LECTURE NOTES
ON
ENERGY CONVERSION-I
4TH SEMESTER

PREPARED BY
MR. NIHAR RANJAN DIKSHIT
PTGF IN ELECTRICAL ENGINEERING
GOVERNMENT POLYTECHNIC PURI

DC Generator

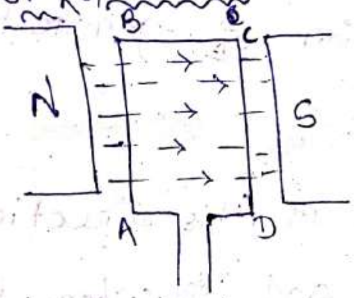
Defination:-

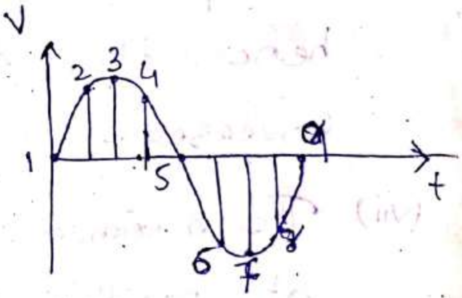
→ Electrical Generator is a machine that Convert mechanical energy into electrical energy.

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

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

Principle of DC 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

Cutting is maximum and the emf generated is maximum.

(iv) When the loop at position no. 4 the generated emf is less because the coil sides are cutting the flux at an angle less than 90°.

(v) At position no. 5 no flux lines are cut the emf induced is 0V.

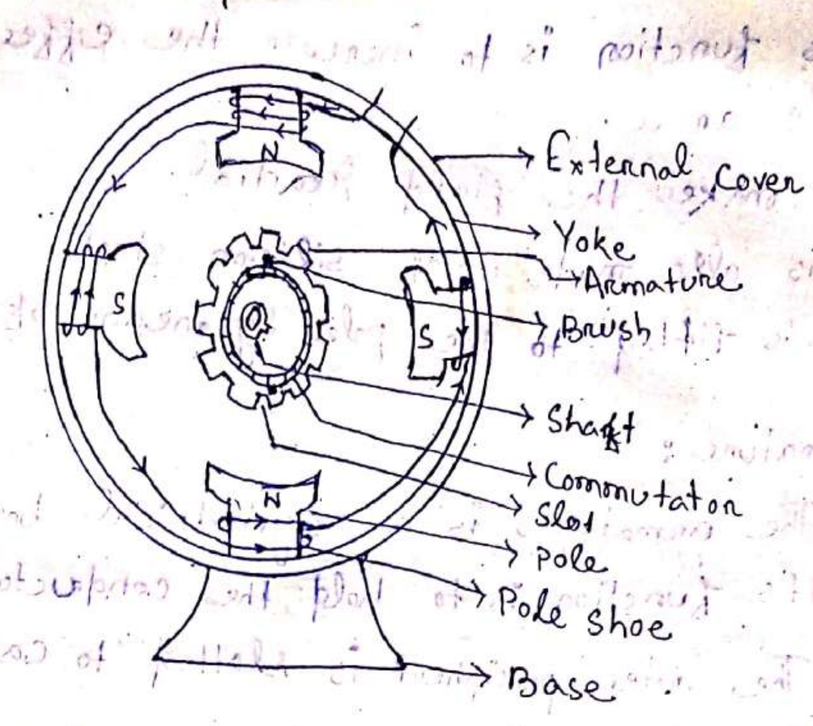
(vi) At the position no. 6 the coil sides moves under a pole of opposite polarity and hence the direction of generated emf is reversed.

(vii) The maximum emf in this direction will be at position no. 7 and 0V when the position is 9.

(viii) The cycle repeats with each revolution.

★ Parts of DG ~~Machine~~ Generator :-

★ 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 creats 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 peripheri is slotted to carry the conductor.

→ Armature is laminated to reduce the eddy current loss.

→ It is made up of CRGO (Cold Roled Grain oriented) material.

(vi) Commutator :-

→ It is placed on the front end of the armature.

→ It is made up of cupper.

→ The total commutator is made up of different commutator segment.

→ The shape of the commutator is circular.

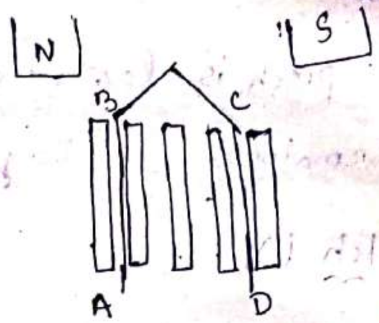
→ It convent AC to DC in case of generator and DC to AC in case of Motor.

(vii) Brush :-

→ It is made up of cupper or carbon.

→ It's function is to collect the current.

Pole pitch :-



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

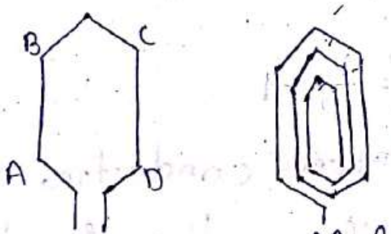
→ It is equal to no. of armature conductor or slot under one pole.

★ **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 begining of next coil to which it is connected called as Resultant pitch.

★ Commutator pitch :-

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

Pole = P = 4

Armature slots = 20

Total conductor = Z = 20 × 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 $Y_B = 11$	Front Connection $Y_F = 9$
1+11 = 12	12 − 9 = 3
3+11 = 14	14 − 9 = 5
5+11 = 16	16 − 9 = 7
7+11 = 18	18 − 9 = 9
9+11 = 20	20 − 9 = 11
11+11 = 22	22 − 9 = 13
13+11 = 24	24 − 9 = 15
15+11 = 26	26 − 9 = 17
17+11 = 28	28 − 9 = 19
19+11 = 30	30 − 9 = 21
21+11 = 32	32 − 9 = 23
23+11 = 34	34 − 9 = 25
25+11 = 36	36 − 9 = 27
27+11 = 38	38 − 9 = 29
29+11 = 40	40 − 9 = 31
31 + 11 = 42 − 40 = 2	42 − 9 = 33
33+11 = 44 − 40 = 4	44 − 9 = 35

Back Connection

35 + 11 = 46 − 40 = 6

37 + 11 = 48 − 40 = 8

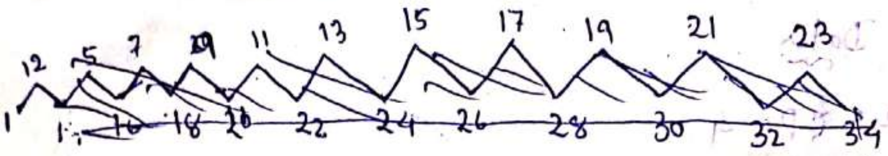
39 + 11 = 50 − 40 = 10

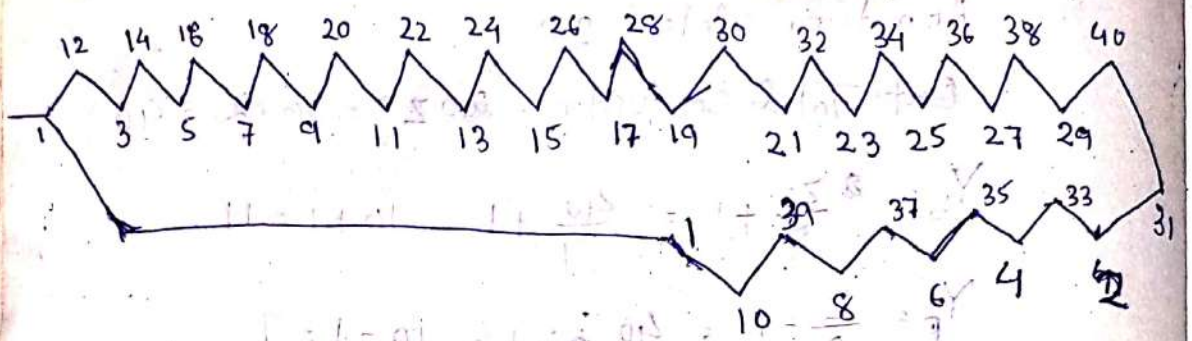
Front Connection

46 − 9 = 37

48 − 9 = 39

50 − 9 = 41 − 40 = 1



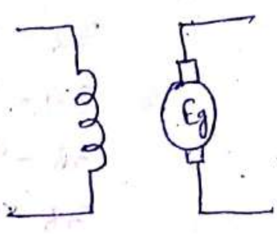


Types of DC Generator :-

DC Generator
- Separately excited DC Generator
- Self excited DC generator

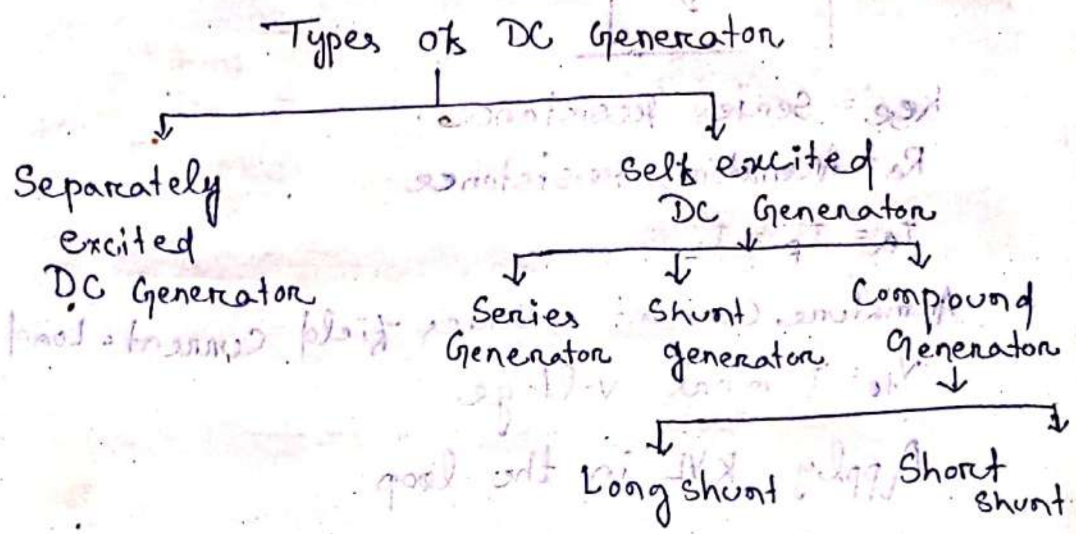
(i) Separately excited DC Generator :-

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

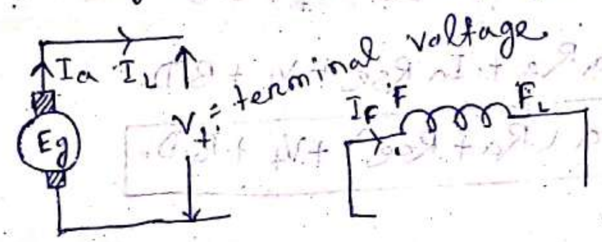


(ii) Self excited DC Generator :-

In self excited DC generator the induced voltage itself giving supply to the field winding.



(i) Separately excited DC generator :-



E_g : Generating voltage

R_a = Armature resistance

I_a = Armature current

I_L = Load Current

V_t = terminal voltage

$I_f = I_{sh}$ = Field current

R_f = field resistance

Applying KVL in the loop,

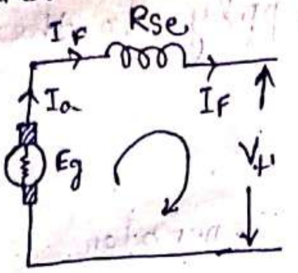
$E_g - I_a R_a - V_t - B.D = 0$

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

$I_a = I_L$

(ii) Self excited DC Generators :-

(a) Series Generator :-



R_{se} = Series resistance.

R_a = Armature resistance

$I_a = I_F = I_L$.

Armature Current = Series field current = Load current

V_t = terminal voltage

Apply KVL in the loop.

$E_g - I_a R_a - I_F R_{se} - V_t - B.D. = 0$

$\Rightarrow E_g = I_a R_a + I_F R_{se} + V_t + B.D$

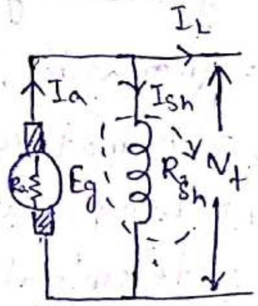
$\Rightarrow E_g = I_a R_a + I_a R_{se} + V_t + B.D.$

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

(b) Shunt generator :-

I_{sh} = Shunt current

R_{sh} = Shunt resistance



$I_a = I_{sh} + I_L$

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

Apply KVL in the loop.

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

$\Rightarrow \boxed{E_g = V_t + I_a R_a + B.D.}$

Scanned by CamScanner

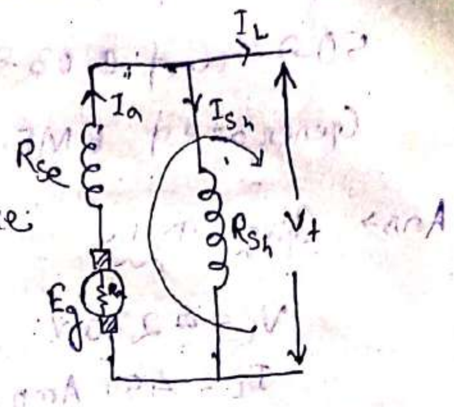
(C) Compound Generator :-

1. Long Shunt Compound Generator :-

R_{se} = Series field Resistance

R_{sh} = Shunt field Resistance

I_{sh} = Shunt field Current



$I_a = I_{sh} + I_L$

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

Apply KVL in the loop.

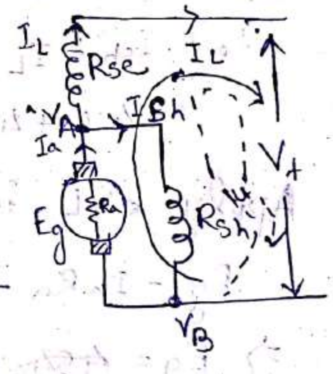
$E_g - I_a R_a - I_a R_{se} - B.D - V_t = 0$

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

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

2. Short Shunt Compound DC Generator :-

$I_a = I_{sh} + I_L$



~~Ish Putti~~

Apply KVL in dotted loop

$V_B + V_t + I_L R_{se} - V_A = 0$

$\Rightarrow V_B - V_A + V_t + I_L R_{se} =$

$\Rightarrow V_A - V_B - V_t - I_L R_{se} = 0$

$\Rightarrow V_A - V_B = V_t + I_L R_{se}$

$\Rightarrow V_{AB} = V_t + I_L R_{se}$

$I_{sh} = \frac{V_{AB}}{R_{sh}} = \frac{V_t + I_L R_{se}}{R_{sh}}$

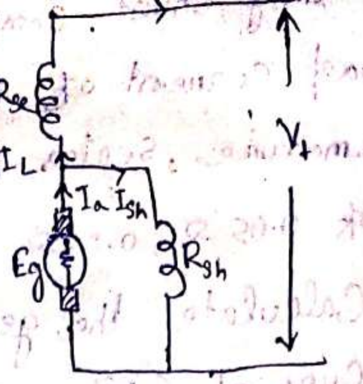
Apply KVL in the Solid loop

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

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

Ans 7. Given Data.

$I_L = 30$ Amp.
$V_t = 220V$
$R_a = 0.05\,\Omega$
$R_{se} = 0.3\,\Omega$
$R_{sh} = 200\,\Omega$
B.D = 1V



$E_g = I_a R_a + I_L R_{se} + V_t + B.D.$

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

$$= \frac{220 + (30 \times 0.3)}{200} = \frac{220 + 9}{200}$$

$$= \frac{229}{200} = 1.145 \text{ Amp.}$$

$I_a = I_{sh} + I_L$

$= 1.145 + 30 = 31.145$ Amp.

$E_g = I_a R_a + I_L R_{se} + V_t + B.D.$

$= (31.145 \times 0.05) + (30 \times 0.3) + 220 + 1$

$= 1.557 + 9 + 221$

$= 231.557\,V$

Equation of EMF generation in DC Generator.

ϕ = Flux per pole

Z = no. of conductor (no. of slot × no. of conductor in each slot)

P = no. of pole

N = no. of revolution in R.P.M.

E_g = EMF generated

$E = n \frac{d\phi}{dt}$ (if no. of conductor is one)

Emf generated per conductor $= \frac{d\phi}{dt}$

No. of flux cut per conductor in one revolution $(d\phi) = P.\phi$

No. of revolution per minute = N rpm

No. of revolution per second = $\frac{N}{60}$ rpm

~~Emf generated = E = $\frac{d\phi}{dt}$~~

~~1 revolution per second~~ = $\frac{1}{\frac{N}{60}}$ rpm.

time taken for 1 revolution $= \frac{60}{N}$ rpm.

Emf generated $= E = \frac{d\phi}{dt}$

$= \frac{P\phi}{\frac{60}{N}} = \frac{P\phi N}{60}$ $(\because d\phi = P\phi)$

~~There are Z~~

If total no. of conductors are Z, then the total emf generated $E = \frac{ZP\phi N}{60}$

There are 2 types of winding

(i) Lap winding

(ii) Wave winding

For Lap winding no. of parallel path (A) is no. of pole.

~~For~~ So, the generated Emf $= \frac{ZP\phi N}{60A}$

for wave winding $\therefore A = 2$

So, the generated Emf $= \frac{P\phi ZN}{60 \times 2}$

Q. A 4 pole generator having wave wound armature winding having 51 slots and each ~~sel~~ slots have 20 conductors. ~~Find the gene~~ what will be the voltage generated in the machine when it is driven 500 rpm assuming flux per pole is ~~7 mwb~~ 7 milliweber.

Ans → Given Data

No. of poles (P) = 4

No. of Slots = 51

Conductors in each slot = 20

Total conductor(Z) = 51×20

= 1020

Flux per pole (ϕ) = 7 mWb

$\phi = 7 \times 10^{-3}$ Wb.

No. of Revolution (N) = 500 rpm.

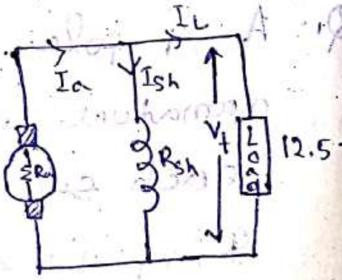
As the armature winding is wave wound

So, A = 2.

$$\therefore E_g = \frac{P\phi ZN}{60A} = \frac{4 \times 7 \times 10^{-3} \times 1020 \times 500}{60 \times 2} = 119 \text{ V}$$

Q2. An 8 pole DC. Shunt generator with 778 wave connected armature conductor running at 500 rpm. Supply a load 12.5 Ω Resistance of terminal voltage is 250 V. The armature Resistance is 0.24 Ω and field Resistance is 250 Ω. Find the armature current, induced emf and flux per pole.

Ans → Given Data



N = 500 Rpm.

$R_L = 12.5\ \Omega$

$V_t = 250$ V

$R_a = 0.24\ \Omega$

$R_{sh} = 250\ \Omega$

A = 2

Z = 778

$$I_L = \frac{V_t}{R_L} = \frac{250}{12.5} = 20 \text{ Amp.}$$

$$I_{sh} = \frac{V_t}{R_{sh}} = \frac{250}{250} = 1 \text{ Amp.}$$

$I_a = I_{sh} + I_a = 21+1 = 21$

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

$= (21 \times 0.24) + 250 + 0$

$= 5.04 + 250$

$= 255.04 \text{ V}$

We know,

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

$$\Rightarrow 255.04 = \frac{8 \times \phi \times 778 \times 500}{60 \times 2}$$

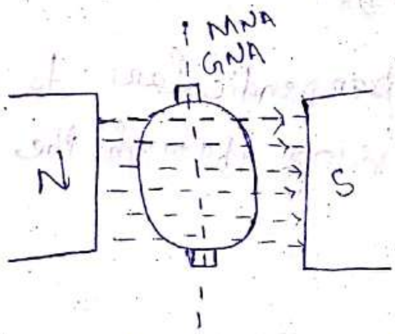
$$\Rightarrow \phi = \frac{255.04 \times 120}{8 \times 778 \times 500}$$

$$\Rightarrow \phi = 9.83 \times 10^{-3} \text{ wb} = 9.83 \text{ mwb}.$$

∴ generated Emf is 255.04 V and flux per pole is 9.83 mWb.

Armature Reaction :-

The effect of Armature flux lines with main magnetic flux lines



(i) absent of Armature Conductor.

Armature Reaction :-

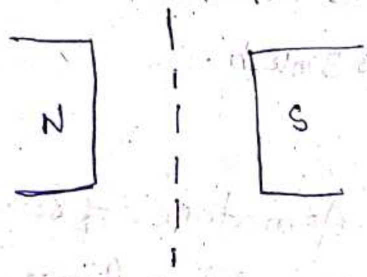
→ The action of armature flux on main flux is called armature reaction.

→ The flux acting in a DC machine is that due to main pole is called main flux.

→ The current through the armature conductor also creates a magnetic flux called armature flux.

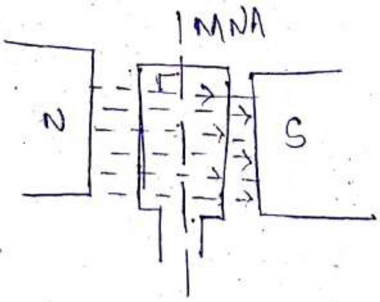
GNA (Geometric Neutral Axis) :-

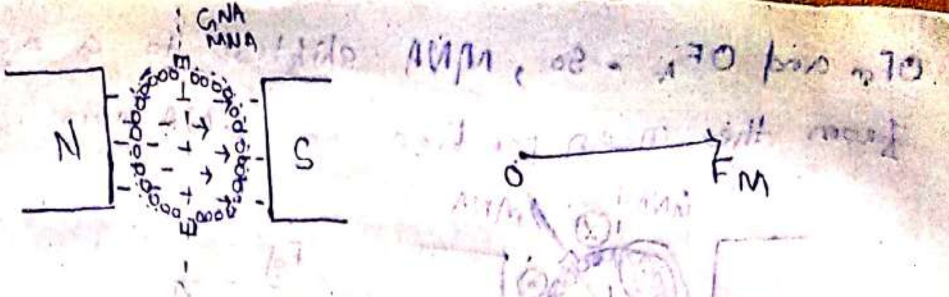
→ The Geometric neutral axis is a axis that bisects the angle between the centre line of adjacent Poles



MNA (Magnetic Neutral Axis):-

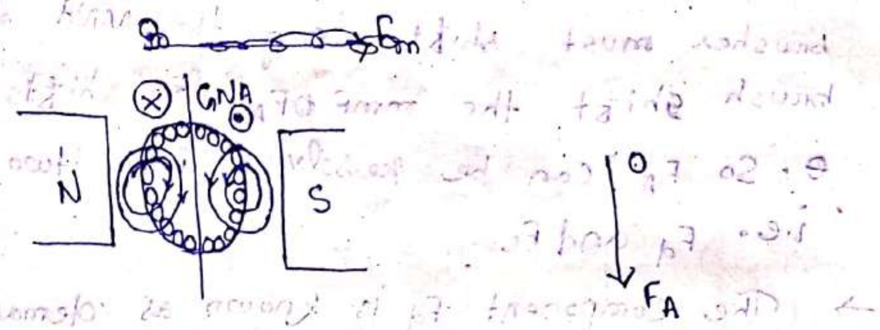
→ It is the axis drawn perpendicular to the main direction of flux passing through the center of the armature.





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

→ The MMF produced during the main flux is OFm

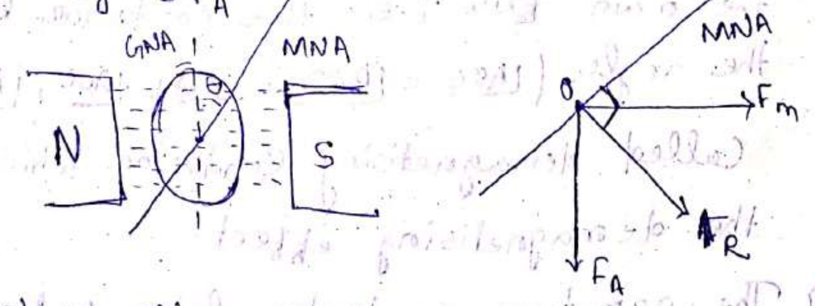


→ The above figure shows the flux due to the current flowing to the armature conductor only

→ 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 (•).

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

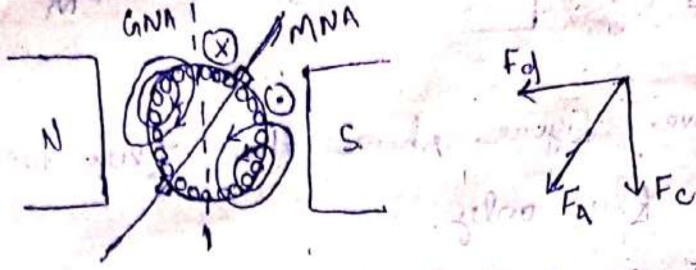
→ The mmf produced in the armature flux is given by OFA.



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

→ Resultant flux OFR is the vector sum of

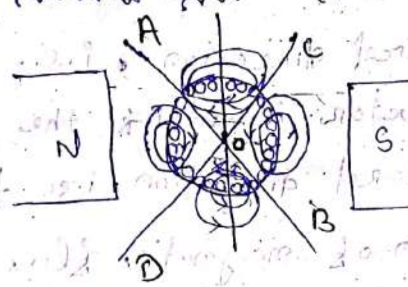
OFm and OF$_A$. So, MNA shifted to a angle θ from the mean position on GNA axis.



→ In order to achieve sparkless commutation, the brushes must shift along the MNA due to the brush shift the mmf OF$_A$ 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 conductor :-



→ 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 (∠AOC = ∠BOD = 2θ) ∠AOC, ∠BOD are called demagnetising conductor which produces the demagnetising effect.

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

Q1. 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 deliver a current of 100 Amp. at 250V to a load of ~~conductor~~ constant resistance. if the generator speed drops to 700 rpm with field current constant. then find the current to the load.

Ans→ Given Data

$R_a = 0.1\Omega$

$B.D. = 2V$

$N_1 = 1000$ rpm.

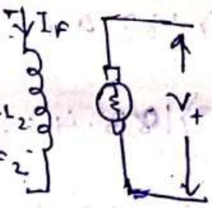
$I_{a_1} = I_{L_1} = 100$ Amp.

$V_{t_1} = 250V$

$N_2 = 700$ rpm.

R_L = constant = R_{L_2}

I_{f_1} = constant = I_{f_2}



$$R_L = \frac{V_t}{I_{L_1}} = \frac{250}{100} = 2.5\Omega$$

$$E_{g_1} = I_a R_a + V_t + B.D.$$
$$= (100 \times 0.1) + 250 + 2$$
$$= 10 + 250 + 2 = 262V$$

$$E_{g_2} = V_t + I_{a_2} R_a + B.D. \quad \text{——— Eq (i)}$$

$I_{a_2} = I_{L_2}$

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

Here, P, Z and A constant.

we know, $\phi \propto I_f$ = constant

So, ϕ also a constant

$\therefore E_g \propto N$

$$\Rightarrow \frac{E_{g_1}}{E_{g_2}} = \frac{N_1}{N_2}$$

$$\Rightarrow \frac{262}{E_{g_2}} = \frac{1000}{700} \Rightarrow E_{g_2} = \frac{262 \times 7}{10} = 183.4V$$

Putting E_{g_2} in Eq (i)

$E_{g_2} = I_{a_2}R_a + V_{t_2} + B.D.$

$\Rightarrow 183.4 = (I_{a_2} \times 0.1) + 250 + 2$

$\Rightarrow 183.4 - 252 = 0.1 I_{a_2}$

$\Rightarrow -68.6 = 0.1 I_{a_2}$

~~$\Rightarrow I_{a_2} =$~~

$\Rightarrow E_{g_2} = I_{a_2}R_a + (I_{a_2} \times R_L) + B.D. \quad (\because I_{a_2} = I_{L_2})$

$\Rightarrow 183.4 = I_{a_2}(R_a + R_L) + 2$

$\Rightarrow 183.4 = I_{a_2}(0.1 + 2.5) + 2$

$\Rightarrow 183.4 = 2.6 I_{a_2} + 2$

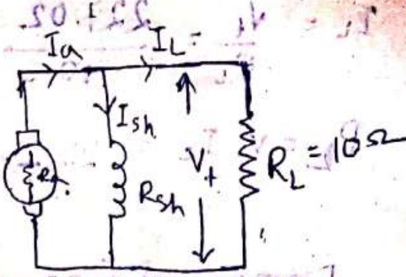
$\Rightarrow 183.4 - 2 = 2.6 I_{a_2}$

$\Rightarrow I_{a_2} = \frac{181.4}{2.6} = 69.76$ Amp

$\therefore I_{a_2} = I_{L_2} = 69.769$ Amp

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

Ans) Given Data



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

$P = 4$ $\quad A = 2$

$R_a = 1\,\Omega$

$Z = 378$

$\phi = 0.02\,wb$

$R_L = 10\,\Omega$

$N = 1000$

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

$$\Rightarrow E_g = \frac{4 \times 0.02 \times 378 \times 1000}{60 \times 2}$$

$$= \frac{4 \times 0.02 \times 378 \times 1000}{120} = 252\,V$$

~~$I_a = \frac{E_g}{R_a}$~~

~~$I_a = I_{sh} = \frac{V}{R}$~~

$I_a = I_L + I_{sh}$

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

$$I_L = \frac{V_t}{R_L} = \frac{V_t}{10}\ \text{Amp.}$$

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

$$I_a = \frac{V_t}{10} + \frac{V_t}{100} = V_t\left(\frac{1}{10} + \frac{1}{100}\right)$$

$$= V_t\left(\frac{10+1}{100}\right) = \frac{11 V_t}{100}$$

We have

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

$$\Rightarrow 252 = \left(\frac{11 V_t}{100} \times 1\right) + V_t + 0$$

$$\Rightarrow 252 = V_t\left(\frac{11}{100} + 1\right)$$

$$\Rightarrow 252 = V_t\left(\frac{111}{100}\right)$$

$$\Rightarrow V_t = \frac{252 \times 100}{111} = 227.02$$

Scanned by CamScanner

$I_L = \frac{V_t}{R_L} = \frac{227.02}{10} = 22.70$

$P_L = V_t I_L = 227.02 \times 22.70 = 5153.967$ Watt.

Demagnetising Ampere turn

→ Demagnetising Ampere turn /pole $= \frac{\theta_m}{360^\circ} \times ZI$

where, $I = \frac{I_a}{A}$

→ Cross magnetising Ampere turn / pole

$$AT/pole = ZI \left(\frac{1}{2P} - \frac{\theta_m}{360^\circ} \right)$$ where, $I = \frac{I_a}{A}$

Q. A 4 pole generator has a wave wound armature with 722 conductors and it delivers 100 Amp on full load. If the brush lead is 8°. Calculate the armature of demagnetising and cross magnetising AT/pole

Ans → Given Data

$P = 4$ $A = 2$

$Z = 722$

$I_a = I_L = 100$ Amp.

Brush lead to the angle $(\theta_m) = 8^\circ$

Demagnetising AT/pole $= \frac{\theta_m}{360} \times ZI$

$I = \frac{I_a}{A} = \frac{100}{2} = 50$

$AT/pole = \frac{8}{360} \times 722 \times 50$

$= 802.22$ AT/pole

Crossmagnetising AT/pole : $ZI\left(\frac{1}{2P} - \frac{\theta_m}{360}\right)A$

$I = \frac{I_a}{A} = \frac{100}{2} = 50$

$AT/pole = 722 \times 50 \left(\frac{1}{2 \times 4} - \frac{8}{360}\right)$

$= 3710.27$ AT/pole.

Q2. A 8 pole lap connected DC shunt generator delivers an output current of 240 Amp at 500V. The armature has 1408 conductors and 160 Commutator segment. if the brushes are given a lead of 4 segment from no. load neutral axis find the demagnetising and cross magnetising AT/pole.

Ans → Given Data

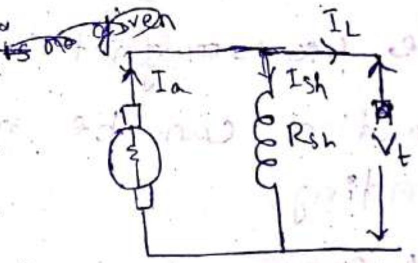
$P = 8$

$A = P = 8$

$I_L = 240$ Amp.

$V_t = 500$ V

$Z = 1408$



Total commutator segment = 160

So, 160 commutator = 360°

1 Commutator = $\frac{360}{160} = 2.25$

Brushes are lead of 4 commutator Segment.

So, angle $(\theta_m) = 2.25 \times 4 = 9$

R_{sh} is not given so, $R_{sh} = 0$

So, $I_a = I_L = 240$ Amp.

Demagnetising AT/pole = $\frac{\theta_m}{360} \times ZI$

$I = \frac{I_a}{A} = \frac{240}{8} = 30$

$$AT_d/pole = \frac{9}{360/40} \times 1408 \times 30 = \frac{1408 \times 30}{40} = 1056 AT$$

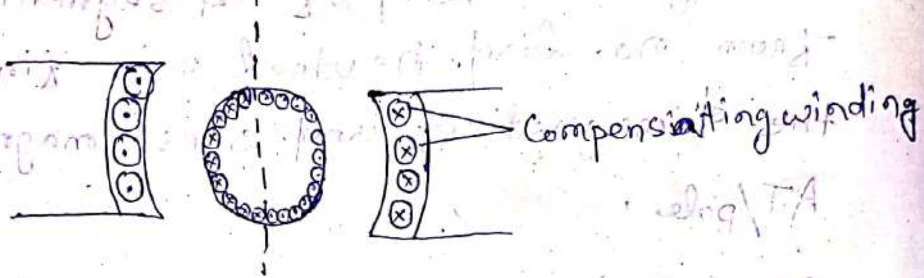
$$\text{Cross magnetising } AT/pole = ZI\left(\frac{1}{2P} - \frac{\theta_m}{360}\right)$$

$$= 1408 \times 30 \left(\frac{1}{2\times8} - \frac{9}{360}\right)$$

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

$$= ~~1576.125~~ = 1584$$

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.