- DC generator:
- DC motor:
- **Working principle of a generator:**
- Function of dc generator:
- **Principle**: Electromagnetic induction
- **Direction of induced emf**: Fleming's right hand rule

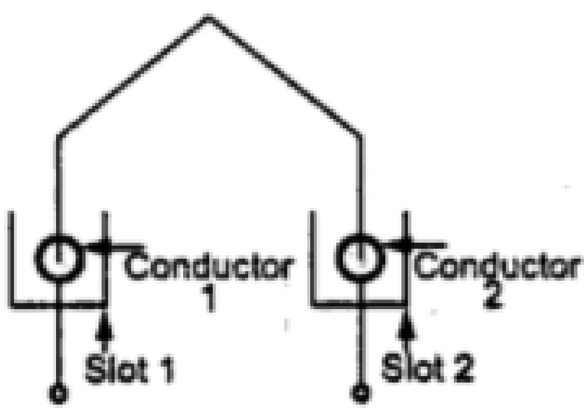
Armature winding:

Armature winding is an arrangement of placing of conductors in the armature slots to develop desired e.m.f by the relative motion of conductors into **field system**, consisting of numbers of magnetic poles in an alternatively **North** and **South** poles in a system.

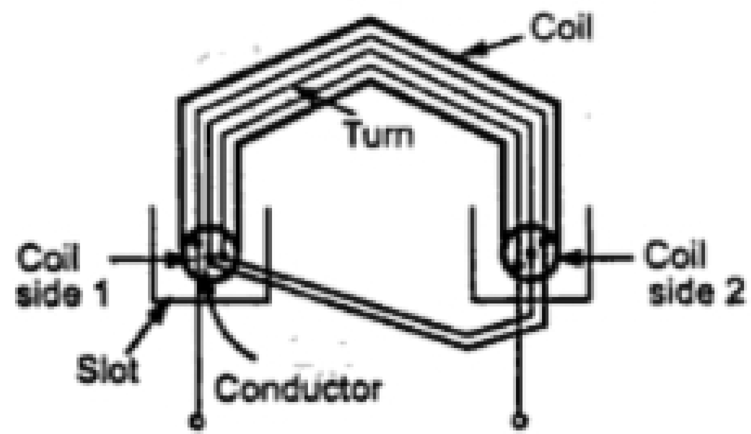
In winding, conductors or group of conductors are distributed in different ways in slots all over the periphery of the armature.

- The armature conductors may be connected in parallel (lap winding) or in series (wave winding) depending upon the current and voltage ratings of the machine.
- **Armature Winding terminology**
- **Conductor:**
- Each individual length of wire placed in the armature slots lying within the magnetic field is called conductor.

- **Turn** : A conductor in one slot, when connected to a conductor in another slot forms a turn. So two conductors constitute a turn.
- **Coil** : As there are number of turns, for simplicity **the number of turns are grouped together to form a coil.**
- Such a coil is called multi-turn coil side : Coil consists of many turns. Part of the coil in each slot is called coil side of a coil



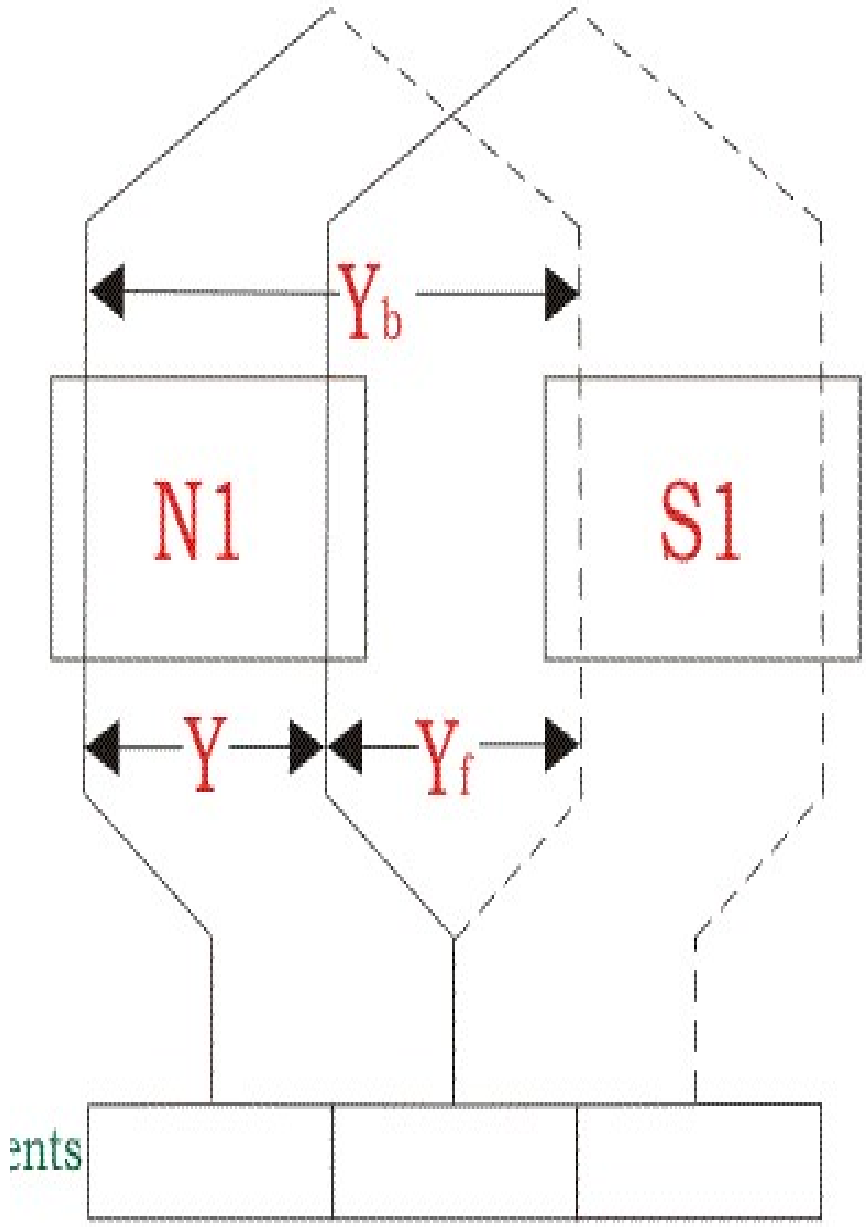
(a)Turn



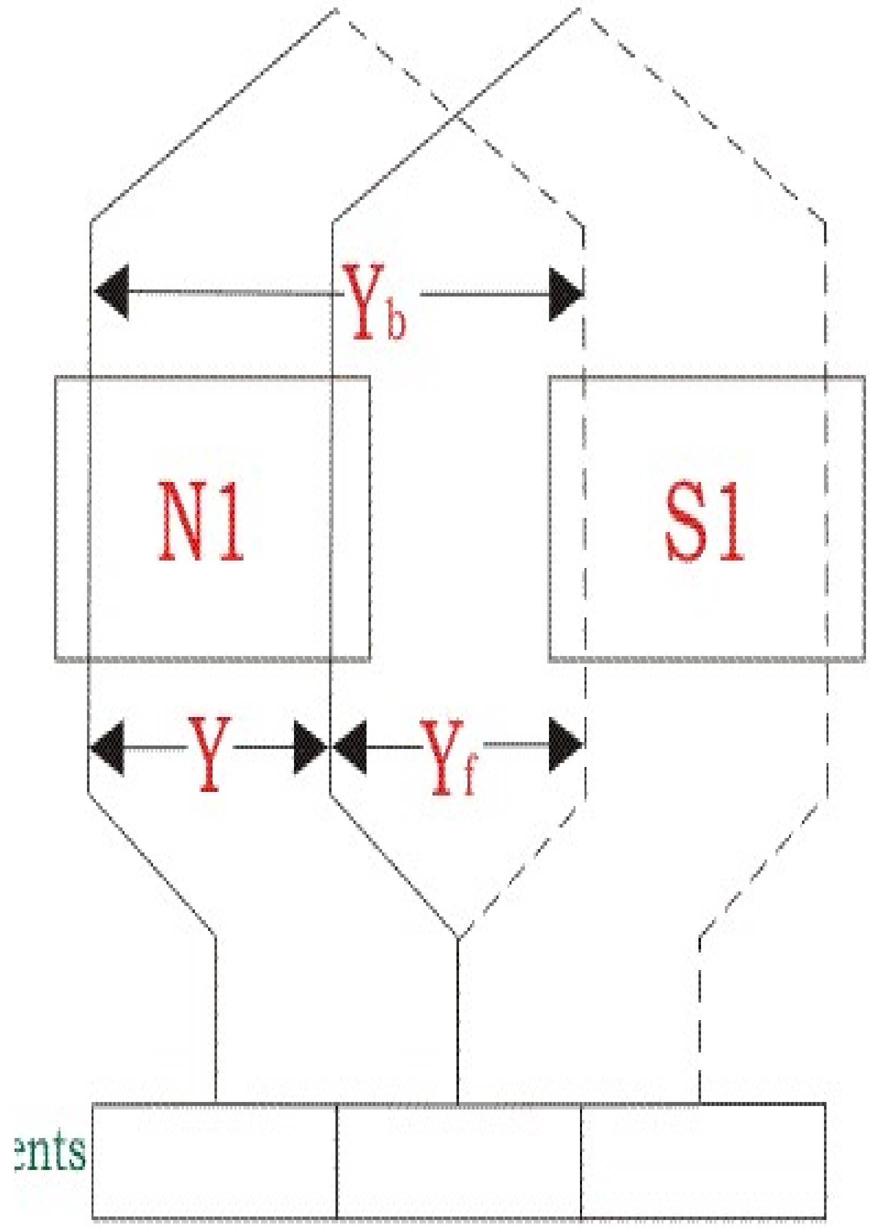
(b)Multiturn coil

- **Pole Pitch** : It is centre to centre distance between the two adjacent poles.
- **Pole pitch**= No. of slots or coils sides/ No. of poles
- **Slot angle** (β) : The phase difference contributed by one slot in degrees electrical is called slot angle β.

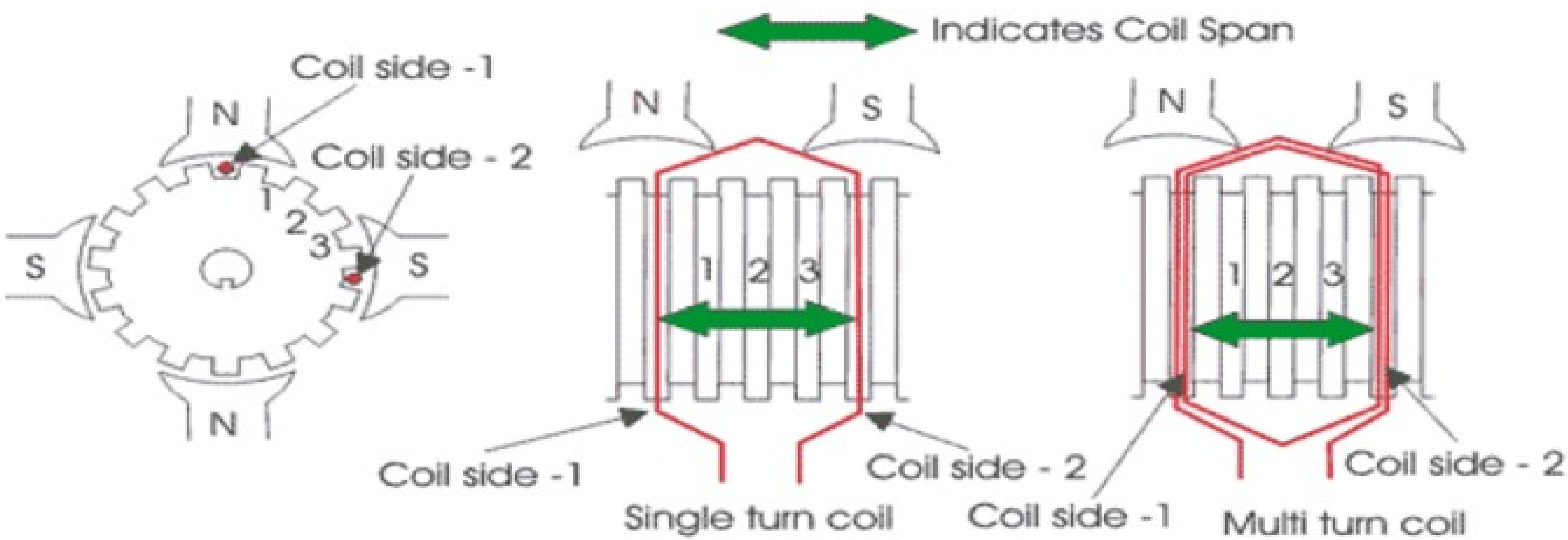
- **Back Pitch (Y_b)**
- A coil advances on the back of the armature. This advancement is measured in terms of armature conductors and is called **back pitch**. It is equal to the number difference of the conductor connected to a given segment of the commutator.



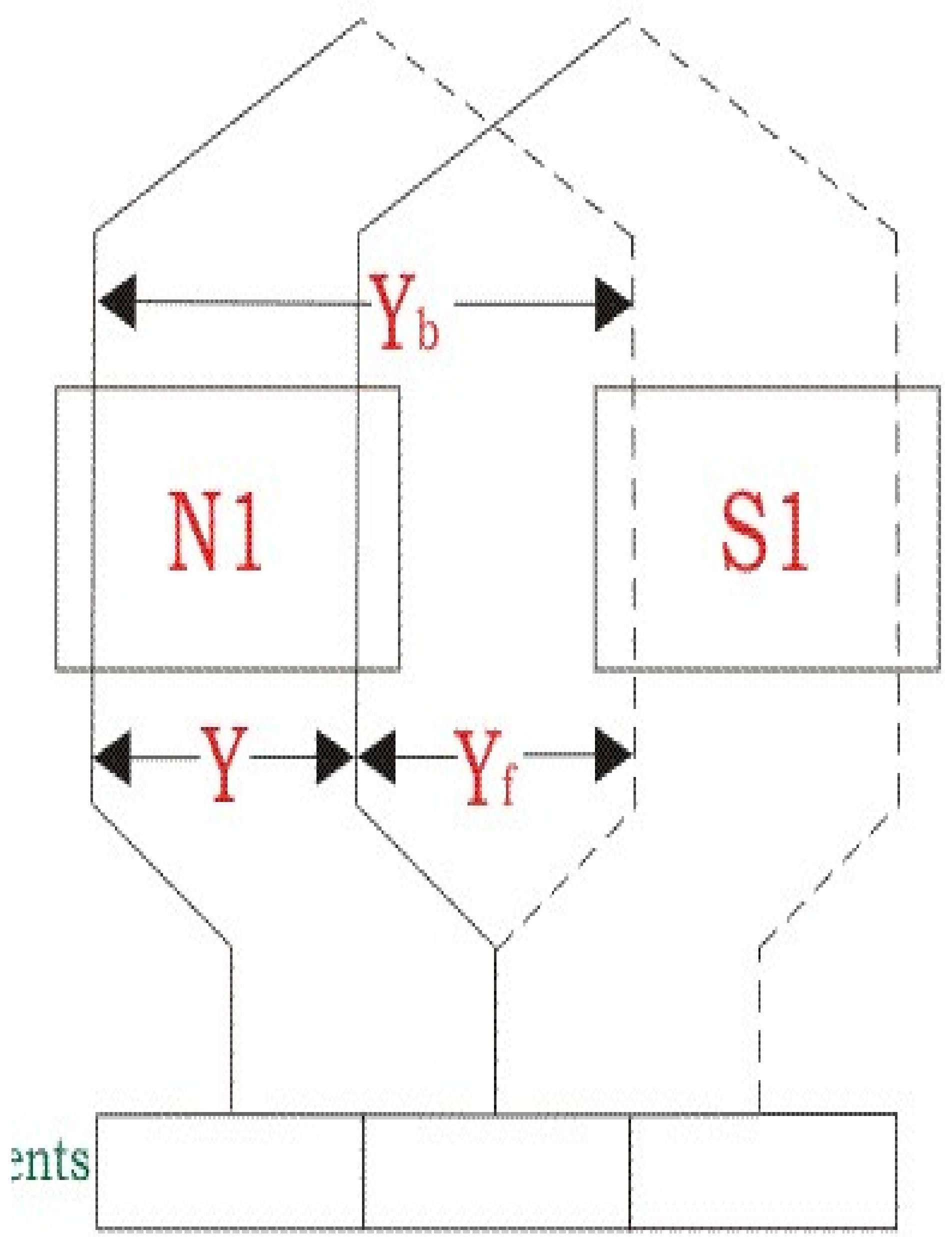
- **Front Pitch (Y_f)**
- The number of armature conductors or elements spanned by a coil on the front is called **front pitch**.
- **Resultant Pitch (Y)**
- It is the distance between the beginning of one coil and the beginning of the next coil to which it is connected.



- **Coil span** is defined as peripheral distance between two sides of a coil, measured in terms of number of armature slots between them.
- That means, after placing one side of the coil in a particular slot, after how many conjugative slots, the other side of the same coil is placed on the armature. This number is known as **coil span**.

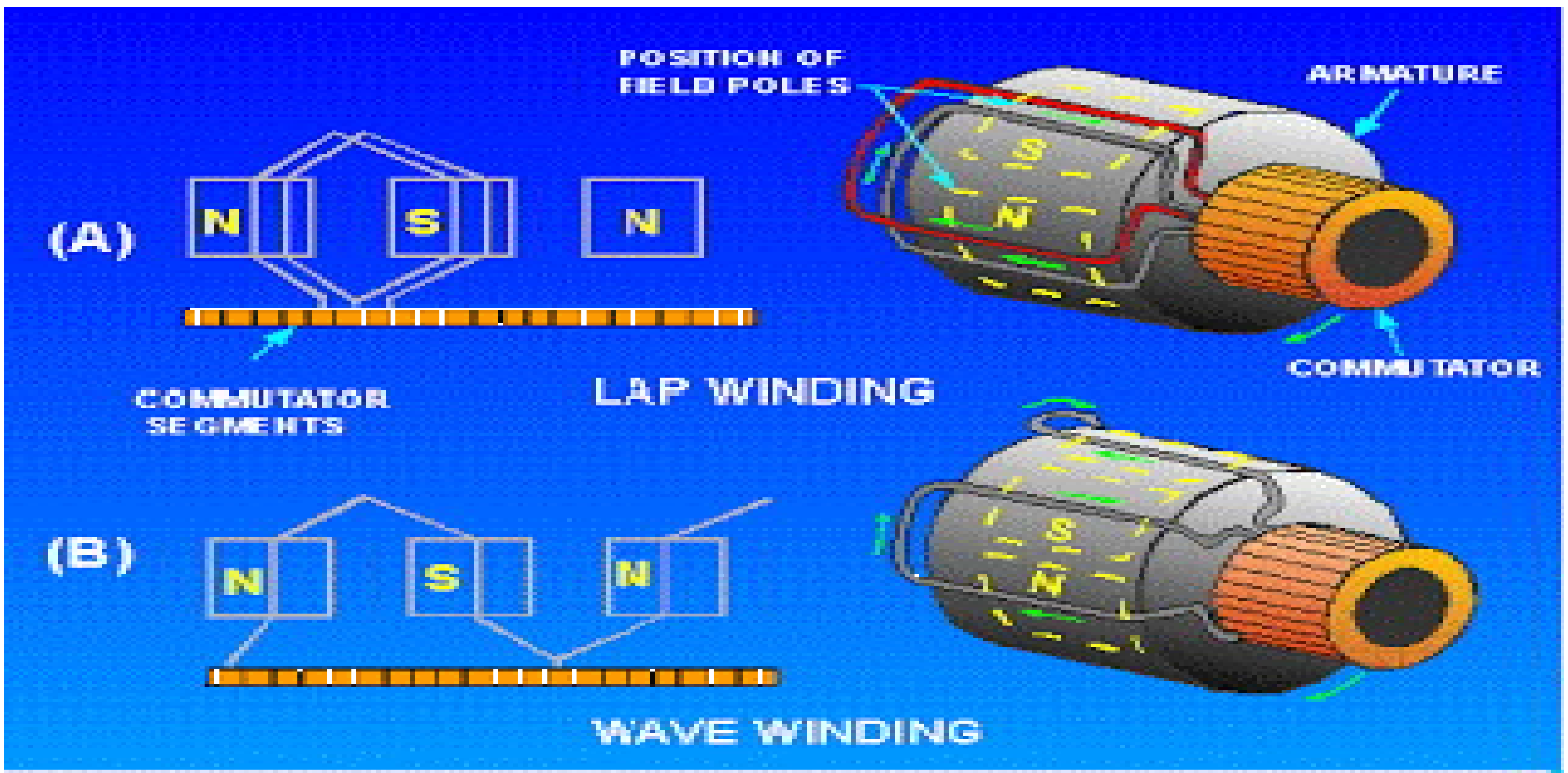


- **Commutator Pitch**
- **Commutator pitch** is defined as the distance between two commutator segments which two ends of same armature coil are connected. Commutator pitch is measured in terms of commutator bars or segment.



Lap winding:

- The winding is called LAP winding if finish end of one coil is connected through the commutator to the starting end of the second coil under same pole.



Feature of lap winding are as follows:

- Back pitch Yb and front pitch Yf both are odd numbers and their values are not equal to 2 or multiple of 2.
- Average pitch Ya= Yb+Yf/2 and should be equal o the pole pitch.
- Yb=Yf±2Yc
- If the value of Yb is more than Yf, winding is of progressive type and winding proceed in the right hand side in the clockwise direction.

- If the value of Yb is less than Yf, winding is of retrogressive type and winding proceed in the left hand side in the anti-clockwise direction.
- For simplex lap winding, Yf=1 so Yb= Yf±2 or Yb-Yf=±2
- Resultant pitch is the difference between the Yb and Yf and it is the even number so the resultant pitch is always even number.
- For double layer winding, the number of slots becomes equal to the number of coil i.e it becomes half the number of coils sides.

- Number of commutator segments also becomes equal to the number of coil.
- Number of parallel paths of conductors in armature=mP,

where, m is the multiplexity of the winding.

For the simplex lap winding, value of m is 1.

So the number of parallel paths becomes equal to the number of poles.

- For progressive winding: Yf= Z/P-1 and Y= Z/P+1
- For the retrogressive winding, Yf= Z/P+1 and

  Yb= Z/P-1

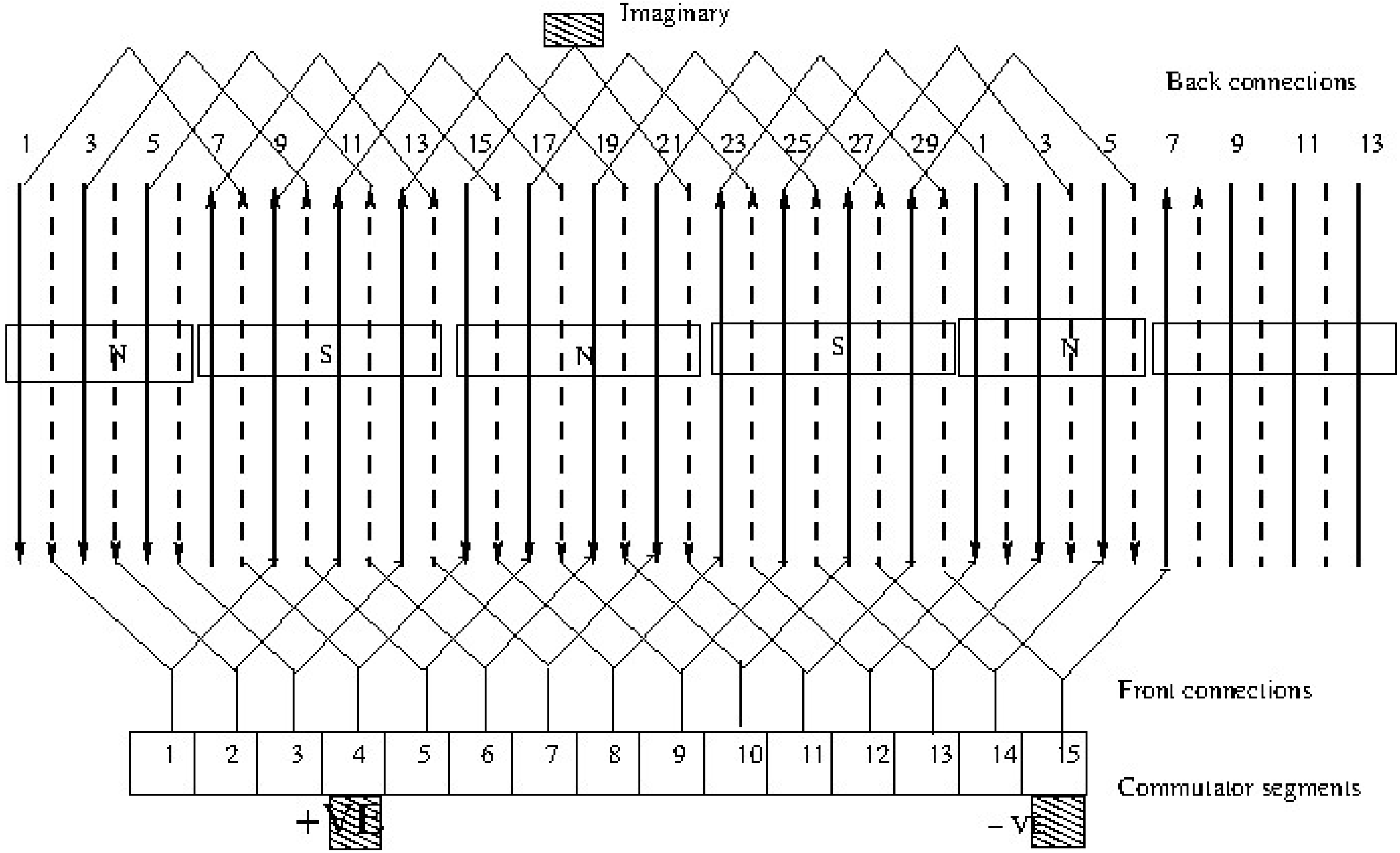
Wave winding:

- In wave winding, one coil side is placed under one pole and another coils side placed under the next pole and proceeded further. The shape of the winding is like wave, the winding is called the wave winding.

Feature of wave winding:

- Both the front pitch Yf and Yb are the odd numbers.
- Resultant pitch = Yr= Yb+Yf
- Average pitch Ya= Yb+Yf/2 and it should be equal to the pole pitch (Z/P)
- Commutator pitch= Yc= Ya
- Number of coils Nc= PY±2/2

- $Nc \times 2 = \pm 2$ thus the number of conductors is equal to 2 less or 2 more than the multiple of number of poles. So the wave winding is not possible for all the even number of conductor.


Imaginary
Back connections
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 1 3 5 7 9 11 13
N
S
N
S
N
Front connections
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Commutator segments
+VL
– V

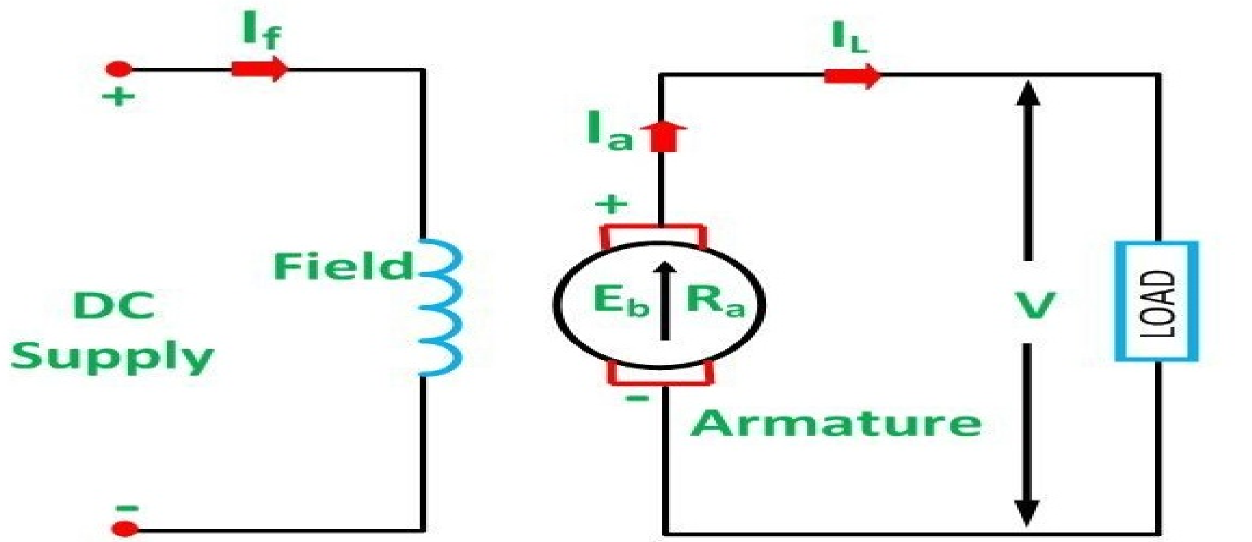
- **Dummy coil or Idle coils:**
- Problem arises in wave winding.
- Mechanical unbalancing,
- Dummy coils are used to achieve mechanical balancing of the armature in such situation.
- Dummy coils are placed in the vacant slots.
- Dummy coils are not connected to the commutator segment but these are shortened and tape is wound over them.
- There is not change in the electrical characteristics of the winding but the mechanical balancing is maintained.

- **Types of DC generator:**
- DC generator classified according to the way in which the fields are excited.
- **Separated excited**
- **Self excited.**
- The process of producing magnetic field in a system is known as excitation.

OR

- The process of passing current through a coil in order to produced a magnetic field is called excitation.

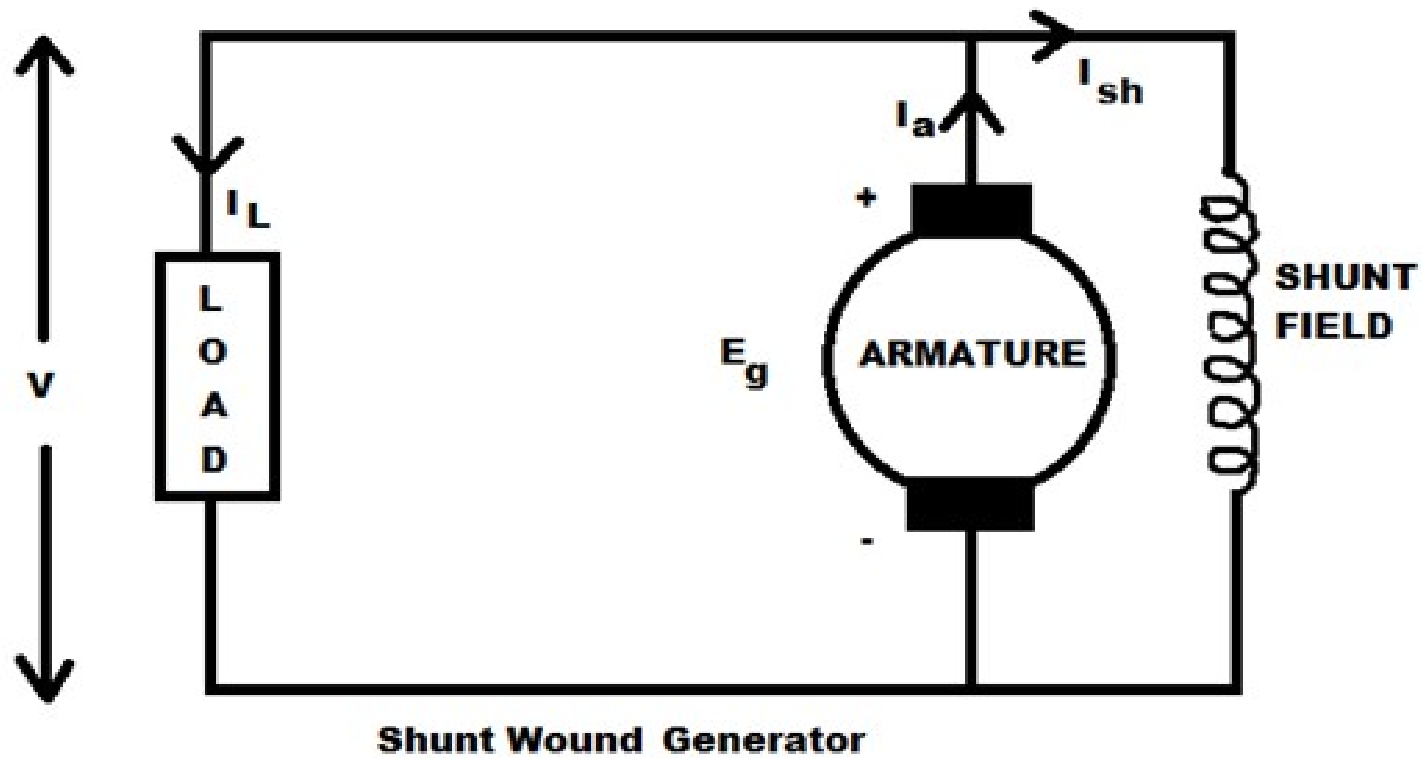
- **Separated excited**
- A d.c generator whose field winding is supplied current from an external d.c source e.g battery is called a separately excited d.c generator.



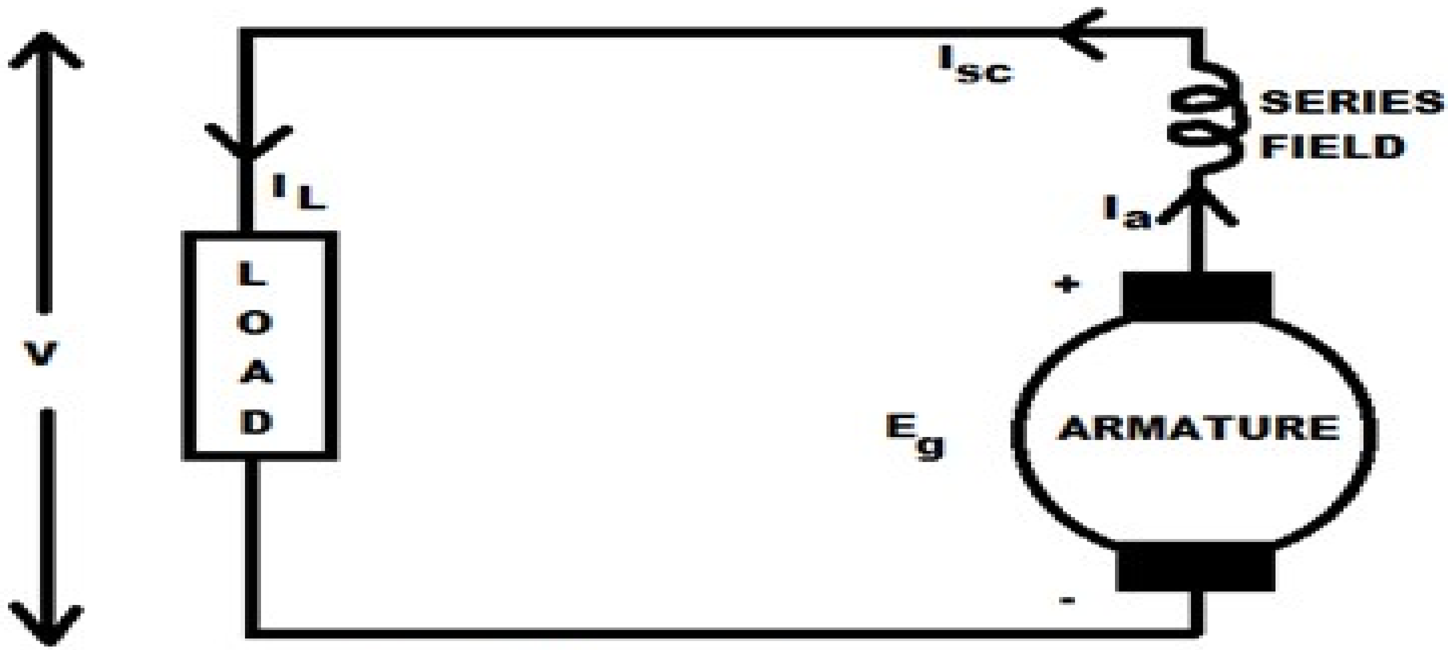
- The circuit shows that field current is independent of load and terminal voltage.
- This types of generators are rarely used in practice.

- **Self excited.**
- A DC generator whose field is supplied current by the generator itself is called a self excited d.c generator.
- Depending upon the field winding connected to the armature, the self-excited generators can be classified as:
- DC shunt generator
- DC series generator
- DC compound generator.
- **Compound Generators can be classified into two ways**:
- Short shunt and long shunt type compound generator
- Cumulative and differential type compound generator.

- **DC shunt generator**
- When the field winding is connected in parallel with the armature winding, the generator is called shunt generator.



- **DC series generator**
- When the field winding is connected in series with armature winding the generator is called as series winding



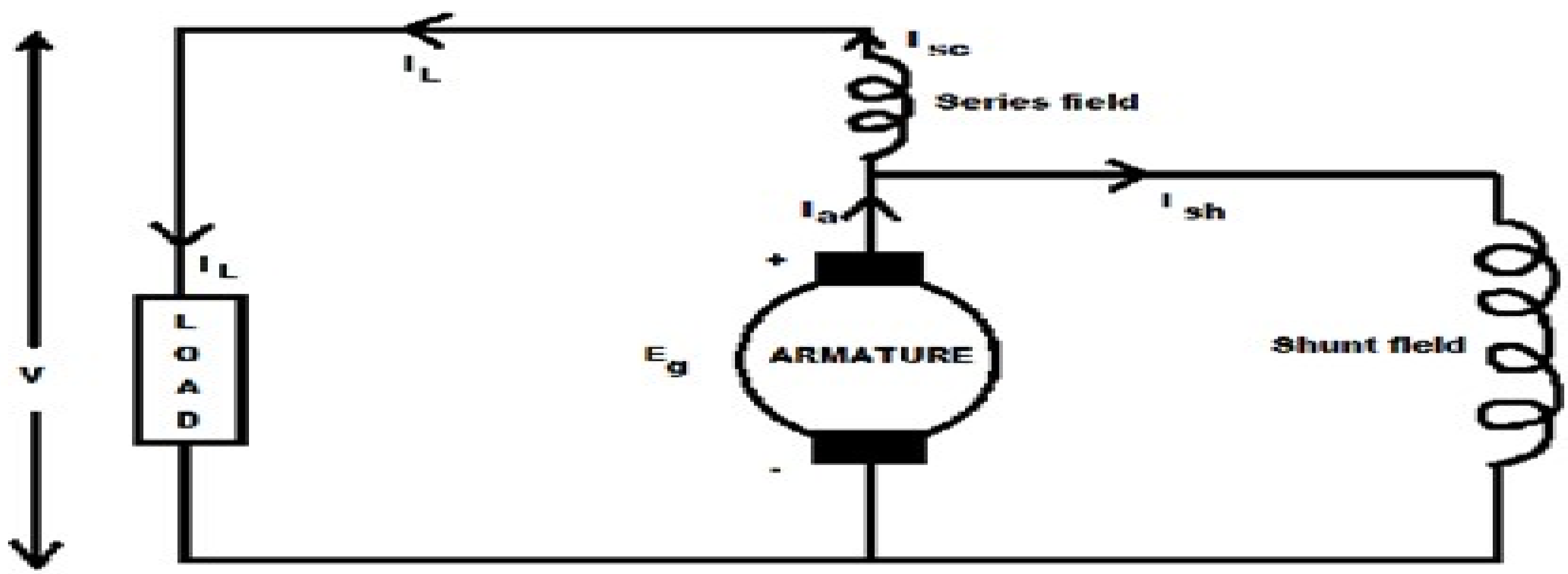
Series Wound Generator

- **DC compound generator.**
- In this type of machine both series and shunt field windings are connected to armature.

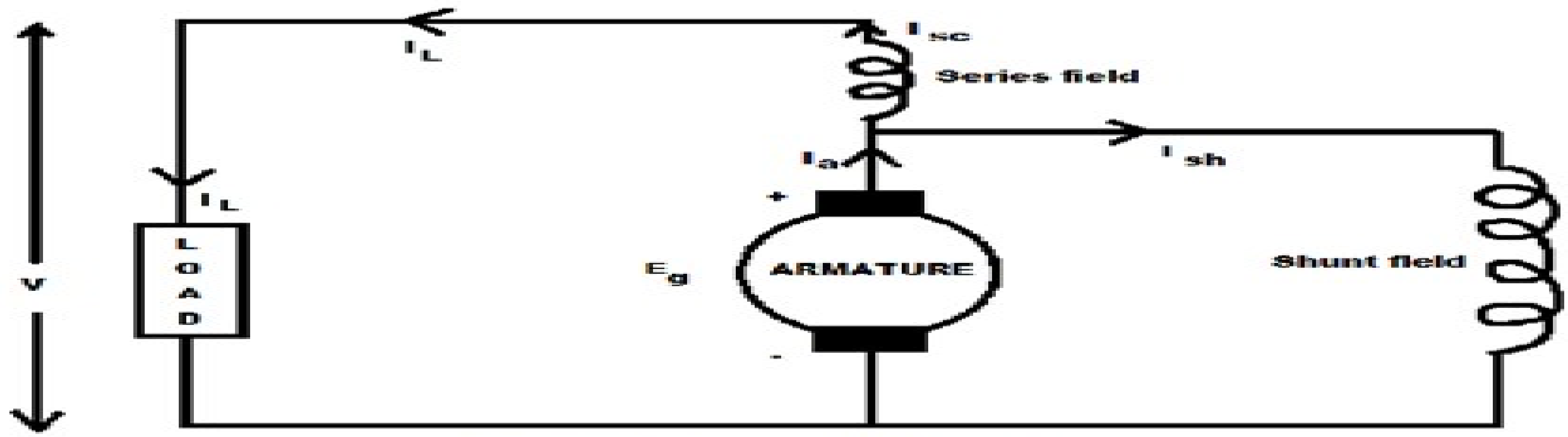
Classification:

- **Short shunt type compound generator**

The generators in which only shunt field winding is in parallel with the armature winding



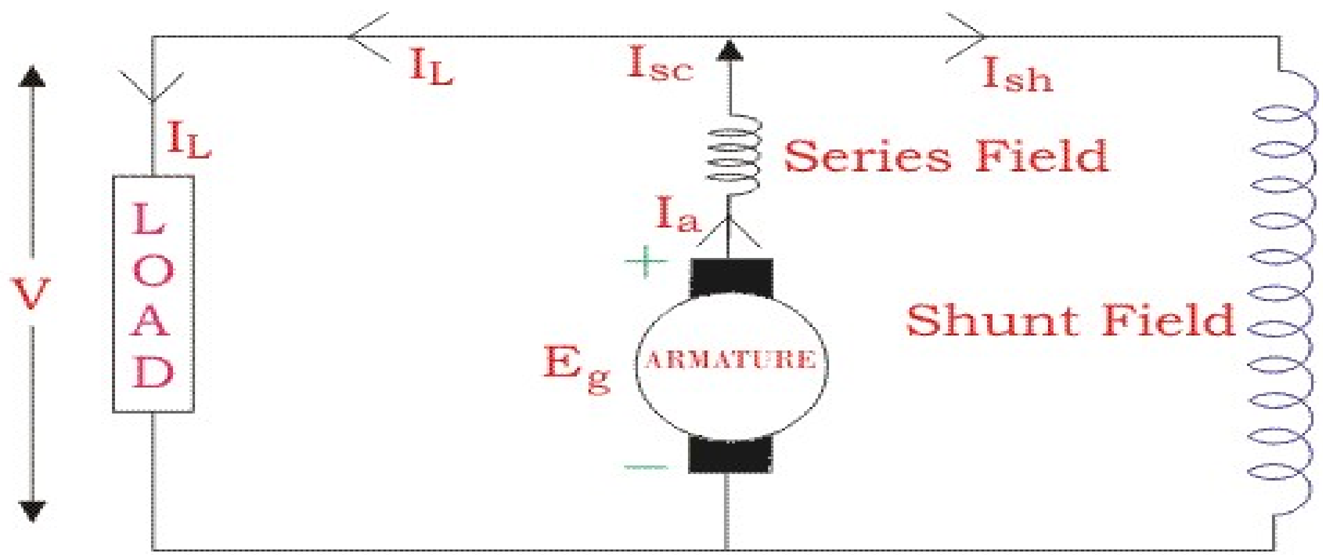
Short Shunt Compound Wound Generator



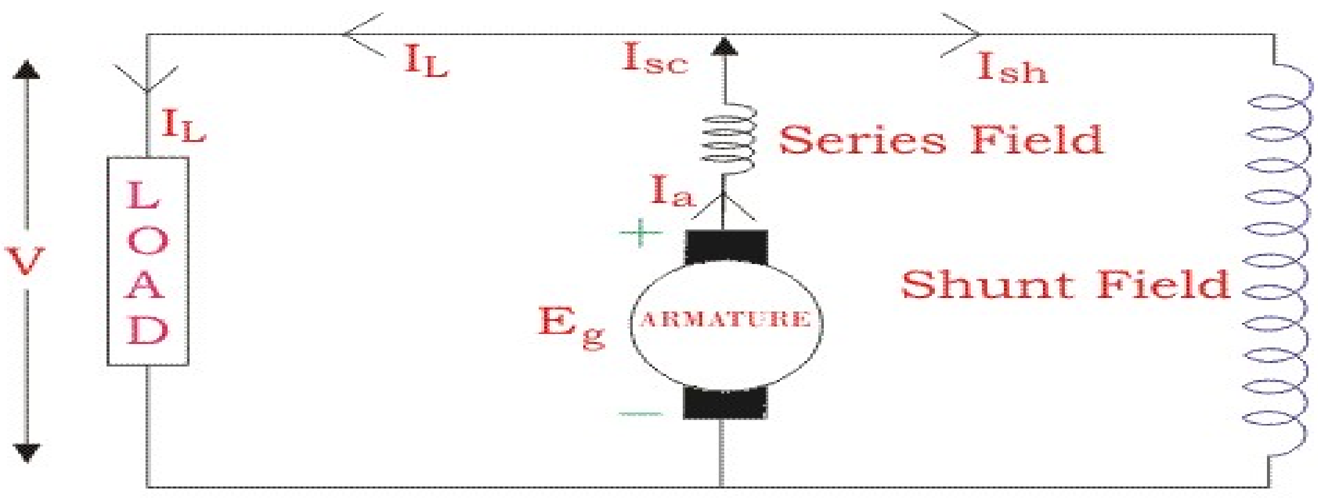
Short Shunt Compound Wound Generator

- Series field current, $I_{sc} = I_L$
- Shunt field current, $I_{sh} = (V+I_{sc} R_{sc})/R_{sh}$
- Armature current, $I_a = I_{sh} + I_L$
- Voltage across the load, $V = E_g - I_a R_a - I_{sc} R_{sc}$
  Power generated, $P_g = E_g \times I_a$
- Power delivered to the load, $P_L = V \times I_L$

- **Long shunt compound generator**
- The generators in which shunt field winding is in parallel with both series field and armature winding



Long Shunt Compound Wound Generator



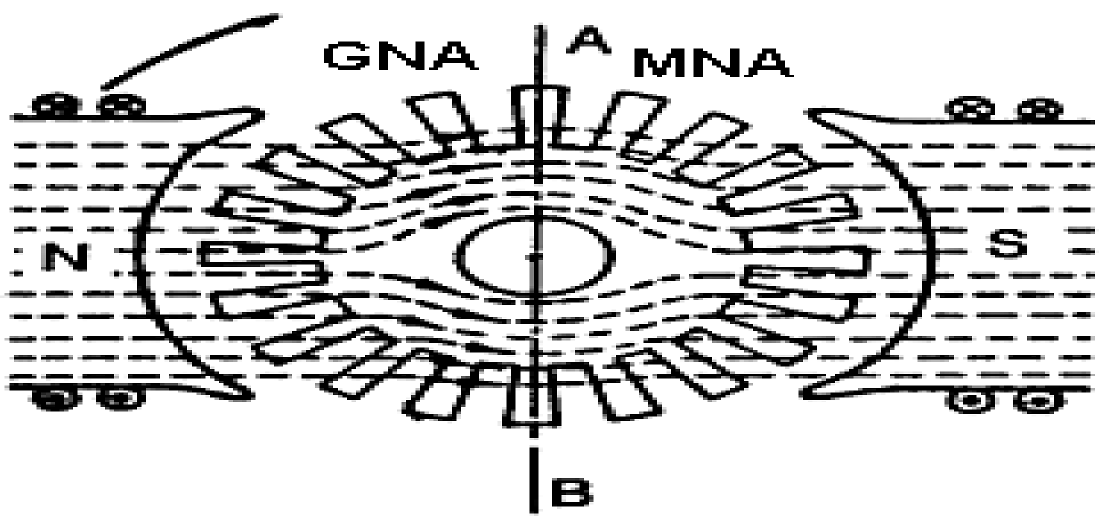
Long Shunt Compound Wound Generator

- Shunt field current, $I_{sh}=V/R_{sh}$
- Armature current, I_a= series field current
- $I_{sc}= I_L+I_{sh}$
- Voltage across the load, $V=E_g-I_a R_a-I_{sc} R_{sc}$
- $=E_g-I_a (R_a+R_{sc})$ $[\therefore I_a=I_{cs}]$
- Power generated, $P_g= E_g\times I_a$
- Power delivered to the load, $P_L=V\times I_L$

Armature Reaction

- In dc generator, the main field is produced when direct current flows through the filed winding.
- When armature winding carries current, the magnetic field is produced due to armature current also.
- Armature field affects the main field. This field is called the armature reaction.
- Hence The armature reaction is the effect of the armature field on the main field.

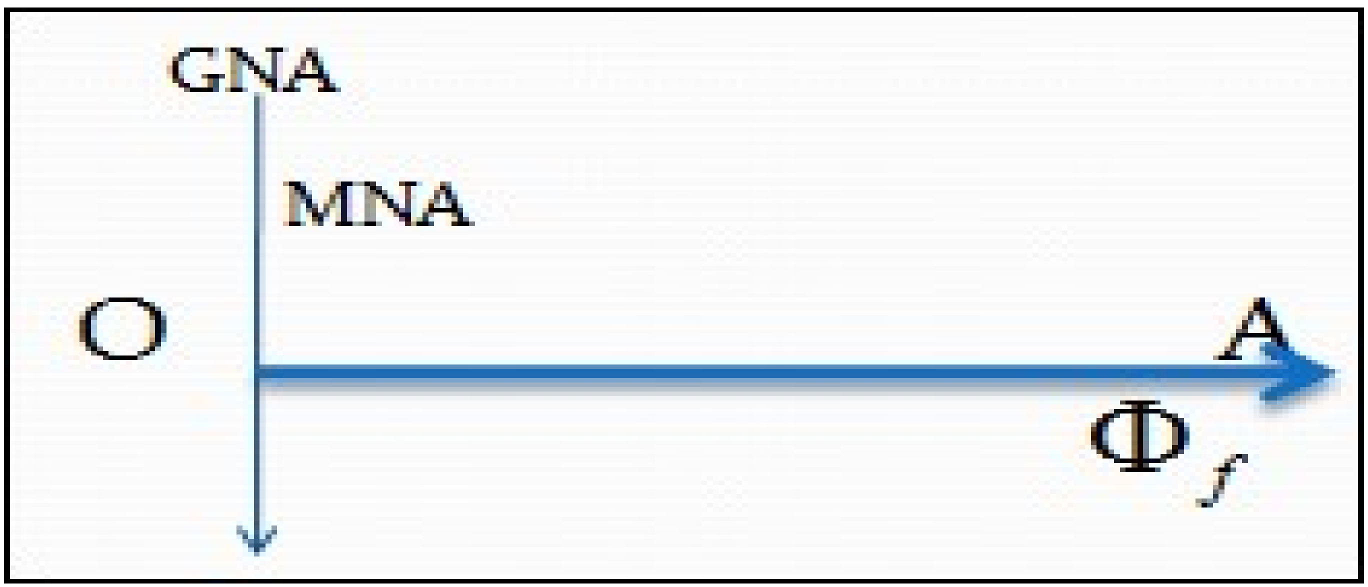
- To understand this process let us first assume a 2-pole d.c. machine at no load .
- At that instant there is no armature current . So the flux due to mmf produced by field current in the machine at north pole of the magnet will flow towards the south pole of the magnet.



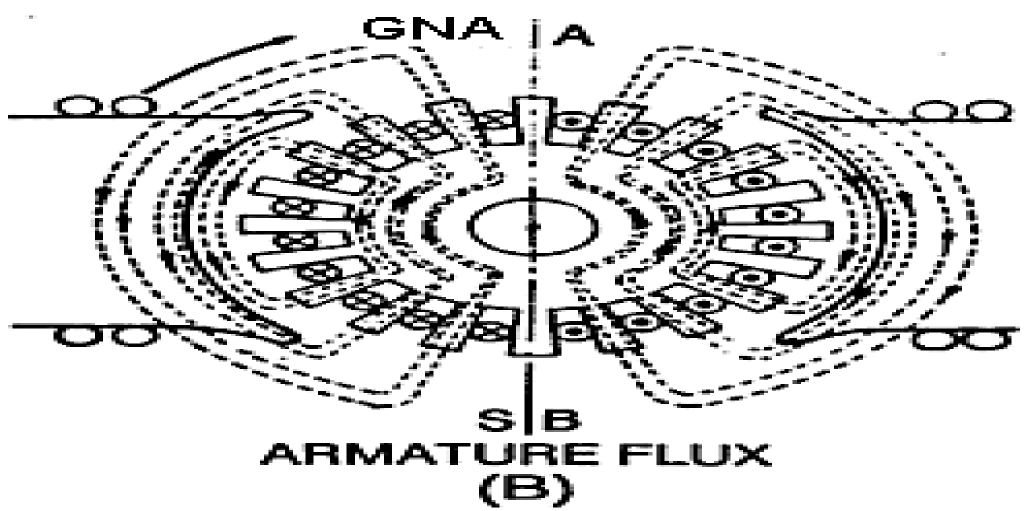
FIELD FLUX
(A)

- Geometrical Natural Axis(**GNA**) means the axis perpendicular to the pole axis.
- MAGNETIC Natural Axis (**MNA**) means the axis perpendicular to the field lines. Brushes are always kept on this axis.

- Also at that instant the Magnetic Neutral Axis (M.N.A) of the machine will coincide with the Geometrical Neutral Axis (G.N.A) of the machine as the M.N.A is always perpendicular to the net flux.



- Now when the dc machine is loaded , current flows in armature windings .
- This armature current set up armature flux . With field windings unexcited , the flux can be shown as vertical lines across armature conductors .
- The conductors on the left side of the M.N.A will have current flowing in inside direction whereas on right side of MNA , the current will flow in outside direction. The direction of the flux thus produced can be determined by using Maxwell‘s Right hand Screw rule.



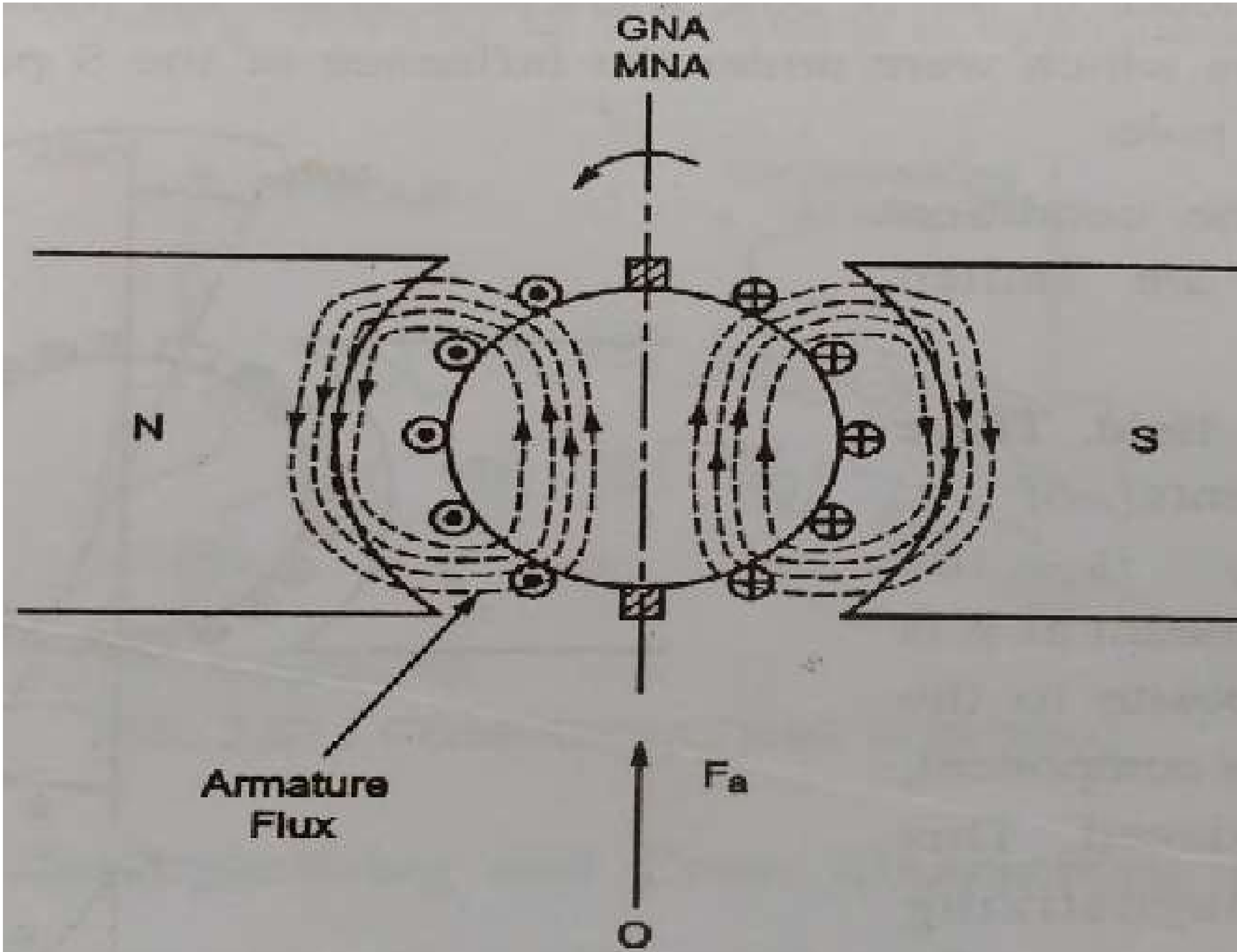
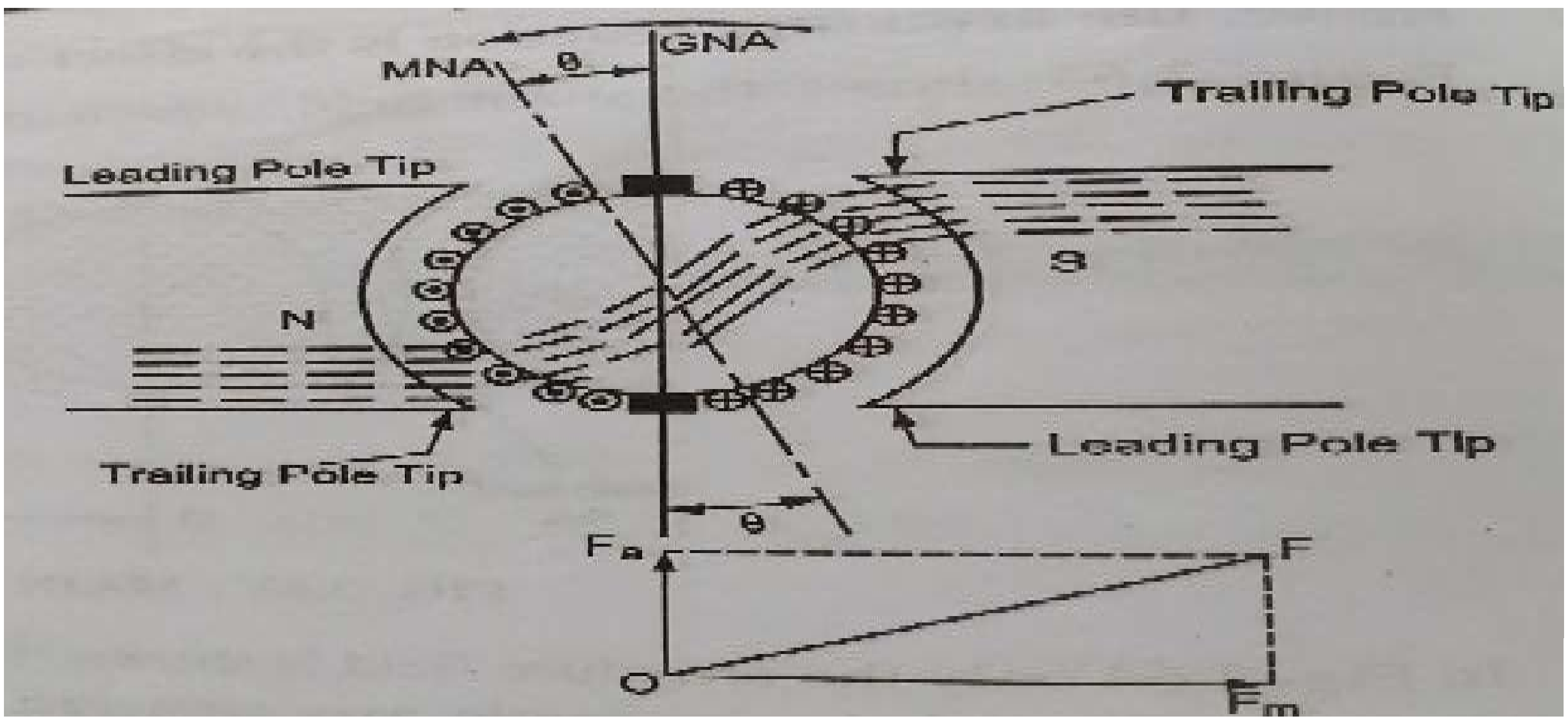


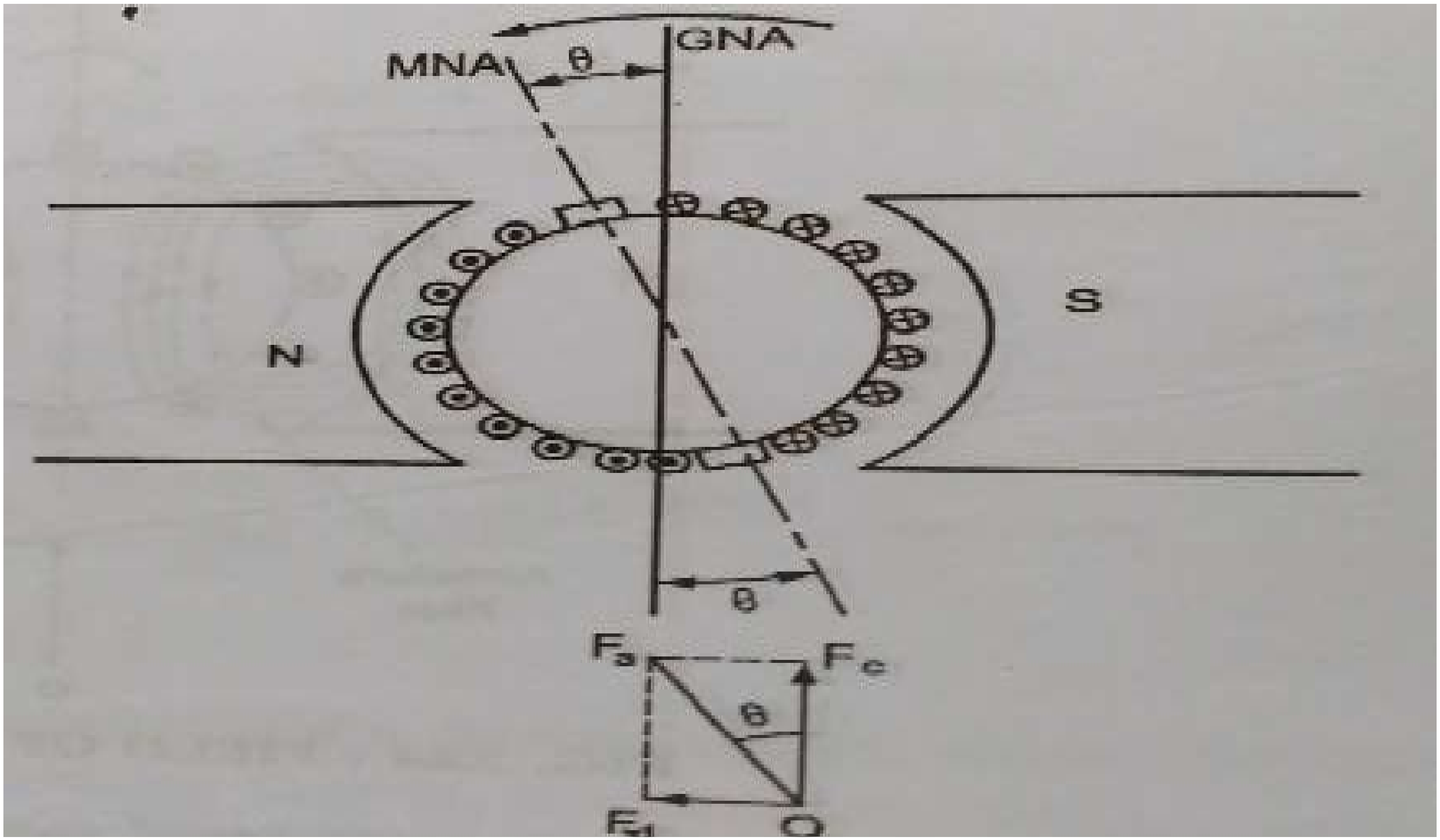
FIG. 3.64 : FIELD OF THE ARMATURE

- When both the fields are considered together, the resultant field is produced.
- Ofm is the main field and Ofa is the armature field.
- OF is the resultant of these two field.

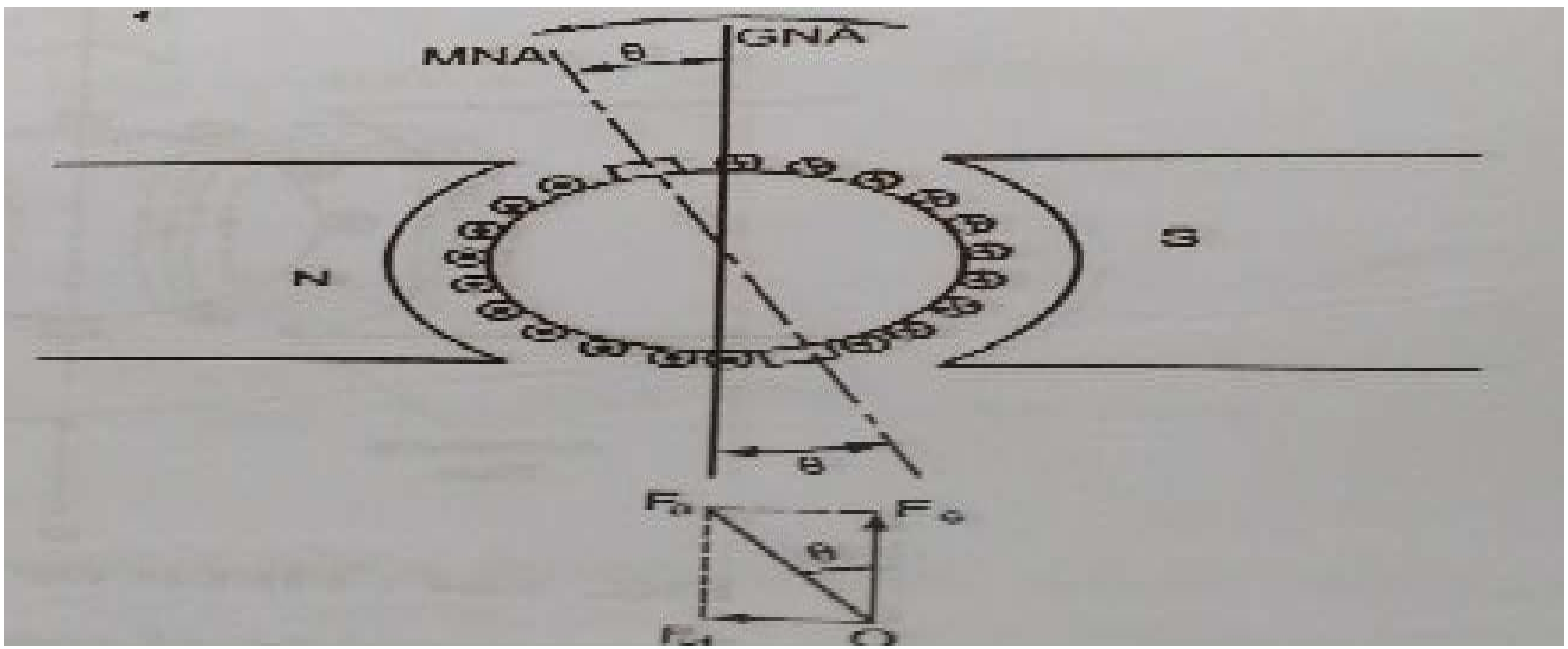


- As a result, the flux lines are diverted.
- The flux lines are reduced at leading pole tips and are concentrated at the trailing pole tips.
- Leading pole tips is the end of pole, which is faced first when armature rotates.
- Thus, the axis of the field lines are diverted.
- Now, MNA perpendicular to the field axis. So MNA is shifted from the GNA through an angle θ and brushes are placed on it. so brushes are also to be shifted by an angle.
- So some conductors which were under the influence of the N pole will come under the influence of S pole and

- Following fig. shows the condition after the brushes are shifted through an angle.

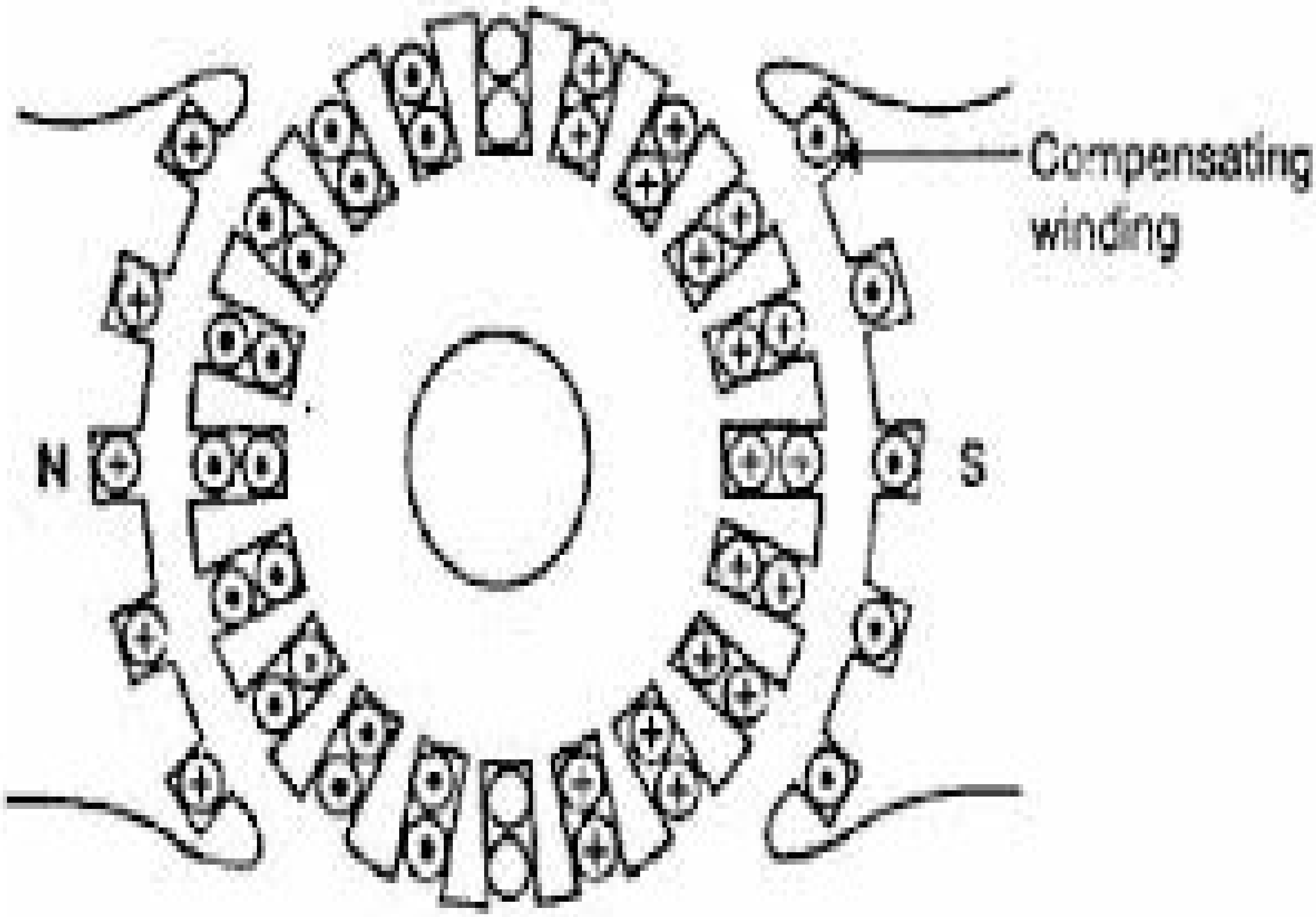


- Ofa is the armature field.
- There are two components of it.
- Component Ofd is the demagnetizing component as it is in the direction opposite to the main field.
- Due to this component, the net field is reduced. This is called demagnetizing component.
- Ofc is the cross magnetizing component due to which the magnetic field lines are diverted

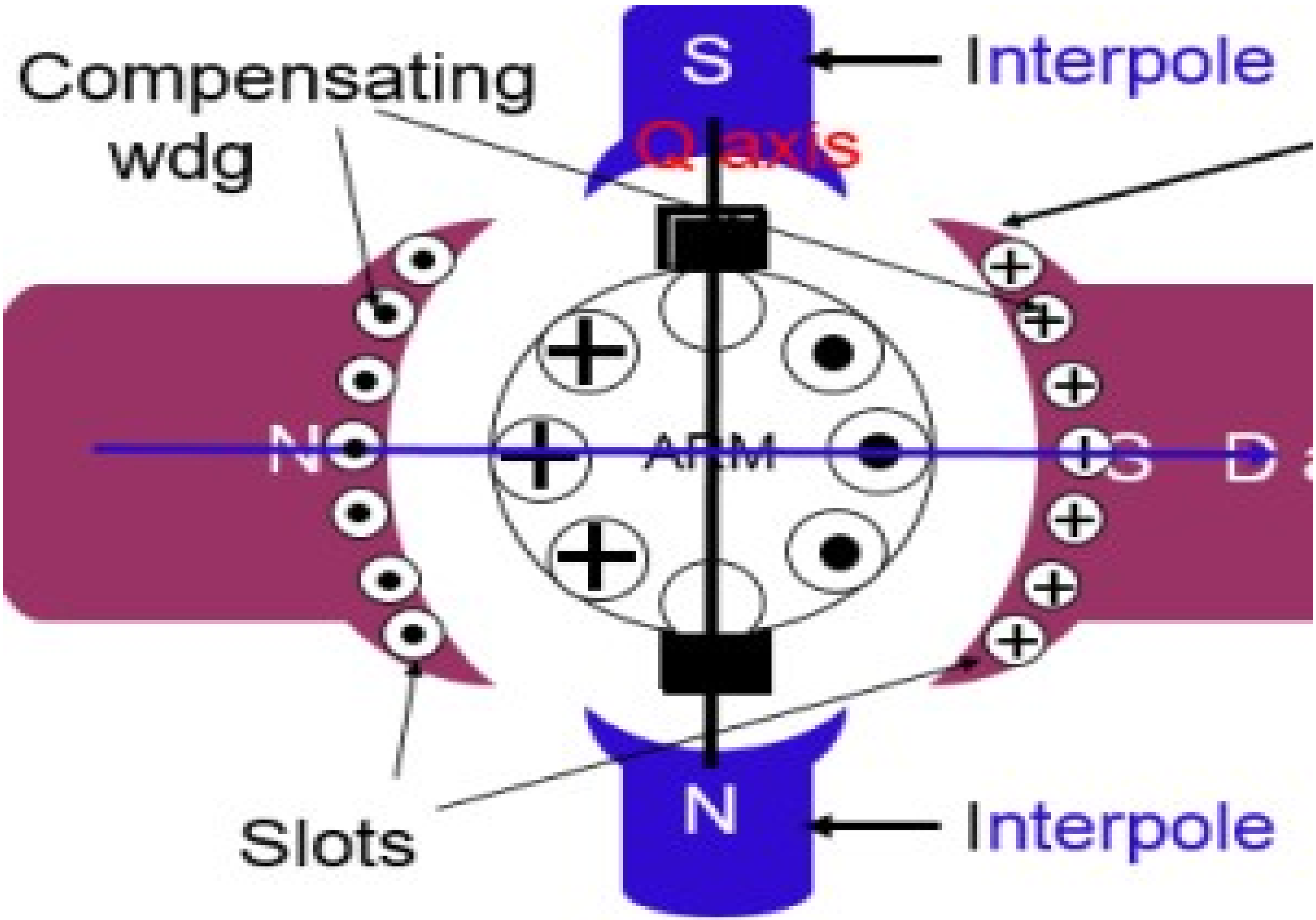


- Thus, the armature reaction is the effect of the armature field on the main field.
- There are two effects of the armature reaction
- **Demagnetizing and cross-magnetizing**
- Methods to overcome the effect of armature reaction:
- **Additional turns on poles:** to compensate the demagnetizing effect, additional turns are wound over the poles so additional magnetic field is produced which overcomes the decrease in the flux due to the armature reaction.

- **Compensating winding:**
- With the use of the compensating winding, the cross magnetizing effect of armature reaction can be overcome.
- For this, the slots are cut in the pole face and winding is place in these slots.
- This winding is connected in series with the armature i.e the armature current flows through the compensating winding.
- Polarity of the current is opposite to that of the armature current.



N
S
Compensating
winding


Compensating
wdg
S
Interpole
Q axis
N
ARM
S
D a
Slots
N
Interpole