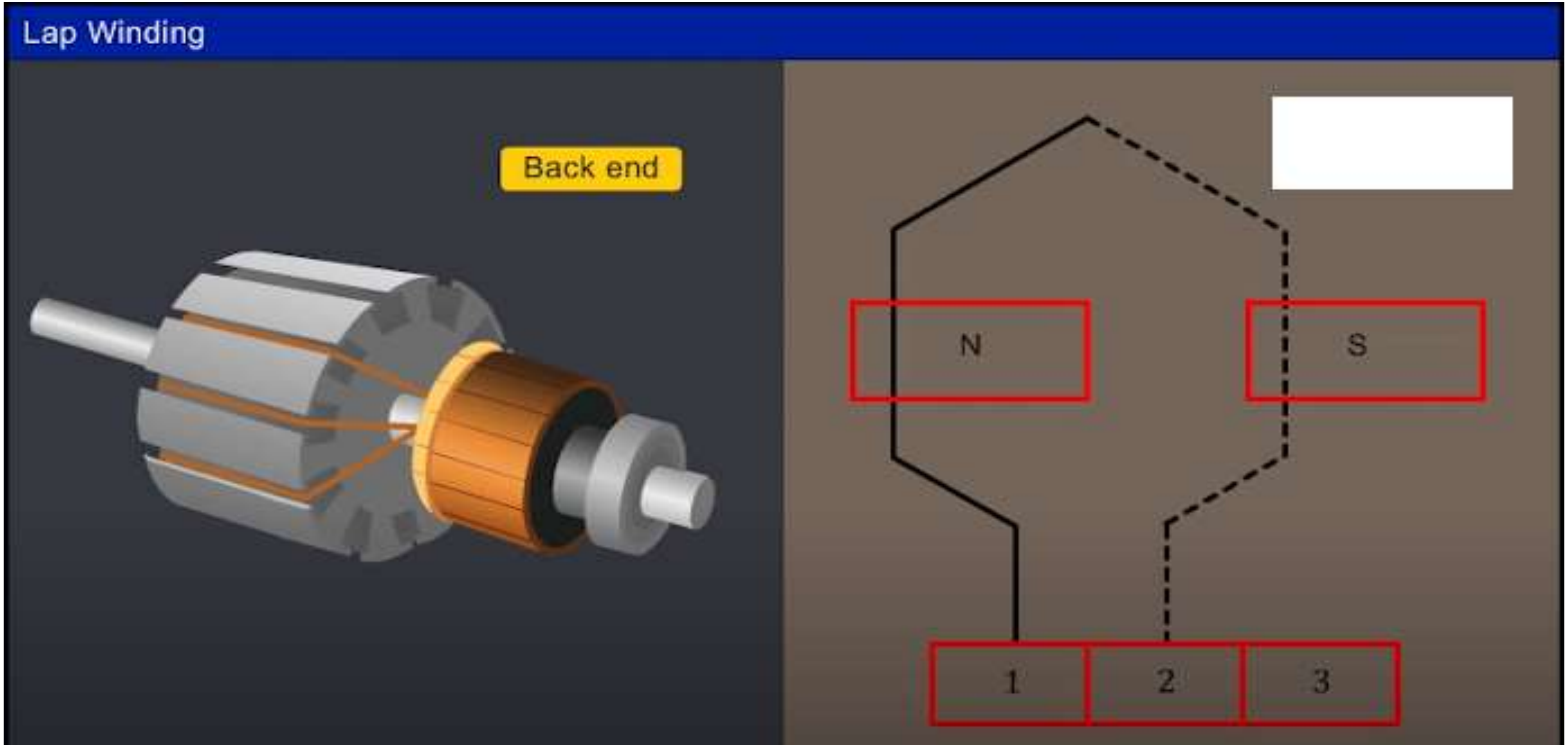
CONSTRUCTION OF DC MACHINE UNIT-III

BY S RATNA KUMAR

LAP WINDING



LAP WINDING AND WAVE WINDING

Lap Winding

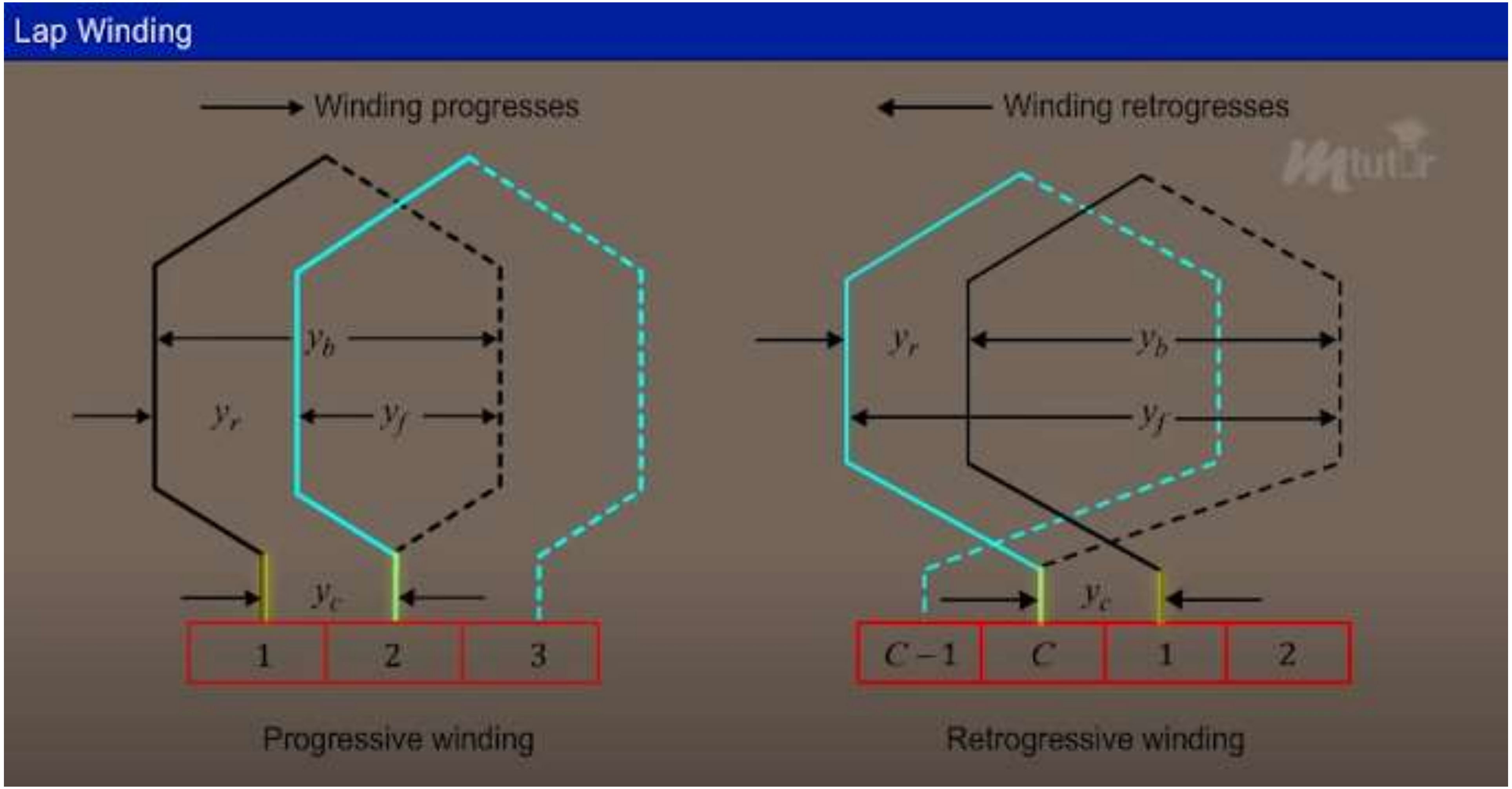
The ends of each armature coil are connected to adjacent segments on the commutator so that the total number of parallel paths is equal to the total number of poles. That is, for LAP winding A = P. This may be remembered by the letters A and P in LAP.

Wave Winding

The ends of each armature coil are connected to commutator segments some distance apart, so that only two parallel paths are provided between the positive and negative brushes. That is, for **WAVE** winding A = 2.

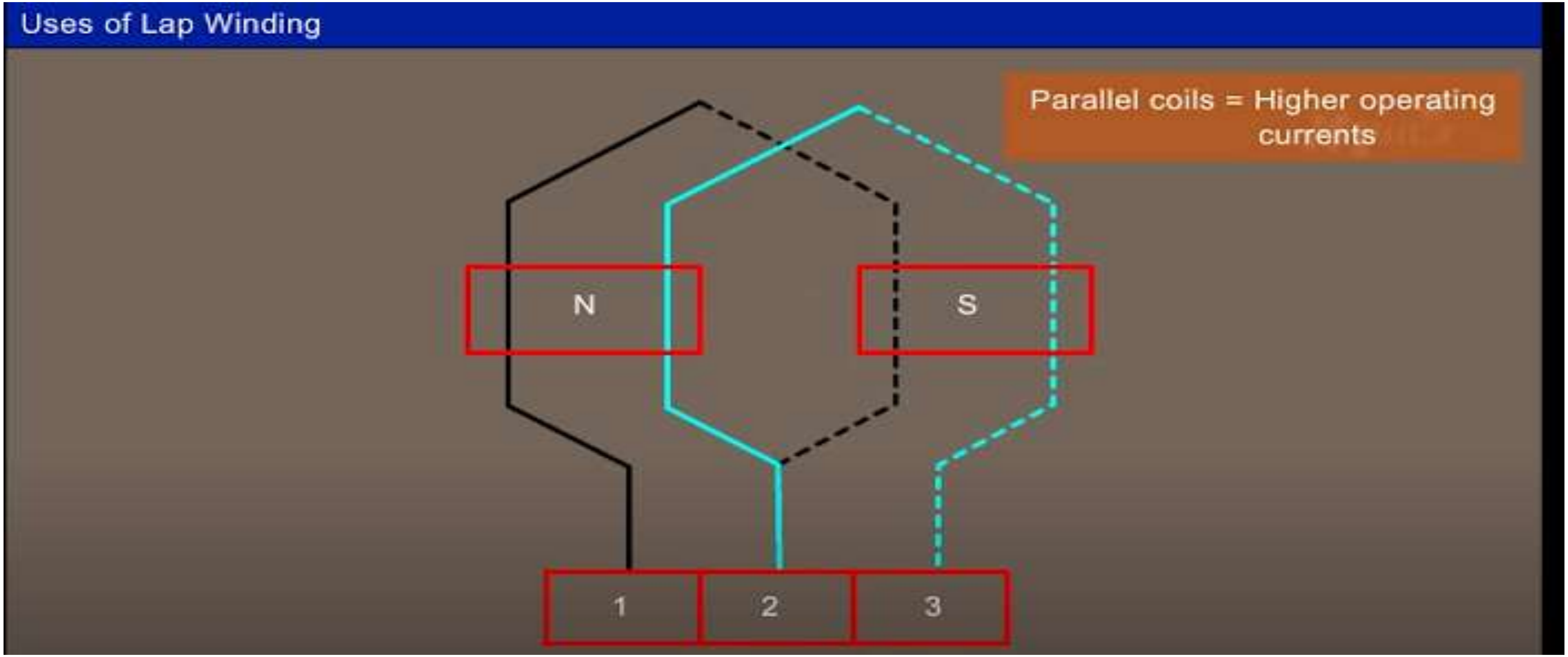
In general, the lap winding is used in low-voltage, high-current machines, and the wave winding is used in high-voltage, low-current machines.

WINDING PROGRESSES ,WINDING RETROGRESSES

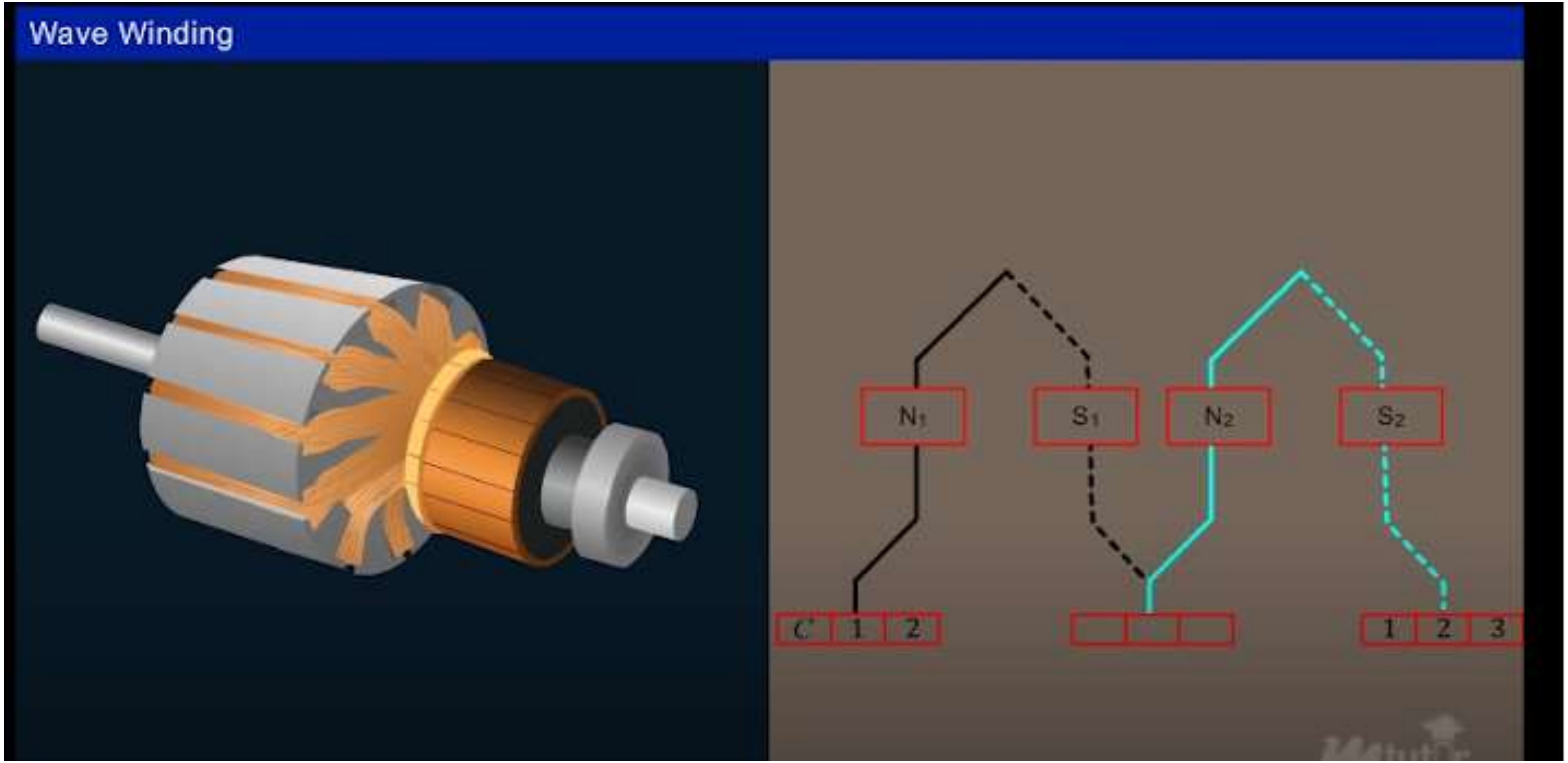


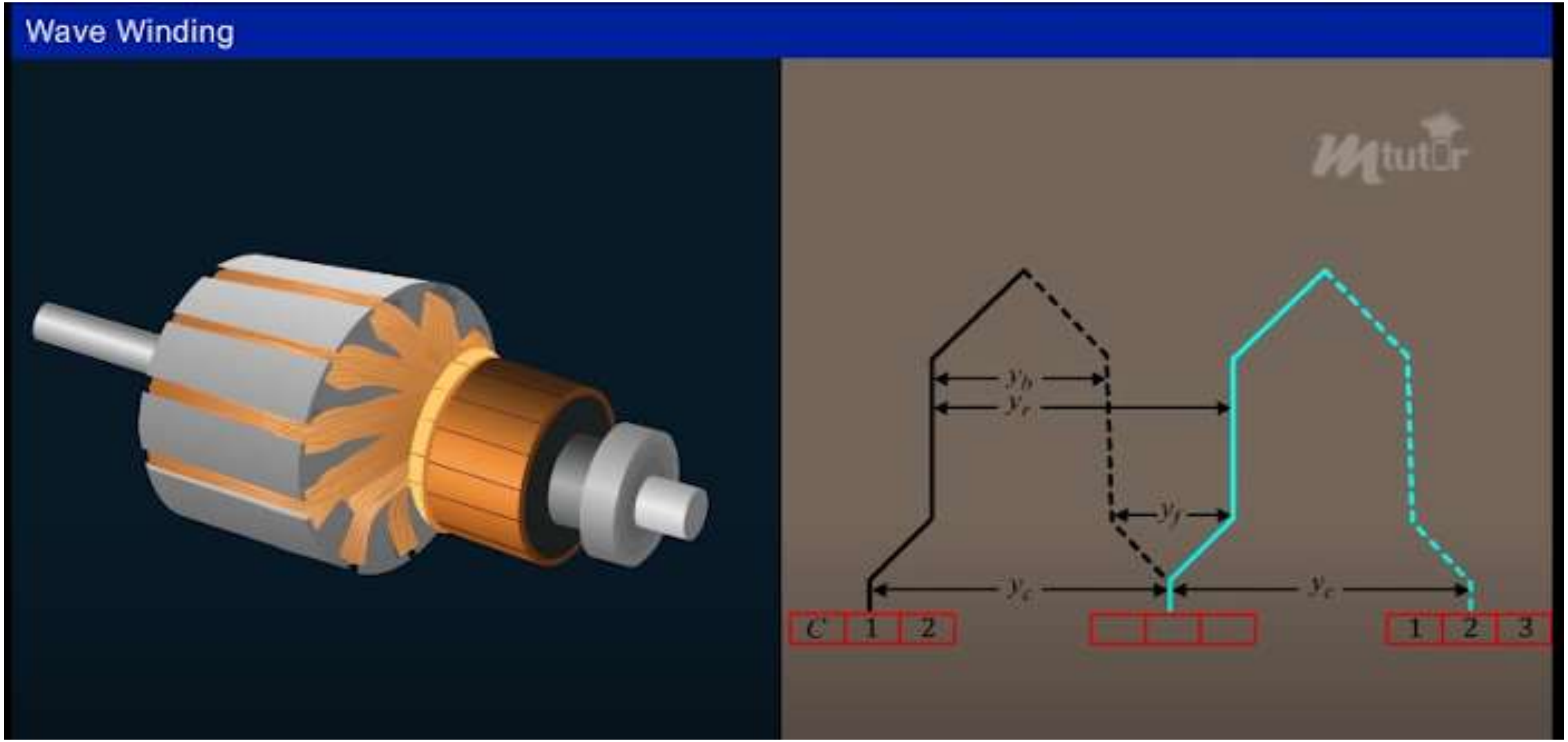
EQUALIZER RINGS

USES OF LAP WINDING

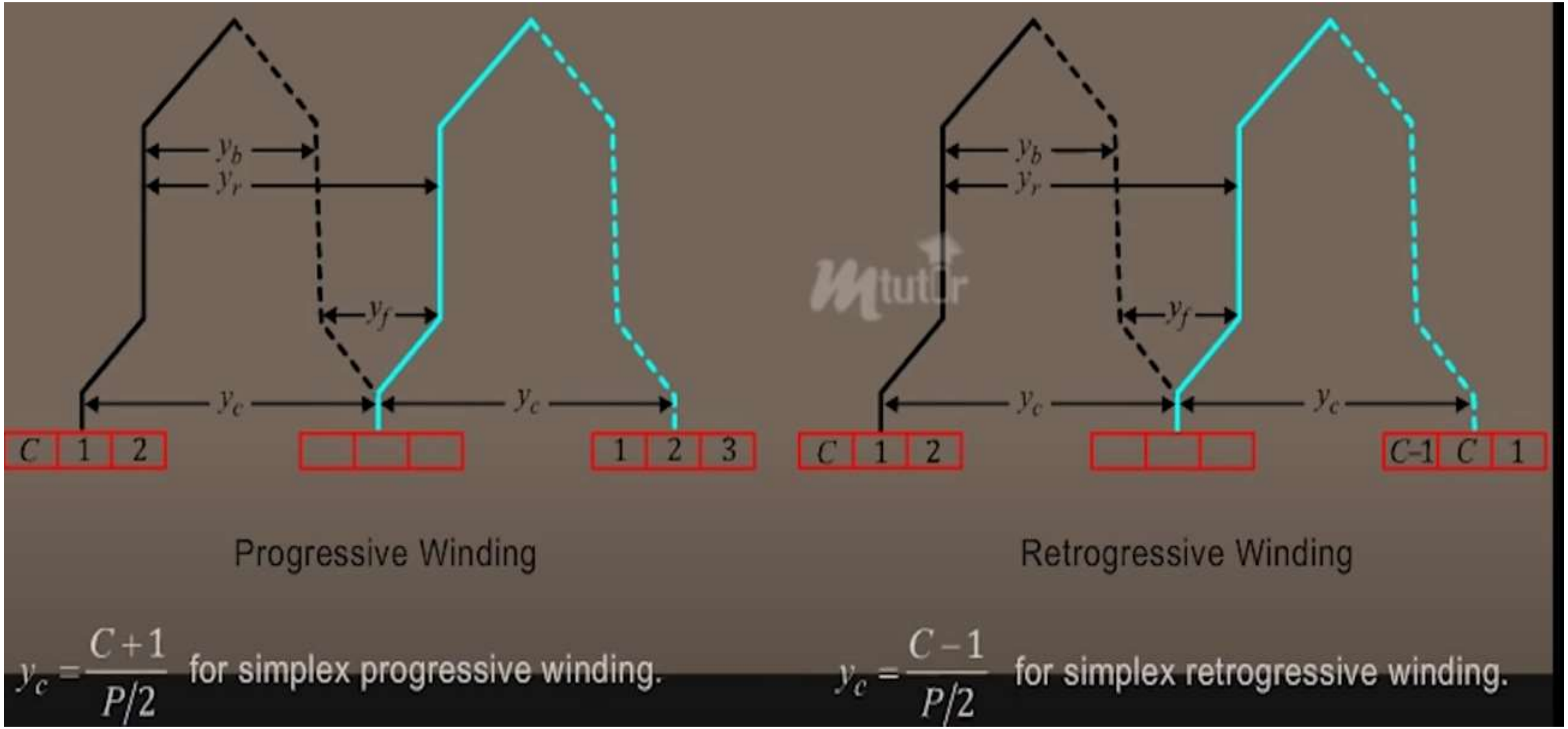


WAVE WINDING

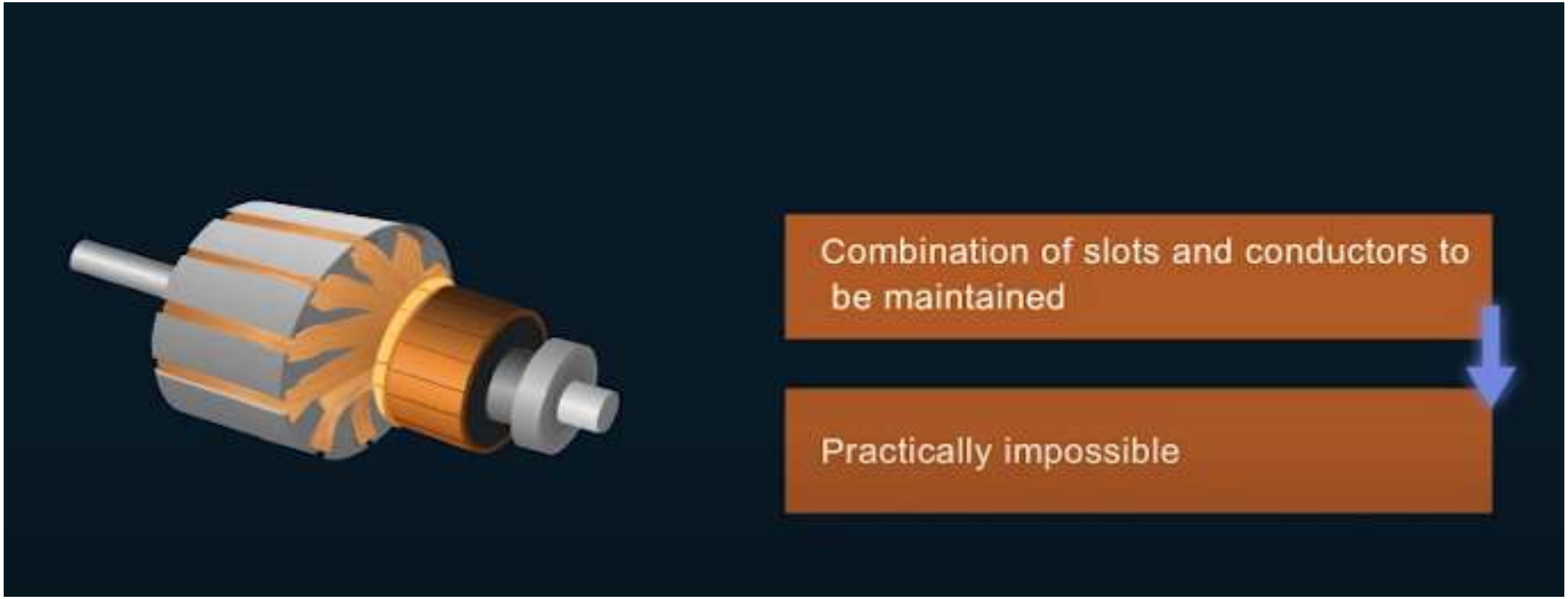



Wave Winding
y_b
y_r
y_f
y_c
y_c
C
1
2
1
2
3

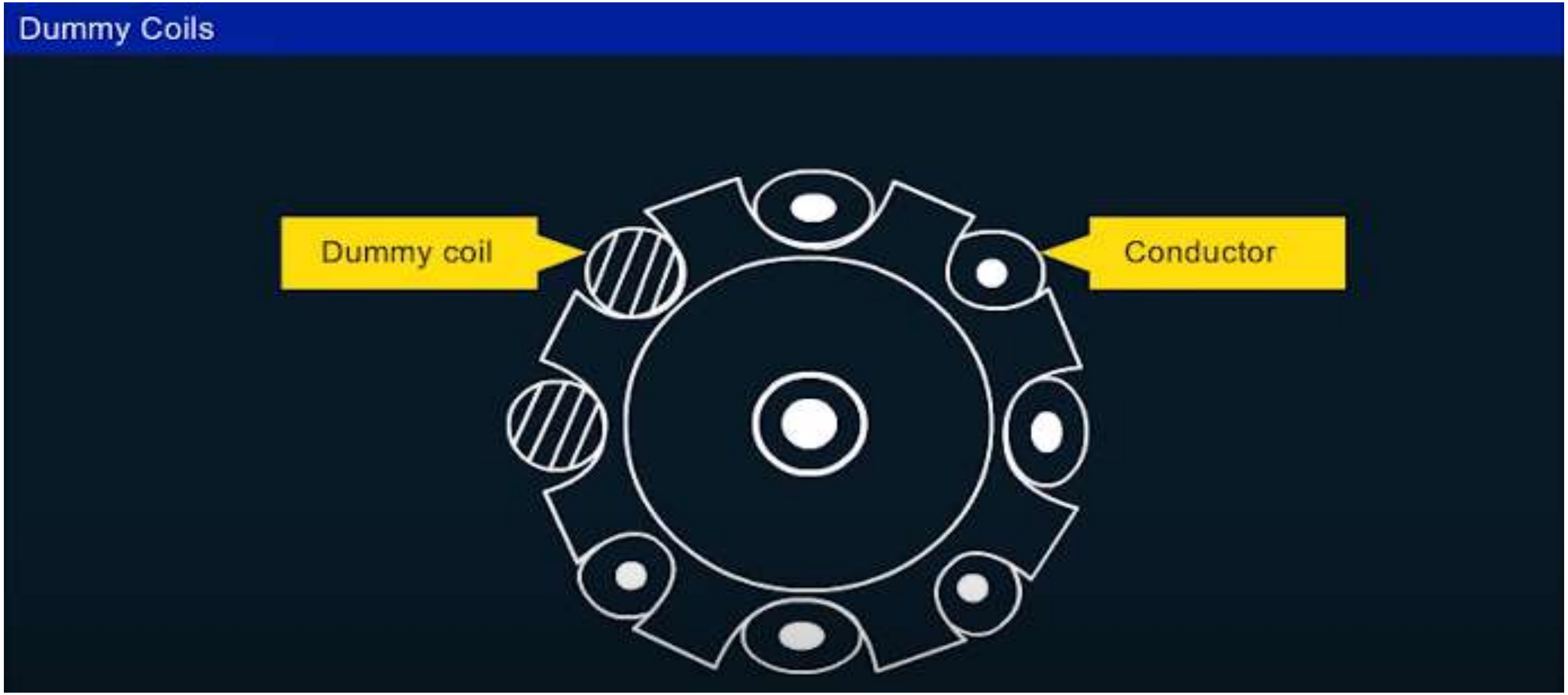
PROGRESSIVE WINDING,RETROGRESSIVE WINDING



DUMMY COILS


Combination of slots and conductors to be maintained
Practically impossible

DUMMY COILS

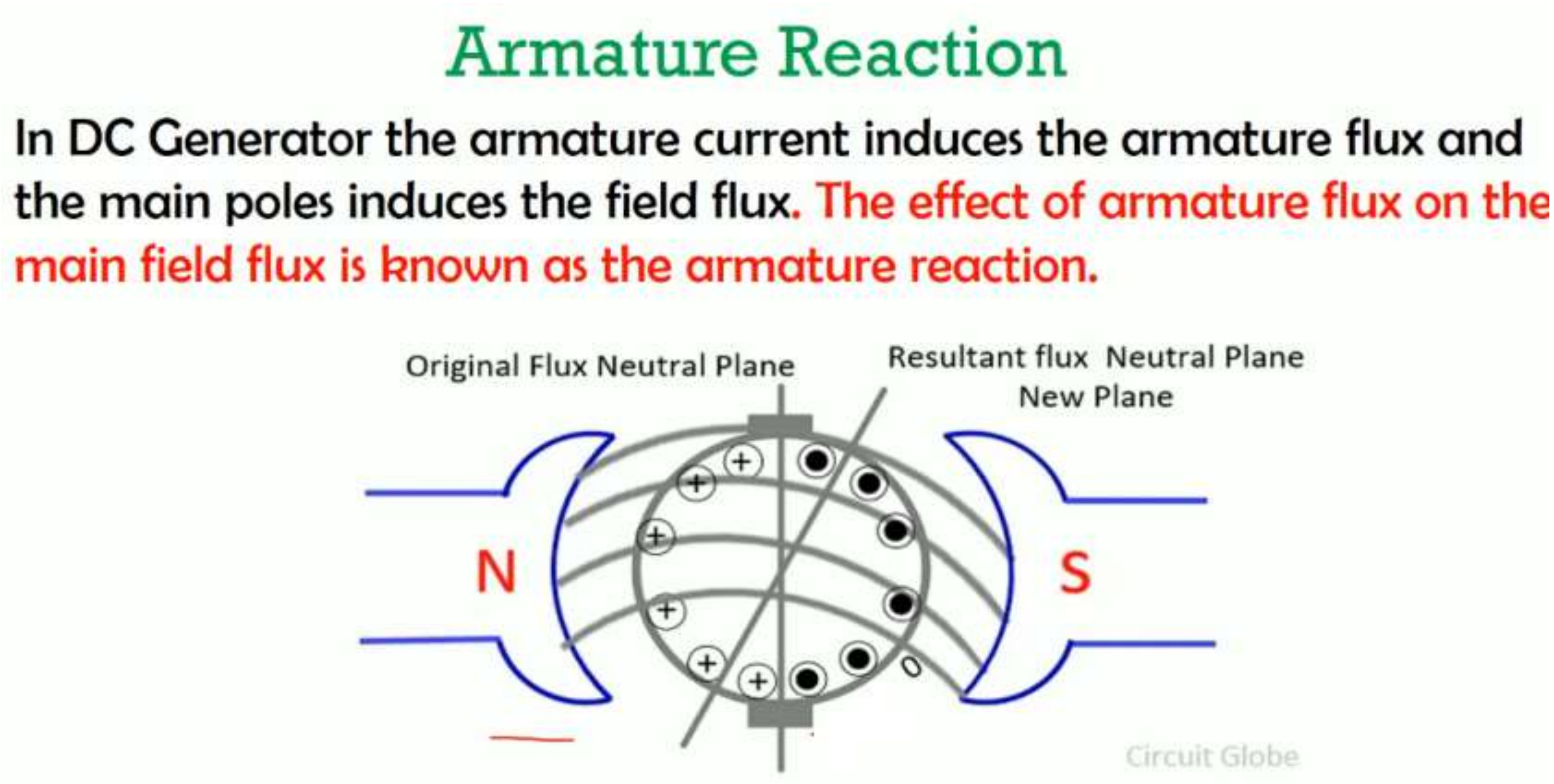


USES OF WAVE WINDING

LAP WINDING AND WAVE WINDING

Lap Winding	Wave Winding
Coils are connected in parallel.	Coils are connected in series.
Parallel winding.	Series winding.
No. of parallel paths (A) = No. of poles (P)	No. of parallel paths (A) = 2
Requires equalizer rings.	No necessity of equalizer rings.
Dummy coils are not required.	May require dummy coils.
Used in low voltage high current machines.	Used in high voltage low current machines.
Generates less emf.	Generates more emf.

ARMATURE REACTION

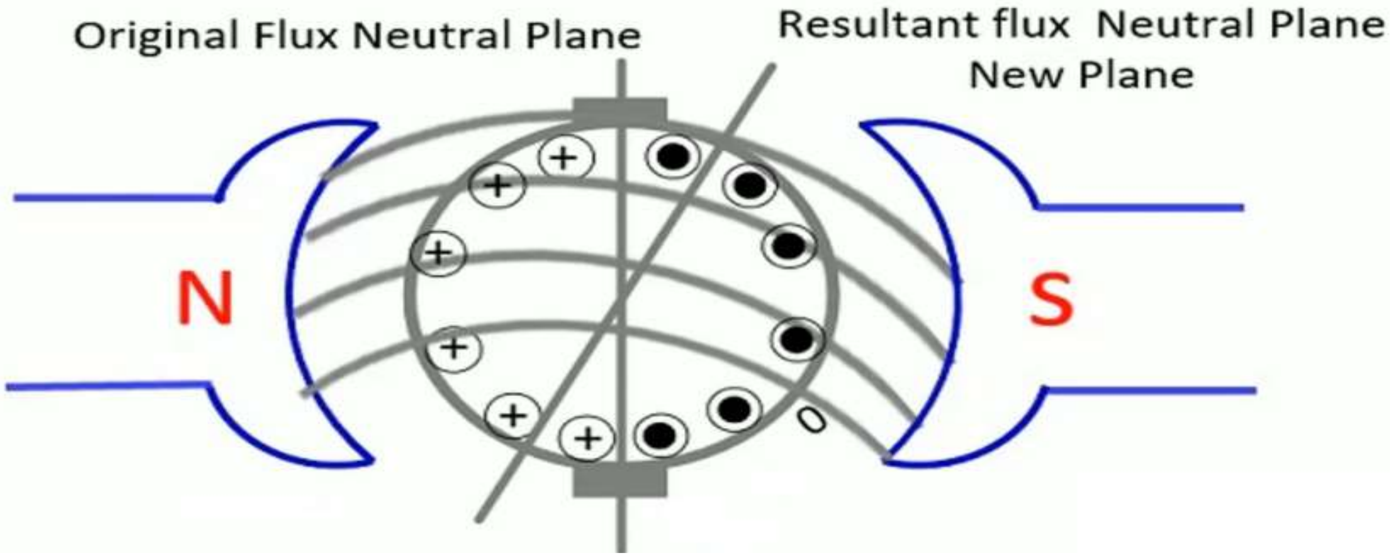


ARMATURE REACTION

Armature Reaction

The armature reaction has two effect on the main field.

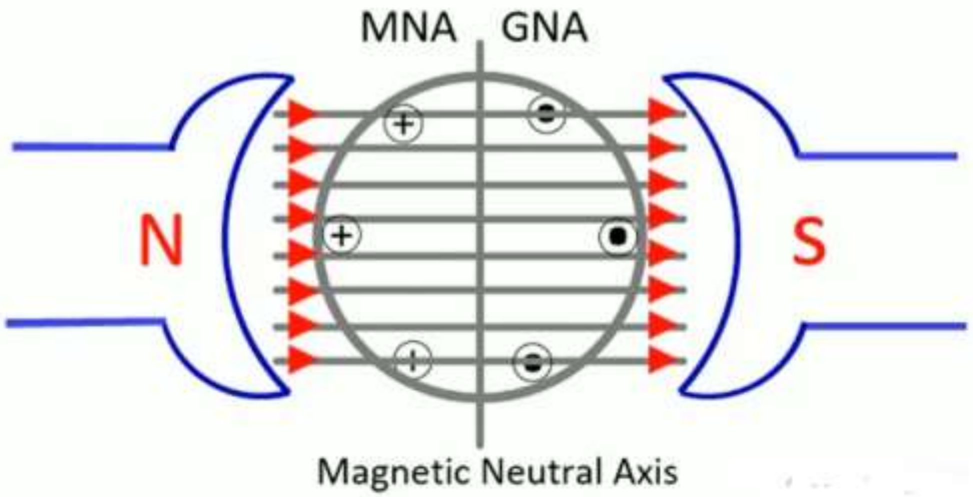
- The armature reaction distorted the main field.
- It demagnetised or weakens the main flux.



GNA ,MNA

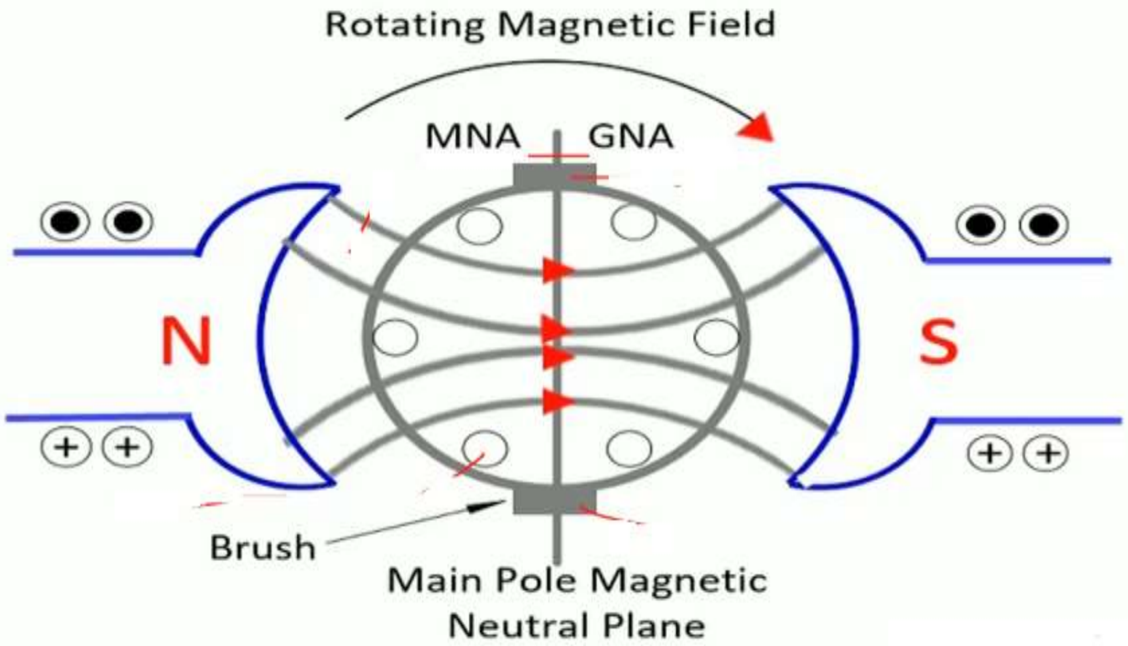
GNA - The geometrical neutral axis is perpendicular to the stator field axis .

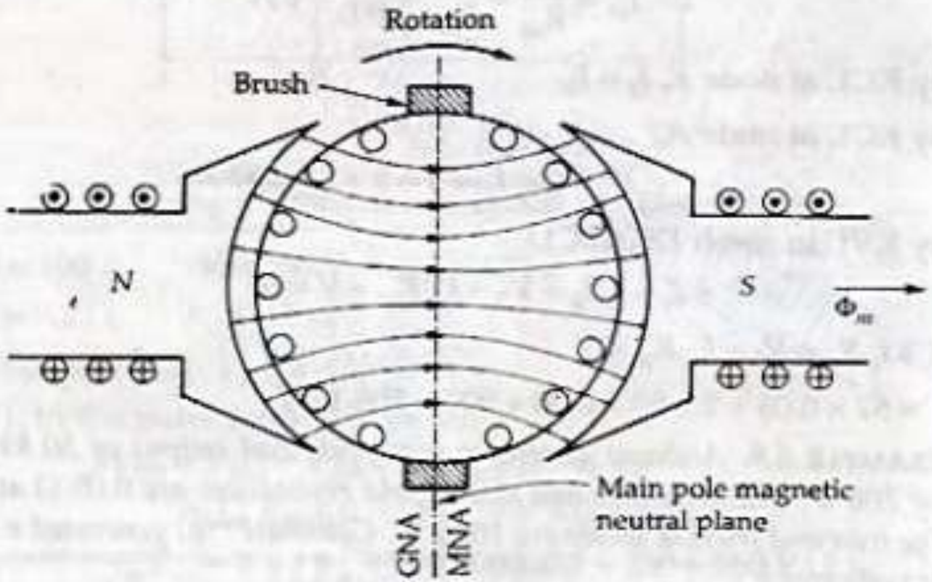
MNA - The axis through which no EMF induces in the armature conductor such type of axis is know as the Magnetic Neutral Axis.



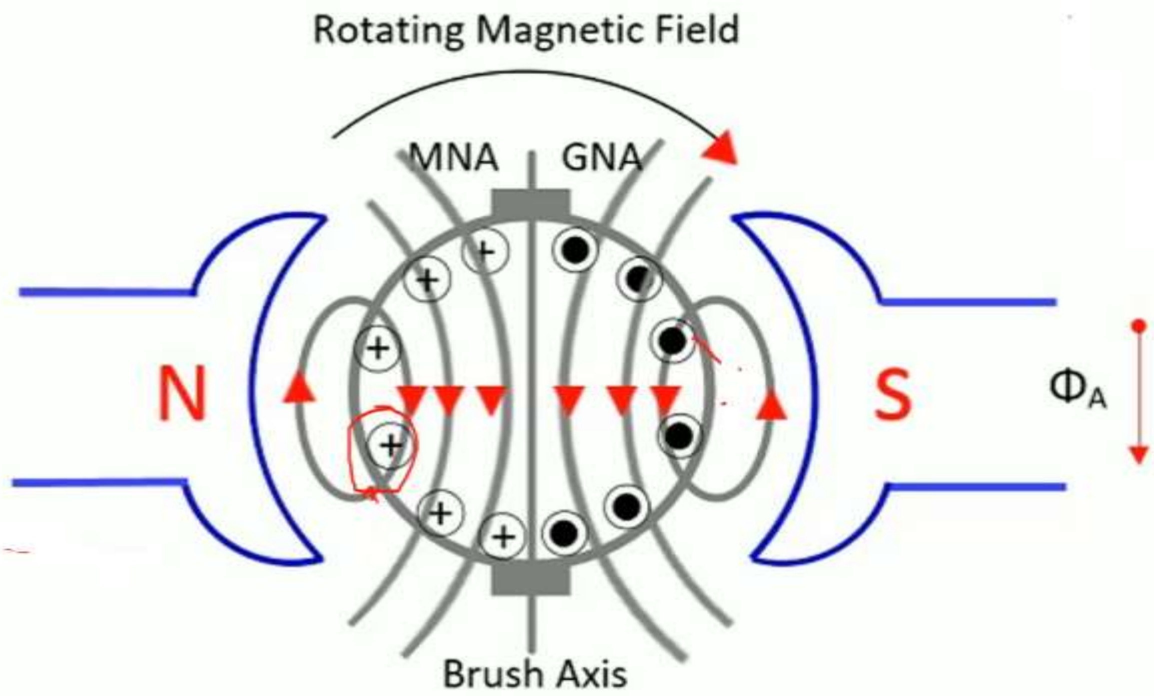
Case 1: When no load is connected to the machines.

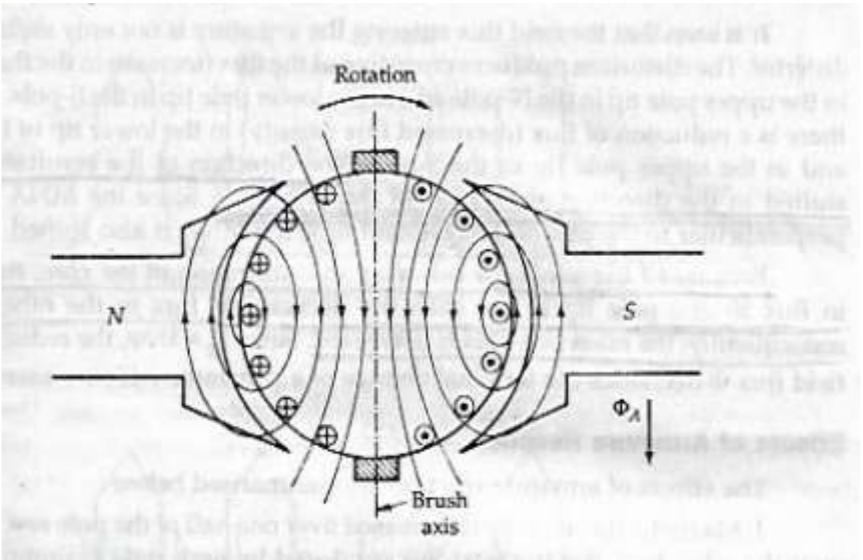
The brushes always placed along the axis of magnetic neutral and hence the this axis is called axis of commutation.



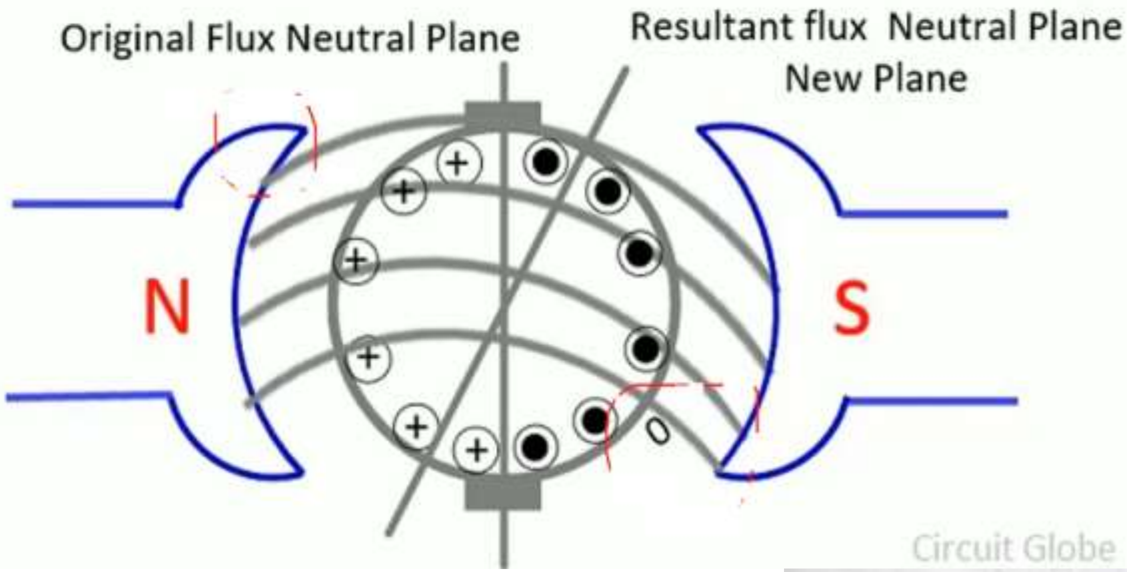


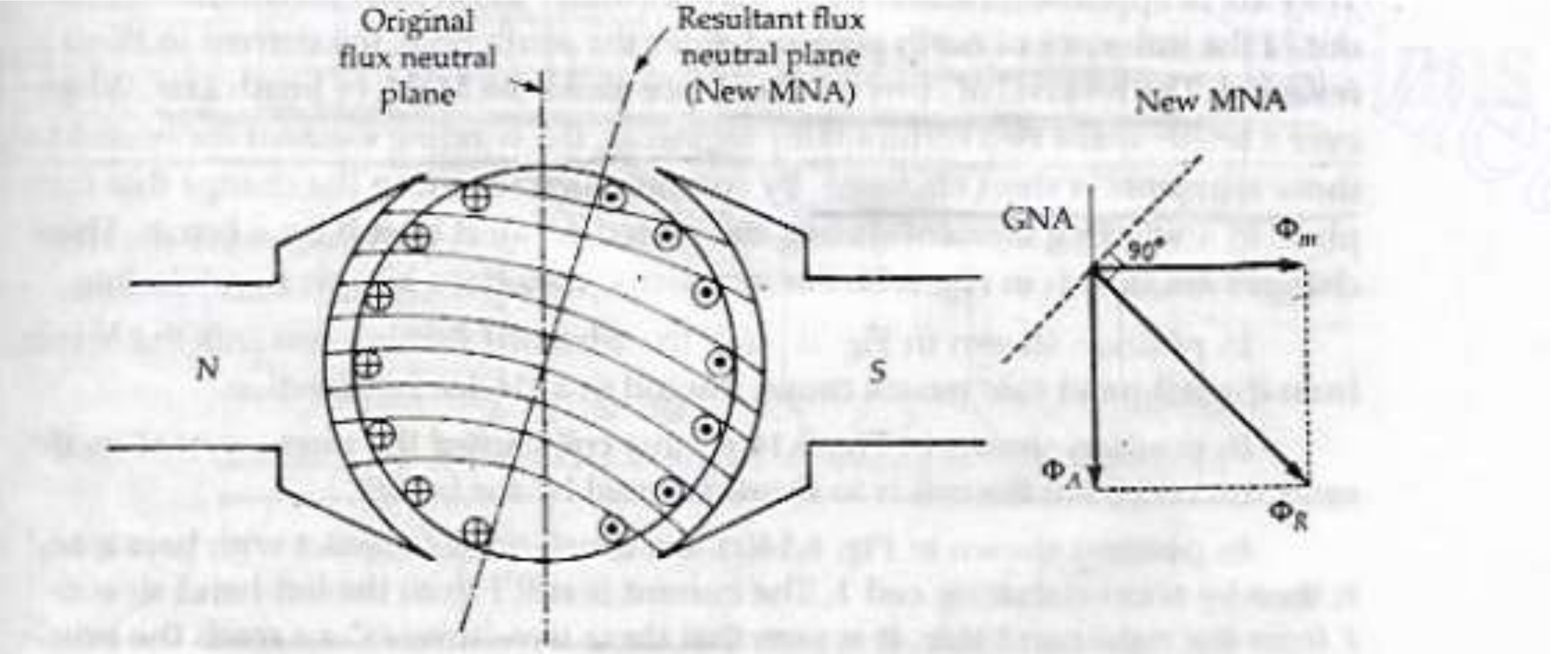
Case 2: **The armature conductor carrying current and no current flows in the field coils.**





Case 3: Field Current and armature current acting simultaneously.





EFFECTS OF ARMATURE REACTION

Effects of Armature Reaction

1. The effect of total flux reduction in the armature reaction is known as the demagnetising effect

2. The waves of the flux is distorted and the position of the magnetic neutral axis is shifted. In case of generator the MNA moves in the direction of the rotation of generator and it rotates in the opposite direction of the motor.

3. The armature reaction established the flux in the commutation or neutral zone. The armature reaction in the zone causes the commutation problem.

UNIT-4 CHARACTERISTICES OF DC MACHINES

DC GENERATOR SYMBOL

Symbolic Representation of D.C. Generator

The armature is denoted by a circle with two brushes. Mechanically it is connected to another device called prime mover. The two ends of armature are denoted as A_1 - A_2. The field winding is shown near armature and the two ends are denoted as F_1 - F_2. The representation of field vary little bit, depending on the type of generator.

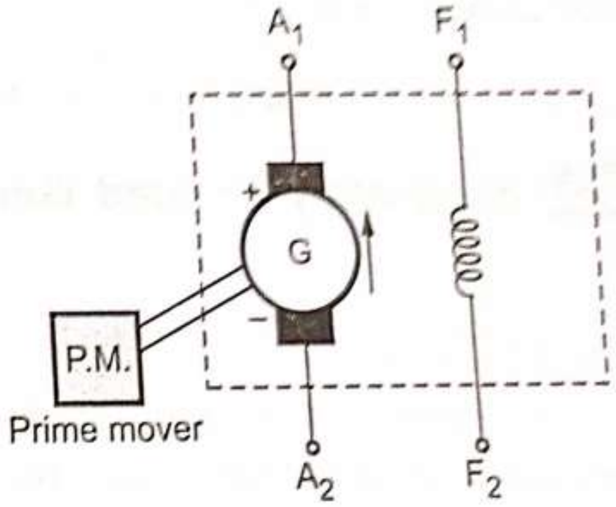


Fig. 3.1.1 Symbolic representation of d.c. generator

The symbolic representation is shown in the Fig. 3.1.1. Many times an arrow (↑) is indicated near armature. This arrow denotes the direction of current which induced e.m.f. will set up, when connected to an external load.

Key Point *Every practical generator needs a **prime mover** to rotate its armature. Hence to avoid complexity of the diagram, prime mover need not be included in the symbolic representation of generator.*

DC COUPLED MACHINES

METHODS OF EXCITATION

Methods of Excitation

The magnetic field required for the operation of a d.c. generator is produced by an electromagnet. This electromagnet carries a field winding which produces required magnetic flux when current is passed through it.

Key Point *The field winding is also called* ***exciting winding*** *and current carried by the field winding is called an* ***exciting current.***

Thus supplying current to the field winding is called excitation and the way of supplying the exciting current is called **method of excitation.**

There are two methods of excitation used for d.c. generators,

1. Separate excitation
2. Self excitation.

Depending on the method of excitation used, the d.c. generators are classified as,

1. Separately excited generator
2. Self excited generator.

In **separately excited generator**, a separate external d.c. supply is used to provide exciting current through the field winding.

The d.c. generator produces d.c. voltage. If this generated voltage itself is used to excite the field winding of the same d.c. generator, it is called **self excited generator.**

SEPERATELY EXCITED GENERATOR

Separately Excited Generator

When the field winding is supplied from external, separate d.c. supply i.e. excitation of field winding is separate then the generator is called separately excited generator. Schematic representation of this type is shown in the Fig. 3.3.1.

The field winding of this type of generator has large number of turns of thin wire. So length of such winding is more with less cross-sectional area. So resistance of this field winding is high in order to limit the field current.

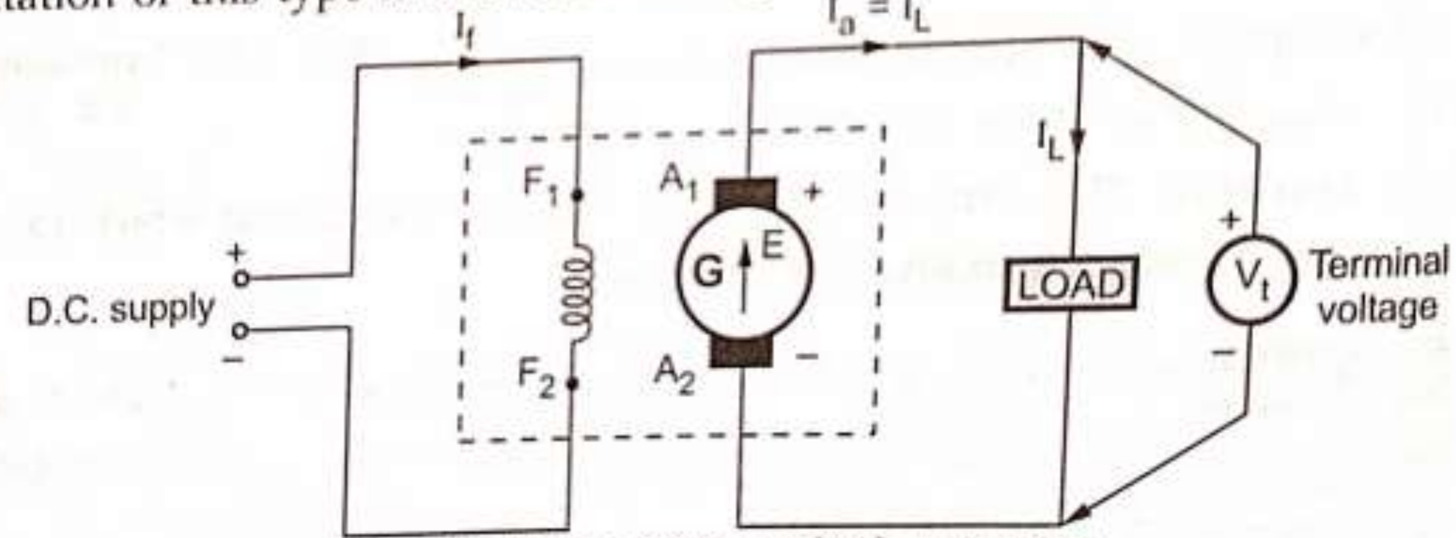


Fig. 3.3.1 Separately excited generator

VOLTAGE AND CURRENT RELATION

... the field current.

Voltage and Current Relations

The field winding is excited separately, so the field current depends on supply voltage and resistance of the field winding.

For armature side, we can see that it is supplying a load, demanding a load current of I_L at a voltage of V_t which is called **terminal voltage**.

Now $$I_a = I_L$$

The internally induced e.m.f. E is supplying the voltage of the load hence terminal voltage V_t is a part of E. But E is not equal to V_t while supplying a load. This is because when armature current I_a flows through armature winding, due to armature winding resistance R_a ohms, there is a voltage drop across armature winding equal to $I_a R_a$ volts. The induced e.m.f. has to supply this drop, along with the terminal voltage V_t. To keep $I_a R_a$ drop to minimum, the resistance R_a is designed to be very very small. In addition to this drop, there is some voltage drop at the contacts of the brush called brush contact drop. But this drop is negligible and hence generally neglected. So in all, induced e.m.f. E has three components namely,

i) Terminal voltage V_t

ii) Armature resistance drop $I_a R_a$

iii) Brush contact drop V_{brush}.

So voltage equation for separately excited generator can be written as,

$$E = V_t + I_a R_a + V_{brush}$$

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

Generally V_{brush} is neglected as is negligible compared to other voltages.

PROBLEM

A 250 V, 10 kW, separately excited generator has an induced e.m.f. of 255 V at full load. If the brush drop is 2 V per brush, calculate the armature resistance of the generator.

Solution : Consider separately excited generator as shown in the Fig. 3.3.2.

$$I_a = I_L$$

Note that 250 V, 10 kW generator means the full load capacity of generator is to supply 10 kW load at a terminal voltage V_t = 250 V.

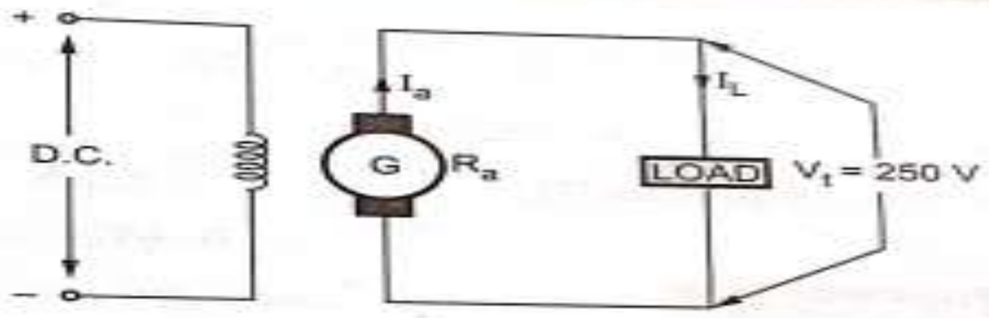


Fig. 3.3.2

$\therefore \quad V_t = 250$ V and P = 10 kW

and $\quad P = V_t \times I_L$

$$\therefore \quad I_L = \frac{10 \times 10^3}{250} = 40 \text{ A}$$

$\therefore \quad I_a = I_L = 40$ A ... As separately excited

Now $\quad E = V_t + I_a R_a + V_{brush}$

There are two brushes and brush drop is 2 V/brush i.e. $V_{brush} = 2 \times 2 = 4$ V

$\therefore \quad E = 250 + 40 \times R_a + 4 \quad$ but $\quad E = 255$ V on full load

$\therefore \quad 255 = 250 + 40 R_a + 4 \quad$ i.e $\quad R_a = 0.025\ \Omega$

SELF EXCITED GENERATOR

Self Excited Generator

When the field winding is supplied from the armature of the generator itself then it is said to be self excited generator. Now without generated e.m.f., field cannot be excited in such generator and without excitation there cannot be generated e.m.f. So one may obviously wonder, how this type of generator works. The answer to this is residual magnetism possessed by the field poles, under normal condition.

Practically though the generator is not working, without any current through field winding, the field poles possess some magnetic flux. This is called **residual flux** and the property is called **residual magnetism.** Thus when the generator is started, due to such residual flux, it develops a small e.m.f. which now drives a small current through the field winding. This tends to increase the flux produced. This in turn increases the induced e.m.f. This further increases the field current and the flux. The process is cumulative and continues till the generator develops rated voltage across its armature. This is **voltage building process** in self excited generators.

Based on how field winding is connected to the armature to derive its excitation, this type is further divided into following three types.

i) Shunt generator   ii) Series generator   iii) Compound generator.

Let us see the connection diagrams and voltage, current relations for these types of generators.

SHUNT GENERATOR

Shunt Generator

When the field winding is connected in parallel with the armature and the combination across the load then the generator is called **shunt generator.**

The field winding has large number of turns of thin wire so it has high resistance. Let R_{sh} be the resistance of the field winding.

Voltage and Current Relations

From the Fig. 3.5.1, we can write

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

Now voltage across load is V_t which is same across field winding as both are in parallel with each other.

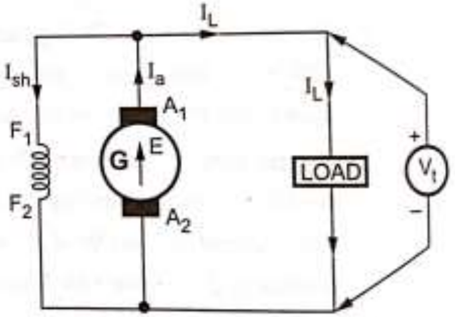


Fig. 3.5.1 Shunt generator

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

While induced e.m.f. E, still requires to supply voltage drop I_aR_a and brush contac drop.

$$\therefore \quad E = V_t + I_aR_a + V_{brush}$$

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

In practice, brush contact drop can be neglected.

PROBLEM

A 20 kW, 200 V shunt generator has an armature resistance of 0.05 Ω and a shunt field resistance of 200 Ω. Calculate the power developed in the armature when it delivers rated output.

Solution : The generator is shown in the Fig. 3.5.2.

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

$$V_t = 200 \text{ V}$$

$$P = V_t I_L$$

$$\therefore \quad 20 \times 10^3 = 200 \times I_L$$

$$\therefore \quad I_L = 100 \text{ A}$$

and

$$I_{sh} = \frac{V_t}{R_{sh}} = \frac{200}{200} = 1 \text{ A}$$

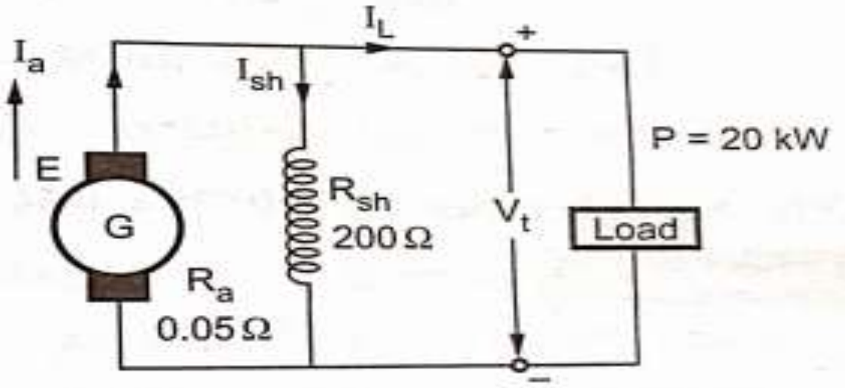


Fig. 3.5.2

$$\therefore \quad I_a = I_{sh} + I_L = 101 \text{ A}$$

Now

$$E = V_t + I_a R_a = 200 + 101 \times 0.05 = 202.05 \text{ V}$$

Thus the power developed in the armature is

$$P_a = E \times I_a = 205.05 \times 101 = \mathbf{20.71005 \text{ kW}}$$

... and terminal voltage is

SERIES GENERATOR

Series Generator

When the field winding is connected in series with the armature winding while supplying the load then the generator is called **series generator**. It is shown in the Fig. 3.6.1.

Field winding, in this case is denoted as S_1 and S_2. The resistance of series field winding is very small and hence naturally it has less number of turns of thick cross-section wire as shown in the Fig. 3.6.1.

Let R_{se} be the resistance of the series field winding.

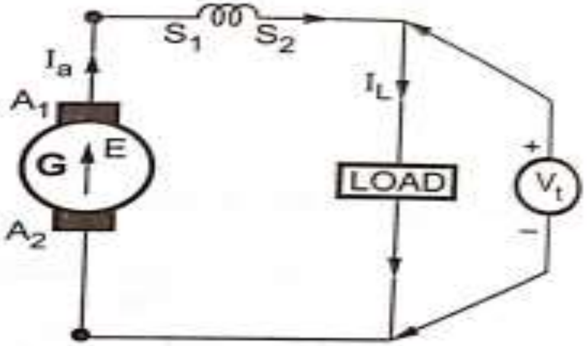


Fig. 3.6.1 Series generator

Voltage and Current Relations

As all armature, field and load are in series they carry the same current.

$$\therefore \quad I_a = I_{se} = I_L$$

where I_{se} = Current through series field winding.

Now in addition to drop $I_a R_a$, induced e.m.f. has to supply voltage drop across series field winding too. This is $I_{se} R_{se}$ i.e. $I_a R_{se}$ as $I_a = I_{se}$. So voltage equation can be written as,

$$\therefore \quad E = V_t + I_a R_a + I_a R_{se} + V_{brush}$$

$$\therefore \quad E = V_t + I_a (R_a + R_{se}) + V_{brush}$$

where $E = \dfrac{\phi P N Z}{60 A}$

PROBLEM

A d.c. series generator has armature resistance of 0.5 Ω and series field resistance of 0.03 Ω. It drives a load of 50 A. If it has 6 turns/coil and total 540 coils on the armature and is driven at 1500 r.p.m., calculate the terminal voltage at the load. Assume 4 poles, lap type winding, flux per pole as 2 mWb and total brush drop as 2 V.

Solution : Consider the series generator as shown in Fig. 3.6.2.

$$R_a = 0.5\ \Omega,\quad R_{se} = 0.03\ \Omega$$

$$V_{brush} = 2\ V$$

$$N = 1500\ \text{r.p.m.}$$

Total coils are 540 with 6 turns/coil.

$\therefore$ Total turns = 540 × 6 = 3240

$\therefore$ Total conductors Z = 2 × Turns = 2 × 3240 = 6480

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

For lap type, A = P

and $\phi = 2\ \text{mWb} = 2 \times 10^{-3}\ \text{Wb}$

$$\therefore \quad E = \frac{2 \times 10^{-3} \times 1500 \times 6480}{60} = 324\ V$$

$$E = V_t + I_a (R_a + R_{se}) + V_{brush}$$

... Total V_{brush} given

where $I_a = I_L = 50\ A$

$$\therefore \quad 324 = V_t + 50\ (0.5 + 0.03) + 2$$

$$\therefore \quad V_t = \mathbf{295.5\ V}$$

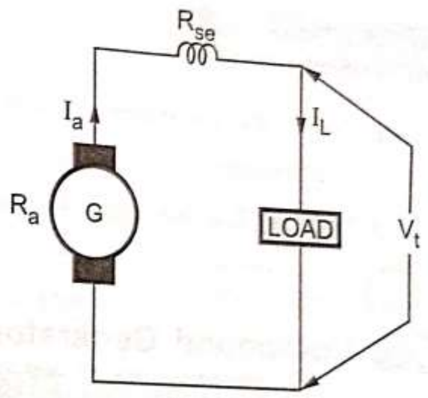


Fig. 3.6.2

SHUNT AND SERIES FIELD WINDING

Comparison between Shunt and Series Field Winding

Sr. No.	Shunt field winding	Series field winding
1.	The resistance is high.	Resistance is low.
2.	The cross-sectional area is small thus wire is thin.	The cross-sectional area is more thus wire is thick.
3.	The length is more thus has large number of turns.	The length is small thus has less number of turns.
4.	The current rating is low.	The current rating is high.
5.	Always connected in parallel with the armature.	Always connected in series with the armature.

LONG SHUNT COMPOUND GENERATOR

Long Shunt Compound Generator

In this type, shunt field winding is connected across the series combination of armature and series field winding as shown in the Fig. 3.7.1.

Voltage and current relations are as follows.

From the Fig. 3.7.1,

$$I_a = I_{se}$$

and

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

Voltage across shunt field winding is V_t.

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

where R_{sh} = Resistance of shunt field winding.

And voltage equation is,

$$E = V_t + I_a R_a + I_a R_{se} + V_{brush}$$

where R_{se} = Resistance of series field winding.

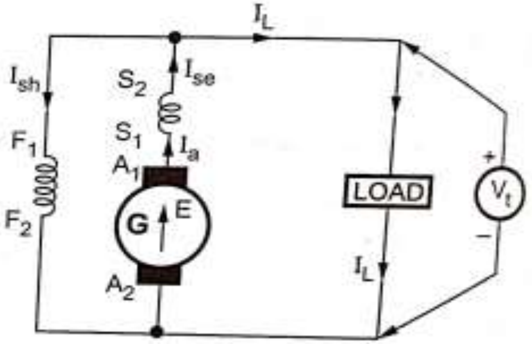


Fig. 3.7.1 Long shunt compound generator

SHOT SHUNT COMPOUND GENERATOR

Short Shunt Compound Generator

In this type, shunt field winding is connected, only across the armature, excluding series field winding as shown in the Fig. 3.7.2.

Voltage and current relations are as follows.

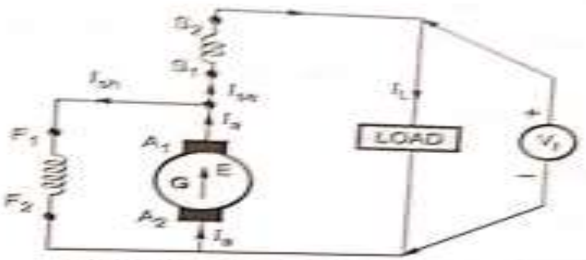


Fig. 3.7.2 Short shunt compound generator

For the Fig. 3.7.2.,

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

and $$I_{se} = I_L$$

$$\therefore \quad I_a = I_L + I_{sh}$$

The drop across shunt field winding is drop across the armature only and not the total V_t, in this case. So drop across shunt field winding is $E - I_a R_a$.

$$I_{sh} = \frac{E - I_a R_a}{R_{sh}}$$

Now the voltage equation is $E = V_t + I_a R_a + I_{se} R_{se} + V_{brush}$

$$I_{se} = I_L$$

$$E = V_t + I_a R_a + I_L R_{se} + V_{brush}$$

Neglecting V_{brush}, we can write,

$$E = V_t + I_a R_a + I_L R_{se}$$

$$\therefore \quad E - I_a R_a = V_t + I_L R_{se}$$

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

Any of the two above expressions of I_{sh} can be used, depending on the quantities known while solving the problems.

Cumulative and Differential Compound Generator

It is mentioned earlier that the two windings, shunt and series field are wound on the same poles. Depending on the direction of winding on the pole, two fluxes produced by shunt and series field may help or may oppose each other. This fact decides whether generator is cumulative or differential compound. If the two fluxes help each other as shown in Fig. 3.7.3 the generator is called **cumulative compound generator.**

\

$$\phi_T = \phi_{sh} + \phi_{se}$$

where ϕ_{sh} = Flux produced by shunt.

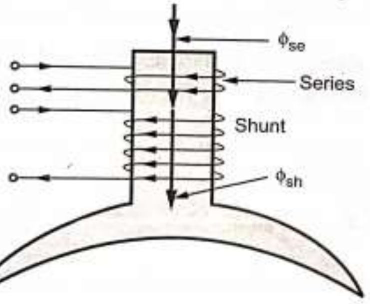
ϕ_{se} = Flux produced by series, field windings.

If the two windings are wound in such a direction that the fluxes produced by them oppose each other then the generator is called **differential compound generator**. This is shown in the Fig. 3.7.4.

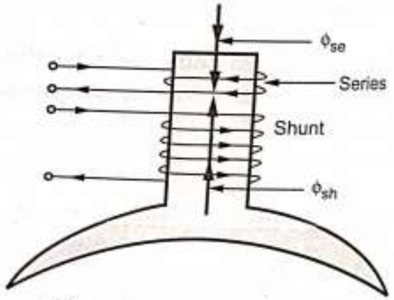
$$\phi_T = \phi_{sh} - \phi_{se}$$

where ϕ_{sh} = Flux produced by shunt field winding.

ϕ_{se} = Flux produced by series field winding.



Cumulative compound generator



Differential compound generator

Fig. 3.7.3

DC SHUNT MACHINE


D.C. Supply
Compound Motor
Loading Arrangment
DC COMPOUND
MOTOR
2
L
A
F
600-Ω-1.2A
Y
YY
Z
ZZ
A
+
230V
REDMI NOTE 9
AI QUAD CAMERA