21EES101T-ELECTRICAL AND ELECTRONICSENGINEERING

EEE-UNIT 3

Machines and Drives

Construction and working principle of DC machines- Construction and Working principle of a single-phase Transformer- Construction and working of three phase Inductor motor, BLDC motor, PMSM, Stepper and Servo motor - Introduction to Electrical Drives-Block diagram explanation of chopper fed DC drives, Selection of drives for real time applications (cranes/EV/ Pumping applications)

Practice on chopper applications, Demo on DC& AC machines

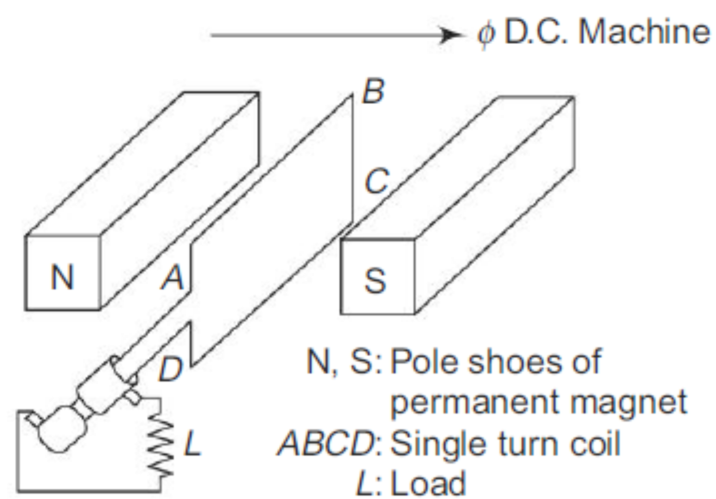
DC GENERATOR

Principle

The generator is a dynamic machine in which mechanical energy is converted into electrical energy. It operates on the principle based on the Faraday's Law of electro-magnetic induction. The emf generated is to be classified as dynamically induced emf. The basic requirements for the dynamically induced emf to exist are the following:

(i) A steady magnetic field
(ii) A conductor capable of carrying current
(iii) The conductor to move in the magnetic field

The working principle of a dc generator is illustrated in Fig. 6.1. It shows a steady magnetic field produced by the pole pieces of a magnet N and S. A single turn coil *ABCD* is placed in the field produced between the pole pieces. The coil is rotated by means of a prime mover. Thus, as per Faraday's law, an emf is induced in the coil. Such an emf is basically alternating. This bidirectional induced emf is made unidirectional using the commutator. Figure 6.2, illustrates the use of commutator.



Construction

For the satisfactory operation of a dc generator, it should consists of a stator and a rotor.

The stator accommodates the yoke, the main field system and the brushes. The rotor has the armature and the commutator as its main parts. Figure 6.3 shows these parts. Each of these parts is described as follows:

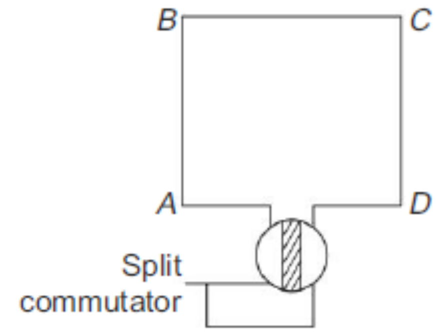
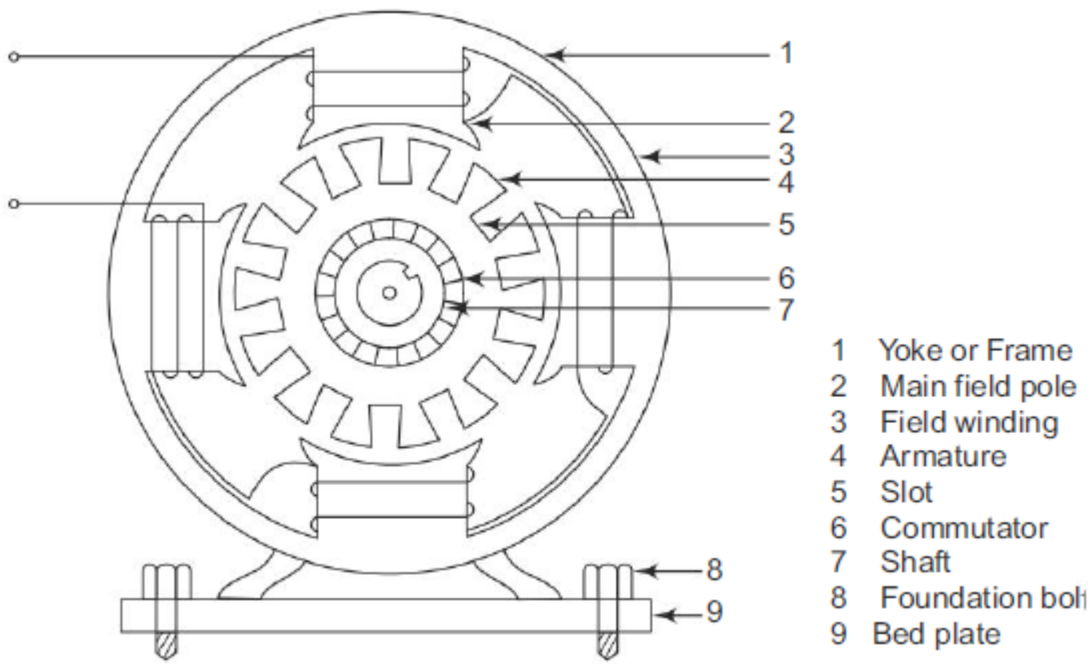


Fig. 6.2



Yoke or Frame It is the outermost solid metal part of the machine. It forms part of magnetic circuit and protects all the inner parts from mechanical damage.

Field System This consists of main field poles and field winding. The field poles are made of laminations of a sutiable magnetic material. Such a magnetic material has very high relative permeability and very low hysteresis loss. The pole face is in the form of horse shoe so that a uniform flux distribution is obtained in the air gap between the poles and the rotating part. The field winding is placed over the each pole and all these are connected in series. Again the field winding is so arranged on the different poles that when a direct current is passed through this winding, the poles get magnetized to N and S polarities alternately. Thus, the field system is responsible for producing the required working flux in the air gap.

Brushes A set of brushes made of carbon or graphic are fixed such that they are always in gentle touch with the revolving armature. The generator is connected to external circuits by means of these brushes. Thus, the brushes are used to tap the generated electrical energy off the rotating part of the generator.

Armature The armature of a dc generator is in the form of laminated slotted drum. Slots are provided over the entire periphery of the armature

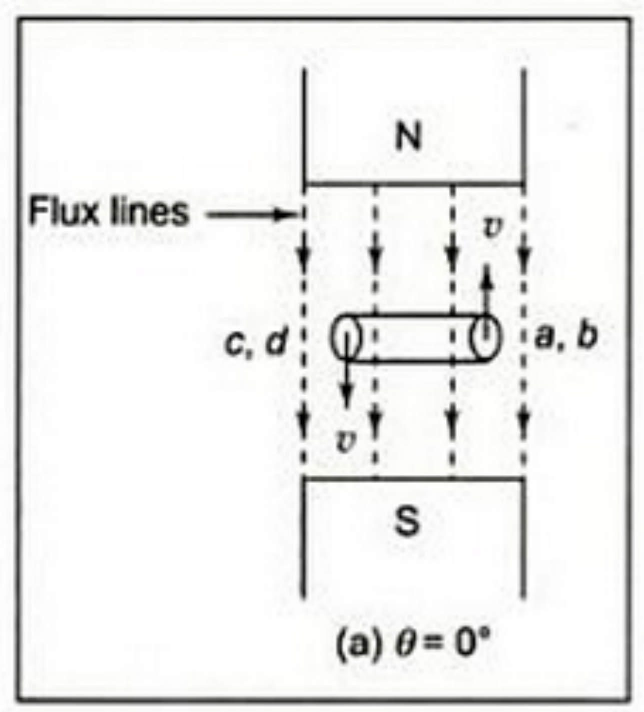
Commutator The commutator is similar in shape to armature. But, it has less diameter than that of the armature. Required number of segments are provided over the complete periphery of the commutator. There is an electrical insulation between every pair of segments. A minimum of two conductors are connected to each segment. But, at the same time the two conductors making a single coil are connected to different commutator segments. The brushes are so placed that they are always keeping to such with the revolving commutator segments.

Generators

- Working Principle
  - Can be explained using velocity components

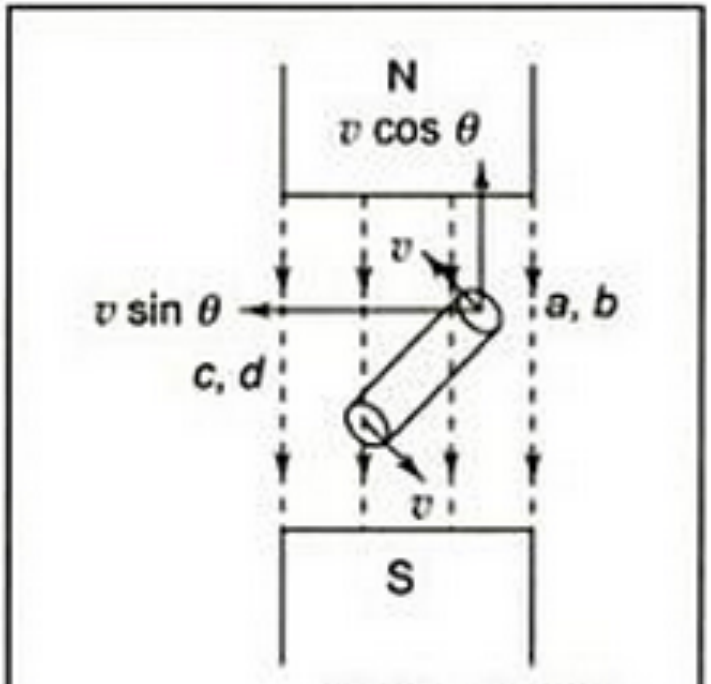
Generators-Working Principle

- Case I: θ=0o
- The velocity component (v) is in parallel with the flux lines or in other words, the angle between the velocity and flux lines is zero.
- Hence the emf induced is zero.
- E=0



Generators-Working Principle

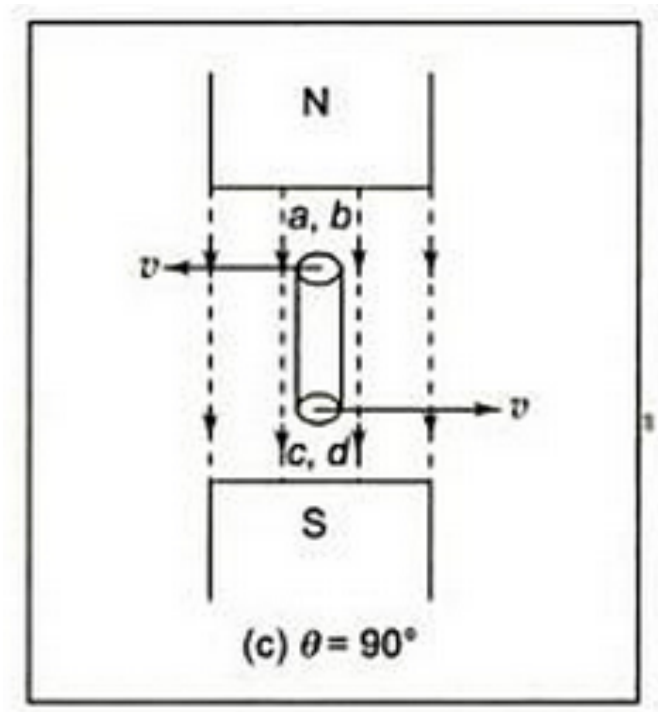
- Case II: 0o< θ < 90o
- The velocity component is making an angle with the flux lines.
- The velocity component is resolved into two components
  - vsinθ
  - Vcosθ
- vcosθ is making 0o with respect to flux lines and is not doing any useful work.
- The vsinθ is 90o with respect to flux lines and it is doing useful work and due to this, emf is induced.
- emin<e<emax



(b) 0° < θ < 90°

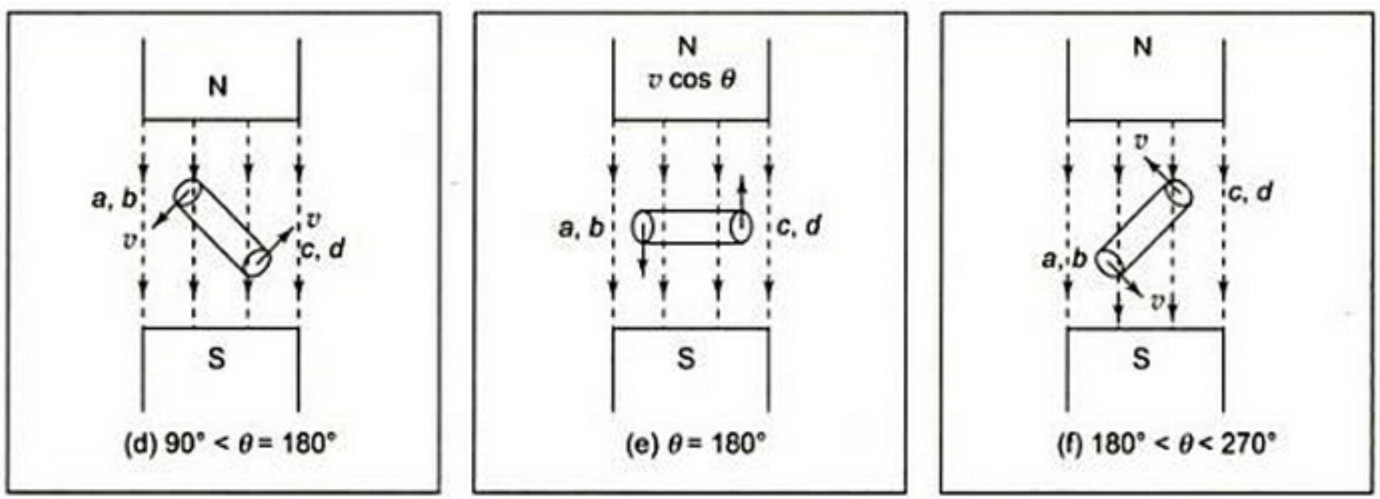
Generators-Working Principle

- Case III: θ = 90o
- The velocity component is making an angle 90o with the flux lines.
- and due to this, emf is induced.
- E=emax



Generators-Working Principle

- For remaining cases, the illustration is shown below,



(d) $90° < \theta = 180°$ (e) $\theta = 180°$ (f) $180° < \theta < 270°$

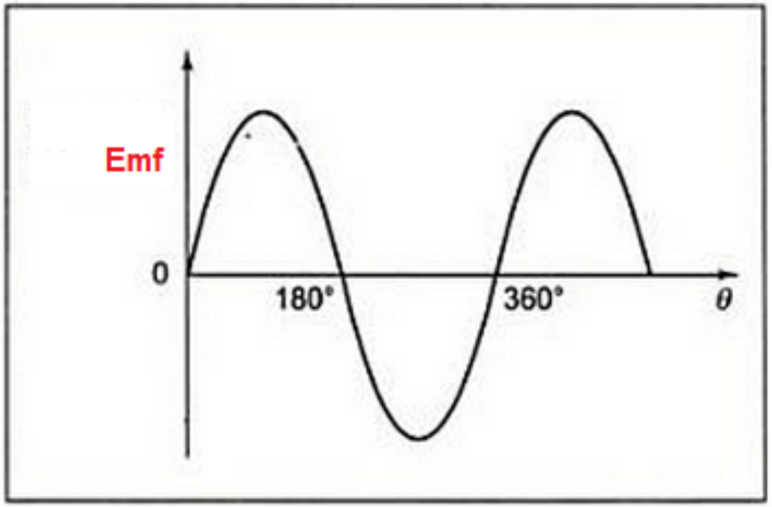
- The emf completes one complete cycle for

Emf induced across the Brush

- Emf induced is the alternating type

- BECAUSE

  - during positive half cycle, the conductor comes under the influence of north pole
  - during negative half cycle, the conductor comes under the influence of south pole

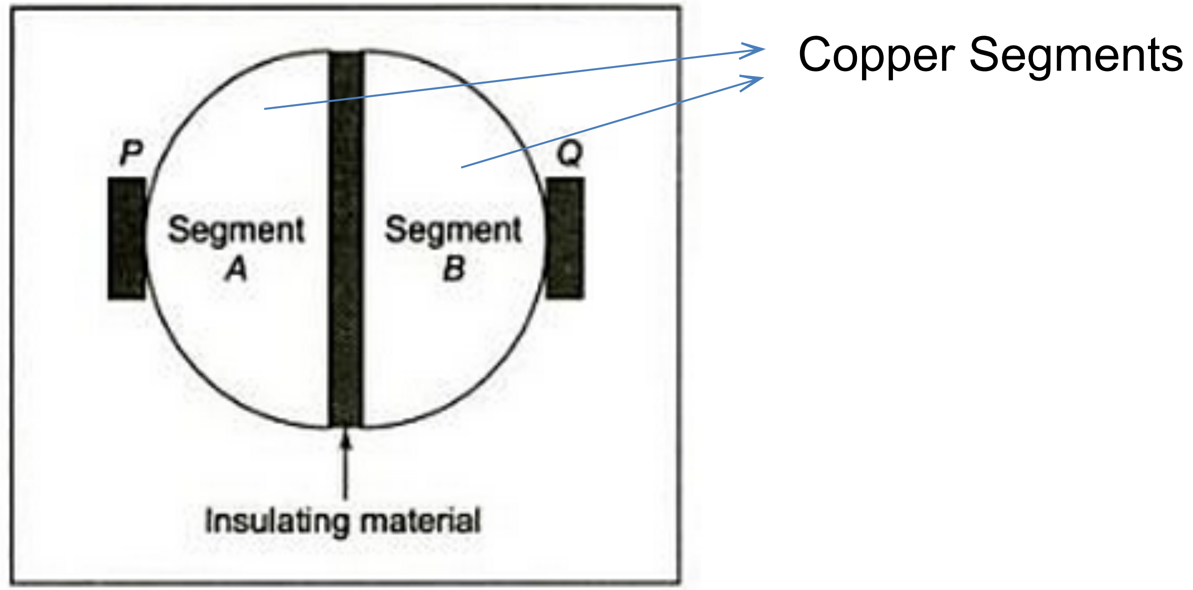


How to convert AC to DC?

- It is observed that the emf induced is the alternating type, but it is required to obtain unidirectional emf from the DC machines.

- The alternating emf can be converted into pulsating dc using the split ring/commutator.

Commutators



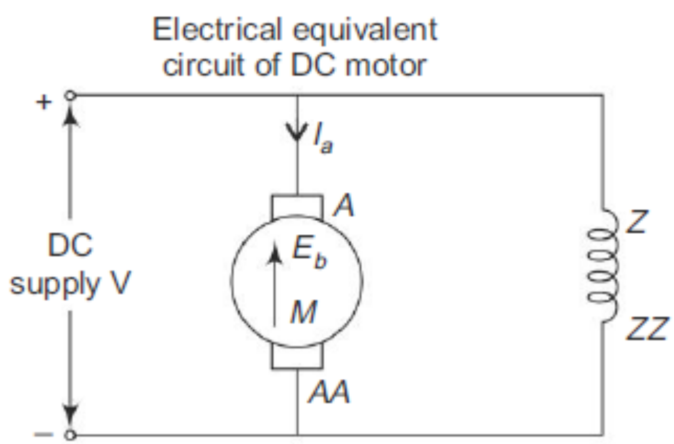
DC MOTOR

Principle

Whenever a current carrying conductor is kept in a stationery magnetic field an electromagnetic force is produced. This force is exerted on the conductor and hence the conductor is moved away from the field. This is the principle used in d.c. motors.

Construction

The construction of dc motor is exactly similar to dc generators. The salient parts of a dc motor are yoke or frame, main field system, brushes, armatures and commutator.



Working

In a dc motor, both the armature and the field windings are connected to a dc supply. Thus, we have current carrying armature conductors placed in a stationery magnetic field. Due to the electromagnetic torque on the armature conductors, the armature starts revolving. Thus, electrical energy is converted into mechanical energy in the armature. When the armature is in motion, we have revolving conductors in a stationery magnetic field. As per Faraday's Law of electromagnetic induction, an emf is induced in the armature conductors. As per Lenz's law, this induced emf opposes the voltage applied to the armature. Hence, it is called the counter or back emf. There also occurs a potential drop in the armature circuit due to its resistance. Thus, the applied voltage has to overcome the back emf in addition to supplying the armature circuit drop and producing the necessary torque for the continuous rotation of the armature.

Figure gives the electrical circuit of a d.c. shunt motor where

E_b = back EMF

I_a = current flowing in the armature circuit

R_a = resistance of armature circuit

V = applied voltage

Thus, the characteristics equation of a dc motor is $V = E_b + I_aR_a$, where I_aR_a represents the potential drop in the armature circuit.

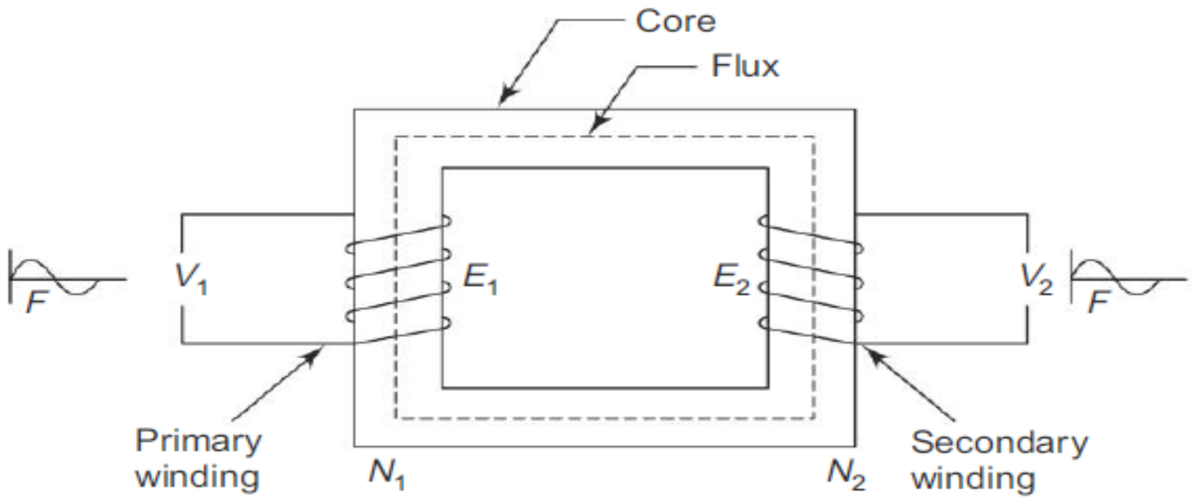
Major applications for DC motors are: **elevators, steel mills, rolling mills, locomotives, and excavators**

Single Phase Transformer

Principle of operation

The transformer works on the principle of electromagnetic induction. In this case, the conductors are stationary and the magnetic flux is varying with respect to time. Thus, the induced emf comes under the classification of statically induced emf.

The transformer is a static piece of apparatus used to transfer electrical energy
from one circuit to another. The two circuits are magnetically coupled. One of the circuits is energized by connecting it to a supply at specific voltage magnitude, frequency and waveform. Then, we have a mutually induced voltage available across the second circuit at the same frequency and waveform but with a change in voltage magnitude if desired. These aspects are indicated in Fig.



Construction

The following are the essential requirements of a transformer:

(a) A good magnetic core

(b) Two windings

(c) A time varying magnetic flux

The transformer core is generally laminated and is made out of a good magnetic material such as transformer steel or silicon steel. Such a material has high relative permeability and **low hysteresis loss**. In order to reduce the **eddy current loss**, the core is made up of laminations of iron. ie, the core is made up of thin sheets of steel, each lamination being insulated from others

Working

Let us say that a transformer has N_1 turns in its primary winding and N_2 turns in its secondary winding. The primary winding is connected to a sinusoidal voltage of magnitude V_1 at a frequency 'f' hertz. A working flux of ϕ webers is set up in the magnetic core. This working flux is alternating and sinusoidal as the applied voltage is alternating and sinusoidal. When this flux link the primary and the secondary winding, emfs are induced in them. The emf induced in the primary is the self induced emf and that induced in the secondary is the mutually induced emf. Let the induced voltages in the primary and the secondary be E_1 and E_2 volts respectively. These voltages will have sinusoidal waveform and the same frequency as that of the applied voltage. The currents which flow in the closed primary and the secondary circuits are respectively I_1 and I_2.

In any transformer, $K = \frac{N_2}{N_1}$, defines the transformation ratio.

Three categories of transformer action are possible:

$$E_2 < E_1 \text{ (i.e. } V_2 < V_1) \ldots \text{ step down transformer}$$

$$E_2 > E_1 \text{ (i.e. } V_2 > V_1) \ldots \text{ Step up transformer}$$

The induced emfs are proportional to the number of turns. In any transformer, the primary ampere turns equals the secondary ampere turns.

i.e. $$N_1 I_1 = N_2 I_2$$

Thus, we have $$\frac{I_1}{I_2} = \frac{E_2}{E_1} = \frac{V_2}{V_1} = \frac{N_2}{N_1} = K$$

Whenever any load is put on the transformer (connected to secondary winding) the primary of the transmission draws the required amount of current in order to keep the working flux constant. Thus, the transformer works with a perfect static balance.

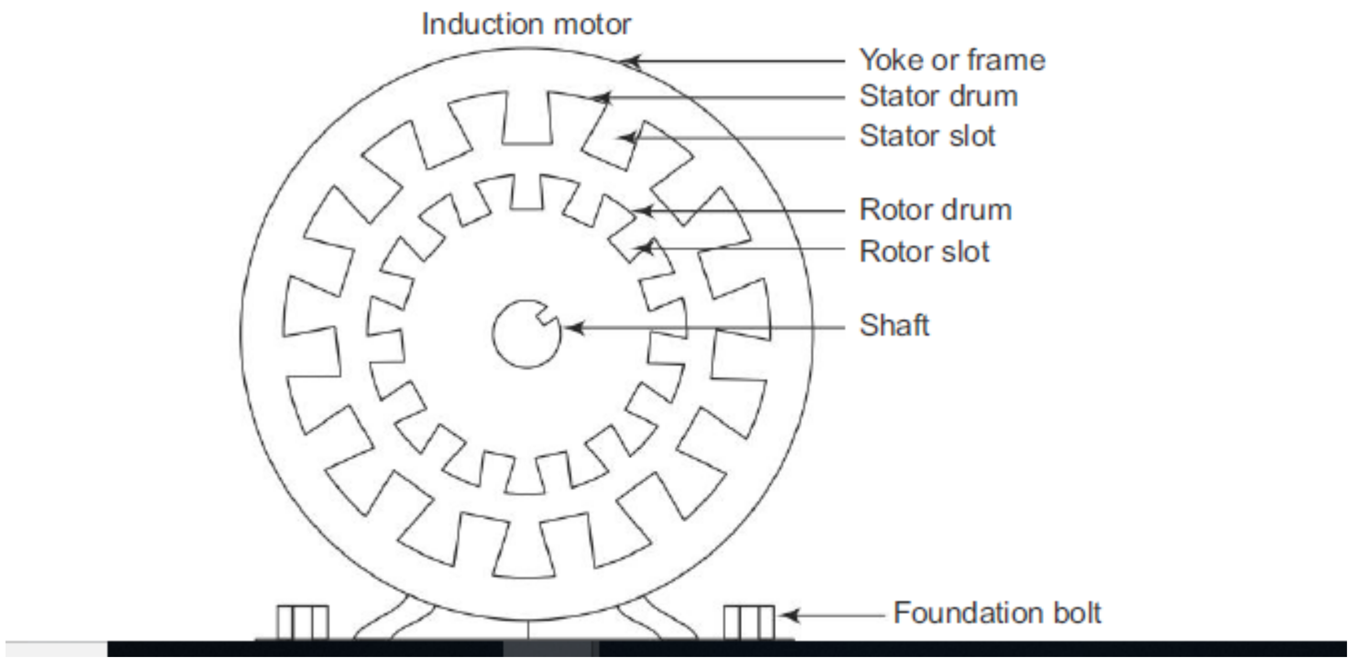
THREE PHASE INDUCTION MOTOR

Principle

When a three phase balanced voltage is applied to a three phase balanced winding, a rotating magnetic field is produced. This field has a constant magnitude and rotates in space with a constant speed. If a stationary conductor is placed in this field, an emf will be induced in it. By creating a closed path for the induced current to flow, an electromagnetic torque can be exerted on the conductor. Thus, the conductor is put in rotation.

Construction

The important parts of a three phase induction motor are schematically represented in Fig. 6.47. Broadly classified, they are stator and rotor. Each of these is described below.



Stator This is the stationary part of the motor. It consists of an outer solid circular metal part called the yoke or frame and a laminated cylindrical drum called the stator drum. This drum ash number of slots provided over the entire periphery of it. Required numbers of stator conductors are embedded in the slots. These conductors are electrically connected in series and are arranged to form a balanced three phase winding. The stator is wound to give a specific number of poles. The stator winding may be star or delta connected.

Rotor This is the rotating part of the induction motor. It is also in the form so slotted cylindrical structure. The air gap between stator and rotor is as minimum as mechanically possible. There are two types of rotors—squirrel cage rotor and slip-ring or wound rotor.

Working

A three phase balanced voltage is applied across the three phase balanced stator winding. A rotating magnetic field is produced. This magnetic field completes its path through the stator, the air gap and the rotor. In this process, the rotor conductors, which are still stationary, are linked by the time varying stator magnetic field. Therefore, an emf is induced in the rotor conductors. When the rotor circuit forms a closed path, a rotor current is circulated. Thus, the current carrying rotor conductors are placed in the rotating magnetic field. Hence, as per the law of interaction, an electromagnetic force is exerted on the rotor conductors. Thus, the rotor starts revolving.

According to Lenz's law, the nature of the rotor induced current is to oppose the cause producing it. Here the cause is the rotating magnetic field. Hence, the rotor rotates in the same direction as that of the rotating magnetic field.

In practice, the rotor speed never equals the speed of the rotating magnetic field (called the synchronous speed). The difference in the two speeds is called slip. The current drawn by the stator is automatically adjusted whenever the motor is loaded.

PMSM

5.2 Permanent Magnet Synchronous Machines

Permanent magnet synchronous machines generally have the same operating and performance characteristics as synchronous machines in general operation at synchronous speed, a single (or) polyphase source of ac supplying the armature windings, a power limit above which operation at synchronous speed is unstable, reversible power flow etc.,

A PM machine can have a configuration almost identical to that of the conventional synchronous machine with absence of sliprings and a field winding.

Construction

Figure 5.1 shows an cross section of a very simple PM synchronous machine.

Stator

This is the stationary member of the machine. Stator laminations for axial airgap machines are often formed by winding continuous strips of softsteel. Various parts of the laminations are the teeth slots which certain the armature windings, yoke completes the magnetic path. Lamination thickness depends upon the frequency of the armature source voltage and cost.

Armature windings are generally double layer (two coil sides per slot) and lap wound. Individual coils are connected together to form phasor groups. Phasor groups are connected together in series/parallel combinations to form star, delta, two phase (or) single phase windings.

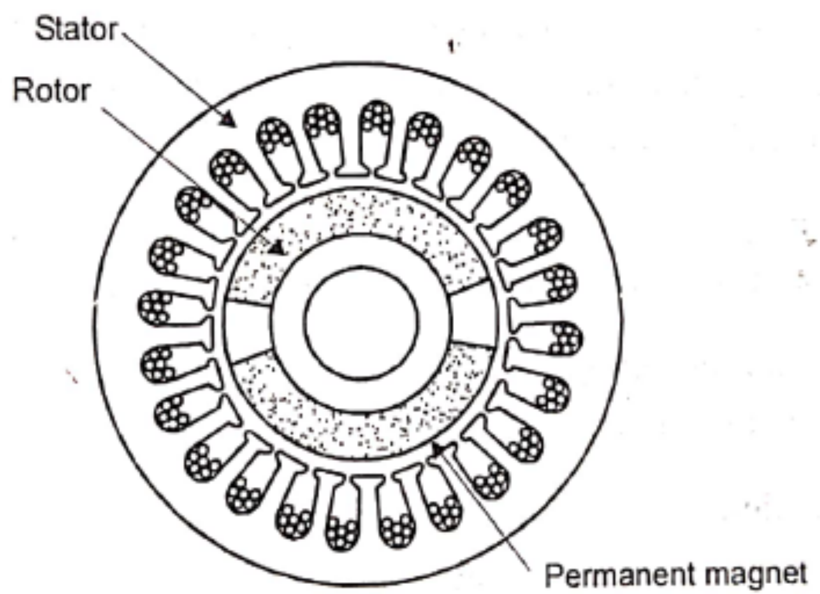


Figure 5.1

AC windings are generally short pitched to reduce harmonic voltage generated in the windings.

Coils, phase groups and phases must be insulated from each other in the end-turn regions and the required dielectric strength of the insulation will depend upon the voltage rating of the machine.

In a PM machine the airgap serves an role in that its length largely determines the operating point of the PM in the no-load operating condition of the machine. Also longer airgaps reduce machine windage losses.

Rotor

The PMs form the poles equivalent to the wound-field poles of conventional synchronous machines. Permanent magnet poles are inherently "salient", of course and there is no equivalent to the cylindrical rotor pole configurations used in many conventional synchronous machines.

Many permanent magnet synchronous machines may be cylindrical or "smooth rotor" physically but electrically the PM is still equivalent to a salient pole structure. Some of the PMSM rotors have the permanent magnets directly facing the airgap. It is shown in figure 5.2.

Rotor yoke is the magnetic portion of the rotor to provide a return path for the PMs and also to provide structural support. The yoke is often a part of the pole structure.

Damper winding is the typical cage arrangement of conducting bars, similar to induction motor rotor bars and to damper bars used on many other types of synchronous machines. It is not essential for all PM synchronous machine applications, but is found in most machines used in power applications.

The main purpose is to dampen oscillations about synchronous speed, but the bars are also used to start synchronous motors in many applications.

The design and assembly of damper bars in PM machines are similar to the other types of synchronous machines.

Rotor Configurations

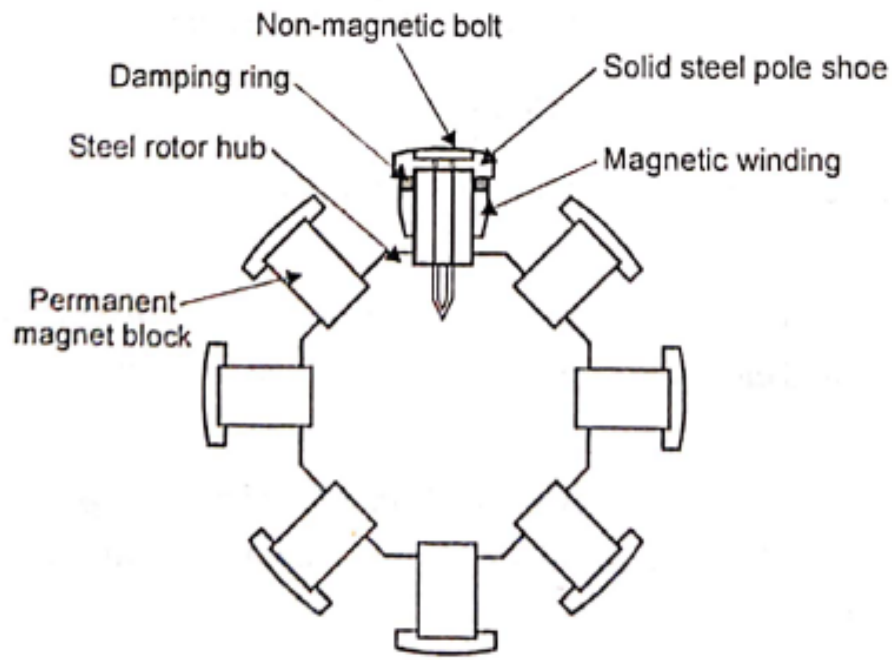


Figure 5.2`

Applications

PMSM is widely used in **robotics, machine tools, actuators**, and it is being considered in high-power applications such as industrial drives and vehicular propulsion. It is also used for residential/commercial applications.

EV applications

BLDC Motor

Introduction

A brushless DC motor is a poly phase synchronous motor with a permanent - magnet rotor. This motor cannot operate without its electronic controller or electronic commutator. Therefore, a brushless DC motor is motor drive system that combines into one unit an AC motor, solid state inverter and rotor position sensor. The simple block diagram PMBL DC motor.

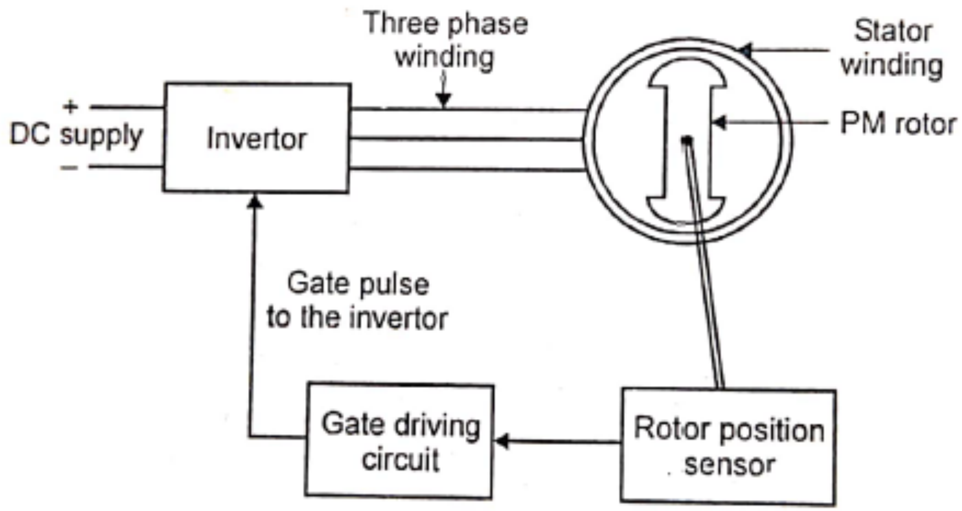
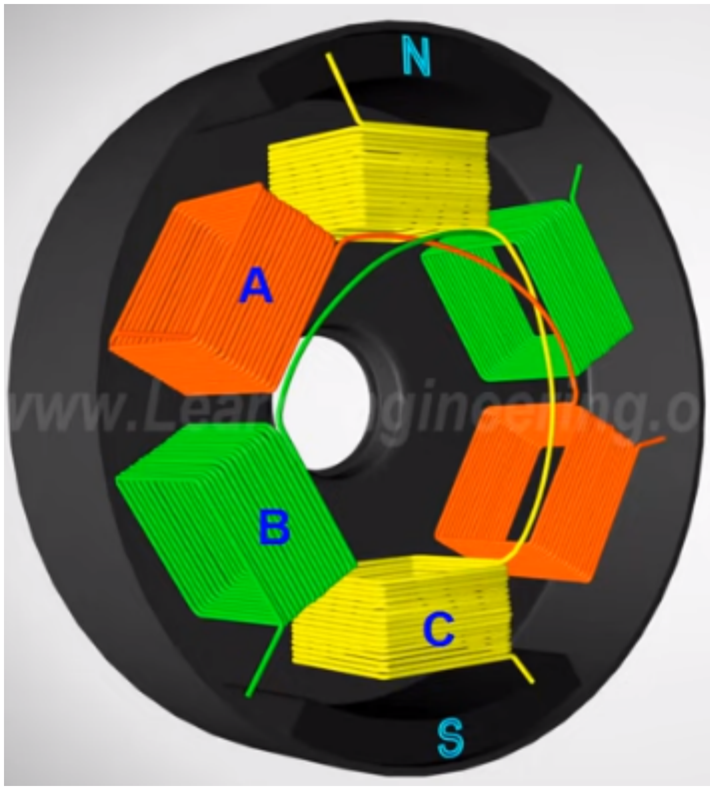


Figure 4.1(e)

The solid state inverter uses transistors, MOSFETs for low and medium power drives and thyristors for high power drives. Here, the rotor position sensor (RPS) monitors the shaft position and sends the contorl signals for turning on the controlled switches of the inverter in an appropriate sequence.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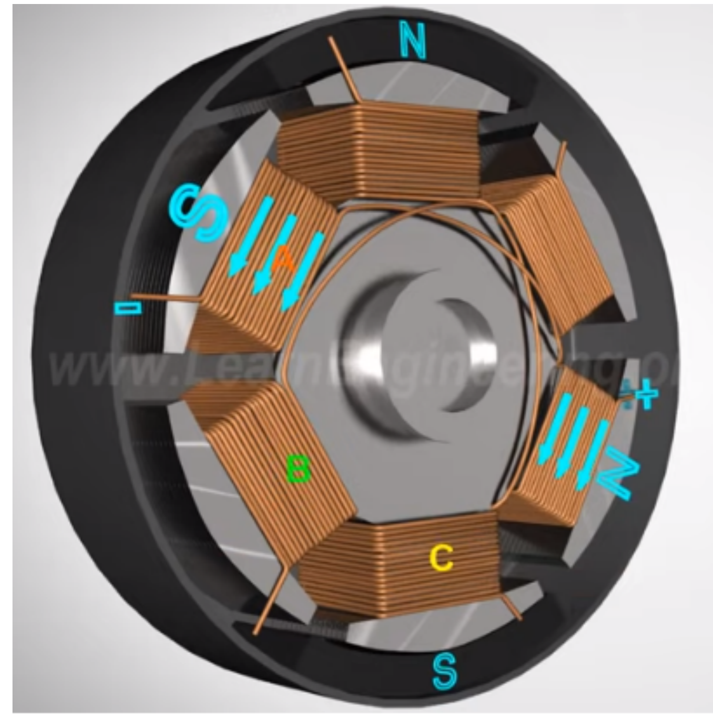
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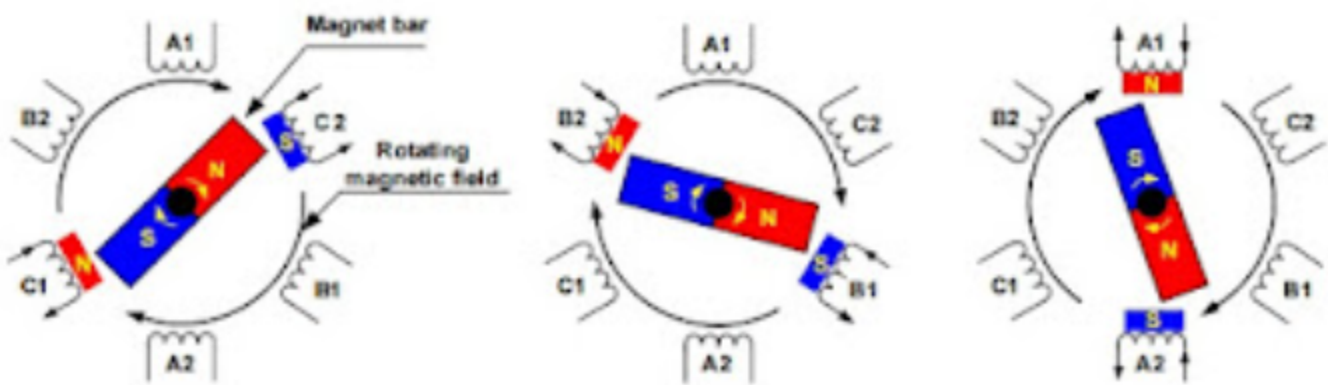
How Does A Brushless DC Motor Work?

BLDC Motor operation is based on the attraction or repulsion between magnetic poles. Using the three-phase motor as shown in figure below, the process starts when current flows through one of the three stator windings and generates a magnetic pole that attracts the closest permanent magnet of opposite pole.

The rotor will move if the current shifts to an adjacent winding. Sequentially charging each winding will cause the rotor to follow in a rotating field. The torque in this example depends on the current amplitude and the number of turns on the stator windings, the strength and the size of the permanent magnets, the air gap between the rotor and the windings, and the length of the rotating arm.



Stator

A brushless DC motor is also viewed as "inside-out" DC motor because its construction is opposite to that of a conventional DC motor.

The stator of the PMBLDC motor is made up of silicen steel stampings with slots its interior surface. There slots are accommodated either in closed or open distrubuted armature winding. This winding is wound for a specified number of poles (even number). This winding is suitable connected to DC supply through a solid state inverter circuit.

Rotor

Rotor accommodates a permanent magnet. The number of poles of the rotor is same as that of stator. The rotor shaft carries a rotor position sensor (RPS). This position sensor provides information about the position of the shaft at any instant to the controller which sends signals to the electronic commutator. This electronic commutator function is similar to the conventional mechanical commutator DC motor.

This motor posses more advantages over conventional DC motor is given below.

1. As no mechanical commutator and brushes are required, it has longer life.
2. Problems relating to radio frequency and electormagnetic interference are minimized.
3. This motor can run at speeds higher than those obtained in a conventional DC motor.
4. This motor is more efficient.

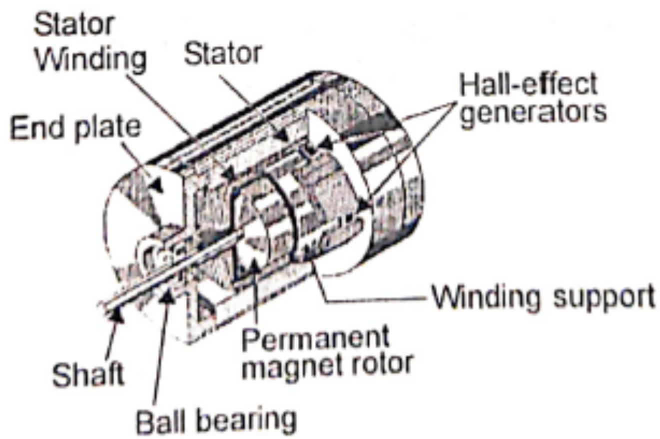


Figure 4.1(f)

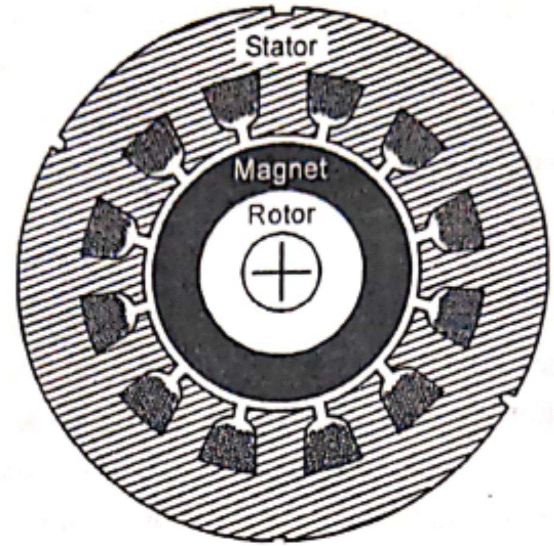


Figure 4.1 (g)

Advantages of PMBL DC Motor

1. There is no field winding so that field copper loss is neglected.
2. Length of the motor is very small as there is no mechanical commutator, so that size becomes very small.
3. Better ventilation because of armature accommodated in the stator
4. Regenerative braking is possible.
5. Speed can be easily controllable.
6. Motor can be designed for higher voltages subjected to the constraint caused by the power semi conductor switching circuit.
7. It is possible to have very high speeds.

Disadvantages

1. Motor field cannot be controlled.
2. Power rating is restricted because of the maximum available size of permanent magnets.
3. It requires a rotor position sensor.
4. It requires a power semi conductor switching circuit.

Applications

1. Automotive applications
2. Verticular electric drive motors
3. Applications in textile and glass industries
4. Computer and Robotics
5. Small appliances such as fans, mixers etc.

Applications

Brushless DC motors (BLDC) use for a wide variety of application requirements such as varying loads, constant loads and positioning applications in the fields of industrial control, automotive, aviation, automation systems, health care equipments etc.

EV applications

Fans, pumps and blowers.

Stepper Motor

- A stepper motor is a "pulse-driven" motor that changes the angular position of the rotor in "steps"
- Stepper motor is a motor which rotates step by step and not continuous rotation. When the stator is excited using a DC supply the rotor poles align with the stator poles in opposition such that reluctance is less.

The general relationship between step angle θ_S, number of stator phases m and rotor teeth N_r is given by

$$\theta_S = \frac{360^o}{m\,N_r}$$

Stepper motor

- Rotated through fixed angular steps
- PWM Signal as a input
- Directly controlled via computers,Microprocessor and PLC
- No feedback
- Suitable where Precise speed and position control is required
- Develops Torque from 1 micro

Stepper motor construction is quite similar to DC motor. It also has a permanent magnet as Rotor. Rotor will be in the center and will rotate when force is acts on it. This rotor is surrounded by a number of stator which is wound by magnetic coil all over it. Stator will be placed as close as possible to rotor so that magnetic fields in stators can influence rotor's movement.

To control the stepper motor each stator will be powered one by one alternatively. In this case the stator will magnetize and act as an electromagnetic pole exerting repulsive force on the rotor and pushes it to move one step. Alternative magnetizing and demagnetizing of stators will move the rotor step by step and enable it to rotate with great control.

Types of Stepping Motors

Permanent Magnet Stepper Motor

- Permanent magnet motors use a permanent magnet (PM) in the rotor and operate on the attraction or repulsion between the rotor PM and the stator electromagnets.
- This is the most common type of stepper motor as compared with different types of stepper motors available in the market.

Variable Reluctance

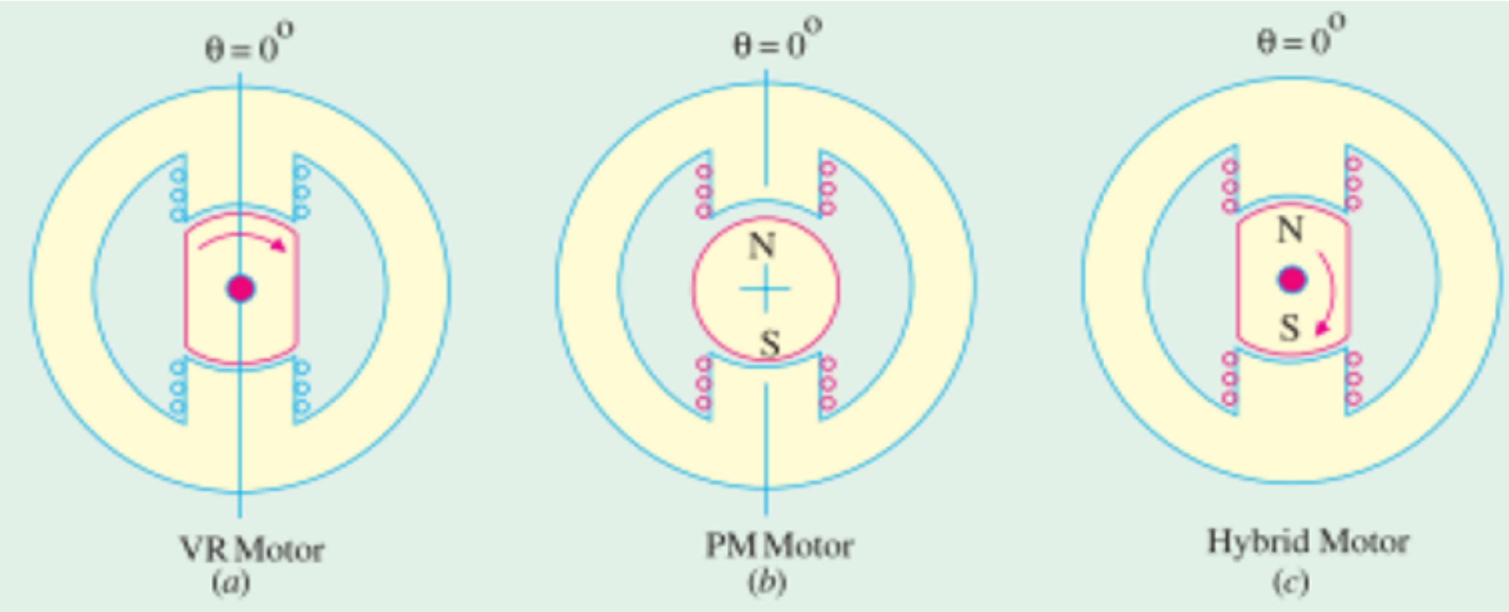
- Variable reluctance (VR) motors have a plain iron rotor and operate based on the principle that minimum reluctance occurs with minimum gap, hence the rotor points are attracted toward the stator magnet poles.
- The stepper motor like variable reluctance is the basic type of motor and it is used for the past many years. As the name suggests, the rotor's angular position mainly depends on the magnetic circuit's reluctance that can be formed among the teeth of the stator as well as a rotor.

Hybrid

- This is a combination of above two motor permanent and variable reluctance stepper motor. This motor consists of permanent magnetic toothed rotor like the ones in permanent magnet stepper motor with set of north and south poles in it. Also just like variable reluctant motor the stators have teeth in it.

Few teeth of stator will be aligned to teeth of rotor while others will not be aligned to each other. When stator is magnetized by supplying current to it, magnetic flux drives the rotor to move by one step. The presence of teeth in both stator and rotor changes the magnetic flux and drives the motor by steps as intended.

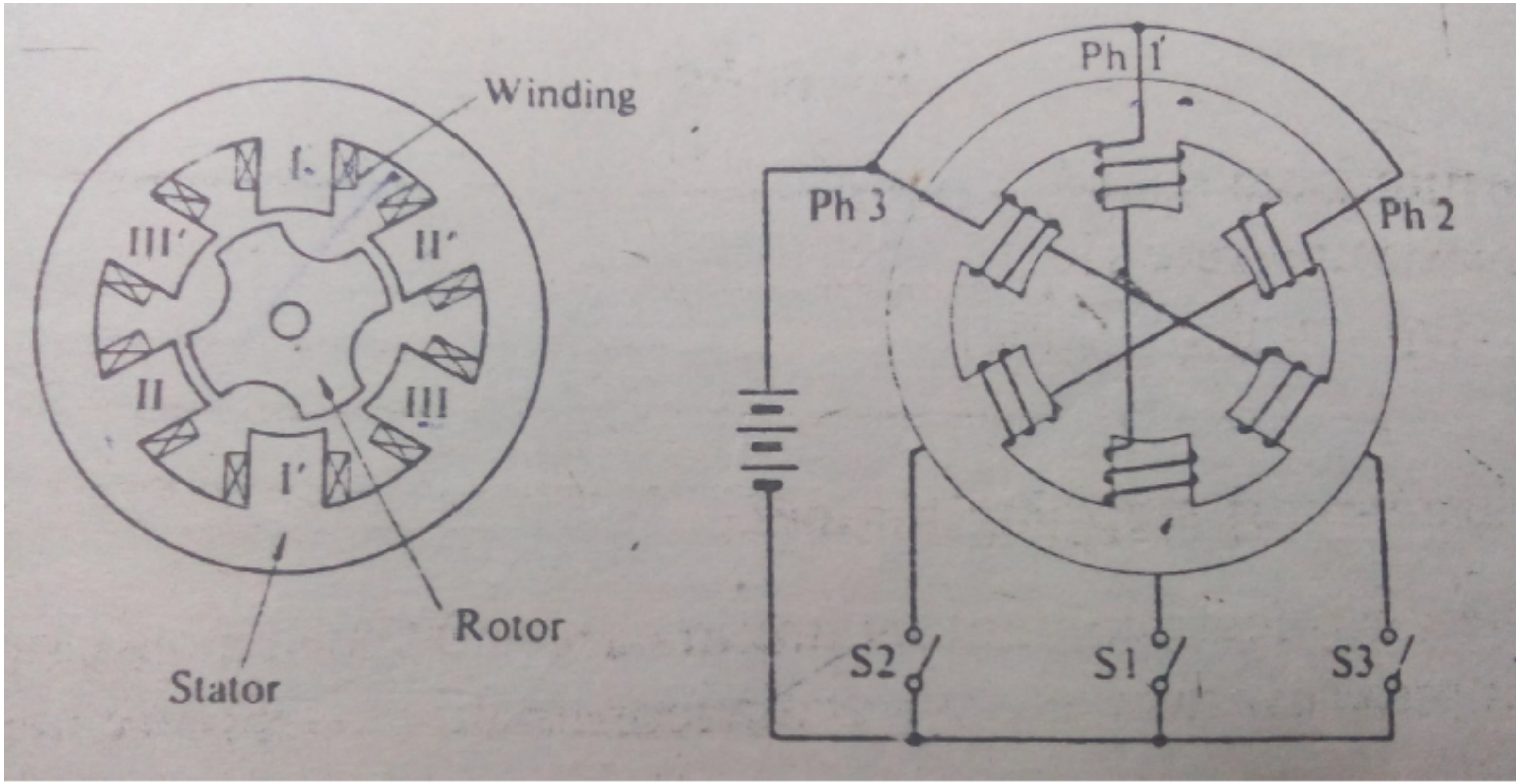
The Hybrid synchronous motor is most popular since it has high torque and resolution. Driving modes like half step can even increase the resolution of this motor. While full step or micro-stepping can be used to increase the torque, accuracy and smooth working. The hybrid motor is most popular because of the advantages it hold but comes with high cost due to its complex construction.



Variable Reluctance Stepper Motor

- It consists of a wound stator and a soft iron multi-tooth rotor.
- The stator has a stack of silicon steel laminations on which stator windings are wound.
- Usually, it is wound for three phases which are distributed between the pole pairs.
- The rotor carries no windings and is of salient pole type made entirely of slotted steel laminations.
- The rotor pole's projected teeth have the same width as that of stator teeth.
- The number of poles on stator differs to that of rotor poles, which provides the ability to self start and bidirectional rotation of the motor.

Cross section model of 3-ph VR stepper motor and winding arrangement



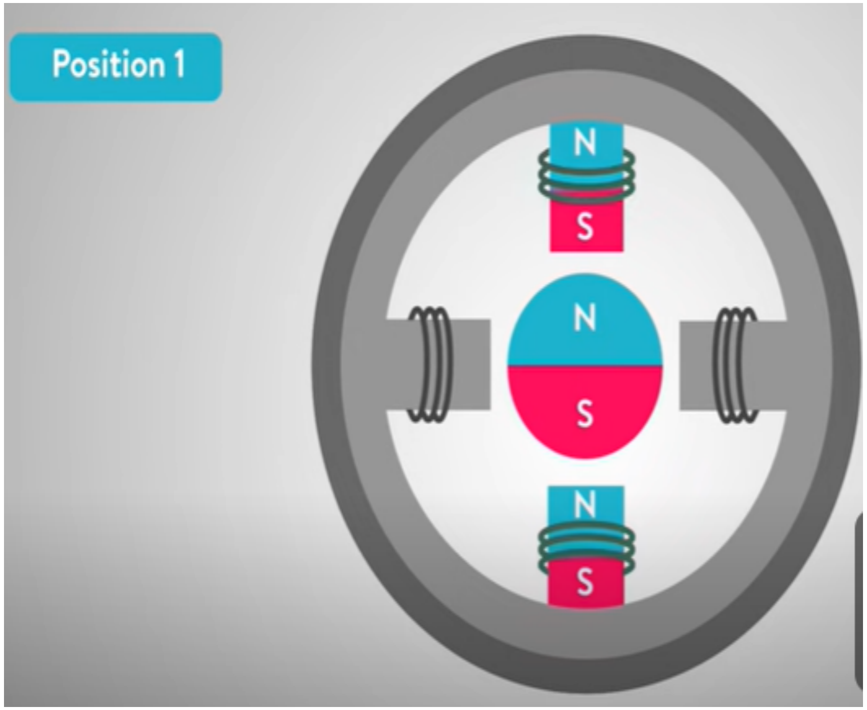
VR Stepper motor has following modes of operation

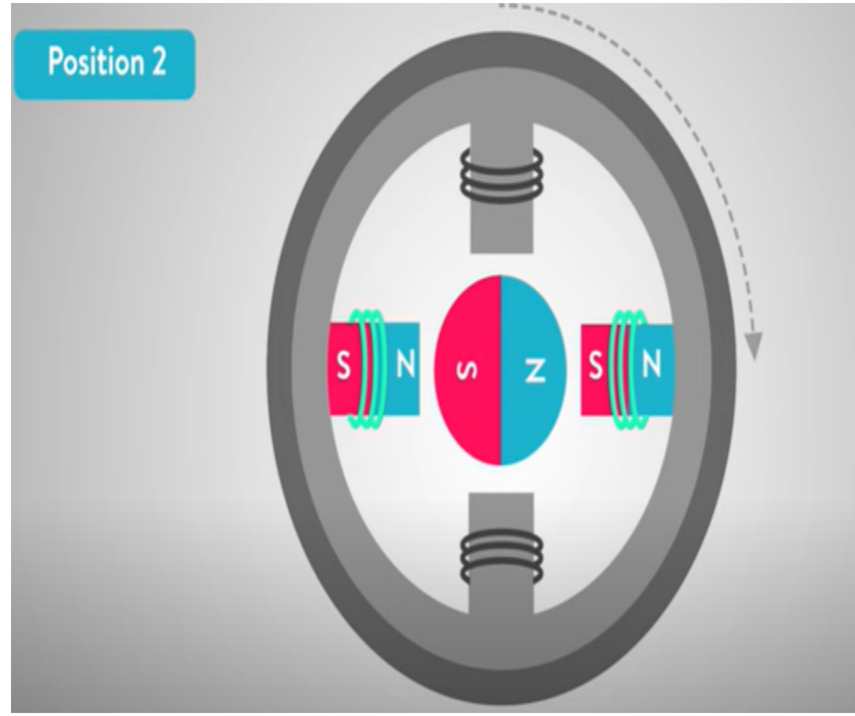
1. 1 phase ON (or) Full step operation mode
2. 2 phase ON mode
3. Alternate 1 phase ON and 2 phase ON mode (or) Half step operation mode
4. Micro stepping operation mode

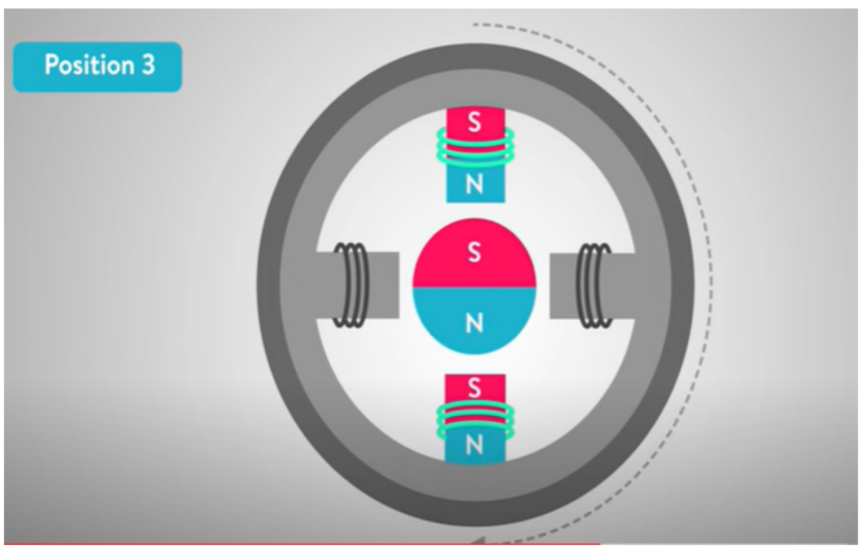
Working of Variable Reluctance Stepper Motor

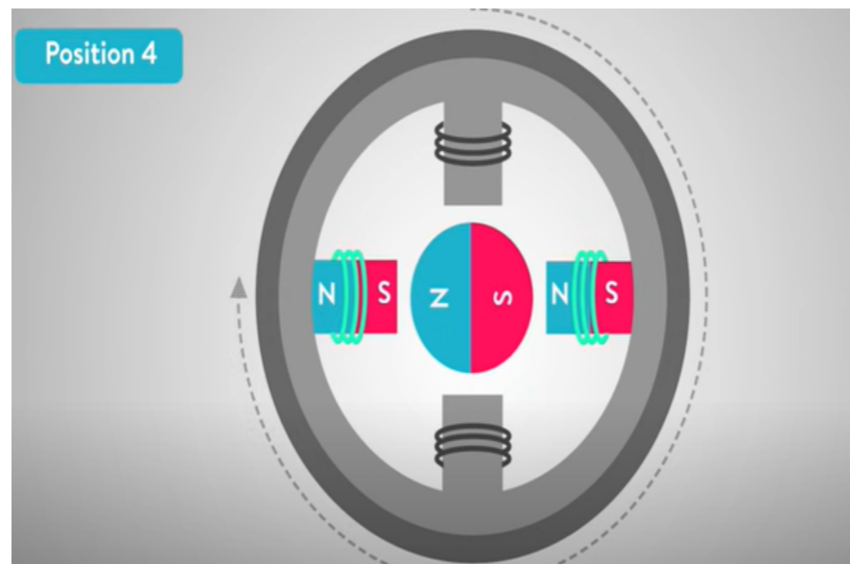
- The stepper motor works on the principle that the rotor aligns in a particular position with the teeth of the excitation pole in a magnetic circuit wherein minimum reluctance path exist.
- Whenever power is applied to the motor and by exciting a particular winding, it produces its magnetic field and develops its own magnetic poles.
- Due to the residual magnetism in the rotor magnet poles, it will cause the rotor to move in such a position so as to achieve minimum reluctance position and hence one set of poles of rotor aligns with the energized set of poles of the stator.
- At this position, the axis of the stator magnetic field matches with the axis passing through any two magnetic poles of the rotor.

- When the rotor aligns with stator poles, it has enough magnetic force to hold the shaft from moving to the next position, either in clockwise or counter clockwise direction.
- The stepper motor works on the principle that the rotor aligns in a particular position with the teeth of the excitation pole in a magnetic circuit wherein minimum reluctance path exist.


Position 1
N
S
N
S
N
S

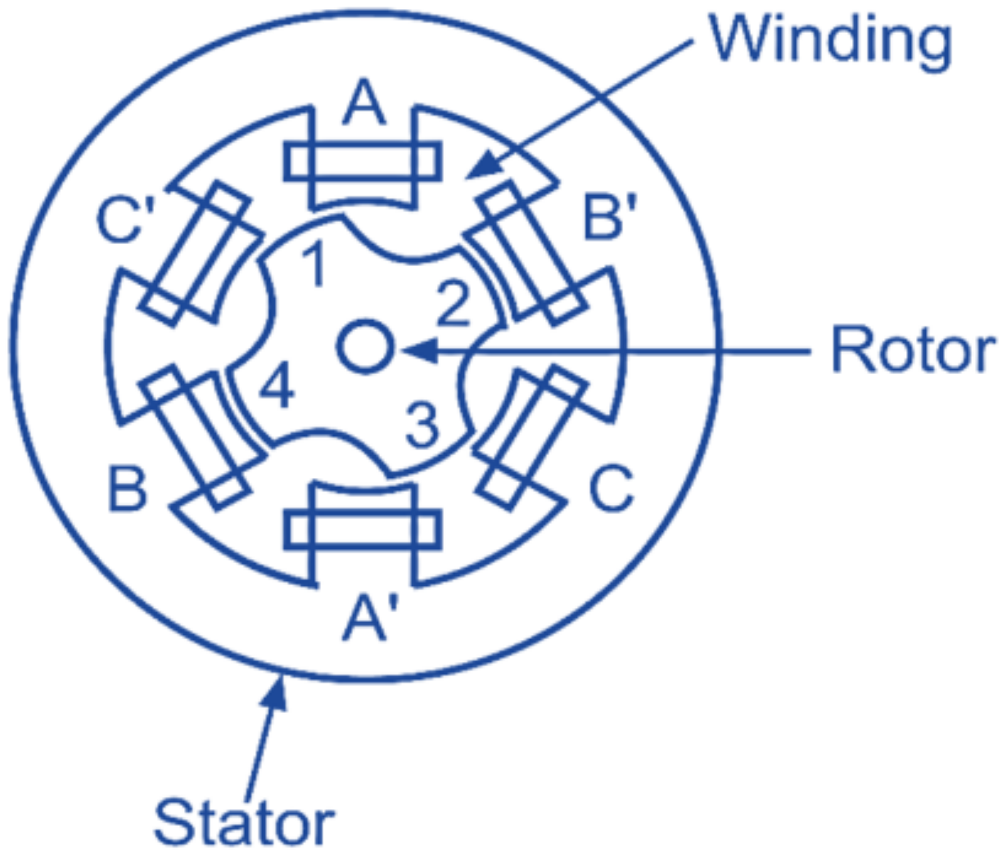

Position 2
S
N
S
N
S
N


Position 3
S
N
S
N
S
N


Position 4
N
S
N
S
N
S

Construction of Variable Reluctance Stepper Motor

Fig. 1 schematically represents such a motor. The stator usually made of laminated silicon steel has six salient poles or teeth and is wound for three phases located 120º apart. The two coils wound around diametrically opposite poles and connected in series form a stator phase. The three phases thus formed are energised from a dc source in a specified sequence through an electronic switching device. The rotor is also normally made of silicon steel laminations and has four salient poles (or teeth) without any exciting winding as shown.


Winding
A
C'
B'
1
2
Rotor
4
3
B
C
A'
Stator

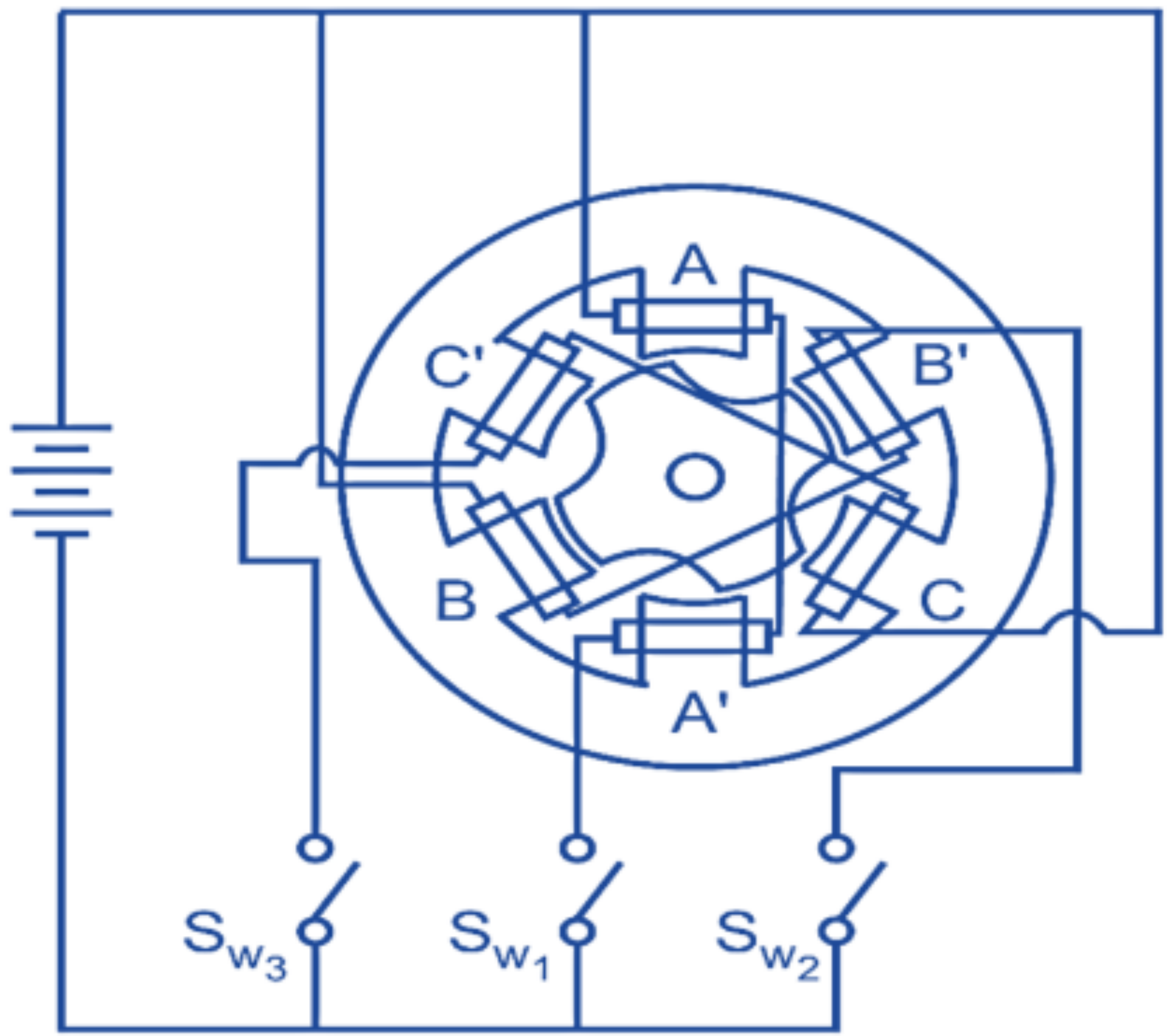
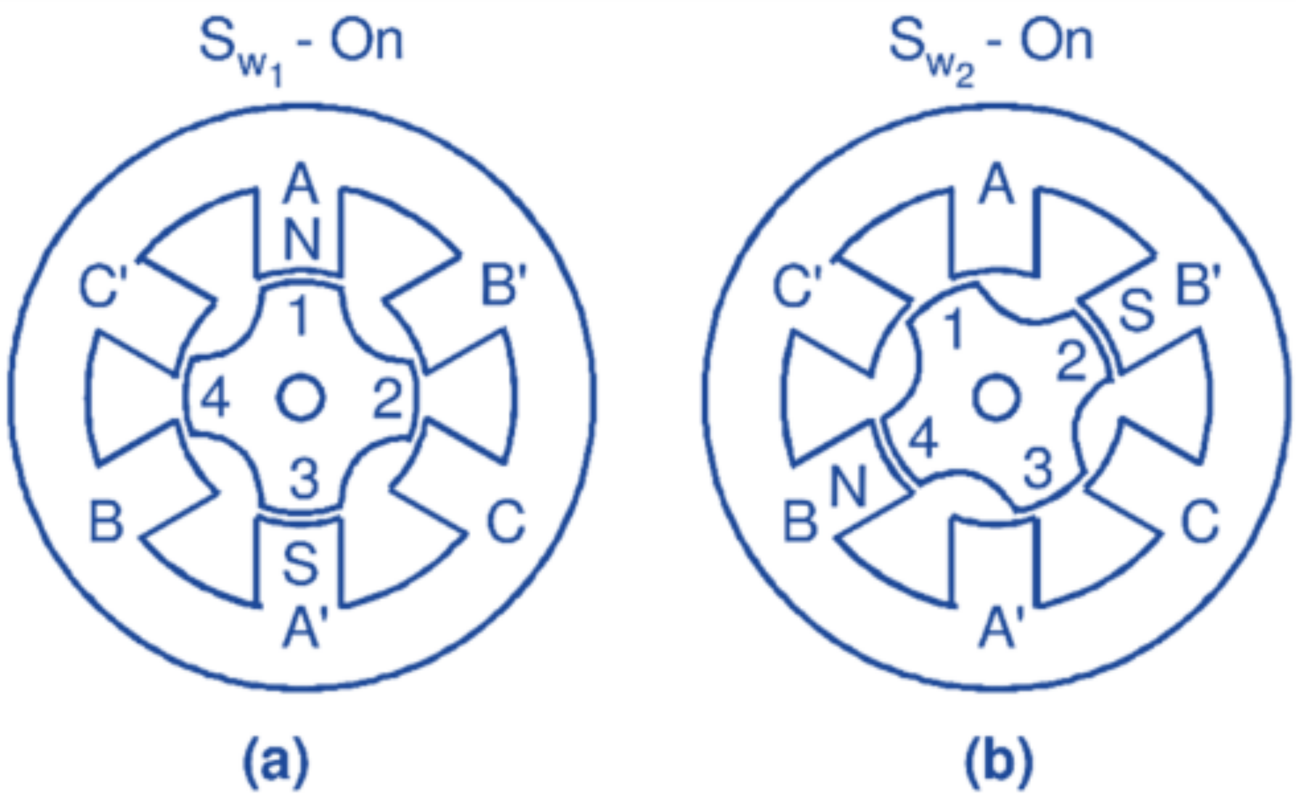


Fig. 1: Schematic representations of a variable-reluctance stepper motor (a) Cross-sectional view. (b) Winding arrangement.

Working of Variable Reluctance Stepper Motor

When phase A is excited (with coil A forming a North-pole and coil A' forming a South-pole), the rotor in its attempt to seek the position of minimum reluctance between the stator and rotor, is subjected to an electromagnetic torque and thereby rotates until its axis coincides with the axis of phase A (Fig. 2 a). If now, phase B is excited (with coil B forming a North-pole and coil B' forming a South-pole), disconnecting the supply to phase A, the rotor will move through 30^0 in an anticlockwise direction and take up the minimum reluctance position shown in Fig. 2 (b). Next, if phase C is energised while disconnecting the supply to phase B, the rotor will move through another 30^0 in an anticlockwise direction and take the position indicated in Fig. 2 (c). Thus, if three phases are successively excited in the above manner by supplying the voltage pulses, the motor will take one Step of 30^0 with each voltage pulse and will require 12 pulses to make one complete revolution.

Further, it will be observed that if the three stator phases are supplied with voltage pulses adopting a switching sequences as A – C – B – A – ...., the rotor will move in the clockwise direction.



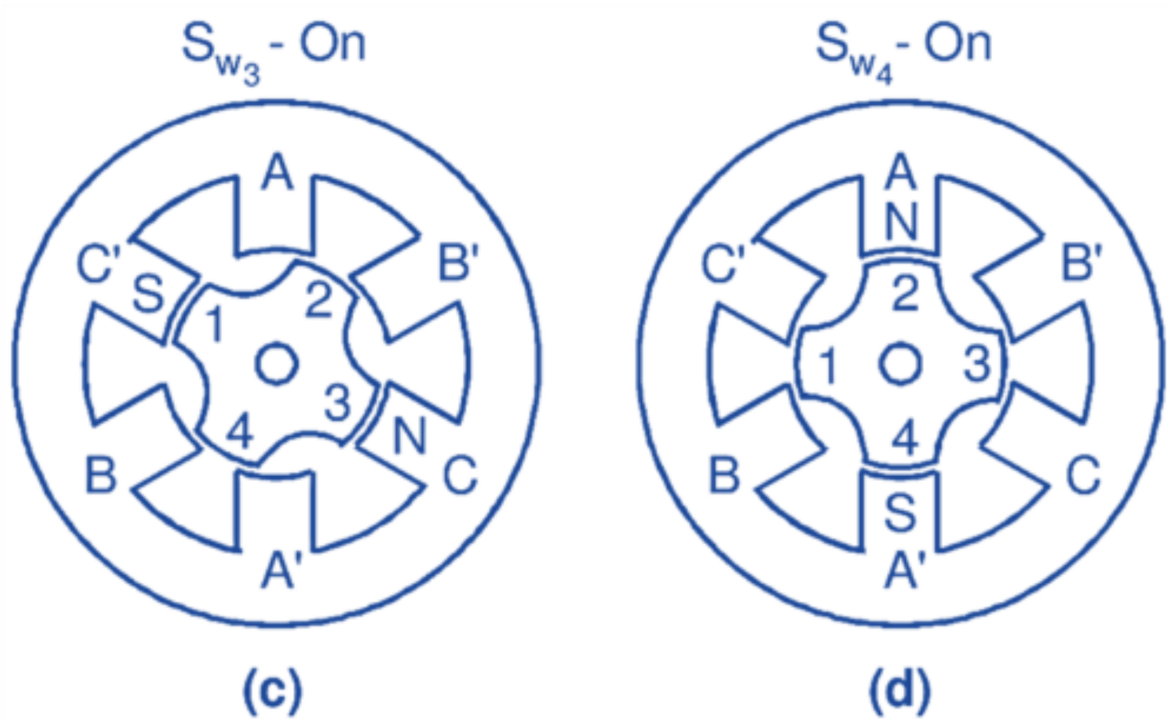
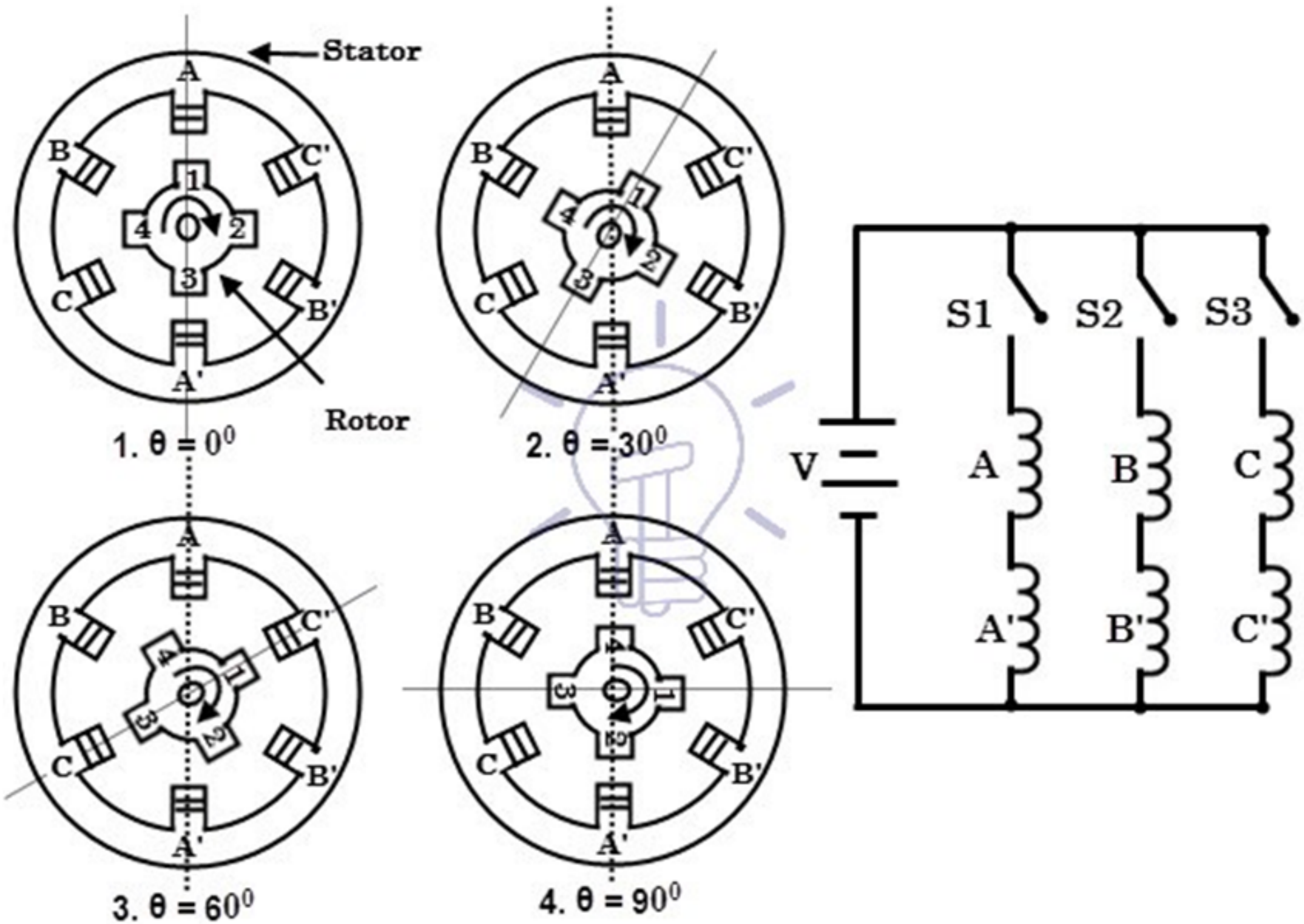


Fig. 2: Step motions as switching sequence proceeds in a three-phase variable-reluctance stepper motor.


Stator
A
B
C'
C
B'
A'
Rotor
1. θ = 0⁰
2. θ = 30⁰
3. θ = 60⁰
4. θ = 90⁰
S1
S2
S3
V
A
A'
B
B'
C
C'

Applications

- computer peripheral
- textile industry
- ROBOTICS
- Type writers
- Line printers
- Tape drives
- Floppy disk drives
- NC machines
- Process control system

Servo Motor

- Servo is an electromagnetic device uses a negative feedback mechanism to converts an electric signal into controlled motion. Basically, servos behave like as actuators which provide precise control over velocity, acceleration, and linear or angular position.
- It consists of four things: DC motor, position sensor, gear train, and a control circuit. The gear mechanism connected with the motor provides the feedback to the position sensor.
- If the motor of the servo is operated by DC then it is called a DC servo motor and if it is operated by AC then it is called as AC servo motor. The gear of the servo motor is generally made up of plastic but in high power servos, it is made up of metal.

Types of Servo Motors on the Basis of Rotation

Positional Rotation Servos: Positional servos can rotate the shaft in about half of the circle. Also, it has the feature to protect the rotational sensor from over-rotating. Positional servos are mainly used in limbs, robotic arms, and in many other places.

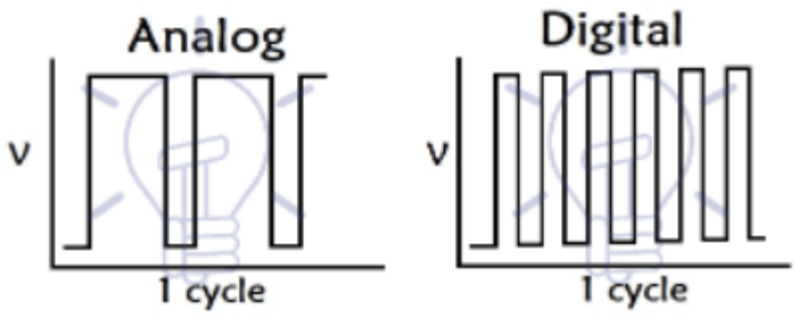
Continuous Rotation Servos: Continuous servos are similar in construction to the positional servo. But, it can move in both clockwise and anticlockwise directions. These types of servos are used in radar systems and robots.

Linear Servos: Again linear servos are also like a positional servo, but with additional gears to the adjust the output from circular to back-and-forth. These type of servos are used in high model airplanes and are rare to find on the stores.

On the Basis of Operating Signal

(i) Analog Servomotors: Analog servos are operated over PWM (Pulse Width Modulation) signals.

(ii) Digital Servomotors: Digital Servo receives signal and acts at high-frequency voltage pulses. Digital servo gives a smooth response and consistent torque, due to faster pulse. Digital servos consume more power than an analog servo.

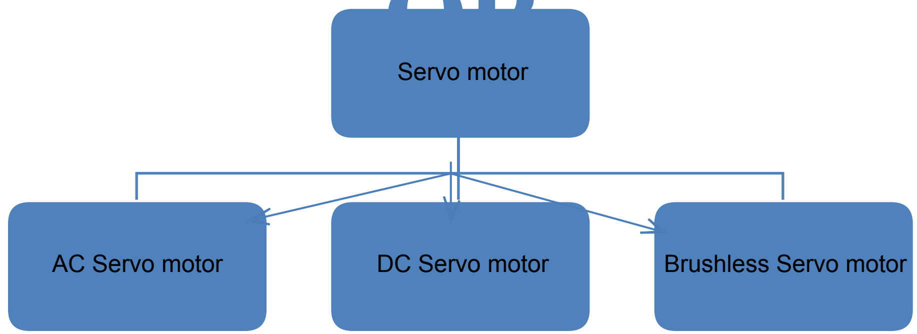


On the Basis of Operating Power

(i) **DC Servo Motor**

(ii) **AC Servo Motor**

SERVOMOTOR



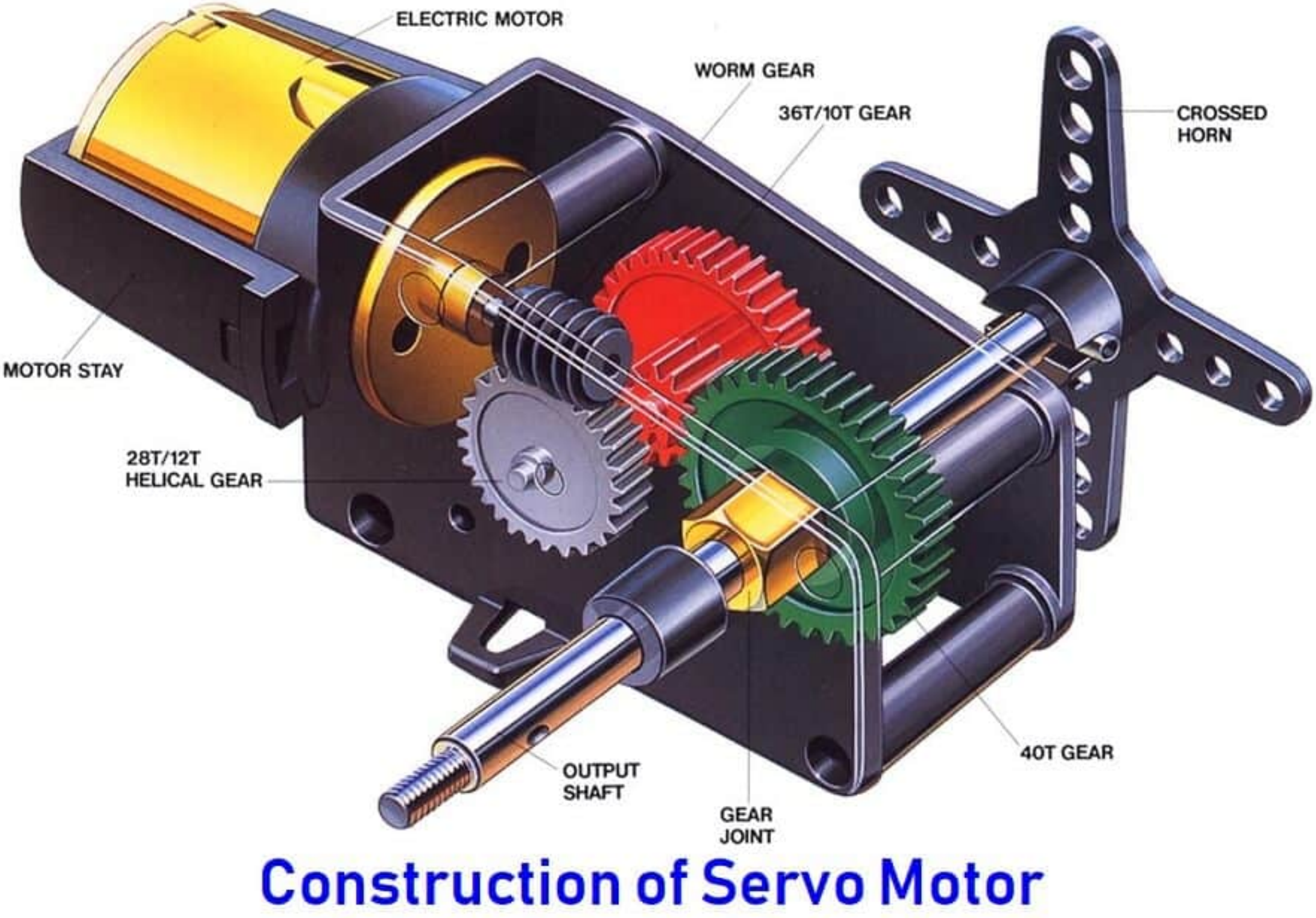
Servomotor differ from large industrial motor in following respects:-

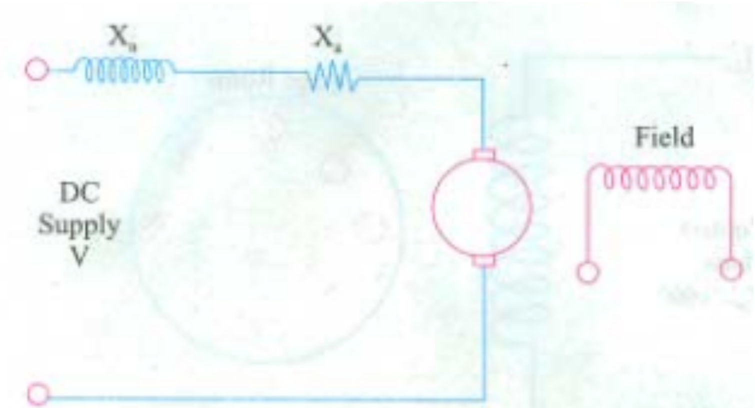
1. **They produce high torque at all speeds including zero speed.**
2. **They are capable of holding a static (i.e. no motion) position.**
3. **They do not overheat at standstill or lower speed.**
4. **Due to low-inertia, they are able to reverse direction quickly.**
5. **They are able to accelerate and de-accelerate quickly.**

Servo Motor-DC

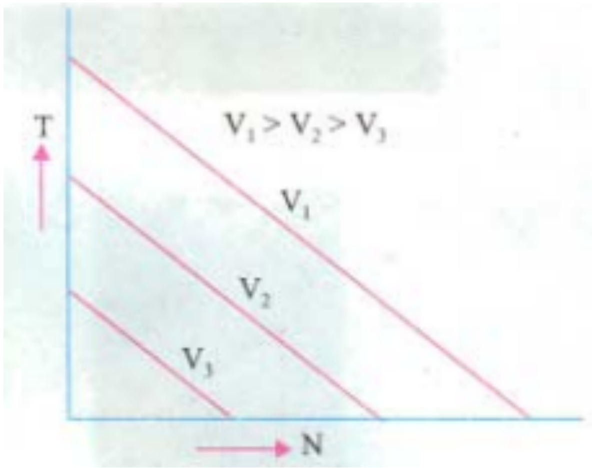
- They produce high torque at all speeds including zero speed.
- They are capable of holding a static(i.e. no motion) position.
- They do not overheat at standstill or lower speeds.
- Due to low-inertia, they are able to reverse directions quickly.
- They are able to accelerate and decelerate quickly.

Construction of Servo Motor:





(a)



Seperately Excited or permanent magnet dc motor. Speed is varied by varying armature voltage. Armature is made of large resistance hence T/N characteristics is linear.

Stator Winding: This type of winding wound on the stationary part of the motor. It is also known as field winding of the motor.

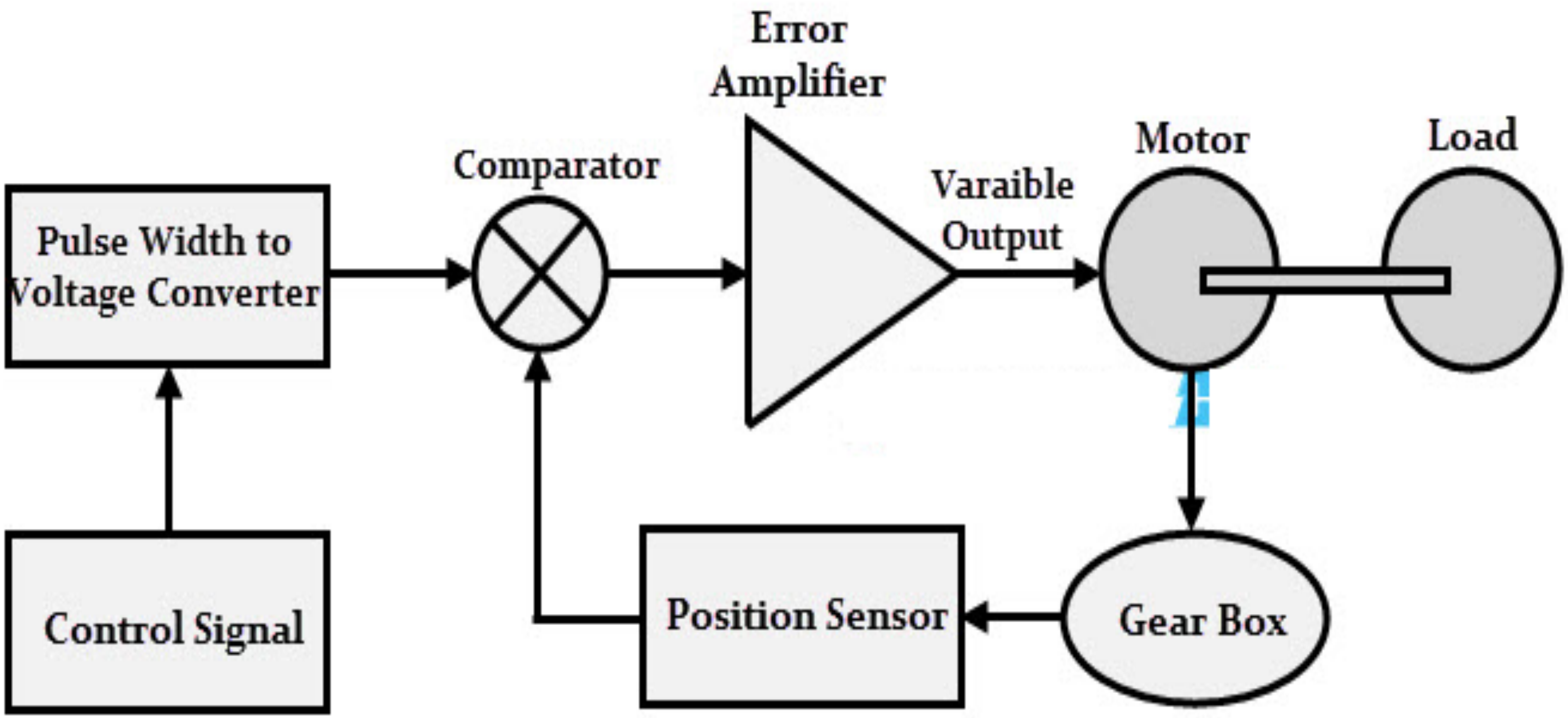
Rotor Winding: This type of winding wound on the rotating part of the motor. It is also known as an armature winding of the motor.

Bearing: These are of two types, i.e, font bearing and back bearing which are used for the movement of the shaft.

Shaft: The armature winding is coupled on the iron rod is known as the shaft of the motor.

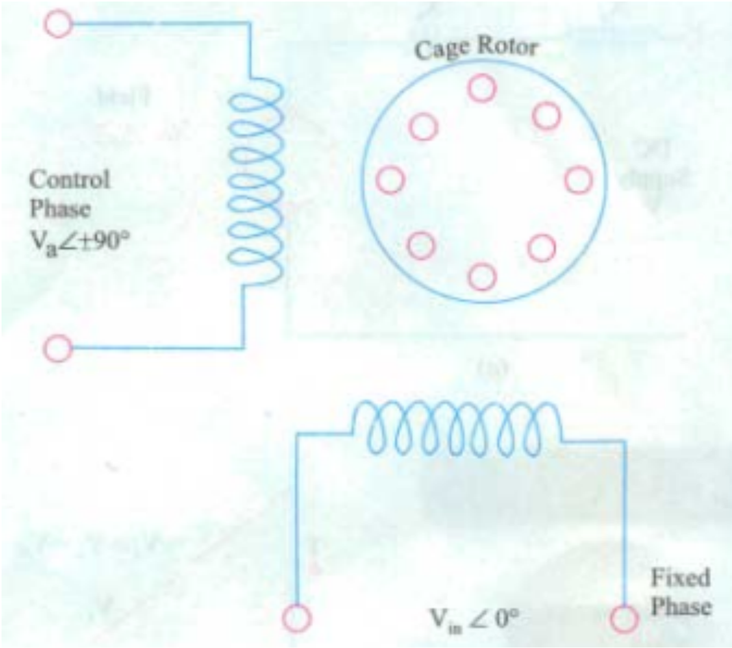
Encoder: It has the approximate sensor which determines the rotational speed of motor and revolution per minute of the motor.

Closed loop system - Servo Motor:



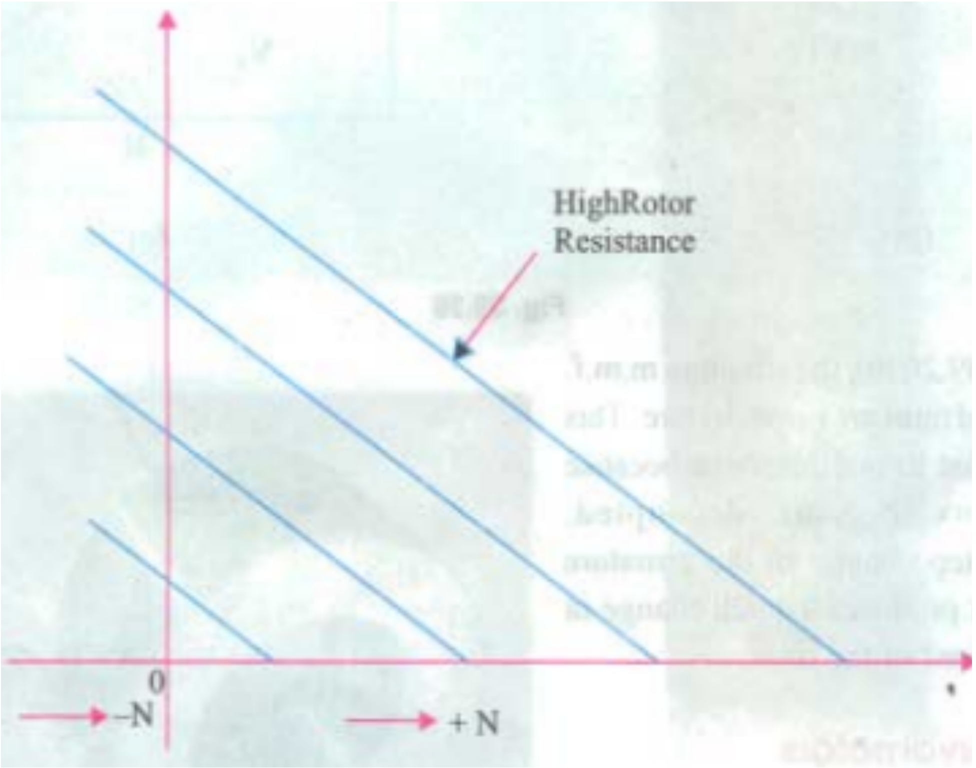
Working of Servo Motors

- The servo has a position sensor, a DC motor, a gear system, a control circuit. The DC motor run at high speed and low torque when getting power from a battery. The position of shaft senses by position sensor from its definite position and supply information to the control circuit.
- The reduction gearbox is connected to a shaft which decreases the RPM of the motor. The output shaft of the reduction gearbox is the same as of motor which is connected with encoder or potentiometer.
- The output of the encoder is then connected to the control circuit. The wires of the servomotor are also connected to the control circuit.
- The motor control through microcontroller by sending signals in the form of PWM which decodes the control circuit to rotate the motor in required angle the control circuit moves the motor in a clockwise or anticlockwise direction, with this the shaft also rotates in the desired direction.



Servo Motor-AC

Two-phase squirrel cage induction type and are used for low power applications. However recently 3-phase induction motors have been modified for high power servo systems which had so far been using high power dc servomotors.



Servo Motor-AC

Control phase is supplied with a variable voltage of the same frequency as the reference phase but is phase-displaced by 900 (electrical). The N/T are controlled by the phase difference between the main and control windings. Reversing the phase difference from leading to lagging reverses motor direction

Applications of Servo Motors

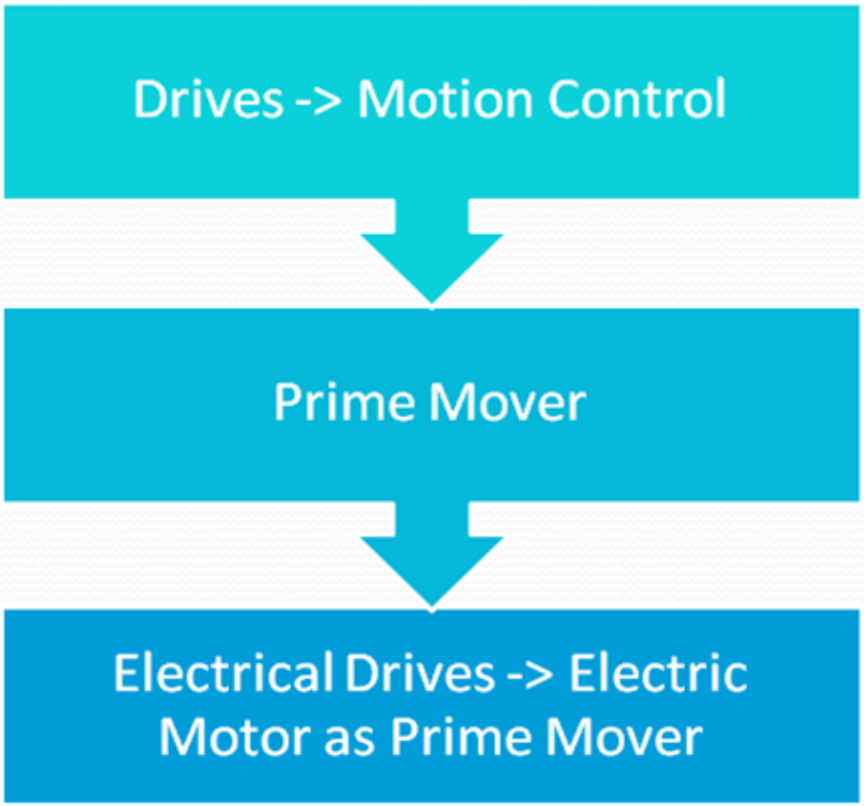
- They are used to control the positioning and movement of elevators in radio controlled airplanes.
- They play an important role in robotics information of robot because of their smooth switching on or off and accurate positioning.
- They are used in hydraulic systems to maintain hydraulic fluid in the aerospace industry.
- In radio controlled toys these are also used.
- They are used to extend or replay the disc trays in electronic devices such as DVDs or Blue-ray Disc players.
- They are used to maintain the speed of vehicles in the automobile industries.

Applications

- Radar tracking and guidance systems
- Process controls
- Computers
- Machine tools

Electrical Drives

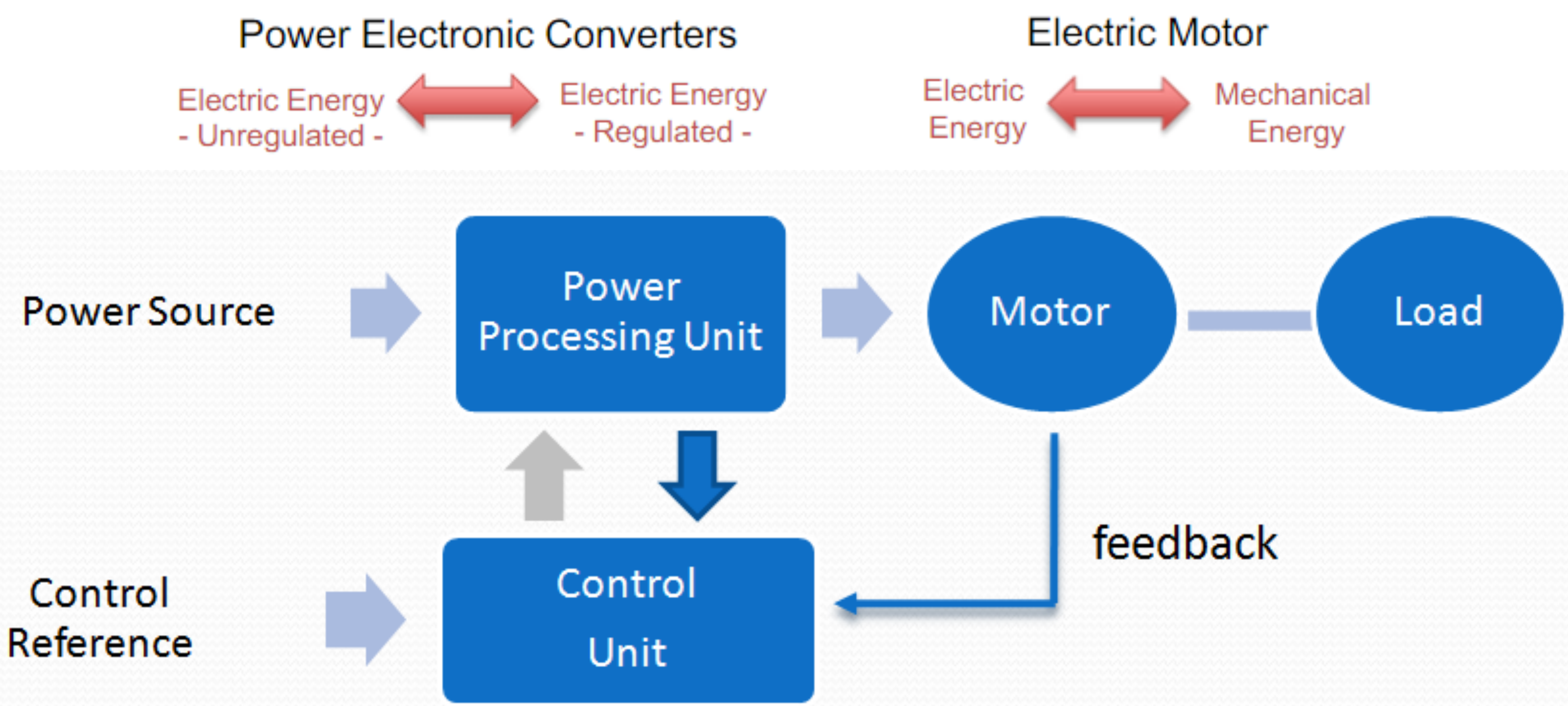
- Drives – system employed for motion control
- Motion control requires prime movers
  Diesel/petrol/gas/stream engines, hydraulic motors, electric motors
- **Electrical Drives** – Drives that employ Electric Motors as prime movers



Advantages of Electrical Drives

- Flexible control characteristic
  - particularly when power electronic converters are employed
- Wide range of speed, torque and power
- High efficiency – low no load losses
- Low noise
- Low maintenance requirements, cleaner operation
- Electric energy easily transported
- Adaptable to most operating conditions
- Available operation in all four torque-speed quadrants

Block Diagram of Electric Drive System



- Power Source
- Motor
- Power Processing Unit (Electronic Converter)
- Control Unit
- Mechanical Load

Components in electric drives

Motors

- DC motors - permanent magnet – wound field
- AC motors – induction, synchronous
- brushless DC
- Applications, cost, environment
- Natural speed-torque characteristic is not compatible with load requirements

Power sources

- DC – batteries, fuel cell, photovoltaic - unregulated
- AC – Single- three- phase utility, wind generator - unregulated

Power processor

- To provide a regulated power supply
- Combination of power electronic converters
    - More efficient
    - Flexible
    - Compact
    - AC-DC, DC-DC, DC-AC, AC-AC

Components in electric drives

Control unit

- Complexity depends on performance requirement
- analog- noisy, inflexible, ideally has infinite bandwidth.
- DSP/microprocessor – flexible, lower bandwidth - DSPs perform faster operation than microprocessors (multiplication in single cycle), can perform complex estimations
- Electrical isolation between control circuit and power circuit is needed:
  - Malfunction in power circuit may damage control circuit
  - Safety for the operator
  - Avoid conduction of harmonic to control circuit

Components in electric drives

Sensors

- Sensors (voltage, current, speed or torque) is normally required for closed-loop operation or protection.
- Electrical isolation between sensors and control circuit is needed.
- The term ‘sensorless drives’ is normally referred to the drive system where the speed is estimated rather than measured.

Applications of Electric Drives

Transportation Systems

Rolling Mills

Paper Mills

Textile Mills

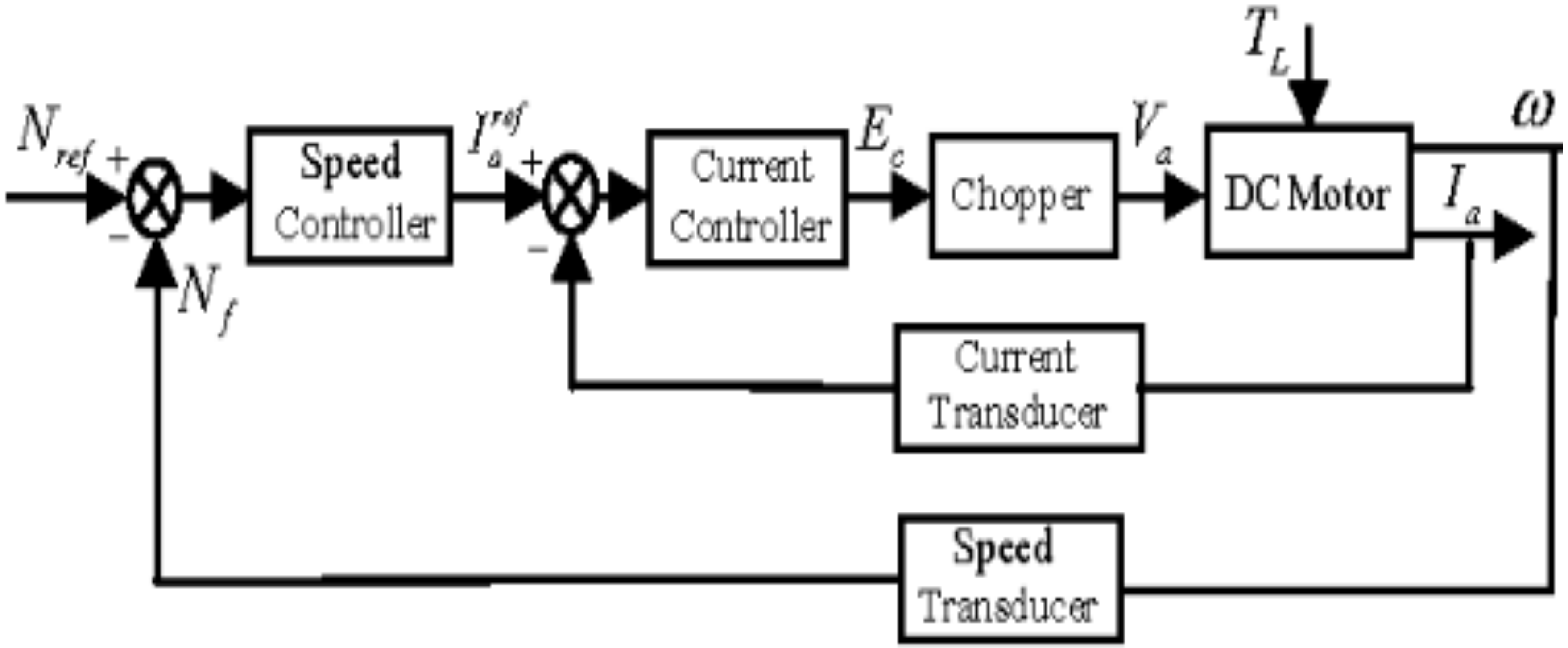
Machine Tools

Fans and Pumps

Robots

Washing Machines etc

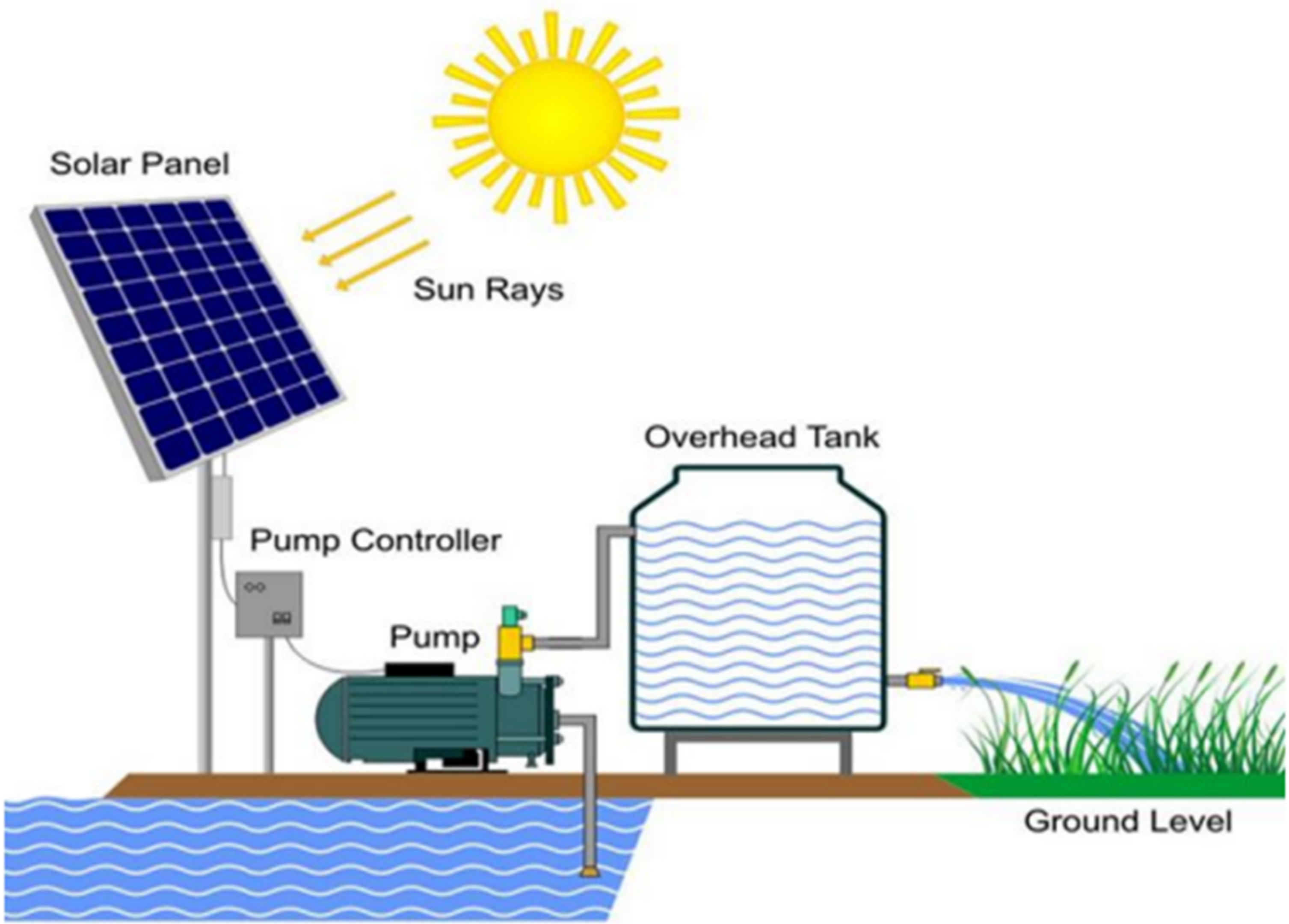
Chopper fed dc drive



Factors for selection of Electrical Drives

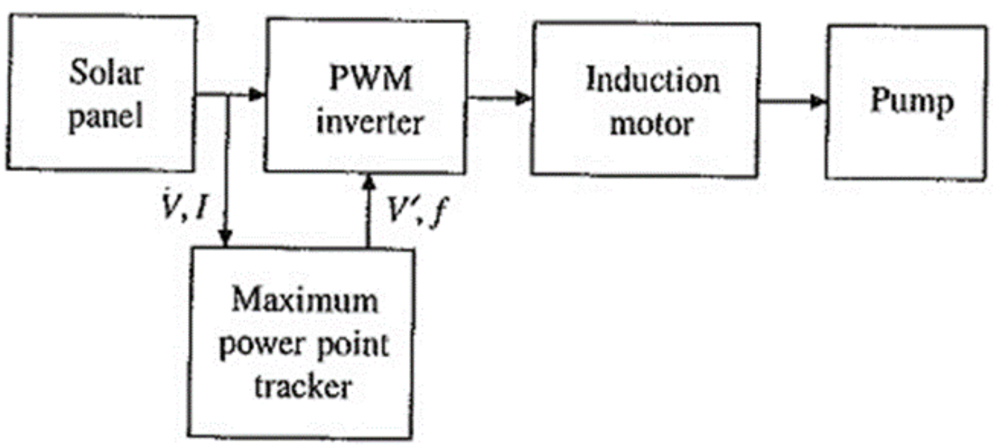
- Several factors affecting drive selection:
  - Steady-state operation requirements
    - nature of torque-speed profile, speed regulation, speed range, efficiency, quadrants of operations, converter ratings
  - Transient operation requirements
    - values of acceleration and deceleration, starting, braking and reversing performance
  - Power source requirements
    - Type, capacity, voltage magnitude, voltage fluctuations, power factor, harmonics and its effect on loads, ability to accept regenerated power
  - Capital & running costs
  - Space and weight restrictions
  - Environment and location
  - Efficiency and reliability

Solar Powered Pump System



Solar Powered Pump Drives with reciprocating pump

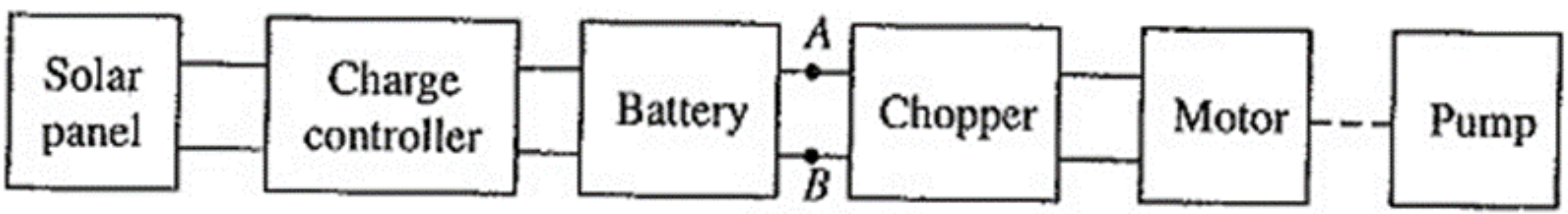
- For pump ratings of 1 kW and above, three phase induction motor drive is employed.
- A PWM voltage source inverter with maximum-power-point-tracker is used for variable frequency control of the squirrel-cage induction motor.



Solar pump drive using induction motor

Solar Powered Pump Drives with battery

- Solar Powered Pump Drives with an intermediate battery, can also be used.
- The drive is fed from the battery charged by solar panel.



Solar pump with a battery

Selection of drives and control schemes for lifts and cranes

Selection of drives and control schemes for lifts and cranes

1) **Quick Lift:** To allow a lightly loaded or empty hoist to move up and down faster than the base speed of the motor

2) **Reverse Plug Simulation:** When reversing directions, the inverter will decelerate at a faster rate than the normal deceleration rate.

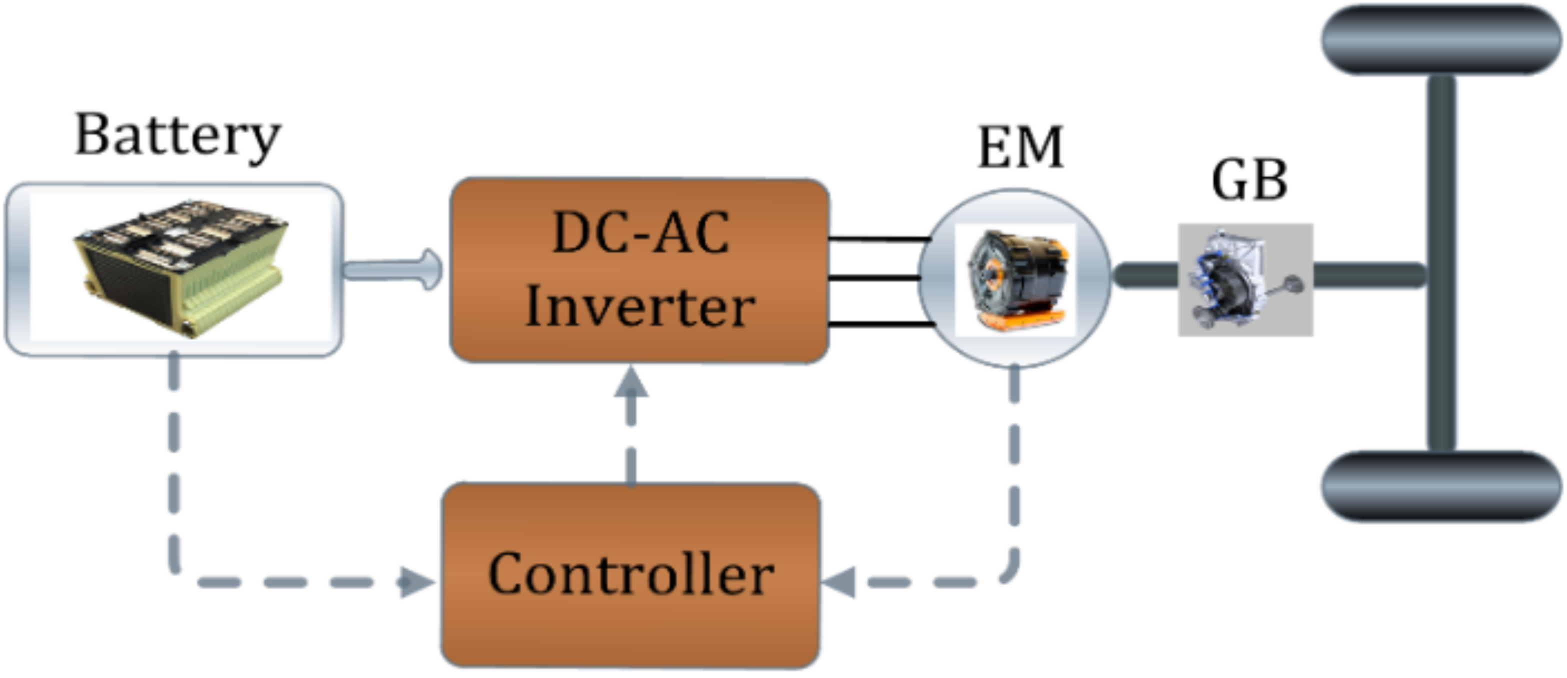
3) **Load Hold (Hang Time):** To hold a load aloft at zero speed without setting the brake. Permit precise positioning of the load without delays normally associated with mechanical operation of the brake.

4) **Fast Stop:** To Rapidly decelerate the drive when the run command is removed i.e. when back-up limit switch is tripped

Selection of drives and control schemes for lifts and cranes

1) **Speed Control:** To accommodate five-speed cabin/pendant control, infinitely variable speed control, and a bi-polar voltage or analog current input speed command
2) **Micro speed Positioning Control:** To Permit extremely slow movements for greater positioning accuracy
3) **Dual Upper and Lower Limit Switch Inputs:** To accommodate limit-switch inputs on both the upper and lower travel of the hoist displayed. Further movement in hoist direction is prevented.
4) **Torque Limits:** Two sets of Fwd and rev torque limits are provided.
5) **Torque Limited Acceleration / Deceleration Times:** For smooth starts and stops to prevent load sway

EV Control schemes



EV Control schemes