Module 5

Permanent Magnet DC motors

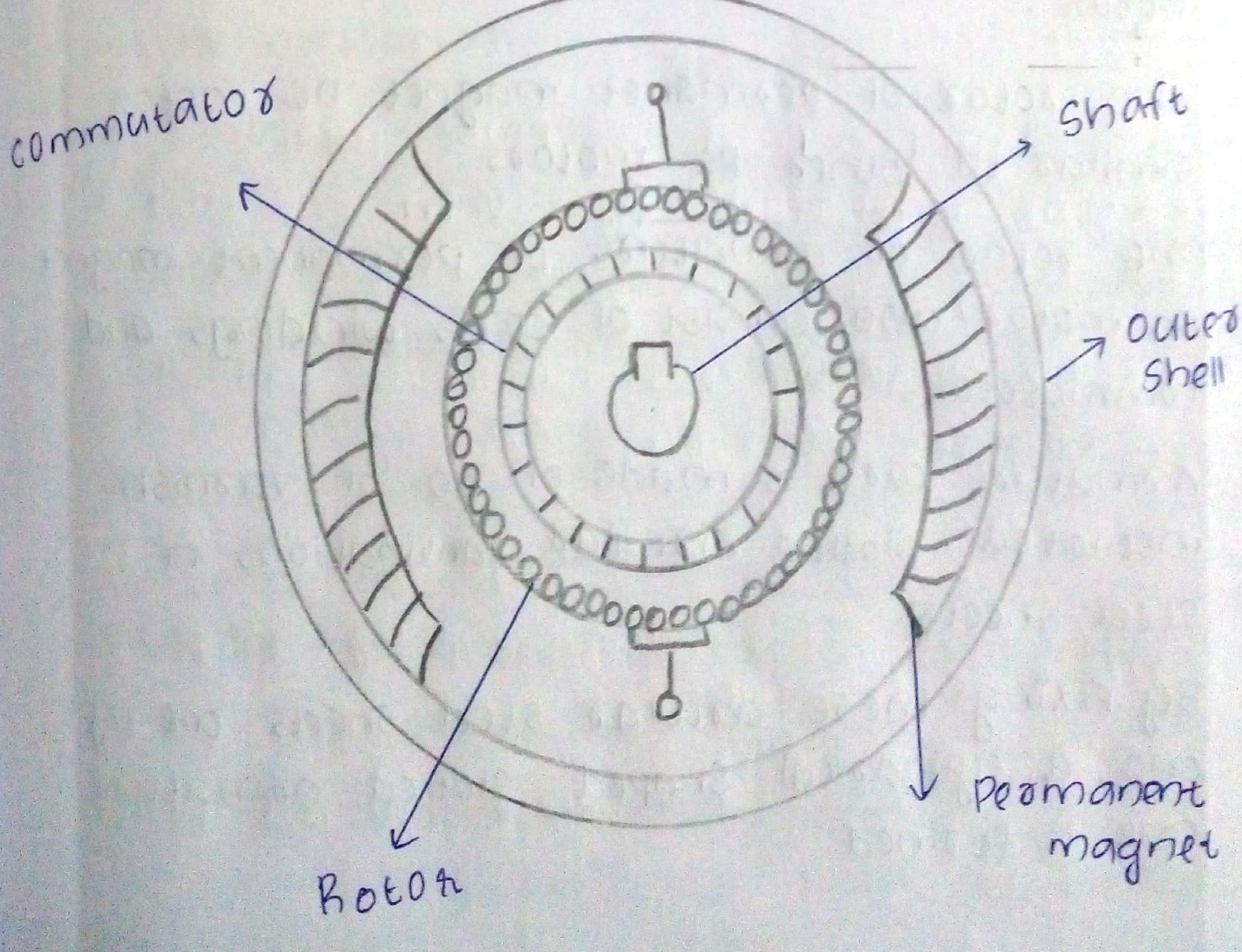
A DC motor whose poles are made of permanent magnet is known as permanent magnet DC motor.

The magnets are radially magnetised and are mounted on the inner periphery of the cylindrical steel stator.

The stator of the motor serves as a return path for the magnetic flux.

The rotor has a DC armature, with commutator segment and brushes.

Constructional Details



Stator :

It is a steel cylinder mounted on its inner periphery of the magnet,

These magnets are usually made from rare earth materials or neodymium.

The magnets are mounted that the north pole and south pole faced towards the armature.

The stator also serves as a low reluctance return path for the magnetic flux

Although field coil is not required in permanent magnet DC motor but still it is sometimes found that they are used along with the permanent magnet.

Rotor :

The rotor of permanet magnet DC motor is similar to other DC motors.

The rotor or armature of permanent magnet DC motor also consist of core, windings and commutator.

Armature core is made of no. of varnish insulated, slotted circular laminations of steel sheets.

By fixing these circular steel sheets one by one, a cylindrical shaped slotted armature core is formed.

The varnish insulated laminated steel sheets are used to reduce eddy current lossess in armature of PMDC motor.

The conductors are placed inside the slots.
The armature conductors are connected in a suitable manner which gives rise to armature winding.
The end terminals of the winding are connected to the commutator segment placed on the motor shaft.

Principle of operation :

It is the same working principle of DC motor.
When a carrying conductor comes inside a magnetic field a mechanical force experienced by the conductor.

We defines the direction of this force by Fleming's left hand Rule.

We place the armature inside the magnetic field of the permanent magnet.
This armature rotates in the direction of generated force.

The compliilation of force produced by each conductor produces a torque which tends to rotate the armature.

The PMDC motor generally operates on 6V, 12V, 24V DC supply obtained from the batteries or rectifiers.

Mechanical Force, $F = BIL$

B = magnetic Field Strength
I = current
L = Length of the conductor

Advantages

- They are Smaller in size
- High efficiency
- For smaller rating permanent magnet reduces the manufacturing cost
- PMDC motors are cheaper
- It has no cu loss

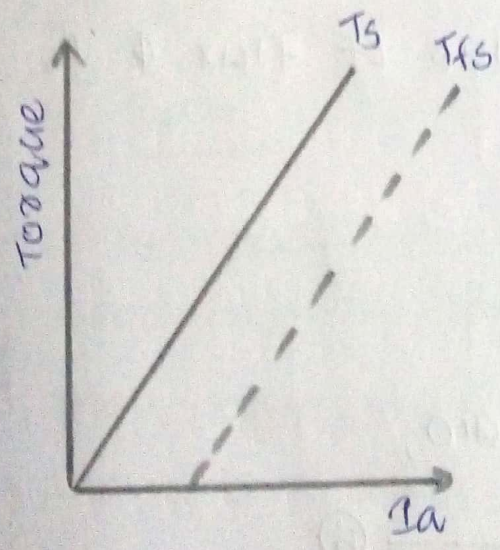
Disadvantages

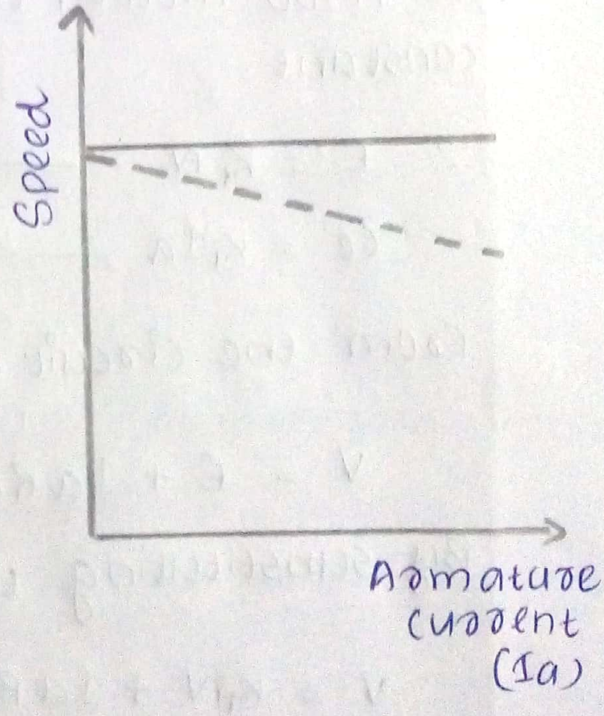
- The magnetic field of PMDC motor is present at all time, even when the motor is not being used.
- Extra Ampere turns cannot be added to reduce the armature reaction.
- There is a risk of demagnetization of the Poles which may be caused by large armature current.
- PMDC motor has a lower induced torque

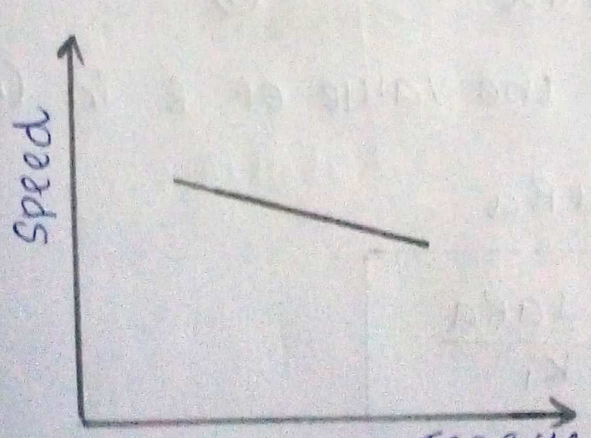
Applications

- PMDC motors are mainly used in automobiles to operate windsheild wipers and washers, to raise the lower window, to drive blowers for heaters and air conditioners etc...
- They are also used in computer drives.
- used in toy industries.
- They are used in electric toothbrushers, portable vaccum cleaners and food mixers.
- used in a portable electric tool such as drilling machine, hedge timers etc...

characteristics of PMDC

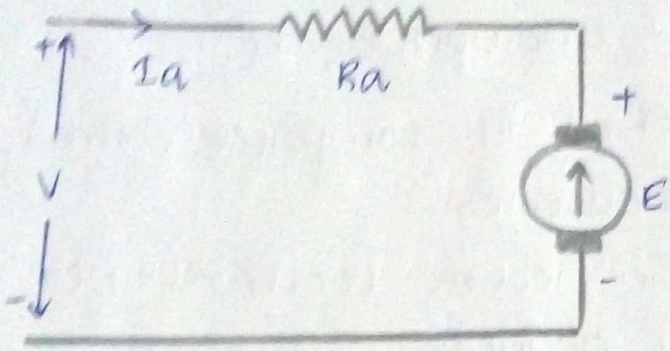






Equivalent circuit of PMDC motor

The circuit diagram of the PMDC motor is shown below.



Back emf, $E = K\phi N$ —— ①

The electromagnetic torque is given by;

$T_e = K\phi I_a$ —— ②

In PMDC motor, the value of flux ϕ is constant.

$\therefore$ $E = K_1 N$ —— ③

$T_e = K_1 I_a$ —— ④

From the circuit diagram,

$V = E + I_a R_a$ —— ⑤

By substituting the value of E in (5)

$V = K_1 N + I_a R_a$

$$\therefore \quad N = \frac{V - I_a R_a}{K_1}$$

where,

$K_1 = K\phi$ = Torque constant

Types of permanent magnet materials

1. Alnicos

- It has low coercive magnetizing intensity
- It has high residual flux density
- Ratings : 0.5 to 150 kW
- used as low current and high voltage is required

2 Ferrites

- used in cost sensitive applications

eg: Air conditioners, compressors etc...

3. Rare earths

- It is made up of samarium cobalt, neodymium - iron - boron.
- They have high residual flux
- They have high coercive magnetizing Intensity
- It is an expensive material.

Permanent Magnet Brushless DC motors

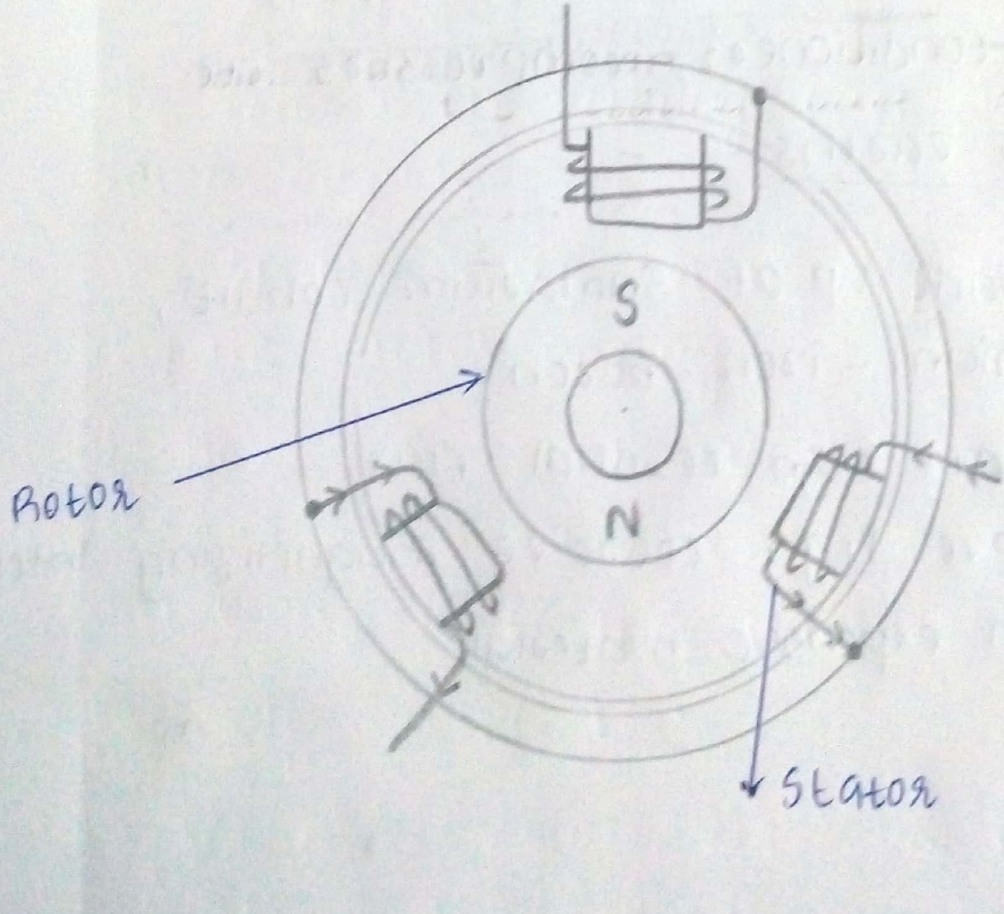
Brushless DC motor may be described as an electronically commutated motor which does not have brushes.

These type of motors are highly efficient in producing a large amount of torque over a vast speed range.

In brushless motors, permanent magnet rotates around a fixed armature.

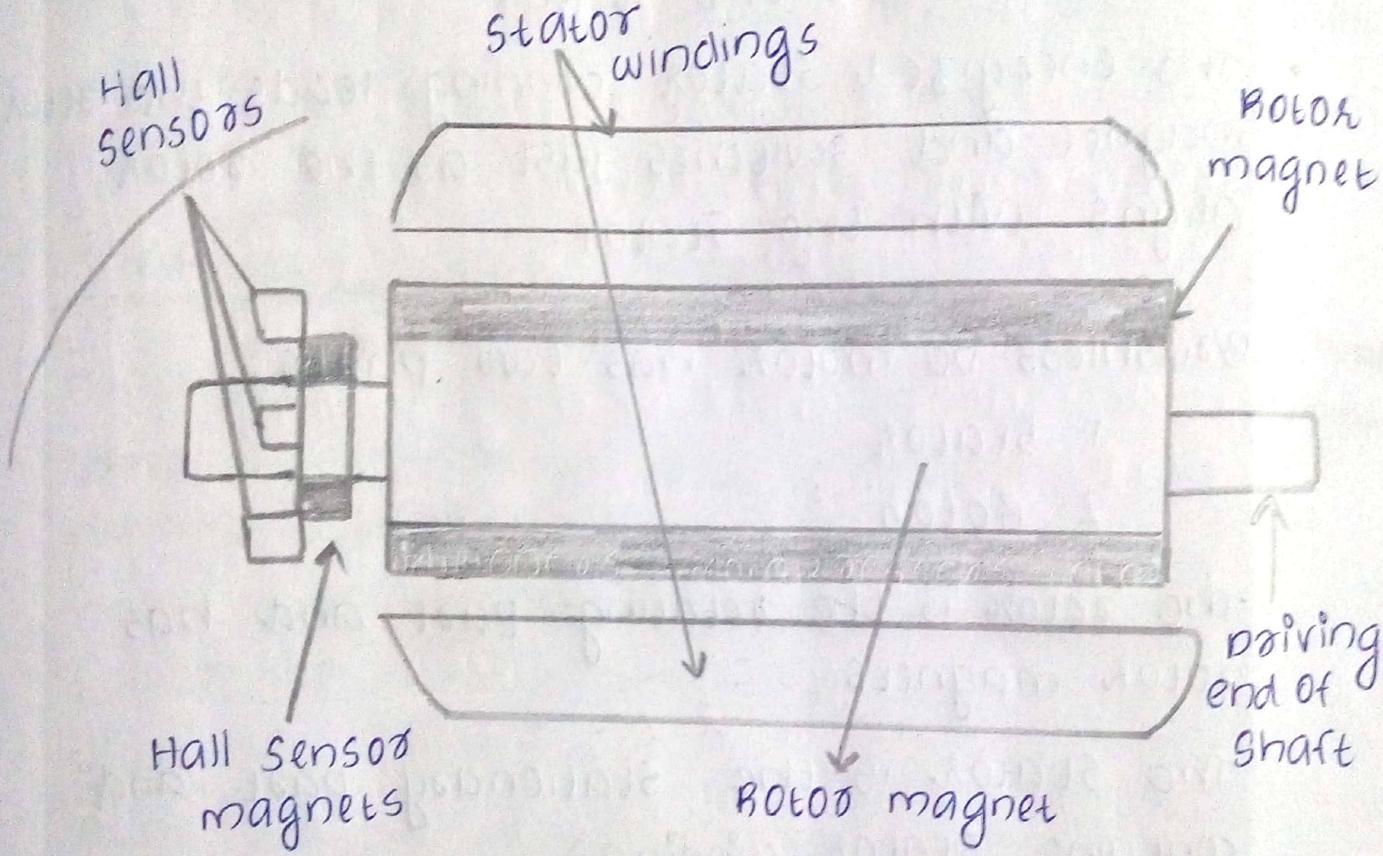
Commutation with electronics has a large scope of capabilities and flexibility.

They are known for smooth operation and holding torque when stationary.



Constructional Details

The brushless DC motor consist of a rotor in form of a permanent magnet and stator in form of polyphase armature windings. It differs from conventional DC motor in such that it does not contains brushes and the commutation is done using electrically.



Brushless DC motor has:

- A rotor with permanent magnets and a stator with windings.
- A BLDC motor is essentially a DC motor turned inside out.

Scanned with CamScanner

- Brushes and commutators have been eliminated and the windings are connected to the control electronics.
- control electronics replace the function of the commutator and energize the proper winding.
- windings are energized in a pattern which rotates around the stator.
- The energized stator winding leads the rotor magnet and switches just as the rotor aligns with the stator.

Brushless DC motor has two parts:

1. Stator
2. Rotor.

The rotor is the rotating part and has rotor magnets.

The stator is the stationary part and contains stator winding.

In BLDC motor, permanent magnets are attached in the rotor and moves the electromagnets to the stator.

Principle of operation

In brushless motors, there are permanent magnets on the outside.

A spinning armature which contains

electromagnet is inside

These electromagnet creates a magnetic field in the armature.

when power is switched on and rotates armature.

The brushes change the polarity of the pole to keep the rotation on the armature.

The basic principles for the brushed DC motor and for brushless DC motor are same. ie, internal shaft position Feedback.

Advantages :

- Brushless motors are more efficient
- There is no sparking and much less noise during operation.
- more electromagnets could be used on the stator for more precise control.
- High life expectancy
- BLDC motors do not have brushes which make it more reliable.
- maintanance free operation.

Disadvantages

- High cost
- The limitted high power could be supplied to BLDC motor, otherwise too much heat weakens the magnets and insulation of winding may get damaged.

Applications

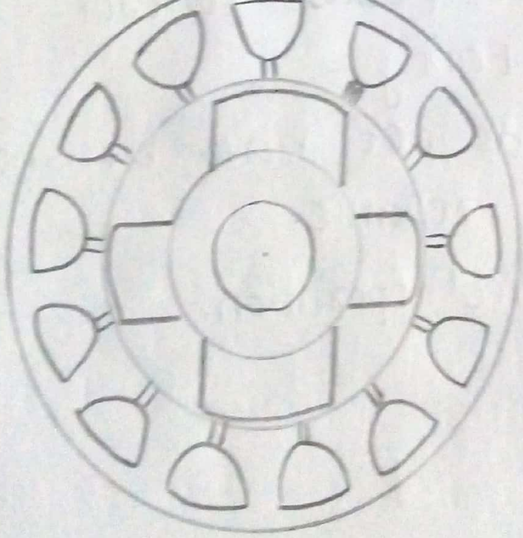
- Consumer electronics
- Transport
- Heating and ventilation
- Industrial engineering
- Model engineering

Types of Brushless DC motor

Basically, BLDC motor are of 2 types. one is outer rotor motor and other is inner rotor motor.

The basic difference between the two is only in designing, their working principle is same.

1. Inner Rotor Design



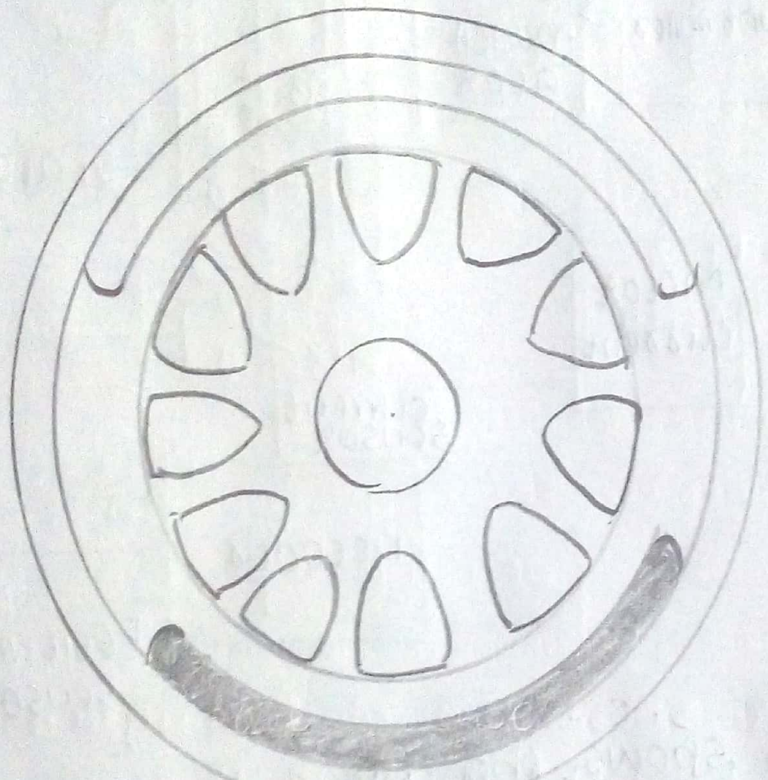
In an inner rotor design, the rotor is located in the centre of the motor.

The stator winding surrounded the rotor.

As the rotor is located in the core, rotor magnets do not insulate heat inside ~~the~~ and heat get dissipated easily.

Due to this reason, inner rotor designed motor produces a large amount of torque.

2 Outer Rotor Design

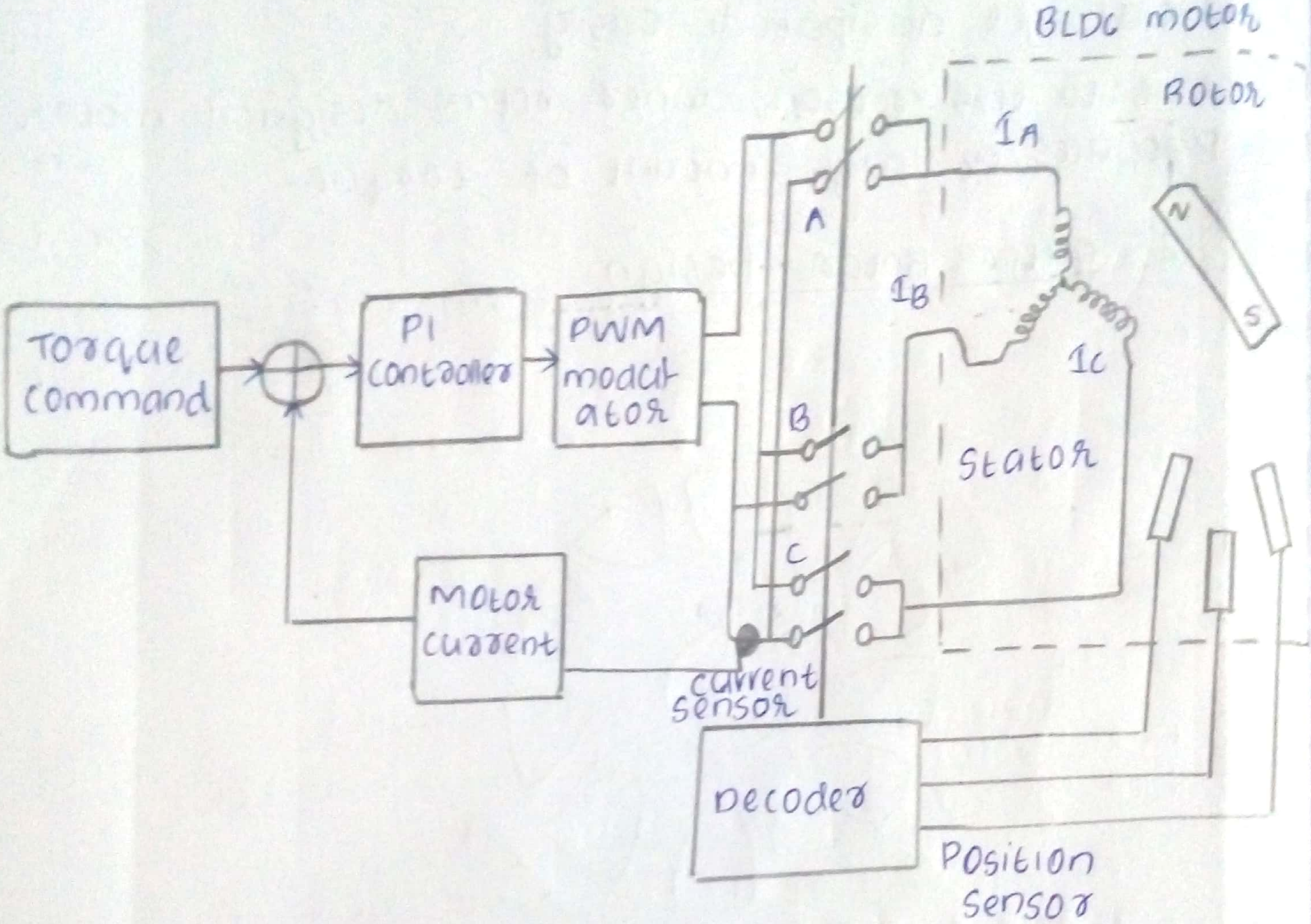


In outer rotor design, the rotor surrounds the winding, which is located in the core of the motor.

The magnets in the rotor trap the heat of the motor inside and do not allow to dissipate from the motor.

Such type of designed motor operates at lower rated current and has low cogging torque.

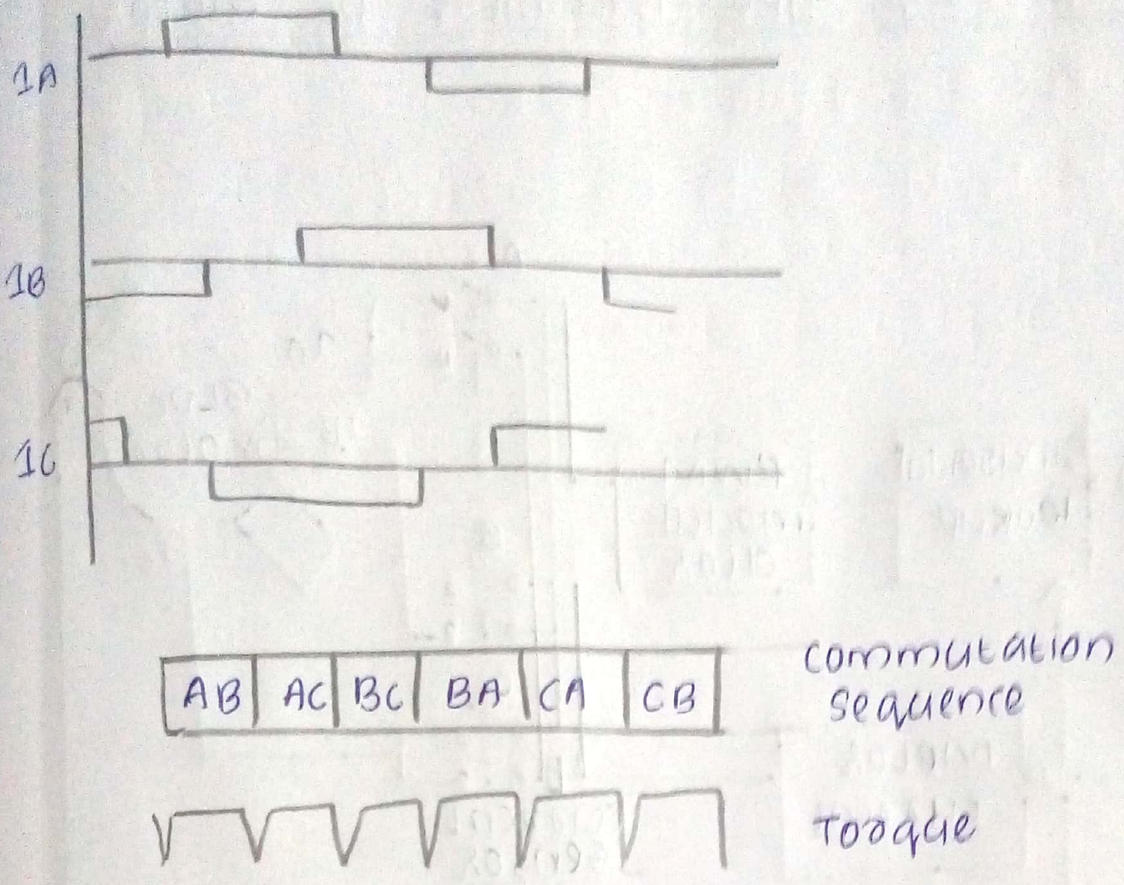
Trapezoidal Type Brushless DC motor



The figure shows the block diagram of Trapezoidal type brushless DC motor.

In this current is controlled through motor terminals one pair at a time, with the third motor terminal always electrically disconnected from the source of power.

The trapezoidal-current drive systems are popular because of the simplicity of their control circuits but suffer from a torque ripple problem during commutation.

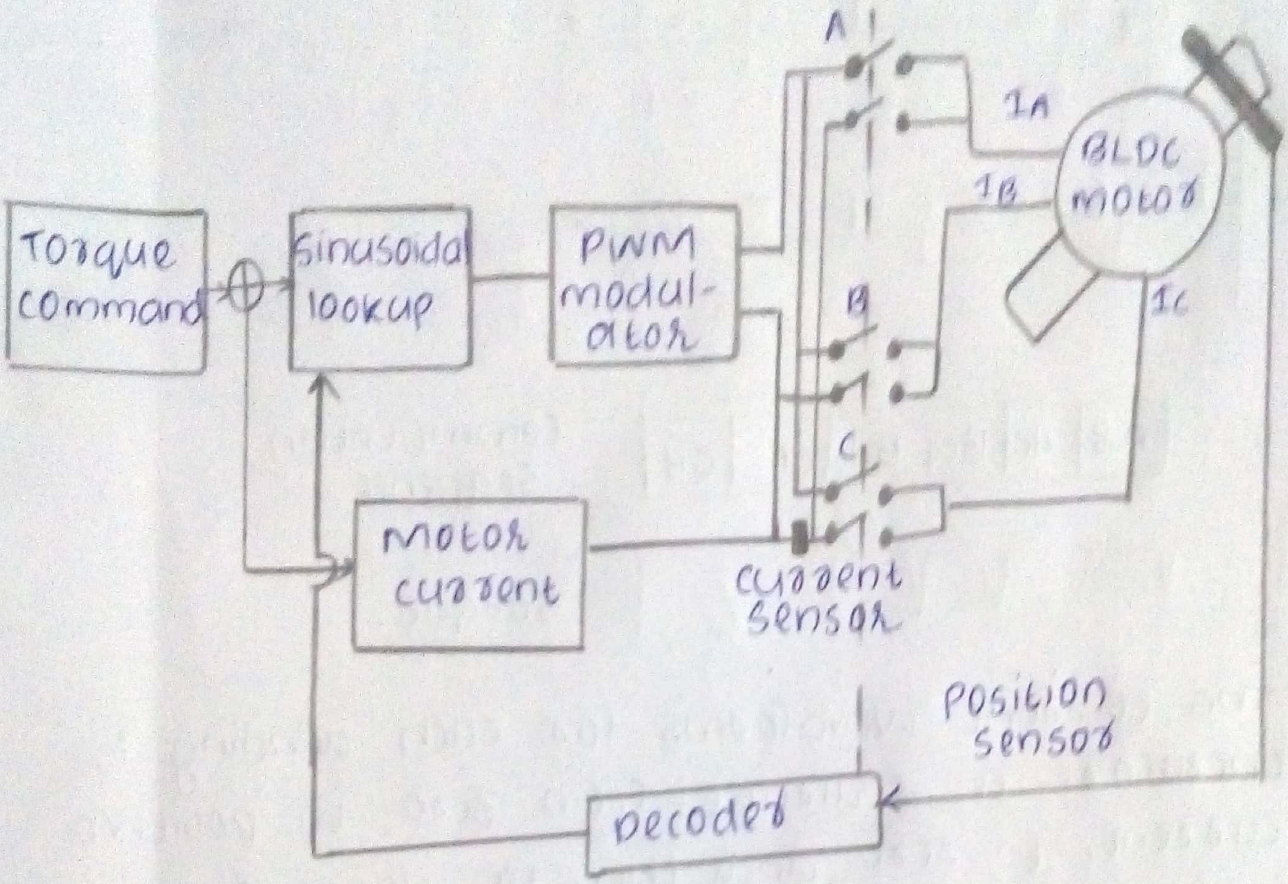


The current waveforms for each winding is therefore a staircase from zero, to positive current, to zero and then to Negative current. this produces a current space vector that approximates smooth, rotation as it steps among six distinct directions as the rotor turns.

In motor applications such as air conditioners and refrigerators use of Hall - Effect sensors is not a viable option.

Back emf sensors that sense the back emf in the unconnected winding can be used to achieve the same results.

Sinusoidal Type Brushless DC Motor



The Figure shows the block diagram of sinusoidal type Brushless DC motor.

Sinusoidally commutated brushless motor controllers attempt to drive the three motor windings with three currents that very smoothly and sinusoidally as the motor turns.

The relative phases of these currents are chosen so that they should result in a smoothly rotating current space vector ie, always in the quadrature direction with respect to the rotor and has constant magnitude.

This eliminates the torque ripple and commutation spikes associated with the trapezoidal commutation.

In order to generate smooth sinusoidal modulation of the motor currents as the motor turns, an accurate measurement of rotor position is required.

The Hall devices provide only the measure of rotor position.

For this reason, angle feedback from an Encoder or similar device is required.

The winding current must combine to produce a smoothly rotating current space vector.

The stator windings are oriented 120° apart from each other.

current in each winding must be sinusoidal and phase shifted by 120°.

Position information from the encoder is used to synthesize two sinusoids,

These signals are then multiplied by the torque command so that the amplitude of the sine wave are proportional to desired torque.

Shaft Torque, is defined by:

$$T_e = K_t\left[I_R \sin\theta + I_S \sin(\theta+120) + I_T \sin(\theta+240)\right]$$

θ ⇒ Electrical angle of the shaft

Kt ⇒ torque constant

IR, IS, IT ⇒ phase currents.