Module-IV

Electrical Machines

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- **Three-phase Induction motors**
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- **Universal motor**
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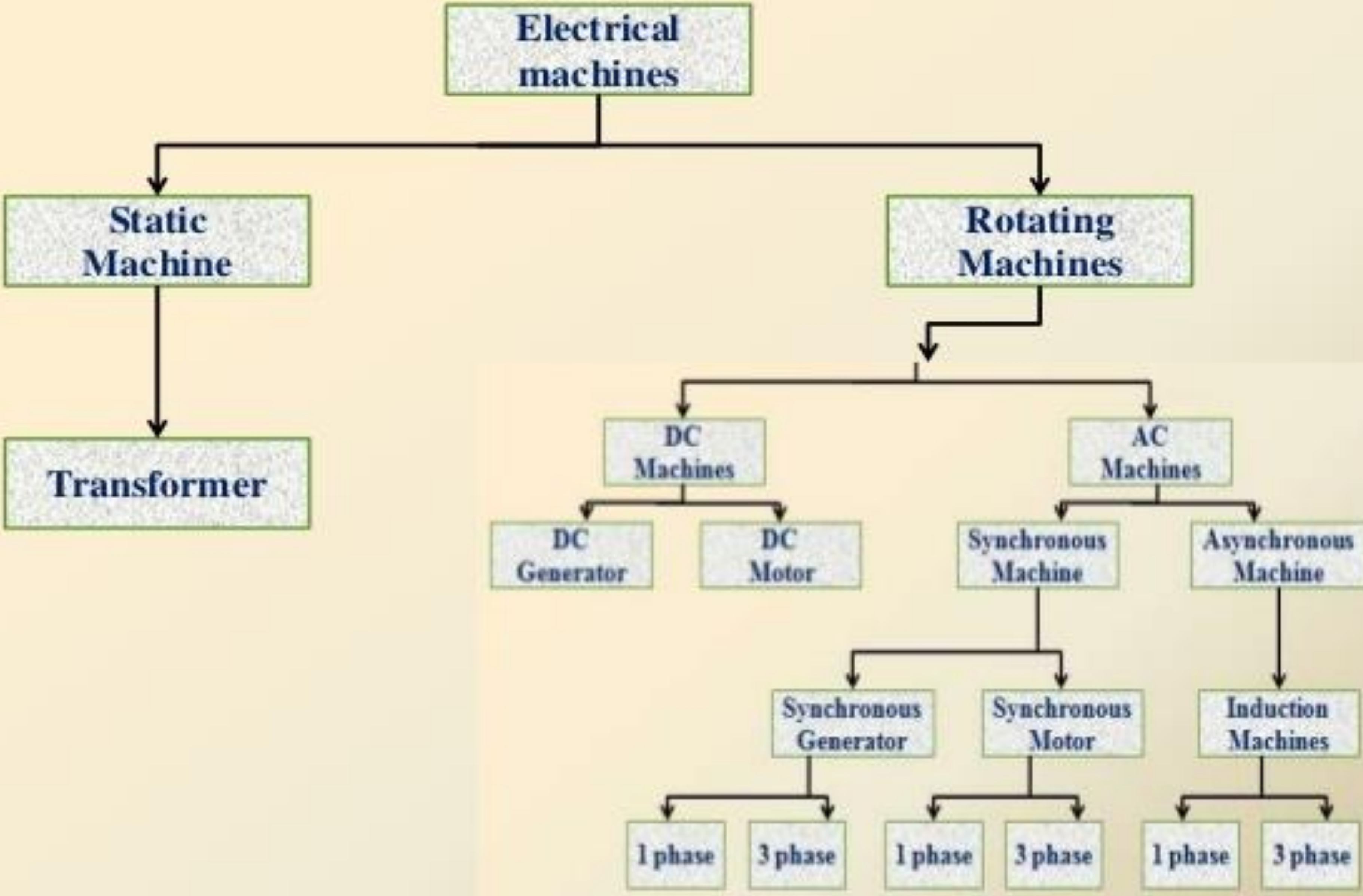
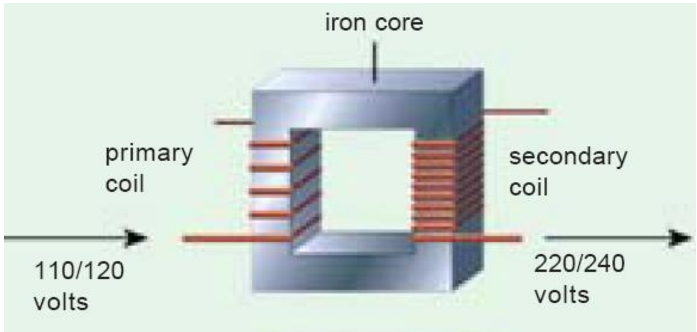
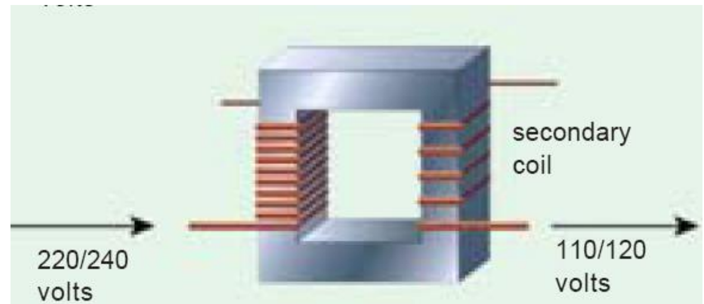
Classification of electrical machines



Transformer

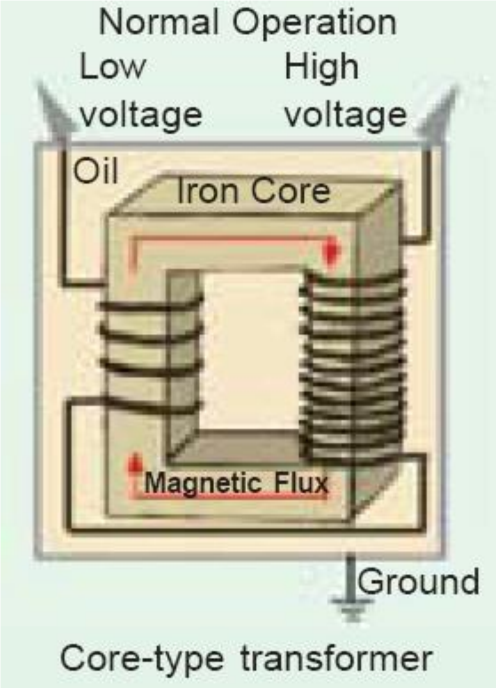
Construction

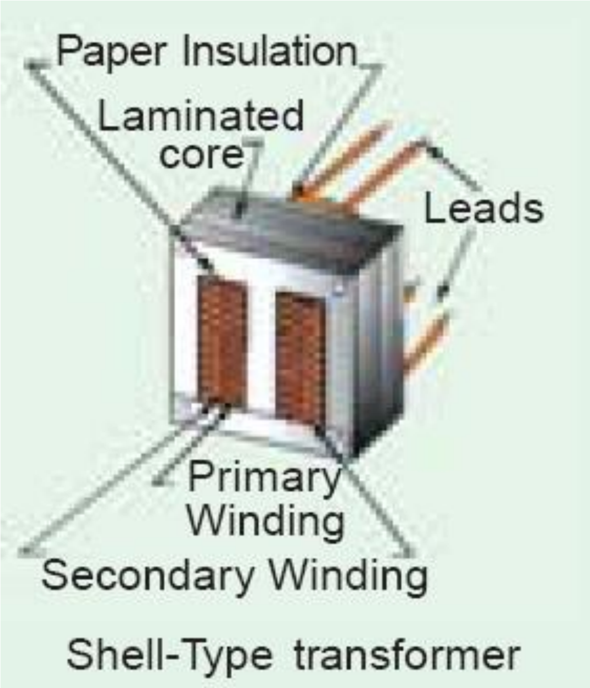




- Elements of a transformer consist of two coils having mutual inductance and a laminated steel core. The two coils are insulated from each other
- Transformer core is constructed of transformer sheet steel laminations assembled to provide a continuous magnetic path with a minimum of air-gap included.
- The steel used is of high silicon content, sometimes heat treated to produce a high permeability and a low hysteresis loss at the usual operating flux densities.
- The eddy current loss is minimized by laminating the core, the laminations being insulated from each other by a light coat of core-plate varnish or by an oxide layer on the surface.
- The thickness of laminations varies from 0.35 mm for a frequency of 50 Hz to 0.5 mm for a frequency of 25 Hz.

Types of Transformer





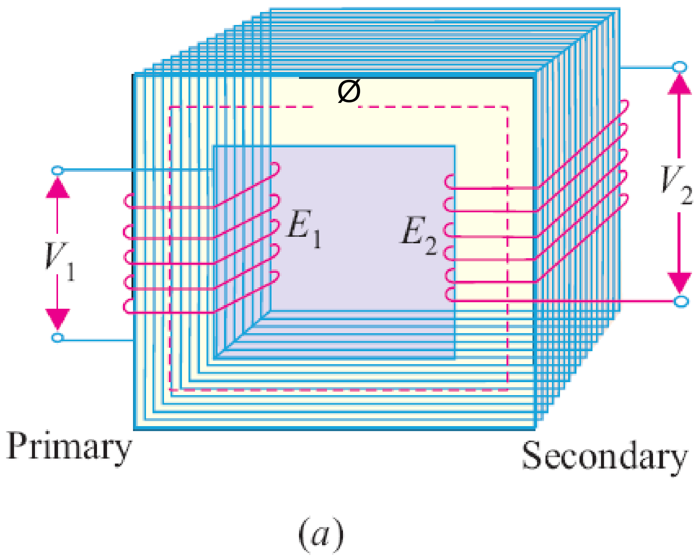
Constructionally, the transformers are of two general types, the two types are known as

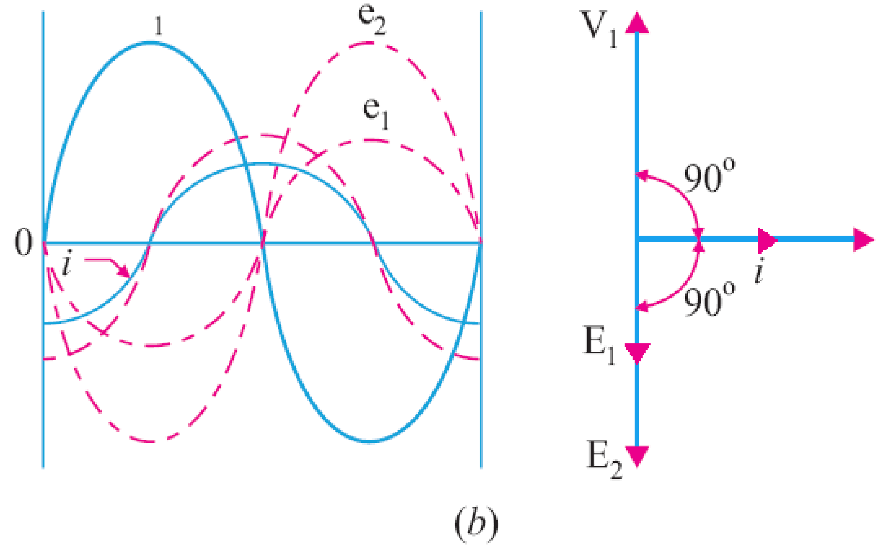
(i) core-type and (ii) shell-type.

In core type transformers, the windings surround a considerable part of the core

In shell-type transformers, the core surrounds a considerable portion of the windings

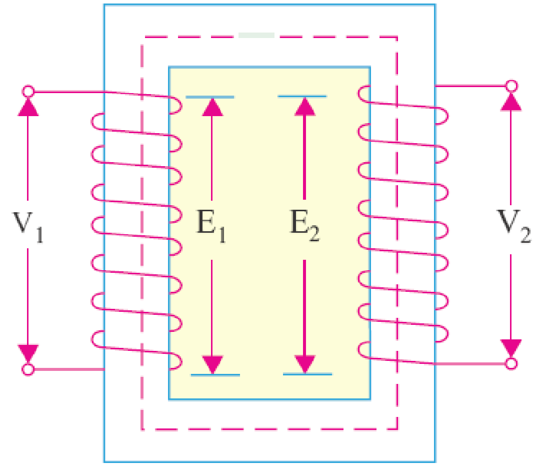
Principle of operation





- Consider an ideal transformer whose secondary is open and whose primary is connected to sinusoidal alternating voltage V_1.
- Potential difference causes an alternating current to flow in the primary.
- The alternating current produces an alternating flux which links with primary as well as with the secondary.
- Therefore, it produces self-induced e.m.f. E_1 in the primary and mutually induced e.m.f E_2 in the secondary

Voltage Transformation Ratio



From equations (*i*) and (*ii*), we get

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K$$

This constant K is known as voltage transformation ratio.

(*i*) If $N_2 > N_1$ *i.e.* $K > 1$, then transformer is called ***step-up*** transformer.

(*ii*) If $N_2 < N_1$ *i.e.* $K < 1$, then transformer is known as ***step-down*** transformer.

Again, for an *ideal* transformer, input VA = output VA.

$$V_1 I_1 = V_2 I_2 \text{ or } \frac{I_2}{I_1} = \frac{V_1}{V_2} = \frac{1}{K}$$

Hence, currents are in the inverse ratio of the (voltage) transformation ratio.

EMF Equation

ϕ = Flux

ϕ_m = Maximum value of flux

N_1 = Number of primary winding turns

N_2 = Number of secondary winding turns

f = Frequency of the supply voltage

E_1 = R.M.S. value of the primary induced e.m.f.

E_2 = R.M.S. value of the secondary induced e.m.f.

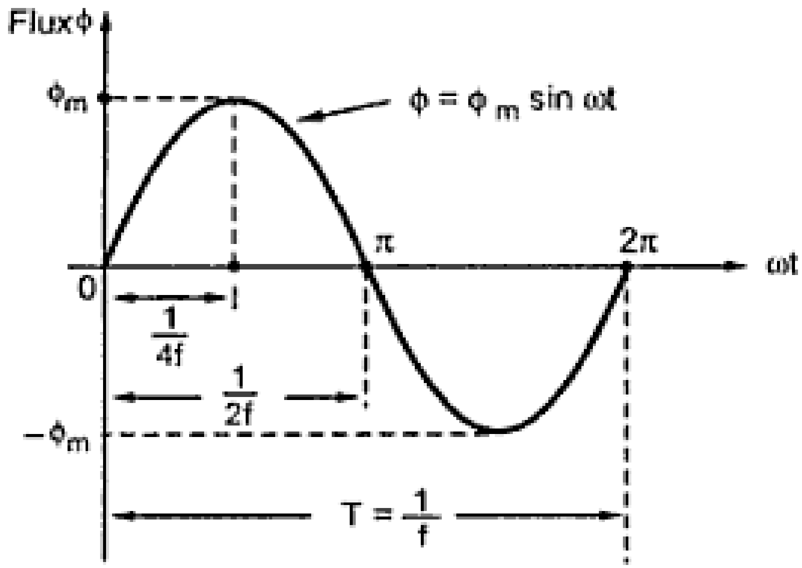


Fig. 1.11 Sinusoidal flux

$\therefore$ average e.m.f. per turn = average rate of change of flux

$\therefore$ average e.m.f. per turn $= \dfrac{d\phi}{dt}$

Now $\dfrac{d\phi}{dt} = \dfrac{\text{Change in flux}}{\text{Time required for change in flux}}$

$\therefore$ $\dfrac{d\phi}{dt} = \dfrac{\phi_m - 0}{\left(\dfrac{1}{4f}\right)}$ as dt for $1/4^{th}$ time period is $1/4f$ seconds

$= 4 f \phi_m$ Wb/sec

$\therefore$ average e.m.f. per turn $= 4 f \phi_m$ volts

Form Factor $= \dfrac{\text{R.M.S. value}}{\text{Average value}} = 1.11$

$\therefore$ R.M.S. value = 1.11 × Average value

$\therefore$ R.M.S. value of induced e.m.f. per turn

$= 1.11 \times 4 f \phi_m = 4.44 f \phi_m$

Applications

- The main application of a transformer is to step-up or step-down the level of voltage or current while maintaining power and frequency is constant in power plant generation stations, receiving end substations and distributing the electrical power to the consumer units for demotic and industrial applications.
- Power Transformer – step up the voltage for transmission from generating stations
- Distribution Transformer – step down the voltage for distribution to consumers
- Autotransformers – isolation
- Current transformers and potential transformers – measuremen.
- Additionally, transformers are also used for impedance matching.

Electric Machine

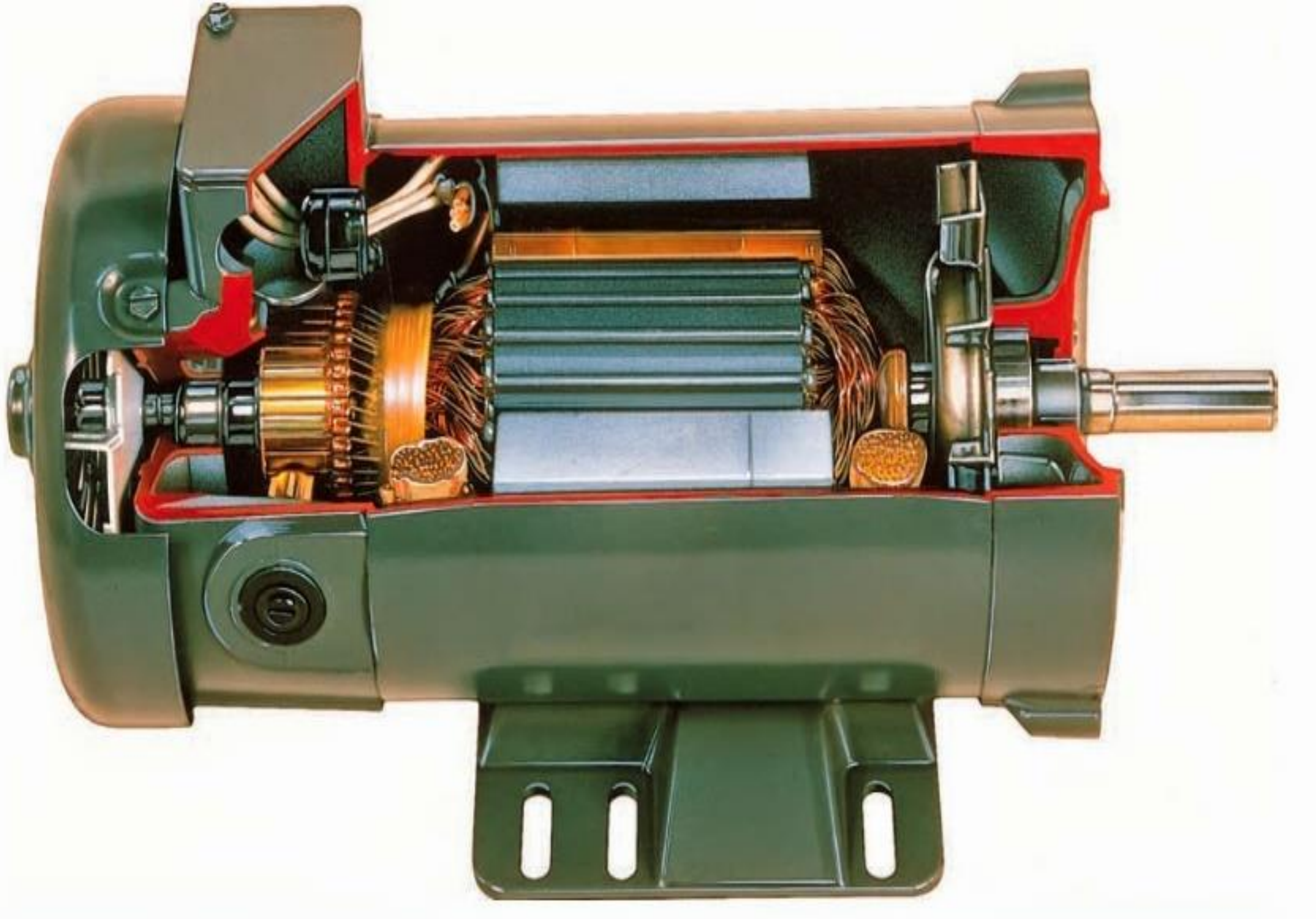
(Rotating Transformer)

Electric machines can be divided into 2 types:

- AC machines
- DC machines
- Special Machines

All Electric machines have:

- Stationary members (stator)
- rotating members (rotor)
- Air gap which is separating stator and rotor



DC motor, field structure, and armature assembly. (Courtesy Reliance Electric Co.)

Complete assembly of D.C. Machine

D.C. machines have components

(i) Magnetic frame
(or) yoke

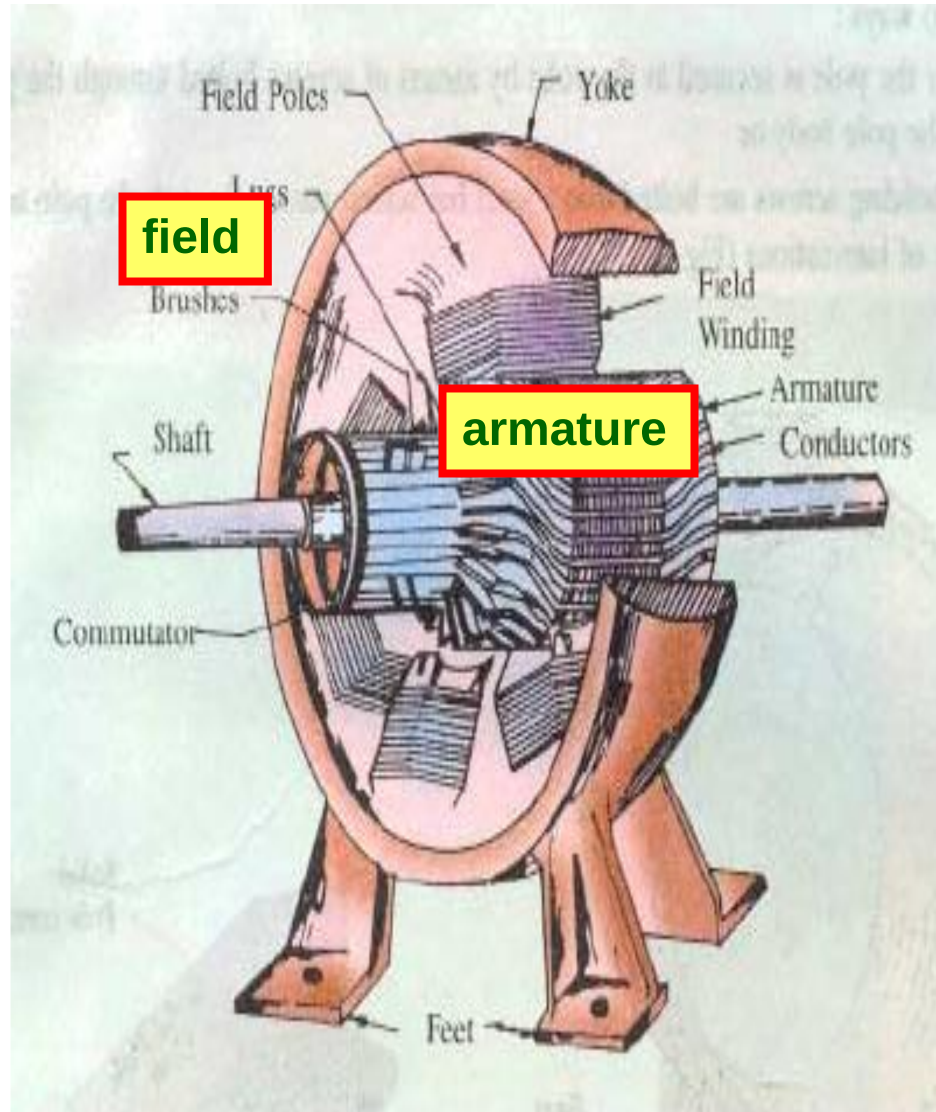
field

(ii) Pole cores
(or) shoes
(iii) field winding
(d.c supply is given to this winding provide magnetic field, it is stationary part)

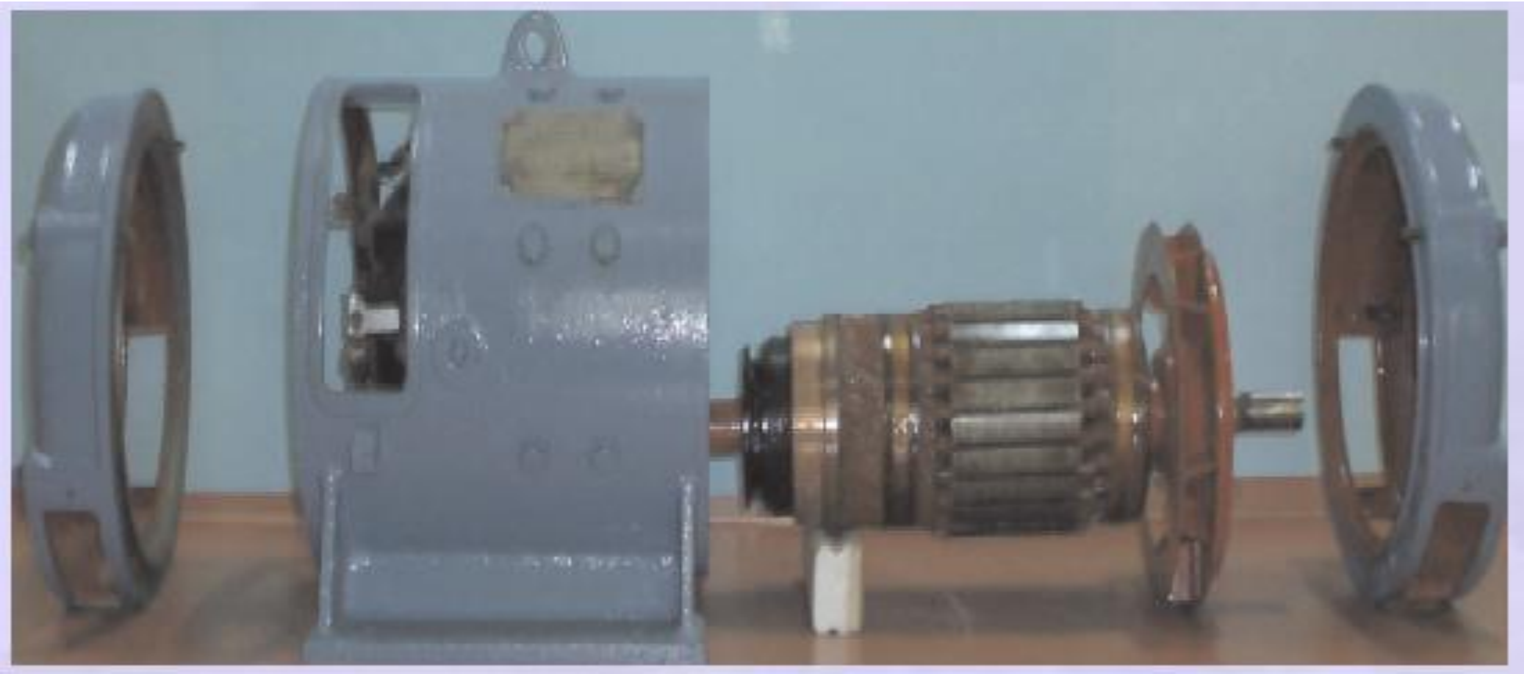
armature

(iv) armature core
(v) armature winding
(Rotating part)

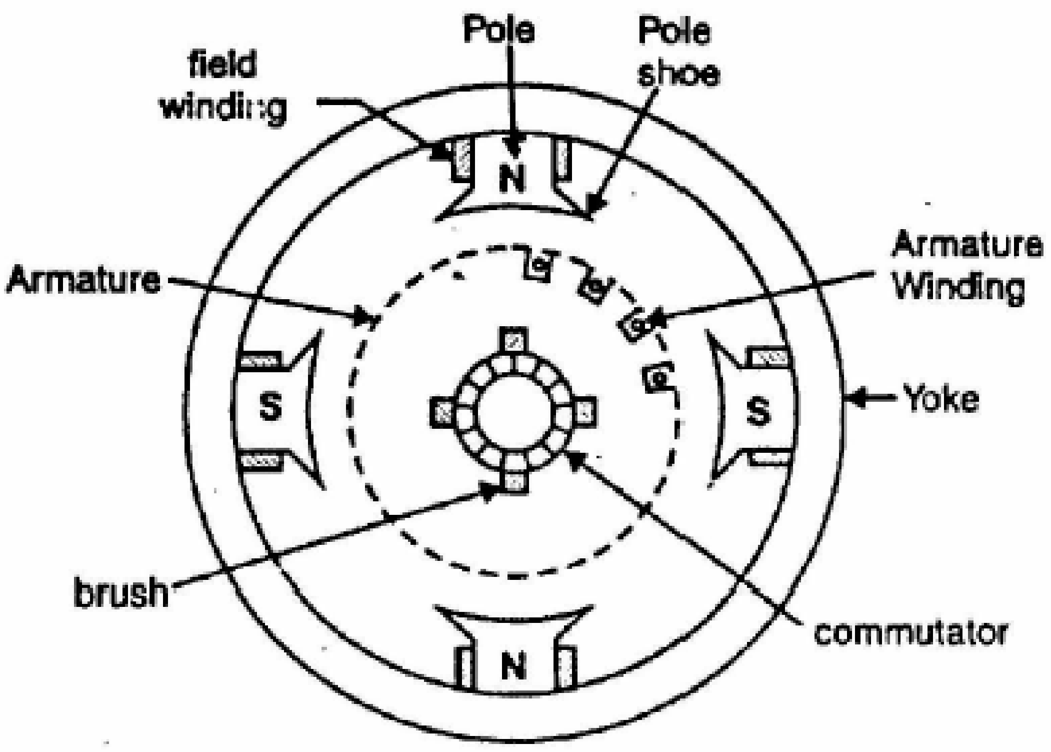
(vi) commutator
(vii)Brushes and bearings



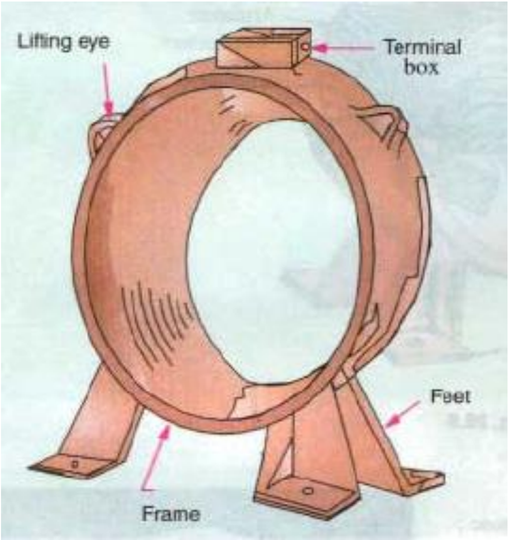
External view: Parts of d.c. machine

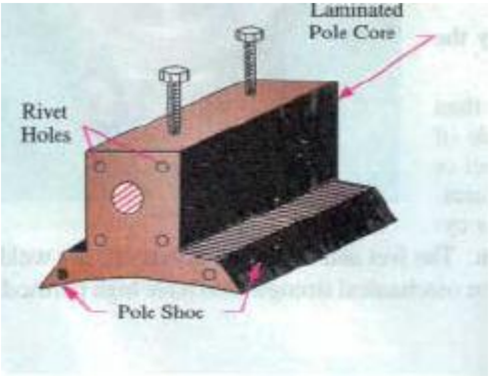


Cross sectional view of d.c. machine



Parts of DC machine





(1) Magnetic frame (or) yoke

It provides

(i) Mechanical support for the whole machine.

(ii) It carries the magnetic flux produced by the poles.

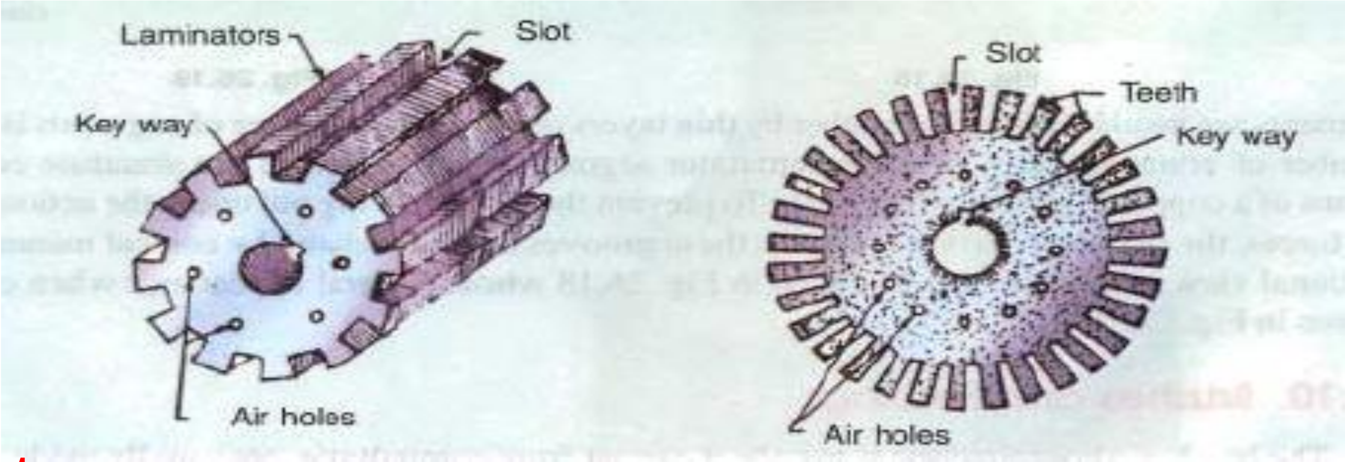
(2) Pole cores (or) shoes

(i) To spread out the flux in the air gap uniformly,

(ii) it supports field or exciting coils.

(3) Field winding

Field coils are copper wires wound over field core, when current is passed through these coils, they electromagnetise the poles which produce necessary flux which is cut by revolving armature conductors.



(4) armature core

The armature core is keyed to the machine shaft and rotates between the field poles. It consists of slotted soft-iron laminations (insulated from each other) that are stacked to form a cylindrical core.

The purpose of laminating the core is to reduce the eddy current loss. Armature core holds the armature winding

(5) Armature winding

The armature winding is placed in armature slots. This is the winding in which e.m.f. 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. The armature winding of a d.c. machine is a closed-circuit winding.

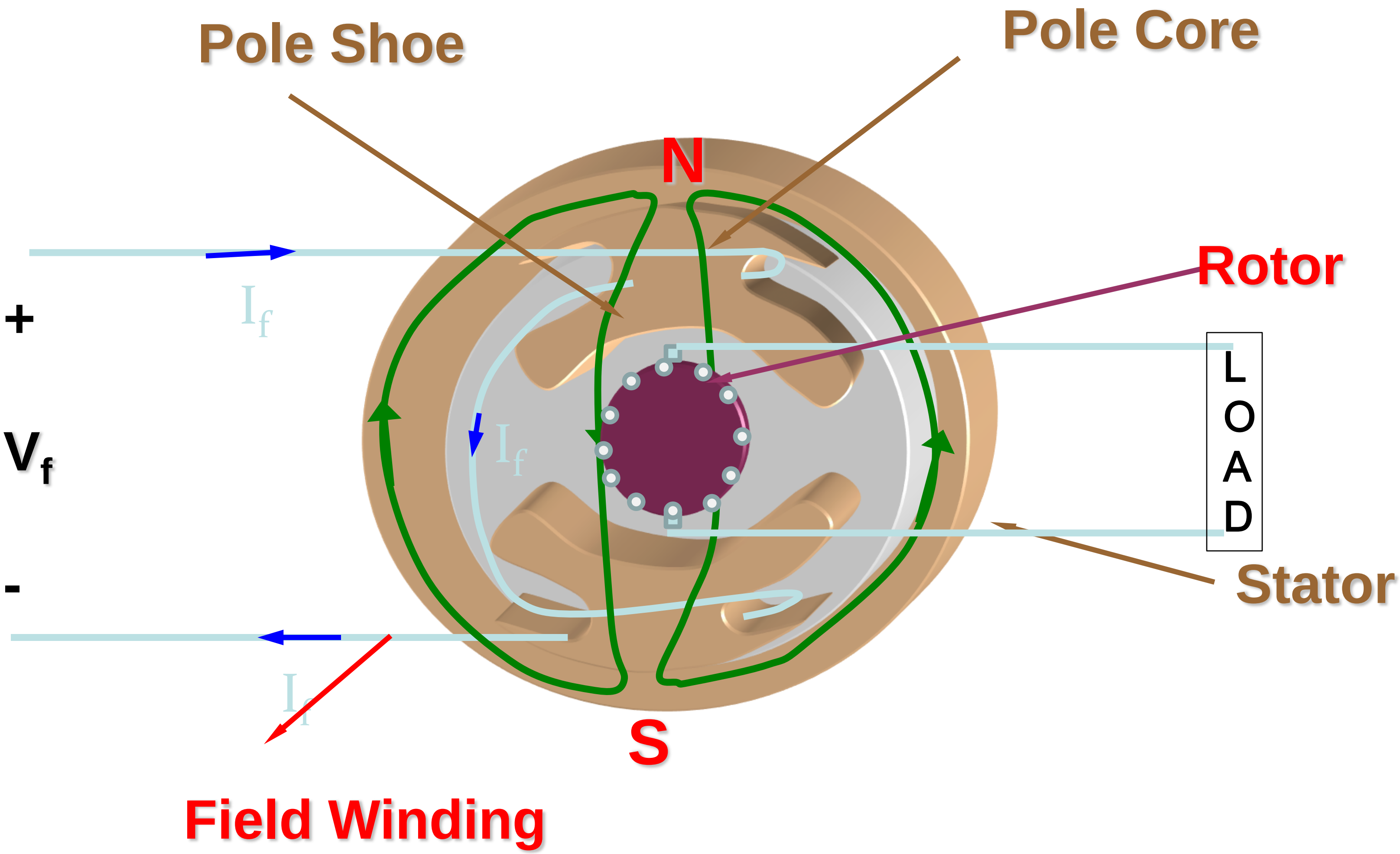
(6) Commutator

A commutator is a mechanical rectifier which converts the alternating voltage generated in the armature winding into direct voltage across the brushes. The commutator is made of copper segments insulated from each other by mica sheets and mounted on the shaft of the machine. The armature conductors are soldered to the commutator segments.

(7) Brushes

The purpose of brushes is to ensure electrical connections between the rotating commutator and stationary external load circuit. The brushes are made of carbon and rest on the commutator.

Construction



D.C Generator

Working Principle

A D.C Generator is the an electrical machine which converts mechanical energy into electrical energy.

It is based on the Faraday's law of Electromagnetic induction principle that whenever flux is cut by a conductor, an e.m.f. is induced, which will cause a current to flow if the conductor circuit is closed. The direction of induced e.m.f. (and hence current) is given by Fleming's right hand rule.

Therefore, the essential components of a generator are:

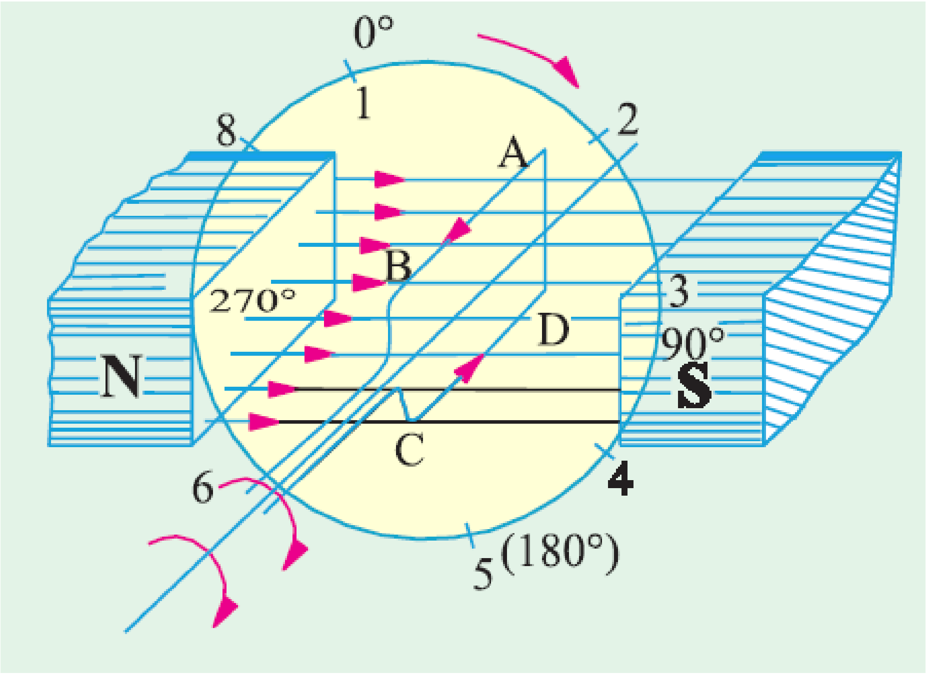
(a) magnetic field (stationary part-stator)

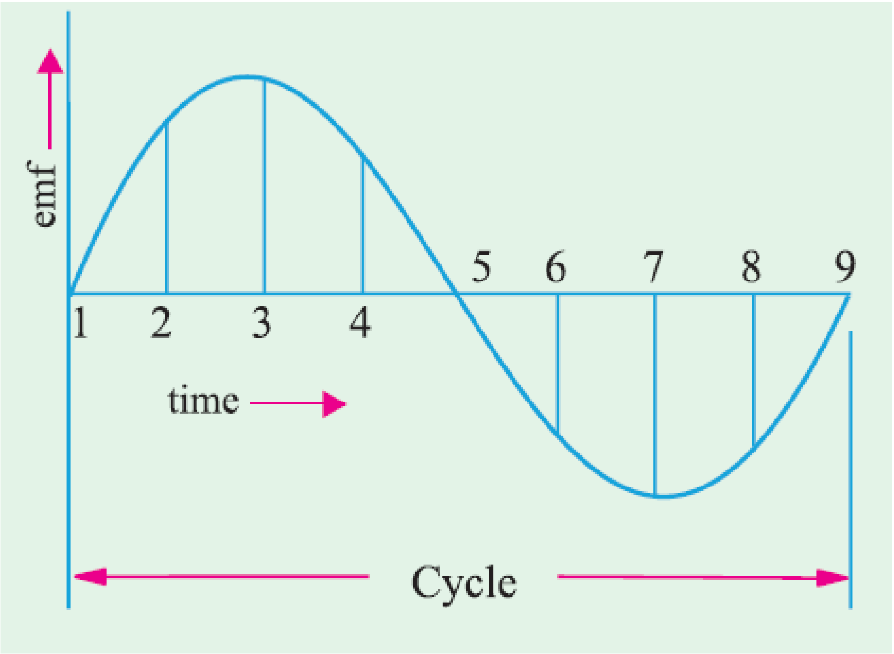
(b) rotating conductor or a group of conductors

(vi) position 6, the coil sides move under a pole of opposite polarity and hence the direction of generated e.m.f. is reversed.

(vii) The maximum e.m.f. in this direction (i.e., reverse direction, See Fig. 2) will be when the loop is at position 7 and zero when at position 1.

This cycle repeats with each revolution of the coil.

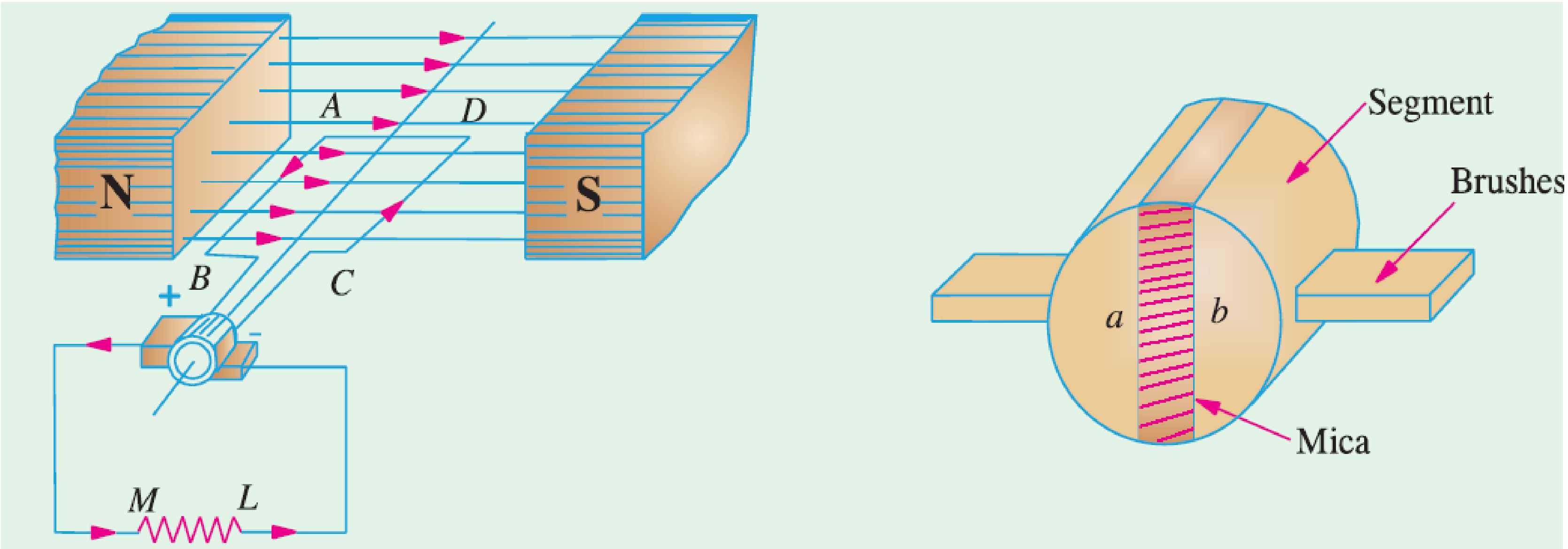




Commutator

The e.m.f. generated in the loop is alternating one. The alternating voltage generated is converted into direct voltage by a device called commutator. **Commutator is a mechanical rectifier.**

The commutator reverses the connection of the coil side to the external load at the same instant the current in the coil side reverses, then the current through the load is direct current.



Generated EMF

Let

φ = Flux/Pole in Wb

Z = Total No. of Armature Conductors

$=$ No. of Slots $\times$ No. of Conductors per Slot

P = No. of Generator poles

A = No. of Parallel Paths in Armature

N = Armature rotation in rpm

E = EMF induced in any parallel path in Armature

Generated EMF E_g = EMF generated in any one of the parallel paths i.e E

$$\text{Average EMF Generated/Conductor} = \frac{d\varphi}{dt} \text{ volt}$$

$$\text{Now, Flux cut/conductor in 1 revolution, } d\varphi = \varphi P \text{ Wb}$$

$$\text{No. of Revolutions/sec} = N/60$$

$$\therefore \text{Time for 1 revolution, } dt = \frac{60}{N} \text{ sec}$$

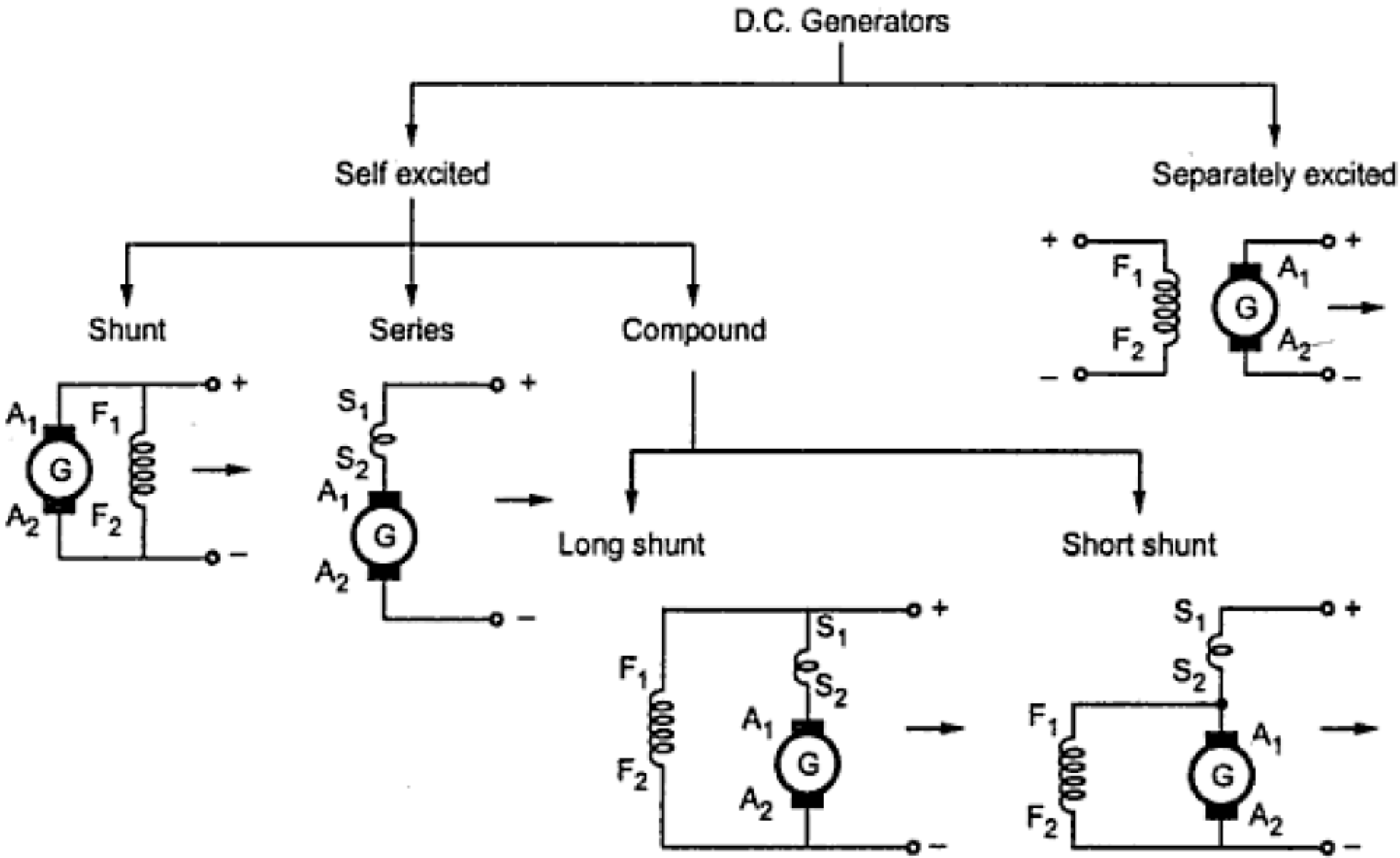
Hence, according to Faraday's Laws of electromagnetic induction,

$$\text{EMF Generated/conductor} = \frac{d\varphi}{dt} \text{ volt}$$

$$= \frac{\varphi P}{60/N} = \frac{\varphi P N}{60} \text{ volt}$$

$$\text{Emf induced per parallel path } E_g = \frac{\varphi Z N}{60}\left(\frac{P}{A}\right) \text{ volt}$$

Types of DC Generator



Applications of various types of Generator

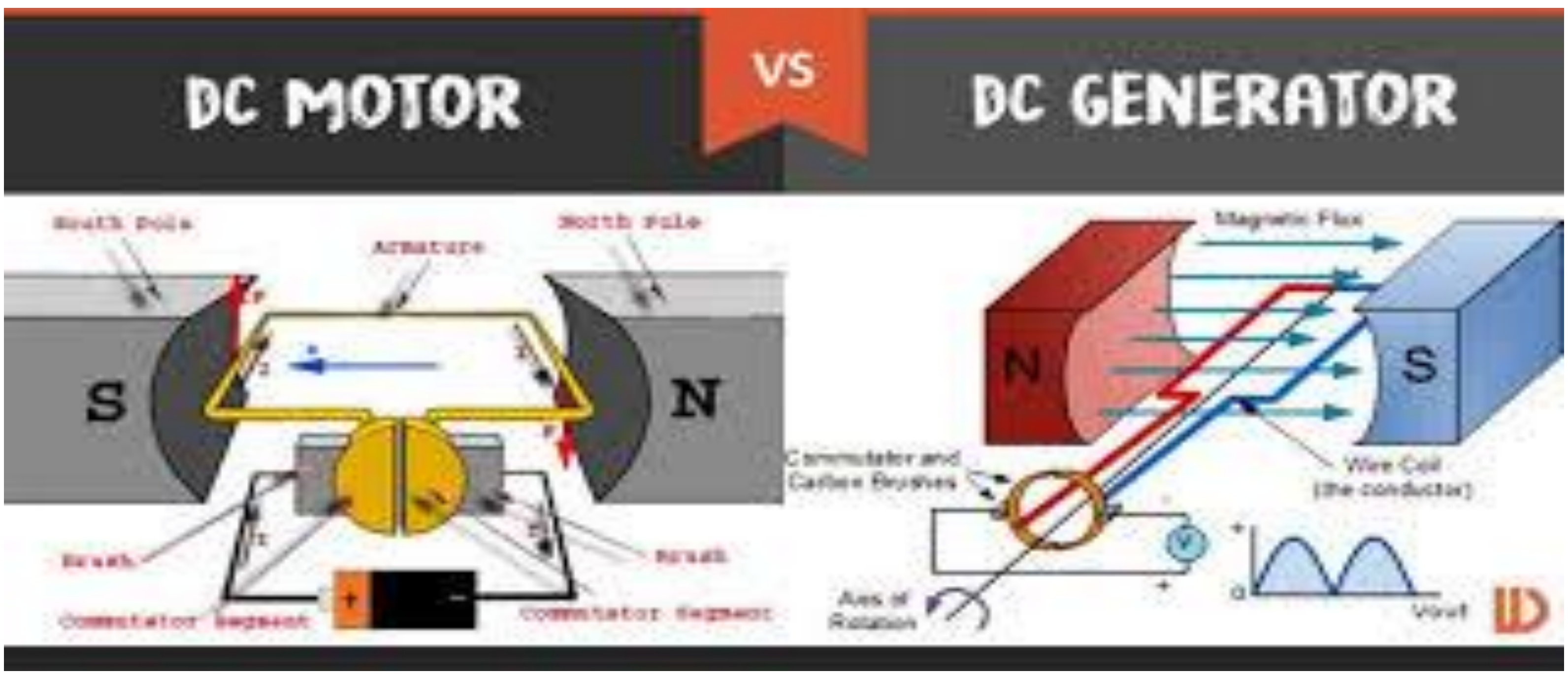
- Separately Excited Generators
  - Use is restricted to special applications like electro-plating, electro-refining of materials etc.
- Shunt Generators
  - Battery charging and ordinary lighting purposes
- Series Generators
  - Boosters on DC feeders, as a constant current generator for welding generator and arc lamps
- Cumulatively Compound generators
  - Domestic lighting purposed and to transmit energy over long distance.
- Differentially compound generators
  - Very rare, used for special applications like electric arc welding

DC Motor

A **motor** is an electrical **machine** which converts electrical energy into mechanical energy.

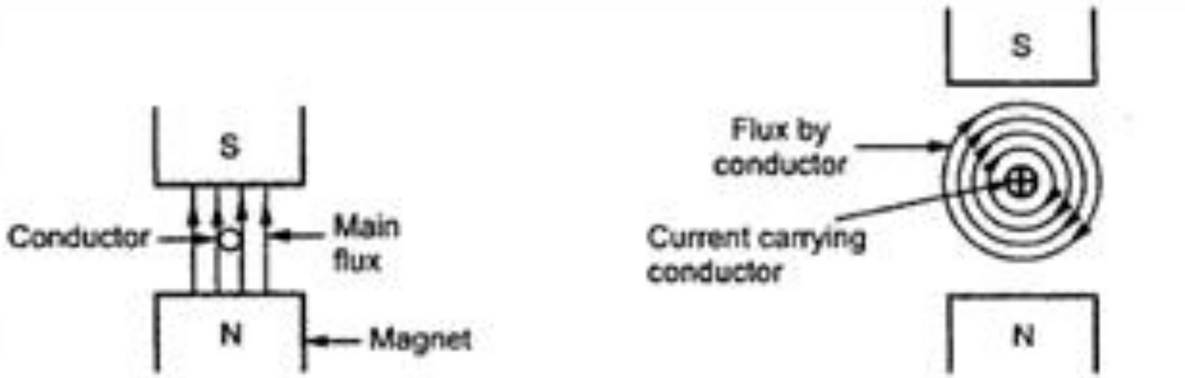
Working principle

The **principle** of **working** of a **DC motor** is that "whenever a current carrying conductor is placed in a magnetic field, it experiences a mechanical force".

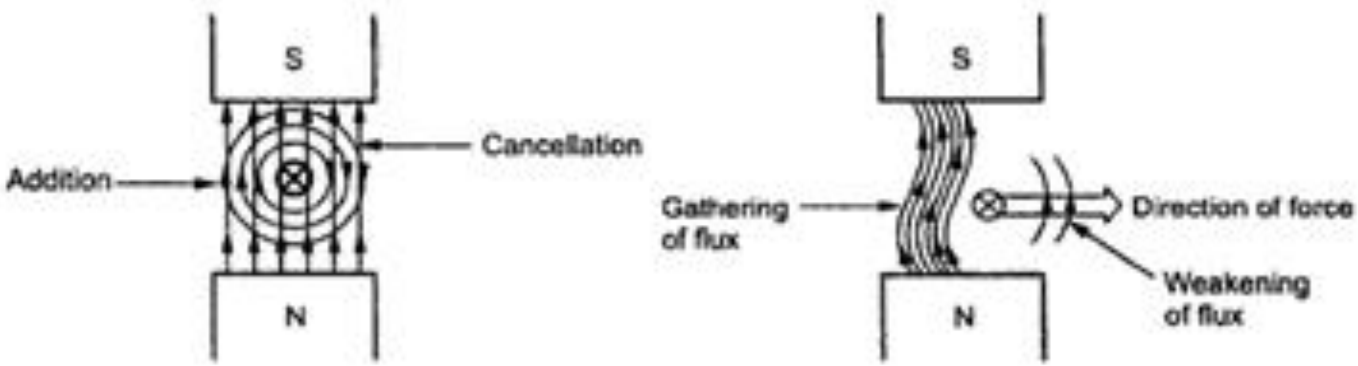


Input is Electrical energy

output is Electrical energy



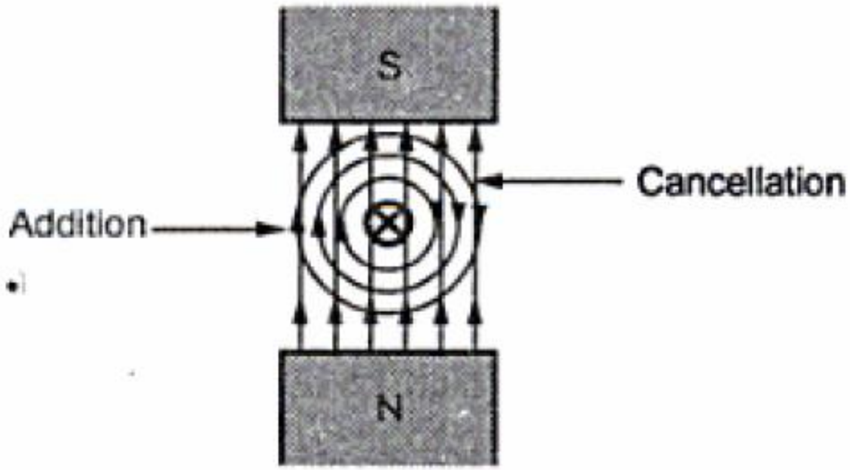
(a) Conductor in a magnetic field (b) Flux produced by current carrying con



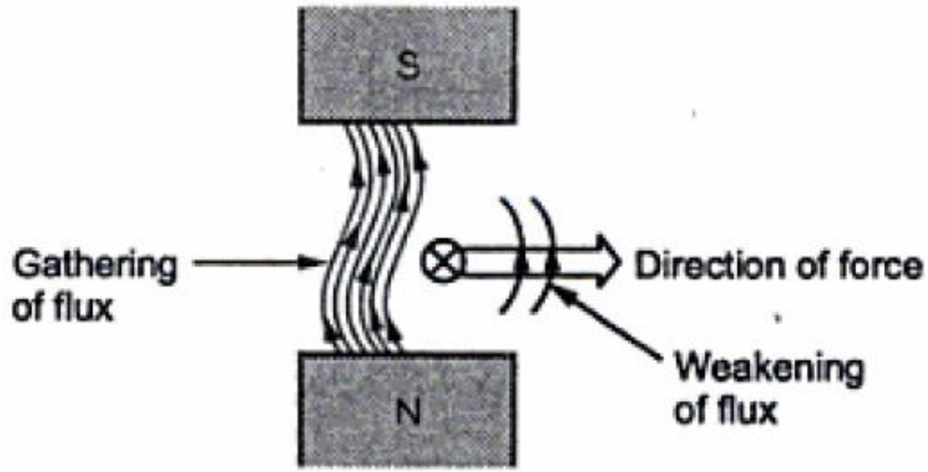
(a) Interaction of two fluxes (b) Force experienced by the conductor

Now there are two fluxes present,

1. The flux produced by the permanent magnet called main flux.
2. The flux produced by the current carrying conductor.

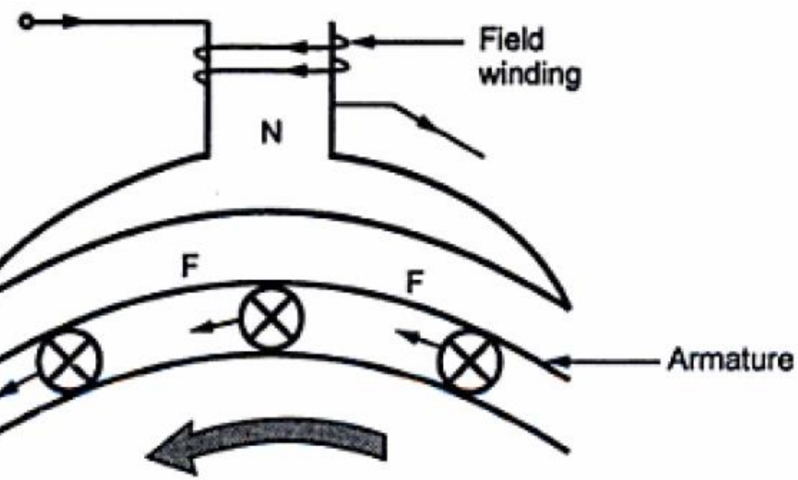


(a) Interaction of two fluxes



(b) Force experienced by the conductor

https://www.youtube.com/watch?v=LAtPHANEfQo&t=190s



Torque exerted on armature

Direction of Rotation of Motor

The magnitude of the force experienced by the conductor in a motor is given by,

$$F = B\,l\,I \quad \text{Newtons (N)}$$

B = Flux density due to the flux produced by the field winding.

l = Active length of the conductor.

I = Magnitude of the current passing through the conductor.

The direction of such force i.e. the direction of rotation of a motor can be determined by Fleming's left hand rule. So **Fleming's right hand rule** is to determine direction of induced e.m.f. i.e. for **generating action** while **Fleming's left hand rule** is to determine direction of force experienced i.e. for **motoring action.**

The rule states that, 'Outstretch the three fingers of the left hand namely the first finger, middle finger and thumb such that they are mutually perpendicular to each other. Now point the first finger in the direction of magnetic field and the middle finger in the direction of the current then the thumb gives the direction of the force experienced by the conductor'.

Significance of Back EMF

It is seen in the generating action, that when a conductor cuts the lines of flux, e.m.f. gets induced in the conductor. The question is obvious that in a d.c. motor, after a motoring action, armature starts rotating and armature conductors cut the main flux. So is there a generating action existing in a motor ? The answer to this question is 'Yes'.

After a motoring action, there exists a generating action. There is an induced e.m.f. in the rotating armature conductors according to Faraday's law of electromagnetic induction. This induced e.m.f. in the armature always acts in the opposite direction of the supply voltage. This is according to the **Lenz's law** which states that the direction of the induced e.m.f. is always so as to oppose the cause producing it. In a d.c. motor, electrical input i.e. the supply voltage is the cause and hence this induced e.m.f. opposes the supply voltage. This e.m.f. tries to set up a current through the armature which is in the opposite direction to that, which supply voltage is forcing through the conductor.

So as this e.m.f. always opposes the supply voltage, it is called **back e.m.f.** and denoted as E_b. Though it is denoted as E_b, basically it gets generated by the generating action which we have seen earlier in case of generators. So its magnitude can be determined by the e.m.f. equation which is derived earlier. So,

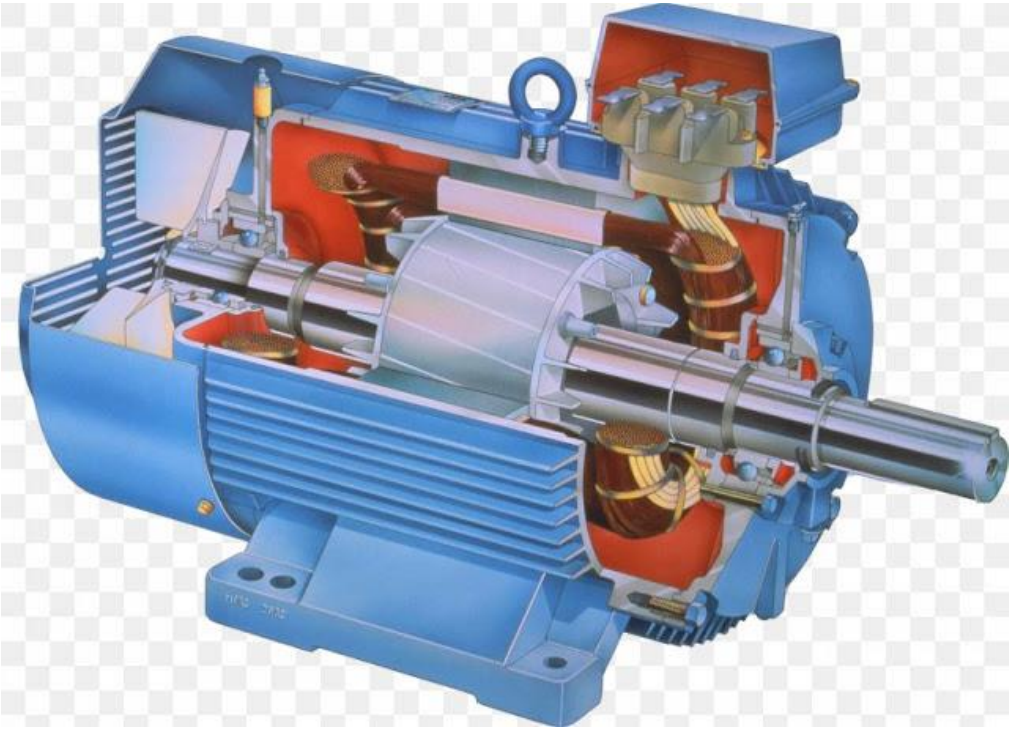
$$E_b = \frac{\phi P N Z}{60 A} \text{ volts}$$

Applications

Type of motor	*Characteristics*	*Applications*
Shunt	Approximately constant speed Adjustable speed Medium starting torque (Up to 1.5 F.L. torque)	For driving constant speed line shafting Lathes Centrifugal pumps Machine tools Blowers and fans Reciprocating pumps
Series	Variable speed Adjustable variying speed High Starting torque	For traction work *i.e.* Electric locomotives Rapid transit systems Trolley, cars etc. Cranes and hoists Conveyors
Comulative Compound	Variable speed Adjustable varying speed High starting torque	For intermittent high torque loads For shears and punches Elevators Conveyors Heavy planers Heavy planers Rolling mills; Ice machines; Printing presses; Air compressors

Induction motors

Single-Phase Induction motors



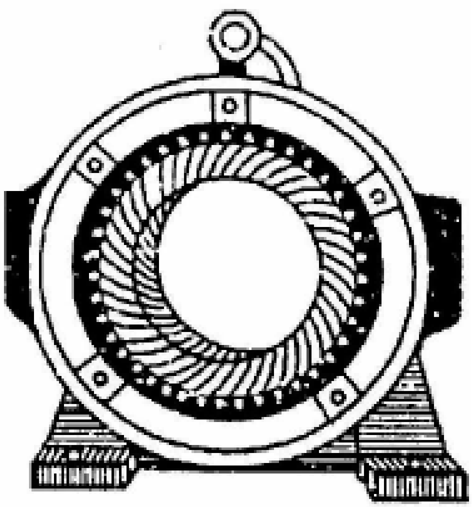
https://www.youtube.com/watch?v=awrUxv7B-a8

Construction

A single phase induction motor has

(i) **Stator:** single phase winding is distributed over the inner periphery of the stator.

(ii) **Rotor**: It is **squirrel-cage type,** with **copper bars** placed in its slots. The ends of these bars are shorted by **end-rings to form closed rotor circuit.**

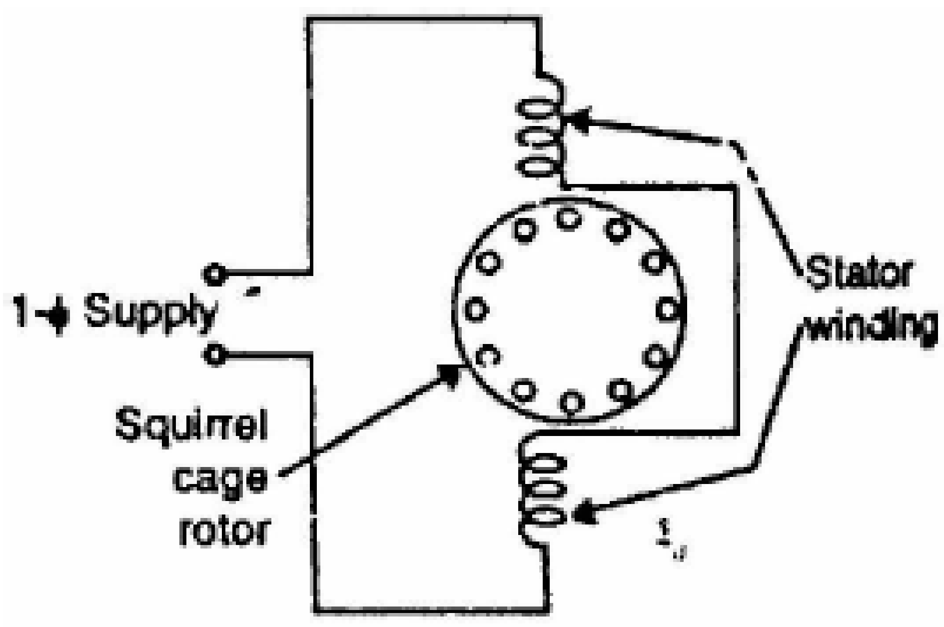


Working Principle

The single-phase stator winding produces a **magnetic field that pulsates** i.e the field polarity reverses after each half cycle but the field does not rotate.

Consequently, **the alternating flux cannot produce rotation in a stationary squirrel-cage rotor** and hence single phase induction motor are **not a self-starting motor**.

However, if the rotor is started by auxiliary means, the motor will quickly attain me final speed.

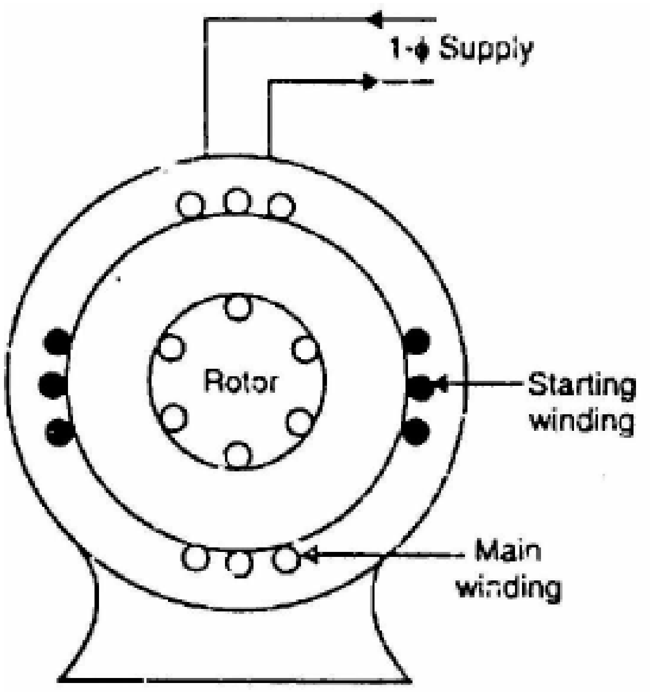


Self-starting

For this purpose, the stator of a single-phase motor is provided with an extra winding, known as ***starting*** (or auxiliary) winding, in addition to the ***main* or *running winding***.

It is so arranged that the phase-difference between the currents in the two stator windings is very large (ideal value being 90º).

Hence, the motor behaves like a two phase motor and produces a revolving flux and hence make the motor self-starting.



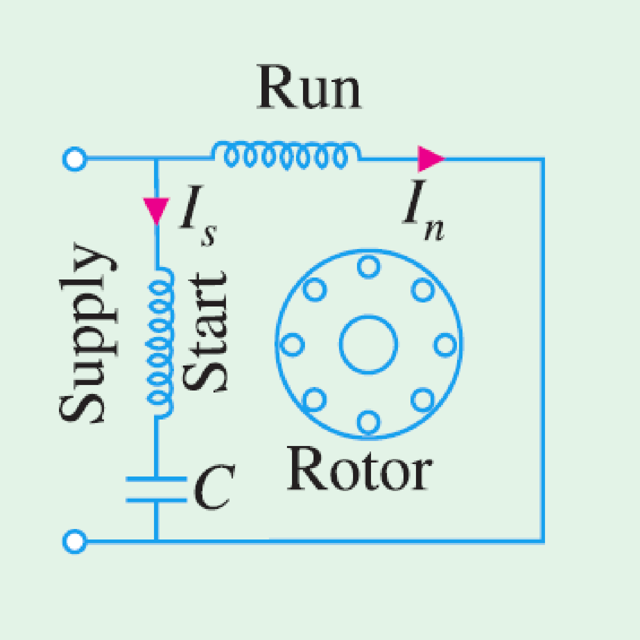
Capacitor Start-and-Run Motor

In these motors, the necessary phase difference between *Is* and *Im* is produced by connecting a capacitor in series with the starting winding.

The capacitor is generally of the electrolytic type and is usually mounted on the outside of the motor as a separate unit

The capacitor is designed for extremely short-duty service and is guaranteed for not more than 20 periods of operation per hour.

The advantages of leaving the capacitor permanently in circuit are **(*i*)** improvement of over-load capacity of the motor **(*ii*)** a higher power factor **(*iii*)** higher efficiency and **(*iv*)** quieter running of the motor which is so much desirable for small power drives in offices and laboratories.

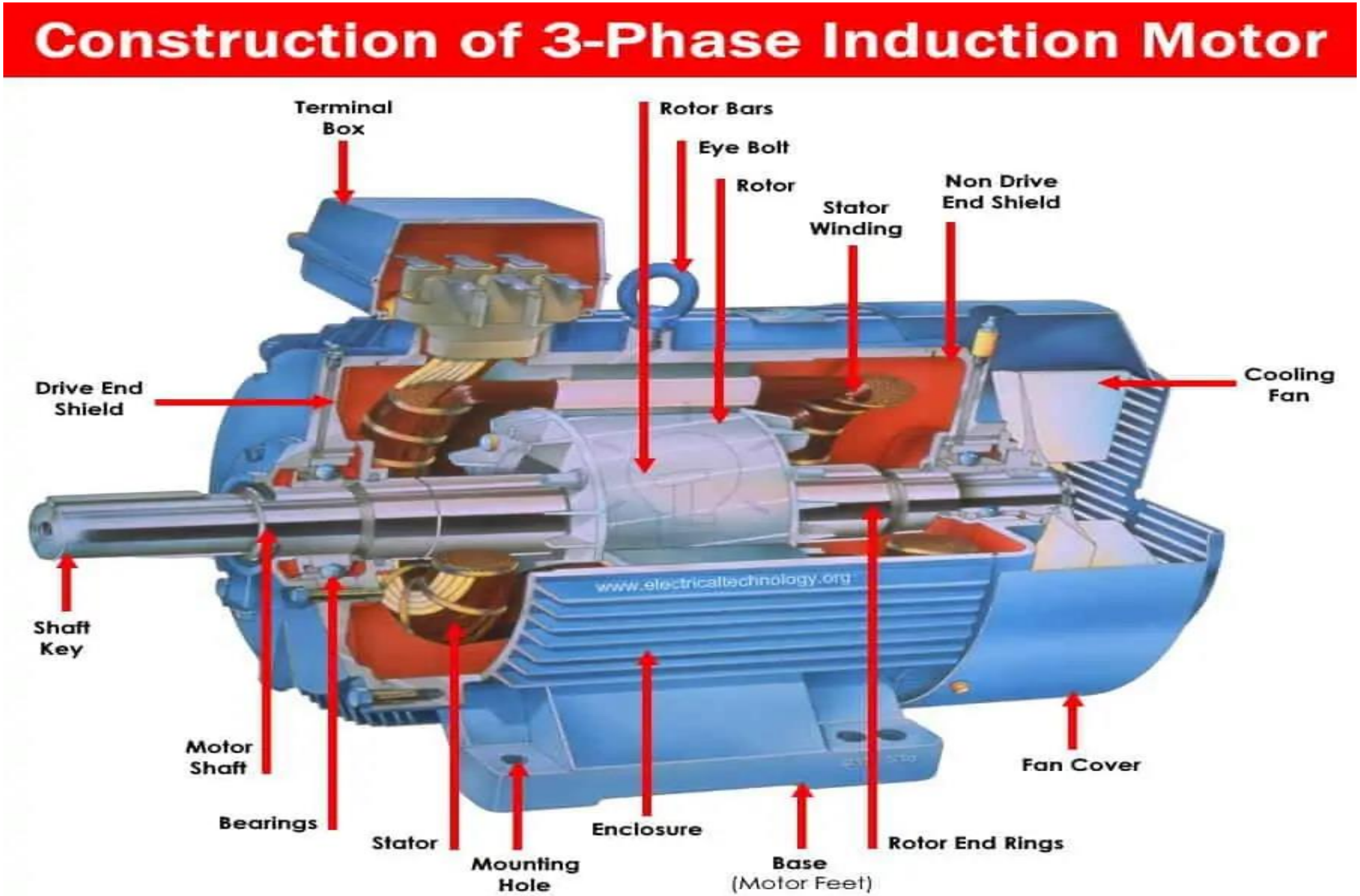


Applications

These are used in low power applications and widely used in domestic applications as well as industrial. And some of those are mentioned below

- Pumps
- Compressors
- Small fans
- Mixers
- Toys
- High speed vacuum cleaners
- Electric shavers
- Drilling machines

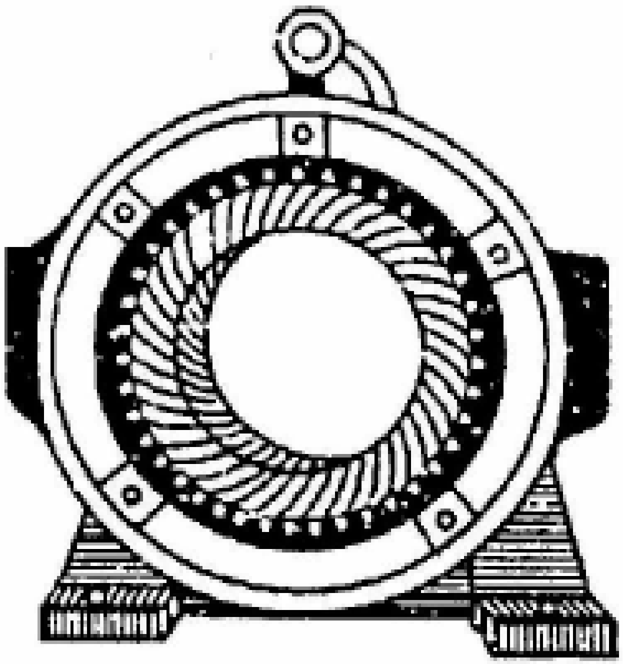
Three Phase Induction Motors



Construction

1. Stator

It consists of a hollow, cylindrical core made up of thin laminations of silicon steel to reduce hysteresis and eddy current losses. This has slots to accommodate a **3-phase star or delta connected winding**, called as stator winding.



2. Rotor

The rotor, mounted on a shaft, is a hollow laminated core having slots on its outer periphery, in which rotor winding is placed. There are two types of rotor winding in three phase induction motors, based on which rotor is classified as

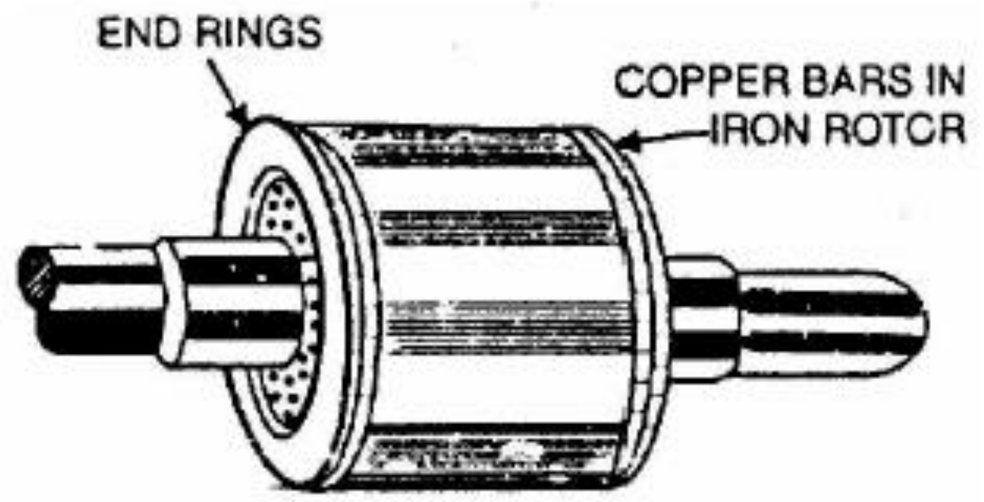
(i) Squirrel cage rotor

(ii) Slip-ring or Wound rotor

(i) **Squirrel cage rotor**. It consists of a laminated cylindrical core having parallel slots on its outer periphery. One copper or aluminum bar is placed in each slot. All these bars are joined at each end by metal rings called end rings. This forms a permanently short-circuited winding.

The entire construction (bars and end rings) **resembles a squirrel cage and hence the name**. Those induction motors which employ squirrel cage rotor are called squirrel cage induction motors.

The disadvantage of squirrel cage motor is its low starting torque.

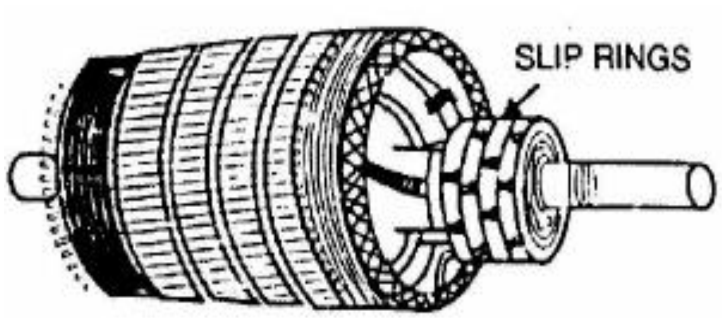


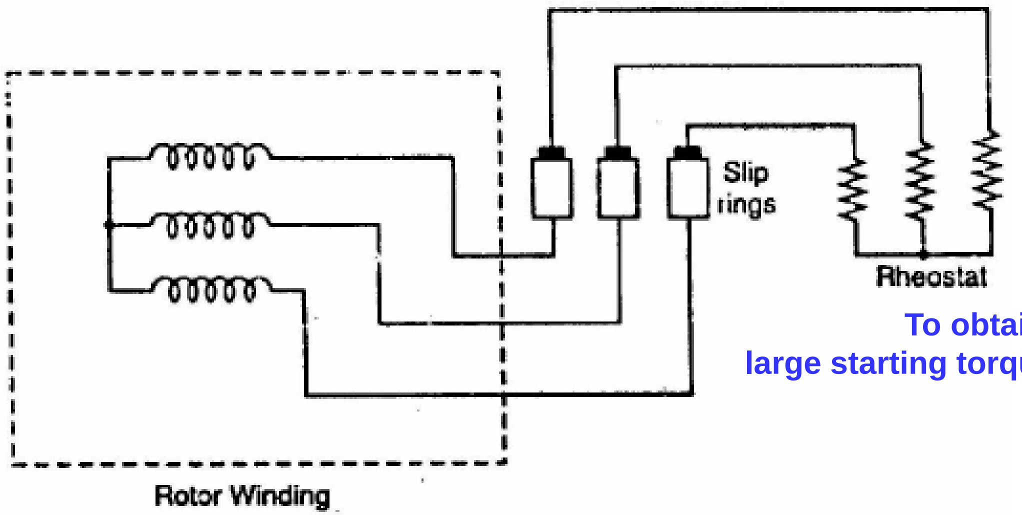
(ii) Wound rotor.

It consists of a laminated cylindrical core and **carries a 3-phase winding, similar to the one on the stator**. The open ends of the rotor winding are brought out and joined to three insulated slip rings which are connected to a 3-phase star-connected rheostat.

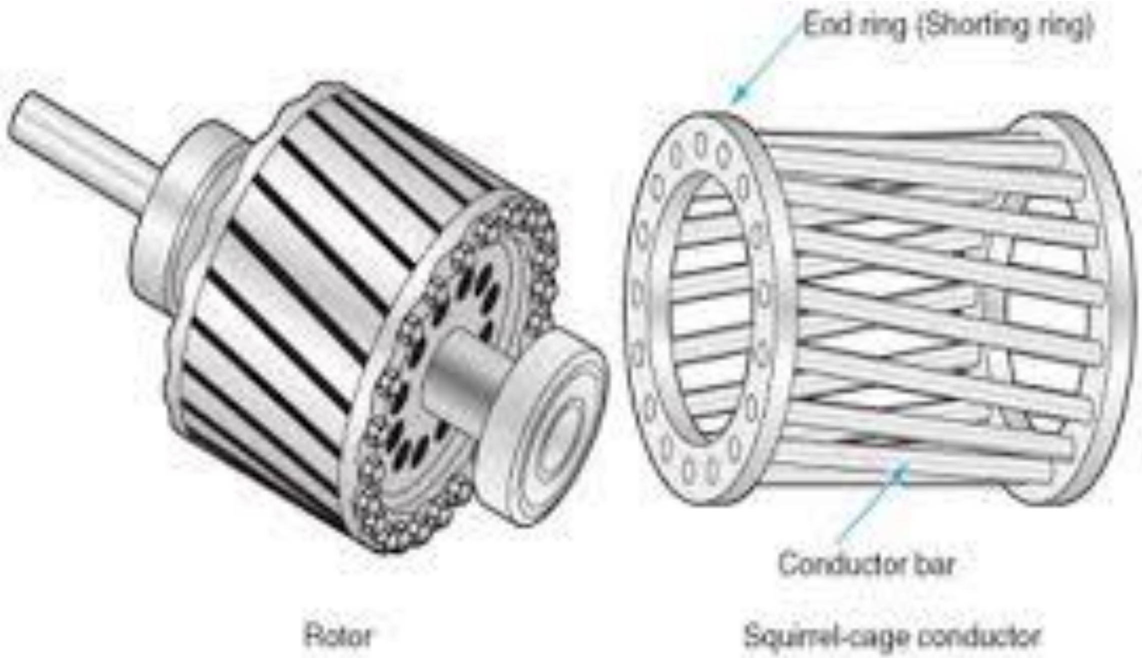
At starting, the external resistances are included in the rotor circuit to give a large starting torque. This is the advantage of slip-ring IM.

When the motor attains normal speed, the external resistances are removed so that the wound rotor runs like a squirrel cage rotor.





To obtain large starting torque


End ring (Shorting ring)
Conductor bar
Rotor
Squirrel-cage conductor

Principle of Operation

Like a transformer, a 3Φ induction motor **works on the principle of electromagnetic induction.** so it is also called as a rotating transformer with a rotating short circuited secondary (rotor). The stator corresponds to primary and rotor corresponds to secondary.

When **a current carrying conductor is placed in magnetic field, a mechanical force acts on the conductor.**

The **operation of Induction motor** can be explained as

(i) When 3-phase stator winding is energized from a 3-phase supply, a rotating magnetic field is set up which rotates at synchronous speed,

N_s (= 120 f/P)

(ii) When the rotating field cuts the rotor conductors, e.m.f is induced in it due to induction principle. Since the rotor circuit is short-circuited, current flows in rotor conductors.

(iii) The nature of this current is to oppose the cause producing it which is the relative speed difference between the stator flux and the rotor and hence it develops a torque to rotate the rotor in the same direction as that of stator flux

Applications

- Lifts
- Cranes
- Hoists
- Large capacity exhaust fans
- Driving lathe machines
- Crushers
- Oil extracting mills
- Textile and etc.

Synchronous Generator

https://www.youtube.com/watch?v=tiKH48
EMgKE

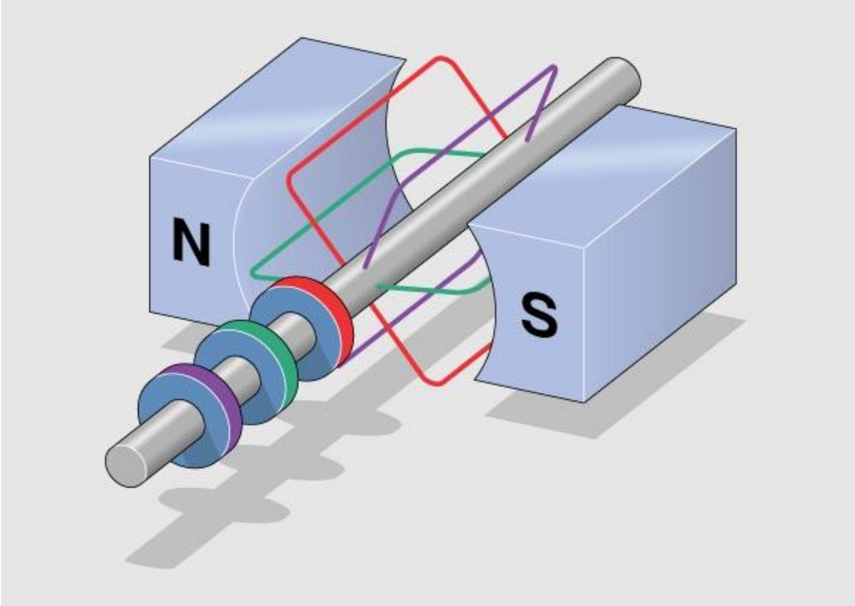
Introduction

- *Synchronous generators* or *alternators* are used to convert mechanical power derived from steam, gas, or hydraulic-turbine to ac electric power
- Synchronous generators are the primary source of electrical energy we consume today
- Almost the entire India is powered by AC generators connected together in parallel.
- The turbines called prime movers use oil, coal, natural gas, or nuclear energy.
- *Synchronous motors* are built in large units compare to induction motors (Induction motors are cheaper for smaller ratings) and used for constant speed industrial drives

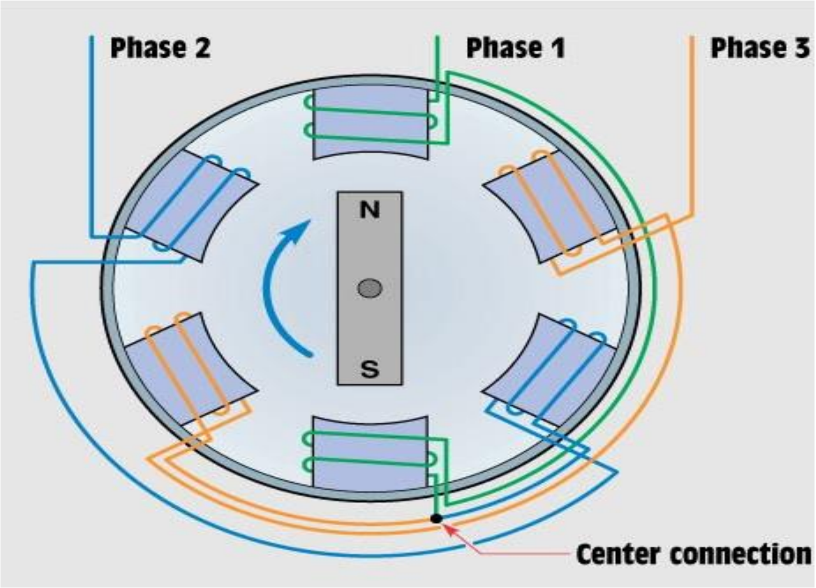
Construction

There are two basic types of alternators:

- Revolving-armature-type alternators
- Revolving-field-type alternators



Revolving armature design.



Revolving field design

Advantages of Rotating Field

- Output current led directly to load circuit without passing through brushes(Stationary armature)
- Easier to insulate stationary armature for high voltage A.C
- Sliding contacts in low power DC field circuit – easily insulated
- No mechanical stress or deformation of heavy rotating conductors

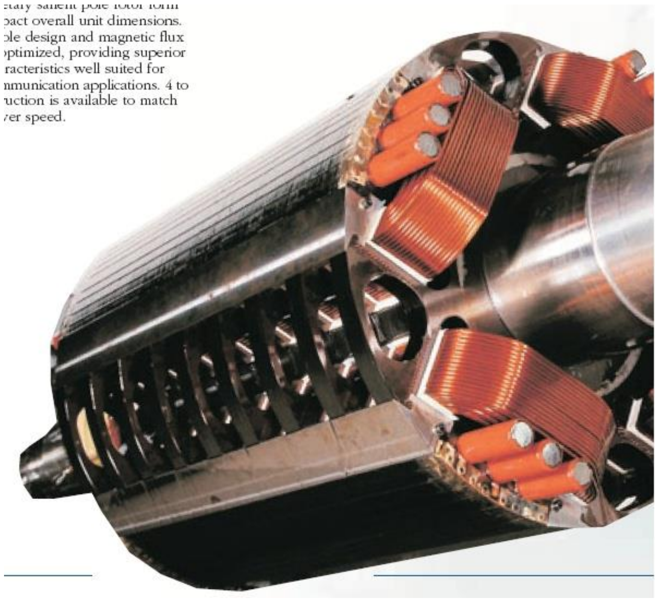
Rotating Field type Alternator

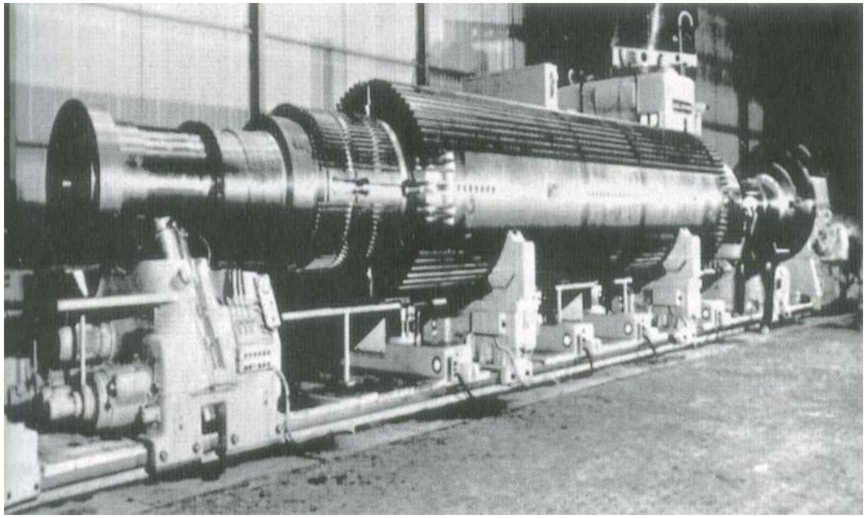
- Basic parts of a synchronous generator:
  - Rotor - dc excited winding
  - Stator - 3-phase winding in which the ac emf is generated

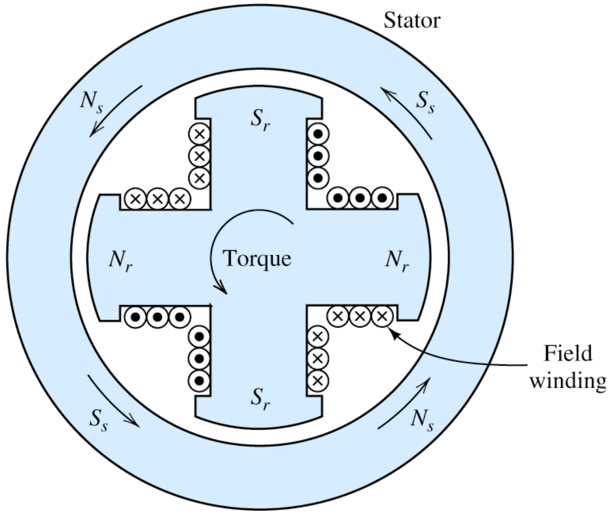
- Stator consists of distributed armature winding whose leads are taken out as R , Y and B
- The rotor is an electromagnet that provides the magnetic field needed to induce a voltage into the stator windings.
- Excitation current (DC) in the rotor is required to establish the magnetic field.

Various Types

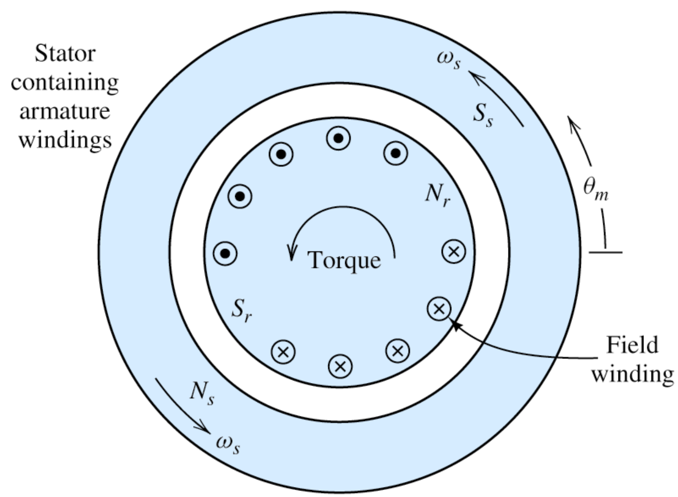
- Salient-pole synchronous machine
- Cylindrical or round-rotor synchronous machine



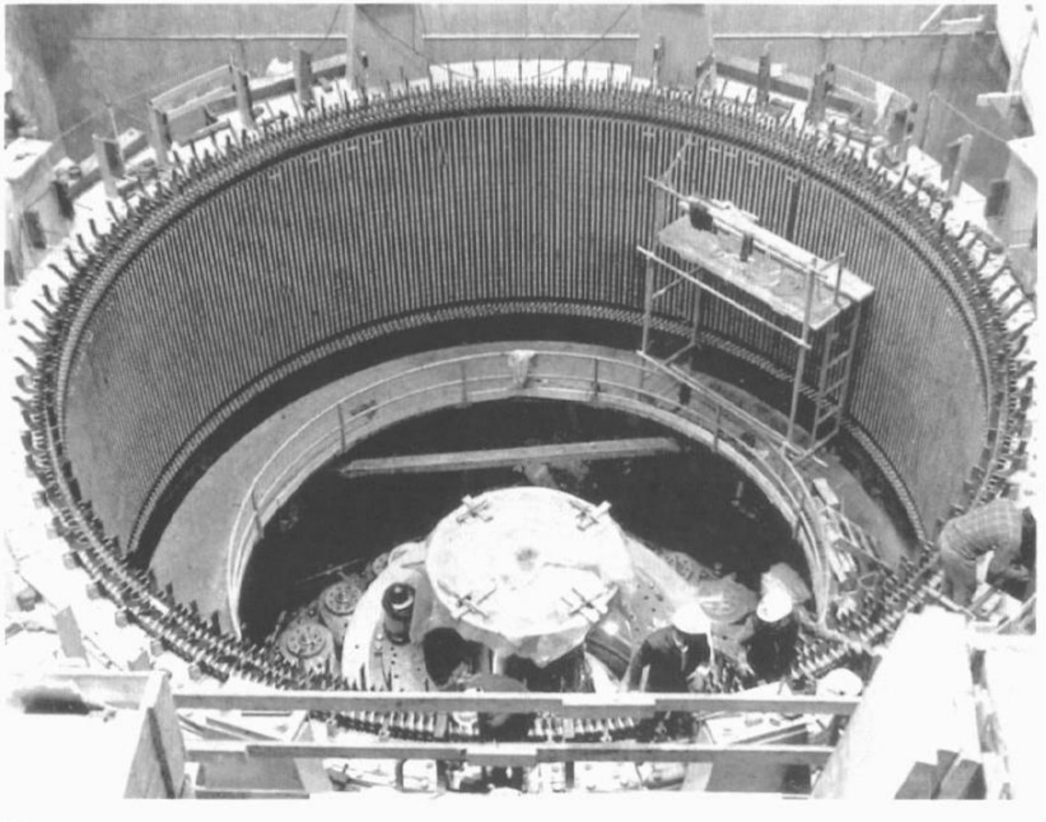
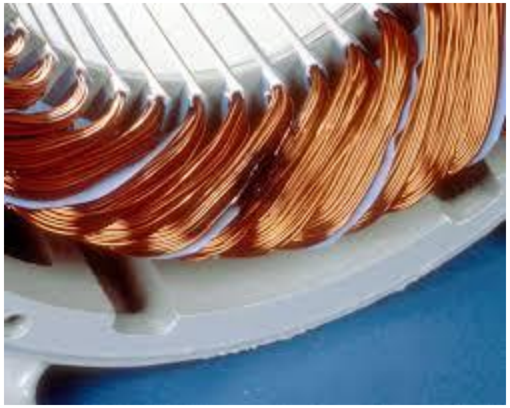


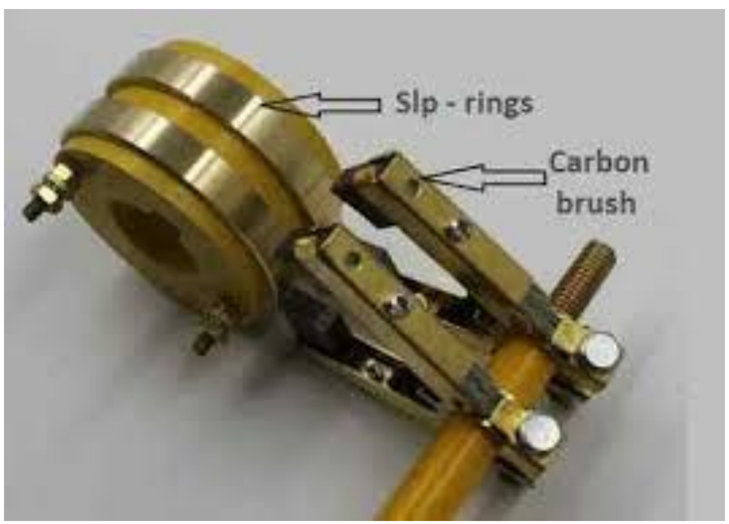


Salient-pole synchronous machine



Cylindrical or round-rotor synchronous machine


Slp - rings
Carbon
brush

Operation Principle

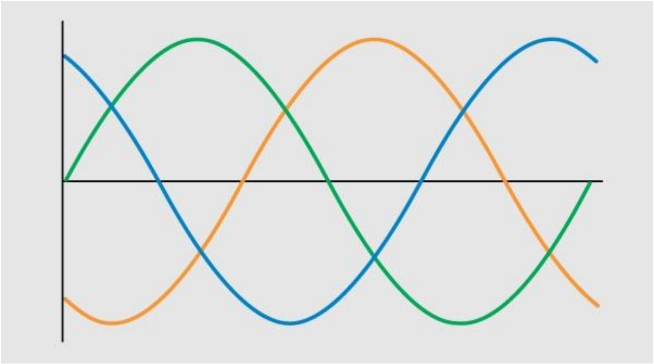
The rotor of the generator is driven by a prime-mover

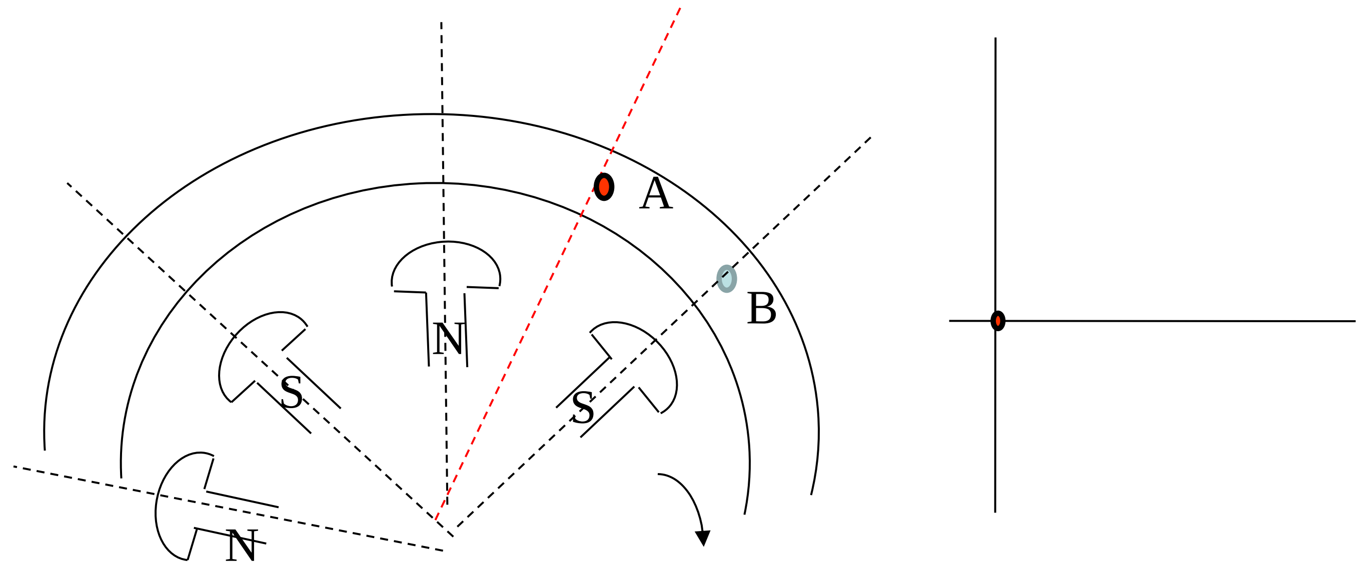
↓

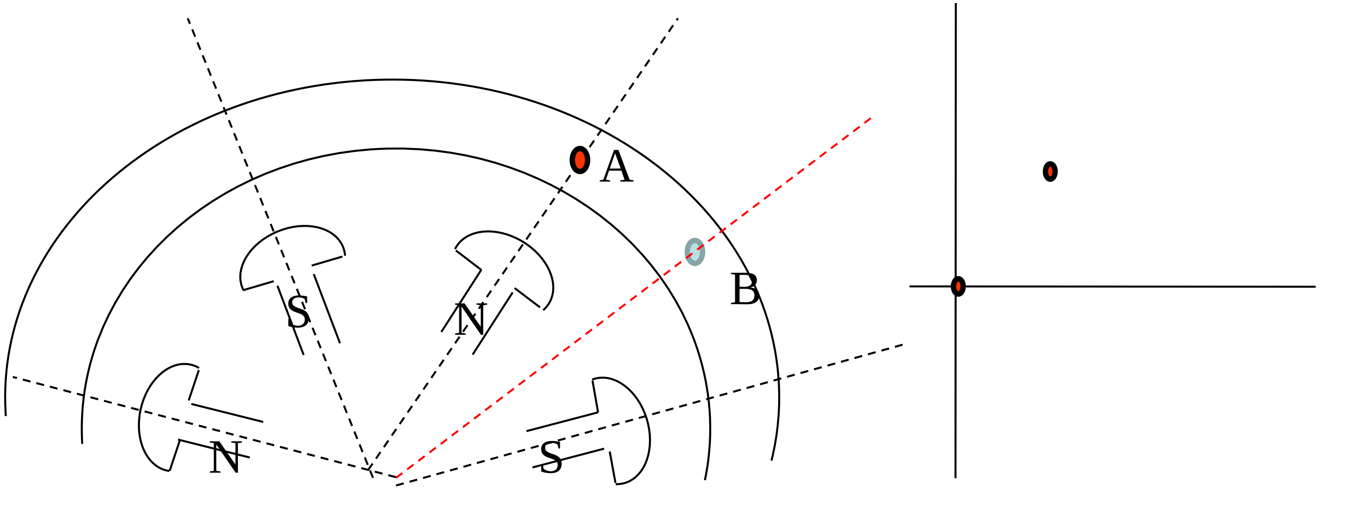
A dc current is flowing in the rotor winding which produces a rotating magnetic field within the machine

↓

The rotating magnetic field induces a three-phase voltage in the stator winding of the generator




A
B
N
S
S
N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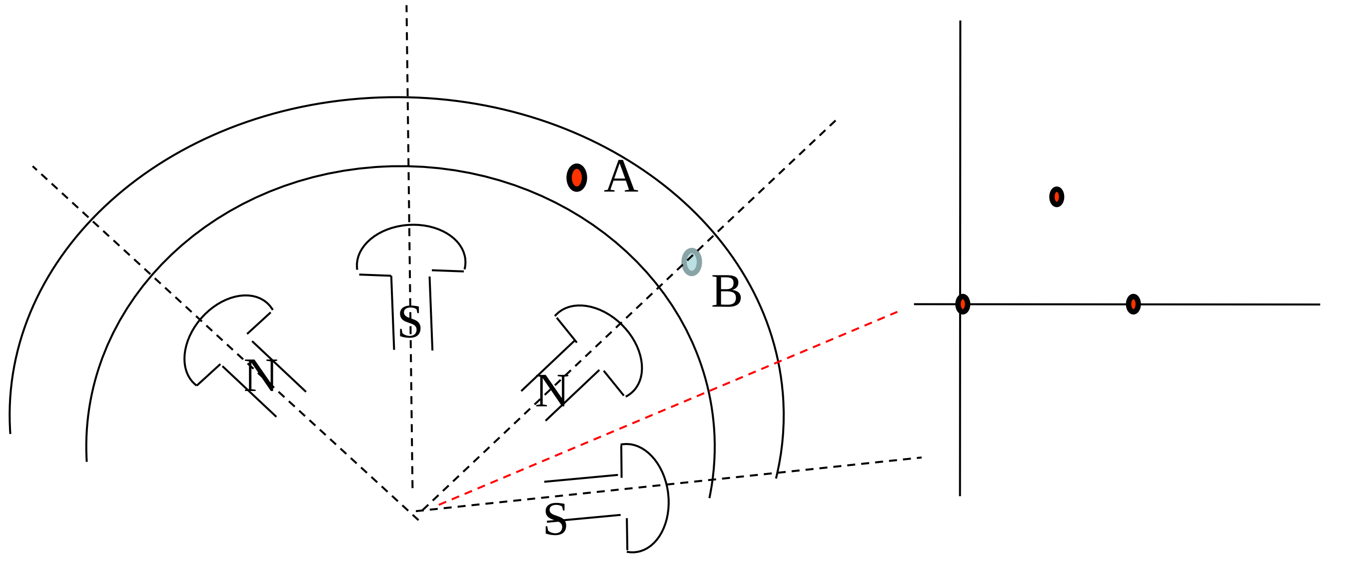

A
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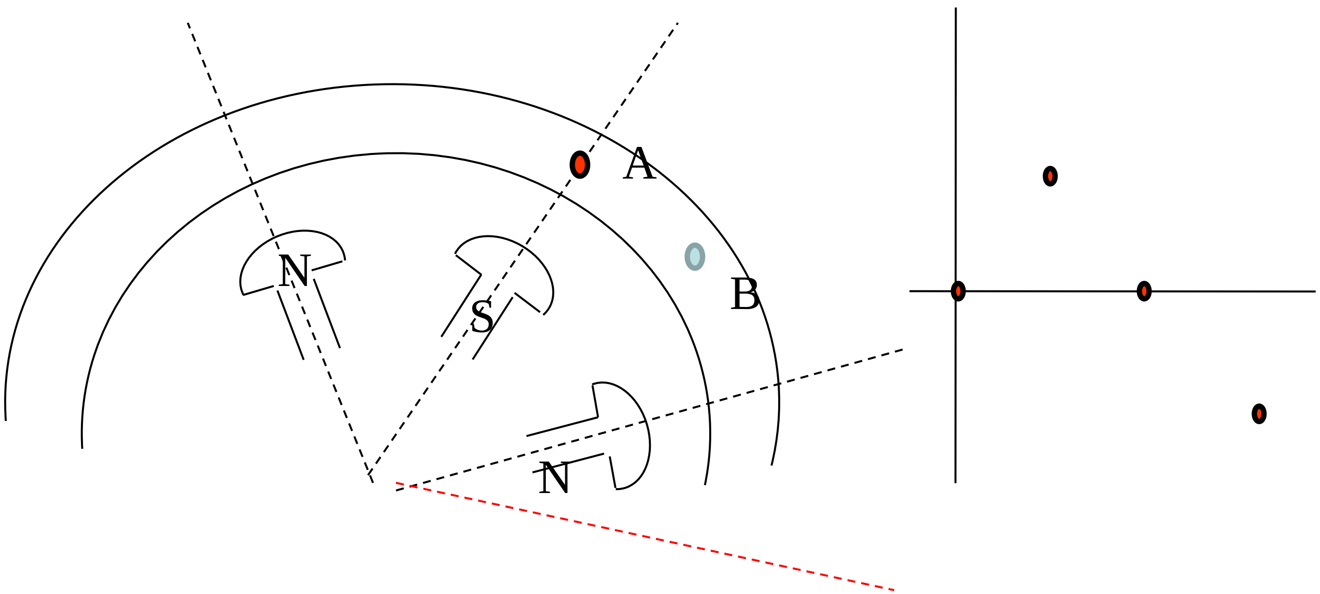
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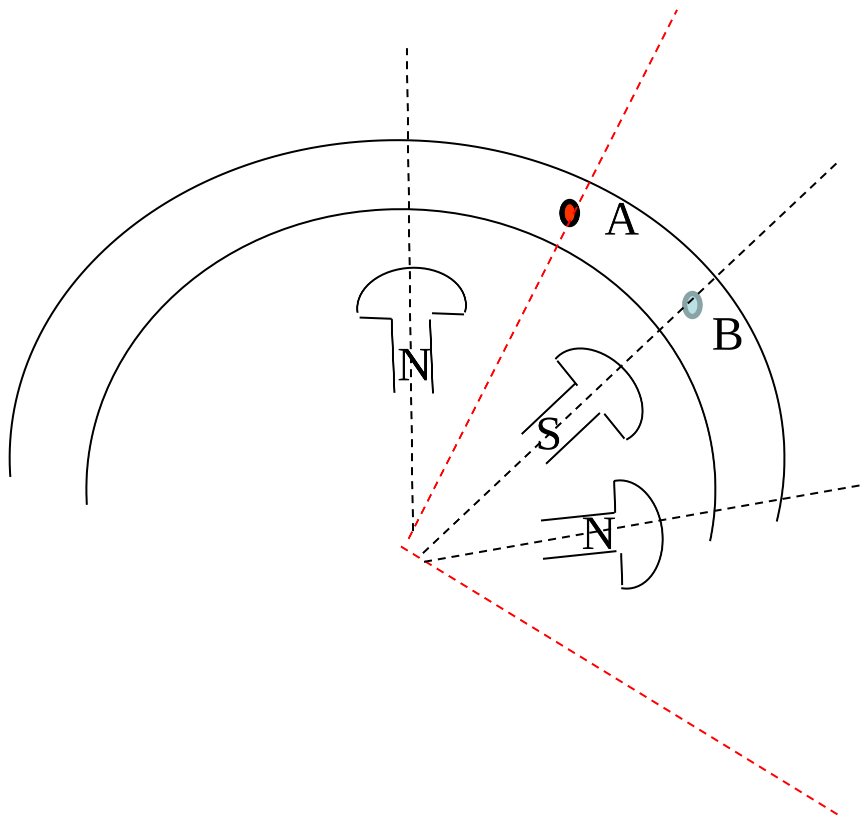
A
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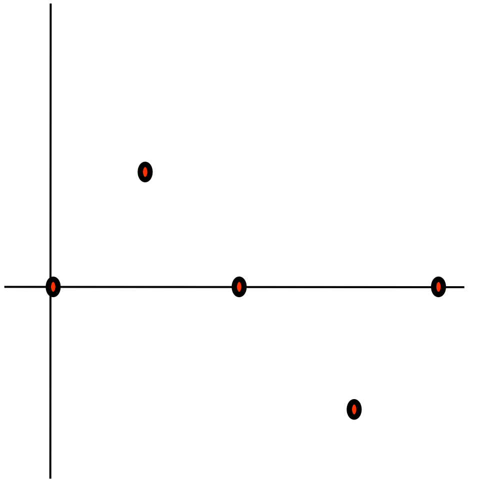


- One cycle of induced emf in a conductor when one pair of poles passes over it.
- If P is no of poles, then pair of poles =P/2
- ∴ For one revolution there will be P/2 cyles i.e P/2 cycles/revolution
- Alternator makes say N/60 revolutions / sec
- Hence Cycles / sec = cycles/revolution * revolution / sec
- i.e Frequency = P/2 * N / 60
- Or $f = NP/120$

Electrical Frequency

Electrical frequency produced is locked or synchronized to the mechanical speed of rotation of a synchronous generator:

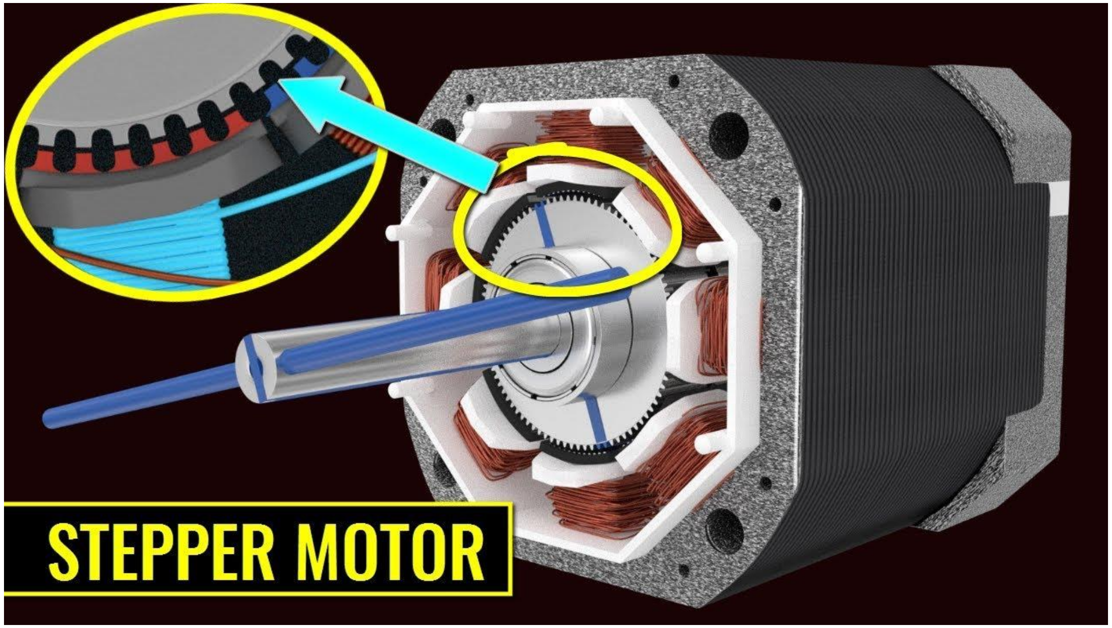
$$f_e = \frac{P\,N}{120}$$

where f_e = electrical frequency in Hz

P = number of poles

N= mechanical speed of the rotor, in r/min

STEPPER MOTORS

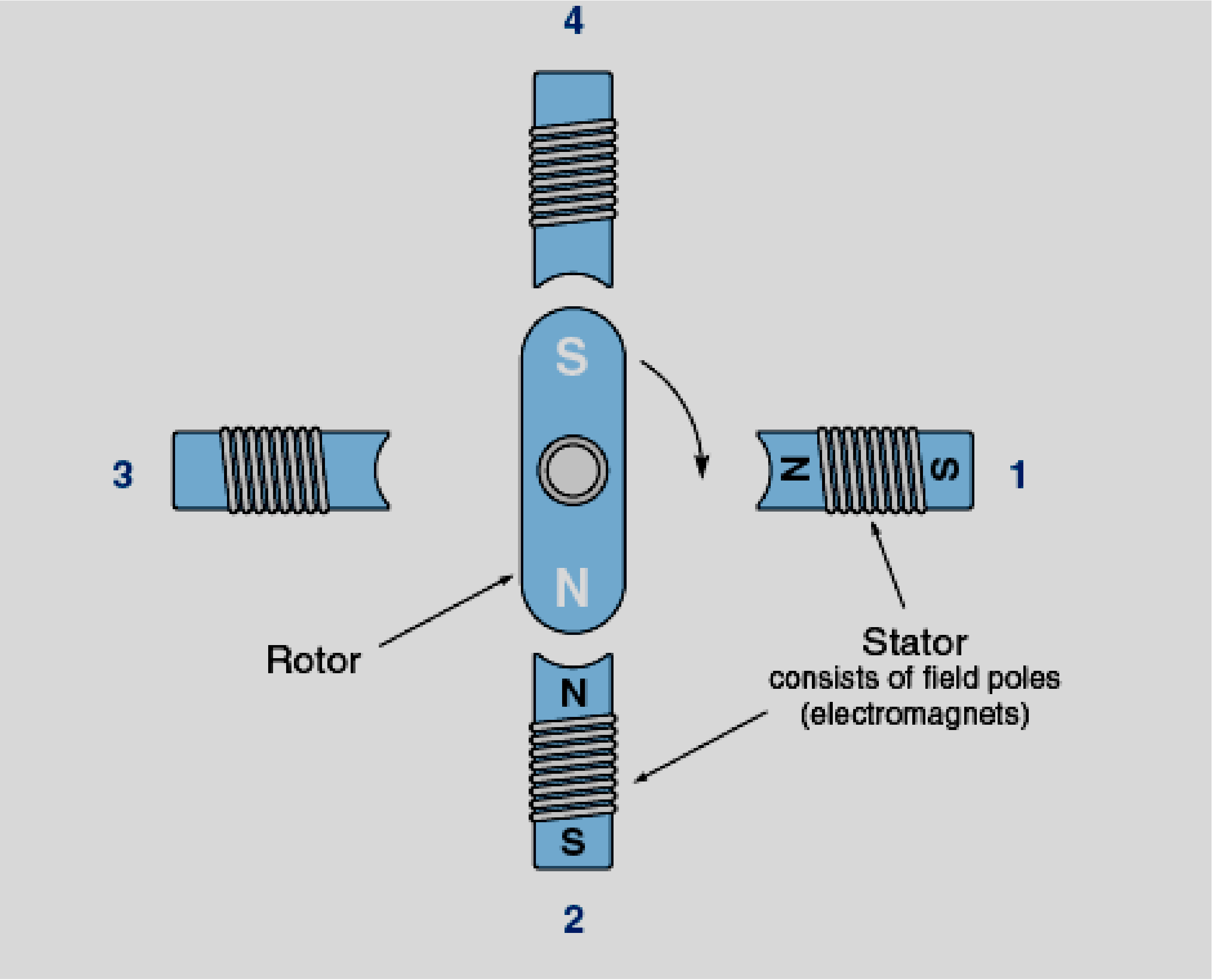


https://www.youtube.com/watch?v=eyqwLiowZiU

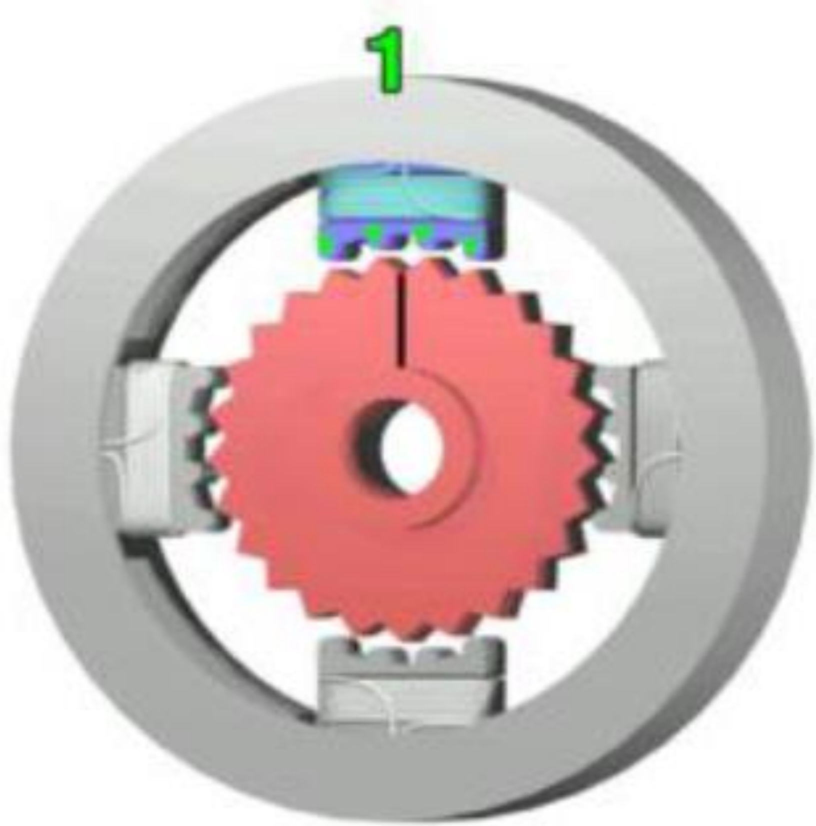
Principle

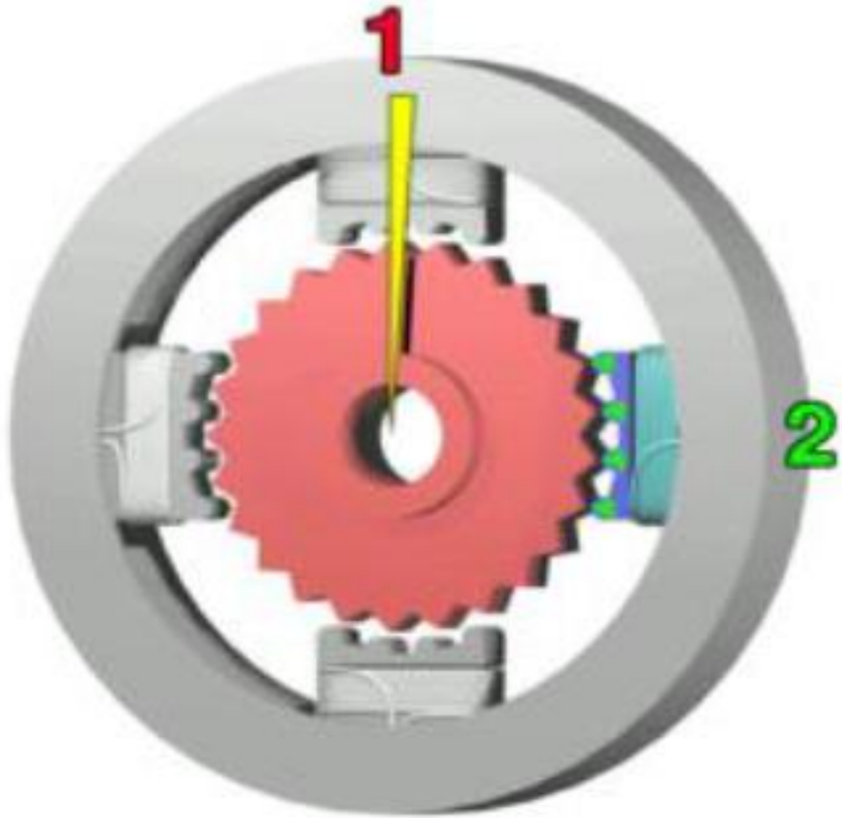
- A stepper motor is a unique type of DC motor that rotates in fixed steps of a certain number of degrees. Step size can range from 0.9 to 90°.
- It *consists of a rotor and stator.*
- *In this case, the rotor is a permanent* magnet, and the stator is made up of electromagnets (field poles).
- The rotor will move (or step) to align itself with an energized field magnet. If the field magnets are energized one after the other around the circle, the motor can be made to move in a complete circle

- The rotor will move (or step) to align itself with an energized field magnet. If the field magnets are energized one after the other around the circle, the motor can be made to move in a complete circle



For more steps

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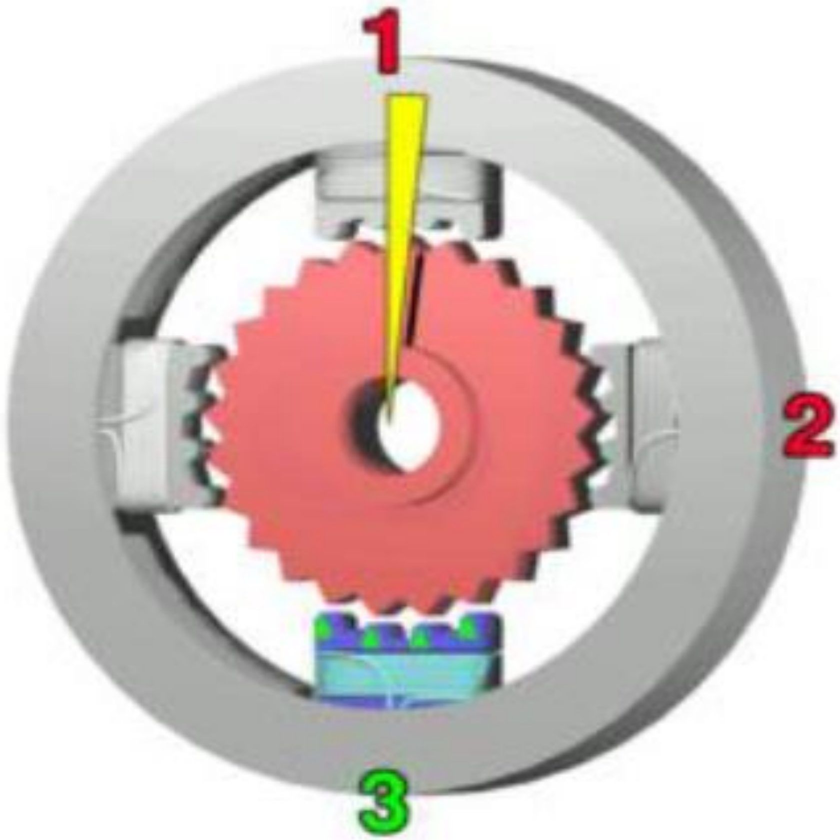
2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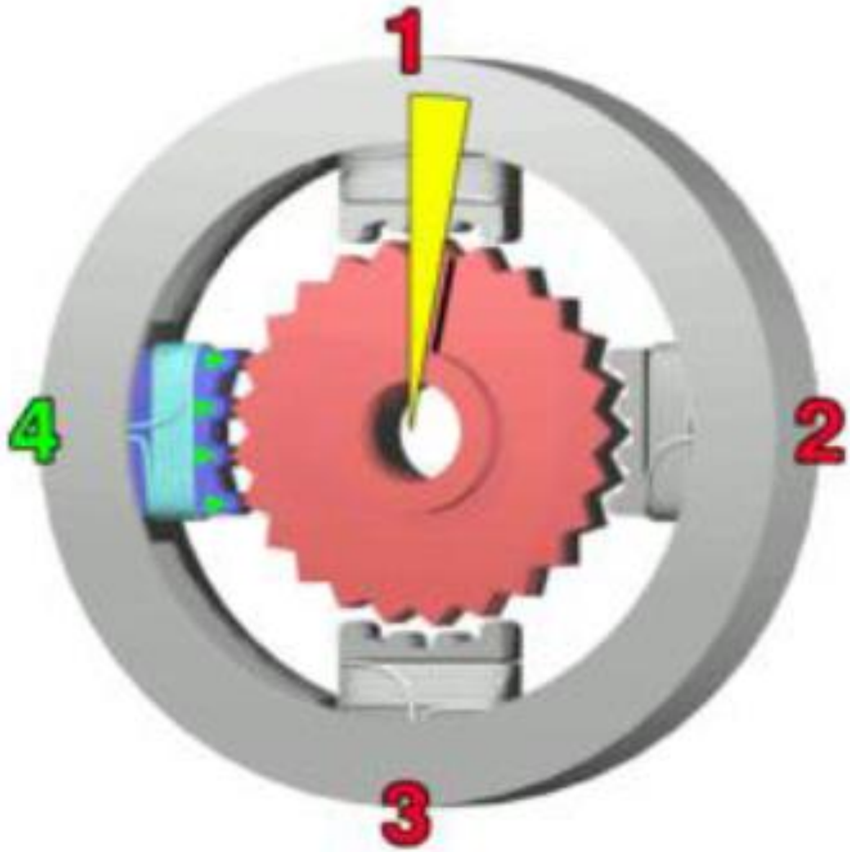
2
3


1
2
3
4

Types of Stepper Motor

Stepper motor are classified as

- Variable Reluctance - VR
- Permanent Magnet - PM
- Hybrid

Variable Reluctance

salient pole rotor, made up of ferromagnetic material.

It is called variable reluctance motor because the reluctance of the magnetic circuit formed by the rotor and stator teeth varies with the angular position of the rotor.

Permanent Magnet:

cylindrical rotor, made of permanent magnet.

Hybrid motor:

salient pole rotor, made up of permanent magnet.

Advantages

Stepper motors are particularly useful in control applications because the controller

- can know the exact position of the motor shaft without the need of position sensors. This is done by simply counting the number of steps taken from a known reference position. Step size is determined by the number of rotor and stator poles
- There is no cumulative error. i.e The controller sends the motor a determined number of step commands and assumes the motor goes to the right place..
- Steppers have inherently low velocity and therefore are frequently used without gear reductions.
- Stepper motors can easily be controlled to turn at 1 rpm or less with complete accuracy.

Applications

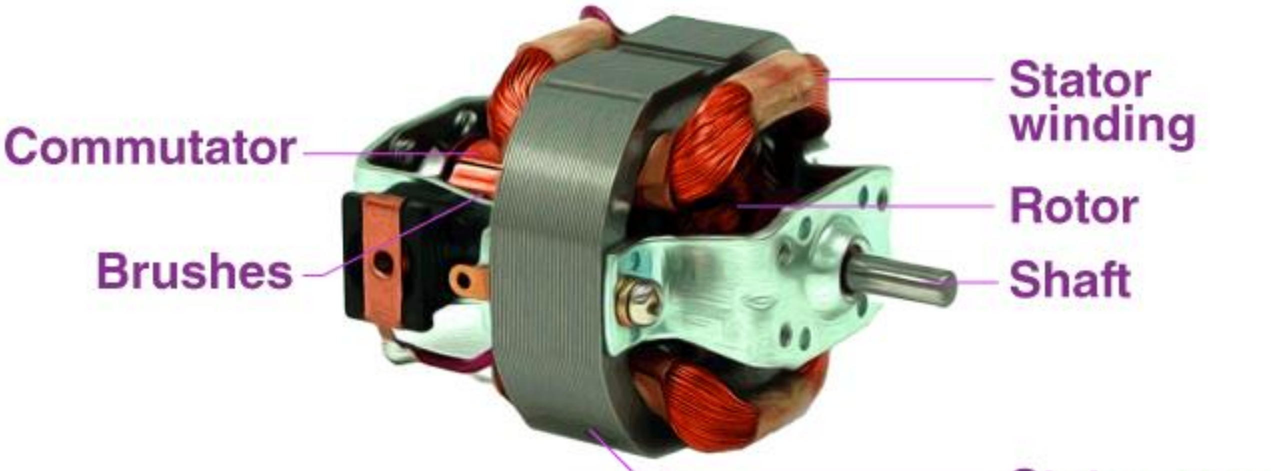
Industrial Machines – Stepper motors are used in automotive gauges and machine tooling automated production equipments.

Security – new surveillance products for the security industry.

Medical – Stepper motors are used inside medical scanners, samplers, and also found inside digital dental photography, fluid pumps, respirators and blood analysis machinery.

Consumer Electronics – Stepper motors in cameras for automatic digital camera focus and zoom functions.

Universal Motor



https://www.youtube.com/watch?v=0PDRJ
Kz-mqE

Introduction

- A universal motor is a special type of motor that runs on both AC and DC power supplies.
- Universal motors are series-wound (the armature and field windings are in series). The series connection allows them to generate high torque; hence the universal motors are generally built into the device they are meant to drive.
- Most of the universal motors are meant to operate at speeds as high as 3500 RPM. These motors run at a higher speed on DC supply than they run on AC supply of the same voltage. This is due to the reactance voltage drop that is present only in AC and not in DC.

Construction

- A universal motor consists of a stator on which the field poles are mounted.
- Field coils are wound around the field poles.
- Both the stator field circuit and armature of a universal motor are laminated.
- Laminations are necessary to reduce the eddy currents that are produced while operating on AC power.
- The universal motor's rotary armature is made of straight or skewed slots on which the commutator and brushes rest.
- The commutation on AC is poorer than that for DC because of the current induced in the armature coils.
- For this reason, the brushes used have high resistance.

Operation

- **When fed with a DC supply**
- When the universal motor is fed with a DC supply, it works as a DC series motor.
- In this case, when the current flows in the field winding, it produces an electromagnetic field.
- The same current also flows in the armature conductors. When a current-carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force.
- This mechanical force causes the rotor to rotate.
- Fleming's Left-hand rule gives us the direction of this force.

Operation

- **When fed with an AC supply**
- A unidirectional torque is produced when the universal motor is supplied with AC power.
- This is because the armature winding and the field winding are connected in series and are in the same phase.
- Therefore, whenever the polarity of the AC changes, the direction of the current in the armature and the field winding changes simultaneously.
- The direction of the magnetic field and the direction of armature current reverse so that the direction of force experienced by armature conductors remains the same.
- Thus, regardless of AC or DC supply, universal motors work on the same principle that DC series motors work on.

Applications

- Universal motors are used in applications where high speed and good speed control is necessary. Following are the various applications of universal motor:
- Universal Motors are used in table fans, hairdryers and grinders.
- They are used in portable drill machines.
- They are used in polishers, blowers and kitchen appliances.

Brushless DC electric motor

https://www.youtube.com/watch?v=bCEiOnuODac

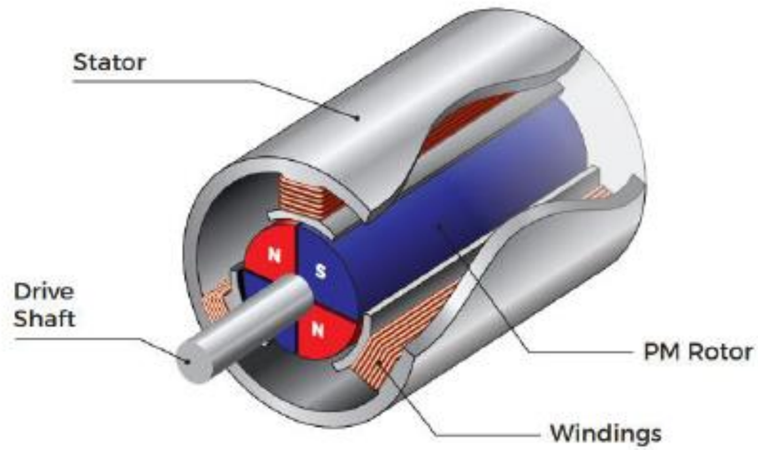
Introduction

- In DC motors section, we have seen that brushes are required to convert alternating current generated in DC generators to direct current (and vice versa for DC motors).
- We have also seen that a field winding is used to produce the magnetic field required for energy conversion. If the winding is replaced by permanent magnets, the rotating magnetic field is then generated without the need of separate winding.
- Besides, the losses in the field will be eliminated.
- There has been a significant improvement in permanent magnet technology since last few years.
- The permanent magnets are alloys like Neodymium Iron Boron (NdFeB) and Samarium Cobalt have become popular in recent years.

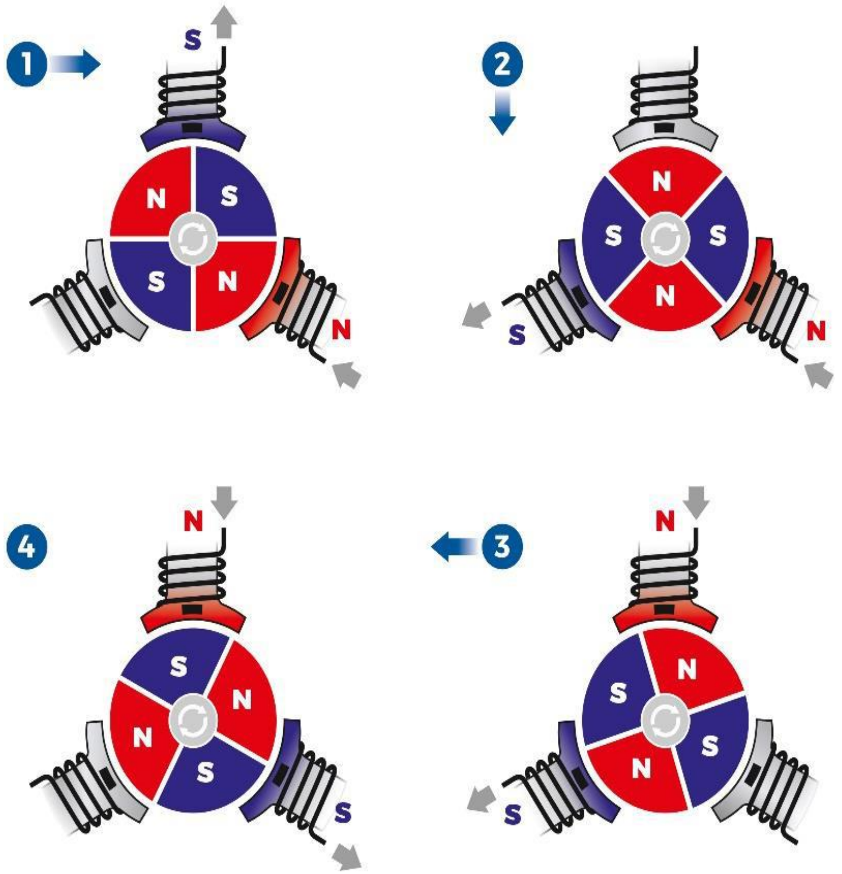
- Now, if permanent magnets are placed on rotor, the armature winding will be stationary and hence brushes can be removed. This has two advantages –
- 1. Resistive losses in brushes are completely eliminated
- 2. Maintenance and safety issues are also taken care of.
- Thus, the DC motor with permanent magnets without brushes is called brushless DC motor or simply BLDC motor.
- Brushless DC motors (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors) are synchronous electric motors powered by direct-current (DC) electricity and having electronic commutation systems
- BLDC motors may be described as Stepper motors, with fixed permanent magnets and possibly more poles on the stator than the rotor, or Reluctance motors.

Principle of operation

- As its name implies, BLDC motors do not use brushes for commutation. Since the coils are static, there is no need of a mechanical commutator to energize the windings. Instead, the commutation is done electronically, usually via a microcontroller unit and semiconductor switches.
- Electronic commutation consists of a series of steps where current from an external drive circuitry is delivered to each phase coil in a controlled sequence, producing a proper motor rotation by magnetic interaction between rotor and stator.



- To achieve this in a three-phase motor, current flows into one of the windings, goes through a common node, and flows out from another; leaving a third one open circuit. That way, when a rotor pole is about to align with its electromagnetic counter-pole on the stator, this is turned off and the next phase turned on, which makes the rotating motion continuous.
- The key part of this process is always keeping track of where the rotor is with respect to the stator so that the right phase can be excited at the right time. This is known as position feedback, which can be achieved with the aid of sensors or by reading the back-EMF produced in the windings.



Application

Brushless Direct Current (BLDC) motors are one of the motor types rapidly gaining popularity.

- Appliances - Washing machines, compressors and dryers , Fans, pumps and blowers
- Automotive
- Aerospace and Aviation
- Medical - health care equipment's
- Industrial Automation Equipment - Industrial robots, CNC machine tools, and simple belt driven systems
- Instrumentation.
- Electric vehicles, hybrid vehicles, and electric bicycles