op~~ by Iron, therefore these losses can also be treated as Iron loss. It is again devided into two categories :-
- Hysteresis loss
- Eddy current loss

Hysteresis loss :-

It is a kind of loss of a magnetic material during the process of magnetization & demagnetization reversal of magnetic pole. that can be redeced improved quality Iron in the core.

Eddy current Loss :-

The unwanted current which is following at the surface of armature core is known as eddy current. Due to ~~it~~ this eddy current the power will loss in the form of heat.

→ This can be avoid or minimise with the help of proper Lamination of individual core.

Copper Losses :-

This kind of losses can be found out across windings of armature, series field & shunt field because the material which is use for this windings are made up of copper. ~~or~~ are the losses of power due to

→ Normally the copper losses otherwise opposition flow of current in the winding therefore armature of windings to flow the current can be ~~detect~~ written as winding copper loss

Armature winding copper loss $= I_a^2 R_a$

shunt to field winding " $= I_{sh}^2 R_{sh}$

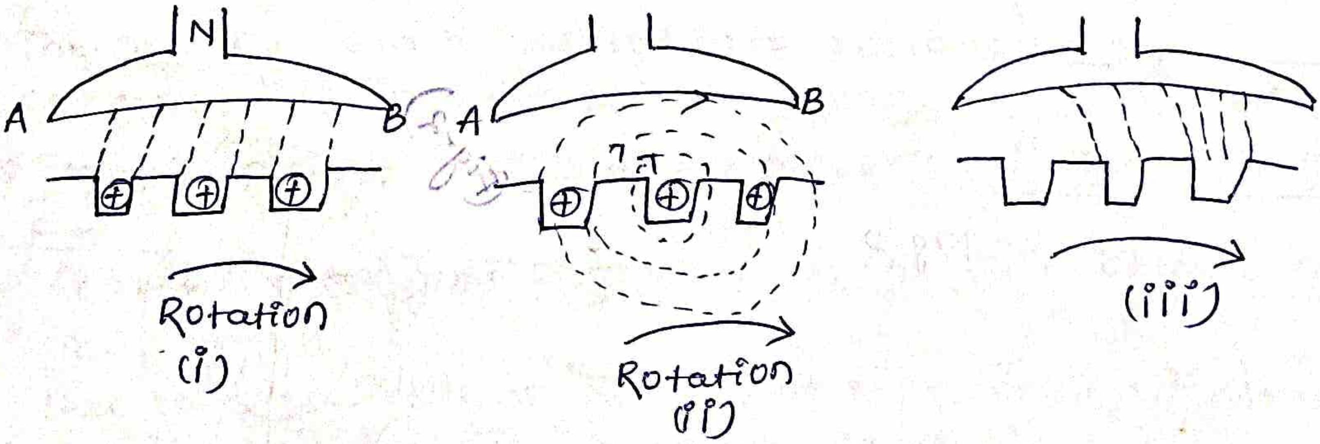
Series " $= I_{se}^2 R_{se}$

Armature Reaction :-

In a dc generator the purpose of field winding is to produce main flux in the generator through which EMF can be induced in the armature but in the mean time flux can be generate at the armature coil due to the flow of current which is referd as armature flux

→ in general behaivour of armature flux is to oppose the main flux.

- the effect of the armature field through which main flux weakens is known as demagnetisation
- the effect of armature flux through which main flux disturbs is known as cross magnetisation.



the first figure represents maximum amount of flux can be reached to the ~~ama~~ armature winding

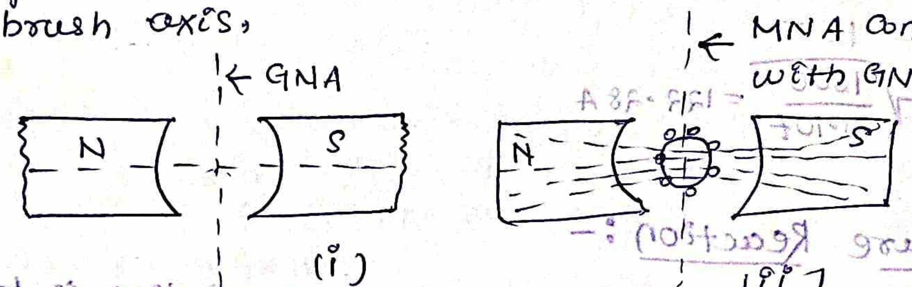
- The 2nd fig represents the flux created by armature winding.
- During the loaded condition the armature flux try to oppose the main flux which results uneven concentration of field flux at the armature end.

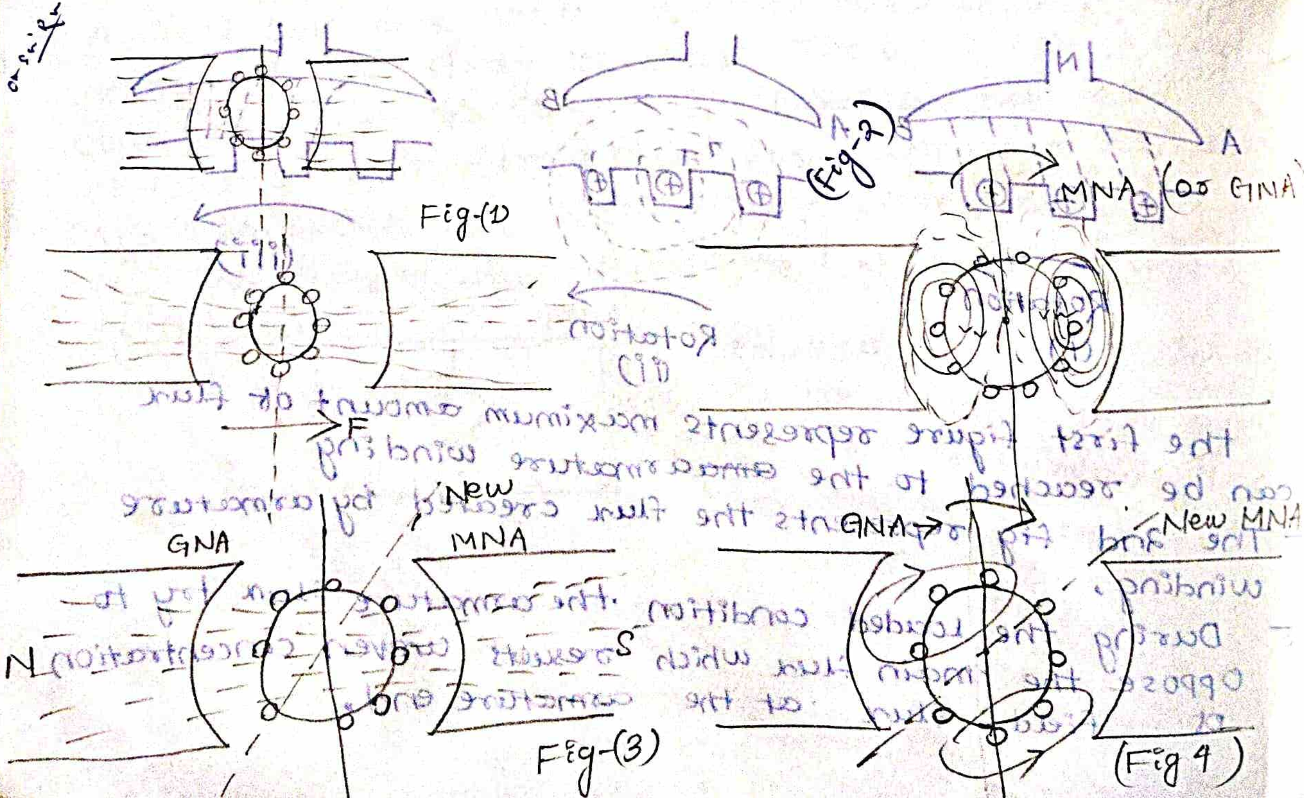
This effect of opposition of armature flux to main flux is known as armature reaction.

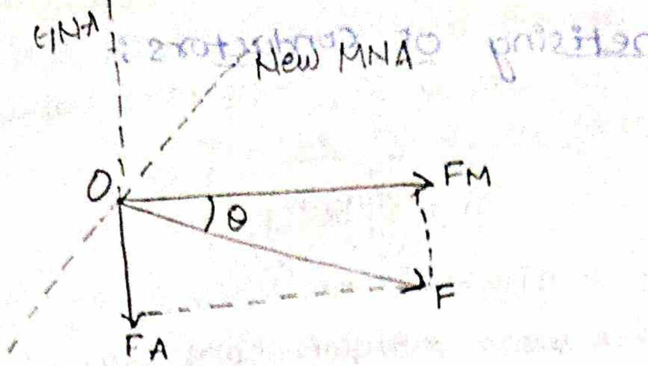
Magnetic Neutral Axis and Geometric Neutral Axis :-

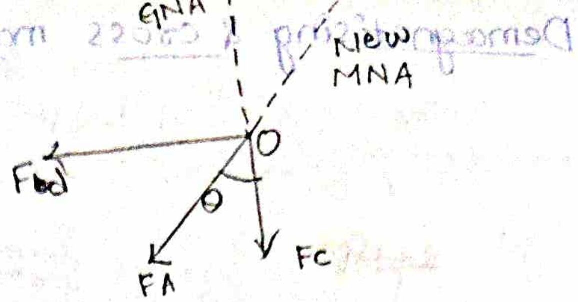
The GNA is the axis that bisects the angle betn the centre line of adjacent pole.

- MNA is the axis which is perpendicular to the main.
- In the case of DC generator brushes are always placed along MNA, hence MNA is also Axis of commutation or brush axis.





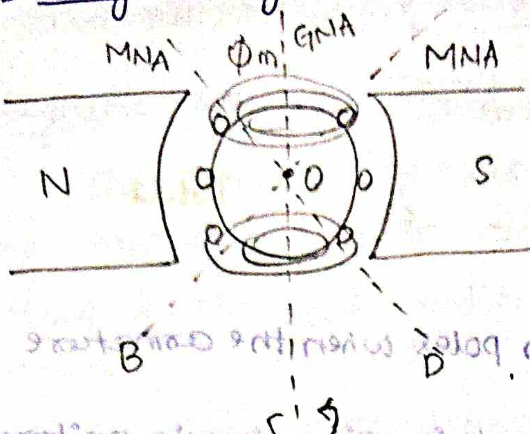


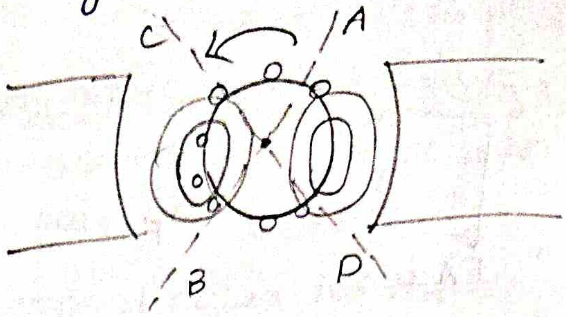


Fig(1) shows the flux due to main poles when the armature conductors carry no current.

- The flux across the air gap during this situation is uniform.
- The mmf producing the main flux is represented in magnitude & direction by the vector.
- Fig 2 represents flux due to current flowing in the armature.
- The armature conductors to the left of GNA carry current "in" and to the right carry current "out".
- The mmf producing by armature flux is represented in magnitude & direction by "OF_A".
- Fig 3 represents flux due to main pole due to current flowing in the armature.
- In the vector representation we can easily identify the resultant mmf "OF" is the vector sum of "OF_m" and "OF_A".
- Since MNA is always perpendicular to resultant mmf therefore MNA is also shifted through an angle "θ".
- Fig(4) represents the shifting of brushes with respect to MNA in order to achieve sparkless commutation.
- Consequently the brushes are shifted through an angle "θ" so as to lie along MNA which results rotation of mmf of armature.
- The new "F_A" can be resolved into rectangular component of "F_d" and "F_c".
- The component "F_d" is direct opposition to the mmf "F_m"
- It has a demagnetising effect on the flux created by main pole.
- Due to these reasons "F_d" can be represented as demagnetising component of armature reaction.
- The component "F_c" is at right angle to the "OF_m".
- It distorts the effect of main field flux therefore it can be represented as cross magnetising component of armature reaction.

Demagnetising & cross magnetising of conductors :-





With the brushes in GNA position there is only cross magnetising property however when the brushes are shifted from GNA there is:

→ the armature reaction will have both demagneting & cross magnetising effect.

- consider a 2 pole generator with brushes shifted "θ_m" mechanical degree from GNA.
- Fig (i) represents the armature conductor shifted "θ_m" on either direction of GNA.
- thus the conductor lying within the angle AOC or ∠BOD with a angle of "$2\theta_m$" (∠$2\theta_m$)
- these angles or the conductors are called demagnetising conductors of armature windings.
- Fig (ii) represents the axis of magnetisation of the remaining armature conductors which are lying in betn AOD or BOC.
- the conductors lying in these are as can be represent as cross magnetising conductors of armature windings.

Calculation of demagnetising Ampere term per pole :-

It is necessary to netralise the demagnetising Ampere turns of armature reaction.

→ It can be achived by adding extra Ampere term to main field winding.

let Z = total no of armature conductors

I = current in each armature conductor

$= I_a / A$ [A = No. of parallel paths]

$= I_a / 2$ [for wave winding]

$= I_a / P$ [For Lap winding]

θ_m = forward mechanical degree

total demagnetising armature conductors = conductors lying in before AOC & BOD

$$= \frac{4\theta_m}{360} \times Z$$

Since 2 conductors constitute 1 turn therefore total demagnetising Ampere turns $= \frac{1}{2}\left(\frac{4\theta_m \times Z}{360}\right) I$

$$= \frac{2\theta_m}{360} ZI$$

The demagnetising Ampere turns are due to a pair of pole therefore demagnetising ampere turn per pole i.e.

$$AT_d/\text{pole} = \frac{2\theta_m}{360} ZI \times \frac{1}{2} = \frac{\theta_m ZI}{360}$$

The demagnetising ampere turns can be neutralised by putting extra turns in the pole of the generator.

- the extra turns in the pole of generator are

$$\frac{AT_d/\text{pole}}{I_{sh}} \longrightarrow \text{shunt}$$

$$= \frac{AT_d/\text{Pole}}{I_a} \longrightarrow \text{Series}$$

Cross magnetising Ampere turn per pole :-

Total number of armature reaction Ampere turn per pole is equals to $= \frac{Z/2}{P} \times I = \frac{ZI}{2P}$

demagnetising Ampere turns per pole is given by

$$\frac{\theta_m ZI}{360}$$

So that cross magnetising Amperes turns per pole

$$= \frac{ZI}{2P} - \theta_m \frac{ZI}{360}$$

$$= ZI\left(\frac{1}{2P} - \frac{\theta_m}{360}\right)$$

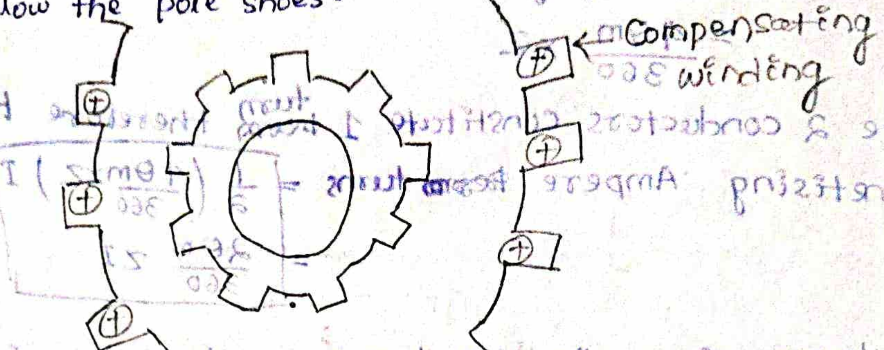
To compensate on to neutralise the cross magnetising effect we have to adopt the compensating winding at the poles of the generator.

Compensating Winding :-

To neutralise the cross magnetising effect of armature reaction compensated winding is used.

* the process of adding compensated winding in the generator makes it too expensive for that reason special application where large fluctuation in load side - appears like rolling meal motor and turbo generators preffered for compensating winding.

* these windings are embeded in the shoe ... with armature in such a way that the current in them flow in opposite direction to that flowing armature conductor directly below the pole shoes.

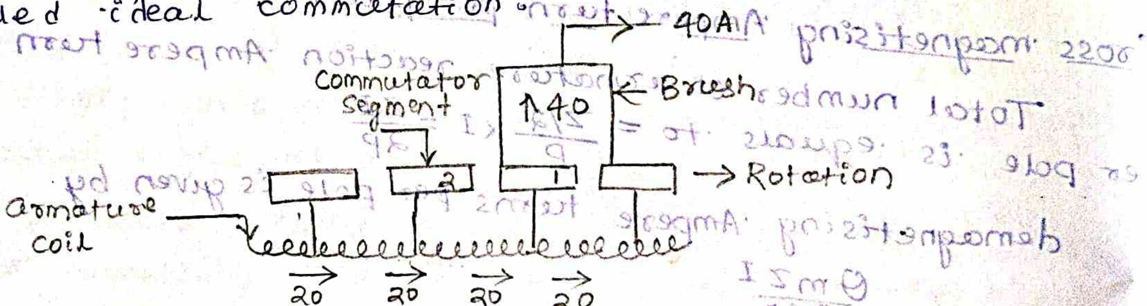


Commutation :-

Commutation is the process of converting the AC voltages and currents in the armature of a DC machine to DC voltage and current at its terminals.

OR. The reversal of current in a coil as the coil passes the brush axis is called commutation.

* when commutation takes place, the coil under goes short circuited by the brush. The period during which the coil remains short circuited is known as commutation period.
* In the commutation process, current in a coil will reverse as the coil passes a brush and if current reversal is complicated by the end of commutation period then it is called ideal commutation.



(i)

* consider one coil 'A' in armature winding as shown in the fig.
* the brush width is equal to the width of one commutator segment of sheet MICA.
* suppose total armature current is 40 A then the amount of current flowing in each coil is 20 A because of 2 parallel paths.

* The commutator segment '1' conducts a current of 40 amp to brush which is the combination of 20 amp from coil 'A' & 20 A from adjacent coil A.

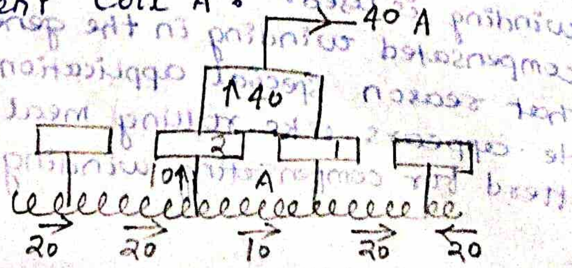
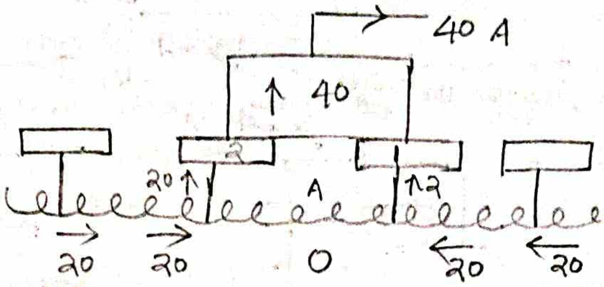


fig (2)

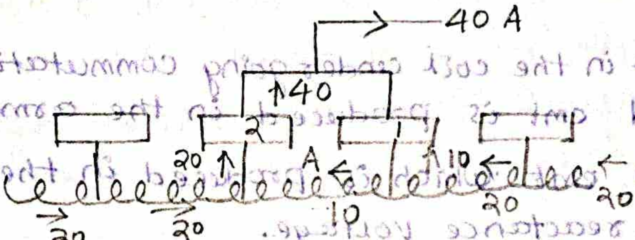
due to the rotation of armature the brush will contact with 1/4 of the segment '2' and 3/4 of the segment '1'.

* The brush conducts current it 40 Amp which is addition of 10 amp current through segment 2 and 30 amp current to segment 1 which makes reduction of current coil A from 20 amp to 10 Amp.



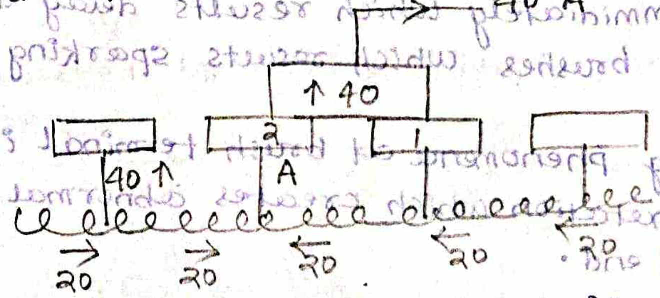
fig(3)

* In fig(3) we can observe the brush conetact with 1 1/2 to segment 2 and 1 1/2 to segment 1.
* During this situation also 40 A current is flowing in the brush with the help 20 amp each in the segment of 1 and 2 which results '0' current in coil A.



(fig-4)

In fig (iv) current flowing in the brush is 40 A which is the combination of 30 amp from seg '2' and 10 amp from seg 1.
During this situation current flowing in the coil is 10 amp reverse direction.

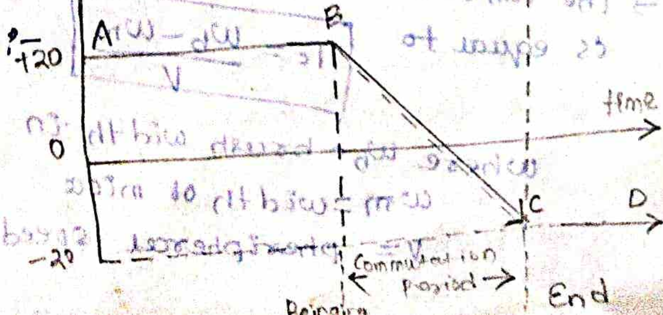


(fig-V)

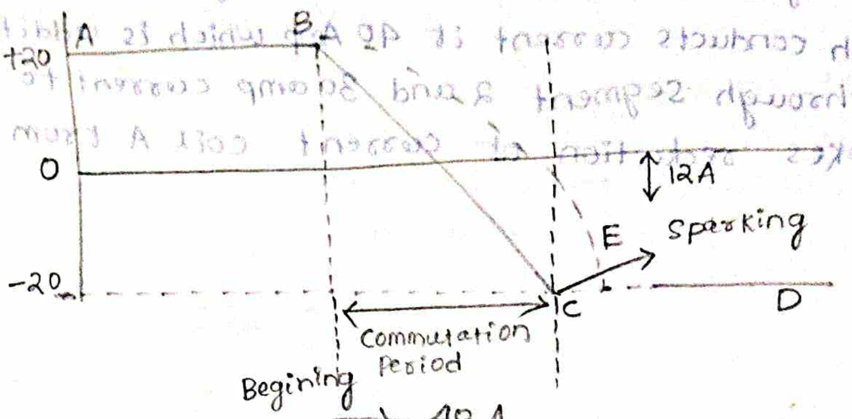
In fig (V) current flowing through brush is 40 A which is only through seg '2'.

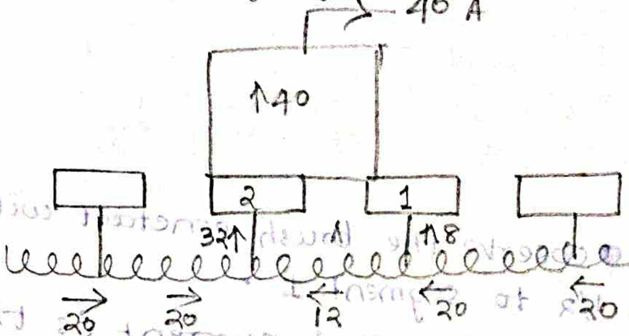
* Amount of current flowing in coil A in 20 amp with reverse direction.

<u>Current time graph of Coil A :-</u>



Practical Commutation :-





In case of practical commutation the full commutation can not be acheived because the presence of inductance in the armature coil.

* when the current in the coil under going commutation changes then self induced emf is produced in the armature coil.
* The self induced emf which is produced in the armature coil is called reactance voltage.
* the reactance voltage always opposes the change in current.
* Due to this opposition the direction of current can't be reversed immidiately which results delay in the shifting of brushes which results sparking at brush terminal.
* the sparking phenomena at brush terminal is reffered as - miscommutation which creates abnormal condition at the load end.

Commutation Period :-

when a coil undergoes commutation, two commutator segments remain short circuited by the brush.

→ The time of short circuit (or commutation Periodic) is equal to

$$T_c = \frac{W_b - W_m}{V}$$

where W_b = brush width in cm

W_m = width of mica

V = pheripheral speed of commutation in cm/s

Reactance voltage :-

Let the current in the coil undergoing commutation charge from +I to −I (ampere) during the commutation.

→ L is the inductance of the coil

→ then reactance voltage is given by

$$E_R = L \times \frac{2I}{T_c}$$

Methods for improving commutation :-

The commutation process can be improved in 2 diff. ways

(1) resistance commutation

(2) EMF commutation.

Resistance commutation :-

→ In this process the copper brushes replaced by carbon brushes because of its high resistance.

→ if the contact resistance betn brush & commutator segments then current would divide in the inverse ratio of contact resistance.

→ The main reason behind the sparking at brushes is reactance voltage which can not be avoided with the help of carbon brushes

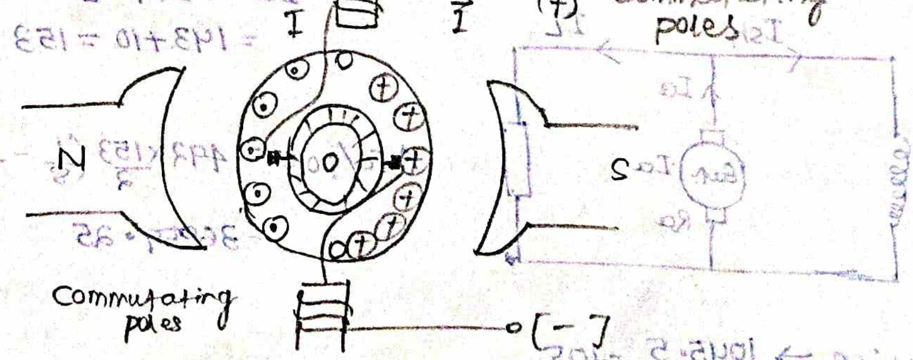
→ Due to the high resistance of carbon brushes approximately 2 volt loss appears the brush arrangement.

EMF Commutation :-

– In this process arrangement is made to neutralise the reactance voltage by producing reverse EMF in the short circuited coil.

– The value of reverse EMF should be equal or more than the reactance voltage.

– this can be acheived by adding interpoles or compoles at the field system.



The interpoles are the small poles placed in betn 2 main poles.

→ They are wounded with heavy gauge copper wire and are connected in series with the armature winding.

→ As the polarity of interpole is the same as that of main pole ahead they induce an EMF in the coil which is under commutation that helps the reversal of current.

12-02-15

DC Generator Characteristics :-

In general fenomena the characterist^ of dc generator can be classified into 3 categories.

(i) open ckt characteristics (O.C.C)
(ii) Internal "
(iii) External "

(i) O.C.C :-

→ It is also known as no-load saturation characteristics or magnetic characteristics.

→ It shows relationship betn no.load generated e.m.f (E_0) and field or exciting current (I_f) at a fixed speed.

→ During this process we have to study the magnetic property of the electromagnet which are treated at poles.

(ii) Internal characteristics :-

It shows the relationship betn generated e.m.f during loaded condn or actual e.m.f(E) & armature current (I_a).

→ As we know that actual e.m.f (E) is always less than no load e.m.f (E_0). Therefore this characteristics always represents a lower value than open ckt characteristics.

→ ~~the diff~~ In this characteristics demagnetising e.m.f of armature reaction involves in the main e.m.f.

(iii) External Characteristics :-

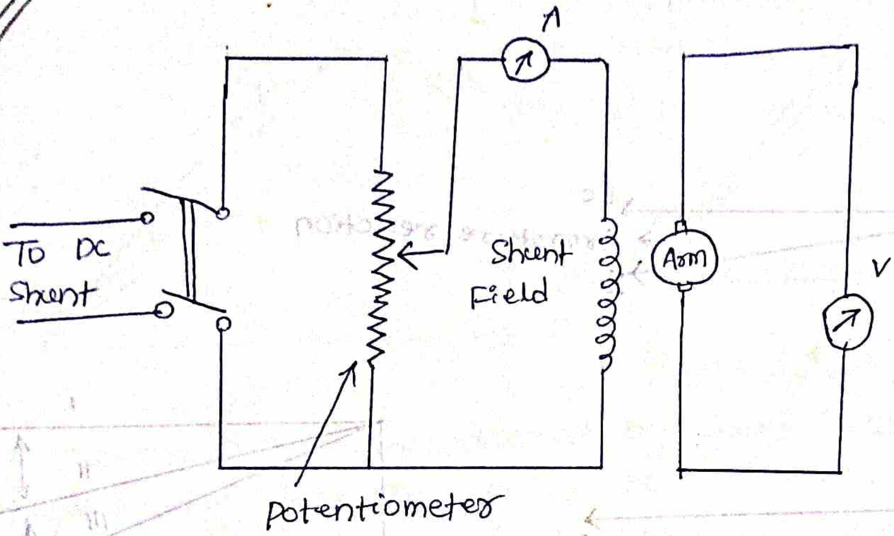
It shows the relationship betn terminal voltage (V) & Load current (I_L).

→ It can also be referred as performance characteristics because through this characteristics we can observe efficiency of the generator.

The External characteristics is always less than internal char.... because involvement of dropping voltage across the armature.

~~Separate~~

Open ckt characteristics for separately excited DC generator :-



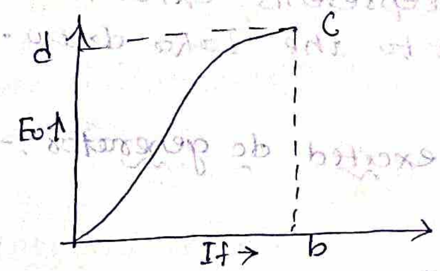
$E_0 \propto \Phi$

~~No-Load Saturation Characteristics~~

The voltage equation of a d.c. generator is

$$E_g = \frac{\phi Z N}{60} \times \left(\frac{P}{A}\right) \text{ volts}$$

Hence if speed is constant as we consider N as constant So $E = K\phi$



we can observe in the char----

→ As for the final equation from its initial value the that when If is increased e.m.f increases directly generated e.m.f or the no load i.e. until the poles are as current till the position D unsaturated

→ As the flux density increases the poles become saturated which makes small variation in (E_0) in compare with If. which can be found out at position 'B'.

Internal & External Characteristics separately excited dc generator:-

As we know that it is characterites in betn E & Ia. but in case of separetely excited dc generator value of

$I_a = I_L$.

As the load current increases the terminal voltage falls down due to two reasons.

(i) the armature reaction weakens the main flux so that the actual e.m.f generated 'E' always less than no load emf 'E_0'.

DC Motor

It is an electromechanical instrument through which we convert electrical energy to mechanical energy.

Working principle of DC Motor:-

when ever the current carring conductor located in which a magnetic field the conductor experience the mechanical force & the direction of the mechanical force is given by fleming left hand rule, and the magnitude is given by $(F = BIl)$

Back emf or Counter emf:-

the moment when conductor starts rotating inside the magnetic field under the influence of driving torque emf will induced in the conductors of armature.

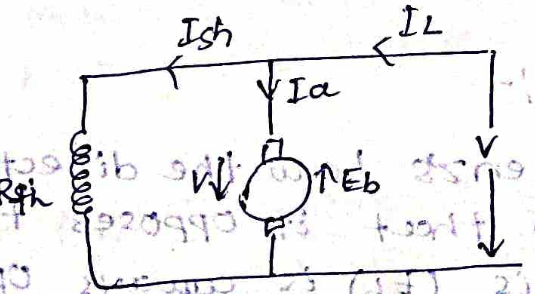
→ the induced emf at its opposite direction to the applied voltage V & it is known as back emf or counter emf.

→ it can be represent as $(E_b) = \frac{P\phi ZN}{60}$

the value of (E_b) is always less than applied voltage (V).

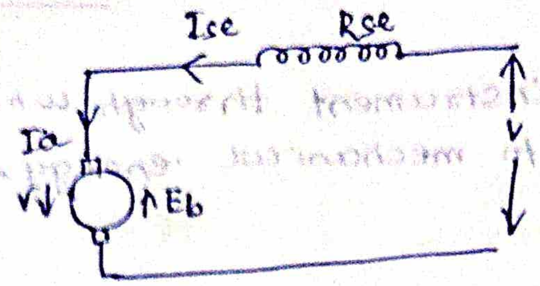
Types of DC Motor:-

(i) shunt wound dc motor



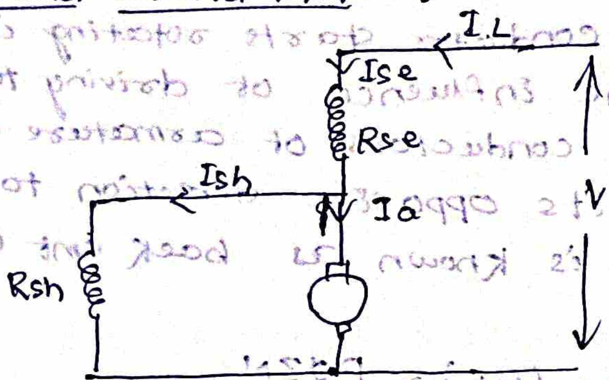
In case of shunt wound dc motor current flowing in the shunt field is lower than the current flowing in the armature winding therefore the shunt winding is wounded with relatively larger no. of turns having higher resistance.

Series-wound Motor :-

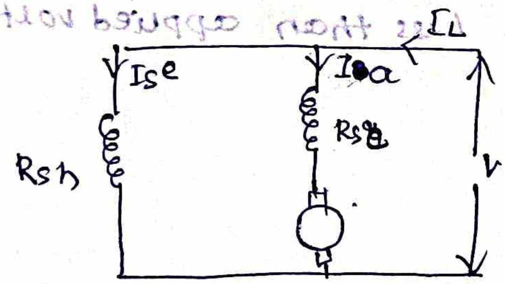


In case of series-wound motor same amount of current flow across field & armature winding therefore, a conductor having low resistance with less turn will be utilise for series field.

Compound-wound Motor :-



(Long)



(Short)

Significanat of Back emf :-

According to lenz's Law the direction of induced emf is such that it opposes the cause producing it that is (E_b) is always Oppose the voltage (V). Therefore the net voltage across the armature ckt will be equal to $V - E_b$ (Applied voltage, generated emf)

net voltage across armature
$= V - E_b$

→ If Ra is the armature ckt resistance then $I_a = \frac{V - E_b}{R_a}$

→ the presence of back emf makes the dc motor is self regulating machine i.e. it makes the motor draw as much as armature current to develope the torque require by the load.

→ When the motor is running in no-load small torque is required to over come of friction and windage losses therefore the armature current I_a very small value & the back emf is nearly equal to applied voltage.

→ If the motor is suddenly loaded the first effect is to slow down the armature, therefore the speed at which the armature conductor moves through the field is reduced & hence the back emf Eb falls down. the decreased of back emf allows a larger current flows through the armature winding which result increasing in driving torque.

→ If the Load on the motor is decreased than the driving torque is momentarily the access of the requirement so that the armature starts accelerate. as the speed increases emf induced in the coil increases which results decreasing in armature current centimately the driving torque also decreases.

→ From this points we can analyse the back emf in a dc motor regulates the flow of armature current as for the load requirement.

→ For the maximum power the value of Eb should be equal to half of the applied voltage

03-03-15

Pow

Power in the dc motor & condⁿ for the Max^m Power :-

power of a DC motor can be represent as ~~VIa~~

$VI_a = E_bI_a + I_a^2 R_a$ where, VI_a = electrical power supply to the armature.

E_bI_a = power developed by the armature or armature output

$I_a^2R_a$ = electrical power wasted at the armature

The mechanical power developed by the motor can be represented as

$$V I_a = E_b I_a - I_a^2 R_a \quad \text{——} (1)$$

$$P_m = E_b I_a \quad \text{——} (2)$$

$$\Rightarrow P_m = V I_a + I_a^2 R_a \quad \text{——} (3)$$

In eqⁿ no-(3) supply voltage V & armature resistance is always constant therefore the developed mech. power is always depending upon armature current I_a

For max^n power $\frac{dP_m}{dI_a}$ should be equal to Zero(0).

$\Rightarrow V - 2I_aR_a = 0$

$\Rightarrow \boxed{I_aR_a = \frac{V}{2}}$ —— 4

The general voltage equation is $V = E_b + I_aR_a$

$\Rightarrow V = E_b + \frac{V}{2}$

$\Rightarrow \boxed{E_b = \frac{V}{2}}$ —— (5)

This shows that max^n power can be deliver value of counter emf or back emf is half of the supply voltage.

N.B

In regular practice it is not advisable to run the motor in the max^m power condition because under such situation value of armature current is much larger as compare to rated current which can burn the conductor of armature winding.

* A 4 pole 500V shunt motor has 720 wave connected conductor in the armature. The full load armature current is 16 amp & the flux per pole is 0.03 wb. the armature resistance is 0.2 Ω & the contact draw is 1V per brush. Calculate the full load speed of the motor & mechanical power developed by the motor.

Given

$P = 4$
$Z = 720$
$\phi = 0.03$ wb
$V = 500$ V
$R_a = 0.2\ \Omega$
$I_a = 60$ A

$V = E_b + I_aR_a + (2\times1)$

$500 = E_b + (60\times0.2) + 2$

$\Rightarrow E_b = 500 - 12 - 2$
$= 486$ V

$E_b = \frac{P\phi ZN}{60A} \Rightarrow 675$ RPM

$P_m = V I_a - I_a^2R_a$
$= 500\times60 - (60)^2\cdot0.2$
$= 30000 - 360\times2$
$\Rightarrow 30000 - 720 \Rightarrow$

N = 675 RPM
PM = 29160 W

29280

Torque of dc motor :-

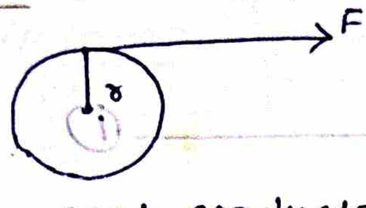
Torque is the turning moment of force acting above axis & it can be measured by the product of applied force & radius 'r' at right angle to which the force acts.

The essential parameter of torque in a dc motor can be categorised into two parts.

(i) Armature torque

(ii) Shaft torque

A) Armature torque :-



In a dc motor each conductor faces a circumference or circular force at a distance "r" which is the radius of the armature therefore each conductor exerts a torque tending to rotate the armature.

The sum of the torques due to all armature conductor is known as brush (or) armature torque (T_a).

suppose it is a p d.c. motor 'r' = avg. radius of armature (m)

l = effective length of each conductor (m)

Z = total no. of armature conductor

A = total no. of parallel path

i = current in each conductor

$= I_a/A$

p = no. of poles

B = Magnetic flux density (Wb/m^2)

ϕ = flux/pole (Wb)

Force on each conductor can be represent as $F = Bil$ Newton

Torque due to one conductor can be represent as $T = Fr$ Nm

Total armature torque can be represent as

$$T_a = \Sigma Fr = ZBilr$$

D.C Motor characteristics

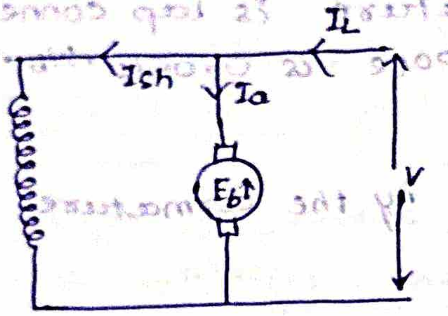
(i) The characteristic of d.c. motor can be analysis on three different way.
- > Armature torque & armature current characteristics
- > Armature current & speed characteristics
- > Speed & torque characteristic

(ii) In between these three characteristics, I_a/T_a can be treated as electrical characteristics an N/T_a can be treated as mechanical characteristics of dc motor.

(iii) With a relationship betn armature current & speed we can analysis the selection of motor for the particular application.

T_a, I_a, N

Characteristics of d.c shunt motor :-



In case of d.c shunt motor the value of field current I_{sh} is always constant because the field winding is directly connected to supply voltage (V). Hence the flux in the shunt motor is approximately constant.

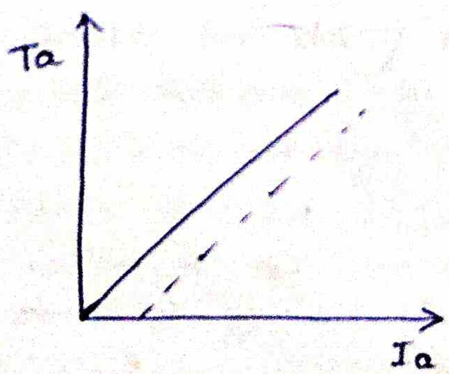
Torque Vs armature Characteristics :-

As we know that ;

$$T_a \propto \phi I_a$$

But in the case of dc shunt motor ϕ can be treated as constant, so $T_a \propto I_a$

With this relationship T_a Vs I_a characteristic is straight line passing through the origin.

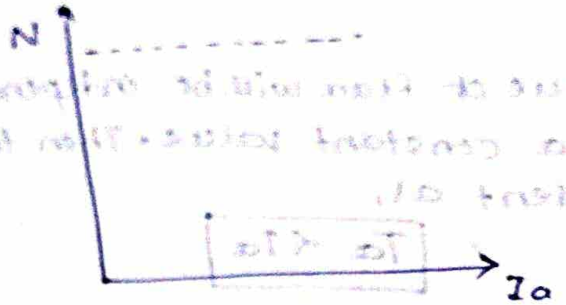


From these graph it is clear that very large current is required to start a d.c motor shunt motor with heavily loaded. Therefore it is advisable not to start a d.c shunt motor with heavy loaded.

Speed Vs Armature current :-

The speed N of a d.c motor can be represent as $N = \frac{E_b}{\phi}$, but the flux ϕ & back emf E_b is a shunt motor can be treated as constant at normal condition. Therefore the speed of d.c shunt motor will remain constant as the armature current raises.

If load is increased the value of 'I' decreases due to the armature resistance torque & armature reaction with the

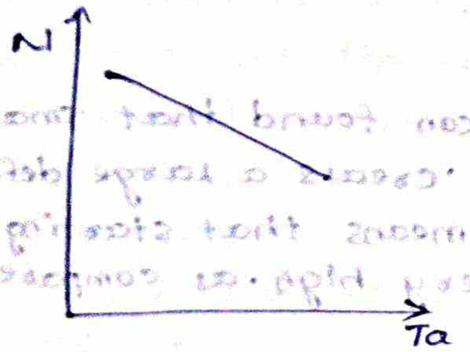


relation

$E_b = V - I_aR_a$

Therefore speed of dc shunt motor sightly decreases from its original value.

Speed Vs Torque Characteristics :-



Conclusion :-

(i) From the above three characteristics of d.c. shunt motor we can conclude that there is a light change in speed from no-load to full-load. Therefore d.c shunt motor can be treated as a constant speed motor.

(ii) The starting torque of dc shunt motor is very slow. Therefore it can be utilise for the application where the condition is light load.

Ch-3

Starting of DC Motor :-

Need of Starter :-

During the initial condn of dc motor the armature will be in the stationary condn which means there is no counter emf generated.

i.e $E_b = 0$

but we know that $I_a = \frac{V - E_b}{R_a}$

→ As the value of $E_b = 0$ therefore the value of I_a is treaminately high in compare with normal full load current. which is approximately 10-12 times more than that of full load currents, which results (i) burning of armature winding due to excessive heat

(ii) damaging the commutator segment & brushes due to heavy sparking.

(iii) Excessive voltage drop in the line to which the motor is connected.

→ In order to avoid such difficulties of variable resistance which is known as starting resistance is insalted in series with armature ckt.

→ This resistance is gradually reduced with motor gain speed and hence E_b increases & the Resistance with completely cut-off when the motor gain maximum speed.

→ the value of starting resistance is generally such that the starting current is limited to 1.25 to 2 times the full load current.

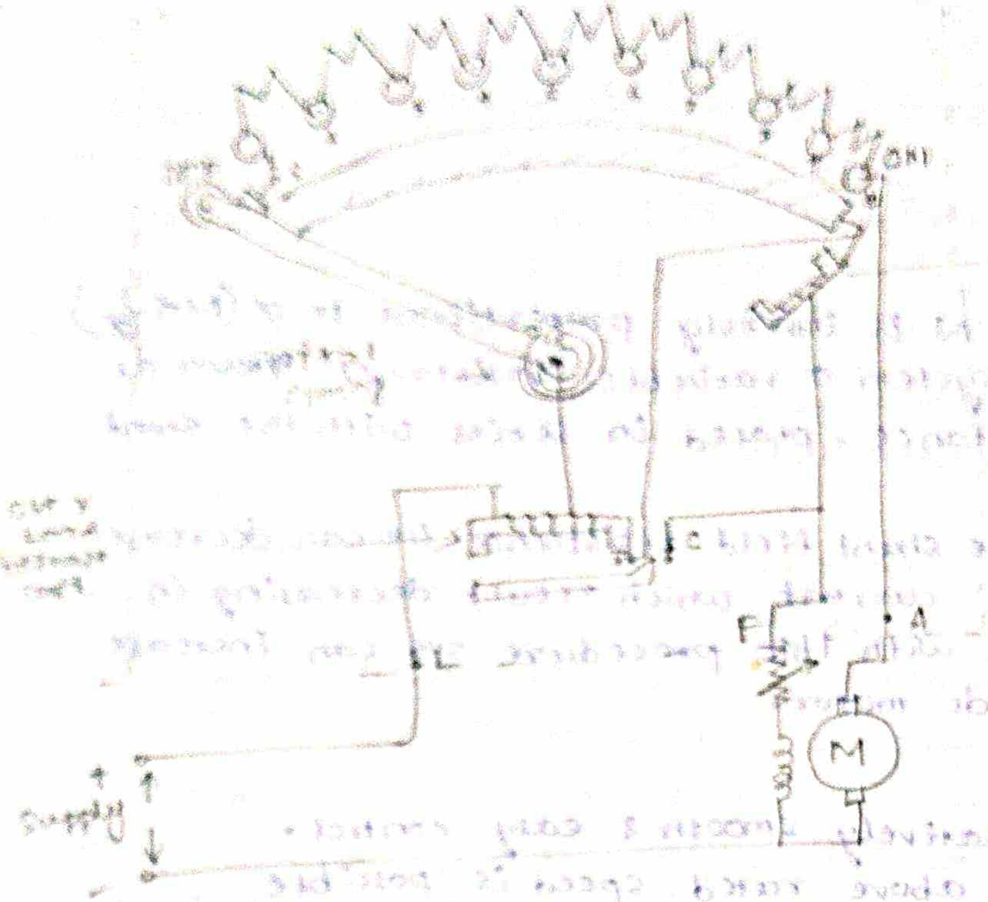
Types of Starter of dc motor :-

Generally we are using 2 kind of starter

(i) Three-point Starter

(ii) Four point Starter

Three point starter :-



12-03-15

Speed control of DC motor :- (Shunt)

As we know that the speed of the dc motor can be given by

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

By dominating the constant term we can get

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

But we know that $E_b = V - I_a R_a$

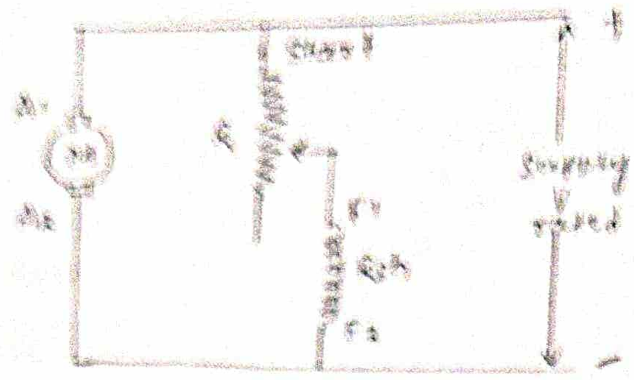
$$\therefore N = \frac{V - I_a R_a}{\phi} \quad \text{———} (1)$$

From these eqn we can conclude that speed of the dc motor depend upon field flux, armature resistance and supply voltage.

Therefore the speed control of dc motor can be devided into 3 categories.

1) Field flux control method
2) Armature Resistance control methode / Armature voltage control method
3) Voltage control method.

1) Field flux control methode :



We know that N is inversly proportional to ϕ ($N \propto \frac{1}{\phi}$)
In this kind of system a variable resistance known as shunt field resistance. placed in series with the shunt field.

> By increasing the shunt field resistance we can decrease the shunt field current which result decreasing in flux. Ultimately with this procedure we can increase the speed of dc motor.

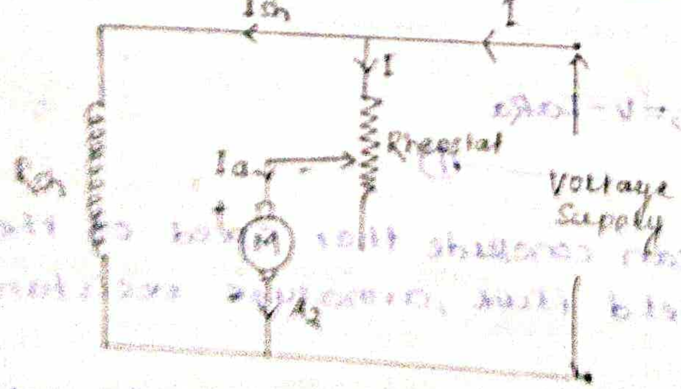
Advantage :-

1) In provides relatively smooth & easy control.
2) Speed control above rated speed is possible
3) This method more economical & efficient.
4) As the field current is small, the size of rheostat required is small.

Disadvantage :-

1) The speed control below normal rated speed is not possible.

2) Armature resistance control methode :-



1) We know that $N \propto V - I_aR_a$
But during this process $N \propto V - I_a(R_a + R_e)$
where R = external resistance offered by the rheostat

(ii) when value of R increases the voltage across armature decreases which result decreasing in speed.
(iii) But the moment when the value of R become zero, the motor will rated at rated speed.

Dis-advantage :-

(i) Due to series resistor less voltage is appeared across armature terminals.
(ii) Power loss in this control is high & efficiency is low.
(iii) Speed regulation is very poor.

3) Voltage control methode :-

(i) In this method the voltage source supply the field current is different from that which supplies to the armature.
(ii) This method avoid the disadvantages of poor speed regulation and low efficiency as in the case of armature resistance control method.
(iii) But it has a disadvantage of expensiveness.
(iv) Therefore such kind of methods are applicable for larger size & higher rating d.c motor where important of efficiency is more.
(V) This process can be done in two different case
(a) Ward-Leonard Methods
b) Multiple voltage control methods

A) Ward-Leonard Method :-