Unit 1

Electromechanical Energy Conversion Principles

Introduction:

Electrical energy is seldom available naturally and is rarely directly utilized. There are two conversion takes place-------

a. One form to electrical form
b. Electrical form to original form or any other desired form

The device through which we convert one form to electrical form & back to original form or any other desired form is studied in EMEC.

Like—Transformers, D.C. Machines, A. C. Machines (Induction and Synchronous)

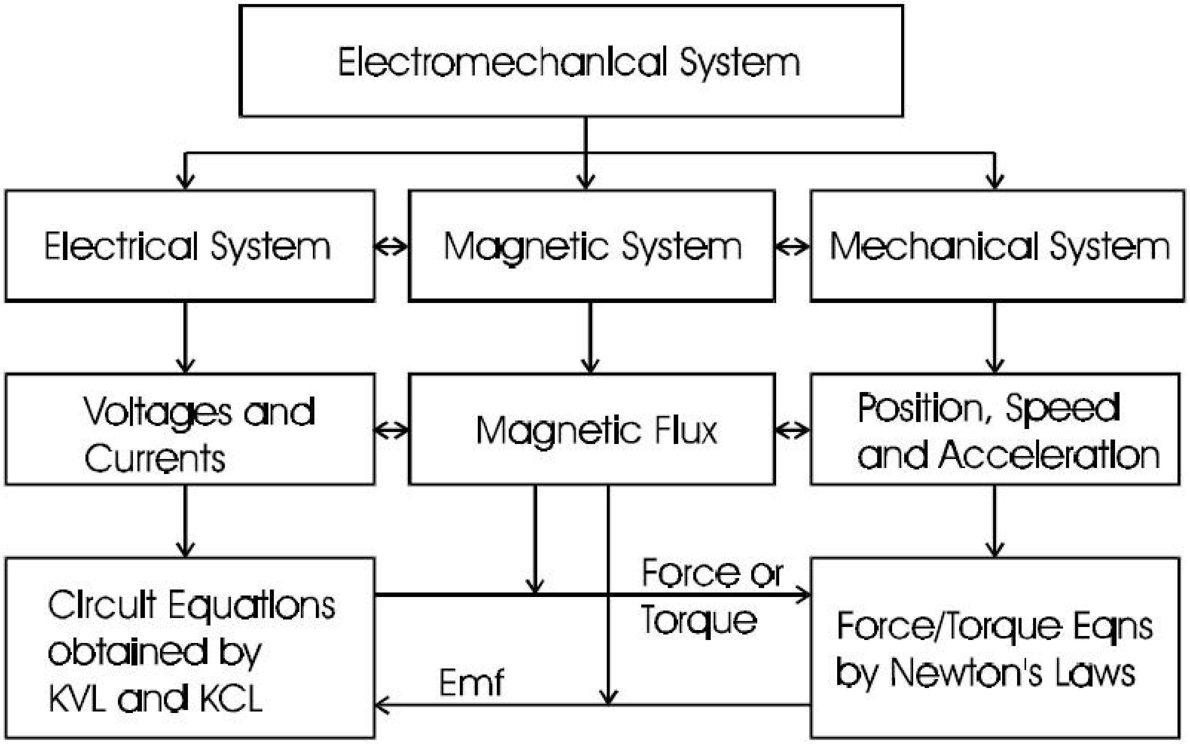
These devices can be transducers for low energy conversion processing and transporting. A second category of such devices is meant for production of force or torque with limited mechanical motion like electromagnets, relays, actuators etc.

A third category is the continuous energy conversion devices like motors or generators which are used for bulk energy conversion and utilization.

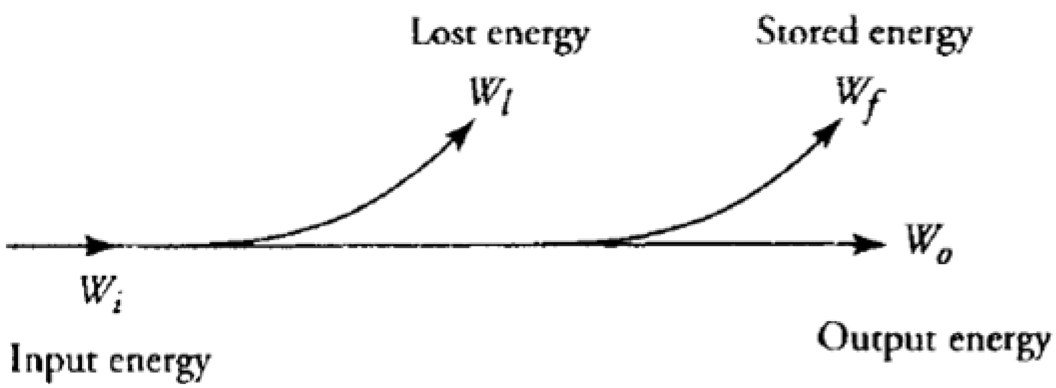
EMEC-----------via----------Medium of magnetic or electric field. For practical devices magnetic medium is most suitable.

When we speak of electromechanical energy conversion, however, we mean either the conversion of electric energy into mechanical energy or vice versa.

Electromechanical energy conversion is a reversible process except for the losses in the system. The term "reversible" implies that the energy can be transferred back and forth between the electrical and the mechanical systems.



Concept map of electromechanical system modeling



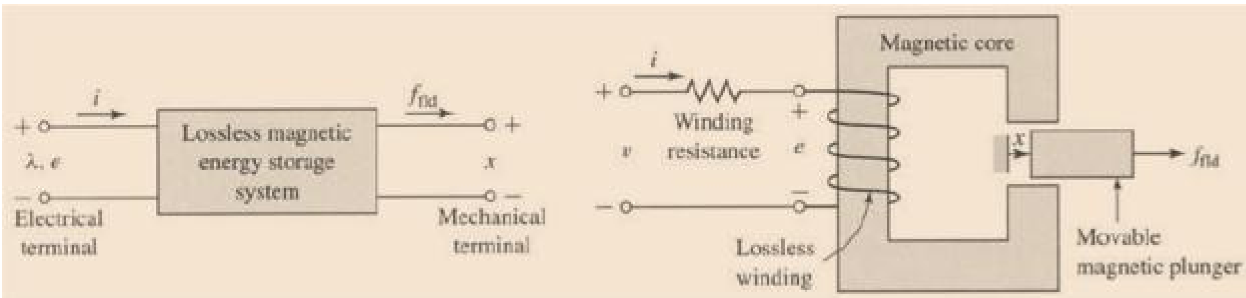
Energy Flow Diagram

From energy diagram we can see that principle of energy conservation is accurately followed.
i.e Input Energy=Losses + Stored Energy + Output Energy.

Singly Excited System:

Consider a singly excited linear actuator as shown below. The winding resistance is R. At a certain time instant *t*, we record that the terminal voltage applied to the excitation winding is *v*, the excitation winding current i, the position of the movable plunger x, and the force acting on the plunger **F** with the reference direction chosen in the positive direction of the x axis, as shown in the diagram. After a time interval dt, we notice that the plunger has moved for a distance dx under the action of the force **F**. The mechanical done by the force acting on the plunger during this time interval is thus

$$dw_m = Fdx$$



Singly Excited system energy conversion

The amount of electrical energy that has been transferred into the magnetic field and converted into the mechanical work during this time interval can be calculated by subtracting the power loss dissipated in the winding resistance from the total power fed into the excitation winding as

$$dw_e = dw_f + dw_m = vidt - Ri^2 dt$$

Since,

$$e = \frac{d\lambda}{dt} = v - Ri$$

So,

$$dw_f = dw_e - dw_m = eidt - Fdx = id\lambda - Fdx$$

we can also write,

$$e = \frac{d\lambda}{dt} = v - Ri$$

$$dw_f(\lambda, x) = \frac{dw_f(\lambda, x)}{d\lambda} d\lambda + \frac{dw_f(\lambda, x)}{dx} dx$$

the energy stored in a magnetic field can be expressed as

$$w_f(\lambda, x) = \int_0^{\lambda} i((\lambda, x)d\lambda$$

For a magnetically linear (with a constant permeability or a straight line magnetization curve such that the inductance of the coil is independent of the excitation current) system, the above expression becomes

$$W_f(\lambda, x) = \frac{1}{2}\frac{\lambda^2}{L(x)}$$

and the force acting on the plunger is then

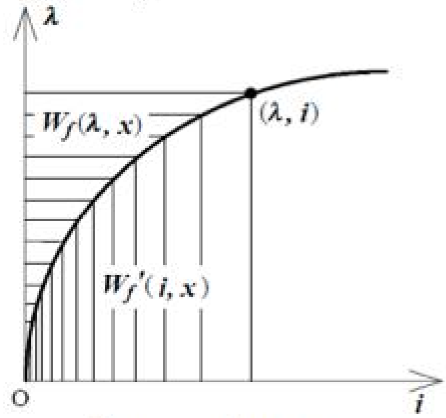
$$F = -\frac{\partial W_f(\lambda, x)}{\partial x} = \frac{1}{2}\left[\frac{\lambda}{L(x)}\right]^2 \frac{dL(x)}{dx} = \frac{1}{2}i^2\frac{dL(x)}{dx}$$

In the diagram below, it is shown that the magnetic energy is equivalent to the area above the magnetization or λ-i curve. Mathematically, if we define the area underneath the magnetization curve as the ***coenergy*** (which does not exist physically), i.e.

$$W_f'(i,x) = i\lambda - W_f(\lambda, x)$$

we can obtain

$$\begin{aligned} dW_f'(i,x) &= \lambda di + id\lambda - dW_f(\lambda, x) \\ &= \lambda di + Fdx \\ &= \frac{\partial W_f'(i,x)}{\partial i}di + \frac{\partial W_f'(i,x)}{\partial x}dx \end{aligned}$$



Energy and coenergy

Therefore,

$$\lambda = \frac{\partial W_f'(i,x)}{\partial i}$$

and $$F = \frac{\partial W_f'(i,x)}{\partial x}$$

From the above diagram, the coenergy or the area underneath the magnetization curve can be calculated by

$$W_f'(i,x) = \int_0^i \lambda(i,x)di$$

For a magnetically linear system, the above expression becomes

$$W_f'(i,x) = \frac{1}{2}i^2 L(x)$$

and the force acting on the plunger is then

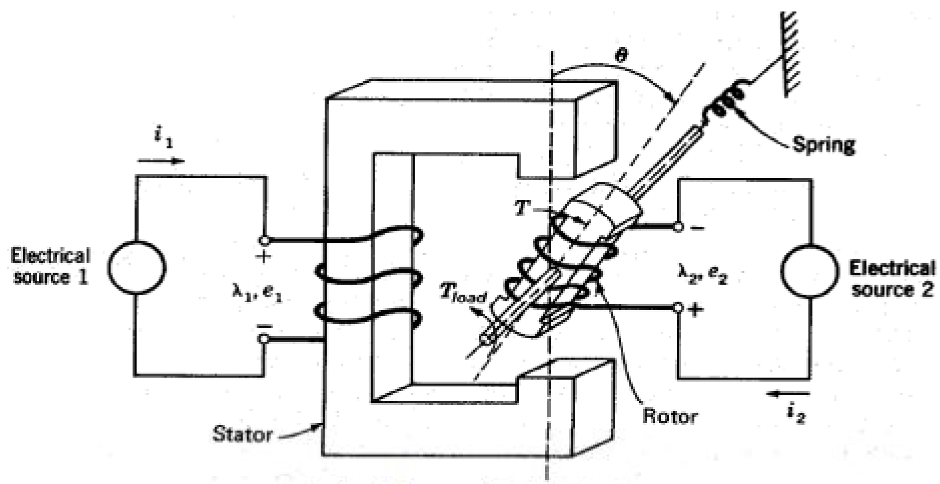
$$F = \frac{\partial W_f'(i,x)}{\partial x} = \frac{1}{2}i^2\frac{dL(x)}{dx}$$

Doubly Excited Rotating Actuator

The general principle for force and torque calculation discussed above is equally applicable to multi-excited systems. Consider a doubly excited rotating actuator shown schematically in the diagram below as an example. The differential energy and coenergy functions can be derived as following:

$$dW_f = dW_e - dW_m$$

where $$dW_e = e_1 i_1 dt + e_2 i_2 dt$$



A doubly excited actuator

$$e_1 = \frac{d\lambda_1}{dt}, \qquad e_2 = \frac{d\lambda_2}{dt}$$

and $$dW_m = Td\theta$$

Hence,

$$dW_f(\lambda_1, \lambda_2, \theta) = i_1 d\lambda_1 + i_2 d\lambda_2 - Td\theta$$

$$
= \frac{\partial W_f(\lambda_1, \lambda_2, \theta)}{\partial \lambda_1} d\lambda_1 + \frac{\partial W_f(\lambda_1, \lambda_2, \theta)}{\partial \lambda_2} d\lambda_2
+ \frac{\partial W_f(\lambda_1, \lambda_2, \theta)}{\partial \theta} d\theta
$$

and

$$
\begin{aligned}
dW_f'(i_1, i_2, \theta) &= d\left[i_1\lambda_1 + i_2\lambda_2 - W_f(\lambda_1, \lambda_2, \theta)\right] \\
&= \lambda_1 di_1 + \lambda_2 di_2 + T d\theta \\
&= \frac{\partial W_f'(i_1, i_2, \theta)}{\partial i_1} di_1 + \frac{\partial W_f'(i_1, i_2, \theta)}{\partial i_2} di_2 \\
&+ \frac{\partial W_f'(i_1, i_2, \theta)}{\partial \theta} d\theta
\end{aligned}
$$

Therefore, comparing the corresponding differential terms, we obtain

$$
T = -\frac{\partial W_f(\lambda_1, \lambda_2, \theta)}{\partial \theta}
$$

$$
T = \frac{\partial W_f'(i_1, i_2, \theta)}{\partial \theta}
$$

01/07/14

DC MACHINES

* It common name given two types:-
  (1) DC genʳ (2) DC motor.

① DC genʳ → * A m/c which is designed to take the advantage of electromegnatic indⁿ in order to convert mech. movement into electricity (dc vol.)

* Faraday's law of electromegnatic indⁿ → * whenever a condʳ cuts megnatic flux a dynamicaly induced emf is produced in the condʳ. The induced emf is directly proportional to rate of change of flux linkage.

Flux → The amount of megnatic field around the megnat represent by lines of force. In generaly it is indicated by ϕ & unit is wb.

Flux linkage → The extent of interaction between the flux & condʳ or condʳ & flux.

* It depands on the nature of flux time varying or time invarying.
* If the flux is time invarying in nature it require a relative motion between the flux & condʳ for the flux linkage.
* If the flux is time varying it automaticaly links with stationary condʳ.
* According to Faraday there are 3 modes of flux linkages

$$\lambda = N \times \phi$$

$$e \propto \frac{d\lambda}{dt} \propto \frac{d(N\phi)}{dt} = N\frac{d\phi}{dt}\ V$$

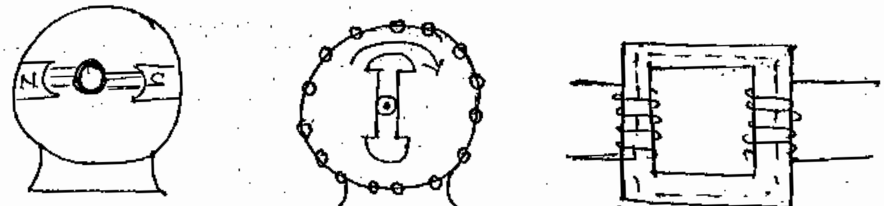
$$e = N\frac{d\phi}{dt} \times \frac{di}{di}\ \text{Volts}$$

$$e = N\frac{d\phi}{di} \times \frac{di}{dt}$$

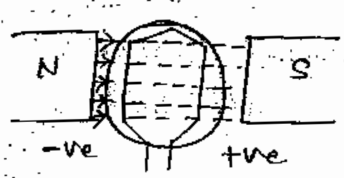
$$\boxed{e = L\frac{di}{dt}}$$

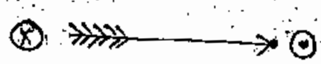
3 modes →

(1.) Conductors (Rotating) flux (stationary) } (Time invarying)
(2.) Conductors (stationary) flux (Rotating) }
(3.) Conductors (~~stationary~~) flux (stationary)

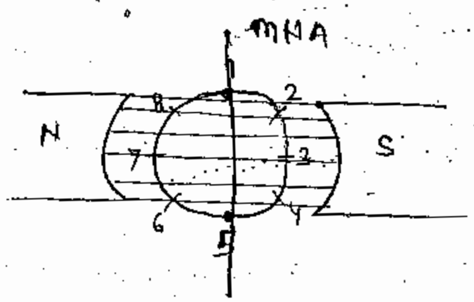


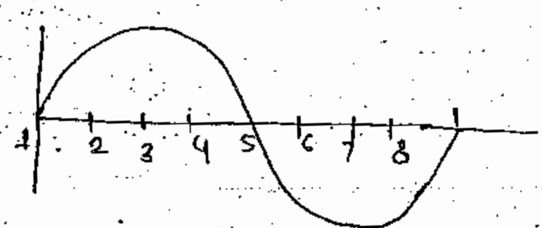
Dc m/c mode(1)   syn. m/c mode(2)   T/F mode(3)





1880 (DC) Thomas Alva Edison
1886 (AC) Nicolas Tesla





$$e = N\frac{d\phi}{dt} \text{ volts}$$

$$e = Blv \sin\theta \text{ volts}$$

FRR
Fore - Dirn of flux
Thumb - Dirn of rot/motion
Middle - Dirn of emf/current

θ = Angle b/w condr rotation & flux line

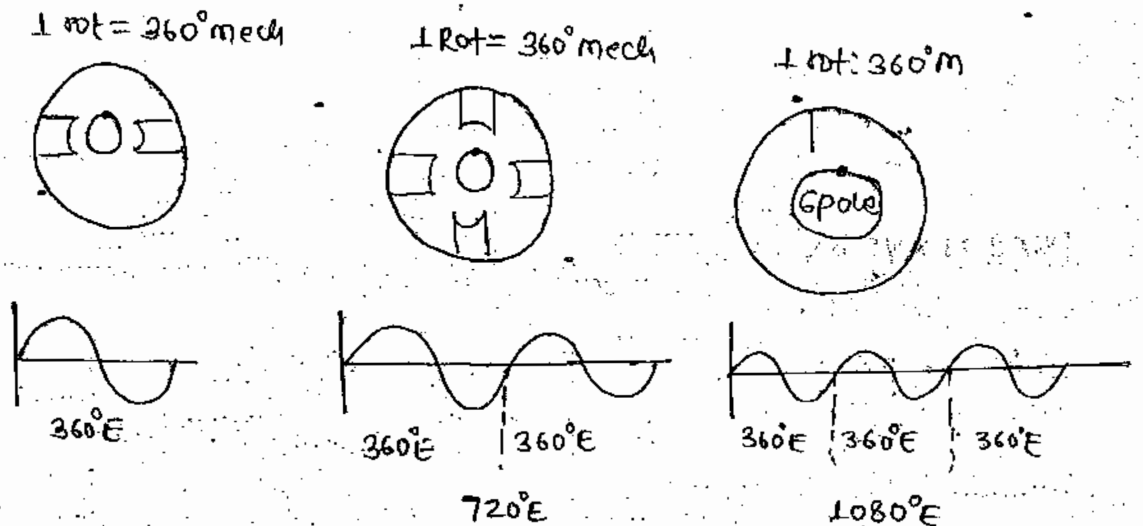
* Consider a simple coil rotating clockwise between 2 poles N & S. In one complete rotation it will produce 1 +ve half cycle & -ve half cycle which is periodic in nature known as alternating vol. or current.
* In positions 1 & 5 the condr movement is exactly parallel to the flux lines ($\theta = 0$)

* Due to this which there is no rate of change of flux linkage & the induced emf is 0. The axis along 1 & 5 where the emf induced is 0 is called as Magnetic Neutral axis.

* At positions 3 & 7, $\theta = 90°$ & the cond^r movement is exactly $\perp$ to the flux lines.

* Concequently max^m induced emf.

* MNA will be always 90° with the flux lines.



* Under a pole there are always 180 ele. degree.

$$\boxed{\begin{aligned} \theta_m &= \theta_e / (P/2) \\ \theta_e &= \theta_m \cdot P/2 \end{aligned}}$$

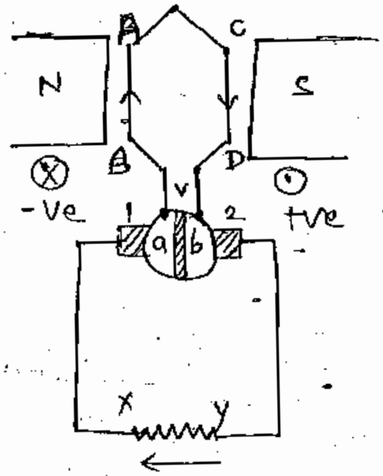
* In AC or DC gen^r there will be alternating vol. induced in the cond^r (AC)

* In AC gen^r AC is directly taken but in a dc gen^r it will be converted into dc using a rotating commutator.

Action of Rotating Commutator →

1→5, 0→180°

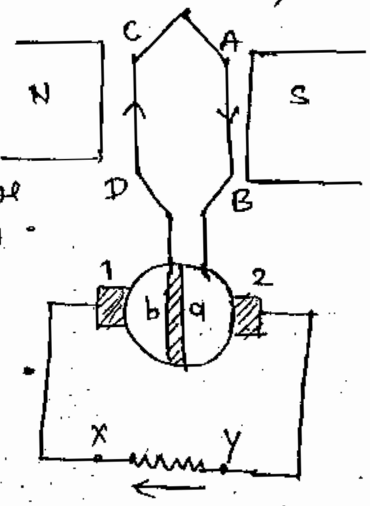
BA CD b 2 YX 1 a B



Commutator is rotating with coil

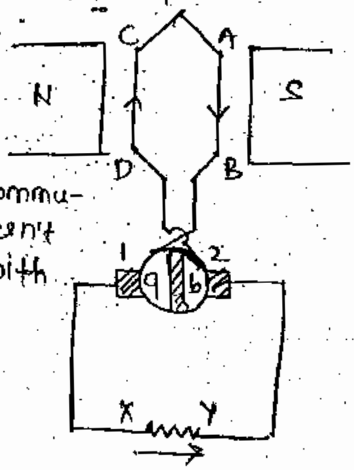
5→1, 180→360°

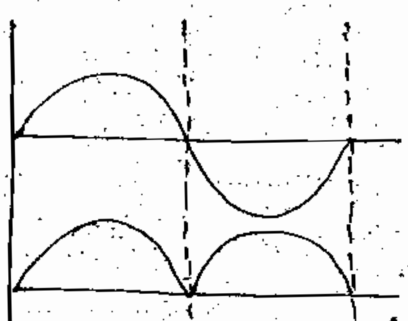
DCAB a 2 YX 1 b D



DCAB a 1 XY 2 b D

when commutator doesn't rotate with coil





* By virtue of its rotation the commutator converts bydirectionaly induced emf into unidirectional (AC into dc) therefore it is called as mech. rectifier.
* In AC genr or dc genr the induced emf is ac.
* In dc genr the construction will be always rotating condr with the stationary field in order to make commutator action possible.
* when a coil rotates across the brushes there is pulsating dc which is not used for commercial dc operation.

In order to improve the shape of waveform there are many no of coils connected in series uniformly distributed known as arm. wdg.

Constructional Details →

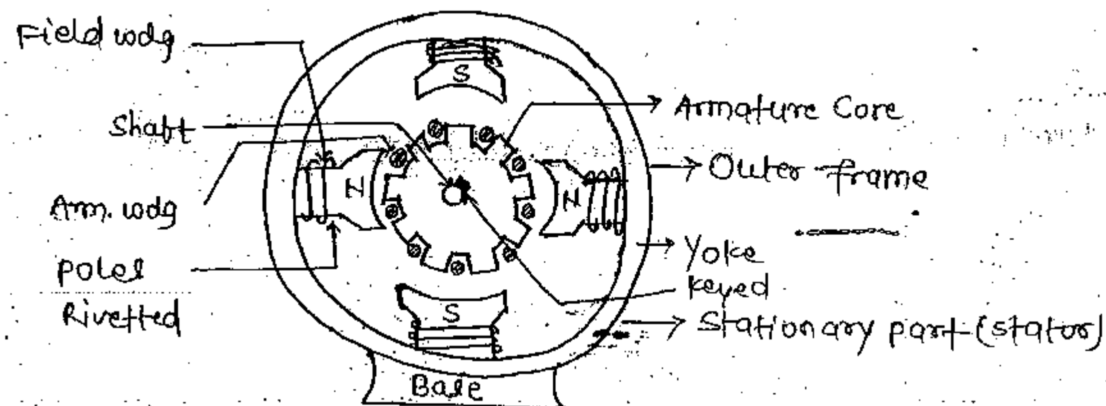
(1) Common features for all rotating ele m/c →

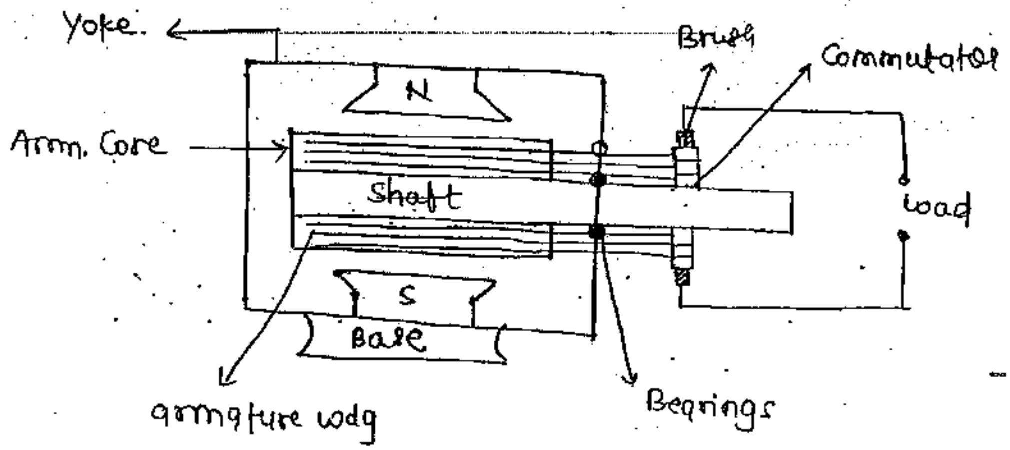
(i) The poles contains Hetropolar st (alternate North & South poles of even no.)

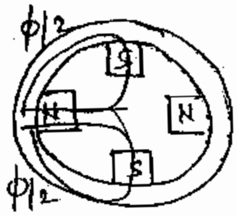
(ii) Excitation should be essentialy in dc.

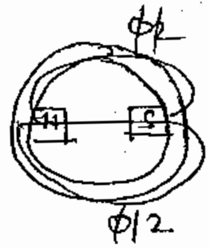
(iii) There will be stator (stationary part) & rotor (rotating part) with a least possible air gap between them.

Air gap → 0.5-2mm







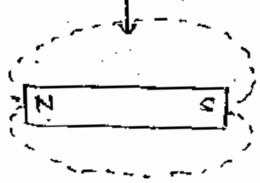


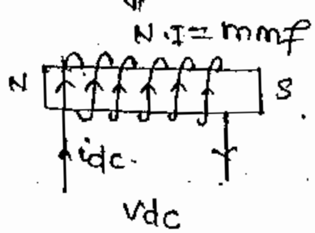
Yoke → * It acts as protective covering to the entire m/c.
* It supports the poles as the poles are directly rivetted to it.
* It offers flux path compliction of $\phi/2$ (if ϕ is flux/pole flux passing through yoke is $\phi/2$). Therfore yoke should be good megnatic material.
* For small m/c cast iron is used, large m/c - Fabricated ~~rote~~ steel.
* If the dc-m/c are operating across power electronic converter laminated yokes are prefered. (to reduce eddy current loss)

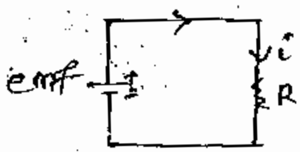
Pole → * It has to produces working flux in the m/c.
* The basic s

Flux

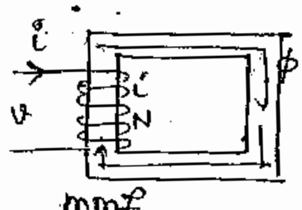
Permanant magnet | Electromagnet







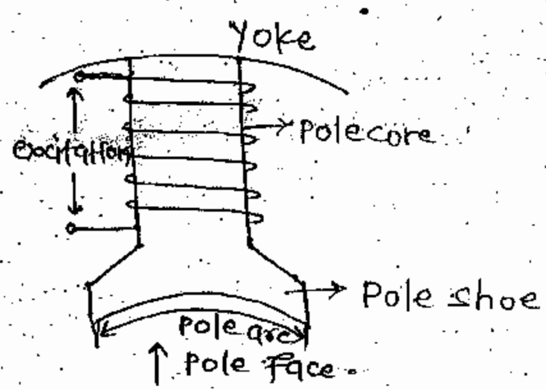
Resistance



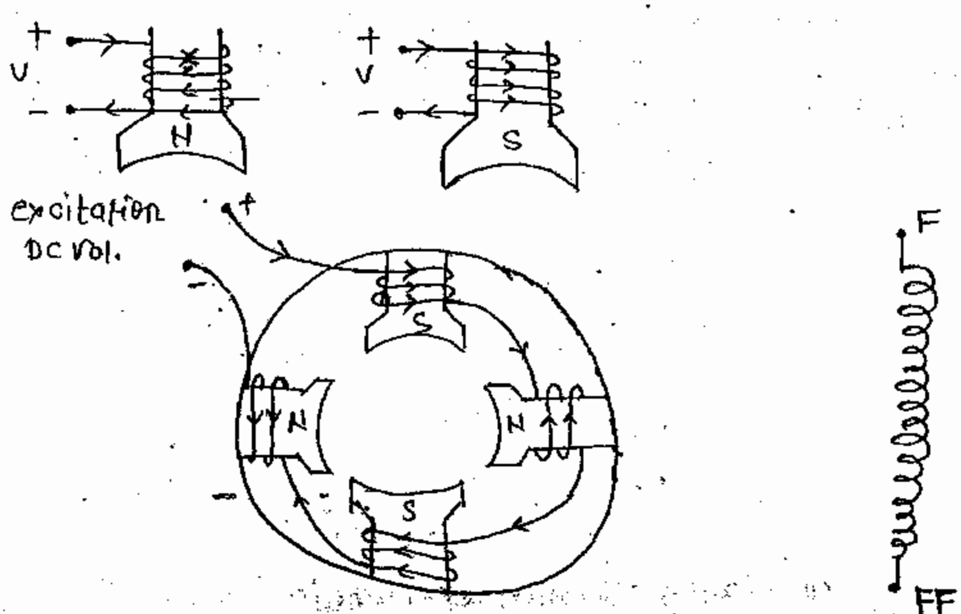
Reluctance

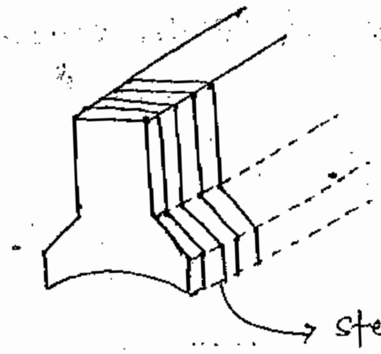
Permeability → Permit to flow the flux.

* Excitation should be always dc for the field wdg.
* The funⁿ of the pole is to produce the working flux in the m/c.
* The basic source of flux is permanant magnet which is uncontrolable.
* In order to control the m/c flux need to be controllable. Therefore electromagnets are prefered which requires wdg & a dc vol. across it called as excitation.
* Excitation is essentialy dc because it produce fixed poles polarity
* The pole is spread out as phole shoe.
* In order to reduce the reluctance in the air gap & to spread flux uniformly on the arm. cond^r



* The polarity of a pole depends on the polarity of excitation & orientation or sense of wdg.





* Poles are also made up of steel laminations.
* In order to reduce eddy current loss when the flux is not ideally dc.

3) Armature Core → * Arm. core is a cylindrical drum like st punched into slot on the peripheral.

* The arm. wdg is placed in this slot with the suitable insulation.
* It is mounted & keyed to the shaft. It should be superior magnetic material.
* As all the electromech. energy conversion happens in this rotating part of m/c (motor or genr), generat
* Generaly si is so used as it has superior megnatic property.
* Due to its high conductivity it will also produce eddy current.
* Therefore solid cores are not prefered but cores are laminated with thin laminations 0.4-1mm thickness.
* Each lamination act as individual core to form single core & the eddy current in each lamination will be considerbly reduced.

Si + Steel

↓

-- low hysteris coefficient

Reduce the conductivity of steel

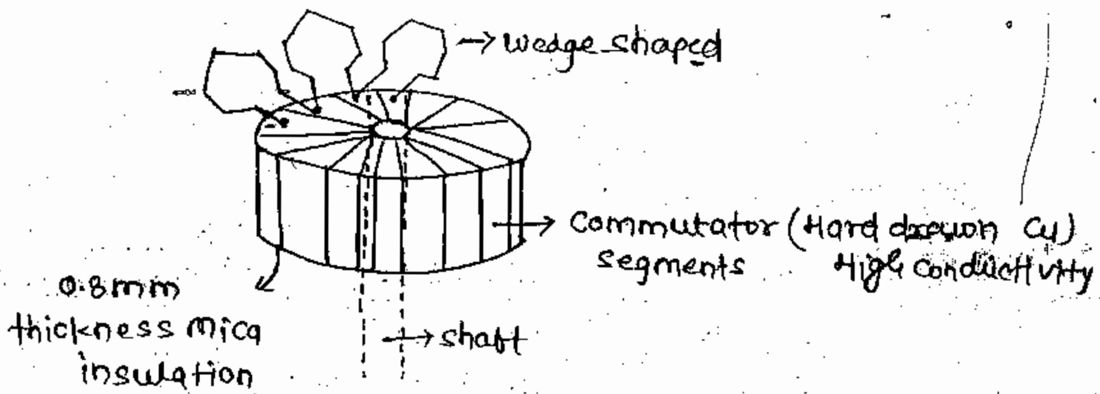
$x = 1.5 - 2.5$

Reduce eddy current & hysteris loss

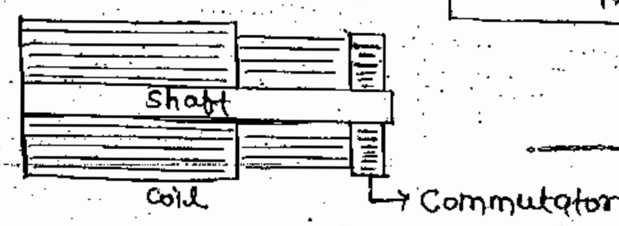
Also called electro~~steel~~ technic

* 3.5-4% Si is added to steel which reduce the losses occuring at core known as iron loss.
* Adding Si reduce the conductivity of steel without destrying its megnatic property as well as it has low hysteris cofficient as 1.6 to reduce it Hysteris loss.
* If more Si is added it will destroy mech. property of steel.

* Commutatore →



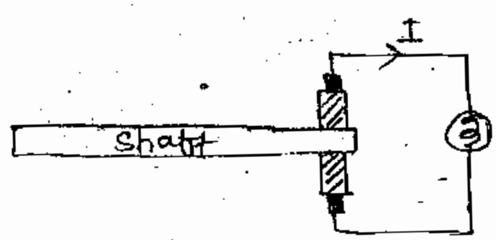
Commutator segments = No. of coils



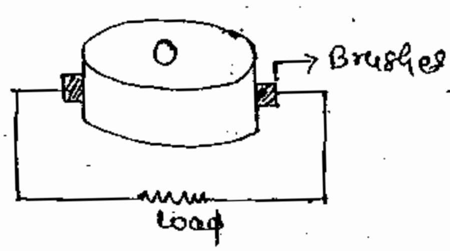
* Commutator is split ring which is segmented through 0.8 mm thickness mica insulation.
* The segments are made up of hard drawn Cu.
* It converts by directional emf or current inside the coil into unidirectional.
* It is the ~~ar~~ image of arm. wdg inside.
* The no of commutator segments are equal to no. of coil.
* Commutation plays the vital role in the operⁿ of dc m/c

Brushes → * Bruches offer ele. connection b/w rotating commutator & stationary load.

* They collect current from the wdg placed on the commutator through brush holders & spring.
* This are stationary sliding contacts.
* If the brushes collect current without any sparking then the commutation is successful
* If there exist any spark while collecting current then the commutation is not successful.
* Due to high peripheral speed any spark will spread into two or 3 segments & sc the coil inside to & produce large current in them.
* In order to insure succesful commutation mech as well as ele condn should be proper.



* In order to insure good mech. condn the brush is placed in a brush holder & placed on the commutator through spring.
* In order to insure good ele. condn & successfull commutation the bruches should be always placed on MNA (Neutral zone).
* The brush materials used are cu, c & electrograpahite.
* C brushes are used generaly to improve commutation. (refer commutation topic).



small dc	C
All dc m/c	Electro-graphite
LVHC dc	cu graphite

Shaft & bearing → * The purpose of a shaft is to provide mech. o/p.

* when the m/c operate as a genʳ & to collect mech o/p. then the same m/c operate as a motor.

* It is hold through bearings which offer rotation.

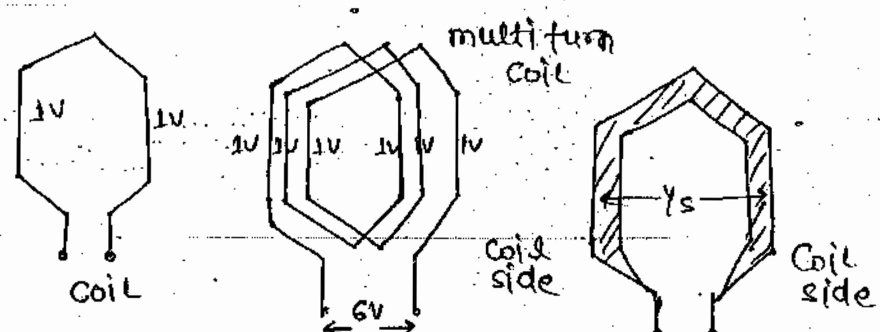
For large m/c →	Rolar bearing
Small →	Ball bearing

***

Armature wdg → * Condʳ may be made into terns & multiturns to form coils which are connected in series & distributed uniformly throughout the entire peripheral of the arm.

Condʳ → (z) The length of the wire lying in megnatic field where emf is induced.

Turn → Two condʳ made 1 turn; if there are z condʳ there will be z/2 turns.

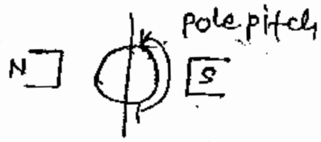


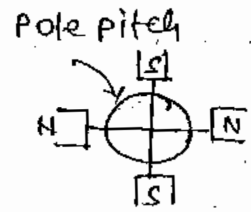
* If a coil consist of 1 turn it is known as 1 turn coil.
* If if there are two are more turns then it will be multiturn coil.
* Practicaly multiturn coil are used, as the provide more voltage
* A multiturn coil consist of two coil sides which are placed in the slots with a coil span.

Coil span → (y_s) Distance b/w 2 coil sides of a coil

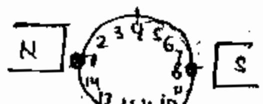
Pole pitch → (Y_p) The peripheral distance b/w 2 adjcent poles expressed in no. of slots or condʳ.

$\boxed{\text{slots/pole or } z/p}$



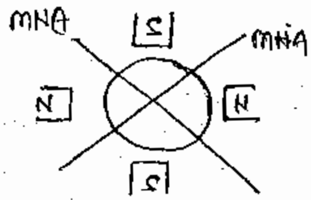


$$\boxed{1 \text{ Pole pitch} = 180^\circ \text{ ele degree}}$$



* For obtaining max^m vol. the coil side must kept at point 1 & end will be at 8.

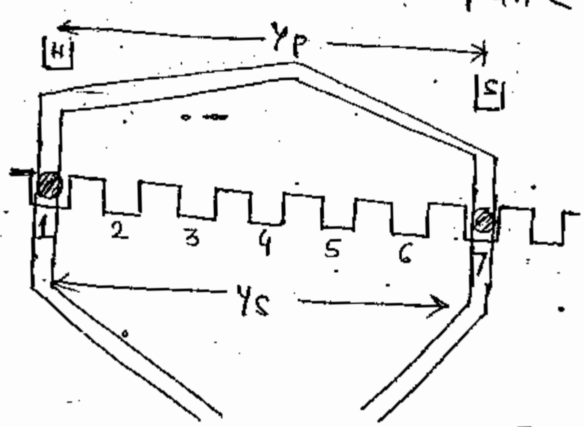
Stots/pole $= \frac{14}{2} = 7$ (Hence put a 8)
(maintain 7 slots gap)



Between the two adjcent pole there is one MNA

* If the coil span ~~is exactly~~ equal to pole pitch then it is known as full pitch coil & wdg. known as full pitch wdg.
* Do m/c arm. wdg are full pitch wdg only
* In order to get max^m induced emf

Coil span < pole pitch



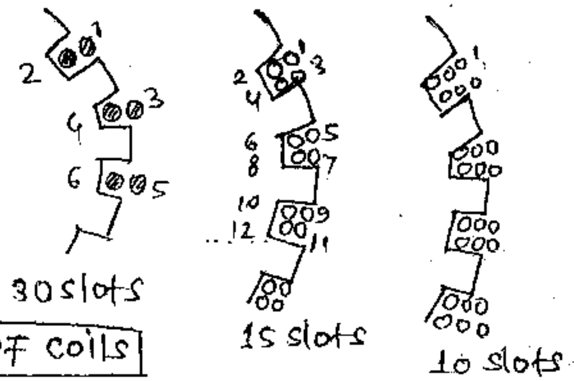
Single layer wdg → One coil side placed in one slot.

60 coil side
30 coil
60 slots

(small m/c)

Double layer → Two coil side placed on one slot.
or
Two layer

large m/c

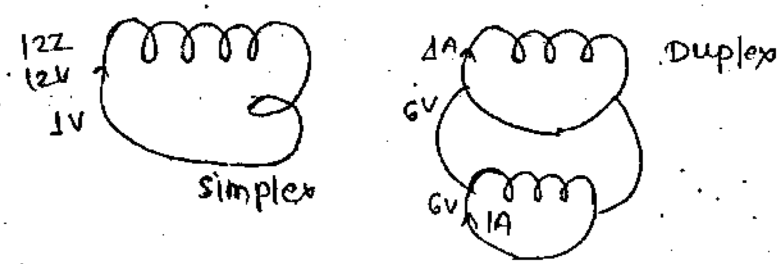


$\boxed{\text{No. of slots} = \text{No. of coils}}$

multiplex wdg →

$\boxed{\text{multiplicity 'm'}}$

* If dc wdgs are closed wdgs if there is one completely closed set of wdg it is known as simplex wdg with multiplicity factor m=1.
* If there are 2 such completly closed sets of wdgs connected in parallel it is known as duplex, m=2
* Similarly 3 sets triplex, m=3
* 4 sets = Quadruplex, m=4



* Multiplex wdg increase the current rating or loading capability of m/c.
* This are more advantageous in wave wdg then lap wdg.
* For a given no. of condr multiplicity is increase the current rating while decreasing its vol. rating.

Back pitch → The no. of cond^r spanned by one coil at the back
(Y_b). end of arm.

Front pitch → The no. of cond^r spanned by one coil at the
(Y_f) front end of arm. (Front end is commutator end)

Resultant pitch → The begining of one coil & its next successive
(Y_R) coil (Distance between then.

Commutator pitch → No. of commutator segments connected to
(Y_c) 2 successive coil.

Types of arm wdg → The basic classification is done depanding on the closure.

Closure :
- Open (ac gen^r / AC ⓖ arm. wdg
- close (dc gen^r)

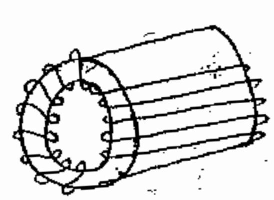
open wdg

close wdg

Closed
- → Gramme Ring
- → Drum
  - → Lap
  - → wave
  - → Frog leg (mixer)

* DC gen^r wdg should be closed type as there is a commutator

Gramme Ring →



* This is the 1st form of arm. wdg which has been totaly replaced with drum type due to the following disad:-

(1.) Half of the turn is wasted which is lying inside the arm. Core.

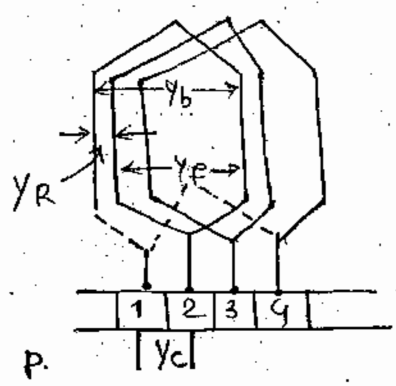
(2.) Insulating maintanance, repairs & design is costly.

Drum →

* The arm. core is a cylindrical drum which is slotted on the periphery where the wdg is placed in that.

* No turns are wasted, designed maintance & repaire is comparitively easy.

Lap wdg →



$$\boxed{y_R = y_b - y_f}$$

Z P.

(1.) Calc y_b, y_f.

(2.) Develop wdg. dia table

(3.) Wdg dia

(4.) Polarity mark brush positions

$$y_s = y_p \simeq y_b \simeq y_f$$

$$\boxed{y_A = \frac{y_b + y_f}{2} = \frac{Z}{P} \text{ avg. value}}$$

b) * In order to support lap wdg format Y_f, Y_b should be opposite signs.

* Therefore $Y_b \neq Y_f$

* Both Y_b, Y_f should be odd no. in order to have symmetric double layer wdg.

* Therefore $\boxed{Y_b - Y_f = \pm 2m}$ $\boxed{Y_c = \pm m}$

$$Y_b > Y_f \rightarrow +2m$$

* It also called RHS wdg / progessive wdg.

$$Y_b < Y_f \rightarrow -2m$$

* So it called as Retrogressive / LHW.

Eg. → Design simplex progressive lap wdg for 24 Cond^r 4 Poles.

soln →

$$\frac{Y_b + Y_f}{2} = \frac{Z}{P} = \frac{24}{4} = 6$$

$$Y_b + Y_f = 12,$$

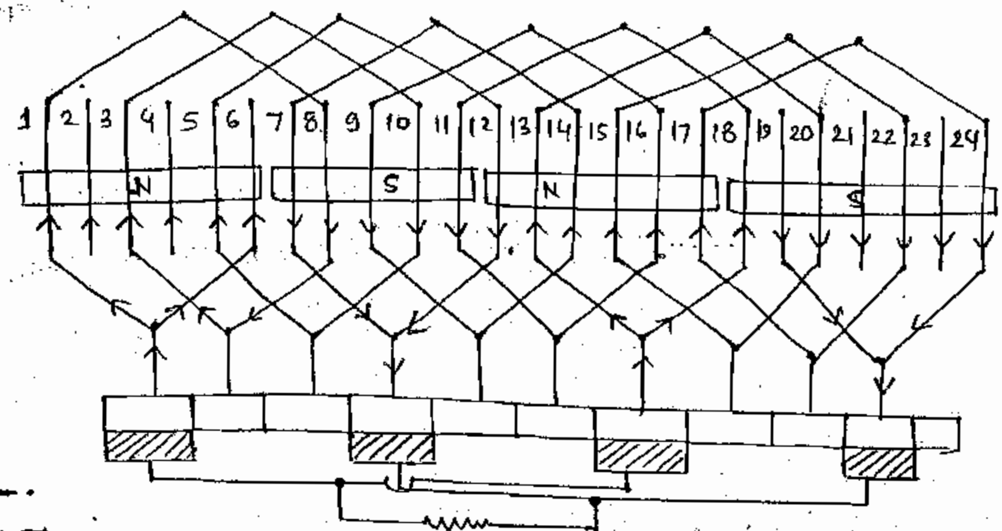
$$Y_b - Y_f = 2$$

$$Y_b = 7, \quad Y_f = 5$$

wdg table →

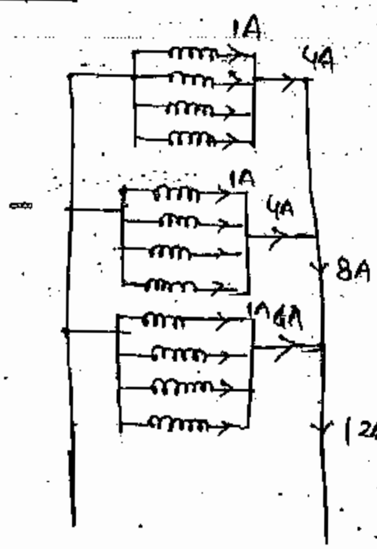
$Y_b = 7$	$Y_f = 5$
1+7=8	8-5=3
3+7=10	10-5=5
5+7=12	12-5=7
7+7=14	14-5=9
9+7=16	16-5=11
11+7=18	18-5=13
13+7=20	20-5=15
15+7=22	22-5=17

Wdg. diagram →



* The no. of parallel paths are always equals to the no. of poles.
* Multiplexcity also increases the no. of parallel path.

Therefore $\boxed{A = PM}$



$A = PM$
$= 4$

$A = PM$
$= 4 \cdot 2$
$= 8$

$A = PM$
$= 4 \cdot 3$
$= 12$

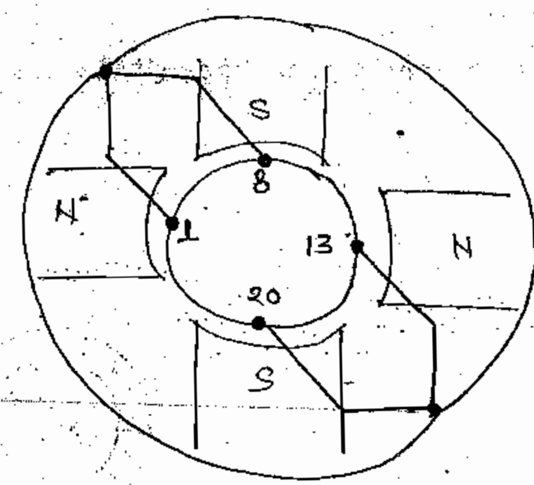
* It is also known as parallel wdg as there are more parallel path in it.
* Consequently no. of condr in series per parallel path is less.

Therefore it is emplyoed for high currents low vol. ratings.

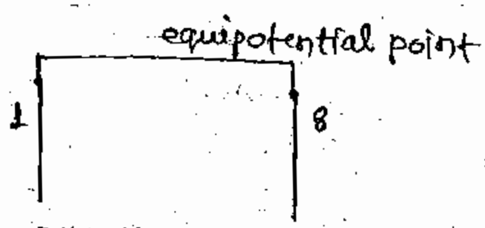
Equilizer rings → This are thick cu condr located at the back end of arm. which has low resistance.

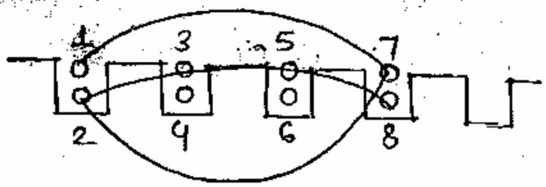
* Equipotential coils are tapped individualy to respective equilizer rings.
* Any circulating current will be bypassed & circulates within the equilizer rings at the back end & doesn't enter into the commutator at front end.

Equipotential coil → * These are exactly located twice the pole pitch distance or 360°E apart.



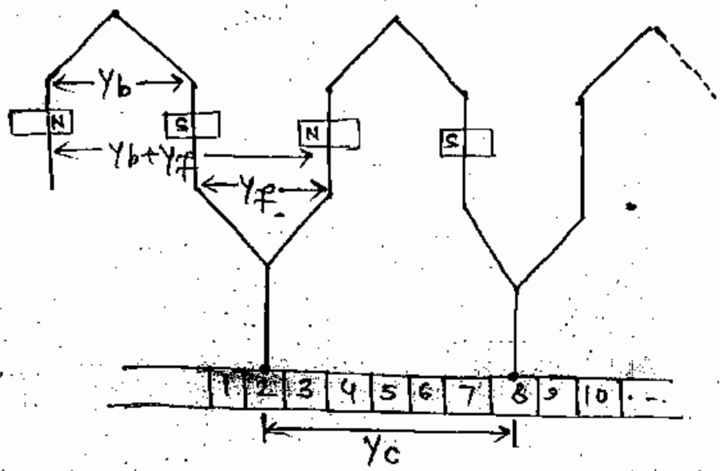
* Any unbalance in the induced emfs in the parallel paths will create a circulating current which interface with commutation when it flow through the bus
* Therefore any circulating current will be bypass through the equlizer ring at the back end & doesn't enter into the commutator at front end.





→ Unsymmetric wdg.

Wave winding →



* The tech. Cons. diff. b/w lap & wave is in the commutator pitch.
* In wave it is twice the pole pitch.

$$\boxed{Y_A = \frac{Y_f + Y_b}{2} = \frac{Z \pm 2^*}{P}}$$

* Y_A should be integer

* Y_B, Y_f have same sign to support wave format

$$\boxed{Y_b = Y_f}$$

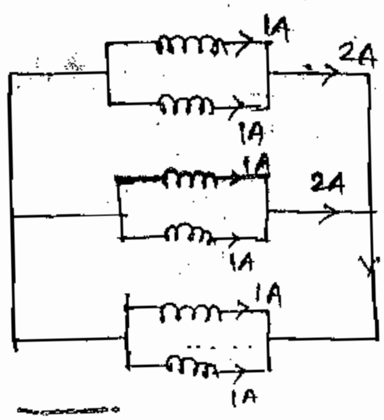
(OR)

$$\boxed{Y_b - Y_f = \pm 2m}$$

$$\boxed{A = 2m}$$

* The no. of parallel paths are indepandant of no. of poles & always = 2 as the multiple wdgs increase the no. of parallel path.

$$\boxed{A = 2m}$$



Simplex
$A = 2 \cdot 1 = 2$

Duplex
$A = 2 \cdot 2 = 4$

Poles	Lap	wave
2	2	2
4	4	2
8	8	2
⋮	⋮	⋮
10	10	2
⋮	⋮	⋮
20	20	2

* Multiplex wdgs are advantageneous in wave then Lap.
* As there are less no. of parallel path it is employed for high voltage low current ratings.

* Dummy Coil →

Q→ Design wave wdgs for 60 Cond^r 15 slots 4 pole simplex.

Sol^n →

$$Y_A = \frac{Z \pm 2}{P} = \frac{\overset{58}{60} \pm 2}{4} \quad 2 \rightarrow \text{missed}$$

$$Y_A = \frac{62}{4} \text{ or } \frac{58}{4} \qquad \frac{60}{4} \text{ or } \frac{56}{4}$$

$$14 \times 4 = 56$$

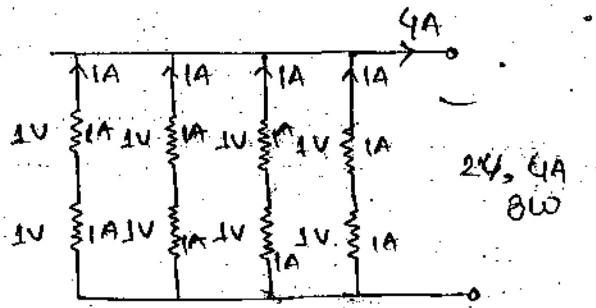
But in 15th slot = ?

* For some set of data Y_A will not be integer in order to make is integer value the nearest possible cond^r will be considred.
* Due to which some cond^r are missing in any one of the slots

In order to maintain mech. balance the missing condr are well insulated & placed in the missing slot as dummy.

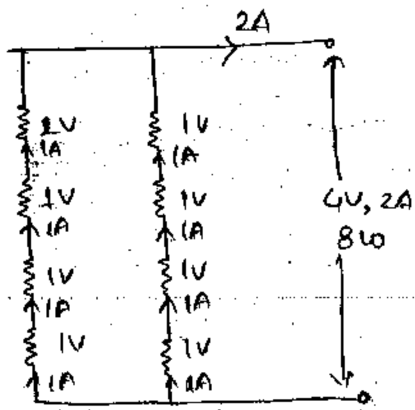
* It is not connected to the rest of the wdg.
* As there are only 2 parallel path any unbalance will become a balanced condn.
* Therefore no need of equilizer rings.

Eg → Consider a 4P simplex lap wound genr arm. with 8 condr is reconnected as wave.



Lap wound

A_L, V_L, I_L, P_L, R_L



wave wound

A_W, V_W, I_W, P_W, R_W

$$\boxed{\begin{aligned} I \propto A &\rightarrow \frac{I_L}{I_W} = \frac{A_L}{A_W} \\ V \propto \frac{1}{A} &\rightarrow \frac{V_L}{V_W} = \frac{A_W}{A_L} \end{aligned}}$$

$$\boxed{P_L = P_W \quad I_L^2 R_L = I_W^2 R_W}$$

Eg. → A 4P dc genr with lap wound arm. is reconnected as a wave what will be the change in V, I & P.?

Soln →

$$\frac{I_L}{I_W} = \frac{A_L}{A_W} = \frac{4}{2} \; , \quad \frac{I_L}{I_W} = 2 \quad \boxed{\frac{I_L}{2} = I_W}$$

$$e = \frac{P\phi}{60/N} = \frac{\phi PN}{60} \text{ voltz}$$

emf induced per parallel path $\frac{\phi PN}{60} \times \frac{Z}{A}$

$$e = \frac{\phi PN}{60} \times \frac{Z}{A}$$

$$\boxed{e = \frac{\phi ZNP}{60A}}$$

$$\boxed{E_g = \frac{\phi ZNP}{60A} \text{ volts}}$$ Gen/induced emf

$$E_g \propto \phi N$$

$$\frac{E_{g1}}{E_{g2}} = \frac{\phi_1}{\phi_2} \frac{N_1}{N_2}$$

(OR)

$$\boxed{\frac{E_{g2}}{E_{g1}} = \frac{\phi_2}{\phi_1} \times \frac{N_2}{N_1}}$$

If N is constant

$$\frac{E_{g2}}{E_{g1}} = \frac{\phi_2}{\phi_1}$$

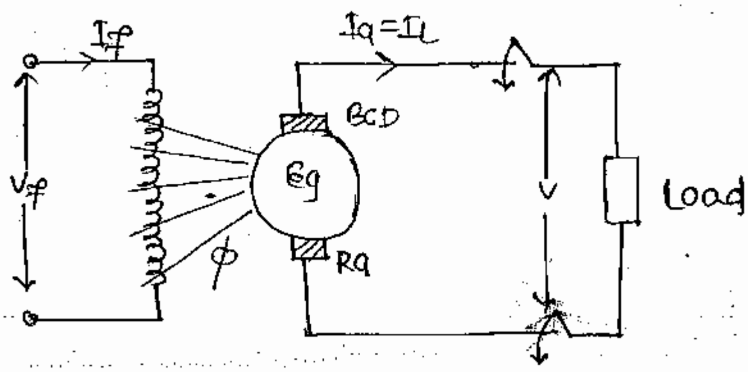
If ϕ is constant

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

* Classification of dc. gen^r → * In order to control the m/c electro-magnets are prefered as poles which requires a dc vol. excitation across it
* The classification of gen^r is according to method of excitation:-

Excitation →
- Seprate Excitation
- Self excitation →
  - Shunt Excitation
  - Series Excitation
  - Compound Excitation

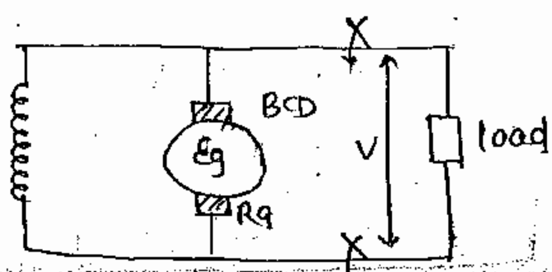
* Seprate Excitation →



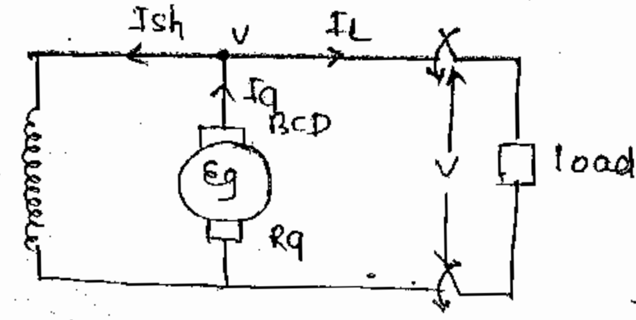
* It requires a seprate dc source for its excitation.
* Its field & arm. wdg are isolated electricaly.
* The terminal voltage (V) across the load doesn't affect its excitation.
* Due to additional voltage source requirement it is rarely used gen^r around 95% dc gen^r used are self excited only.

$$\boxed{\begin{array}{l} \text{gen/Ind emf} \\ E_g - I_aR_a - BCD = V \;\; \text{Terminal V} \\ I_a = I_L \end{array}}$$

* Self Excitation → * The field wdg will be excited by its own arm. which requires some essential cond^n starts with residual flux.



Shunt excitation →



$$E_g - I_a R_a - BCD = V$$

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

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

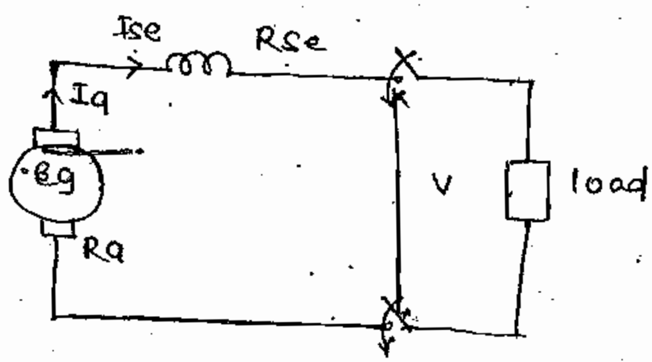
* The field wdg is connected in parallel with arm. through brushes.
* The terminal vol. itself act as excitation.
* Shunt field turns are very large in no. due to its resistance is high with thin condr.

Range 50–250Ω

$\boxed{\text{Loading any m/c = Reducing the ~~cu~~ resistance}}$

* The field ~~turn re~~ current remains approx. same from NL to rated value.
* Concequently flux is approx. same in the operating region.
* In this mode it is known as shunt genr & vol. operated field.

Series Excitation →

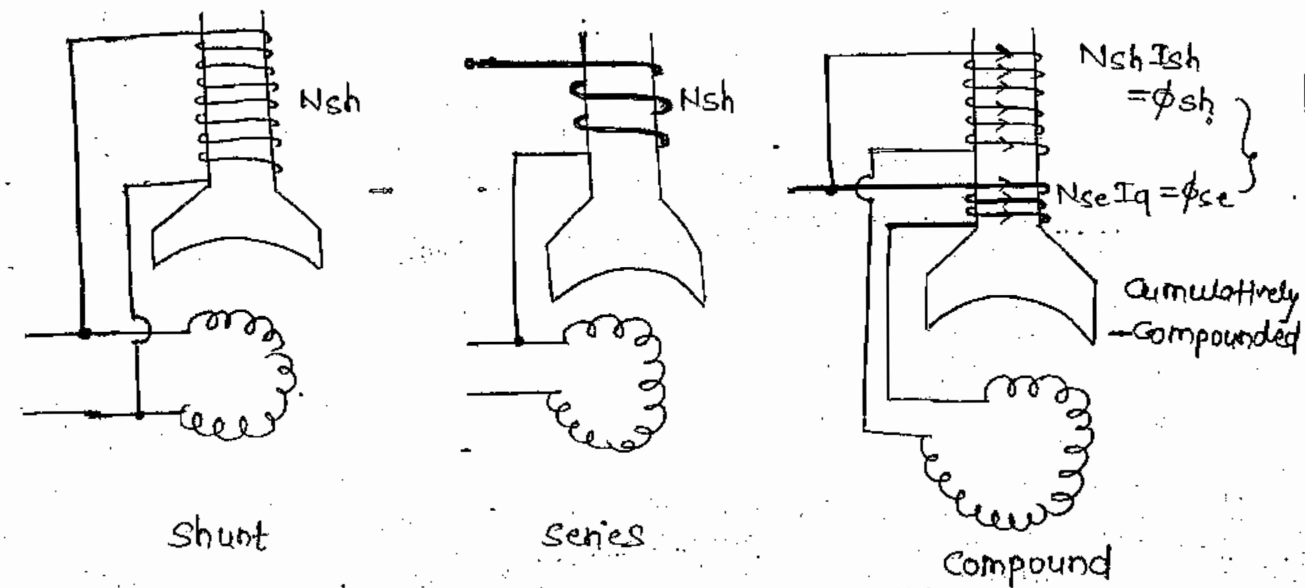


* In this mode it is known as series genr & current operated field.

$$E_g = I_a(R_a + R_{se}) - BCD = V$$

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

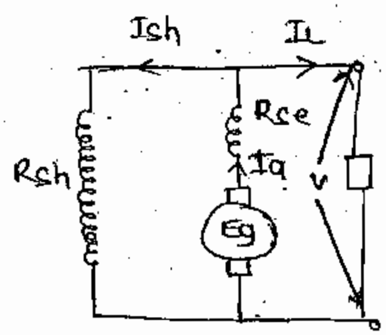
* The series field wdg contain less no. of turns with thick cond^r.



* Shunt flux always dominate series flux
* If series field wdg is reversed than $\phi_{sh} - \phi_{se}$: Differently

DATE- 04/07/14

Long shunt →

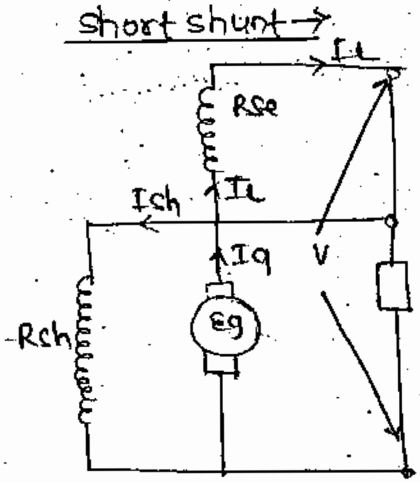


$$E_g - I_a(R_a + R_{se}) - BCD = V$$

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

$$I_{sh} = V/R_{sh}$$

Short shunt →

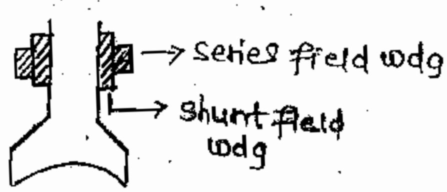


$$E_g - I_aR_a - I_LR_{se} - BCD = V$$

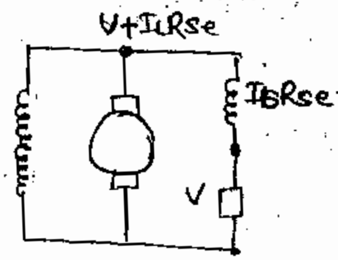
$$I_a = I_{sh} + I_L$$

$$I_{sh} = \frac{V + I_LR_{se}}{R_{sh}}$$

* ~~There is no~~



Short shunt



* There is no distinctive diff b/w long shunt & short shunt genr.
* The induced emf in long shunt is sligktly greater than that of short ~~short~~ shunt ($I_a > I_L$)
* If the series field wdg is reversed than the cumulative mode becomes differential.

Cumulative: currents in both field wdg same dirn on the pole core. Therefore both fluxes add each other. and the net flux increases with load.

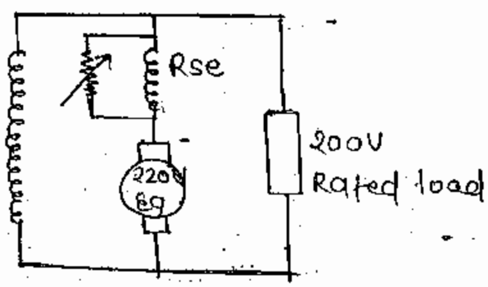
In differential the series flux oppose the shunt flux & the net flux decreases with load.

Exc

- Seprately
- Self-excited
  - Shunt
  - Series
  - Compound
    - long shunt
      - Differential
      - Cumula.
        - Over
        - Flat/level
        - under
    - Short shunt
      - Differential
      - Cumulative
        - over
        - Flat/level
        - under

Compounding → * Adjusting the terminal voltage of cumulative compound genr by varying its series field ampere turns by connecting a diverter across its series field wdg.

* Depanding on the degree of compounding a cumulative compound genr can act as under, flat, over compound genr.
Compounding is done at rated load. to adjust the terminal vol. below rated, exactly rated & above rated respectively.



* By varying the diverter resistance from 0 to max^m value a cumulative compound genr can be acted in 4 other modes.

(i) Rd = 0 (shunt)
(ii) Rd ↑ Basic cumulative
(iii) Rd ↑↑ Under
(iv) Rd ↑↑↑ Flat/level
(V) Rd ↑↑↑↑ Over

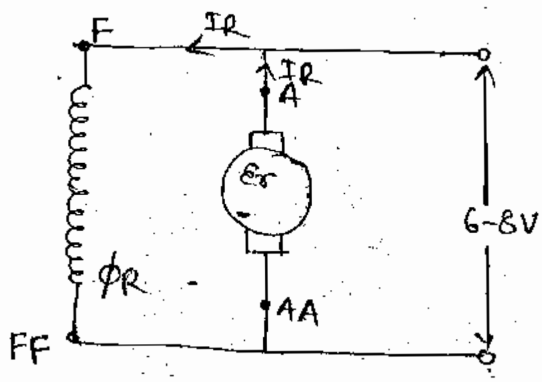
* Compounding can't be done with differential compound genr as its series flux opposes shunt flux.
* NL induced emf of flat compound genr is exactly equal to rated voltage at rated load.
Since series flux is adjusted to compensate all the drops at rated load.

Voltage build up → [In self excited genr]

* In a separately excited genr there is a seprate source to exite the field & produce flux.

* In a self excited gen^r there is no such source to exite the field wdg. Therefore in order to buildup voltage in self excited gen^r the poles should contain the residual flux.

Shunt gen^r →



1) * Consider a shunt gen^r made to run at rated speed with residual flux in its poles small voltage is induced in the arm. (6-8V) which produces small current.

* If the gen^r is on NL, all the initial current will flow into field wdg. to produce initial mmF with field wdg turns.

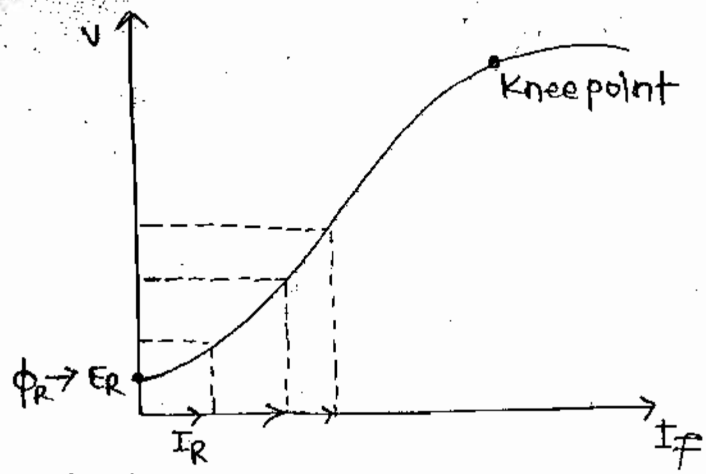
2) * The field should be properly connected to the arm. in order to make initial mmf at the residual flux.

* It is a cumulative process as the current increases the flux out of the pole increases & the induced voltage also increases after saturation of poles even though the current increase. Flux doesn't increases. Concequently voltage becomes constant.

$$\phi_R \longrightarrow E_R \longrightarrow I_R$$

$$I_R N_{sh} \longrightarrow \phi_1 + \phi_R \longrightarrow E_1 + E_R \longrightarrow I_1 + I_R$$

$$(I_1 + I_R) N_{sh} \longrightarrow \phi_2 + \phi_1 + \phi_R \longrightarrow E_2 + E_1 + E_R \longrightarrow I_2 + I_1 + I_R$$



(3.) The operating speed of the gen^r should be greater than critical speed.

(4.) The resistance of field wdg should be less than critical resistance value.

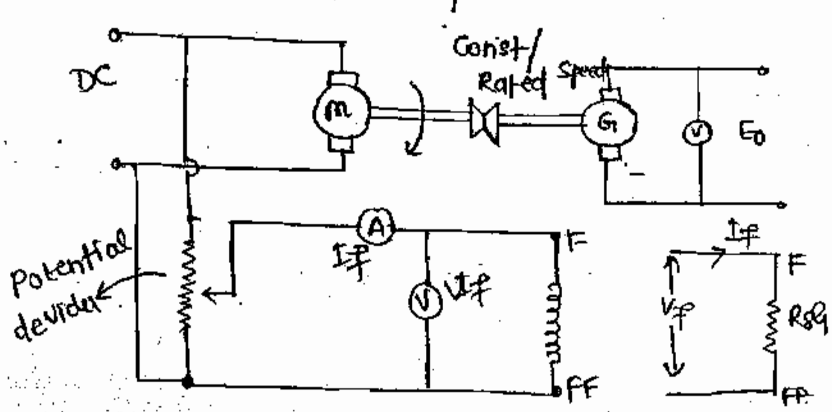
(5.) The best cond^n for a shunt gen^r to build up voltage successfully is it should be on NL.

(6.) In-spite of all the above 5 cond^n satisfied if the vol. doesn't build up it may be due to improper contact across brushes & commutator.

Determination of critical resistance & critical speed →

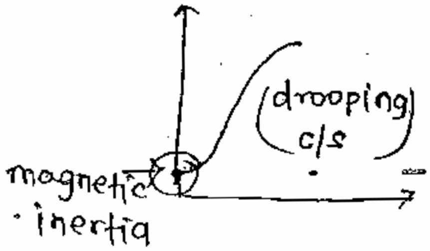
OCC (open circuit c/s)
NLS (No load saturation) } Eo Vs I_f
Magnetisation c/s

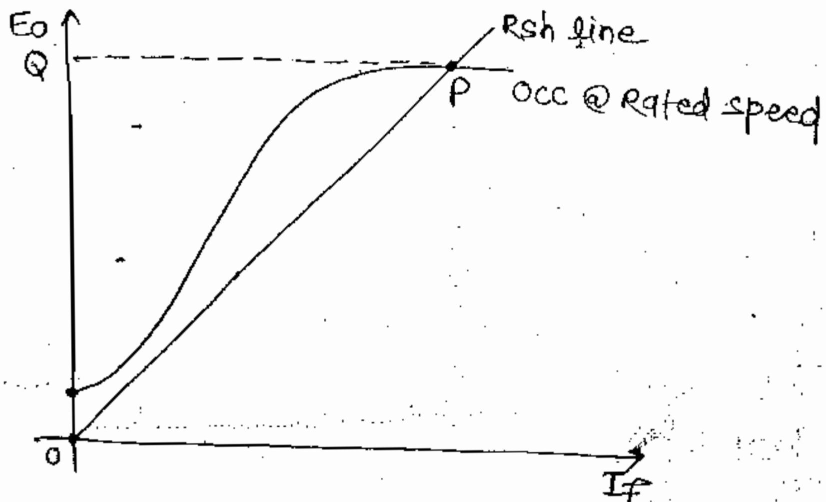
* In order to plot OCC to determine R_c & N_c of a self exc. shunt gen^r it requires to be seprately excited.



S.N.	V_f	I_f	E_0
1	0	0	6-8
2	10	0.1	30
3	20	0.2	60
4	30	0.3	80
⋮			

linear



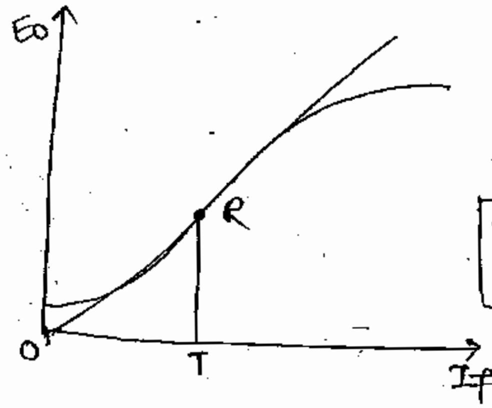


<u>Critical Resistance</u> → The resistance of the field wdg <u>about</u> which the genr doesn't build up voltage ~~this is~~

<u>Critical speed</u> → The speed of genr <u>below</u> which the genr doesn't build up voltage. S

<u>Determination of critical resistance</u> →

* The field resistance line intercepts OCC at a point P.
* Length of OQ in volts is the maxm emf induced in the genr.



$$\boxed{R_c = \frac{RT_V}{OT_A}}$$

Sagar Sen
8871453536

Steps:- (1) Draw the occ line.

(2) Plot a tangent through occ.

Critical speed ~~Determination~~ →

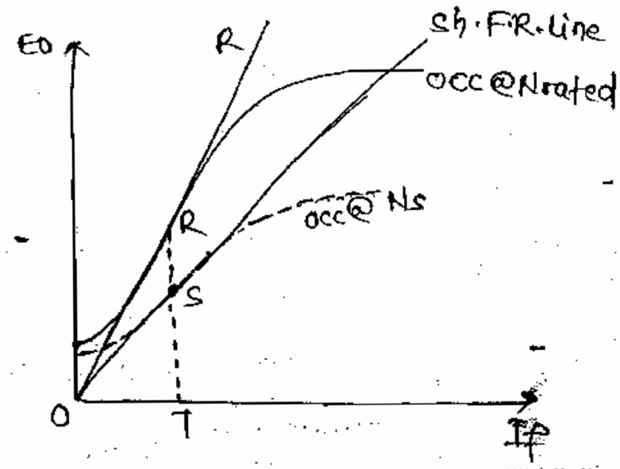
Steps → (1) Draw original shunt field resistance line.

length of (ST) $\propto N_c$

length of (RT) $\propto N_{rated}$

$$\frac{ST}{RT} = \frac{N_c}{N}$$

$$\boxed{N_c = \frac{ST}{RT} N}$$



* The critical resistance of a given genr depends on the operating speed. from critical speed & above.
* It varies proportionaly with speed.
* When the m/c is running at critical speed its field resistance value itself is critical resistance.

Eg. → A shunt genr building up vol. normaly. If the field wdg is reversed & operated ~~that~~

(a.) Build up vol. normaly

(b) Build up vol. with −ve polarity

(c) No build up of vol.

(d) GV across the arm.

Ans. → (c.)

Eg. → Same above que. Dirn of rotation of genr is reversed. options same.

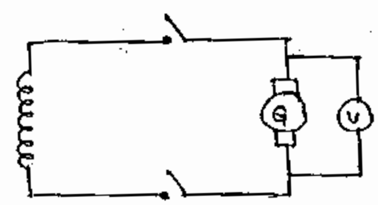
Ans. → (c) $-E_g \propto \phi(-N)$

e.g. → If both dirn of rotation as well as field wdg. is reversed.

$E_g \propto (-\phi)(-N)$; E_g (+ve)

Ans. (a)

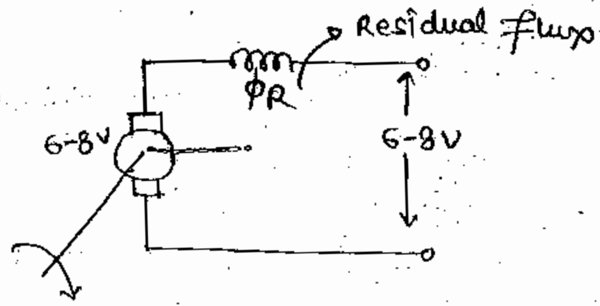
2/1



	switch Open	Close
A.	8V	8V
B.	8V	12V
C.	8V	0V

1. Critical Resistance
2. load resistance
3. Field polarity

★ Voltage build up is series genr →



(1.) It require residual flux.

(2.) The terminals should be closed with some load. As the load current flows into the field wdg the initial mmf is considerably good value & no need of large series field wdg terms.

(3.) The total resistance ($R_a+R_{se}+R_L$) should be less than its critical resistance.

$$\boxed{(R_a+R_{se}+R_L) < R_c}$$

(4.) Its speed should be greater than critical speed.

Cumulative Compound genr →

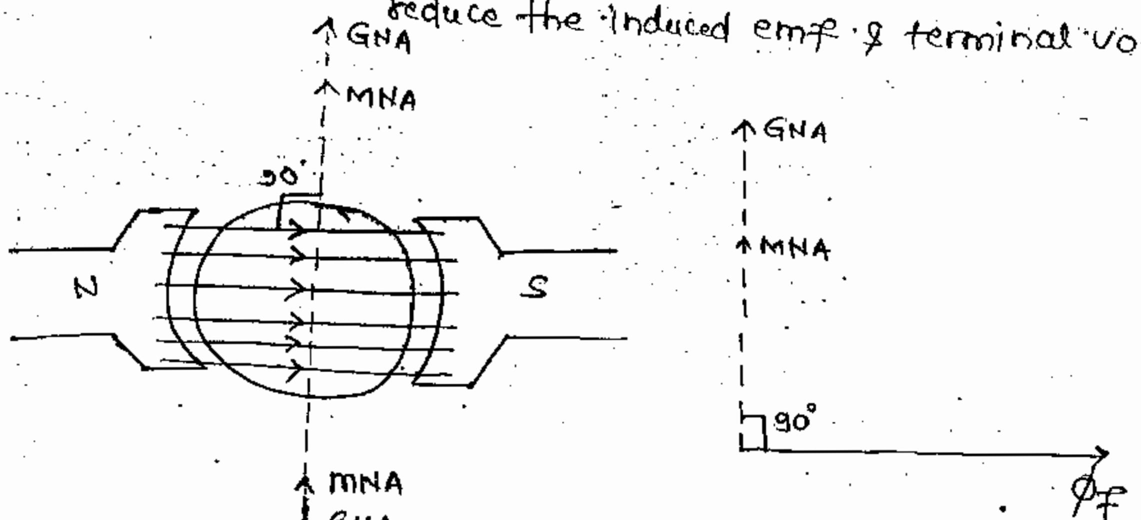
★ A compound genr is eq. to a shunt genr on NL. Therefore its vol. build up is eq. to shunt genr.

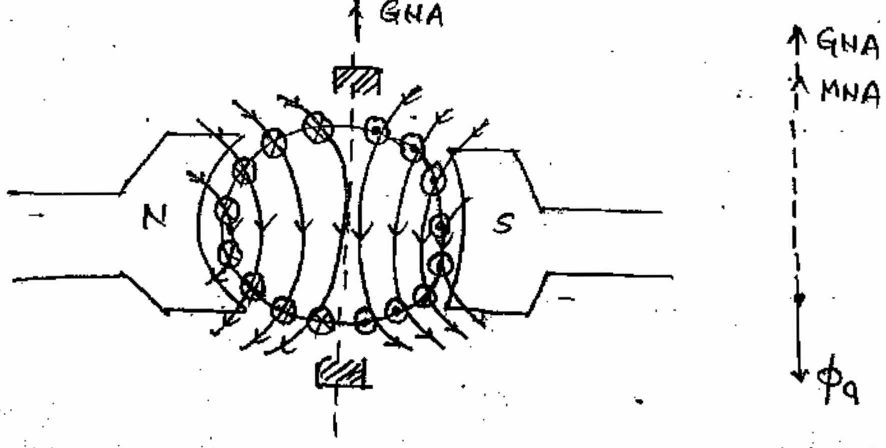
Armature Reaction →

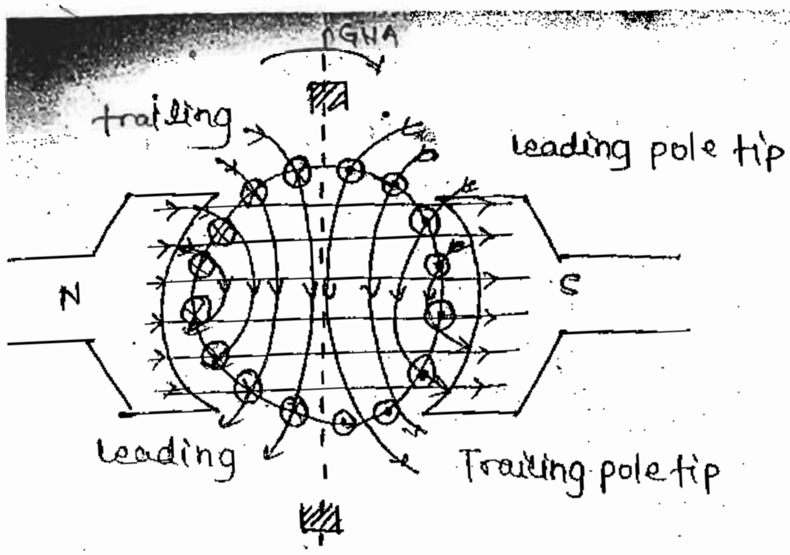
* On NL the arm. current is negligible. Concequently there is only main flux in the air gap distributed uniformly in flat topped nature.
* As the arm. is loaded load current flows in the arm. condr or turns which produce arm. mmf & arm. flux which is also distributed uniformly throughout the arm. peripheral in the air gap.
* The arm. flux will take an action on main flux distribution which is called as arm. reaction.
* The effect of the arm. flux on main flux produce :-
  (1.) Cross magnetisation.
  (2) Demagnetisation.

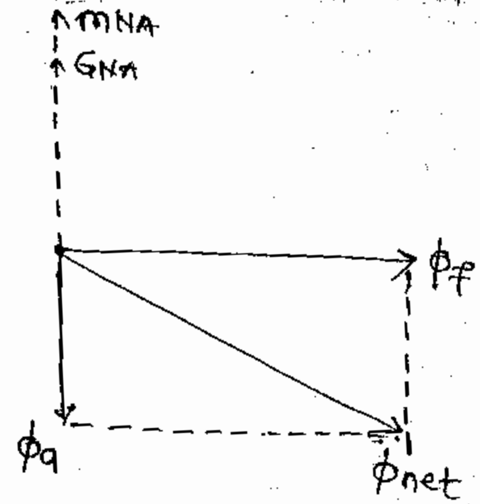
Cross magnetisation → It is distortion of main flux due to which MNA is shifted. & the commutation will not be successful due to sparking.

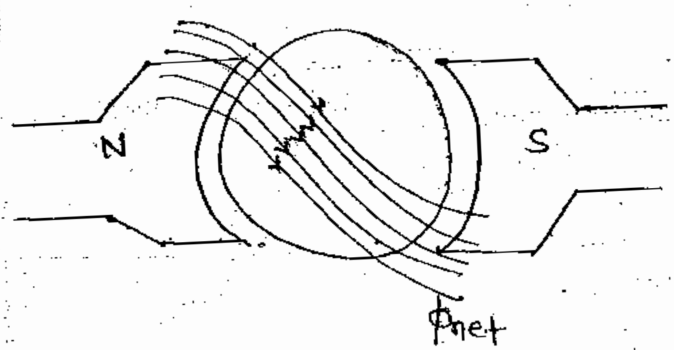
Demagnetisation → It is Reduction in the main flux which reduce the induced emf & terminal voltage.

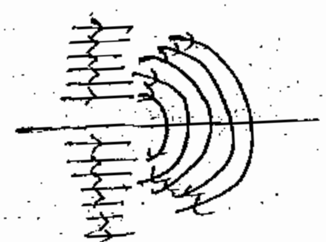




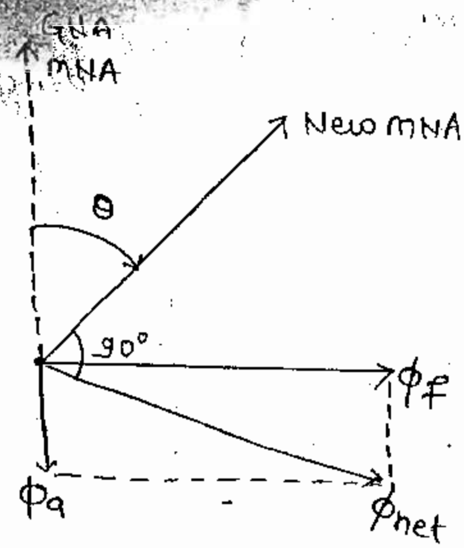






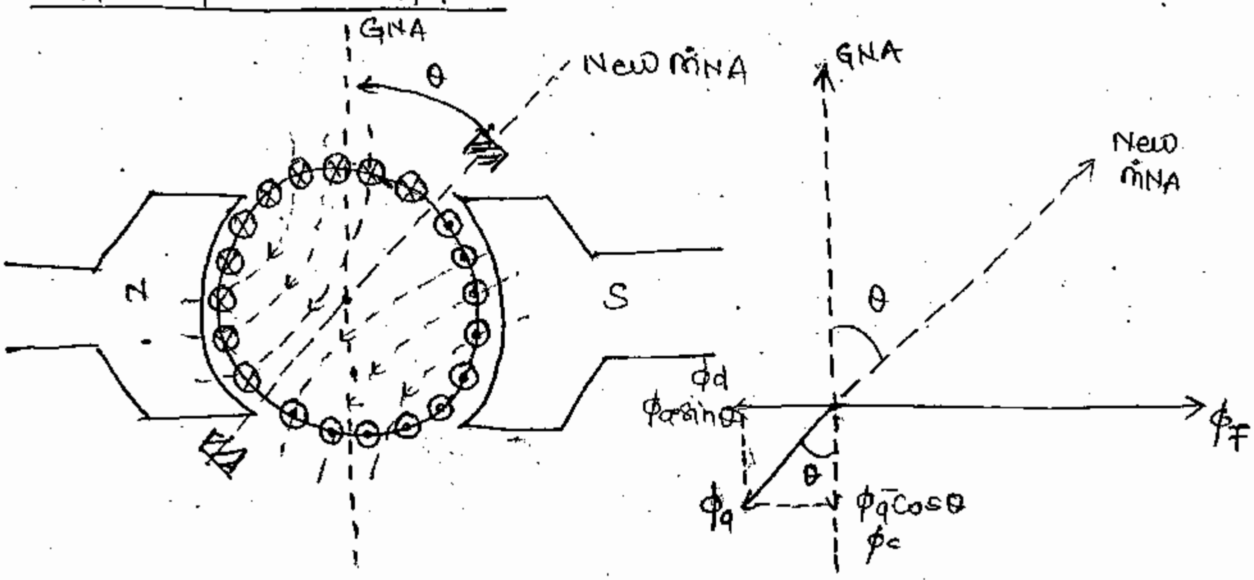


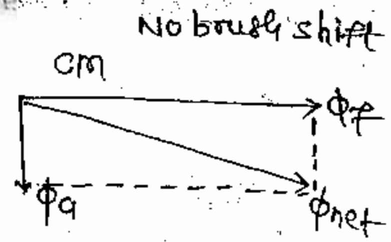
* Depanding on the dirn of rotation the pole tips are named as leading & trailing.
* The arm. flux under the trailing pole tips of genr will increase the flux density as it is in the same dirn with the main flux.
* The arm. flux under the leading pole tips will demagnetise the main flux as it is in the opposite dirn
* If the amount of magnetisation & amt of DM are equal than there is no net reduction in main flux but only distortion.
* Underpractical condn the poles get magneticaly saturated & conceguently the increase in flux density under trailing pole tips is comparitively less than that of decrease in the flux under leading pole tips.

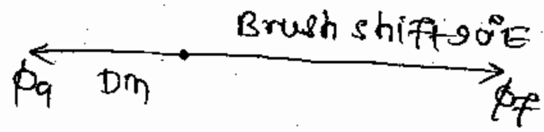


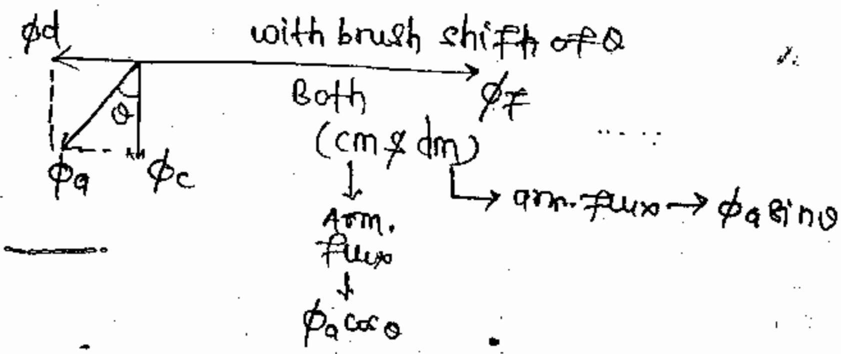
* Due to arm. flux which is also called as cross flux the main flux is distorted. known as cross magnetised due to which MNA is shifted in the dirn of rotation of genr.
* In order to improve commutation the brushes also need to be shifted in the dirn of rotation of genr.
* Due to the affect of brush shift to an angle θ there exist additional demagnetisation.
* Brush shift is not done generally. It has been replaced with interpole as it is not reliable method & also produce additional demagnetisation.

Affect of brush shift →









ϕ_c ~~=~~ $= \phi_a \cos\theta$ is cross magnetisation of arm. flux

$\phi_d = \phi_a \sin\theta$ is Demagnetisation of arm. flux

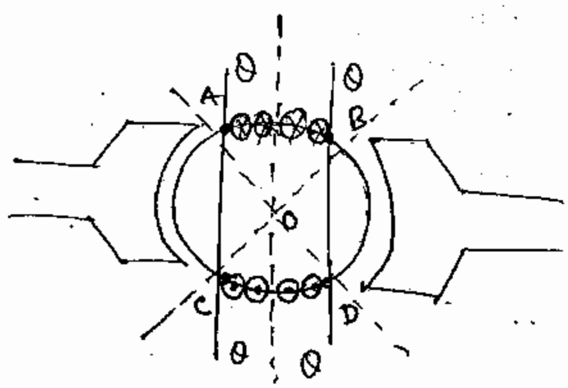
when $\theta = 0$

$\phi_d = 0$, $\phi_c = \phi_a$ (arm. flux is cm in nature)

when $\theta = 90°$

$\phi_d = \phi_a$, $\phi_c = 0°$ (arm. flux is demagnetisation in nature)

De-magnetising Amp-turns/pole AT_d/p →



$$\frac{2\theta°}{180°}$$

OAB, OCD } Dm

OAC, OBD } cm

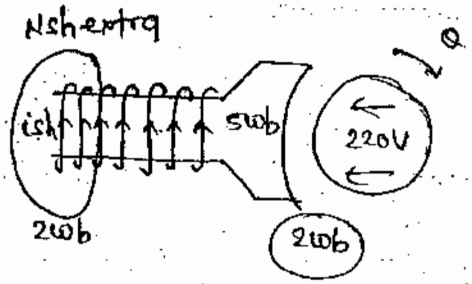
$$\boxed{\frac{2\theta°}{180°} \times \frac{I_a}{A} \times \frac{Z}{2P}}$$

Cross-magnetising Amp-turns/pole →

$$\boxed{ATc/p = \frac{180-2\theta}{180°} \times \frac{Iq}{A} \times \frac{Z}{2p}}$$

$$\boxed{\text{Total arm. mmf} = \frac{Iq}{A} \times \frac{Z}{2p}}$$

* ATd/p is representing the arm. flux which produce addiotional demagnetisation.
* In order to compensate this additional demagnetisation extra amp-turns need to be provided on each pole.



$$\boxed{Nsh\,extra \times Ish = ATd/p}$$

$$\boxed{Nsh\,extra = \frac{ATd/p}{Ish}}$$

$$\frac{AT}{A} = T$$

* The no. of extra turns to be added on each pole of shunt gen^r in order to compensate additional demagnetisation produced by the brush shift is equal to ATd/p/Ish.
* Similarly in a series gen^r $\boxed{Nse\,extra = \frac{Atd/p}{Iq\,(\text{or})\,Ise}}$

DATE - 07/07/14

* Other effects of arm. reaction →

(1) Decrease in efficiency due to increased iron loss →

The increased flux density under the pole tips will increase iron loss in the core as iron loss is directly proportional to flux density.

(2) Increased maintenance & repair →

Due to CM Commutation is not successful & there will be unacceptable sparking which damage the brush surface.

(3) Increased design cost →

* Methods to reduce armature reaction & its effects →

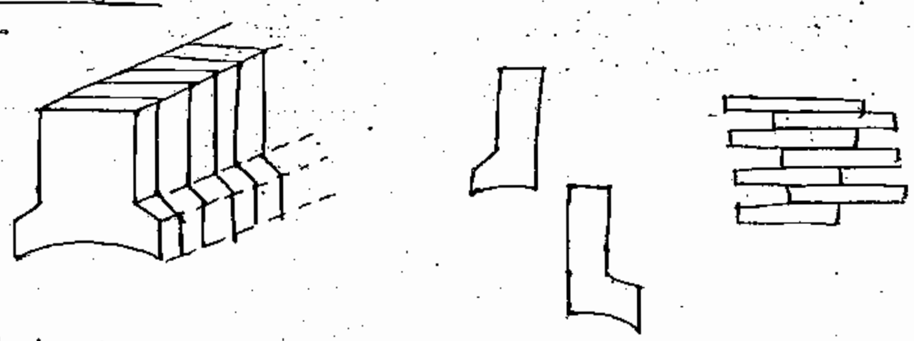
(1) Pole stacking

(2) Pole chamfering

(3) Pole core slotting

(4) ** Compensating wdg.

(1) Pole stacking →



* The pole laminations are alternately stacked to introduced air gap under the pole tips.

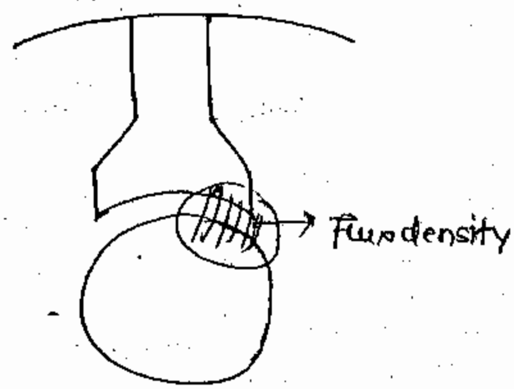
* The increased reluctance will reduce the flux density & reduce the iron loss but the net reluctance in the m/c increased which demands more mmf which increase the size & cost of m/c.

Stacking → ↑ Reluctance

② Pole chamfering →

minm reluctance at the center & increased reluctance towards the pole tips.

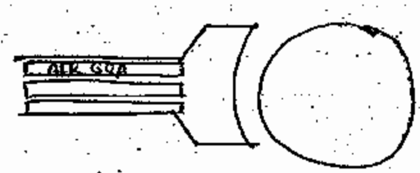
Concept is same as pole stacking.



③ Pole core slotting →

* The pole core contanin rectangular slots to introduce air gap to some part of the flux, & reduces it to some extent.

$$\boxed{\text{Flux} = \frac{\text{mmf}}{\text{Reluctance}}}$$



***

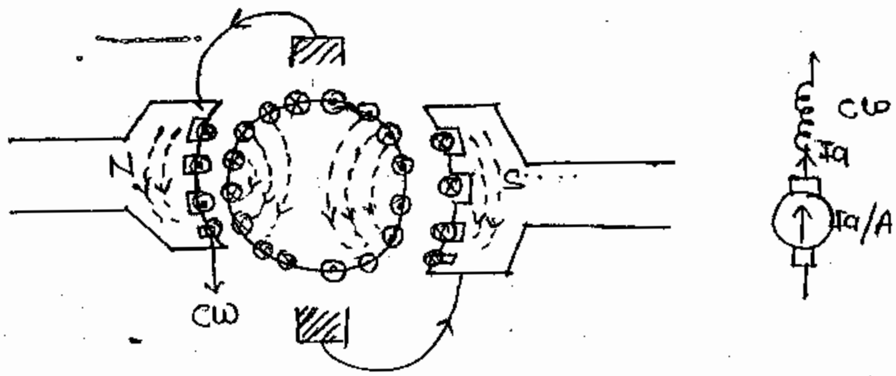
(4.) Compensating winding →

* In large rating dc m/c operating at variying load condn running at high speeds compencating wdgs are escential in order to reduce flachover on the commutator.

* As the load vary arm. current vary & produce a varying flux on the arm. links with arm. condr. & produce staticaly induced emf. which results in circulating currents which interfare with commutation & produce sparking.

* Due to high speeds if the spark spreads it will become a flash over to damage the wdg. Compensating wdg in provided in the pole shoe or pole face by cutting into teeth or slots.

* It is always connected in series with arm wdg. through brushes
* In order to automatically neutralise the arm. flux under the pole.



* The current flowing in the cw under any pole should exactly opposite dirn to the arm condr current dirn under the pole. in order to cancel out the arm. flux

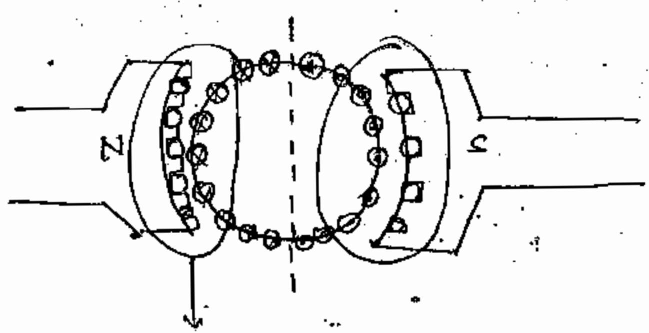
Let Z_c be cw condr, Z be A.W condr

$$I_a \cdot \frac{Z_c}{2} = \frac{I_a}{A} \cdot \frac{Z}{2}$$

$$\boxed{Z_c = Z/A}$$

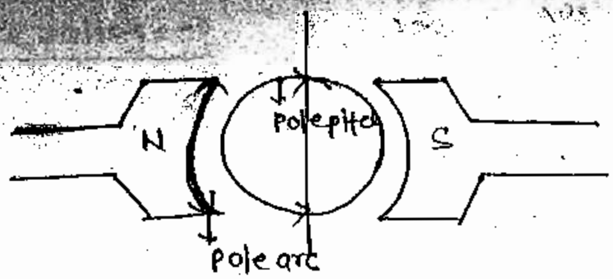
No. of compensating wdg under each pole

$$\boxed{Z_c = Z/AP}$$

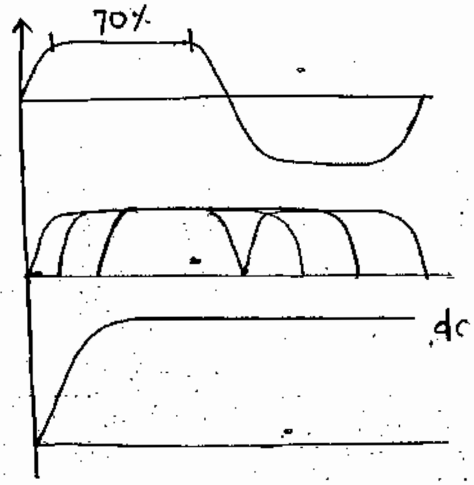


CW area.

$$\boxed{\frac{\text{Pole are}}{\text{Pole pitch}} \text{ factor} = 0.7 \text{ or } 70\%}$$



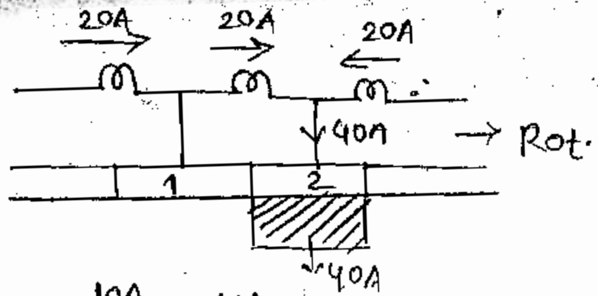
* Flux distribution under the pole in dc m/c is flat topped nature.

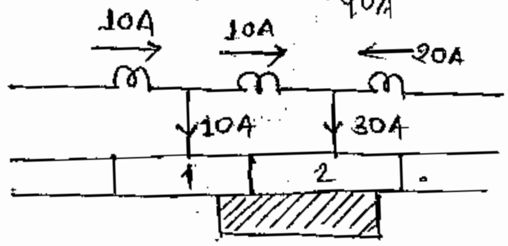


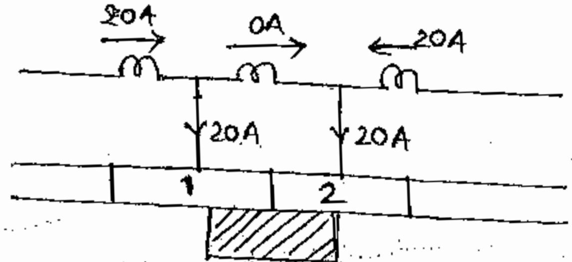
$$\boxed{Z_C = \frac{Z}{Ap} \times \frac{\text{Pole Arc}}{\text{pole pitch}}}$$

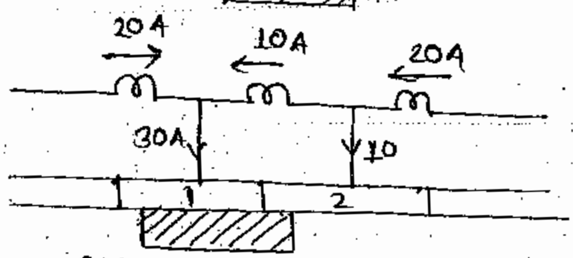
Because Z_c is placed on pole arc region thats why multiplying with pole arc/pole pitch.

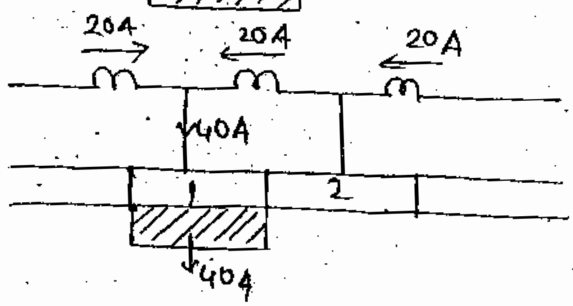
* COMMUTATION → The process of current reversal in the coil when it passes through a brush is known as commutation.
* The time taken for the brush to span from 1 segment to the other is known as commutating time.
* If the current reverses completely within the commutation time in the coil undergoing commutation then commutation is successful also called as linear, ideal or straight line commutation.
* There will be no sparking at the brush.
* If the current doesn't reverse completely within the commutating time in the coil undergoing commutation there will be sparking at the brush & the commutation is unsuccessful known as delayed commutation or non-linear.

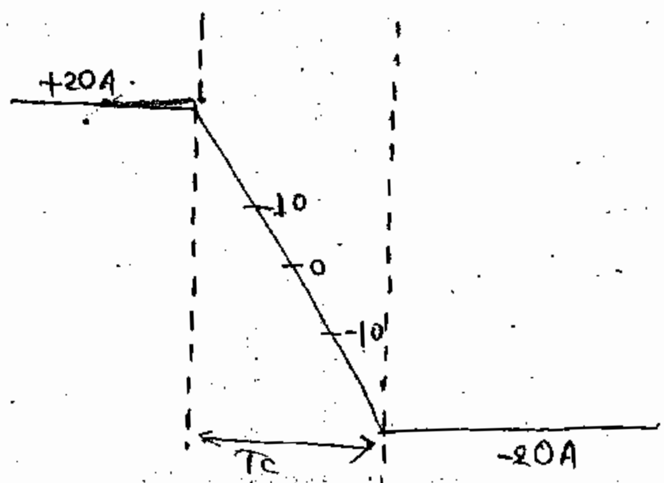

20A
20A
20A
40A
→ Rot.
1
2
40A


10A
10A
20A
10A
30A
1
2


20A
0A
20A
20A
20A
1
2


20A
10A
20A
30A
10
1
2

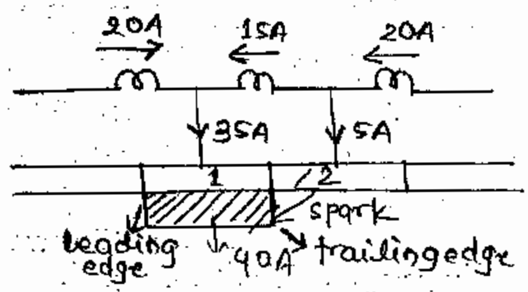

20A
20A
20A
40A
1
2
40A


+20A
10
0
-10
Tc
-20A

Reactance voltage →

$$e_r = N\frac{d\phi}{dt} = \underbrace{L}_{L_{self}}\frac{\overbrace{di}^{2I}}{\underbrace{dt}_{T_c}}$$

* In the coil undergoing commutation there is a total change of current from I_a/A to $-I_a/A$ within commutating time T_c which produce the reactance voltage due to self inductance property of the coil.
* According to Lenz law it will oppose the cause i.e. change in current. Therfore by the end of commutating time T_c the current will not be reversed completely.



* Any unchanged current by the end of commutating time will jumped into the brush through spark at the trailing edge of brush.

* Methods to improve Commutation →

(1.) Resistance Commutation

(2.) Voltage Commutation → Brush shift, * Interpole

① Resistance commutation →

* Replacing low resistance Cu brush with high resistance C brush to improve Commutation by reducing the chances of sparking to some extent.
* C brushes have high resistance compare to Cu.
* Due to its high resistance C brush doesn't incourage sparking at trailing edge & improve commutation.

* The added ad. of c brush are:-

(1) It is not hard material as cu.

(2) It is self lubricating (polishing) in nature which offers good mech. condn with the comm. surface.

(3) If any spark occurs it will gets less damaged than cu.

disad. →

① more brush contact drop.

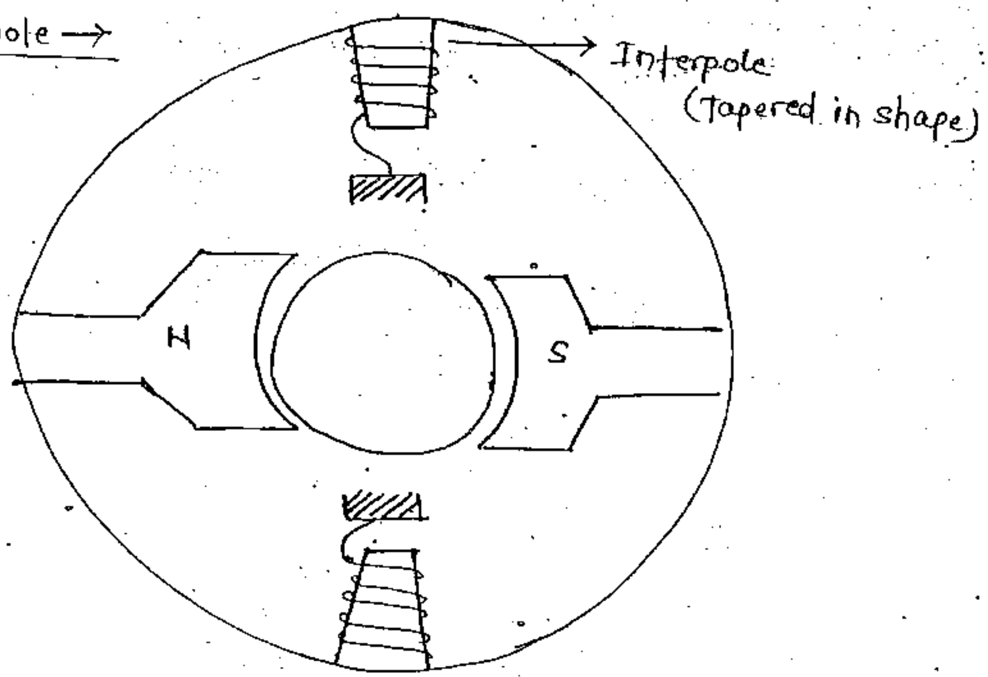
② Low current density, requires larger brush.

* Brush shift → * It is the 1st method of improving comm. which is complecated & not reliable because MNA changes with loads contineously & after the design brushes can't be changed.

* Due to brush shifting there is addiotional DM.

* It is not ~~turn~~ done after the invention of interpole.

* Interpole →



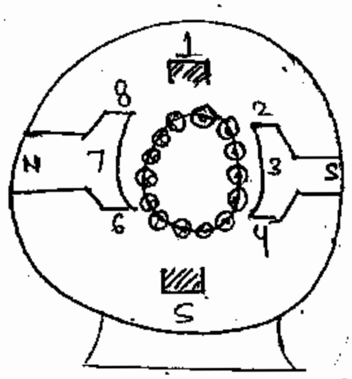
* Interpoles are small poles compare to main ploes placed in the inter polar region between the main poles on the yoke.
* These are also electromagnets with interpole wdg which is connected in series with arm. wdg through brushes in order to have automatic neutralisation of arm. flux in the interpolar region.
* It performs 2 funⁿ:-

(1) Produce a counter flux on the coil undergoing commutation to nullyfy the <u>reactance voltage</u> (2) It also remove the inequality in the flux densities on the top & bottom region of arm.

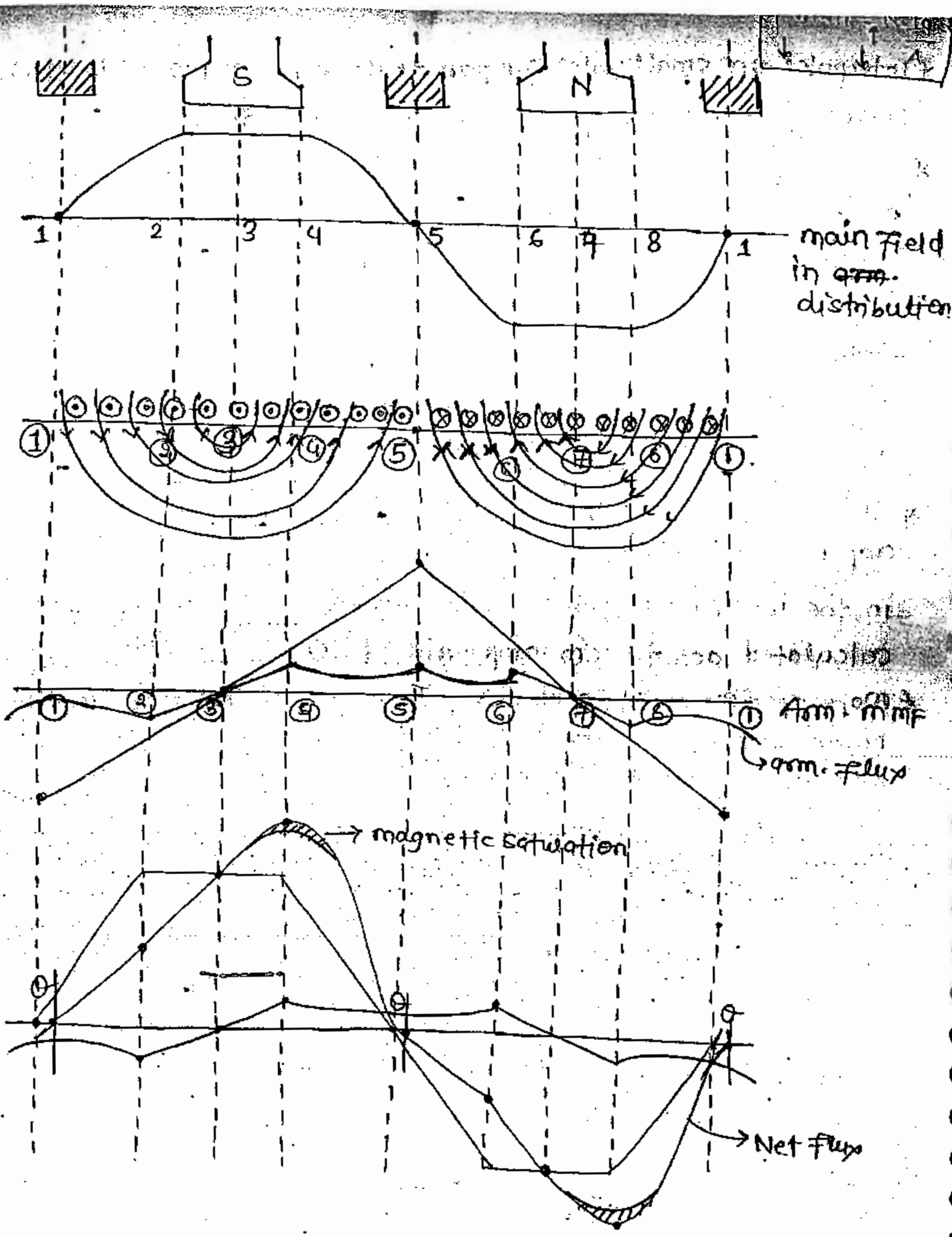
* The interpoles are tapered in shape with comparetively more air gap in order to avoid easy saturation as the load current flows in the interpole wdg. The no. of turns on the interpole are calculated acc. to cw amp turns / pole.
* More specificaly it is the amp turns in ~~th~~ of arm. in the inter-polar region. & some additional turns are also required in order to produce reactance voltage.

CW → Reduces arm. reaction
IPW → Improve Commutation

Interpole are directly improve comm. & cw indirectly improve comm.



	turns (or) mmf	
1-3	↓	-ve
3-5	↑	+ve
5-7	↓	+ve
7-1	↑	-ve
3-1	↑	-ve


S
N
main field in arm. distribution
Arm. mmf
arm. flux
magnetic saturation
Net flux

(Reluctance)

* In the m/c if air gap is uniform then the arm. mmF & arm. flux follow the same shape but magnitude may vary.

$$\boxed{\text{Armature flux} = \frac{\text{Arm. mmF}}{\text{Reluctance(Air gap)}}}$$

	Reluctance	
1-2	↓	-ve
2-3	↓ min^m	-ve
3-4	↑	+ve
4-5	↑ max^m	+ve
5-6	↓	+ve
6-7	↓ min^m	+ve
7-8	↑	-ve
8-1	↑ max^m	-ve

* For drawing arm. flux arm. ~~flux~~ mmF is taken as ref.

(1.) main field flux distribution is having flat topped shape. or trapezoidal.

(2.) Arm. mmF is triangular in shape increasing or directed towards the brush axis.

(3.) Net flux due to arm. reaction is having peaky (If not given peaky then Δ)

(4.) Arm. flux is saddle shape (If not given then prefer Δ).

*** The main flux & arm. flux are always 90°E wrt each other (quadrature or ⊥)/ orthogonal.

* Without arm. flux the main flux is exactly 0 along GNA.

* with arm. flux the neutral (MNA) has been shifted in the dirn of rotation of genr. ~~to/motor~~

* To improve comm. the brushes need to be given a forward shift.

* The arm. flux stationary wrt poles.

62/12

$$\frac{I_a}{A} = \frac{50}{6} \times \cancel{\frac{720}{2\times 6}} \qquad AT/P$$

$$\cancel{\frac{I_a}{A}} \qquad T = \frac{720}{2}$$

$$P = 6$$

$$AT/P = \frac{50}{6} \times \frac{720}{2 \times 6} = 600\,AT$$

* Factors affecting terminal voltage of dc generator →

* When the genʳ is on NL the NL induced emf is E_0. When it is loaded there is voltage drop due to arm. reaction demagnetisation.

$$E_0 - E_g = \text{Arm. reaction drop.}$$

* Due to arm. resistance there will be arm. resistance drop $I_a R_a$.
* These drops are proportional to load.
* In a seprately excited generator there are only above two drops effecting the terminal voltage.
* In a shunt genʳ its excitation is the terminal vol. Therefore reduction in V in turn reduces the terminal vol. itself.
* This will be a cumulative effect when the genʳ is loaded beyond its rated value known as break down point.

* Characterstics →

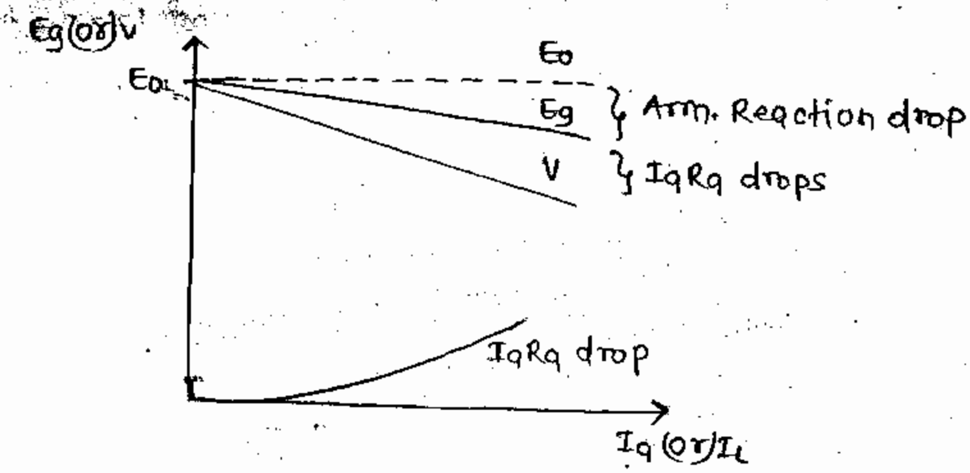
* This are the graphical representation of the key parameters which are plotted to know the suitability of applⁿ.

→ No load → E_0 Vs I_f

→ load → Internal (E_g Vs I_a)

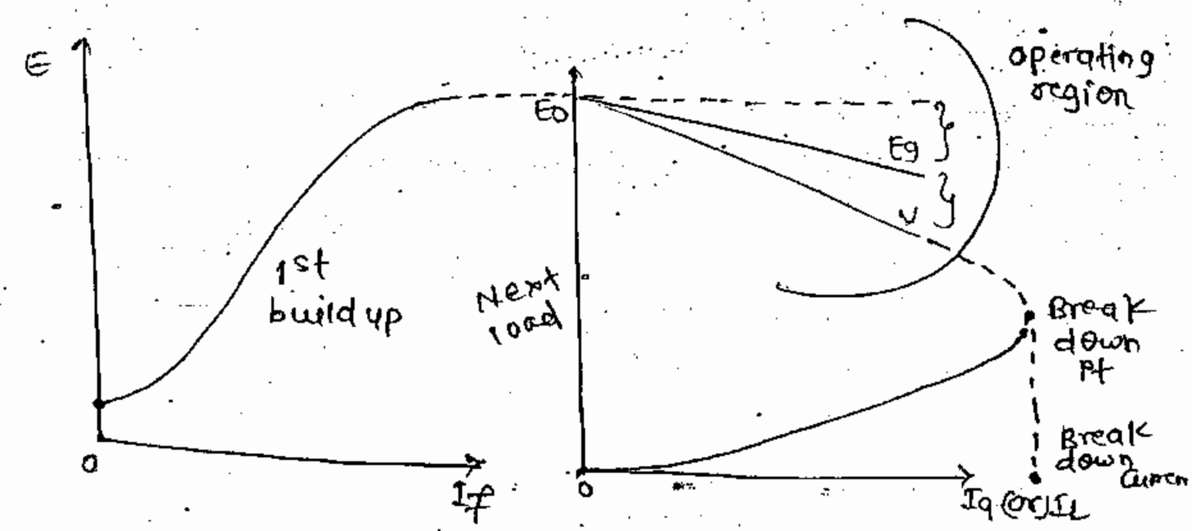
→ External (V Vs I_L)

* separately excited genʳ →



* This are not commertialy used for normal power supply because it requires addiotional dc vol. source
* It was used in excitation sys. of power plant genʳ.
* Dc supplies in air crafts /ships.
* Used in a speed control method known as ward-leonard method.

* Shunt genʳ →

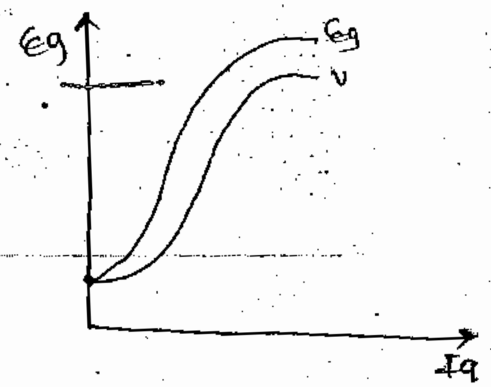


* In its operating region its flux remains approx. same, but beyond break down value a cumulative reduction of vol. happen reduce the terminal vol. 0 drasticaly.

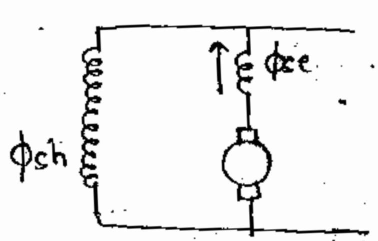
* Generaly the operating region will be around 125% of rated load.
* It is used as small dc power supply & exclusively used for battery charging.
* It was also used in excitation sys. of power plant genr. along with seprately excited genr.

* Series Genr →

* As the field wdg is in series with arm. & load as the load increases flux increases to inturn increase the voltage. Therefore in its operating region it has rising vol. o/s also called as variable vol. genr. not suitable for ordinary power supplies but used as boosters in long feeders. perticularly in dc distribution sys.

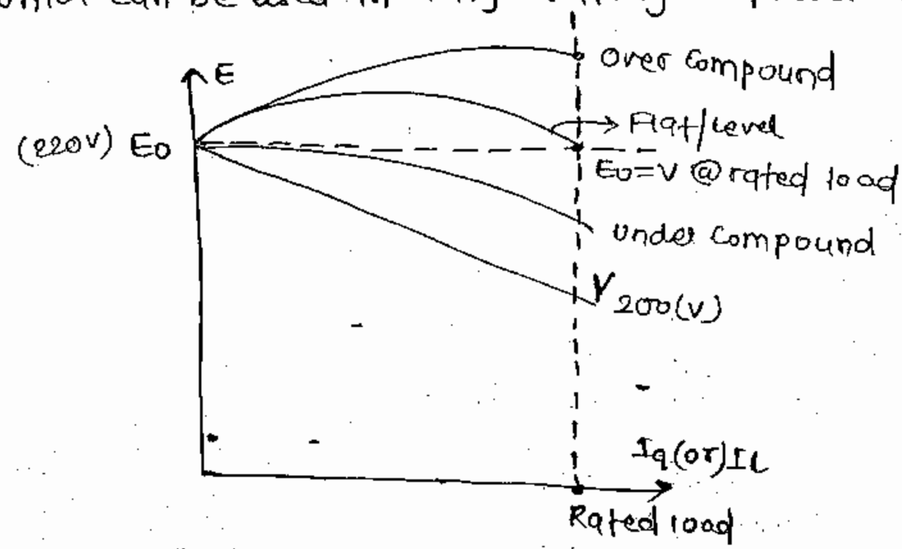


Cumulative →

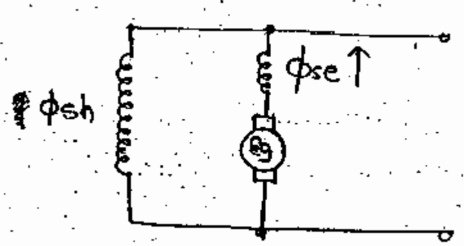


* As the series flux add its shunt flux the net flux increases with load. Conceqeuntly it has better vol. o/s. then seprately & shunt genr.

* It can be compounded to adjust its terminal voltage.
Therefore it is widely manufactured dc genr due to its flexible c/s which can be used in large rating dc power supplies.

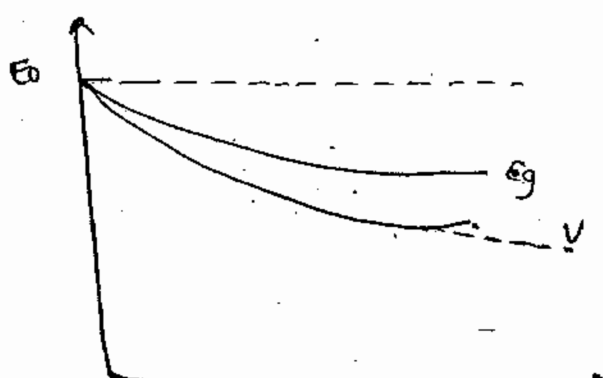


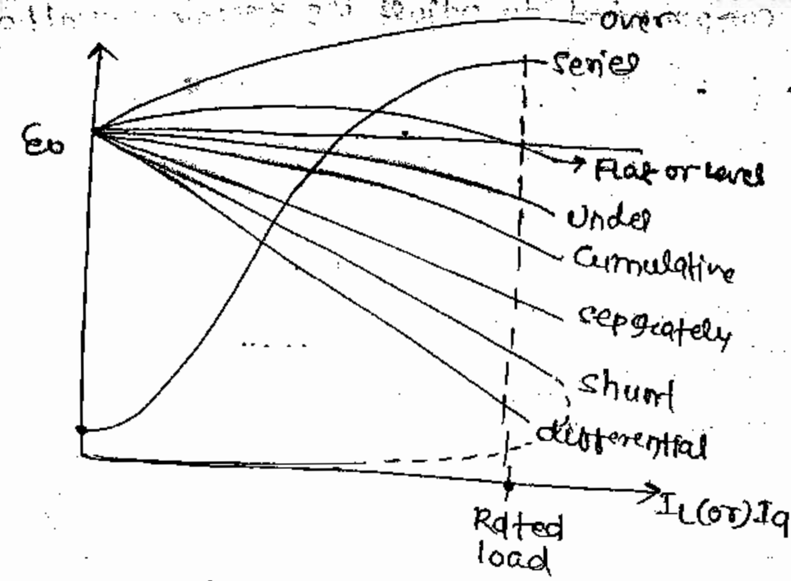
Differentialy →



* Arc weldings

* The net flux decreases with load to decrease the terminal vol. This is not use for ordinary power supply but specifically used in welding purposes to limit the welding currents.





Voltage Regulation → * It is the change in terminal vol. when the full or rated load across the terminal is disconnected. keeping the flux & speed constant.

$$\boxed{\% VR = \frac{E-V}{V}}$$

E → NL induced vol.

V → Rated terminal vol. @ rated load

* VR is % drop in the m/c.

$$\boxed{VR = \frac{V_{drop}}{V}}$$ V_{drop} ↓ as possible

* It should be as min^m as possible, best/ideal value is 0. which happens for only flat/level compound gen^r.
* For series & over compound VR becomes -ve. not suitable for ordinary load purpose.

DATE - 08/07/14

* PARALLEL OPERATION →

operating genʳ in parallel across the common terminals known as bus bars provide the following ad. :-

(1.) High ele inertia across the busbars (constant voltage sys.)

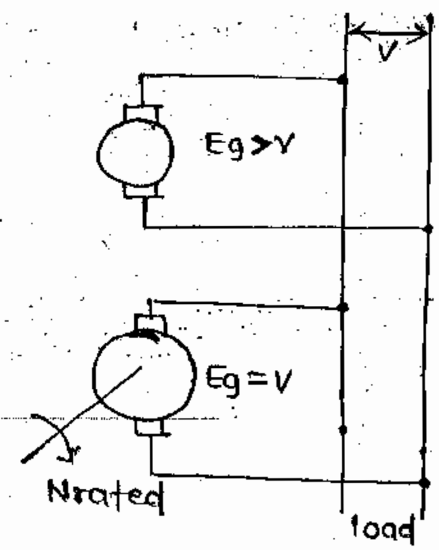
(2.) High reliability.

(3.) Efficiency. (η)

(4.) Future expansion.

(5.) Continuety of supply during maintanence & repairs.

Due to this reasons universaly the genʳ in the power plants & all the power plants are operating in parallel to form a grid st.



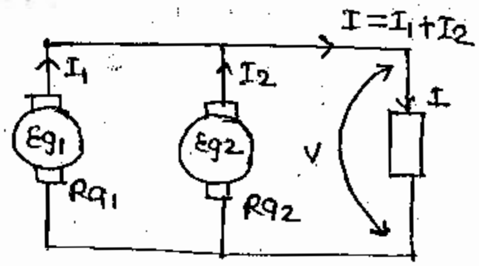
Eg > V	Generating mode
Eg = V	Floating mode
Eg < V	motoring mode

* In order to connect 2 dc genʳ in parallel it requires 2 essential condⁿ :-

(1.) Terminal vol. should be same.

(2.) Palarity should be matched.

* Consider 2 dc genʳ operating in parallel at a common terminal vol. V & sharing a common load with induced emfs E_{g1}, E_{g2} respectively.



$Eg_1 - I_1 Ra_1 = V$

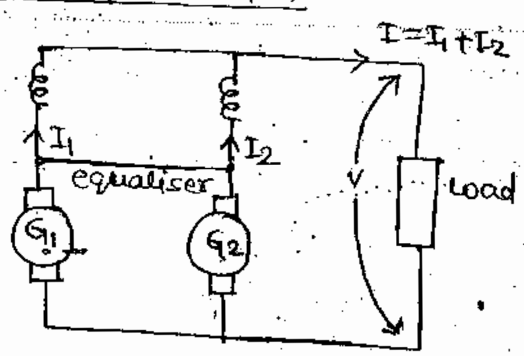
$Eg_2 - I_2 Ra_2 = V$

$$\boxed{I_1 = \frac{Eg_1 - V}{Ra_1}} \quad \boxed{I_2 = \frac{Eg_2 - V}{Ra_2}}$$

** The load sharing of genr operating in parallel is significantly depanding on induced emf (directionaly praportional)

* In order to have stable or proper parallel operation the voltage c/s should be slightly drooping in nature but not rising.

* series genr in parallel →



$I_2 \uparrow$ $\phi se_2 \uparrow$ $Eg_2 \uparrow$ (gain load sharing capability)

$I_1 \downarrow$ $Eg_1 \downarrow$ (It goes in motoring mode)

* If we connect an equaliser with the both series genr then only it operate in parallel.

* If any one genr share more load the increase in its current will increased its flux & induced emf.

* Concequently its load sharing capability will increase in a cumulative manner & that genr gets overloaded leaving the other.

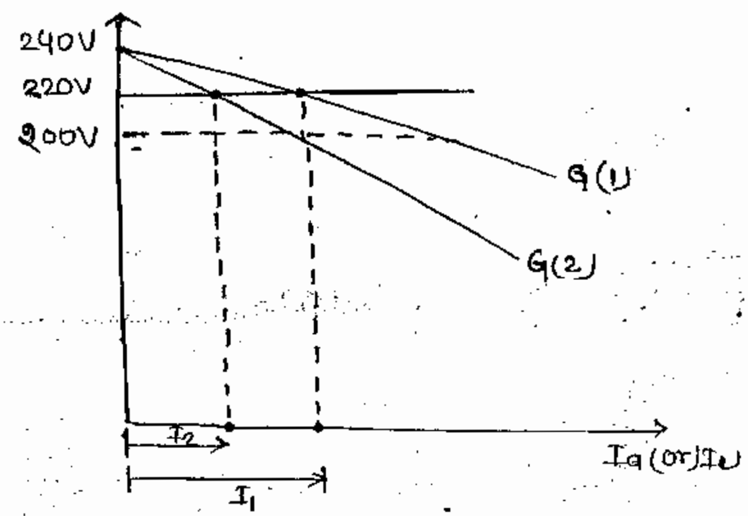
* This is due to the rising c/s of series genr.

* In order to make them in parallel an equaliser is required.

* The increased current will bypass into both field wdg to increase there flux & induced emf equaly.

* Equalisers are required for cumulative compound genʳ also.

* Shunt genʳ in parallel →



* Shunt genʳ are best suitable for parallel operation due to there drooping c/s.
* The genʳ which is more drooping will share less load (viceversa)
* By adjusting the c/s the genʳ can be loaded according to there ratings.