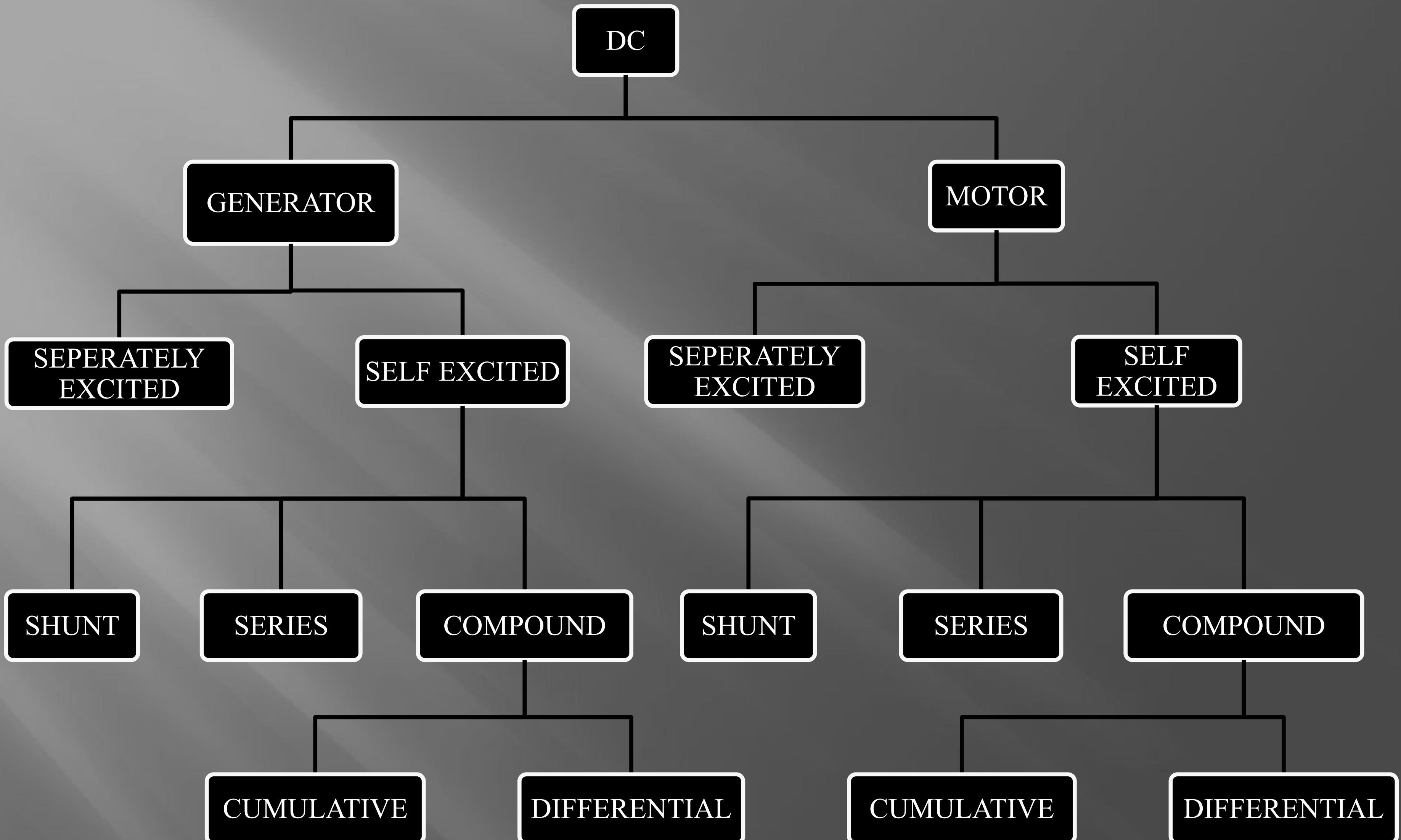
DC GENERATOR

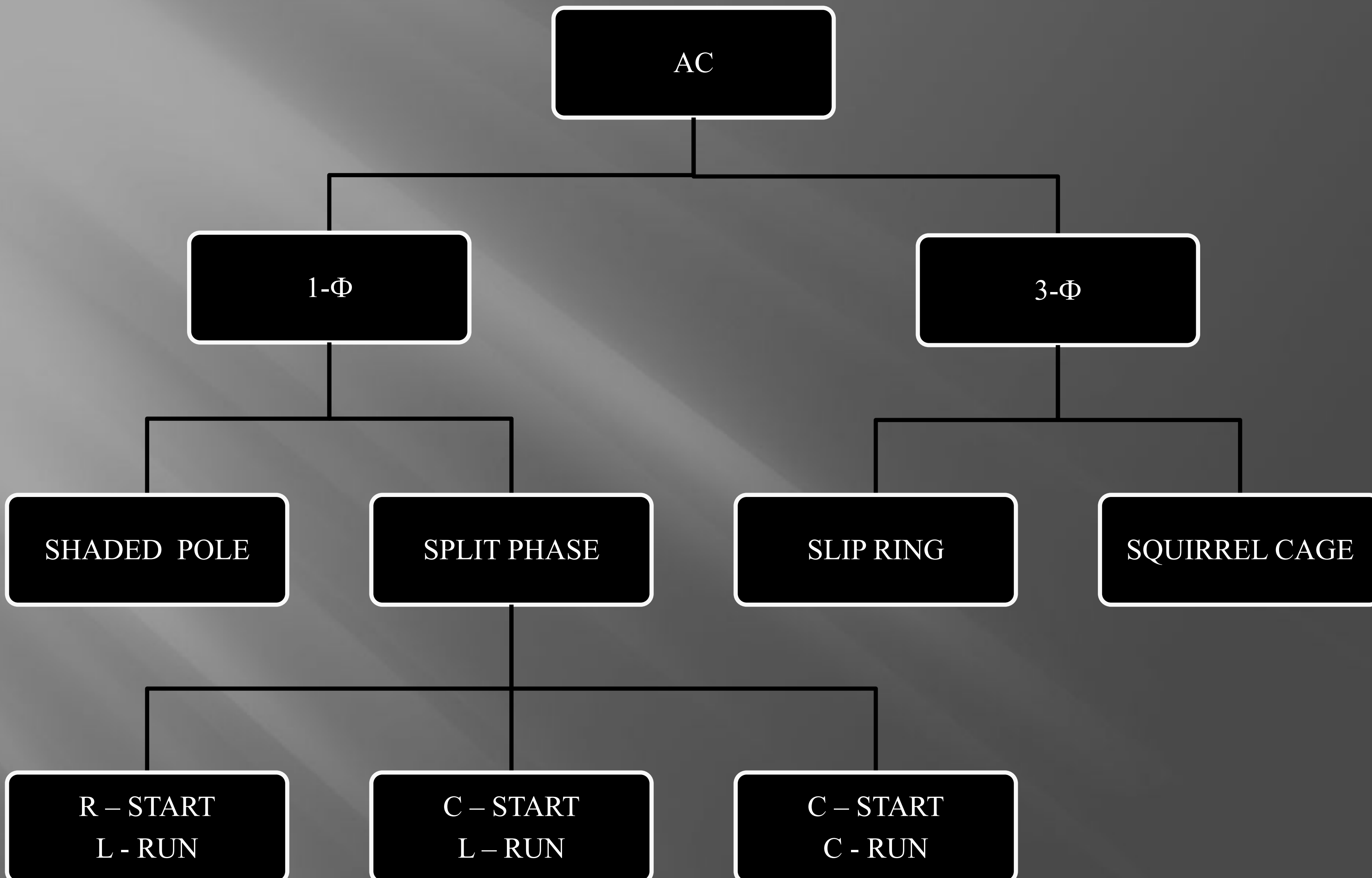
By:- DHARMESH N. DEVANI

Classification

- Electrical Machines
  - DC Machines
  - AC Machines

Classify D.C. machine

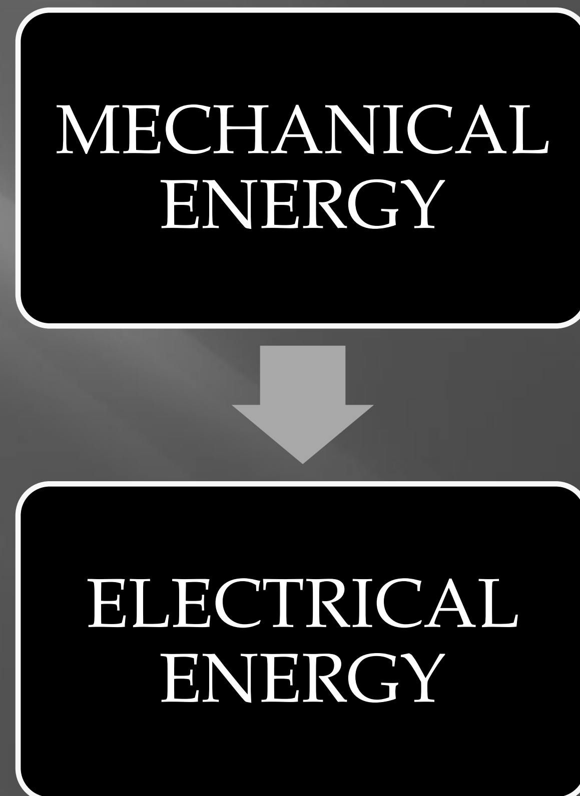

DC
GENERATOR
MOTOR
SEPERATELY EXCITED
SELF EXCITED
SEPERATELY EXCITED
SELF EXCITED
SHUNT
SERIES
COMPOUND
SHUNT
SERIES
COMPOUND
CUMULATIVE
DIFFERENTIAL
CUMULATIVE
DIFFERENTIAL


AC
1-Φ
3-Φ
SHADED POLE
SPLIT PHASE
SLIP RING
SQUIRREL CAGE
R – START
L - RUN
C – START
L – RUN
C – START
C - RUN

Explain the principle of D.C. Generator

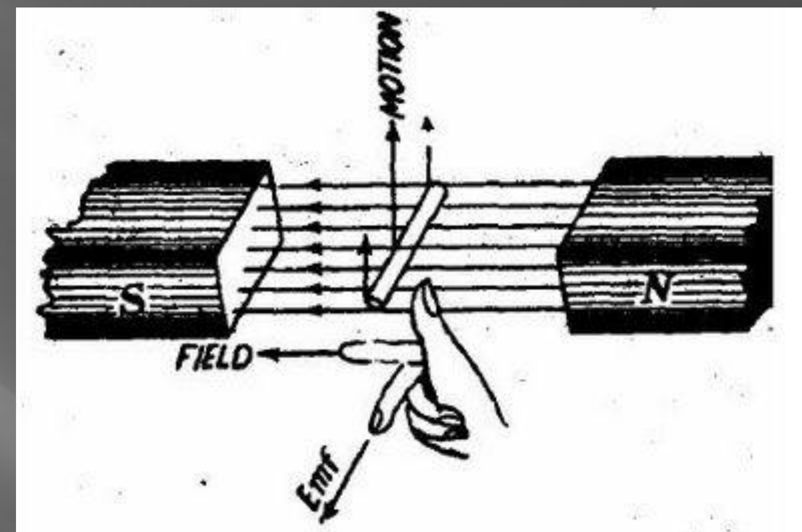
DC GENERATOR
PRINCIPLE

- The energy conversion in generator is based on the principle of the **production of dynamically induced emf.**
- Whenever a conductor cuts magnetic flux , dynamically induced emf is produced in it according **to Faraday's Laws of Electromagnetic induction**.
- This emf causes a current to flow if the conductor circuit is closed.
- Block diagram is shown in figure.



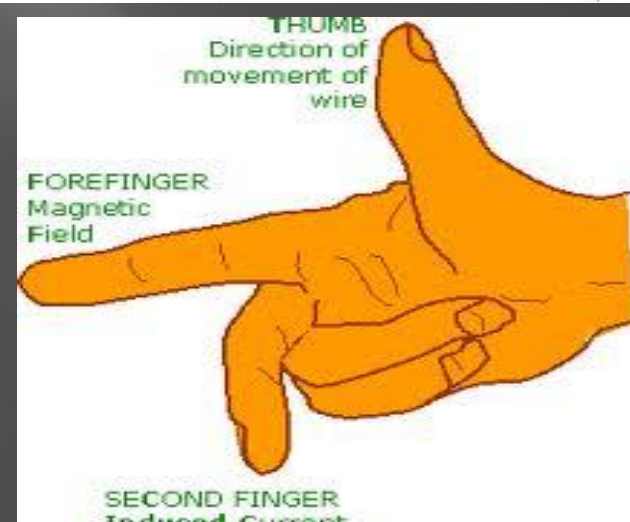
FLEMING'S RIGHT HAND RULE

- The direction of induced emf in the conductor is given by **<u>Fleming's Right Hand Rule</u>**.
- Keep first two fingers and thumb perpendicular to each other.
- First finger indicate direction of magnetic flux, Thumb indicate direction of motion than emf induced is indicated by Second finger.



$$\boxed{E = BLV\sin\theta}$$

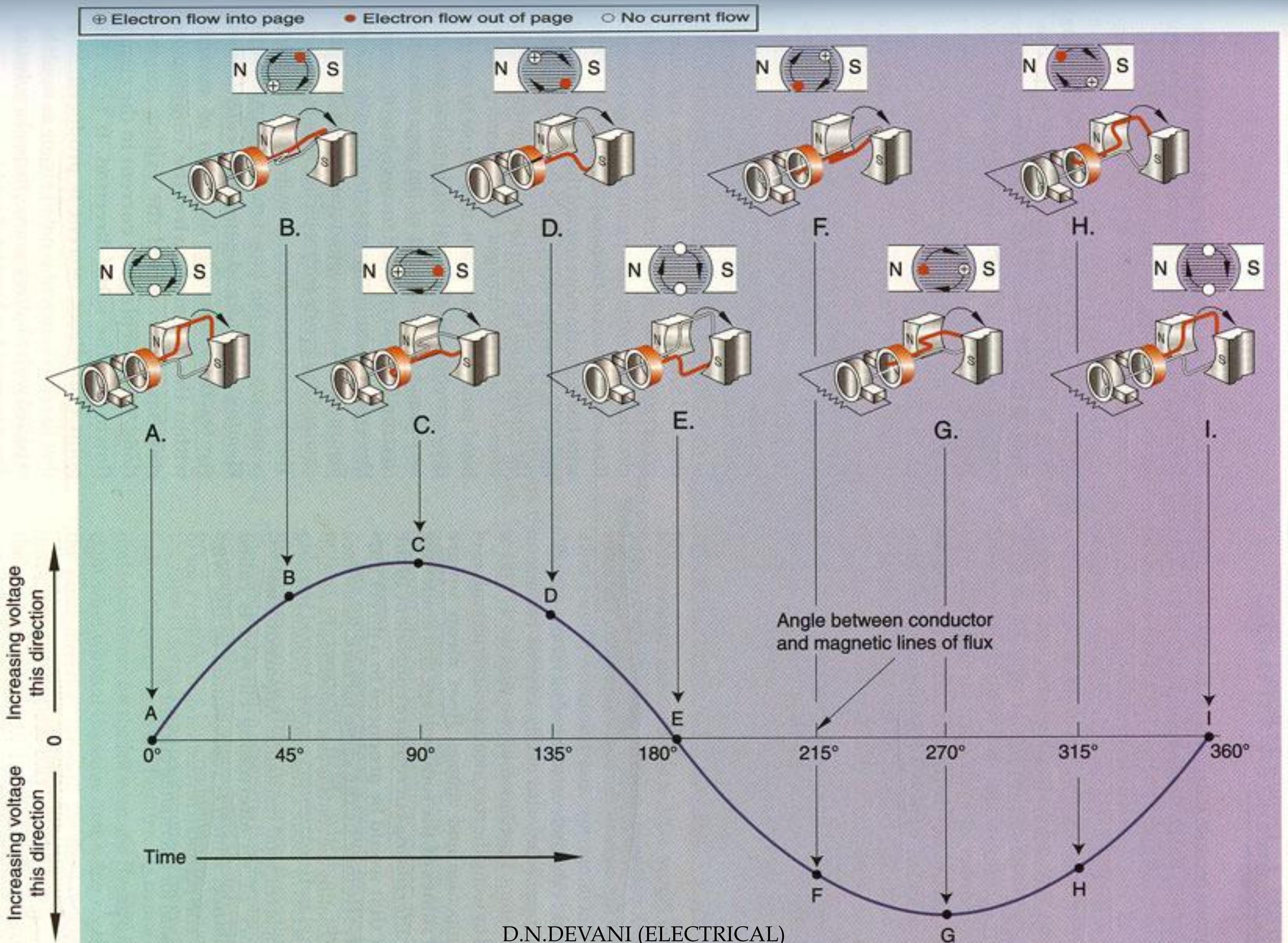
B = Mag. Flux Density
L = Length of Conductor
V = Velocity
θ = Angle between Flux line and conductor



Explain Commutator action

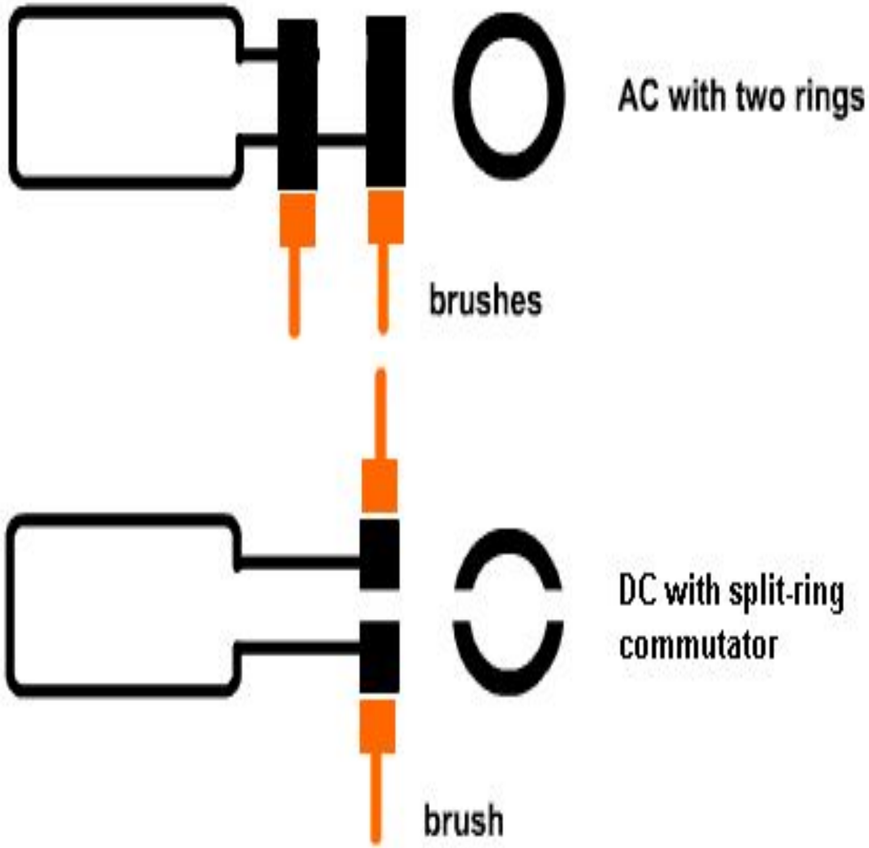
or

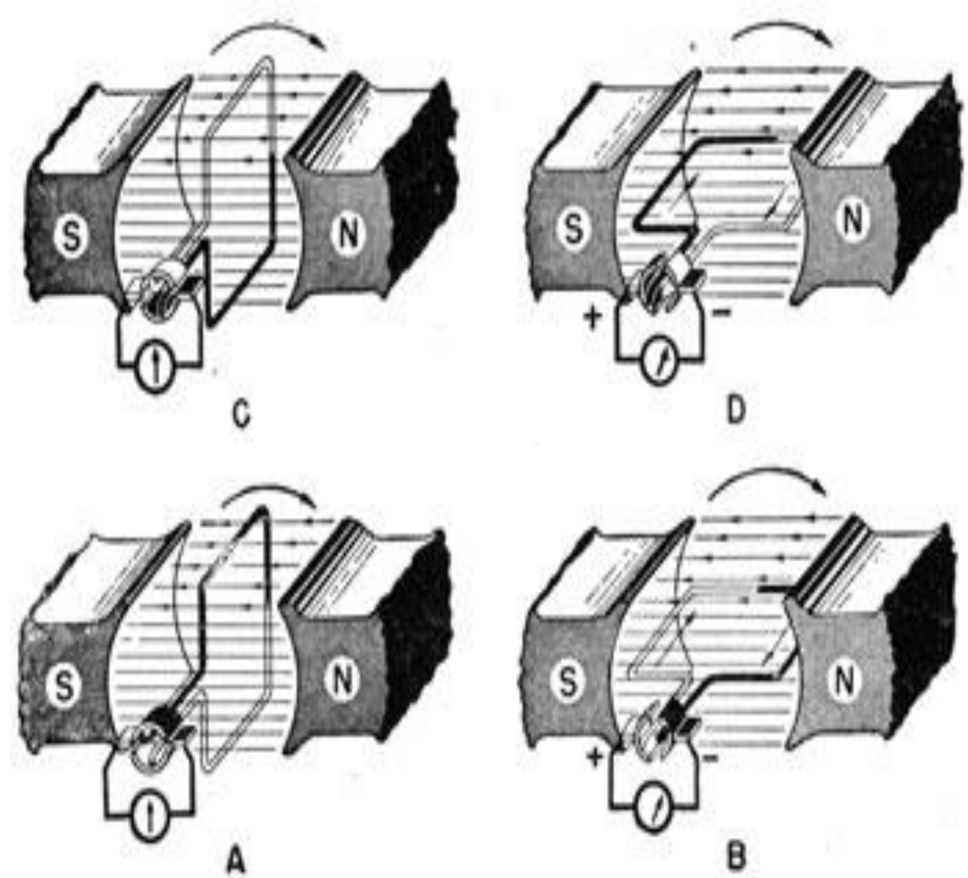
Explain need of commutator



⊕ Electron flow into page
● Electron flow out of page
○ No current flow
N
S
A.
B.
C.
D.
E.
F.
G.
H.
I.
Angle between conductor and magnetic lines of flux
Increasing voltage this direction
0
Increasing voltage this direction
Time
0°
45°
90°
135°
180°
215°
270°
315°
360°

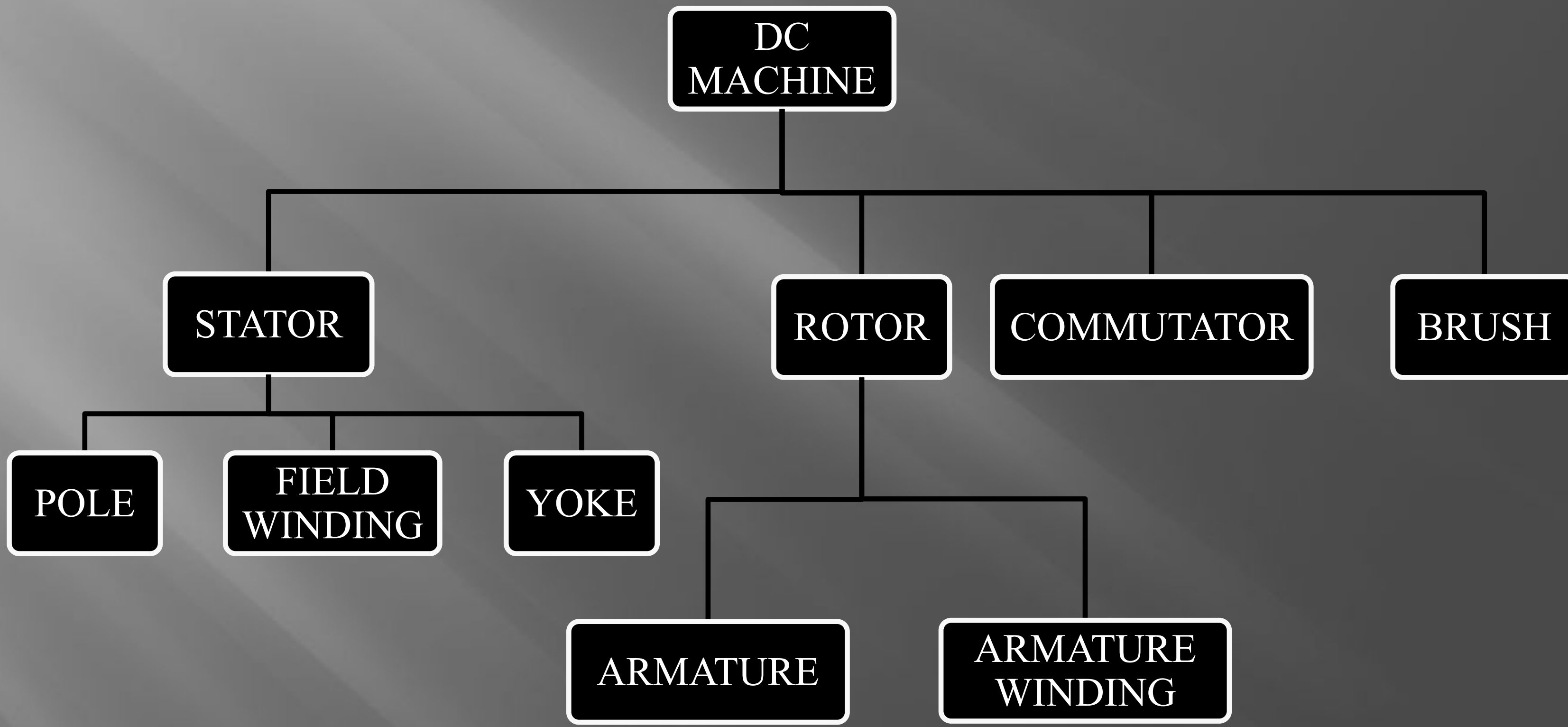
SPLIT RING COMMUTATOR





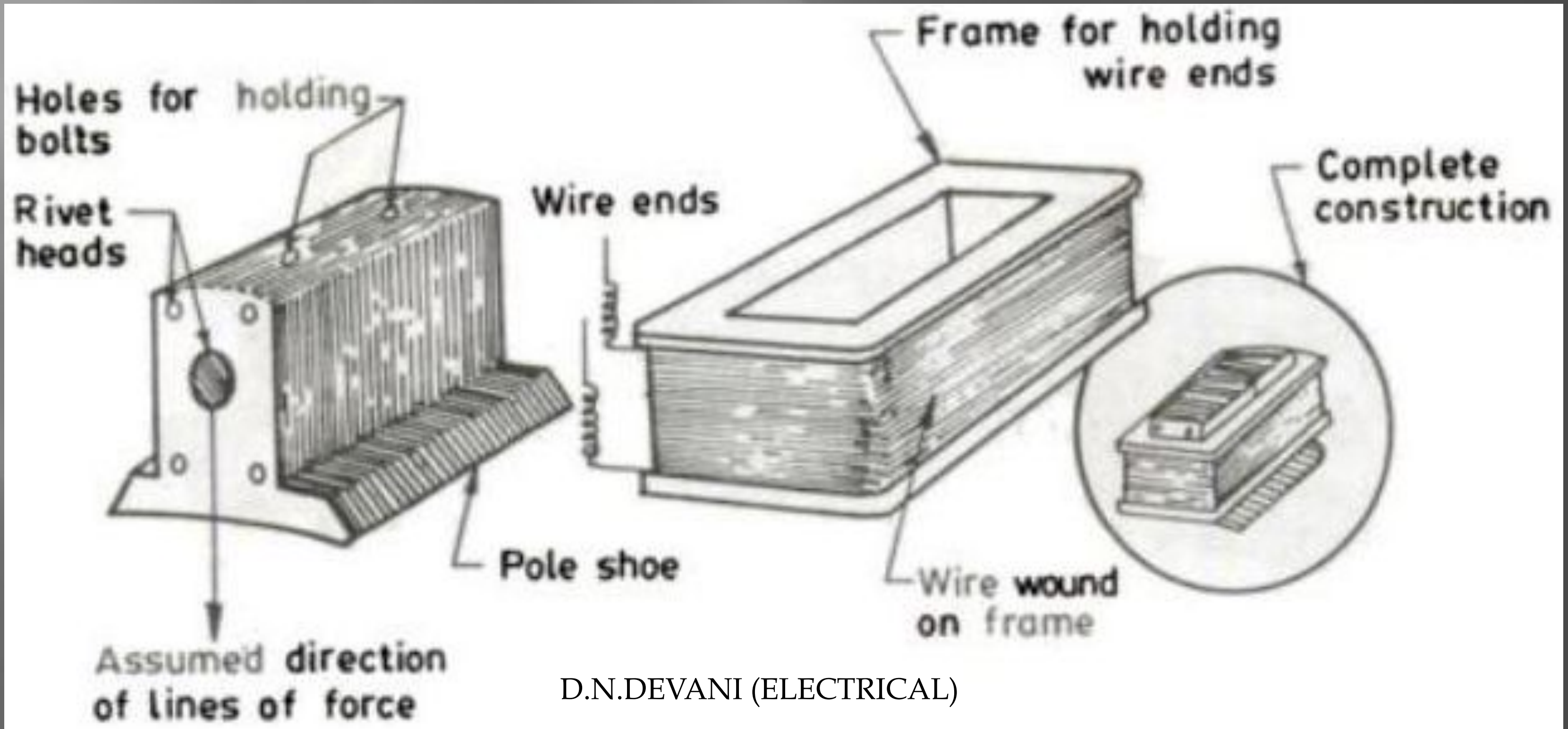
Explain construction of D.C. machine

CONSTRUCTION OF DC MACHINE



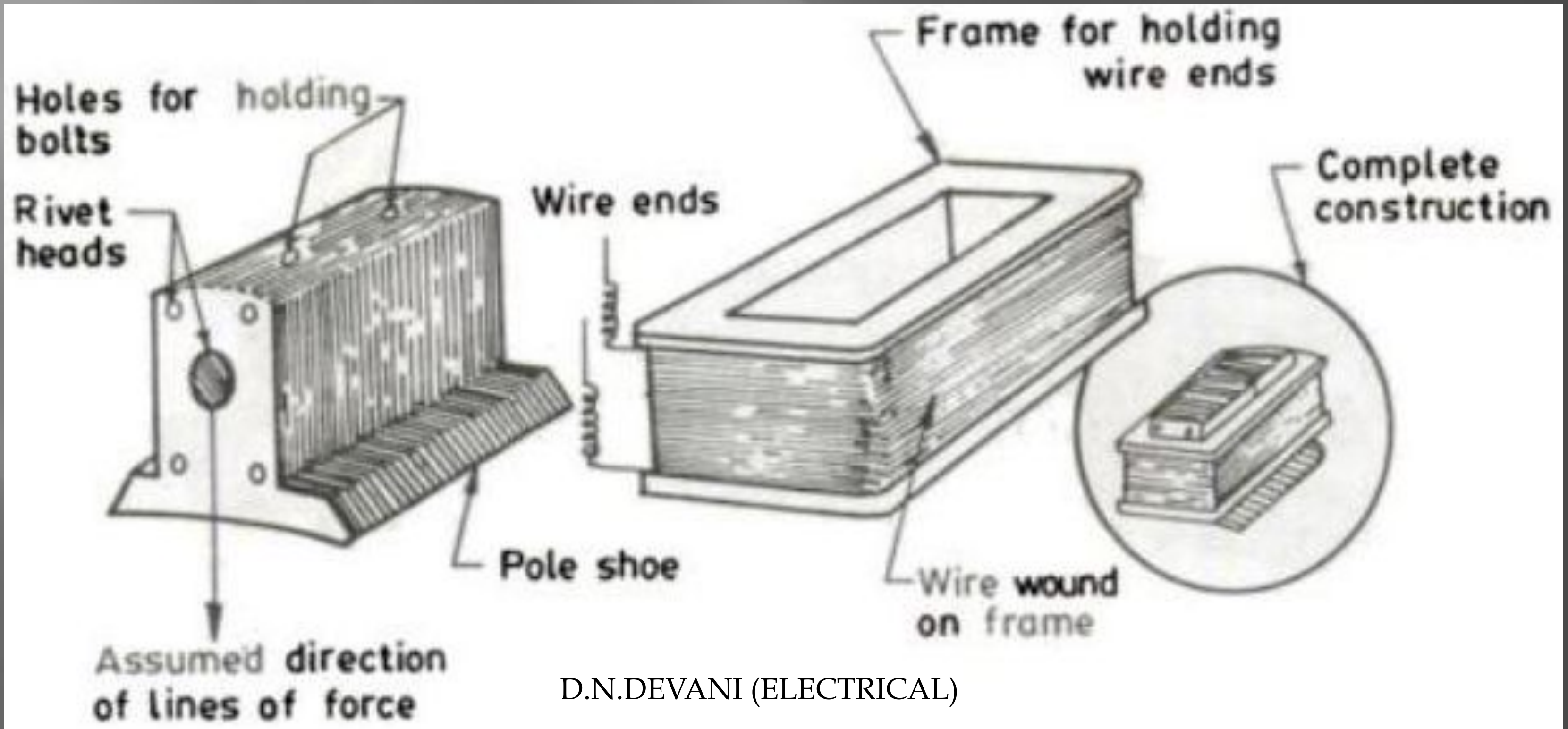
POLE AND FIELD WINDING

- Poles are made by **silicon steel** to reduce **hysteresis loss**.
- It is also **laminated** to reduce **eddy current loss**.
- Pole shoes spread magnetic field.
- Poles are bolted to the yoke.
- It provide support to the field winding.



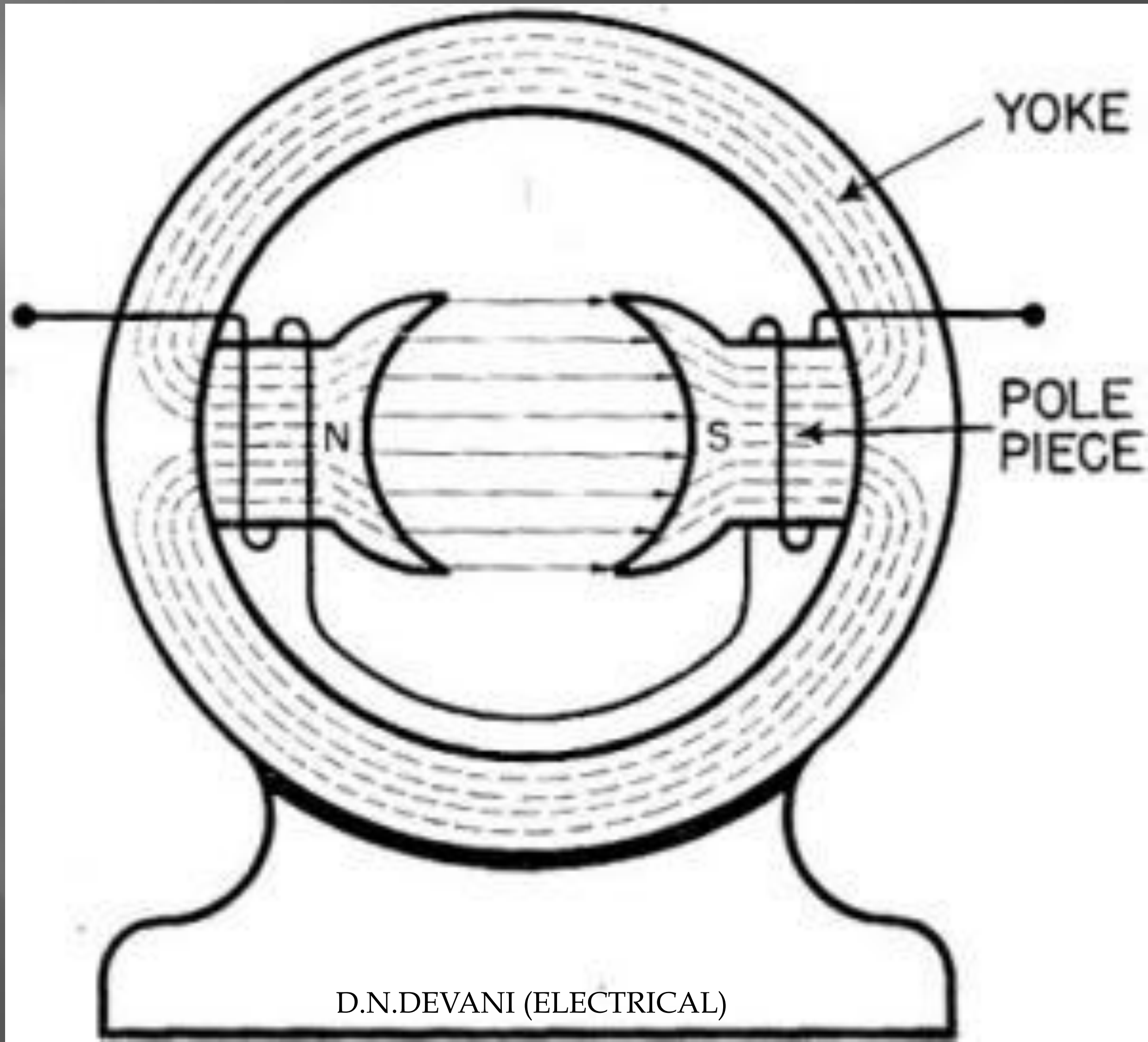
POLE AND FIELD WINDING

- Field winding is made by **copper conductor**.
- Field winding is wounded on the former and than former is placed around the pole.
- When field winding is excited by DC source, it produce magnetic flux.



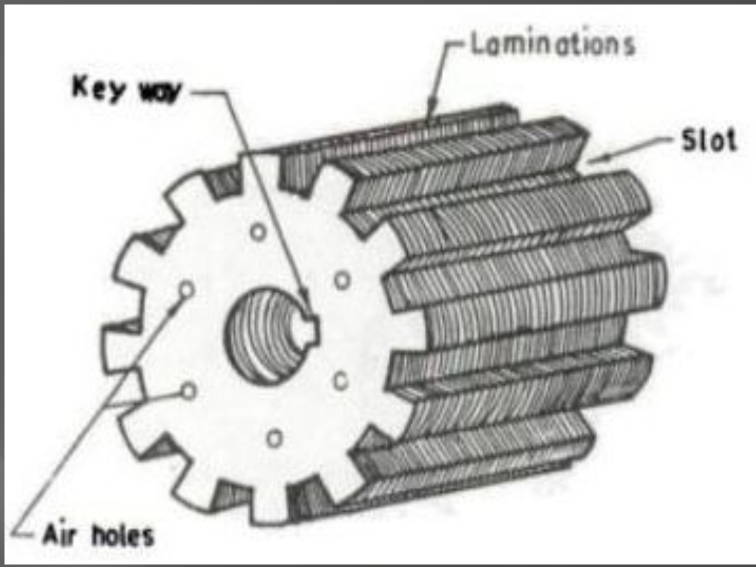
YOKE

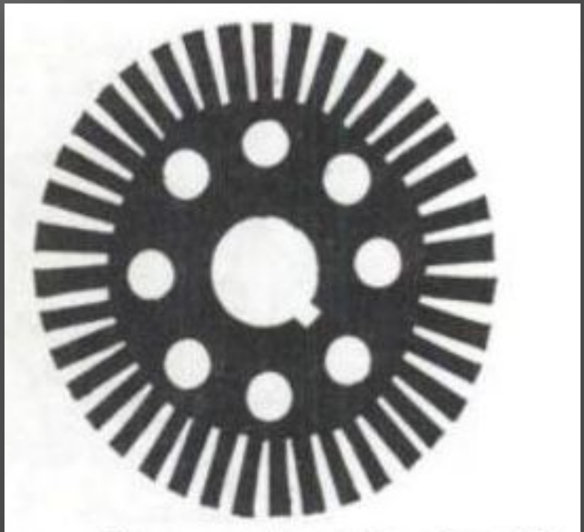
- In small machines it is made by **cast iron** because of cheapness.
- In large machines it is made by **fabricated steed** due to its high permeability.
- It provide support to the pole.
- It provide protection to the internal parts from outer damage.
- It provide return path to the magnetic flux.



ARMATURE

- It is made by **laminated cast iron** to reduce iron losses.
- The armature core is a **cylindrical drum type**.
- Slots are made on the surface of the armature.
- These slots are parallel to the shaft.
- Armature conductors are placed in this slots.
- The air holed are provided for the air circulation for cooling.
- Armature provide accommodation to the armature winding.





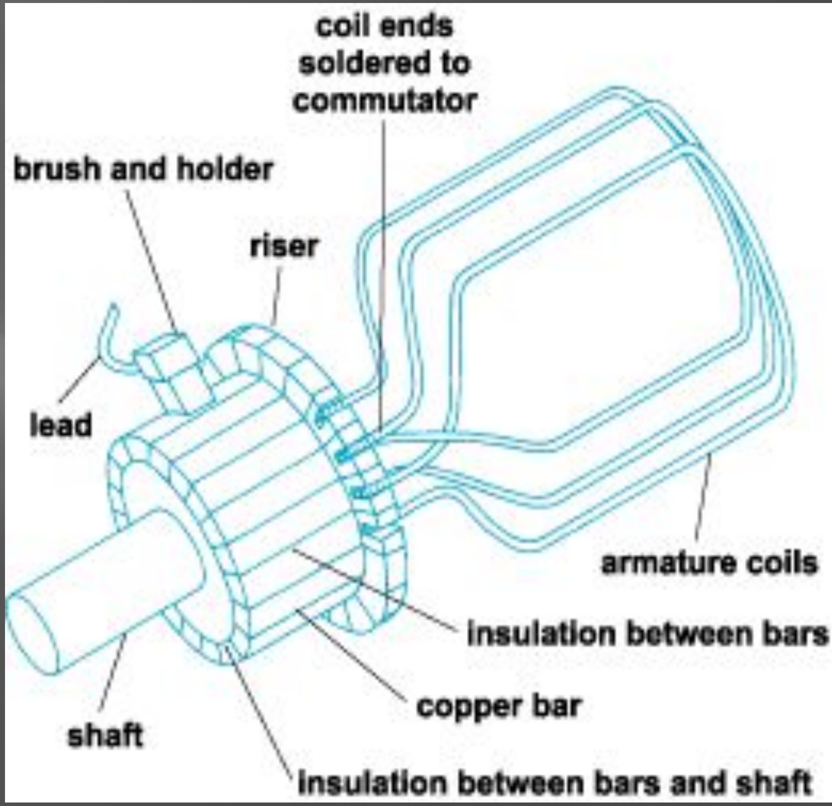
ARMATURE

ARMATURE WINDING

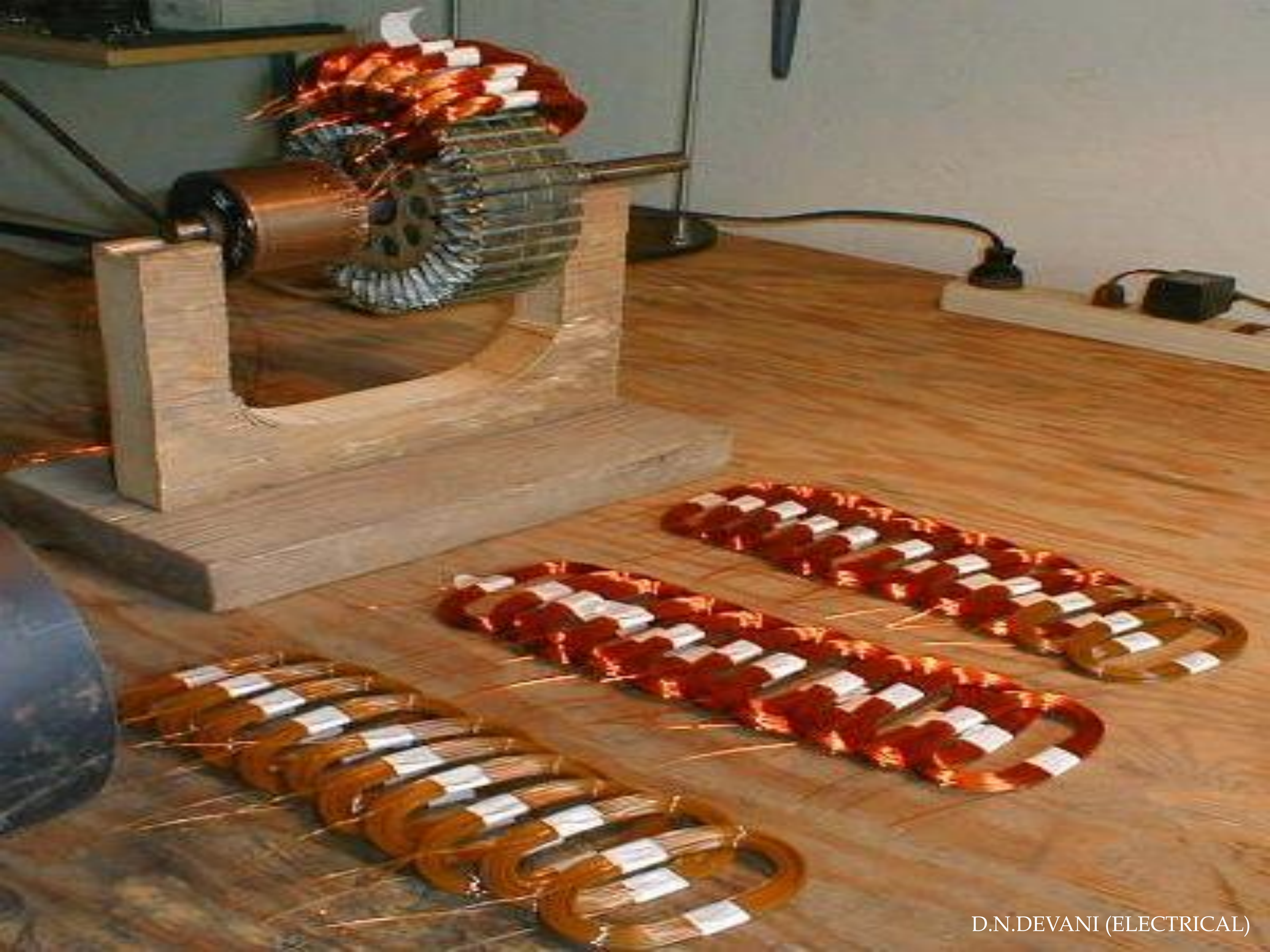
- Armature winding is made by **copper conductor** and insulated.
- The slots of the armature core hold this insulated conductors that are connected in a suitable manner.
- This is the winding in which “working” emf. is induced.
- The armature conductors are connected in **series-parallel**.
- The conductors being connected in series so as to increase the voltage and in parallel paths so as to increase the current.
- After placing armature winding each slot is closed by **bamboo strip**.

COMMUTATOR

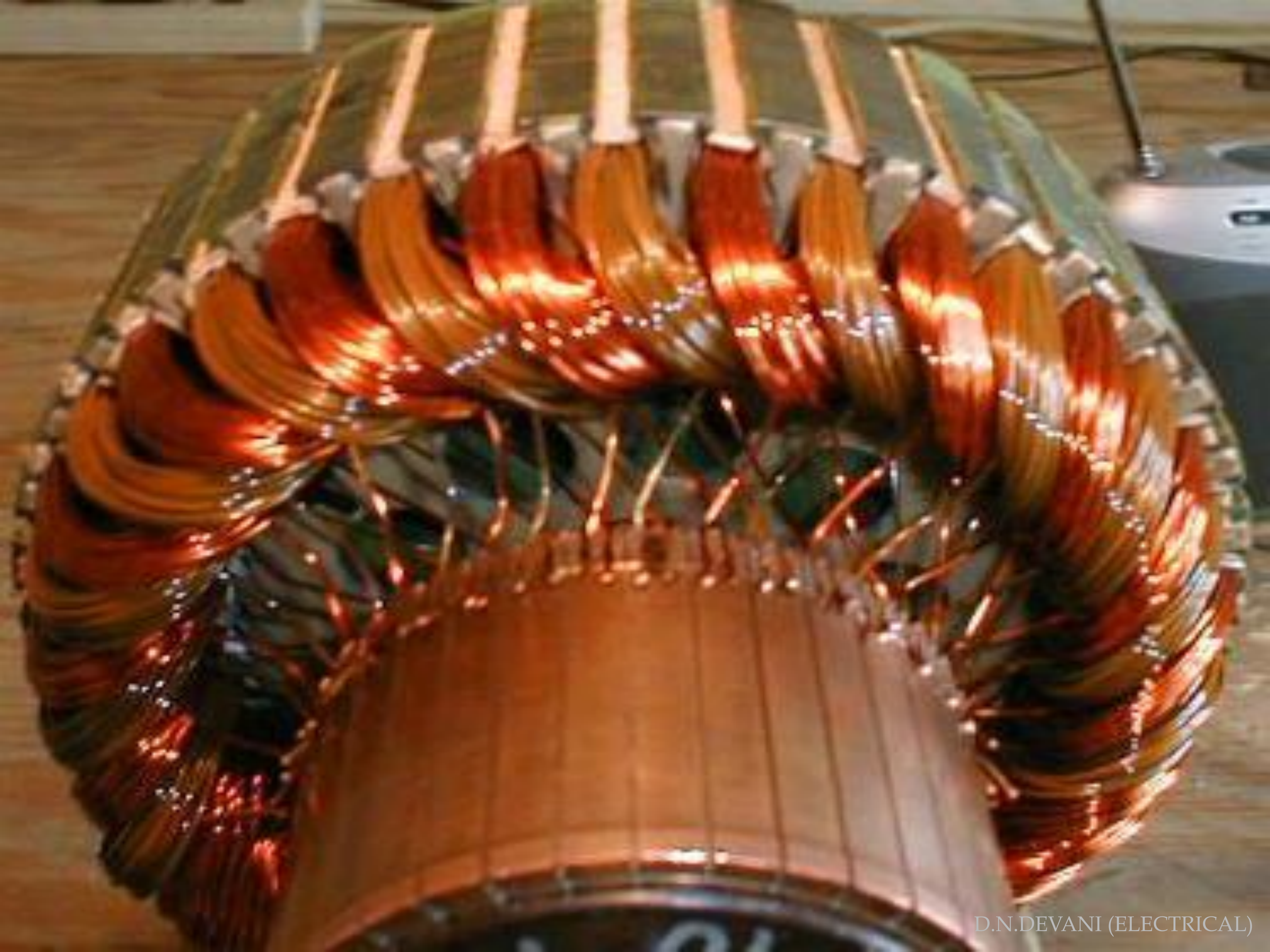
- A commutator converts **alternating voltage into direct voltage**.
- A commutator is a cylindrical structure built up of segments made of hard drawn copper.
- These segments separated from each other and from frame by means of **mica strips**.
- These segments are connected to the winding by means of **risers.**
- The risers have air spaces between one another or that the air is drawn across the commutator there by keeping the commutator cool.



POSSITION OF COMMUTATOR

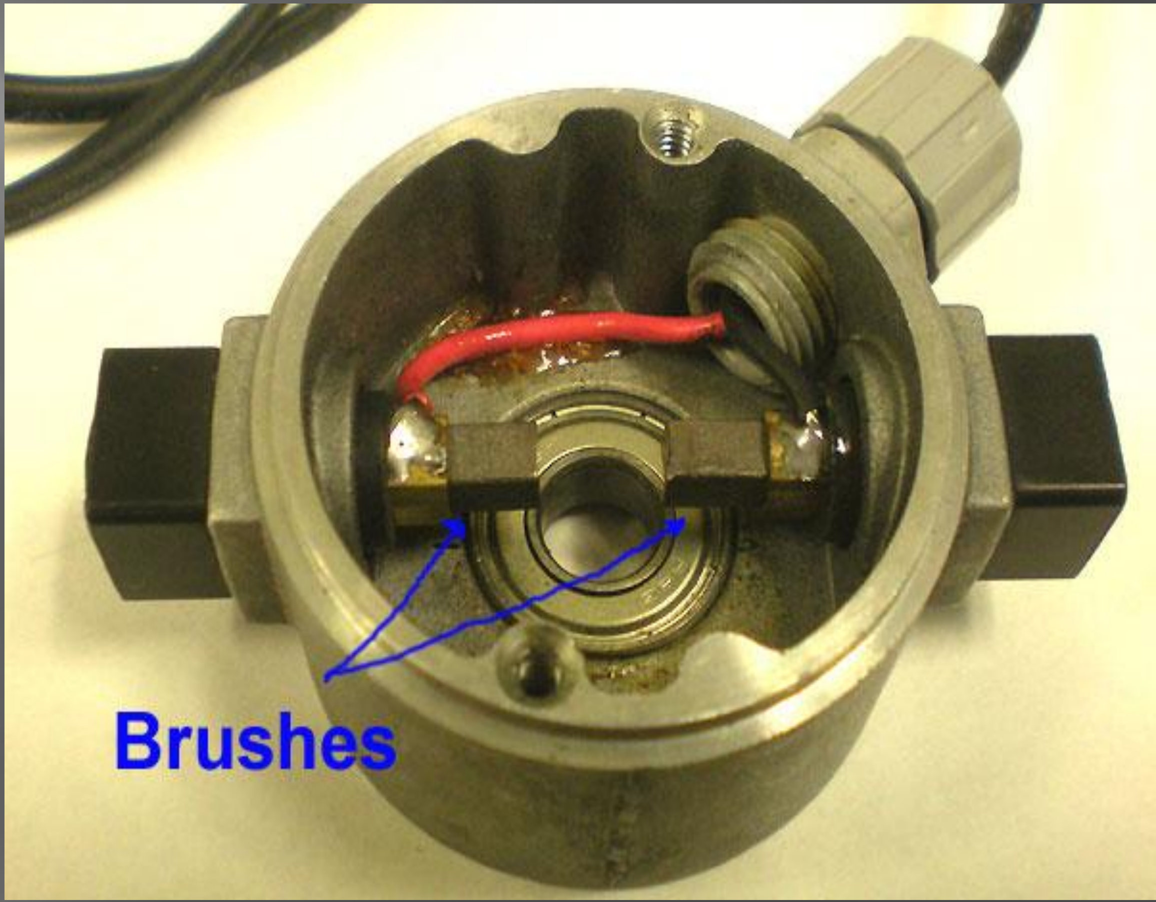


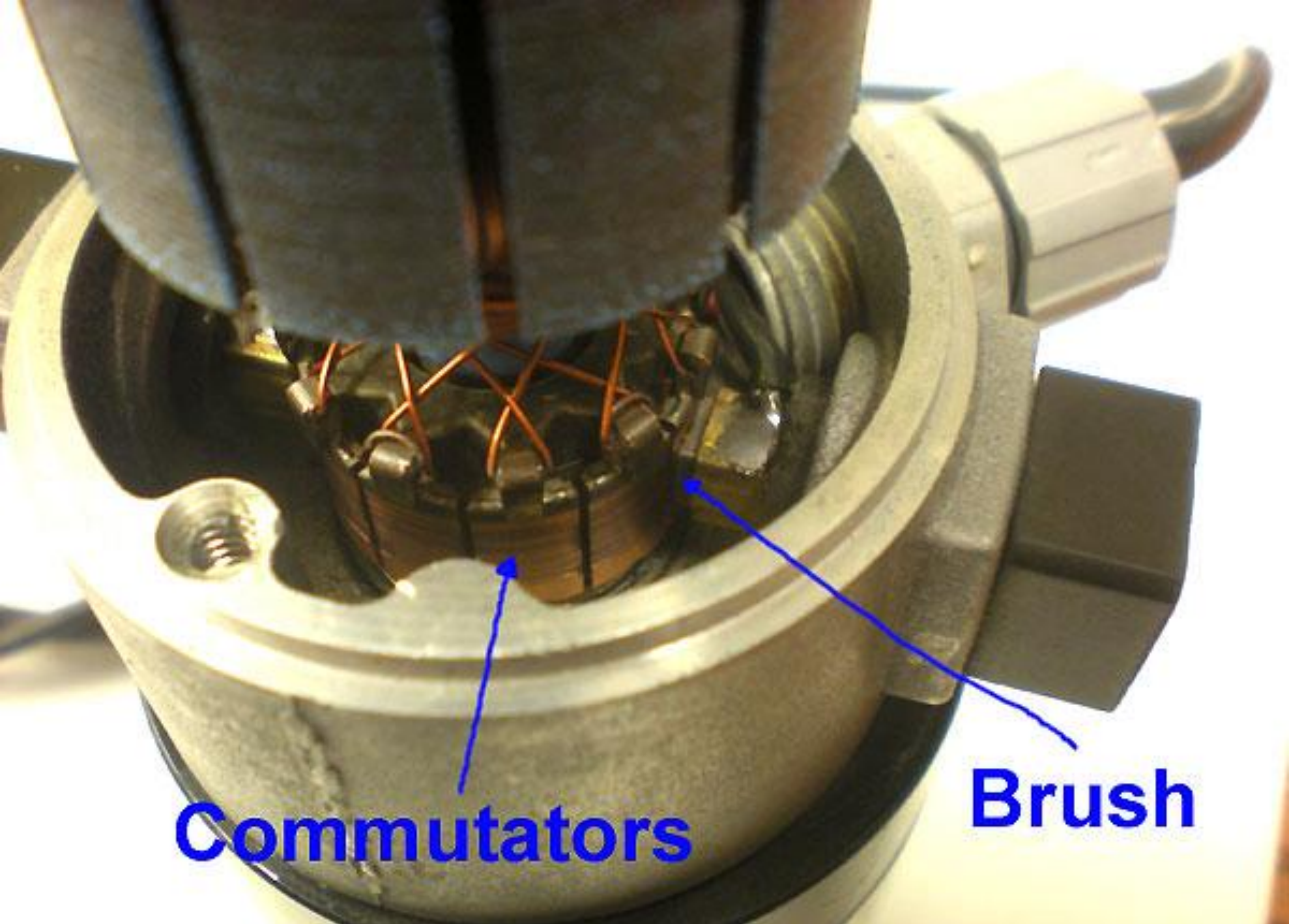
D.N.DEVANI (ELECTRICAL)



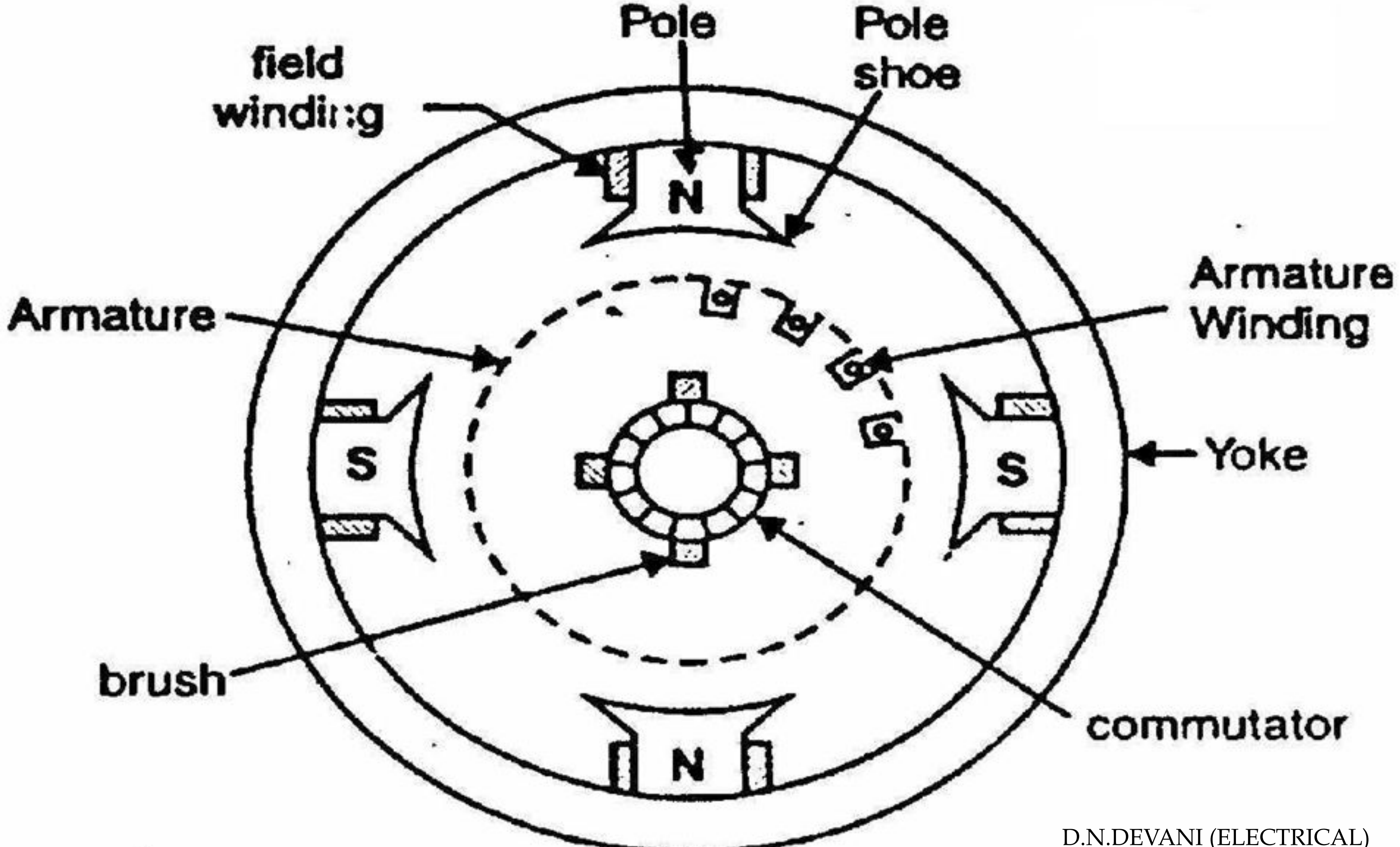
BRUSHES

- The brushes usually made of **carbon or graphite**.
- Function is to collect current from commutator,
- Brushes are in the shape of a rectangular block.
- These brushes are housed in brush-holders usually of the box type variety.



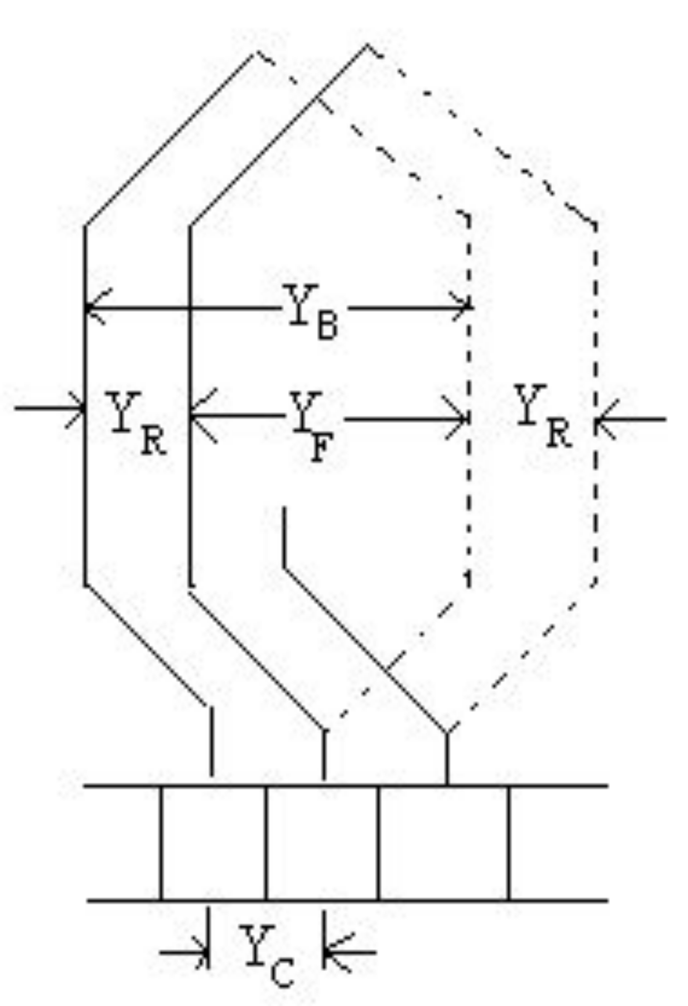

Commutators
Brush

CONSTRUCTION OF MACHINE

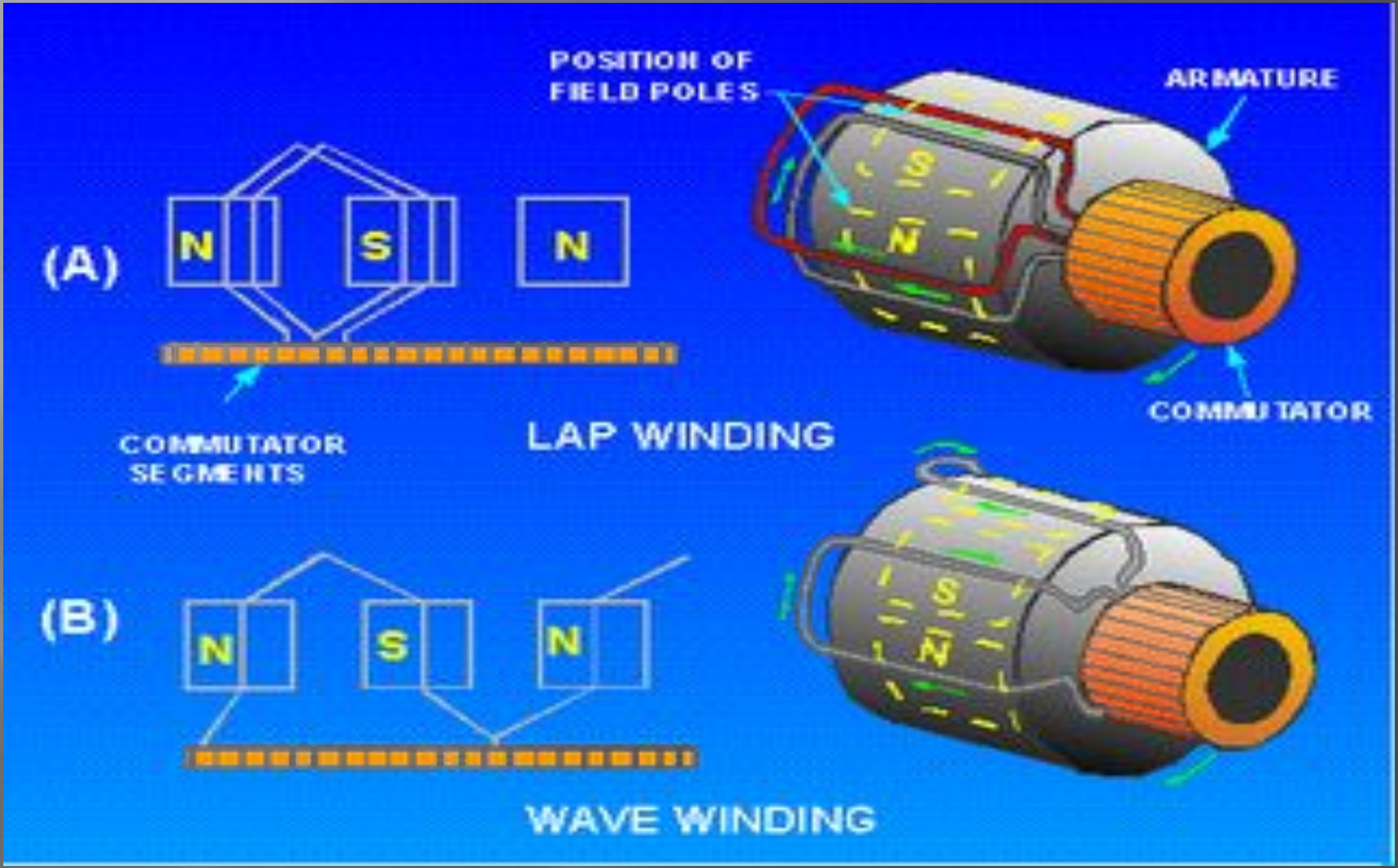


ARMATURE WINDING

- **Pole pitch (Y_P)**
  = No. of conductors per pole.
- **Front Pitch (Y_F)**
  = No. of conductors between two conductors which are connected to the same commutator.
- **Back Pitch (Y_B)**
  = No. of conductors between two conductors of any coil.
- **Resultant Pitch (Y_R)**
  = No. of conductors between first conductor of first coil and first conductor of second coil.
- **Commutator Pitch (Y_C)**
  = No. of commutator segments between two segments at which two conductors of one coil is connected.



TYPES OF ARMATURE WINDING



E.M.F. EQUATION

Let

$\varnothing$ = flux/pole in Wb

Z = total number of armature conductors

P = number of poles

A = number of parallel paths

= 2 ... for wave winding

= P ... for lap winding

N = speed of armature in r.p.m.

Eg = e.m.f. of the generator

= e.m.f./par allel path

Flux cut by conductor in one revolution of armature,

$$d\phi = P\phi$$

Time taken to complete one revolution ,

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

E.M.F. generated per conductor,

$$E = \frac{d\phi}{dt} = \frac{P\phi}{\left(\frac{60}{N}\right)} = \frac{P\phi N}{60}$$

E.M.F. of generator,

$$E_g = \text{E.M.F. per conductor} \times \text{No. of conductor per parallel path}$$

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

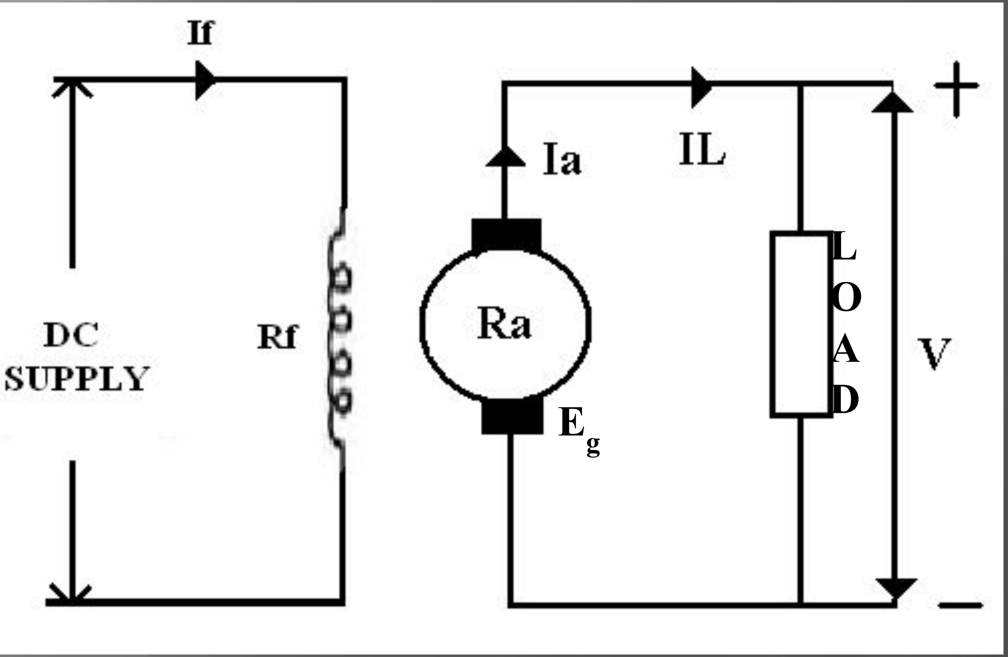
$$E_g = \left(\frac{P\phi ZN}{60A}\right)$$

Where, A = 2 for wavw winding

A = P for lap winding

TYPES OF DC GENERATOR

SEPERATELY EXCITED GENERATOR



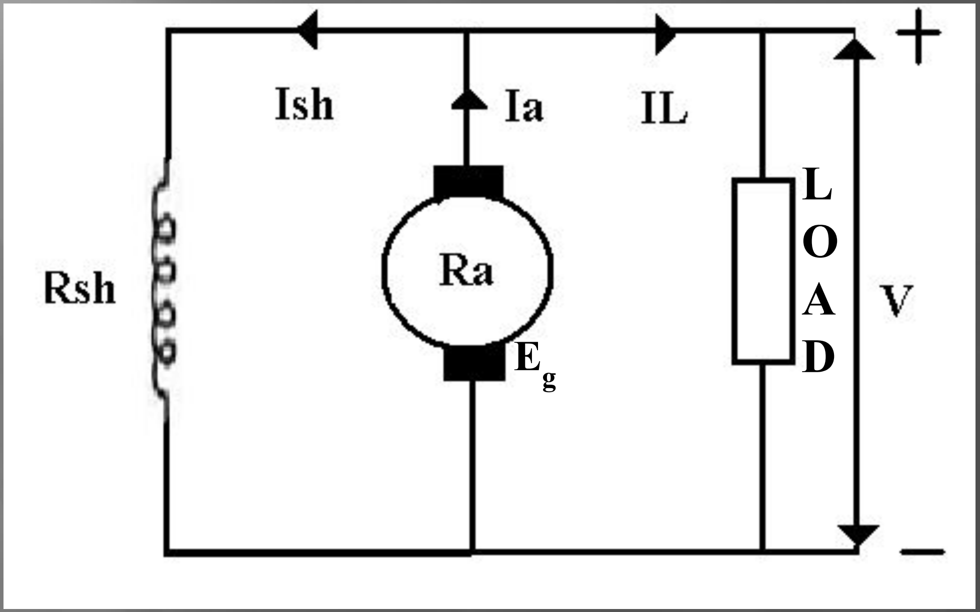
Armature current, $I_a = I_L$

Terminal voltage, $V = E_g - I_a R_a$

Electric power developed $= E_g I_a$

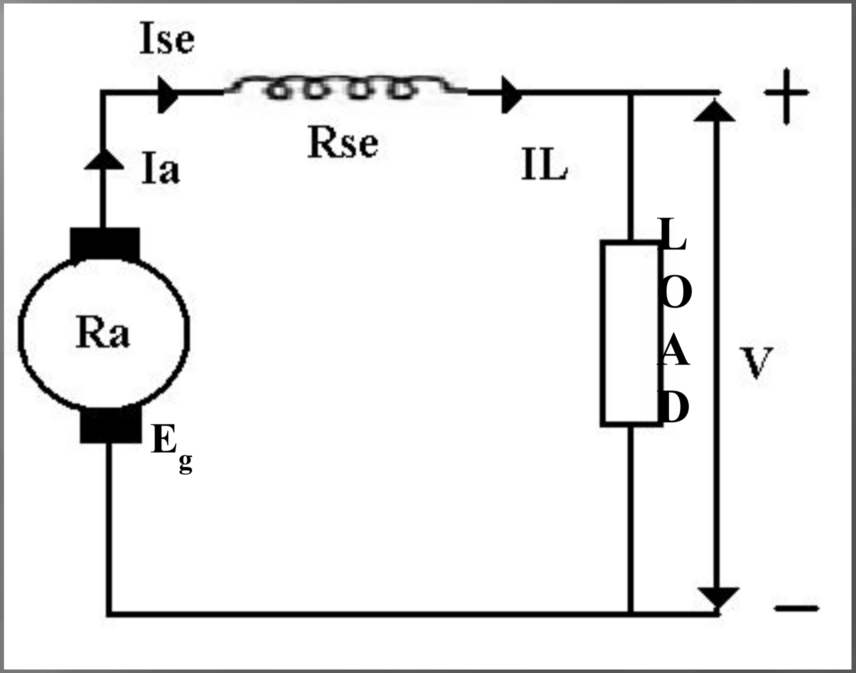
Power delivered to load $= E_g I_a - I_a^2 R_a = I_a\left(E_g - I_a R_a\right) = VI_a$

SELF EXCITED SHUNT GENERATOR



Shunt field current, $I_{sh} = V/R_{sh}$
Armature current, $I_a = I_L + I_{sh}$
Terminal voltage, $V = E_g - I_aR_a$
Power developed in armature $= E_gI_a$
Power delivered to load $= VI_L$

SELF EXCITED SERIES GENERATOR



Armature current, $I_a = I_{se} = I_L = I(\text{say})$

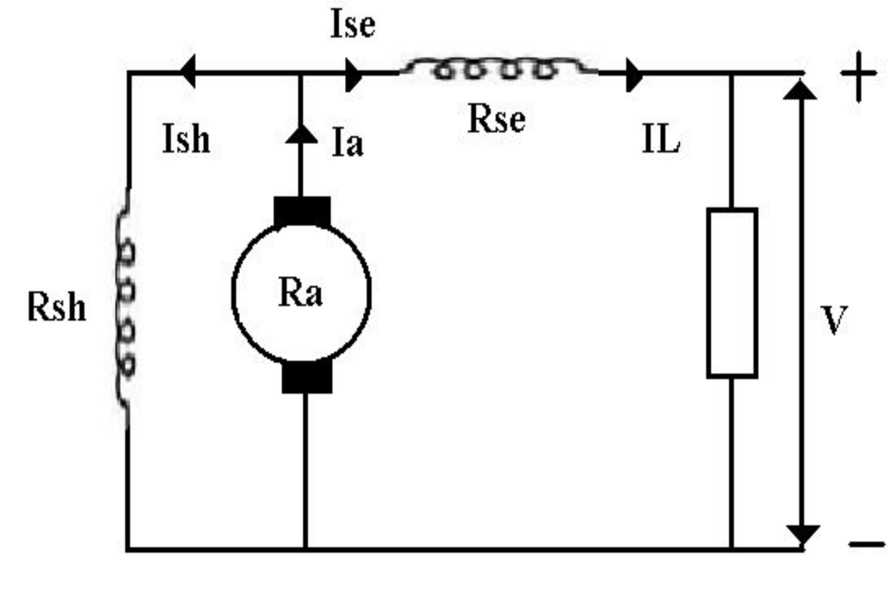
Terminal voltage, $V = E_G - I(R_a + R_{se})$

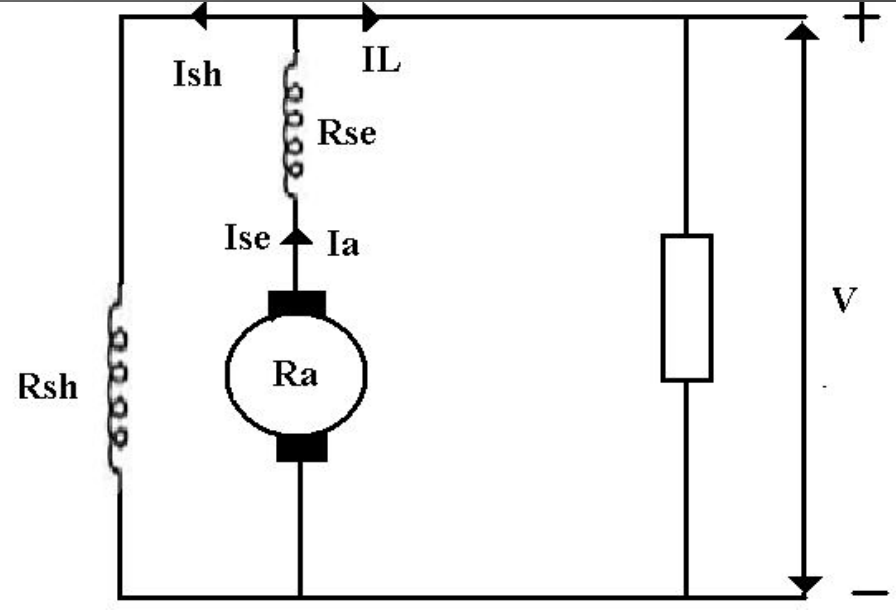
Power developed in armature = $E_g I_a$

Power delivered to load

$$= E_g I_a - I_a^2(R_a + R_{se}) = I_a\left[E_g - I_a(R_a - R_{se})\right] = VI_a \text{ or } VI_L$$

SELF EXCITED COMPOUND GENERA.





Short shunt

Series field current, $I_{se} = I_L$

Shunt field current, $I_{sh} = \dfrac{V + I_{se}R_{se}}{R_{sh}}$

Terminal voltage, $V = E_g - I_aR_a - I_{se}R_{se}$

Power developed in armature $= E_gI_a$

Power delivered to load $= VI_L$

Long shunt

Series field current, $I_{se} = I_a = I_L + I_{sh}$

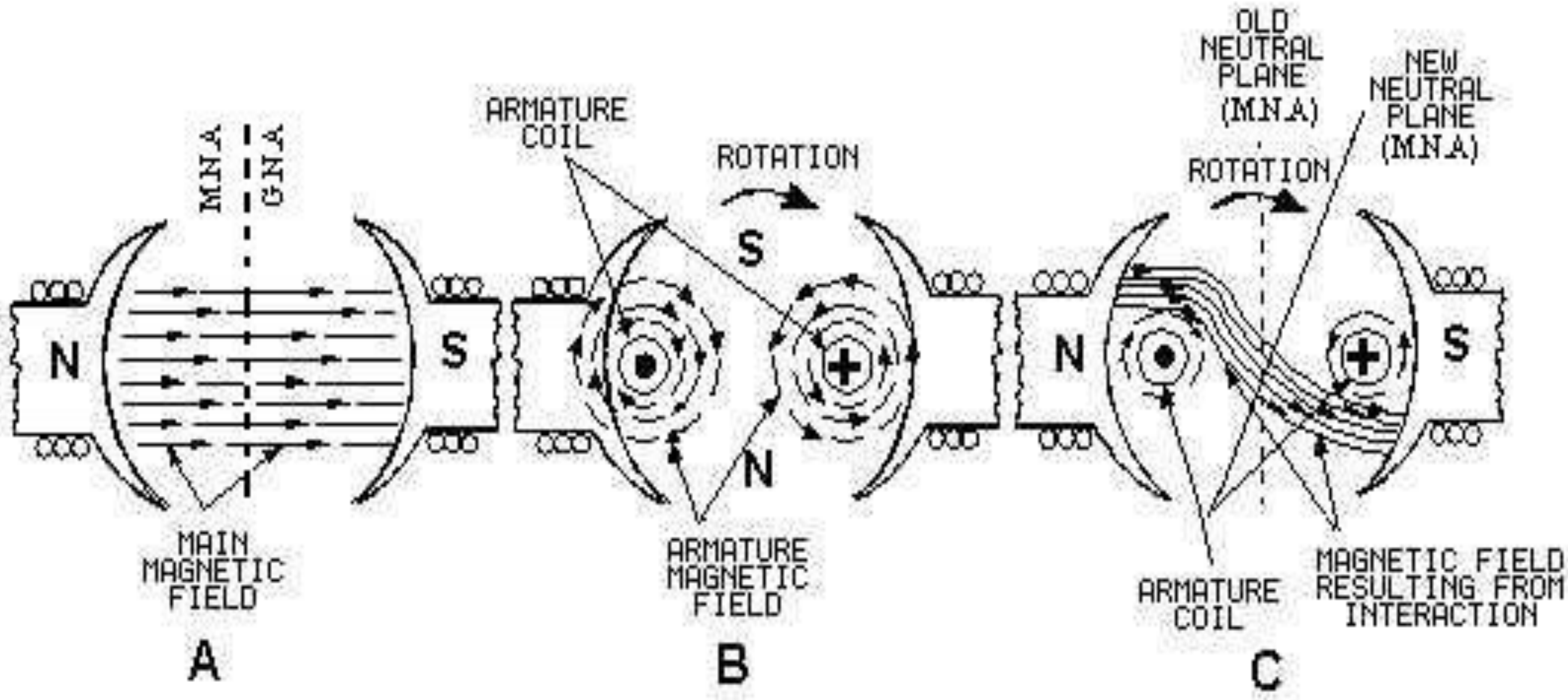
Shunt field current, $I_{sh} = V/R_{sh}$

Terminal voltage, $V = E_g - I_a(R_a + R_{se})$

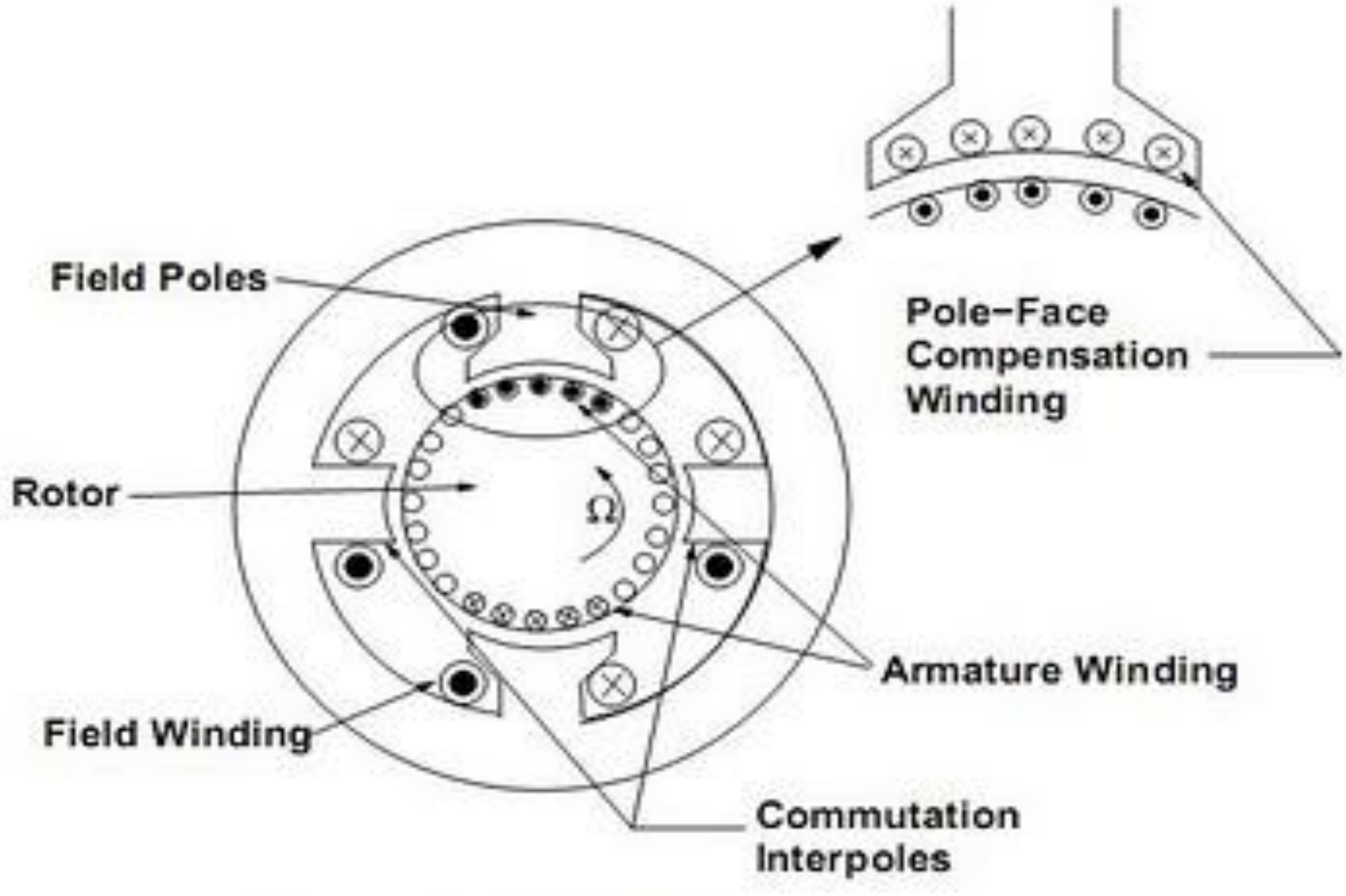
Power developed in armature $= E_gI_a$

Power delivered to load $= VI_L$

ARMATURE REACTION

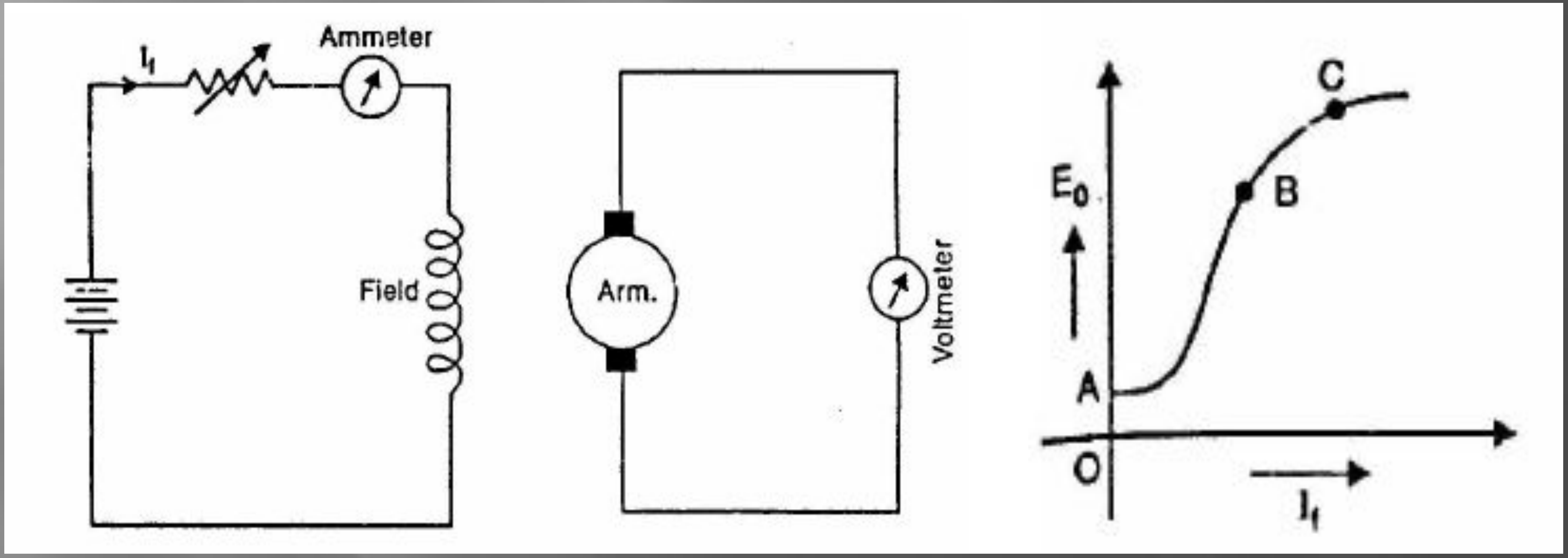


COMPENSATING WINDING



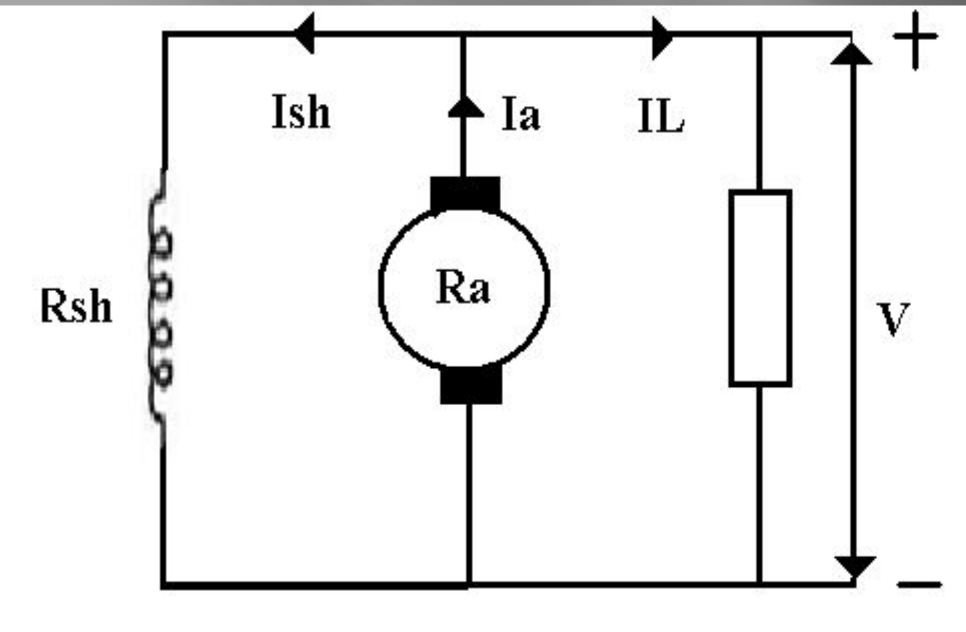
Pole Face Compensation Winding

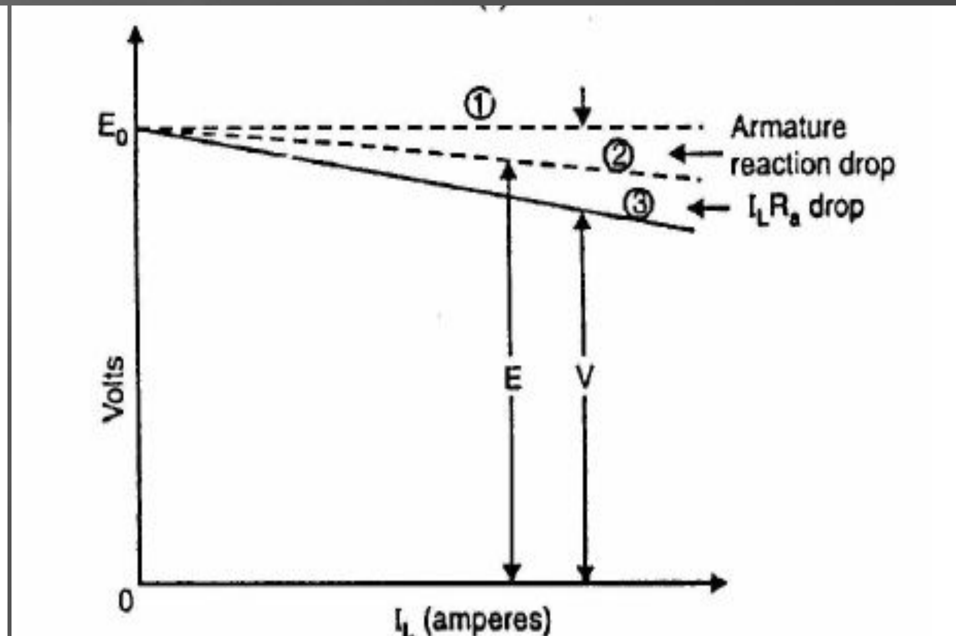
OPEN CIRCUIT CHARACTERISTIC



CHARACTERISTIC

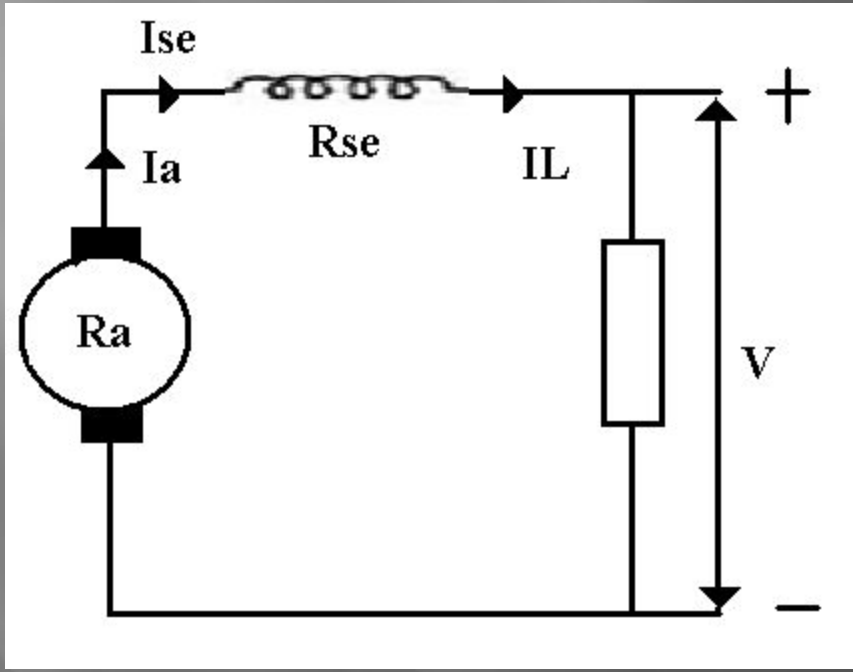
SHUNT GENERATOR

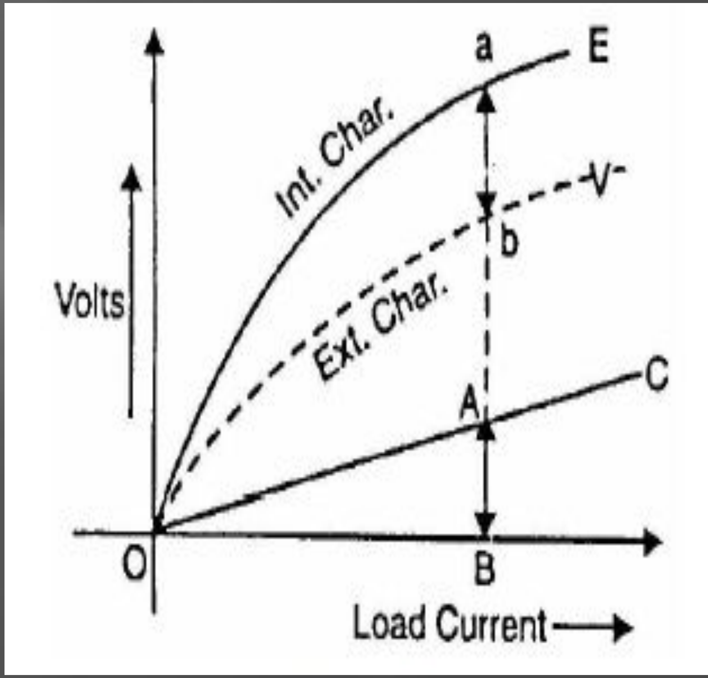




CHARACTERISTIC

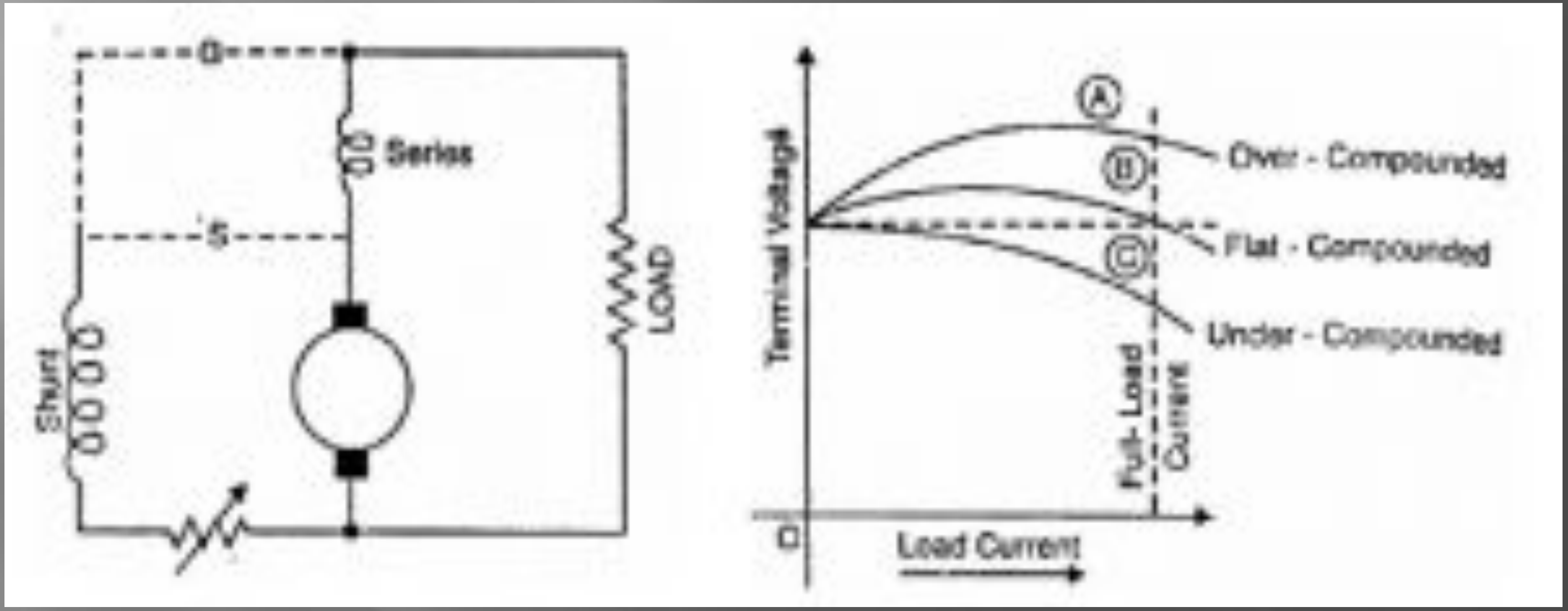
SERIES GENERATOR





CHARACTERISTIC

COMPOUND GENERATOR



VOLTAGE REGULATION

- The change in terminal voltage of a generator between full and no load (at constant speed) is called the voltage regulation.

$$\boxed{\%\ \text{Voltage regulation} = [\,(V_{NL} - V_{FL})/V_{FL}\,] \times 100}$$

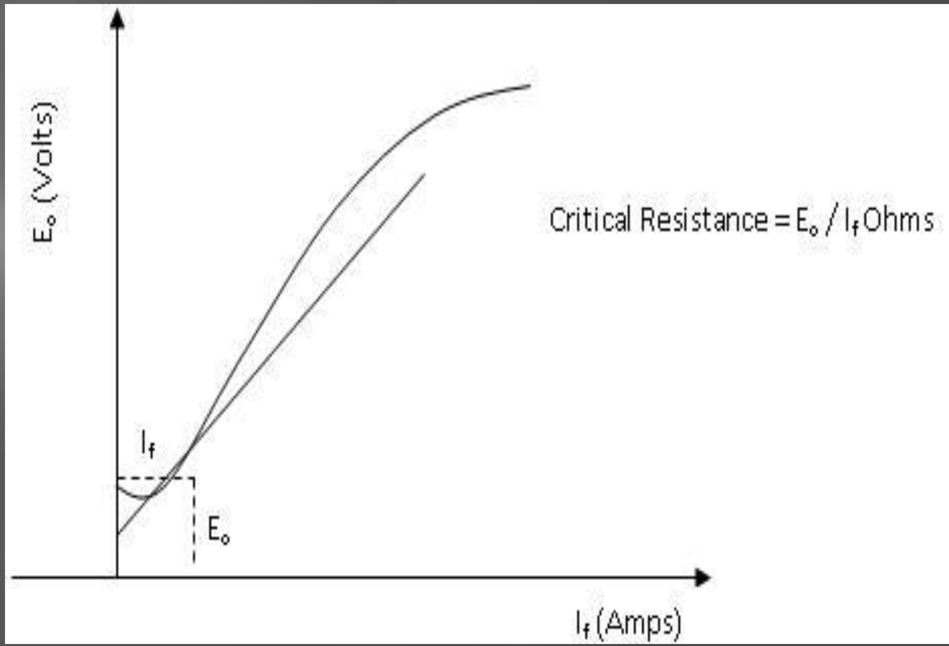
Where,

V_{NL} = Terminal voltage of generator at no load

V_{FL} = Terminal voltage of generator at full load

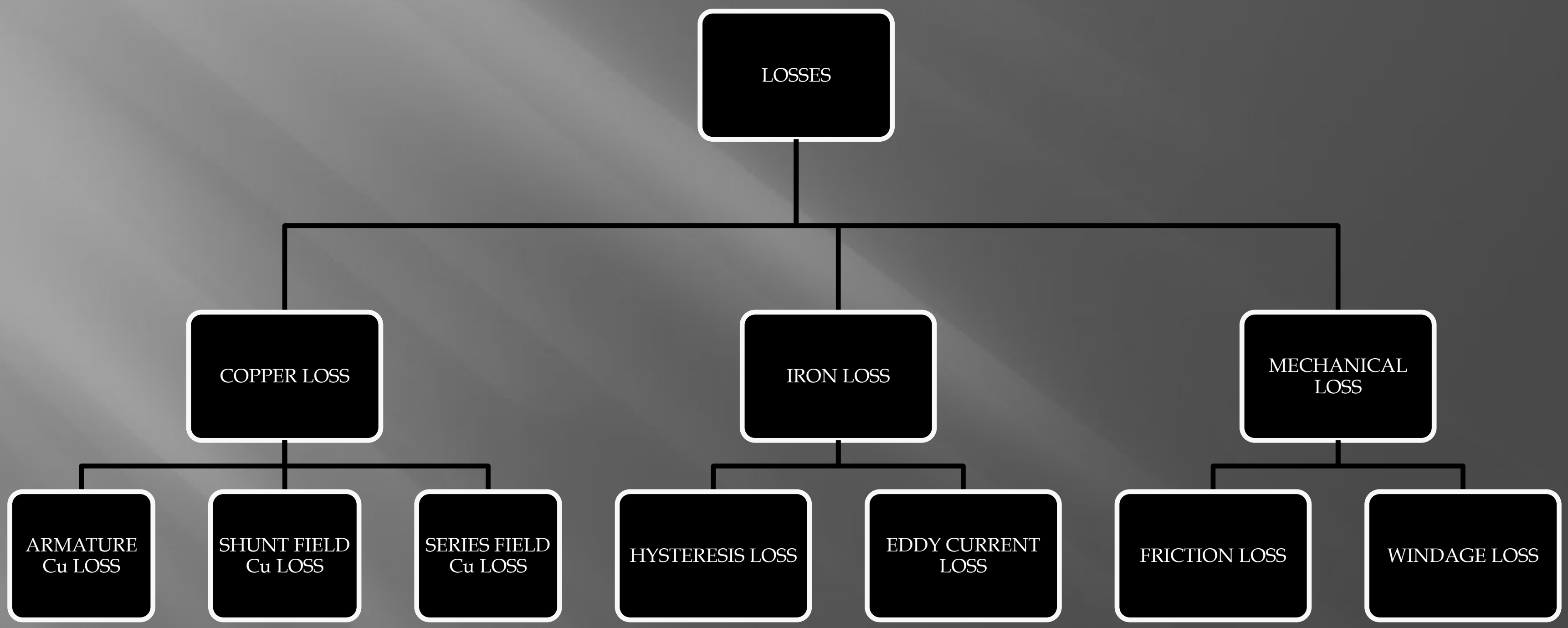
CAUSE OF FAILURE TO BUILD UP VOLTAGE

1. No residual magnetic field
2. Reversal of field connection
3. Reversal of rotation
4. In series motor load resistance is more than critical resistance.
5. In shunt motor shunt field resistance I more than critical resistance.



EXPLAIN LOSSES IN DC MACHINE

LOSSES

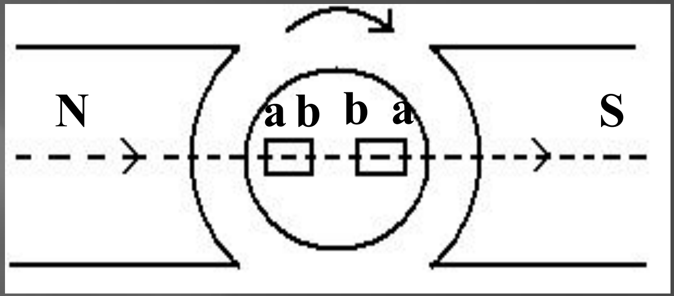

LOSSES
COPPER LOSS
IRON LOSS
MECHANICAL LOSS
ARMATURE Cu LOSS
SHUNT FIELD Cu LOSS
SERIES FIELD Cu LOSS
HYSTERESIS LOSS
EDDY CURRENT LOSS
FRICTION LOSS
WINDAGE LOSS

COPPER LOSS

- Armature cu loss = Ia^2Ra
  - Ia = Armature Current
  - Ra = Armature Resistance
- Shunt Field cu loss = Ish^2Rsh
  - Ish = Shunt Field Current
  - Rsh = Shunt Field Resistance
- Series Field cu loss = Ise^2Rse
  - Ise = Series Field Current
  - Rse = Series Field Resistance

HYSTERESIS LOSS

- Consider a small piece ab of the armature.
- When the piece ab is under N-pole, the magnetic lines pass from a to b.
- Half a revolution later, the same piece of iron is under S-pole and magnetic lines pass from b to a.
- so that magnetism in the iron is reversed.
- In order to reverse continuously the molecular magnets in the armature core, some amount of power has to be spent which is called hysteresis loss.
- It is given by Steinmetz formula.



HYSTERESIS LOSS

$$\boxed{P_h = \eta B_{max}^{1.6} f V}$$

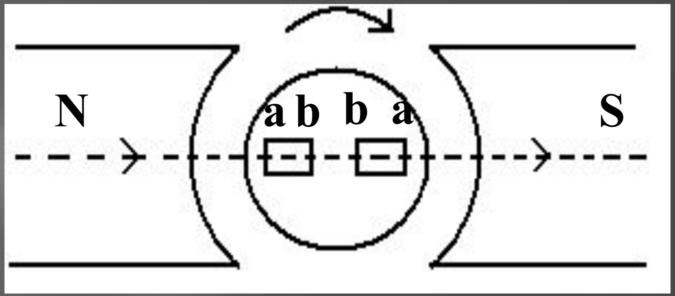
Where,

η = Steinmetz constant

B_{max} = Maximum Flux Density

f = Frequency

V = Volume of armature



- The hysteresis loss is minimized by selecting the core material having low hysteresis coefficient.

EDDY CURRENT LOSS

- When armature core rotates, it cuts the magnetic flux and e.m.f. gets induced in the core.
- This induced e.m.f. sets up eddy currents which cause the power loss.
- This loss is given by,

$$\boxed{P_e = K_e B_{max}^{2} f^{2} t^{2} V}$$

Where,

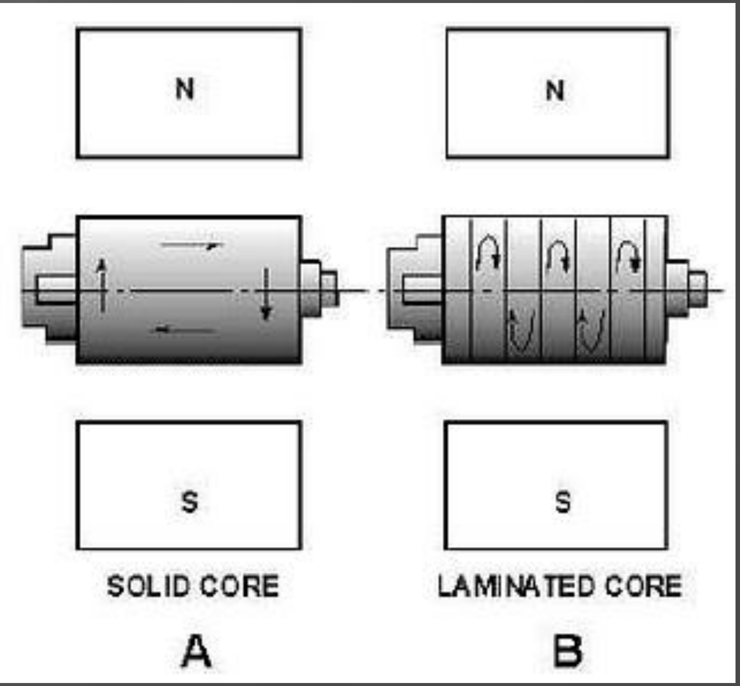
K_e = Constant

B_{max} = Maximum Flux Density

f = Frequency

t = Thickness of Lamination

V = Volume of armature



- eddy current loss is minimized by selecting the laminated construction for the core.

MECHANICAL LOSS

- These losses consist of friction and windage losses.
- Some power is required to overcome mechanical friction and wind resistance at the shaft.
- This loss is nothing but the friction and windage loss.
- The mechanical losses are also constant for a d.c.

- The magnetic and mechanical losses together are called stray losses.
- For the shunt and compound d.c. machines where field current is constant, field copper losses are also constant.
- Thus stray losses along with constant field copper losses are called constant losses.
- While the armature current is dependent on the load and thus armature copper losses are called variable losses.
- Thus for d.c. machine,

Total losses = Constant losses + Variable losses

POWER FLOW CHART

MECHANICAL POWER INPUT

IRON LOSS	WINDAGE LOSS	FRICTION LOSS

↓

ELECTRICAL POWER DEVELOPED IN ROTOR = $E_g I_a$

Cu LOSS

↓

ELECTRICAL POWER OUTPUT = VI_L

EFFICIENCY

- MECHANICAL EFFICIENCY

$$\eta_m = \frac{B}{A} = \frac{E_g I_a}{\text{Mechanical power input}}$$

- ELECTRICAL EFFICIENCY

$$\eta_e = \frac{C}{B} = \frac{V\, I_L}{E_g\, I_a}$$

- COMMERCIAL & OVERALL EFFICIENCY

$$\eta_c = \frac{C}{A} = \frac{V\, I_L}{\text{Mechanical power input}}$$

Clearly $\eta_c = \eta_m \times \eta_e$

APPLICATION

SHUNT GENERATOR

- OUTPUT IS CONSTANT

  SO, USE FOR CONSTANT OUTPUT PURPOSE.
- FOR BATTERY CHARGING AND LIGHTNG PURPOSE.

SERIES GENERATOR

- OUTPUT IS VARY WITH LOAD

  SO, USE AS A VOLTAGE BOOSTER
- USE IN ELECTRIC TRAINS.

CUMULATIVE COMPOUND GENERATOR

- FOR LIGHTENING AND POWER SERVICES

DIFFERENTIAL COMPOUND GENERATOR

- FOR ARC WELDING GENERATOR

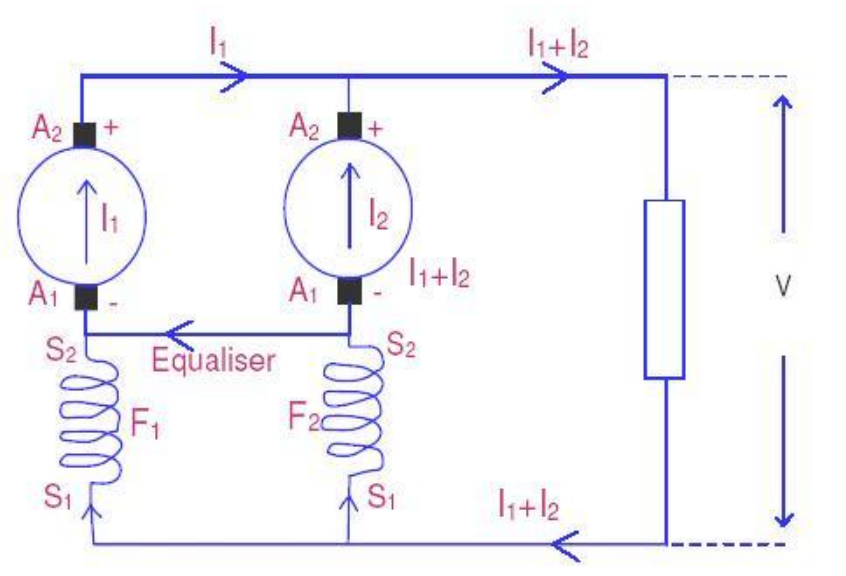
PARALLEL OPERATION

NEED OF PARALLEL OPERATION

1. Continuity of service
2. Efficiency
3. Maintenance and repair
4. Increasing plant capacity
5. Non-availability of single large unit

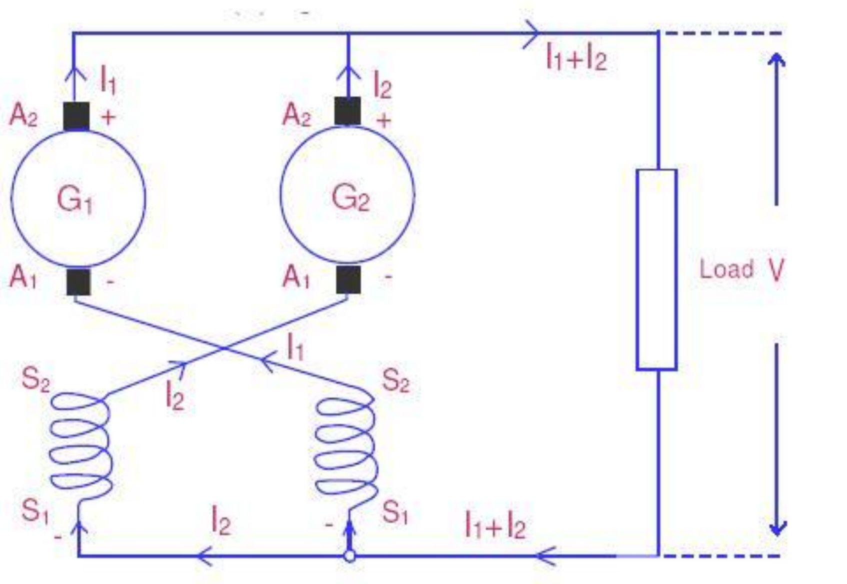
SERIES GENERATOR

WITH EQUALIZER CONNECTION



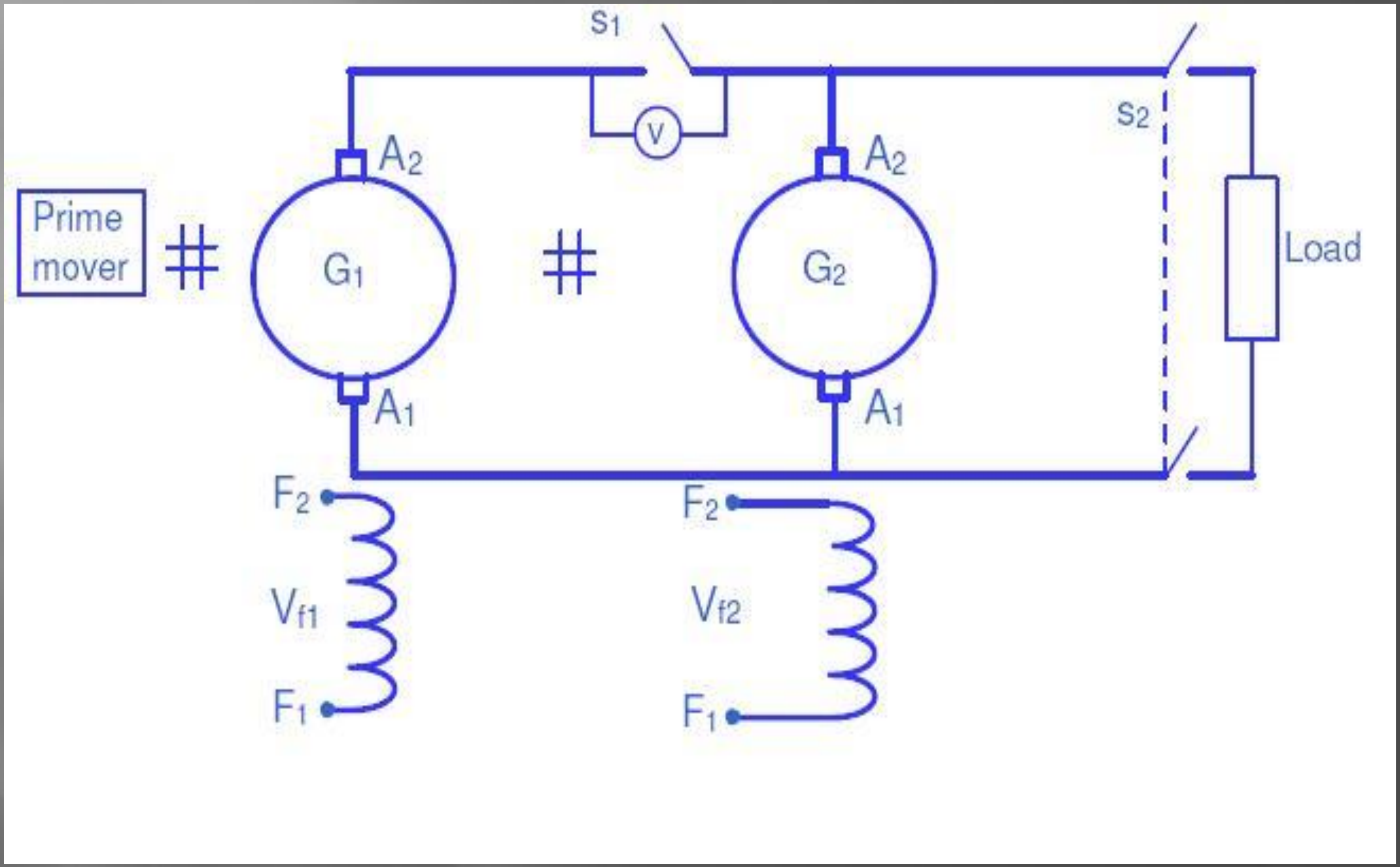
(a)Equalizer connection

WITH CROSS CONNECTION

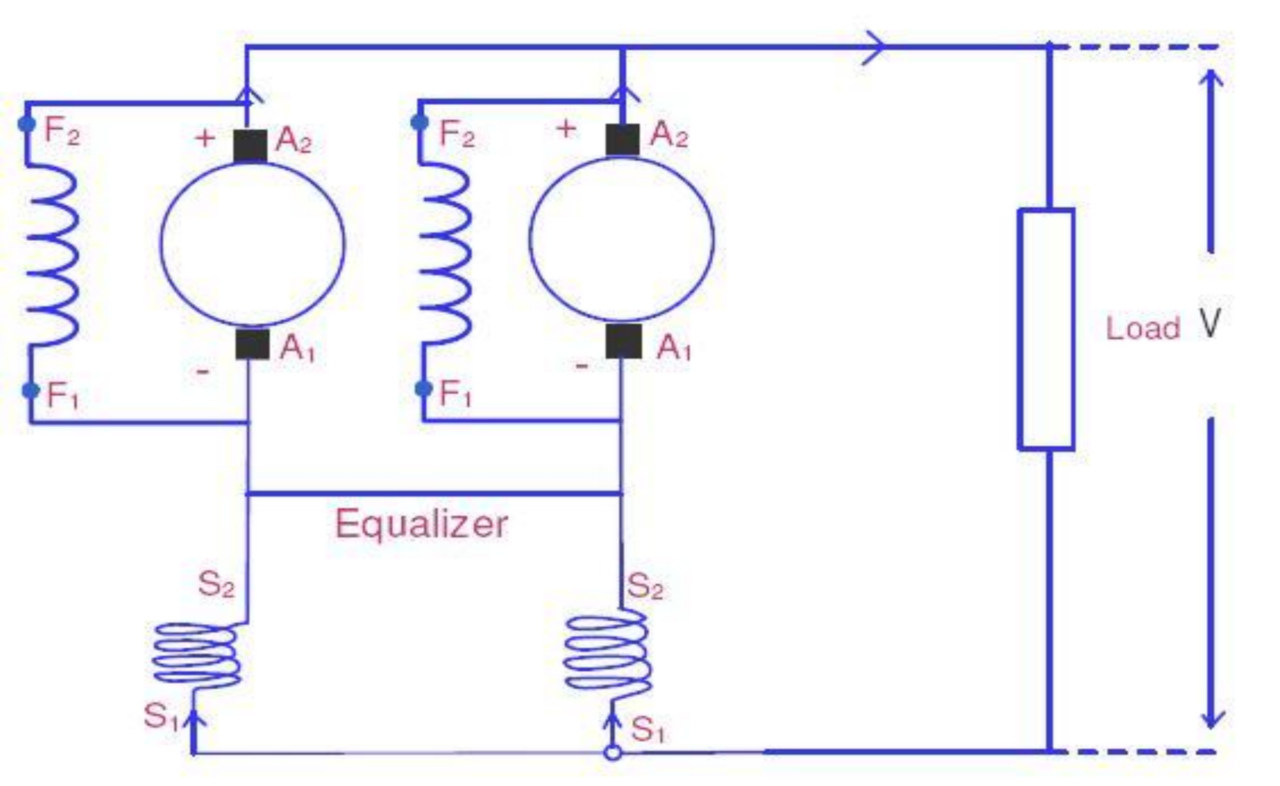


(b)Cross connection of fields

SHUNT GENERATOR



COMPOUND GENERATOR



(a)Equalizer connection