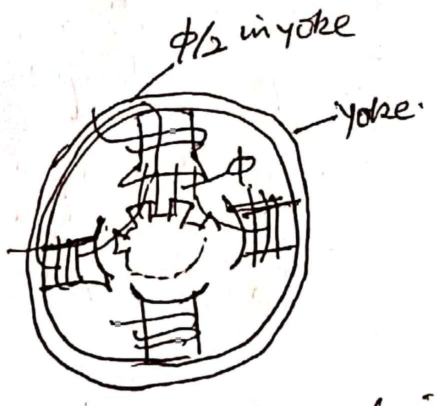
DC machines.



Flux path in a DC m/c.

Stator Components

A) Yoke → Serves 1) to provide path for pole flux ϕ and carries $\frac{1}{2}\phi$.

2) provides mechanical support for whole machine.

Material used → Cast iron for small dc m/c.
Fabricated Steel for large dc m/c.
When used with power electronic Converters, yoke will be laminated to reduce eddy current losses.

B) Field poles. pole and pole shoe. pole core made up of cast steel, pole shoe is laminated.
alternatively laminated pole core and pole shoe.

C) Field or exciting windings Copper is used.
the no. of turns and cross section depends on
1) dc shunt m/c → large no. of turns with small crosssect
2) dc series m/c → Small no. of turns with large crosssection
3) Compound m/c → Combination of above.

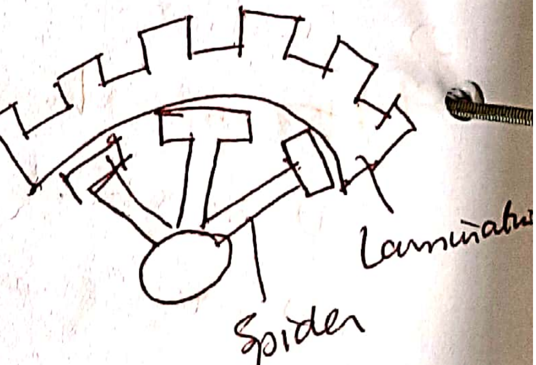
d) Interpoles :- Fixed between main poles of the machine. Winding consists of few turns of wire of thick cross section, in series with the armature

e) <u>Compensating windings</u> placed in the slots cut on the pole faces and connected in series with the armature circuit, used only in large m/c.

f) <u>Brushes</u> made of carbon, for small m/s and electrographite for all dc m/c. and copper graphite for low voltage high current dc m/c.

<u>Rotor Components</u>-

A) <u>Armature core</u> serves (1) purpose of holding armature coils in the armature slots, (2) provides low reluctance path for the magnetic flux $\phi/2$, made of 0.35 to 0.50 mm silicon steel laminations. For large m/cs, the armature core is placed on <u>Spiders</u>



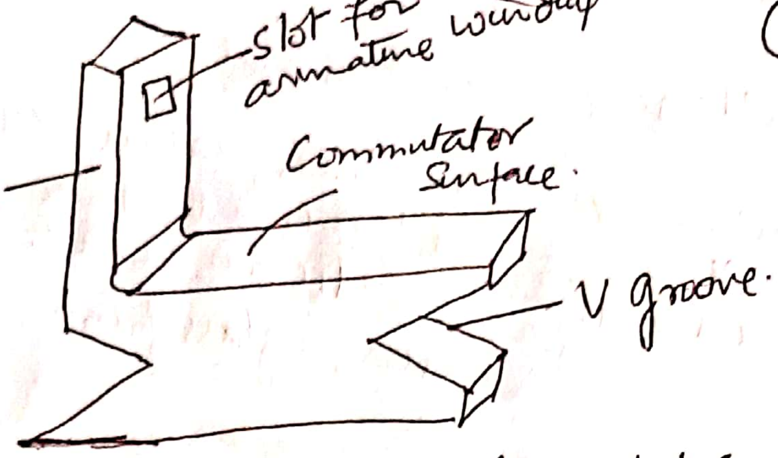
B) <u>Armature windings</u>

Copper winding, → Coils → no of turns.
Coils are "former wound", placed in slots, connected in series or parallel, based on type of winding. — LAP winding, wave winding

Two coil ends are connected to the riser of the commutator segment. Coils can be fullpitched or short pitched placement

Commutator

1) Copper segments of high conductivity hard drawn copper
2) Insulated by 0.8mm thick mica sheets.
3)



Wedge shaped Commutator Segment.

Shaft of solid steel, mounted with Spider for large m/c, armature core, bearings.

Endshields provides support to the rotor and encloses the m/c, protecting the inner parts.

Types of enclosures :- 1) TEFC → Totally enclosed Fan Cooled

2) SPDP → Screen protected Drip proof

3) Hose proof, Drip proof

4) Flameproof.

Insulation of windings → class E, A, B, C, H, F

	E	B	F	H
max. Temp	120	130	155	180

Class 'E' → Synthetic resin enamel, Cotton, paper

Class 'B' → mica, glass fibre, asbestos

Class 'F' → Class 'B' with more thermally bonded material

Class 'H' → Silicone elastomer, Combination of mica, glass fibre, asbestos etc

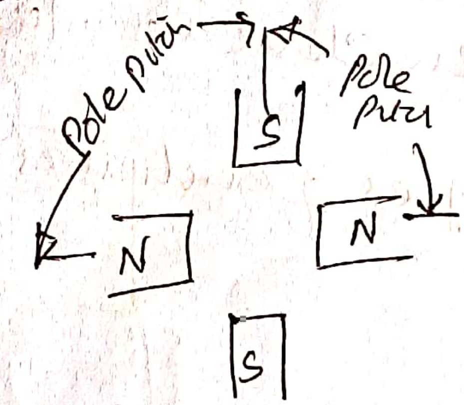
<u>Rating</u>

Continuous rating → Continuous without exceeding temp

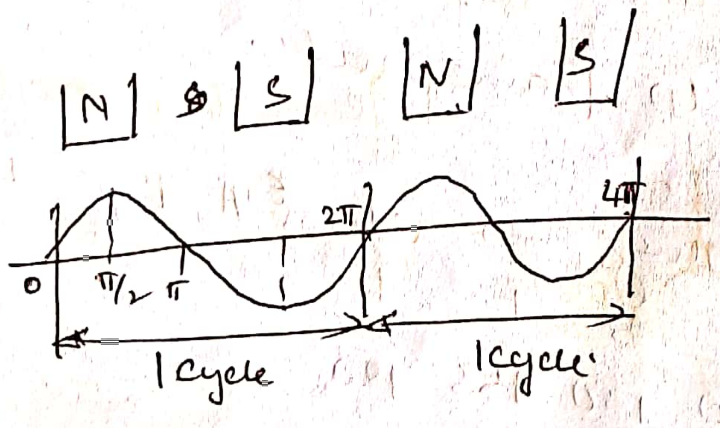
Short time rating → Output for a specified time, in cycles per hour.

Intermittent rating → Continuous rating with load and unloading / or rest cycles.

<u>Pole pitch</u> The angular distance between a pole pair is pole pitch



$$\text{pole pitch} = \frac{360}{\text{No of poles}}$$



720 elect degrees

$$= \frac{P}{2}(360 \text{ mech degrees})$$

$$\theta_{elect} = \frac{P}{2}\,\theta_{mech}$$

P = no of poles

Continu---

In a 4 pole m/c
one revolution → 2 electrical cycles genr

$\Rightarrow \frac{P}{2}$ cycles.

one revolution/sec ⇒ $\frac{P}{2}$ cycles/sec.

n revolutions/sec → $\frac{n.P}{2}$ cycles/sec.

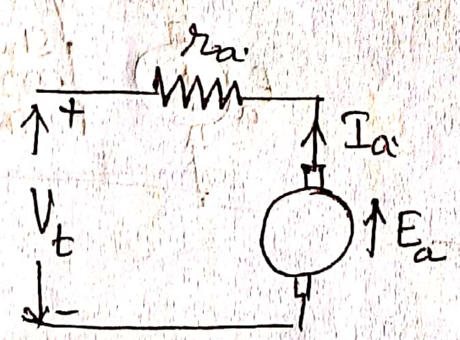
cycles/sec = frequency in hertz.

$f = \frac{n.P}{2}$ n rev/sec = $n \times 60 = N$ rev/min

$\therefore f = \frac{N}{60} \cdot \frac{P}{2} = \frac{PN}{120}$

or $\boxed{N = \frac{120f}{P}}$

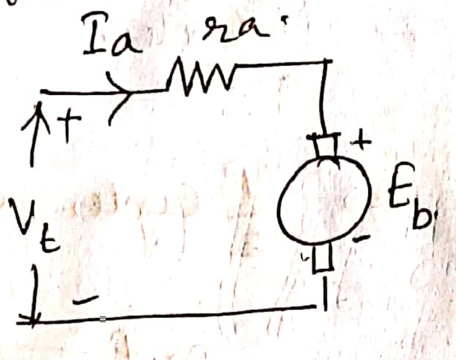
Representation of a dc m/c



Generating mode

$V_t = E_a - I_a \cdot r_a$.

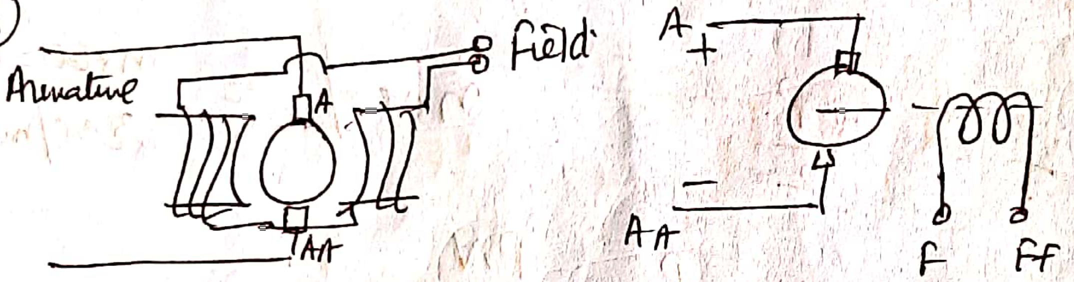
motoring mode



$$V_t = E_b + I_a r_a$$

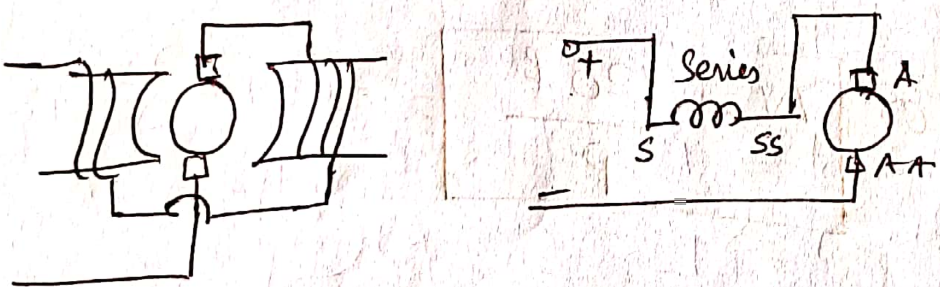
Seperately excited

(A)



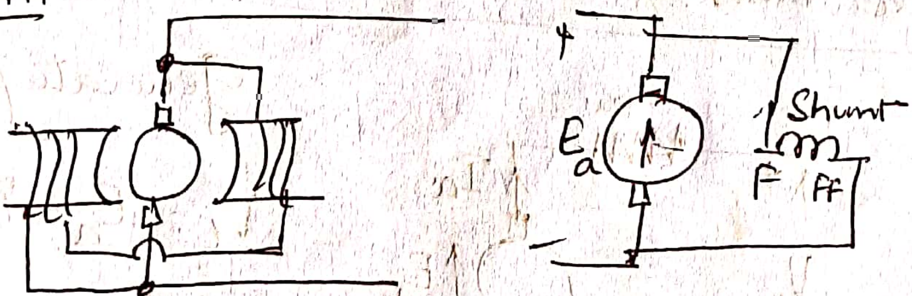
Series

(B)

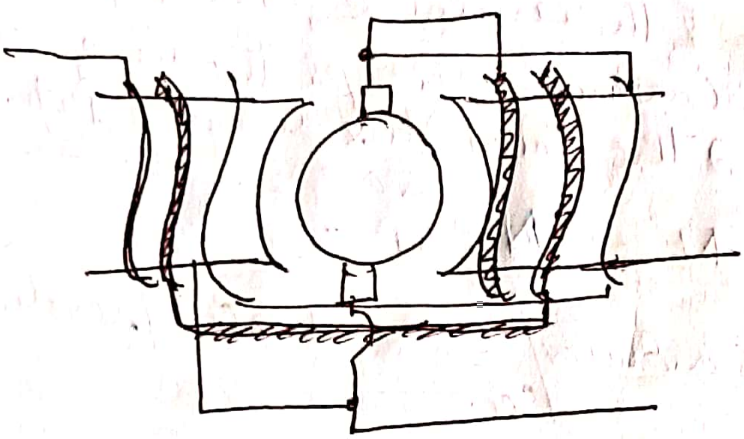


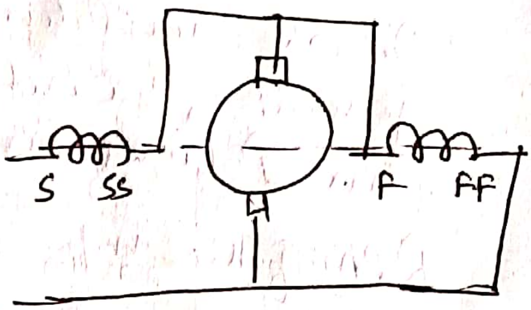
Shunt

(C)

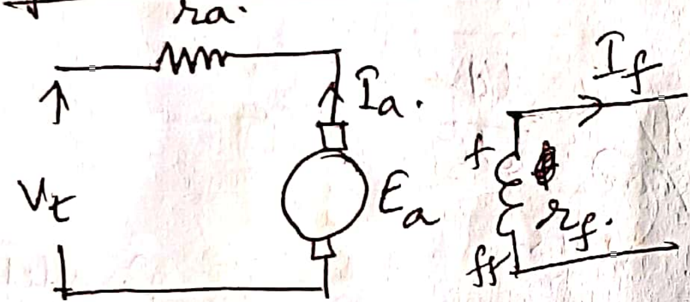


(D) Compound m/c





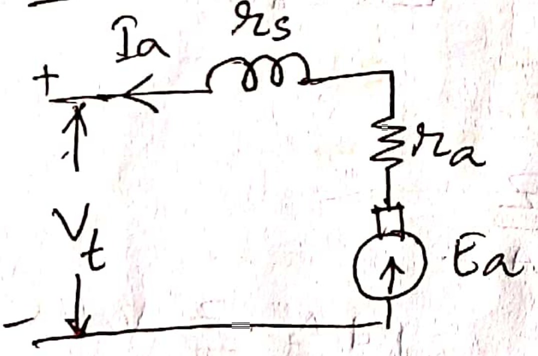
Seperately excited



$V_f = I_f \cdot R_f$

$V_t = E_a - I_a r_a$

Series



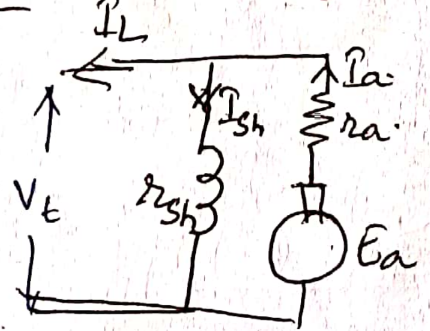
$V_t = E_a - I_a(r_s + r_a)$

$I_a = I_{se} = I_L$

$P_g = E_a \cdot I_a$

$P_{load} = V_t \cdot I_a$

Shunt



$I_a = I_L + I_{sh}$

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

$V_t = E_a - I_a R_a$

$P_g = E_a \cdot I_a$

$P_L = V_t \cdot I_L$

$$e = -\frac{d\phi}{dt}$$

In one revolution of the armature, of a P pole generator, each conductor sweeps the magnetic flux P times and the total flux swept in one rev. = $P\phi$. web

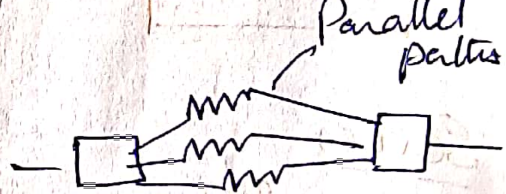
RPM of the m/c = N = $\frac{N}{60}$ rps..

Flux cut by each conductor/sec = Flux cut/revolution × rev/sec

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

Since induced emf/cond $\propto \frac{d\phi}{dt}$

$\therefore$ e/cond $= P\phi \cdot \frac{N}{60}$. volts.



If Z = total Conductor and A is the parallel path

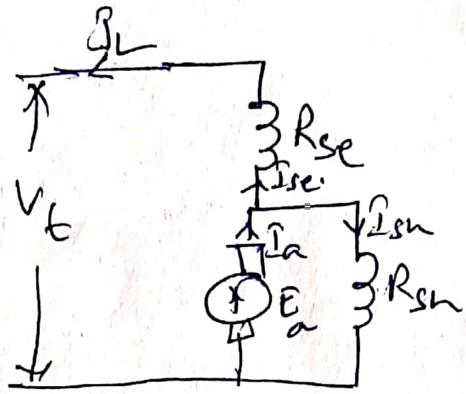
Conductors/parallel path = $\frac{Z}{A}$.

Total emf between terminals = $P\phi \frac{N}{60} \cdot \frac{Z}{A}$ volts

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

Compound

1) Short Shunt



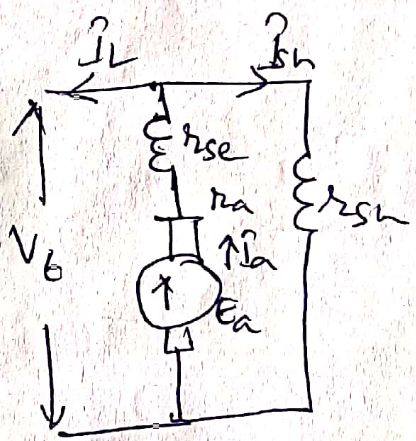
$I_{se} = I_L$; $I_a = I_L + I_{sh}$

$$I_{sh} = \frac{E_a - I_a r_a}{R_{sh}}$$

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

$$V_t = E_a - I_a R_a - I_{se} R_{se}$$

2) Long Shunt



$I_a = I_L + I_{sh}$

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

$$V_t = E_a - I_a r_{se} - I_a r_a = E_a - I_a (r_a + r_{se})$$

$P_g = E_a \cdot I_a$ $\quad$ $P_L = V_t \cdot I_L$

Wave winding = no of parallel paths = 2
Lap winding = " " = no of poles.

$$E = \frac{\phi Z N P}{60 \times A} \text{ volts.}$$

① 12 pole m/c; $I_a = 250A$.
What is current per path
i) Lap wound (ii) wave wound

Wave winding → Parallel path = 2
Current/path = $\frac{250}{2}$ = 12A

Lap wound → parallel path = no of poles
Current = $\frac{250}{12}$ = 20.83 A.

emf = 100V ϕ per pole = 20 mWb

N = 800 rpm.

Calculate (1) emf with same flux and N = 1000 rpm.

(2) with ϕ/pole = 24 mWb and N = 900 rpm

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

$E \propto \phi N$ Others being constant

$E_1 \propto \phi_1 N_1$

$E_2 \propto \phi_2 N_2$

$$\frac{E_1}{E_2} = \frac{\phi_1 N_1}{\phi_2 N_2}$$

$$\frac{100}{E_2} = \frac{20 \times 10^{-3} \times 800}{20 \times 10^{-3} \times 1000}$$

$$E_2 = \frac{1000 \times 100}{800} = 125V$$

(2) $$\frac{E_1}{E_2} = \frac{\phi_1 N_1}{\phi_2 N_2}$$

$$\frac{100}{E_2} = \frac{20 \times 10^{-3} \times 800}{24 \times 10^{-3} \times 900}$$

$$E_2 = \frac{100 \times 24 \times 9}{20 \times 8} = 135V.$$

(3) 4P, lap, 144 slots, 2 coil sides/slots, each coil has 2 turns.

$\phi = 20 mWb$ $N = 720 rpm$

$E = ?$

Z = no of conductors

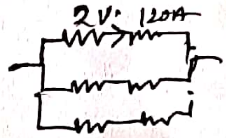
= no. of slots × coil sides per slot × turns/coil

= 144 × 2 × 2 = 576 conductors

lap wound = parallel path = no of poles = 4

$$E = \frac{20 \times 10^{-3} \times 576 \times 720 \times 4}{60 \times 4} = 138.24V$$

6P, 498 cond, av. emf per cond = 2V.
Current in conductor = 120A
find total current & gen emf if
a) wave, b) Lap.
find total power generated



$E = \frac{\phi 2 N}{60} \cdot \frac{P}{A}$ $\frac{E}{Z} = 2V =$

Arm. lap connected no of parallel paths = no of poles = 6

no of conductors / path = $\frac{498}{6}$ = 83.

Terminal voltage = 83 × 2 = 166 V.

Output current on full load = Current per conductor × no of parallel paths

= 120 × 6 = 720 A

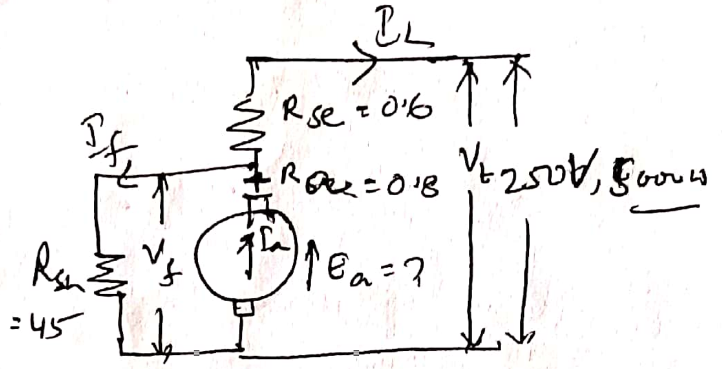
Wave Connected no of parallel paths = 2
no of Conductors / path = $\frac{498}{2}$ = 249.
Term Voltage = 249 × 2 = 498 V
Full load Current = 120 × 2 = 240 A.

Scanned with CamScanner

Short Shunt Compound gen:

$R_a = 0.8\Omega$, $R_{sh} : 45\Omega$ $R_{se} = 0.6\Omega$

load - = 5000 W @ 250V



$V_t + I_L \cdot R_{se} = V_f$

$I_L = \frac{5000}{250} = 20A$

$250 + 20 \times 0.6 = 262V = V_f$

$I_f = \frac{V_f}{R_{sh}} = \frac{262}{45} = 5.822 A.$

$I_a = I_f + I_L = 5.822 + 20 = 25.822 A$

$V_f + I_a R_a = E_a.$

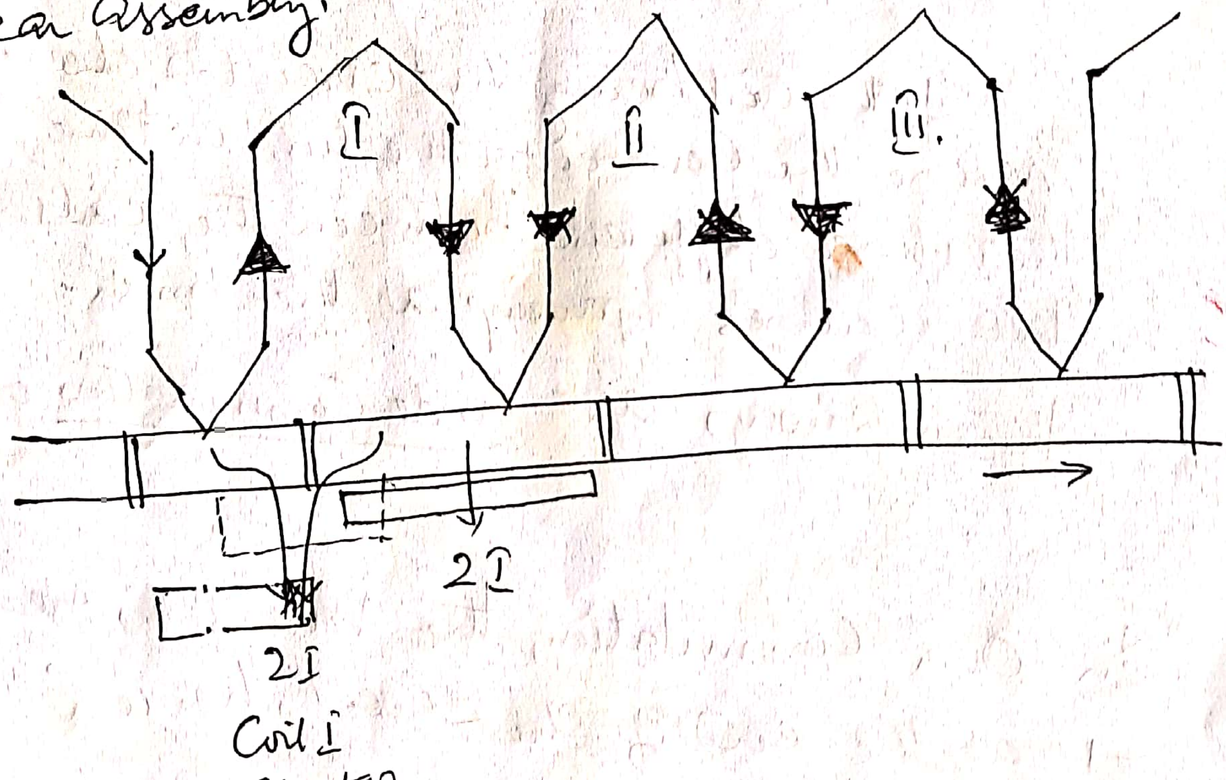
$262 + 25.822 \times 0.8 = \underline{282.66 V}$

b) Calculate E_a, If Connected in Long Shunt

Commutation

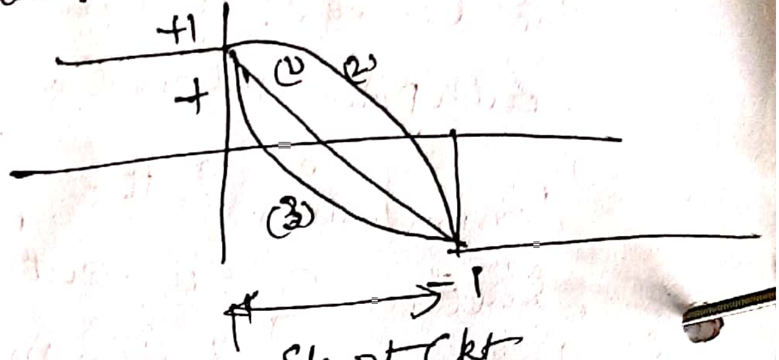
Currents induced in the winding of a dc generator are alternating in nature.

The currents flow in opposite directions under South pole, when compared to that of North pole. Commutation is the process of changing this direction of current flow to unidirectional by means of commutator segments and brush gear assembly.



The time of short ckt by the brush of the coil is called period of commutation.

Commutation is of 3 types
1) Ideal or Straight line Commutation
2) Delayed or under Commutation
3) Over Commutation or accelerated Commutation



- If the coil being short circuited does not reverse the current direction in time, then the voltage difference between the coils adjacent to it, causes sparking at the brush. this is known as under Commutation or delayed Commutation.

In Over Commutation, the voltage is nearing -1 at the end of short circuit, hence satisfactory Commutation.

Reactance Voltage

L be the inductance of the coil

then induced emf in the coil → $e = L\frac{di}{dt}$

the current changes from +I to −I

Total change = $+I-(-I) = +2I$

this occurs in time 'dt'

$$\therefore \quad e = L \cdot \frac{2I}{dt}$$

this is known as reactance voltage

Methods to improve Commutation

① Resistance Commutation →

use carbon brushes, which make the contact resistance between segments high. this will force the change in current.

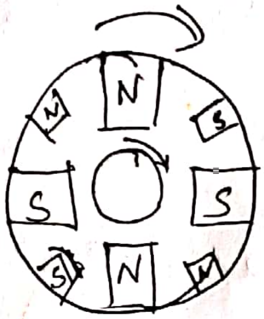
② Voltage Commutation

1) By shifting of brushes
2) By using commutating poles or interpoles or compoles.

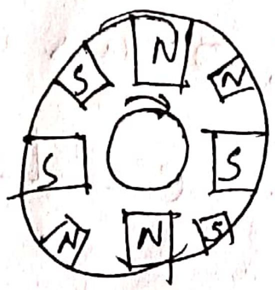
Compoles are in series with the armature

For generator, the interpole polarity is the same as that of the next main pole, ahead in the direction of rotation

For motor, the compole polarity is opposite to that of the next main pole, ahead of rotation



Generator



Motor

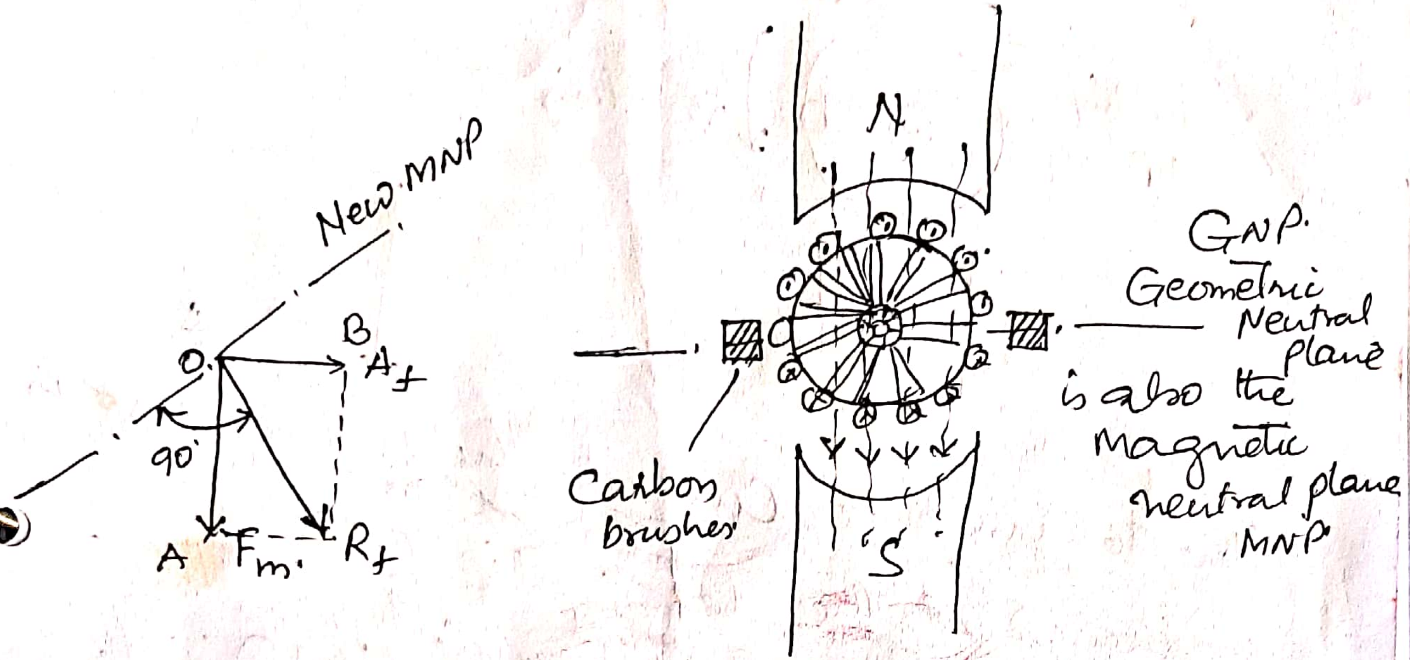
Compensating winding in pole faces

Connected in series with armature winding

Direction of current in the conductor of armature, just below the pole face should be opposite. So that it demagnetizes the armature flux

EM-I

Armature Reaction

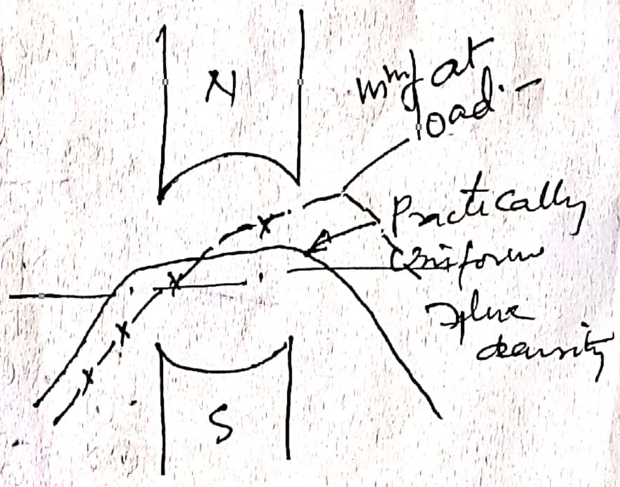


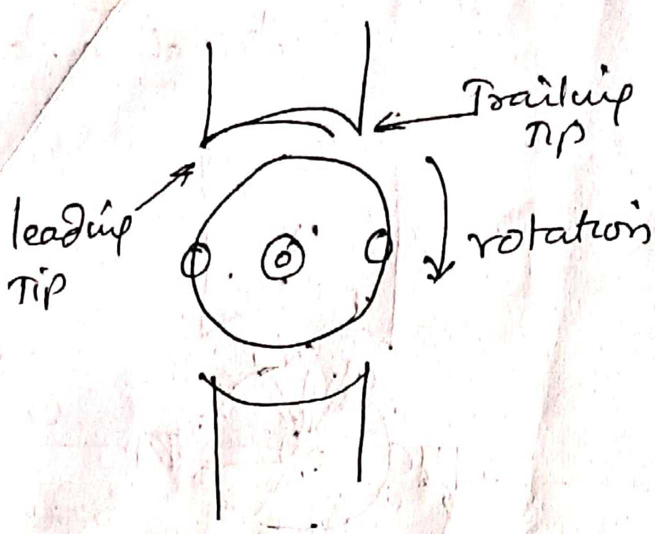
OA is the vector of field of the machine alone.

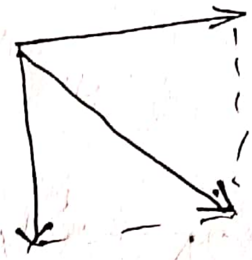
OB is the vector of the field of the armature alone.

R_f is the resultant field when both are present.

the MNP will shift and be $\perp^{lar}$ to R_f.



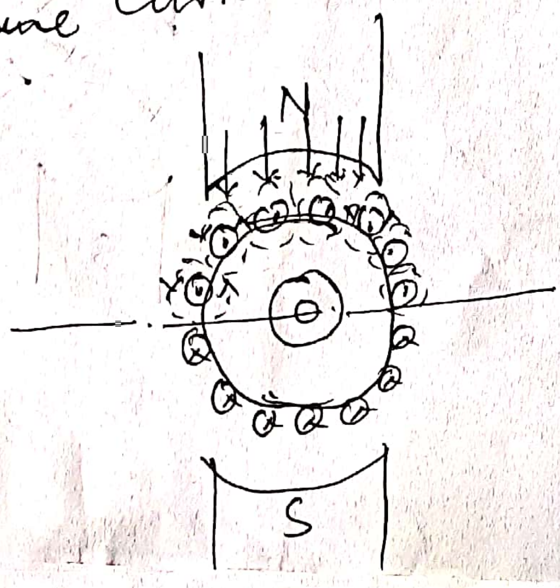


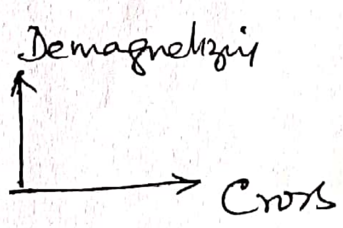


Due to armature current, the main flux is weakened at the leading tip and strengthened at the trailing tip. This results in distortion of the main field.

The carbon brushes are to be advanced in the direction of rotation, to align with the magnetic neutral axis.

This results a change in distribution of armature currents in the armature conductors.





Armature reaction → ① Cross magnetizing effect

Distorts the main field
- Creates field in the interpolar region
- weakens field under leading tip and strengthened under trailing tip.

Field distortion on load Causes

1) Increase in Iron losses
2) Sparking while commutation.

② demagnetizing effect - reduces total flux per pole.

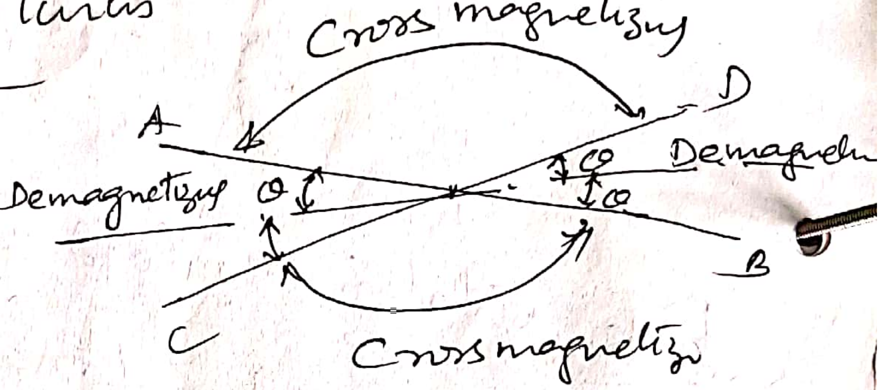
Remedies

① Flatten pole tips such that air gap is longer at tips than at centre thereby increasing reluctance at tips.

② By increasing length of the trailing horn, of the pole piece.

③ reducing the cross section of the poles.
4) providing interpoles & compensating winding

Armature ampere turns



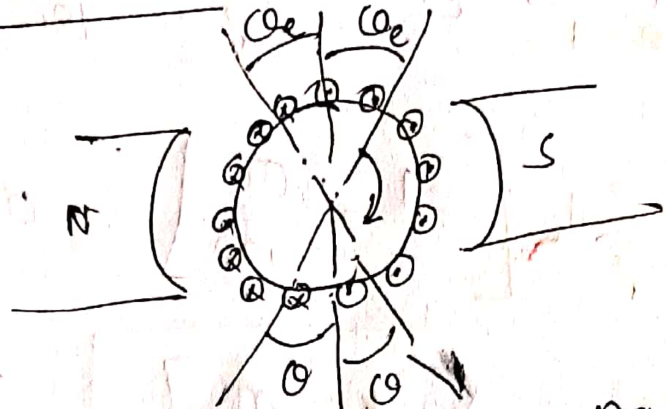
expression
Z = total no. of armature conductors
A = no. of parallel paths.
θ = angle of brush lead in mechanical deg.
P = no of poles.
I_a = armature current = $\frac{I_a}{P}$ for lap, $\frac{I_a}{2}$ for wave
I_c = armature current per conductor = $\frac{I_a}{A}$

Total armature ampere turns = $\frac{\text{Total armature ampere conductors}}{2}$

$= \frac{Z \cdot I_c}{2}$

Per pole $\rightarrow \frac{Z I_c}{2P}$

Demagnetizing & Cross magnetizing AT



Z = Total Conductors | A = no. of parallel paths
P = no. of poles | θ = Brush shift in mech. degrees
I_a = armature current ; I_c = Current / Conductor

→

Conductors per pole $= \frac{Z}{P}$

Turns per pole $= \frac{1}{2} \cdot \frac{Z}{P}$ (2 Conductors per turn)

Ampere turns per ~~Conductor~~ pole $= \frac{1}{2} \cdot \frac{Z}{P} \cdot I_c$.

Ampere turn per ~~Conductor~~ pole per electrical degree

$$= \frac{1}{2} \cdot \frac{Z}{P} \cdot \frac{I_c}{180} \quad \left(180^\circ_e \text{ between N \& S pole}\right)$$

Demagnetizing AT/pole = (AT per degree)($2\theta_e$)

$$= \frac{1}{2} \cdot \frac{Z}{P} \cdot \frac{I_c}{180} \times 2\theta_e$$

$$= \frac{1}{2} \cdot \frac{Z}{P} \cdot \frac{I_a}{a} \cdot \frac{2\theta_e}{180} = \frac{Z I_a}{P a}\left(\frac{\theta_e}{180}\right)$$

Cross magnetizing AT/pole = Total AT/pole − Demag AT/pole

Comm 6

$$\frac{1}{2} \frac{Z}{P} \cdot I_c - \frac{Z}{P} I_c \cdot \frac{\theta}{180}$$

$$= \frac{Z}{P} I_c \left[\frac{1}{2} - \frac{\theta}{180} \right] \quad \text{or}$$

$$\boxed{\text{CrossAT} = \frac{Z}{P} \cdot \frac{I_a}{a} \left[\frac{1}{2} - \frac{\theta}{180} \right]}$$

Z = Total armature Conductors

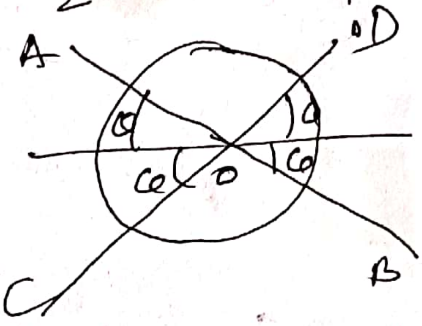
a = parallel path

θ_m = mechanical degree forward lead of brush.

p = no of poles.

I = current in armature Conductor

$= \frac{I_a}{P}$ for lap winding ; $\frac{I_a}{2}$ for wave winding



Demagnetizing AT per pole. AT_d.

Conductors in AOC & BOD

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

Total no of turns in $4\theta_m \rightarrow \frac{4\theta_m}{2 \times 360} \times Z = \frac{2\theta_m \times Z}{360}$

Demag. ampere turns per pole pair

$= \frac{2\theta_m}{360} \times Z \times I.$

Demag. AT per pole $= \frac{\theta_m}{360} \times Z \times I.$

$\therefore AT_d = \frac{\theta_m}{360} \times ZI$

$\longrightarrow$

Cross magnetizing in AOD & BOC

Total arm. Conductors / pole $= \frac{Z}{P}$.

Demag. Conductors / pole $= \frac{Z \times 2\theta_m}{360}$

Scanned with CamScanner

Cross magnetizing Conductors / pole

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

Cross magnetizing ampere Conductors / pole

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

Cross magnetizing ampere turns / pole = AT_c

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