What is a DC Generator?

A DC generator or **direct current generator** is one kind of electrical machine, and the main function of this machine is to **convert mechanical energy into DC (direct current) electricity.** The energy alteration process uses the principle of energetically induced electromotive force. The **dc generator diagram** is shown below.

DC Generator

When a conductor slashes **magnetic flux**, then energetically induced electromotive force will be generated in it based on the Electromagnetic Induction principle of **Faraday's Laws**. This electromotive force can cause a flow of current when the conductor circuit is not opened.

Construction

A DC generator is also used as a **DC motor** without changing its construction. Therefore, a DC motor otherwise a DC generator can be generally called a **DC machine.** The construction of a **4-pole DC generator** is shown below. This generator comprises of **several parts** like yoke, poles & pole shoes, field winding, an armature core, armature winding, commutator & brushes. But the two

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Stator

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Rotor or Armature Core

Rotor or **armature core** is the second essential part of the DC generator, and it includes slotted iron laminations with slots that are stacked to shape a **cylindrical armature core**. Generally, these laminations are offered to decrease the loss because of the **eddy current**.

Yoke

The external structure of the DC generator is Yoke, and it is made with cast iron otherwise steel. It gives the necessary mechanical power for carrying the **magnetic-flux** given through the poles.

Poles

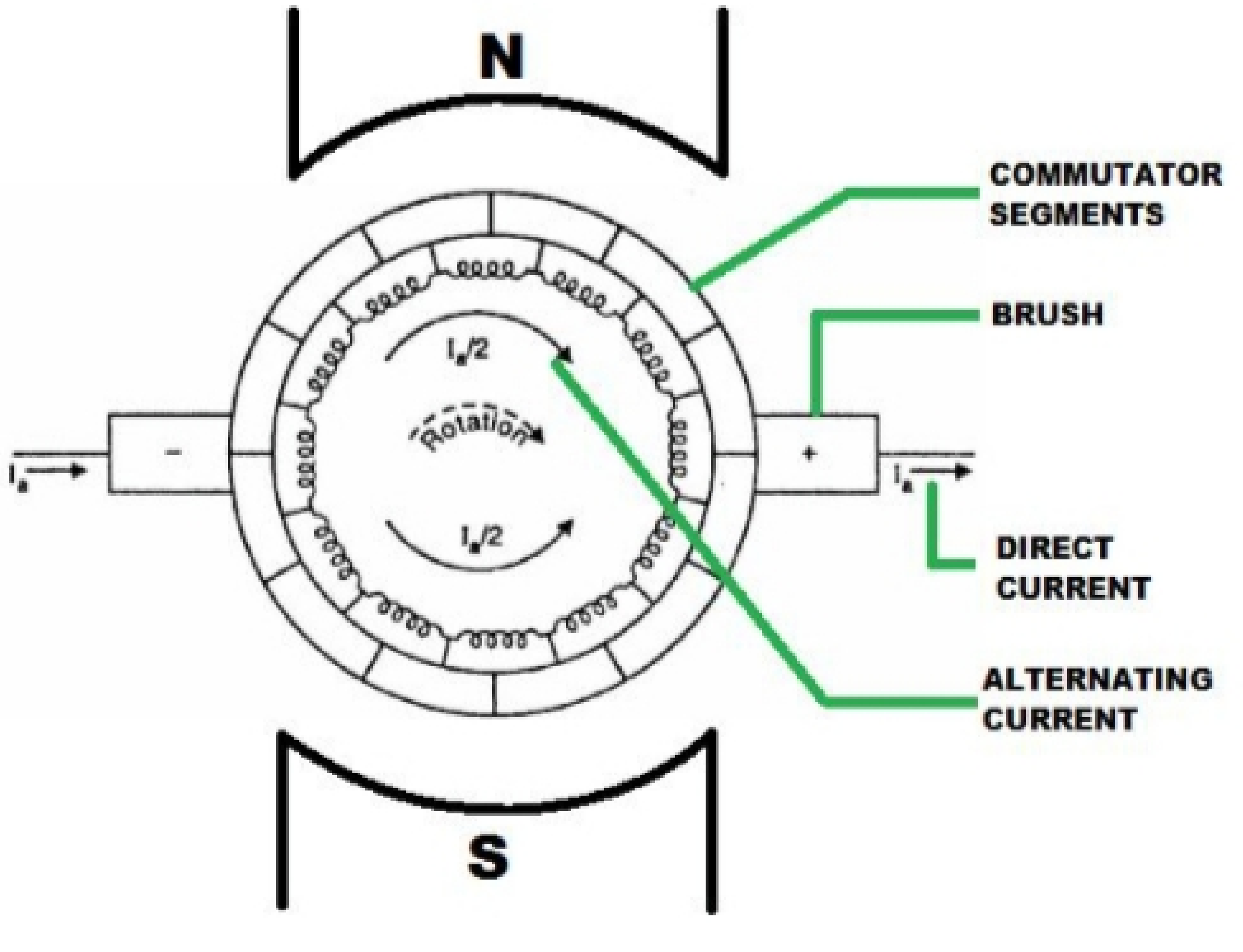
These are mainly used to hold the field windings. Usually, these windings are wound on the poles, & they are connected in series otherwise parallel by the **armature windings**. In addition, the poles will give joint toward the yoke with the welding method otherwise by using screws.

Pole Shoe

The pole shoe is mainly utilized for spreading the magnetic flux as well as to avoid the field coil from falling.

Commutator

The working of the commutator is like a rectifier for changing **AC voltage** to the **DC voltage** within the armature winding to across the brushes. It is designed with a copper segment, and each copper segment is protected from each other with the help of **mica sheets**. It is located on the shaft of the machine.



Commutator in DC Generator

DC Generator Commutator Function

The main function of the commutator in the dc generator is to change the AC to DC. It acts like a reversing switch and its role in the generator is discussed below.

The emf which is induced within the armature coil of the generator is alternating. So, the flow of current within the armature coil can also be alternating current. This current can be reversed through the commutator at the accurate moment once the armature coil crosses the magnetic unbiased axis. Thus, the load attains a DC or uni–directional current.

The commutator guarantees that the flow of current from the generator will flow forever in a single direction. The brushes will make high–quality electrical connections among the generator & the load by moving on the commutator.

Brushes

The electrical connections can be ensured between the **commutator** as well as the exterior load circuit with the help of brushes.

Working Principle

The **working principle of the DC generator** is based on Faraday's laws of **electromagnetic induction**. When a conductor is located in an unstable magnetic field, an electromotive force gets induced within the conductor. The induced e.m.f magnitude can be measured from the equation of **the electromotive force of a generator**.

If the conductor is present with a closed lane, the current which is induced will flow in the lane. In this generator, field coils will generate an electromagnetic field as well as the armature conductors are turned into the field. Therefore, an electromagnetically induced

DC Generator E.M.F Equation

The **emf equation of dc generator** according to Faraday's Laws of Electromagnetic Induction is **Eg= PØZN/60 A**

Where **Φ** is

flux or pole within Webber

'Z' is a total no.of armature conductor

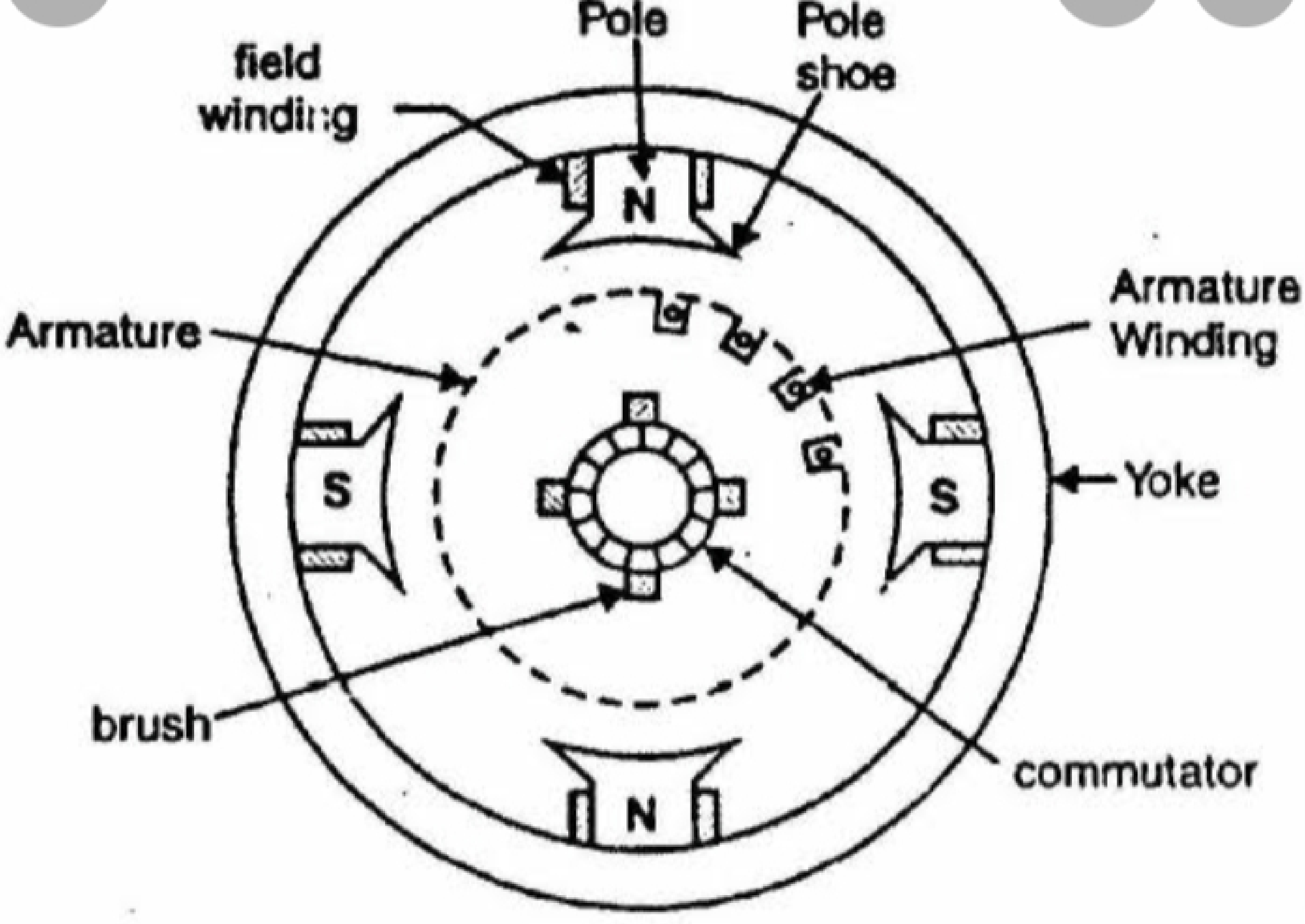
'P' is a number of poles in a generator

'A' is a number of parallel lanes within the armature

'N' is the rotation of armature in r.p.m (revolutions per minute)

'E' is the induced e.m.f in any parallel lane within the armature

'Eg' is the generated e.m.f in any one of the parallel lanes



Pole
Pole
shoe
field
winding
N
Armature
Armature
Winding
S
S
Yoke
brush
commutator
N

‘N/60’ is the number of turns per second

Time for one turn will be dt = 60/N sec

Types of DC Generator

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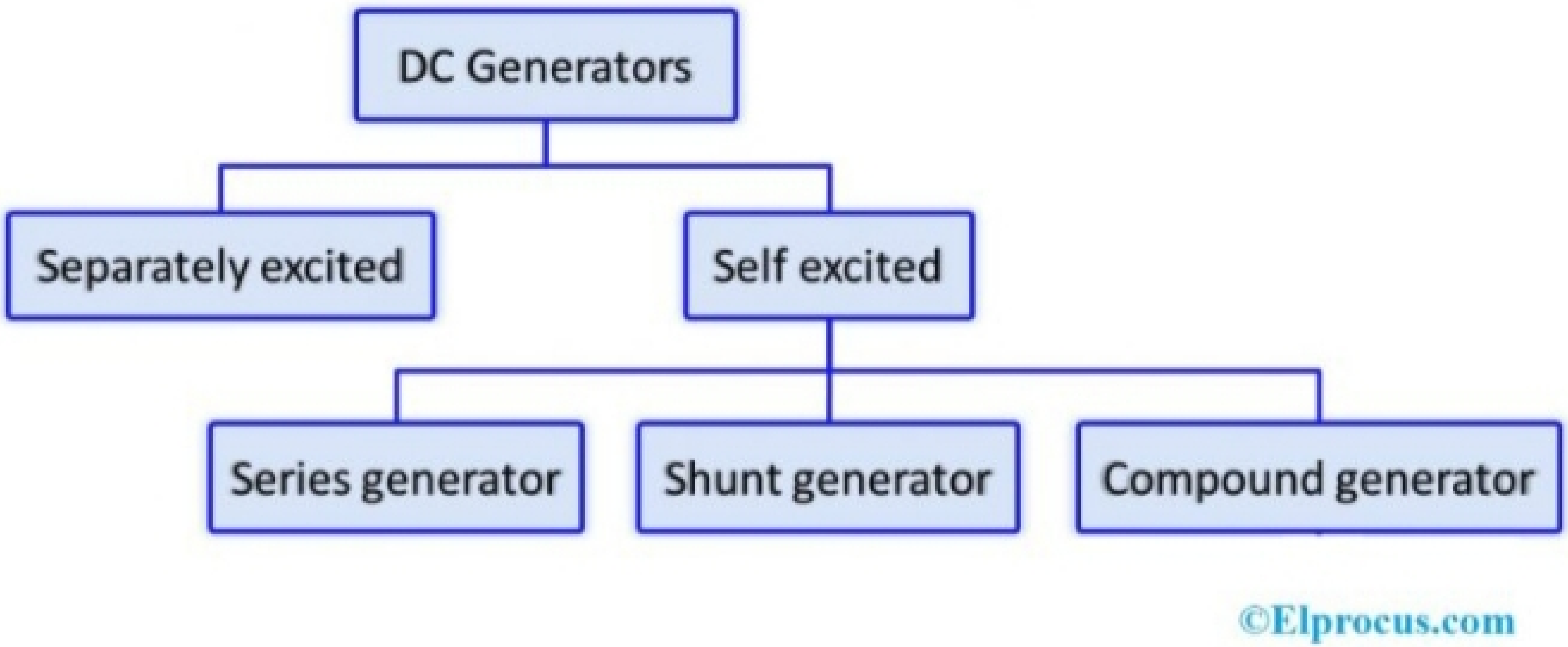

Types of DC Generators

Separately Excited

In separately excited type, the field coils are strengthened from an autonomous exterior DC source.

Self Excited

In the self–excited type, the field coils are strengthened from the generated current with the generator. The generation of the first electromotive force will occur because of its outstanding magnetism within field poles.

The produced electromotive force will cause a fraction of current to supply in the field coils, therefore which will increase the field flux as well as electromotive force generation. Further, these types of dc generators can be classified into three types namely series wound, shunt–wound, and compound wound.

Losses in DC Generator

There are different kinds of machines available in the market where the total input energy cannot be changed into output due to the loss in the input energy. So different losses can occur in this type of generator.

Copper Loss

In armature copper loss (Ia2Ra), where the armature current is 'Ia' & the armature resistance is 'Ra'. For generators like shunt–wound, the field copper loss is equivalent to Ish2Rsh which is almost stable. For generators like a series wound, the field copper loss is equivalent to Ise2 Rse which is also almost stable. For generators like compound–wound, the filed copper loss is similar to Icomp2 Rcomp which is also nearly stable. In full load losses, copper losses occur 20–30% because of the brush contact.

Core or Iron or Magnetic Loss

The classification of core losses can be done into two types like hysteresis and eddy current

Hysteresis Loss

This loss mainly occurs because of the reversal of the armature core. Every part of the rotor core passed below the two poles like north & south alternately & achieves S & N polarity correspondingly. Whenever the core supplies below one set of poles, then the core will finish one series of frequency reversal. Please refer to this link to know more about What is Hysteresis Loss: Factors & Its Applications

Eddy Current Loss

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Eddy Current Loss

The armature core slashes the magnetic flux throughout its revolution & e.m.f can be induced within the outside of the core, based on the electromagnetic induction laws, this emf is extremely tiny, however, it sets up a large current in the surface of the core. This huge current is known as eddy current whereas the loss is called the eddy current loss.

Core losses are stable for compound & shunt generators because their field currents are nearly stable. This loss mainly occurs 20 % to 30 % in full–load losses.

Mechanical Loss

Mechanical loss can be defined as the rotating armature's air friction or windage losses Friction loss mainly occurs 10 % to 20 % of full load losses at bearings & commutator.

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Stray Loss

Stray losses mainly occur by combining the losses like core as well as mechanical. These losses are also called rotational losses.

Armature Reaction In Machines

In a DC machine, two kinds of magnetic fluxes are present; 'armature flux' and 'main field flux'. The effect of armature flux on the main field flux is called as **armature reaction**.

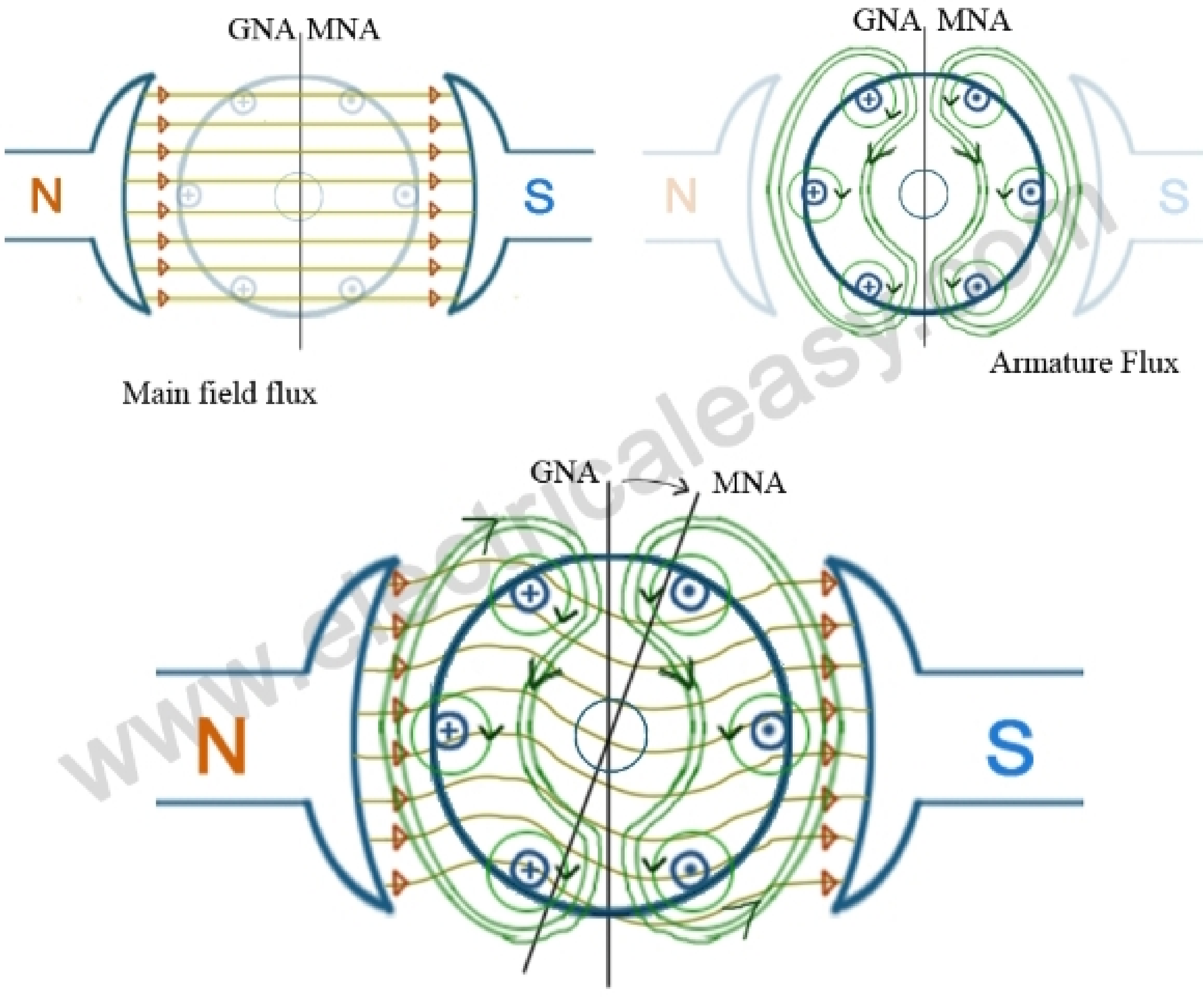
MNA And GNA

EMF is induced in the armature conductors when they cut the magnetic field lines. There is an axis (or, you may say, a plane) along which armature conductors move parallel to the flux lines and, hence, they do not cut the flux lines while on that plane. MNA (Magnetic Neutral Axis) may be defined as the axis along which no emf is generated in the armature conductors as they move parallel to the flux lines. Brushes are always placed along the MNA because reversal of current in the armature conductors takes place along this axis.

GNA (Geometrical Neutral Axis) may be defined as the axis which is perpendicular to the stator field axis.

Armature Reaction

The **effect of armature reaction** is well illustrated in the figure below.



Distortion of main field flux due to armature flux - Armature reaction

Consider, no current is flowing in the armature conductors and only the field winding is energized (as shown in the first figure of the

Consider, no current is flowing in the armature conductors and only the field winding is energized (as shown in the first figure of the above image). In this case, magnetic flux lines of the field poles are uniform and symmetrical to the polar axis. The 'Magnetic Neutral Axis' (M.N.A.) coincides with the 'Geometric Neutral Axis' (G.N.A.).

The second figure in the above image shows armature flux lines due to the armature current. Field poles are de-energised.

Now, when a DC machine is running, both the fluxes (flux due to the armature conductors and flux due to the field winding) will be present at a time. The armature flux superimposes with the main field flux and, hence, disturbs the main field flux (as shown in third figure the of above image). This effect is called as **armature reaction in DC machines**.

1. Armature reaction weakens the main flux. In case of a dc generator, weakening of the main flux reduces the generated voltage.
2. Armature reaction distorts the main flux, hence the position of M.N.A. gets shifted (M.N.A. is perpendicular to the flux lines of main field flux). Brushes should be placed on the M.N.A., otherwise, it will lead to sparking at the surface of brushes. So, due to armature reaction, it is hard to determine the exact position of the MNA

For a loaded dc generator, MNA will be shifted in the direction of the rotation. On the other hand, for a loaded dc motor, MNA will be shifted in the direction opposite to that of the rotation.

How To Reduce Armature Reaction?

Usually, no special efforts are taken for small machines (up to few kilowatts) to reduce the armature reaction. But for large DC machines, compensating winding and interpoles are used to get rid of the **ill effects of armature reaction**.

Compensating winding: Now we know that the armature reaction is due to the presence of armature flux. Armature flux is produced due to the current flowing in armature conductors. Now, if we place another winding in close proximity of the armature winding and if it carries the same current but in the opposite direction as that of the armature current, then this will nullify the armature field. Such an additional winding is called as compensating winding and it is placed on the pole faces. Compensating winding is connected in series with the armature winding in such a way that it carries the current in opposite direction.

Interpoles: Interpoles are the small auxiliary poles placed between the main field poles. Winding on the interpoles is connected in series with the armature. Each interpole is wound in such a way that its magnetic polarity is same as that of the main pole ahead of it. Interpoles nullify the quadrature axis armature flux.

Differences between Lap Winding and Wave Winding

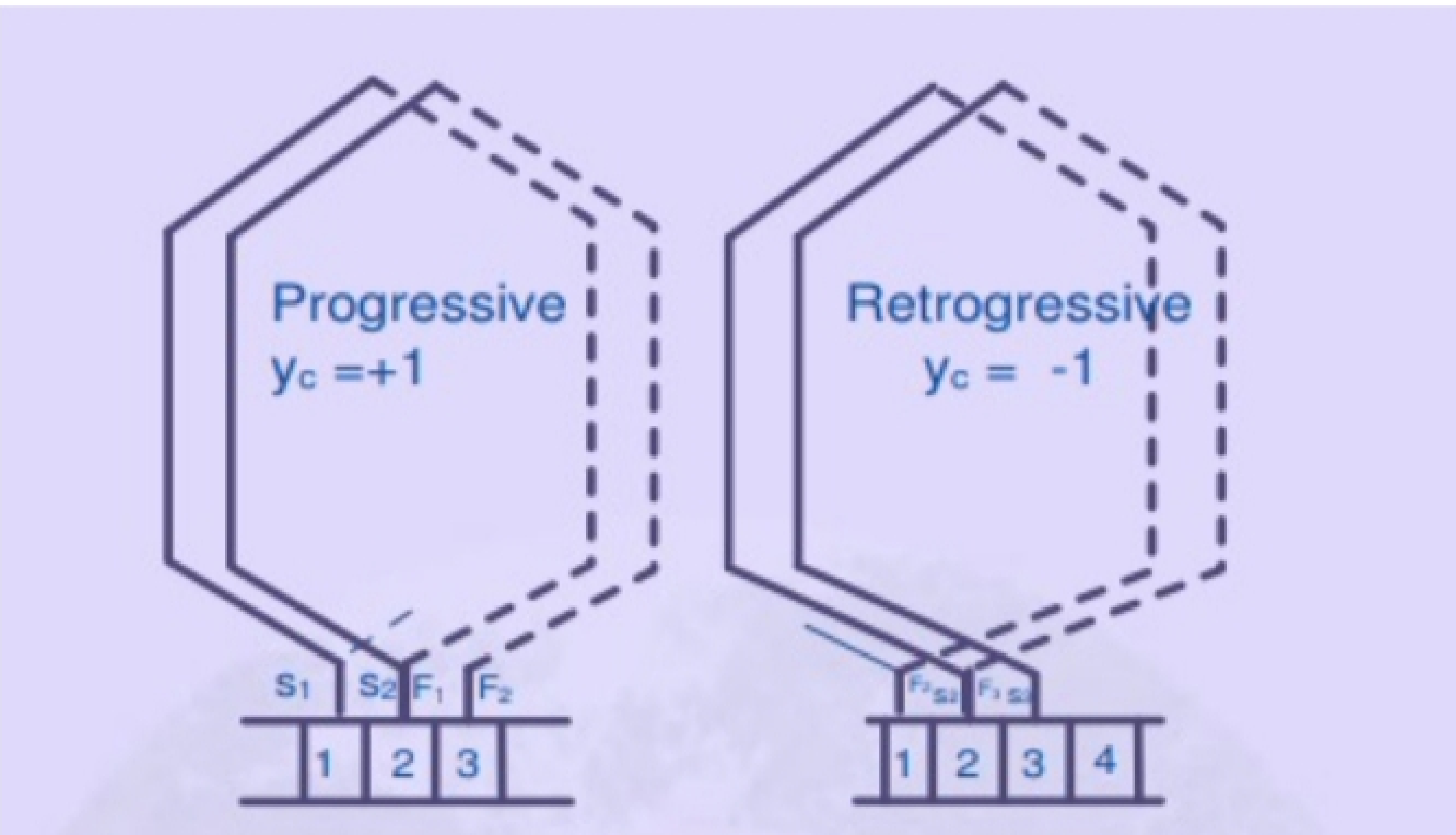
The rotating machine which has an essential part which is known as **armature winding**. The energy conservation can take place in this winding by converting the **mechanical energy into electrical energy**, as well as the **electrical energy into mechanical energy**. Armature winding is classified into two types namely **lap winding** as well as **wave winding**. The main difference between these two is, in the lap winding, One of the major difference between them is that in a lap winding, the last part of every coil is associated with the nearby sector while in the wave winding the last part of armature coil is associated with the commutator sector at a distance apart. This article discusses an overview of **the main differences between the lap winding and wave winding**.

Wave Winding Definition

In wave winding, one end part of the coil is allied to the beginning end part of another coil which has a similar polarity like the first coil. These coils are allied in the waveform and thus it is named as wave winding. The conductor of

Lap Winding Definition

Lap Winding is one type of winding with two layers, and it is used in electric machines. Every coil in the machine is allied in series with the one nearby coil to it. The applications of lap winding mainly include low voltage as well as high current machines.

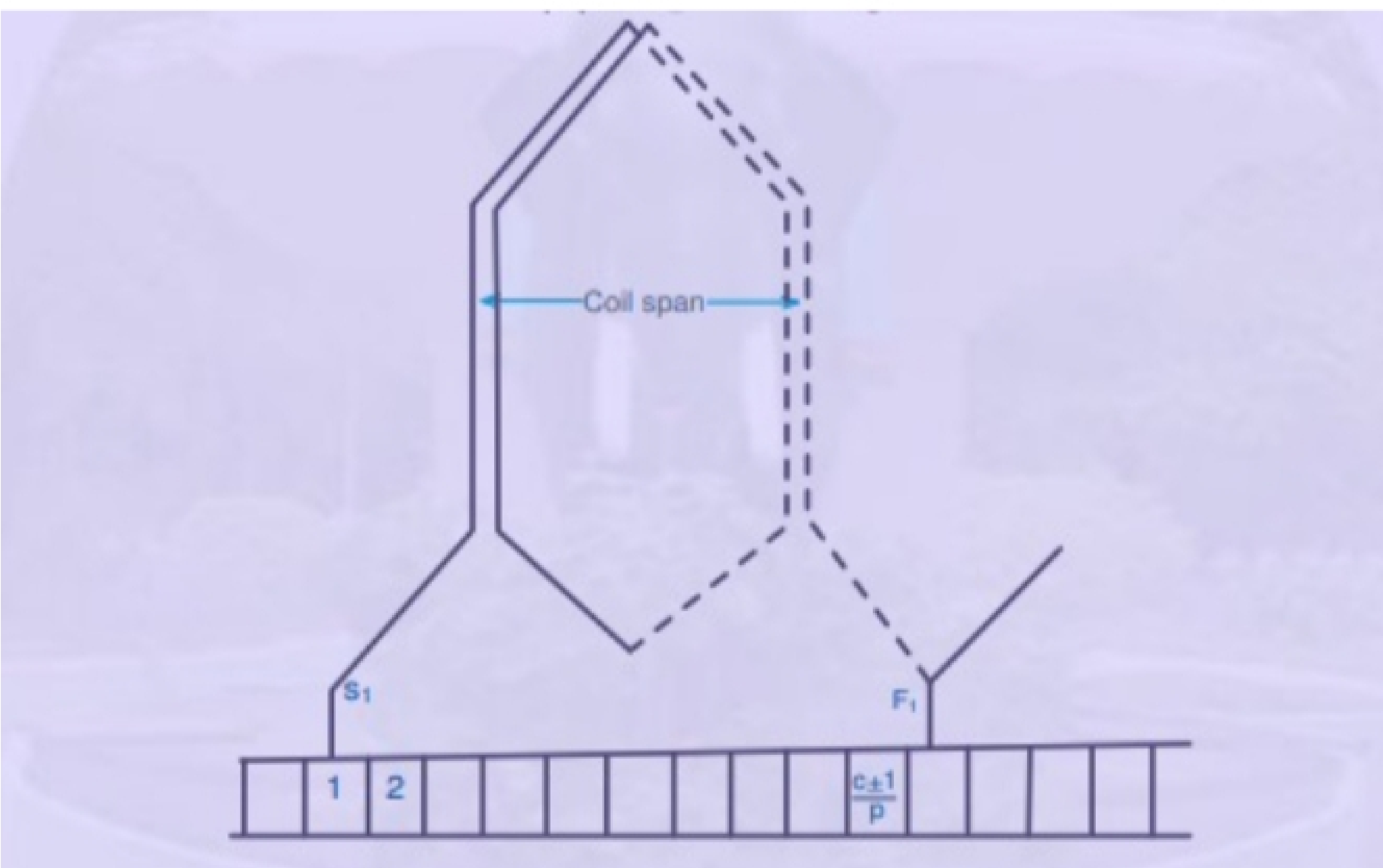


Lap Winding

These windings are mainly linked for providing numerous parallel lanes for armature current. Due to this reason, this type of winding is used in dc generators, and it requires some pairs of brushes and poles. In this type of winding, the

Wave Winding Definition

In wave winding, one end part of the coil is allied to the beginning end part of another coil which has a similar polarity like the first coil. These coils are allied in the waveform and thus it is named as wave winding. The conductor of this winding is divided into two parallel lanes, & every lane had Z/2 conductors which are connected in series. The amount of brushes is equivalent to 2, that is the digit of parallel paths.



Wave Winding

Lap Winding	Wave Winding
The lap winding can be defined as a coil which can be lap back toward the succeeding coil.	The wave winding can be defined as the loop of the winding can form the signal shape.
The connection of the lap winding is, the armature coil end is connected to the nearby section on the commutators.	The connection of the wave winding is, the armature coil end is connected to commutator sections at some distance apart.
The numbers of the parallel path are equal to the total of number poles.	The number of parallel paths is equal to two.

Another name of lap winding is **multiple winding** otherwise **Parallel Winding**	Another name of wave winding is **Series Winding** otherwise Two-circuit
The e.m.f of lap winding is Less	The e.m.f of wave winding is More
The no. of brushes in lap winding is Equivalent to the no. of parallel paths.	The no. of brushes in wave winding is Equivalent toTwo
The types of lap winding are **Simplex lap winding** & Duplex lap winding.	The types of wave winding are **Progressive & Retrogressive**
The efficiency of the lap winding is Less	The efficiency of the wave winding is High
The additional coil used in the lap winding is Equalizer Ring	The additional coil used in the wave winding is Dummy coil

Torque Equation of a DC Motor

When a DC machine is loaded either as a motor or as a generator, the rotor conductors carry current. These conductors lie in the magnetic field of the air gap.

Thus, each conductor experiences a force. The conductors lie near the surface of the rotor at a common radius from its centre. Hence, a torque is produced around the circumference of the rotor, and the rotor

When the current-carrying current is placed in the magnetic field, a force is exerted or it which exerts turning moment or torque F x r. This torque is produced due to the electromagnetic effect, hence is called **Electromagnetic torque.**

The torque which is produced in the armature is not fully used at the shaft for doing the useful work. Some part of it gets lost due to mechanical losses. The torque which is used for doing useful work in known as the **shaft torque**.

Since,

$$V = E_b + I_a R_a \quad \dots\dots..(1)$$

Now, the mechanical power developed by the armature is Pm,

$$P_m = E_b I_a \text{ ……..(3)}$$

Also, the mechanical power that rotates the armature can be given regarding torque T and speed n.

$$P_m = \omega T = 2\pi nT \text{ ……..(4)}$$

Where n is in revolution per seconds (rps) and T is in Newton-Meter.

Multiplying the equation (1) by I_a we get

$$VI_a = E_b I_a + I_a^2 R_a \quad \ldots\ \ldots\ldots (2)$$

Where,

VI_a is the electrical power input to the armature.

$I^2{}_a R_a$ is the copper loss in the armature.

We know that,

Total electrical power supplied to the armature = Mechanical power developed by the armature + losses due to armature resistance

Where n is in revolution per seconds (rps) and T is in Newton-Meter.

Hence,

$$2\pi\, nT = E_b I_a \quad \text{or}$$

$$T = \frac{E_b I_a}{2\pi n}$$

But,

$$E_b = \frac{\varphi ZNP}{60\ A}$$

Where N is the speed in revolution per minute (rpm) and

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

So, the torque equation is given as:

$$T = \frac{\varphi ZP}{2\pi A} \cdot I_a$$

For a particular DC Motor, the number of poles (P) and the number of conductors