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

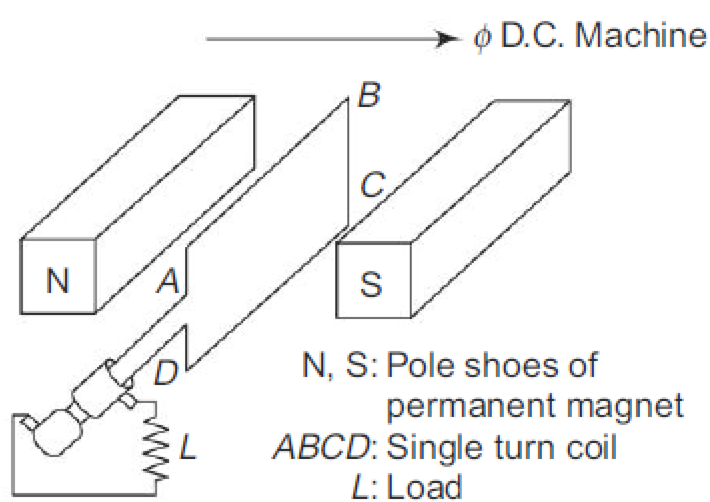
The generator is a dynamic machine in which mechanical energy is converted into electrical energy. It operates on the principle based on the Faraday's Law of electro-magnetic induction. The emf generated is to be classified as dynamically induced emf. The basic requirements for the dynamically induced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

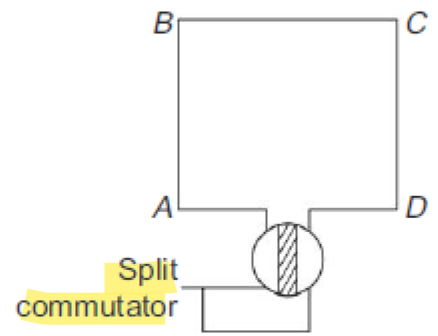
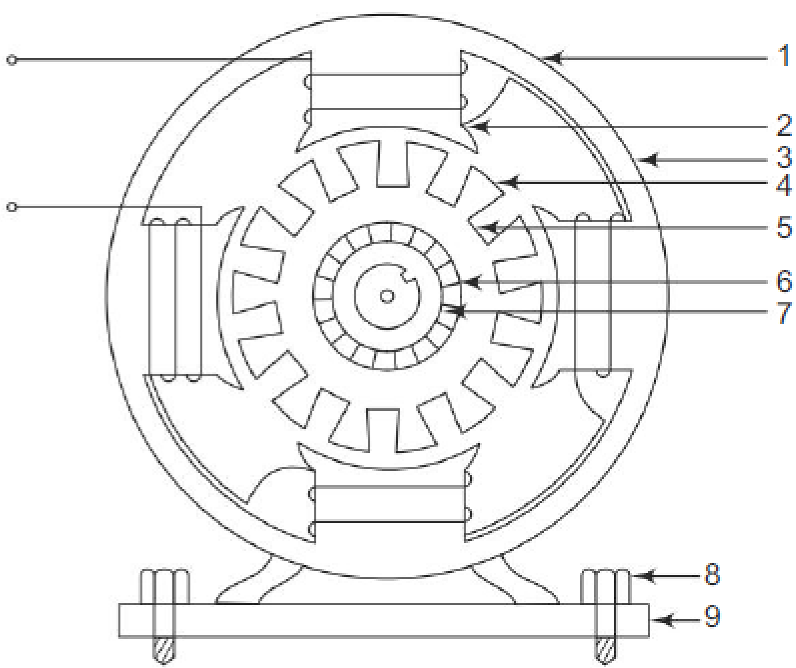


Fig. 6.2



1 Yoke or Frame
2 Main field pole
3 Field winding
4 Armature
5 Slot
6 Commutator
7 Shaft
8 Foundation bolt
9 Bed plate

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.

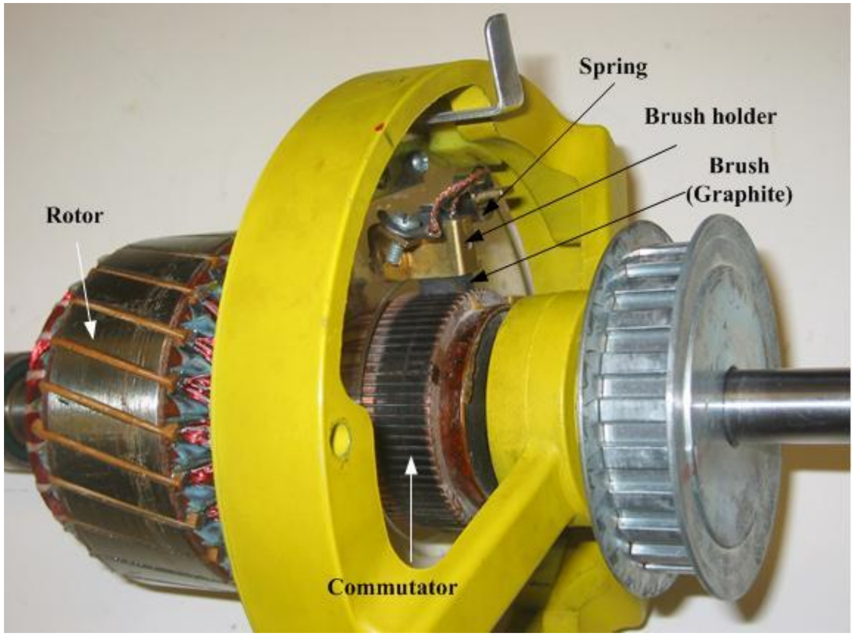
Field System This consists of main field poles and field winding. The field poles are made of laminations of a sutiable magnetic material. Such a magnetic material has very high relative permeability and very low hysteresis loss. The pole face is in the form of horse shoe so that a uniform flux distribution 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.

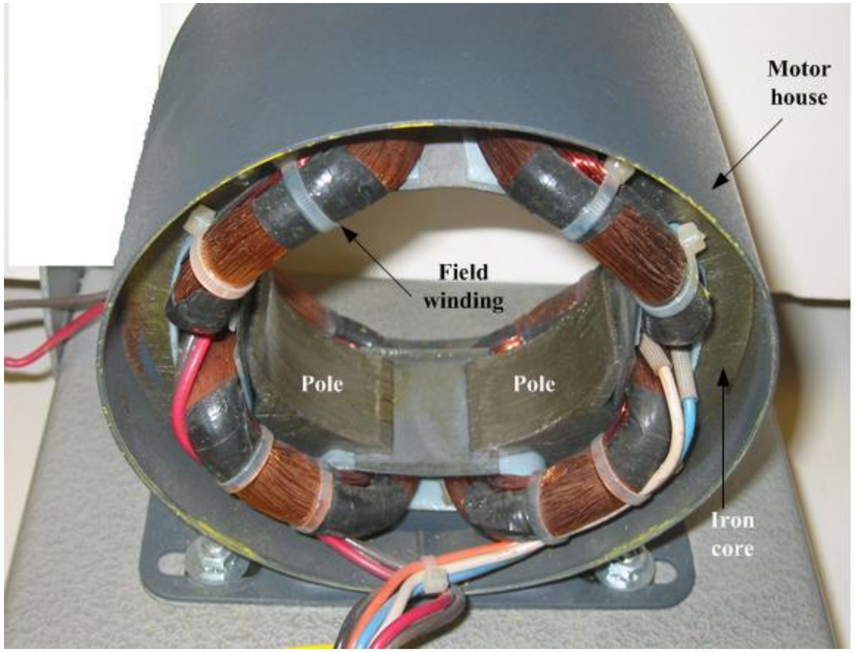
Armature The armature of a dc generator is in the form of laminated slotted drum. Slots are provided over the entire periphery of the armature

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.

Construction of DC machine



Cutaway view of a dc motor
(Rotor-Armature)



Stator with poles visible.

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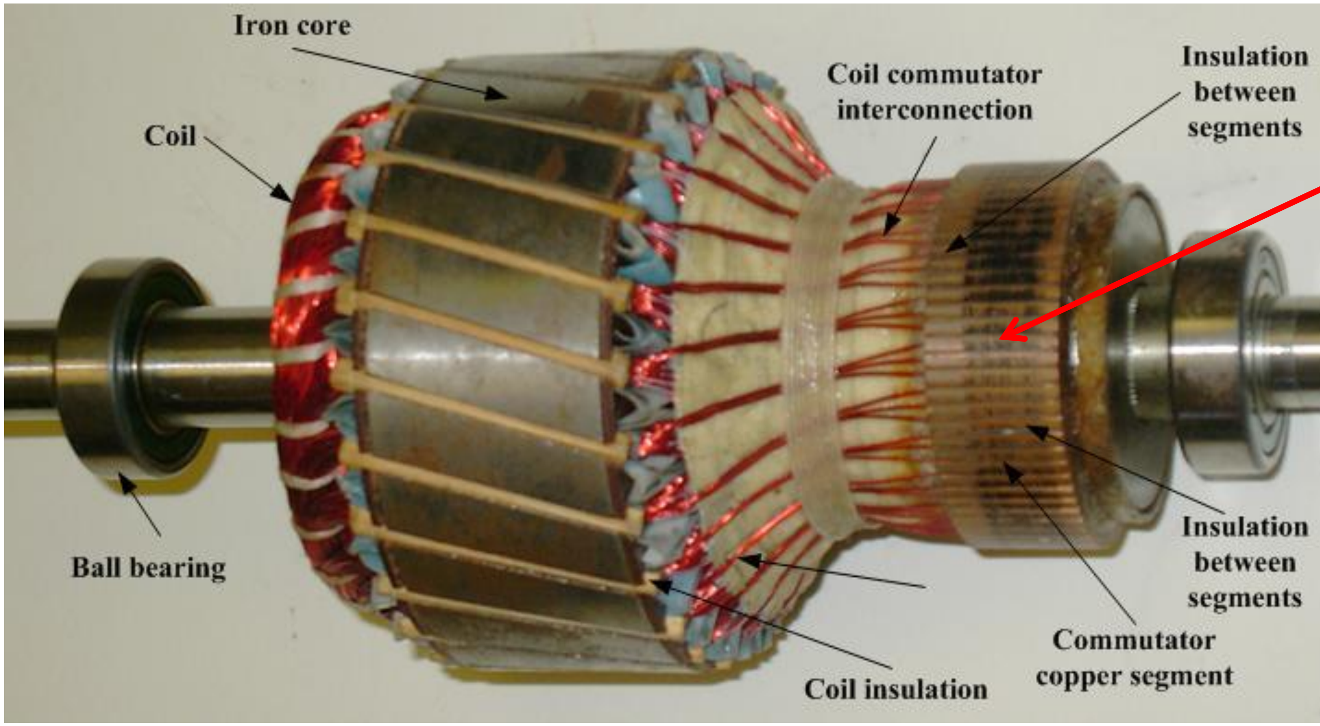
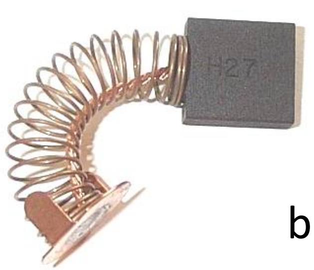
Construction of DC machine



segments

Rotor of a dc motor.



brushes

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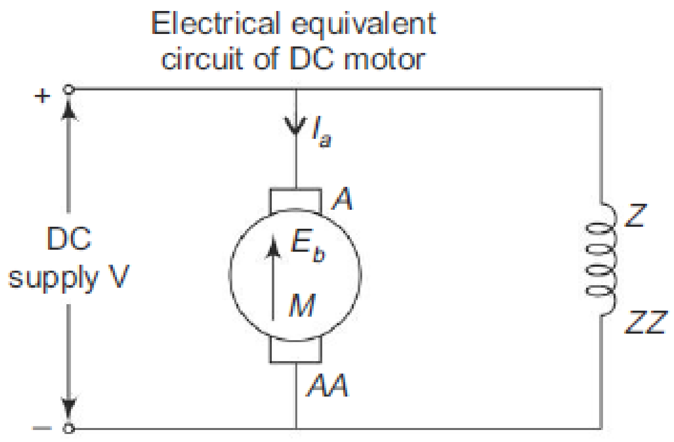
DC MOTOR

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.



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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

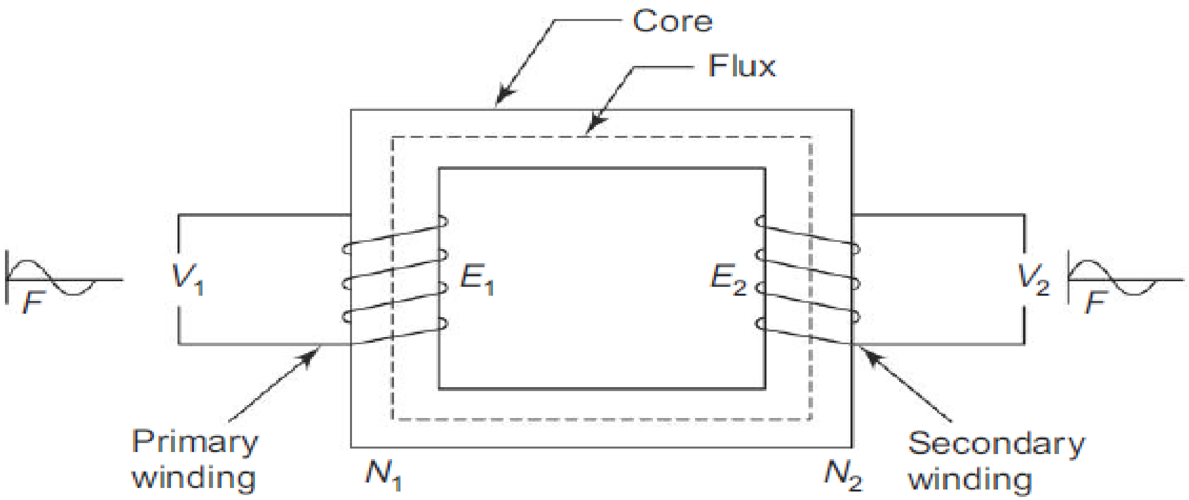
Thus, the characteristics equation of a dc motor is $V = E_b + I_a R_a$, where $I_a R_a$ represents the potential drop in the armature circuit.

Single Phase Transformer

<u>Principle of operation</u>

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:

$E_2 < E_1$ (i.e. $V_2 < V_1$) ... step down transformer

$E_2 > E_1$ (i.e. $V_2 > V_1$) ... 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.

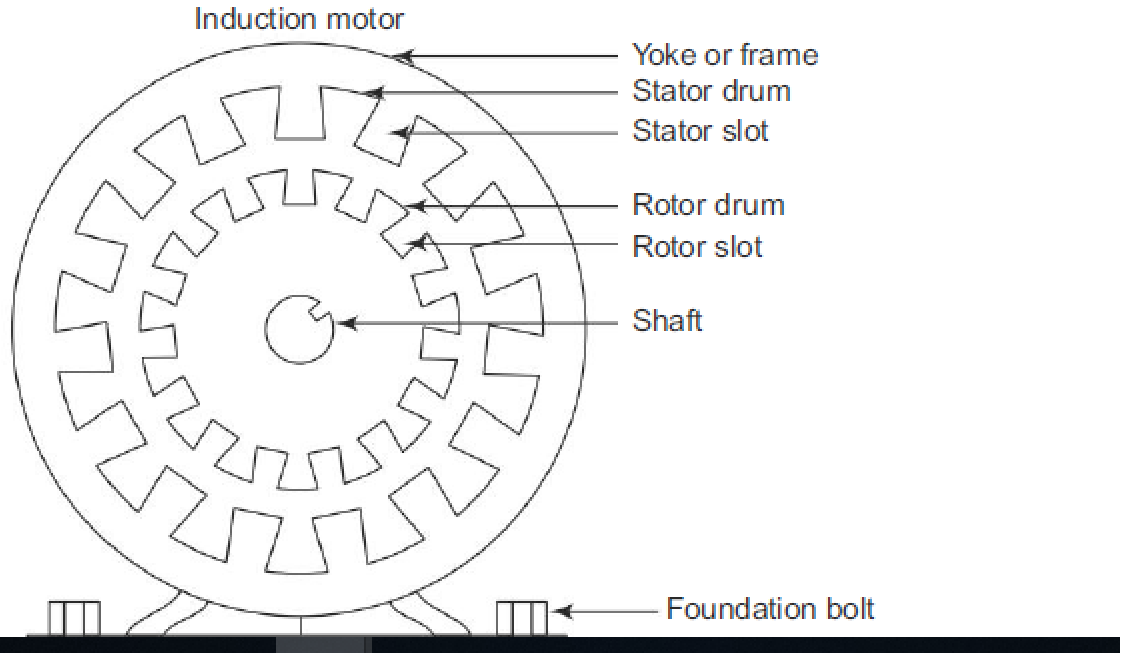
THREE PHASE INDUCTION MOTOR

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.

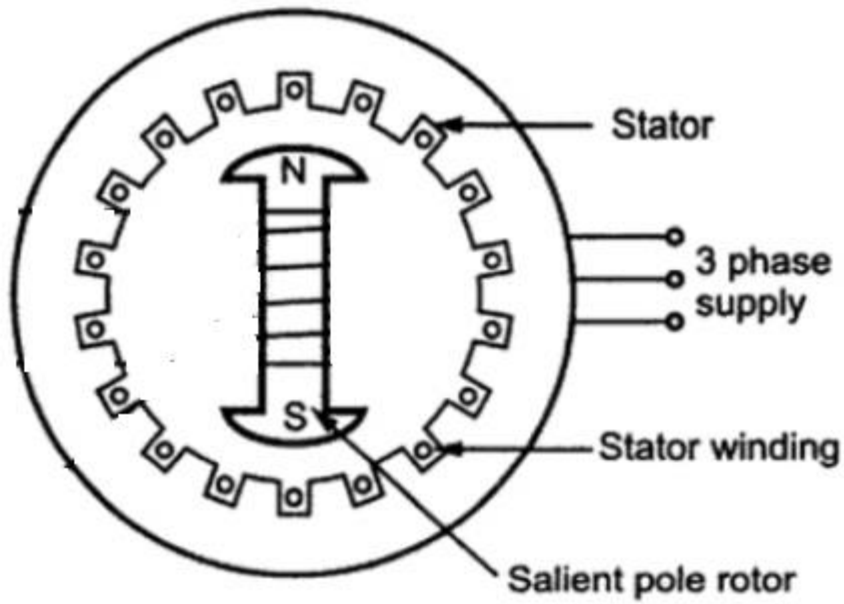
Construction

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.



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

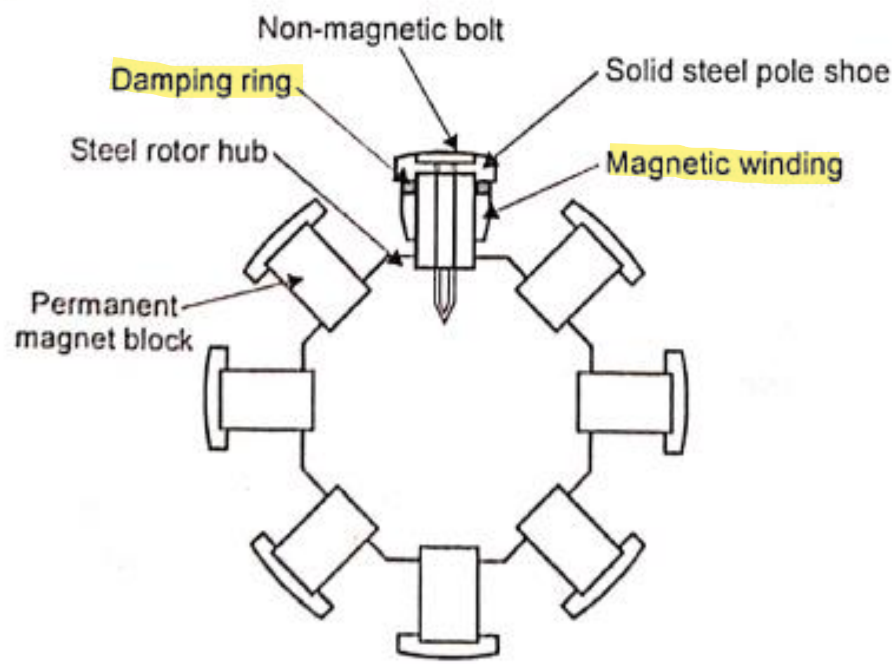


Figure 5.2`

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.

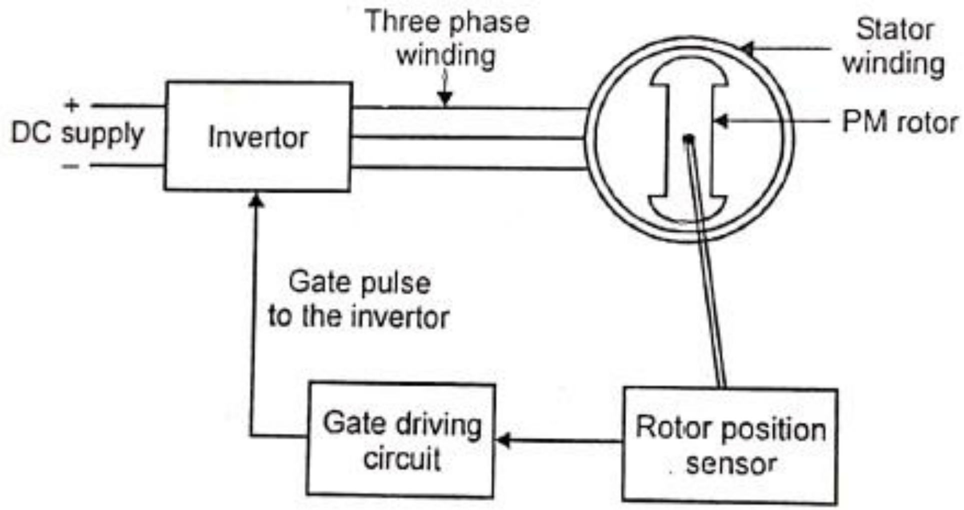
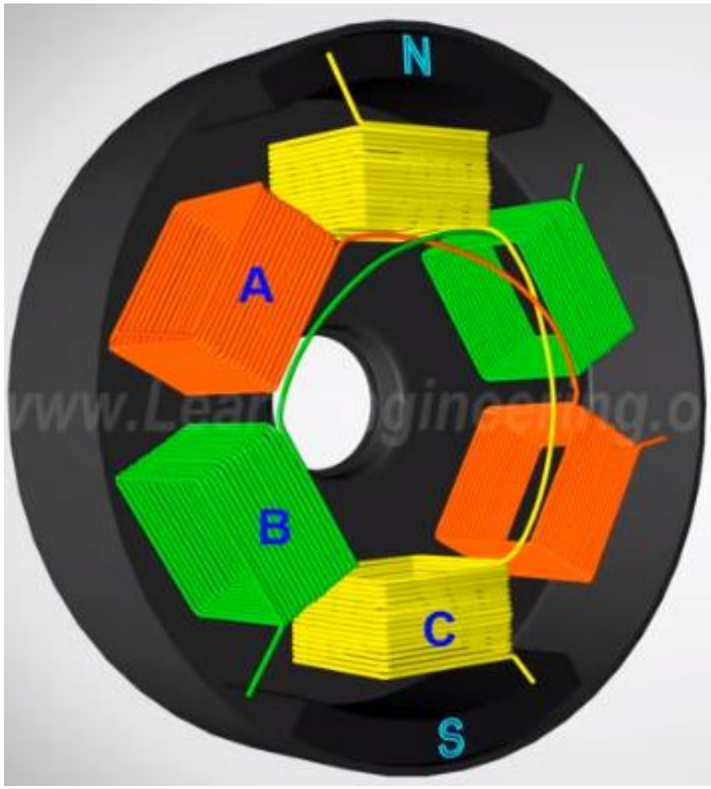
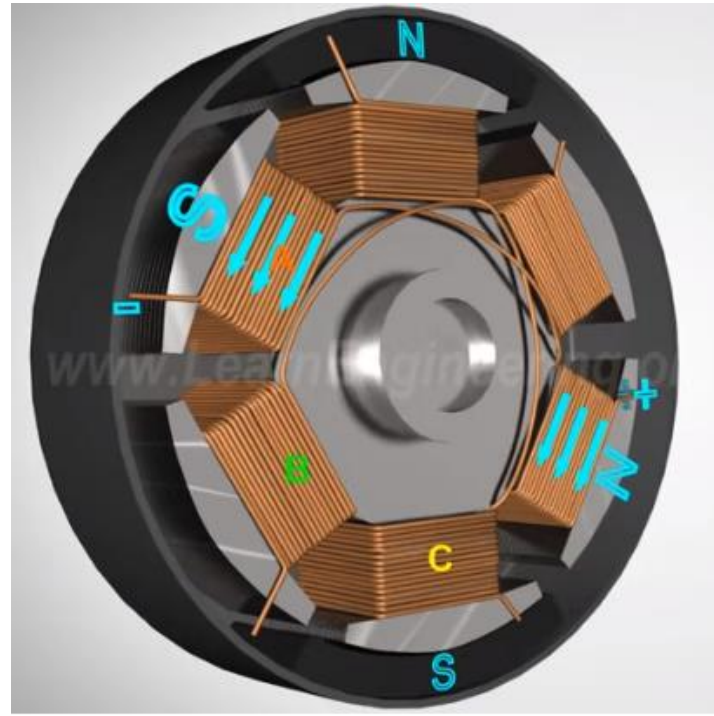


Figure 4.1(e)

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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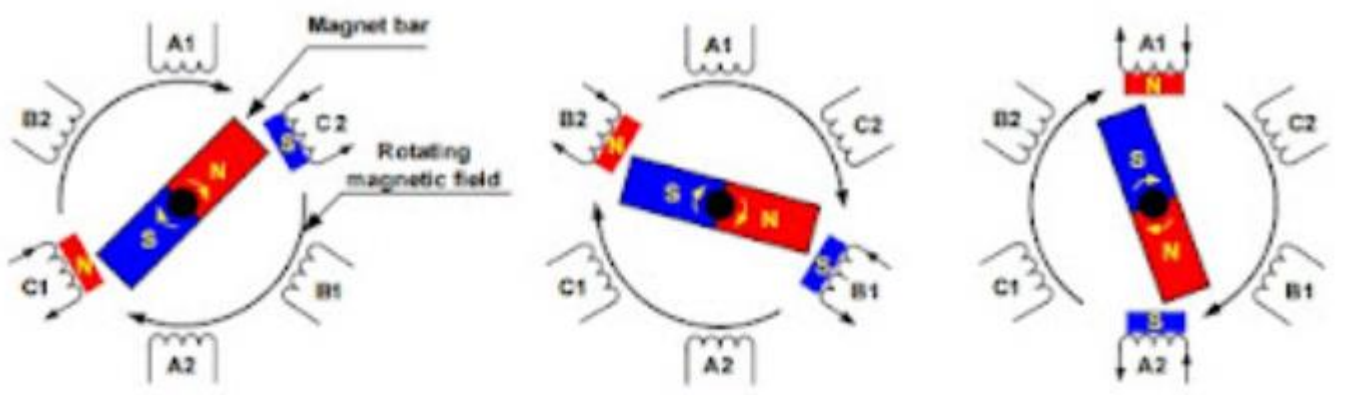
How Does A Brushless DC Motor Work?

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.

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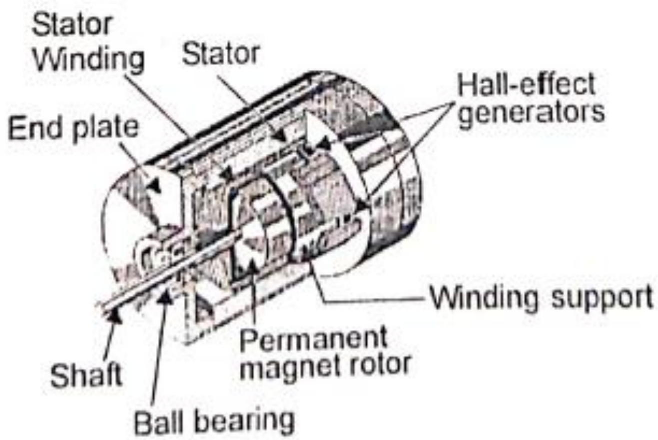


Figure 4.1(f)

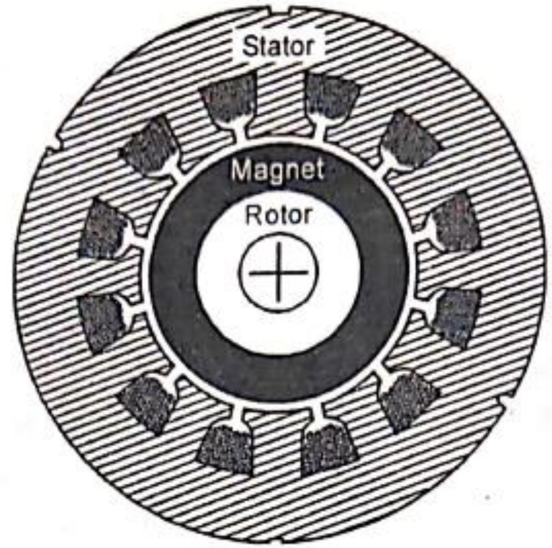


Figure 4.1 (g)

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.

Stepper Motor

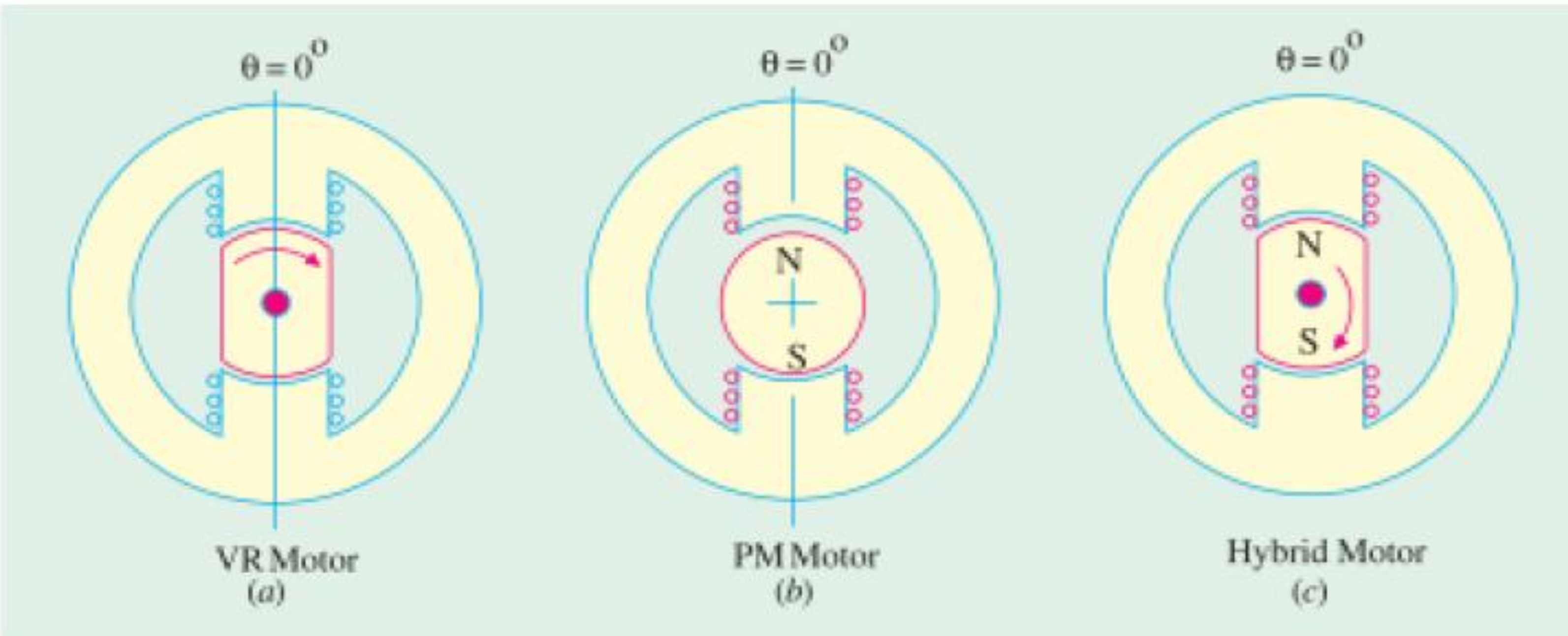
- A stepper motor is a "pulse-driven" motor that changes the angular position of the rotor in "steps"
- Stepper motor is a motor which rotates step by step and not continuous rotation. When the stator is excited using a DC supply the rotor poles align with the stator poles in opposition such that reluctance is less.
- Define
  - β = the step angle (per input pulse)
  - Resolution = the number of steps/revolution
  - θ = total angle traveled by the rotor
    - = β X No. of steps
  - n = the shaft speed = $(\beta \times f_p) / 360°$
    - f_p = No. of pulses/second
    - Step number (S) = $360° / \beta$

Why Stepper Motor?

- Motor that moves one step at a time
  - A digital version of an electric motor
  - Each step is defined by a Step Angle
- Relatively inexpensive
- Ideal for open loop positioning control – Can be implemented without feedback – Minimizes sensing devices – Just count the steps
- Torque – Holds its position firmly when not turning – Eliminates mechanical brakes – Produces better torque than DC motors at lower speeds
- Positioning applications

Types of Stepping Motors

- Permanent Magnet
  - Magnetic rotor
- **Variable Reluctance**
  - Non-magnetic, geared rotor
- Hybrid
  - Combines characteristics from PM and VR
  - Magnetic, geared rotor

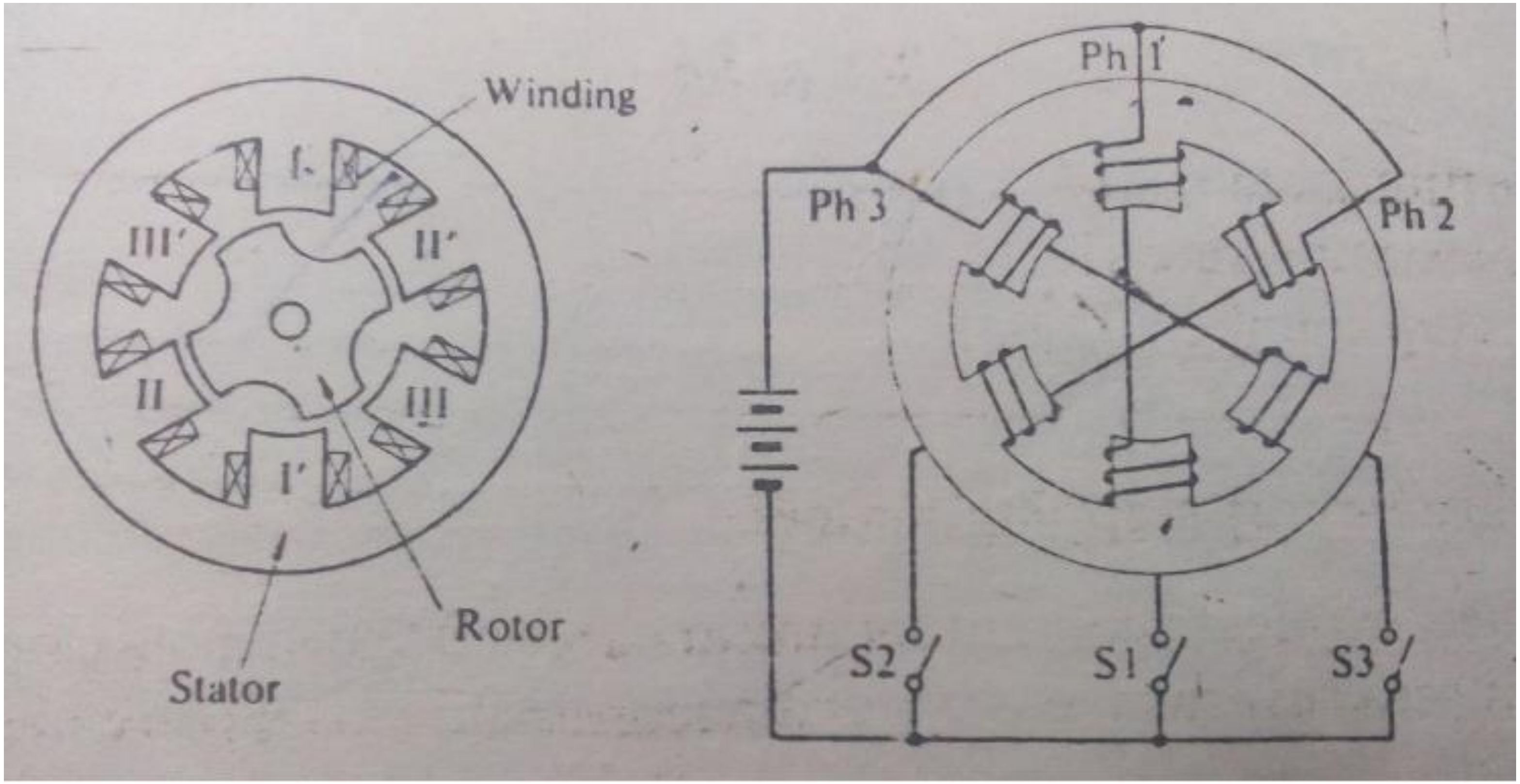


θ = 0°
VR Motor
(a)
θ = 0°
N
S
PM Motor
(b)
θ = 0°
N
S
Hybrid Motor
(c)

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



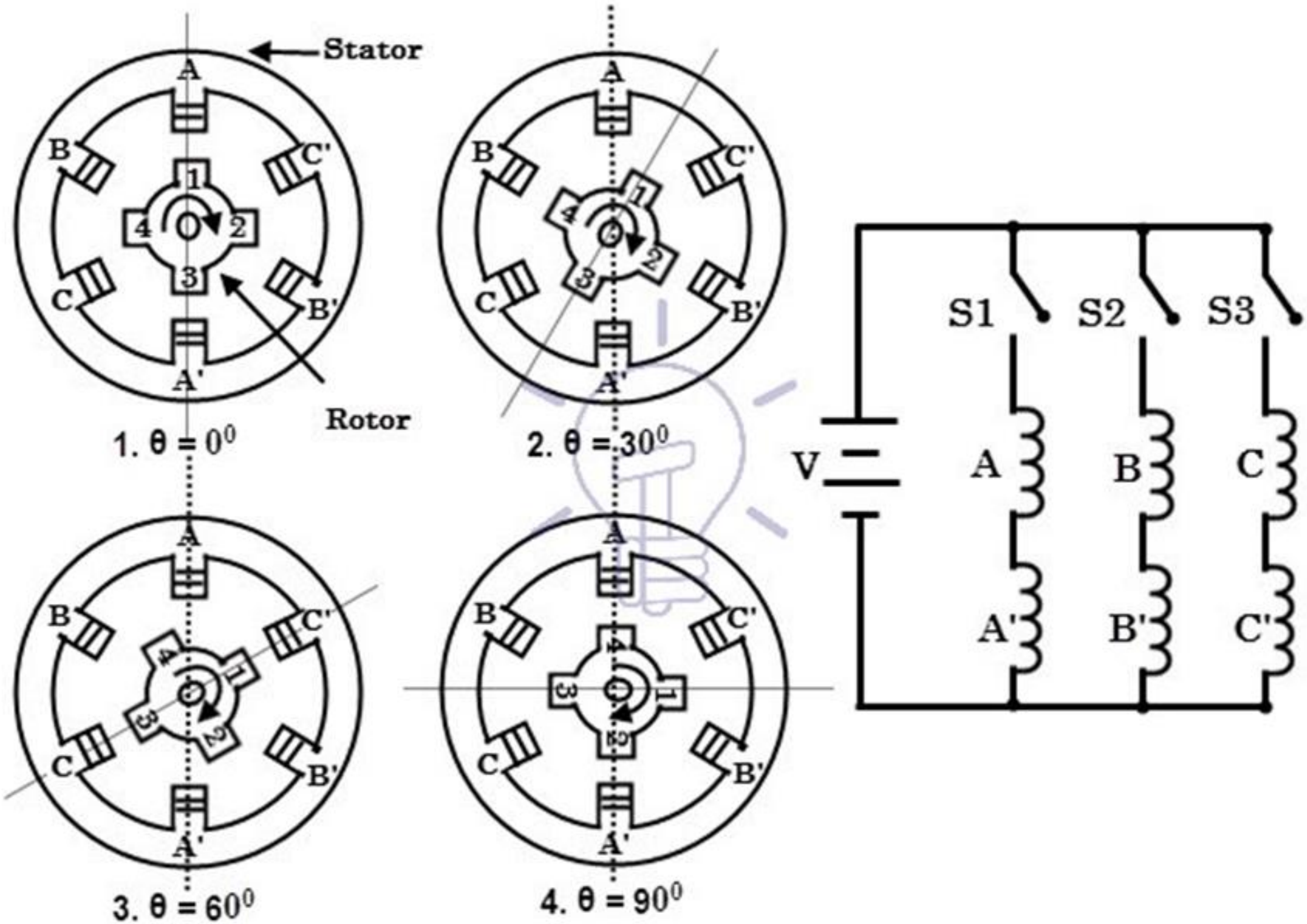
VR Stepper motor has following modes of operation

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.
- 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.


Stator
A
B
C'
1
4
2
3
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'

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.

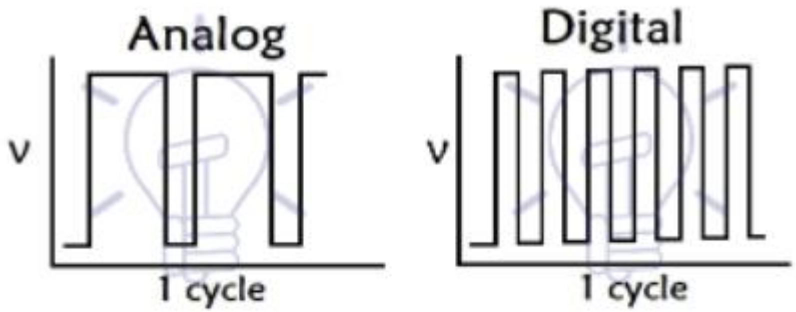
Continuous Rotation Servos: Continuous servos are similar in construction to the positional servo. But, it can move in both clockwise and anticlockwise directions. These types of servos are used in radar systems and robots.

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.

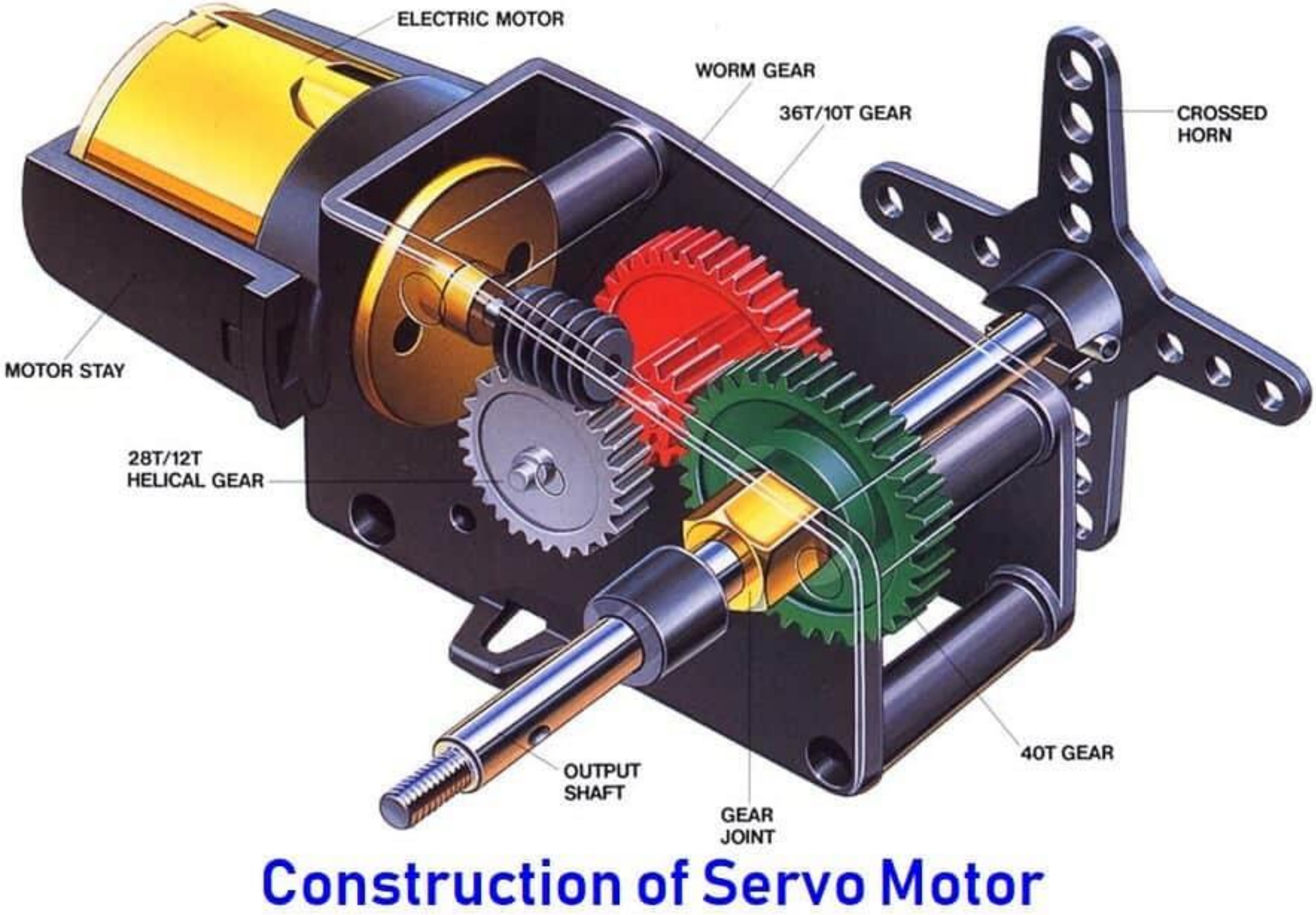


On the Basis of Operating Power

(i) DC Servo Motor

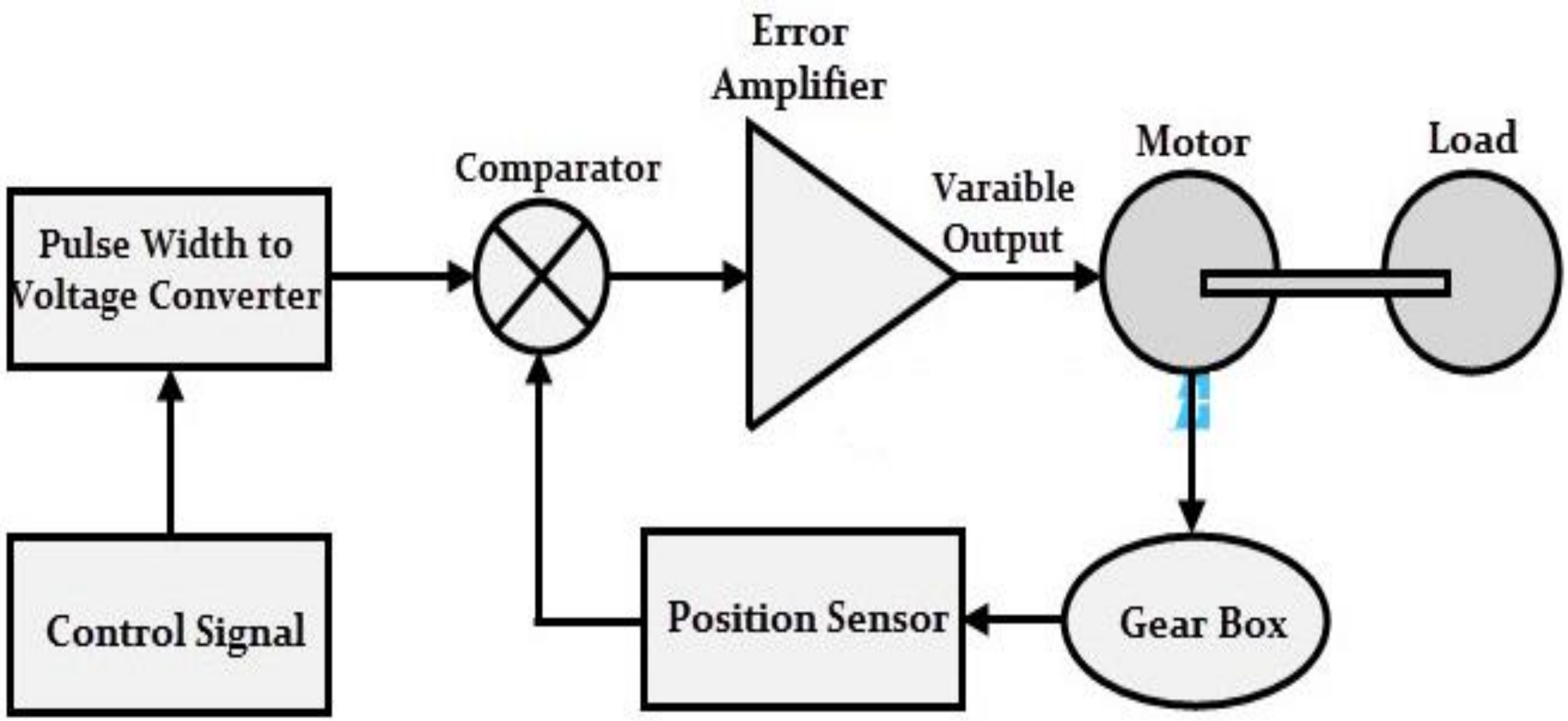
(ii) AC Servo Motor

Construction of Servo Motor:



No need to draw this diagrams in exam

Closed loop system - Servo Motor:



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.

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.

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.

Introduction to Electrical Drives

1.1.2 Basic Elements of Electrical Drive System

An Electric drive system consists of an Electric Motor, which is used to drive (rotate) the Mechanical load. Here the Electric motor acts as a Prime mover and it is known as Electric Drive motor. The Electric drive motor can be a DC motor or an AC motor. The drive system with Electric motor as Prime mover is known as Electric Drive System. If DC motor is used as a drive motor then the drive system is known as DC drives. If AC motor is used as a drive motor then drive system is known as AC drives.

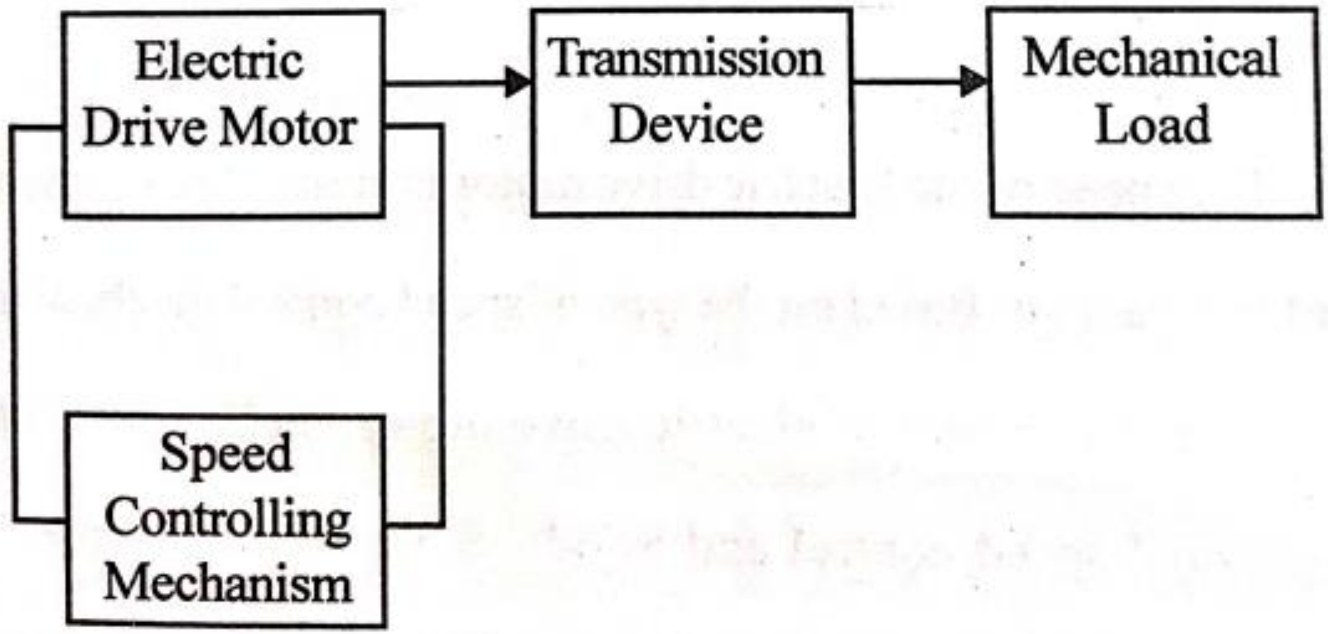


Fig : 2 General Block Diagram Of The Electric Drive System

The mechanical equipment (load) that is set into motion is also known as driven load. The devices that are used to interconnect Electric motor and Mechanical load is collectively known as Energy Transmission Devices. The mechanical load can be permanently or temporarily connected with the Electric Drive Motor. For permanent connection Shaft with fixed coupling is used. For temporary connection Gears and Multistepped Pulleys and Belt arrangement are used.

Transmission equipment is used to transmit the rotary motion of the Electric drive motor to the Mechanical load. In some cases the transmission device is also used to convert the rotary motion of the drive motor into linear motion of mechanical load. If gears are used as transmission device then speed of the mechanical load can also be varied.

The speed of the Electric drive motor is controlled by speed control mechanism. Based on the type of speed control mechanism used, the speed control of electric drive motor is classified into Conventional speed control and Solid - State speed control. In Conventional speed control, manually controlled electrical equipments such as Rheostat (variable resistor) is used to control the speed of the Electric drive motor. In Solid State speed control, Electronics or Semiconductor devices (Solid State devices) are used to control the speed of the Electric drive motor.

The main advantages of Electric drive over the other drives are as follows:

1. The electric drive provides almost noiseless operation.
2. The troubles involved in staring procedure of other drives are eliminated in case of electric drive.
3. The electric drive never pollutes the working environment i.e. no smoke and no leak.
4. The wear and tear associated with the other drives is completely eliminated. So the life of electrical drive is more.

5. The braking of electric drive is done electro-dynamically i.e. brake drum and belt is not needed which is noisy. So less maintenance is needed. Here the drive motor act as a braking device.

6. The working characteristics of electric drive are smooth and can be easily modified.

7. The speed of the electric drive is controlled over wide range is possible i.e., from almost zero speed to speed above the rated speed. The electric drive is efficient during speed control.

8. The electric drive provides neat and flexible layout. It is compact

9. The electric drive can make use of wonderful advancements in the semiconductor industry and hence its speed control is accurate. Here the speed control circuitry is made of semiconductor (solid state) devices

10. The electric drive is easily automated i.e., it can be controlled by microprocessor or by computer. So its efficiency and accuracy is further increased.

Applications of Electric Drives

Transportation Systems

Rolling Mills

Paper Mills

Textile Mills

Machine Tools

Fans and Pumps

Robots

Washing Machines etc

Factors Influencing Choice Of Electrical Drives

There are certain factors that governs or influences, the selection or choice of electrical drives. They are:

1) Availability of Electrical Supply

The electric drive is a drive system with electrical motor as a Prime mover.The selection of electrical drive is based on the availability of electrical supply. There are three-types electrical supplies, namely AC supply, DC supply, and Rectified DC supply. If AC supply is available, then AC drive is selected. An AC drive consists of AC motor as a drive motor. If DC supply is available, then DC drive is selected. DC drive consist of DC motor as a drive motor. Hence the nature of electrical supply available governs selection of electric drive.

2) Nature of Operating Characteristics of Electric drive motors

The electric drive motor has different types of operating characteristics such as

1) Starting characteristics.
2) Running characteristics.
3) Speed control characteristics.
4) Braking characteristics.

For example the running characteristic of electric drive motor shows how the motor behaves when it is loaded. In some cases, if the load is increased, the speed of the motor is drastically reduced. So such motors are not selected for constant speed applications.

3) Economic Consideration

The electrical motor is selected based on two economic considerations, namely

1. Initial cost :

The initial cost is nothing but capital cost. This is the cost occured during purchase and erection.

2. Running cost:

This is the cost of running the electric drive. E.g. maintenance cost, fuel cost etc.

4) Type of the Drive System

The type of the drive system available also governs the choice of electric motor. There are three types of drive system namely Group drive, Individual drive and Multi motor drive. Assume that at any particular location, different small loads are available. Since the loads are separate unit, it can be driven by single large motor (group drive). So here a DC motor or an AC motor is selected with huge HP rating.

5) Types of Load

The type of load available, also governs the selection of electric drive. Generally the loads are classified based on the Torque characteristics. Torque is the twisting force required to drive (rotate) the load. Based on the Torque characteristics loads are classified as follows:

1. Load requiring constant Torque with speed.
2. Load requiring increasing Torque with speed
3. Load requiring high starting Torque (high inertia load)

Assume that load with high inertia is available. This high inertia loads cannot be accelerated or deaccelerated quickly. They require high starting Torque . Therefore motor with high starting Torque such as DC series motor or 3ϕ (Three Phase) Slip ring induction motor is selected. Thus type of load influence the choice of electric motor.

6) Mechanical Considerations

i) Type of enclosure

ii) Type of bearings

iii) Type of Transmission devices

7) Environmental Considerations

i) Noise pollution

ii) Environmental Pollution

8) Load-Withstanding Capability of motors

The size and rating required for the drive motor influence the selection of the electric drive motor. The size of the motor describes load-withstanding capability. When the motor is loaded, the line current drawn by the motor increases. As a result losses increases and more heat is developed. If the heat is not dissipated then insulation in the motor fails leading to complete breakdown of the motor. Here duty cycle of the load and the Torque requirement are important factors in deciding size and rating of the motor.

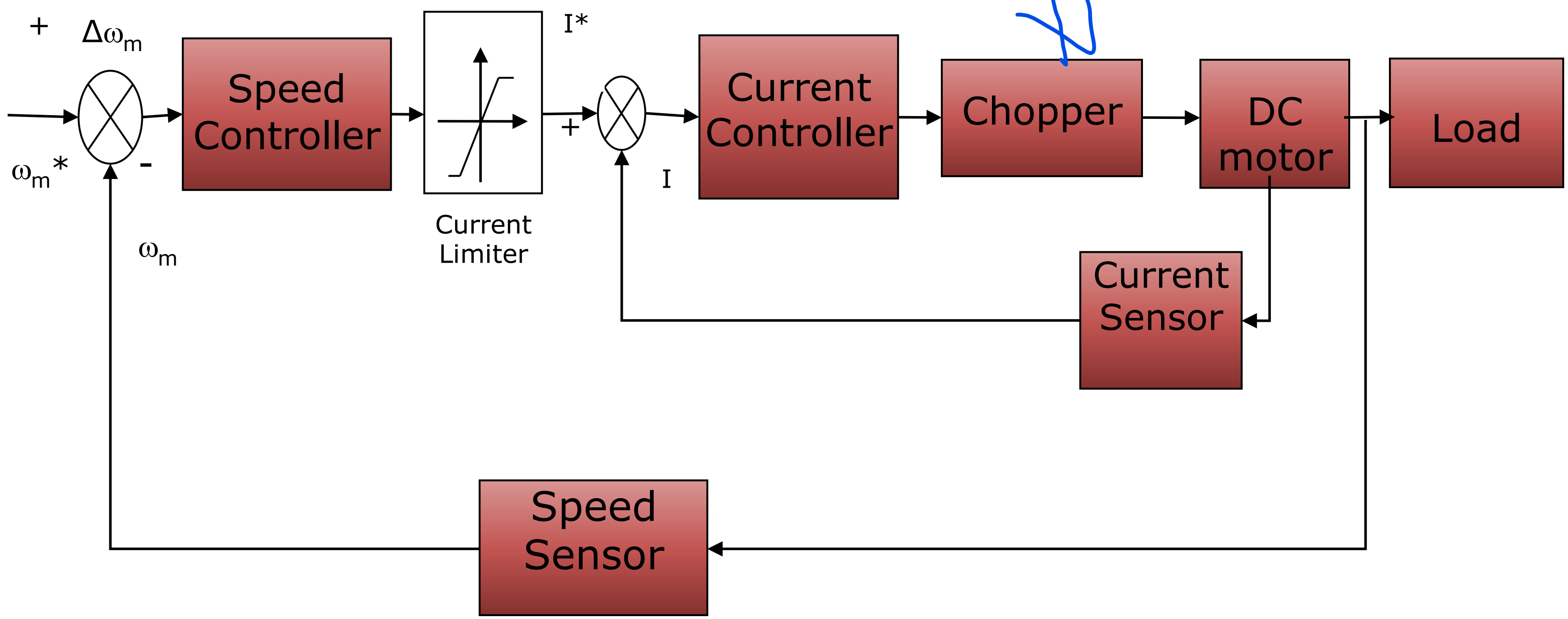
Chopper fed DC drives

- A dc chopper is connected between a fixed-voltage dc source and dc motor to vary the armature voltage.
- A chopper is a high speed on/off semiconductor switch which connects source to load and disconnects the load from source at a fast speed.
- Choppers are used to get variable dc voltage from a dc source of fixed voltage.
- Chopper circuits are used to control both separately excited and Series circuits.

- Ripple content in the output is small.
- Peak/average and rms/average current ratios are small.
- The chopper is supplied from a constant dc voltage using batteries.
- Current drawn by the chopper is smaller than in phase controlled converters.
- Chopper circuit is simple and can be modified to provide regeneration and the control is also simple.

Closed loop speed control of chopper fed DC drives

DC Supply

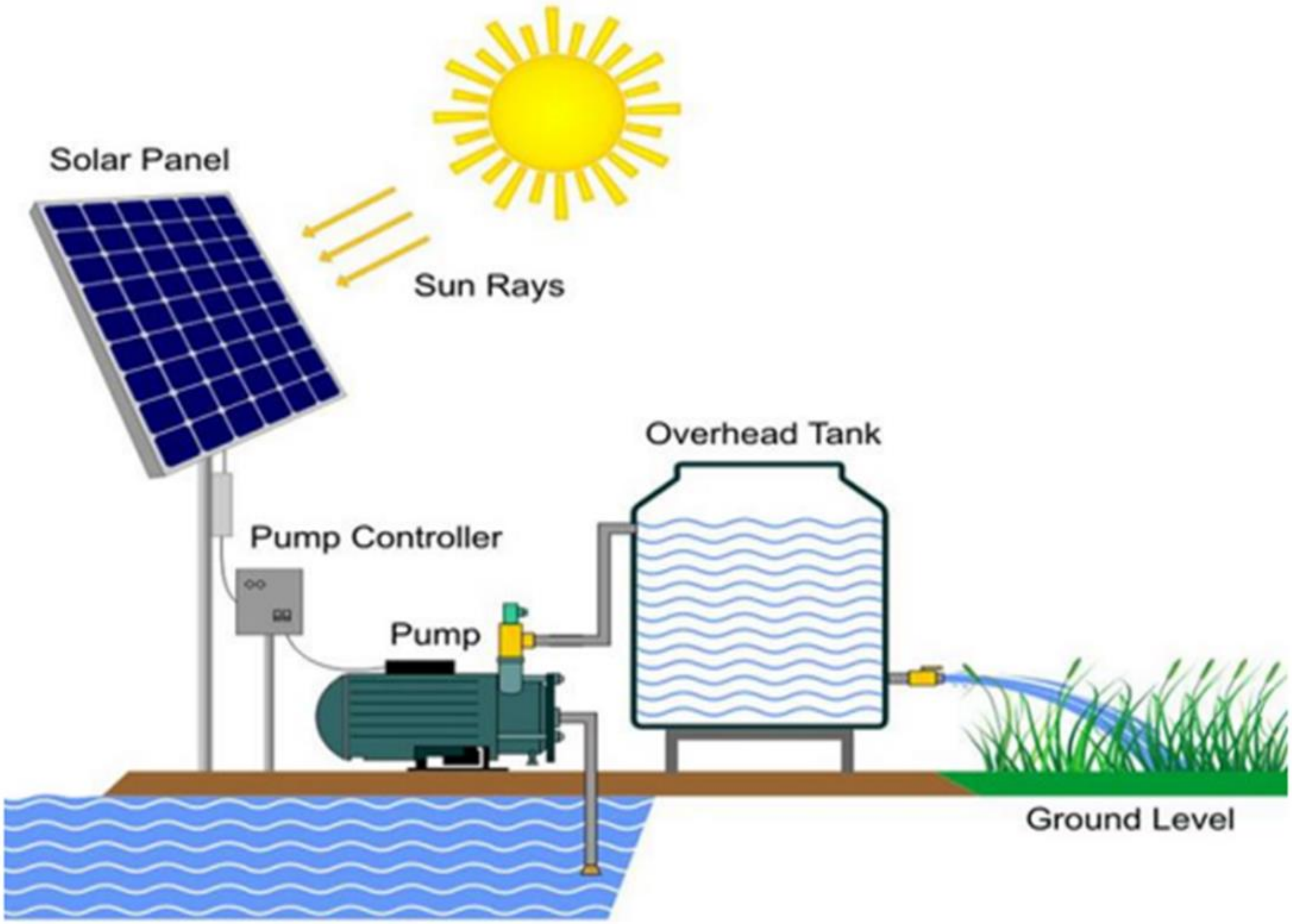


- Speed control loops are perhaps the most widely used feedback loops for drives.
- From the diagram that there are two control loops, which can be said as an inner loop and outer loop.
- The inner current control loop limits the converter and motor current or motor torque below the safe limit.
- Suppose the reference speed W_m^* increases and there is a positive error ΔW_m, which indicates that the speed is needed to be increased.
- Now the inner loop increases the current keeping it under maximum allowable current.
- And then the driver accelerates, when the speed reaches the desired speed then the motor torque is equal to the load torque and there is a decrease in the reference speed W_m^* which indicates that there is no need of any more acceleration but there must be deceleration, and braking is done by the speed controller at maximum allowable current.
- So, that during speed controlling the function transfers from motoring to braking and from braking to motoring continuously for the smooth operation and running of the motor.

Selection of drives for real time applications (cranes/EV/ Pumping applications)

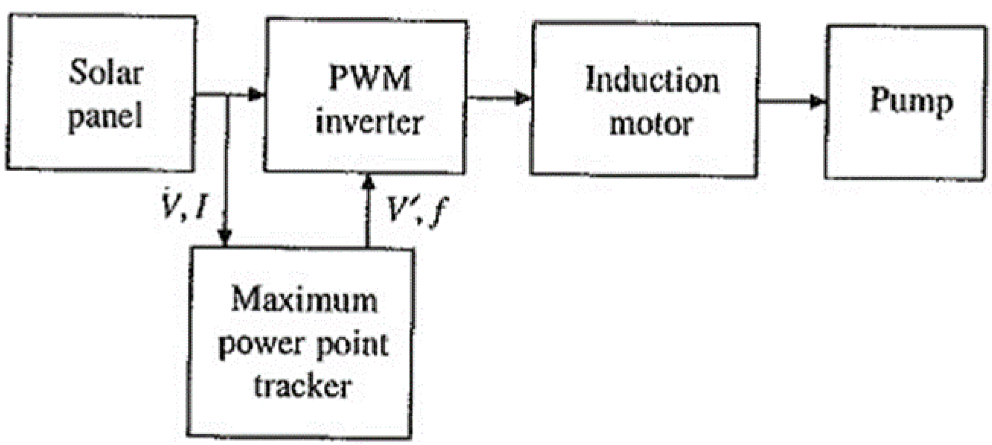
	DC Drives	AC Drives (particularly Induction Motor)
Motor	• requires maintenance • heavy, expensive • limited speed (due to mechanical construction)	• less maintenance • light, cheaper • high speeds achievable (squirrel-cage IM) • robust
Control Unit	Simple & cheap control even for high performance drives • decoupled torque and flux control • Possible implementation using single analog circuit	Depends on required drive performance • complexity & costs increase with performance • DSPs or fast processors required in high performance drives
Performance	Fast torque and flux control	Scalar control – satisfactory in some applications Vector control – similar to DC drives

Solar Powered Pump System



Solar Powered Pump Drives with reciprocating pump

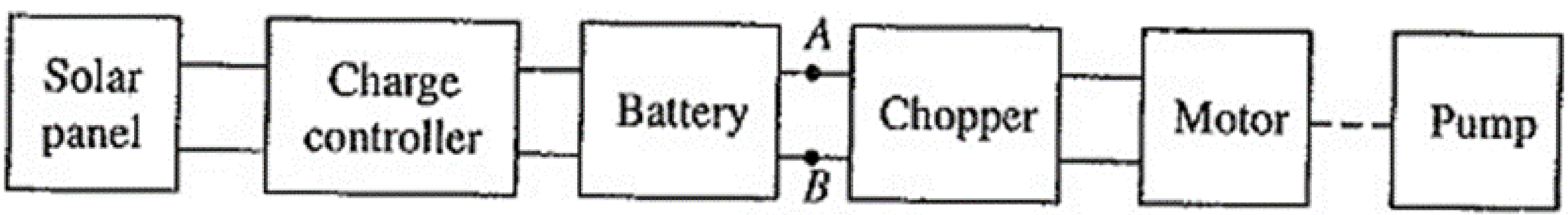
- For pump ratings of 1 kW and above, three phase induction motor drive is employed.
- A PWM voltage source inverter with maximum-power-point-tracker is used for variable frequency control of the squirrel-cage induction motor.



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

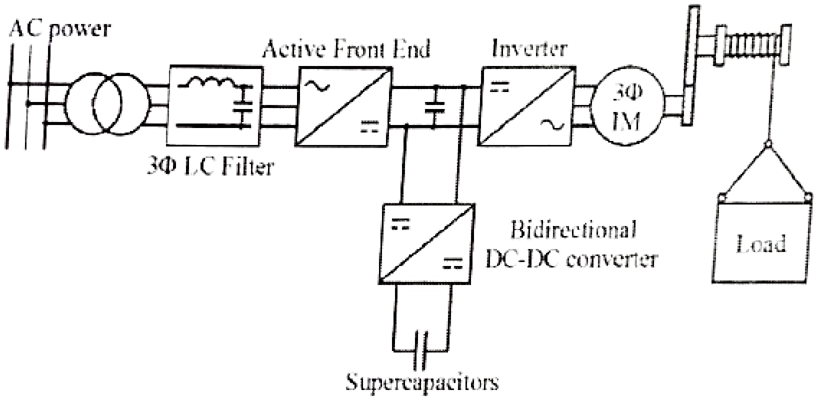


Fig. 3.14 Crane

1. The motion of the crane hook is in all three dimensions.
2. In crane drives, the acceleration and retardation must be uniform. This is more important than the speed control.
3. For exact positioning of the load creep speeds must be possible.
4. When the motion is in the horizontal direction braking is not a problem. This is a problem if the load overhauls the motor in vertical motion. In the case of vertical motion the movement of the empty cage has to be carefully The speed must be constant while lowering the loads. The steady braking of the motor against cnierhauling must be possible.
5. The drive must have high speeds in both the directions. The motor must have high speeds at light loads.
6. Mechanical braking must be available under emergency conditions.
7. The crane motors can be either dc or ac motors.
8. Even though the electrical characteristics make dc motors suitable as crane motors, the lower inertia and simple and economical construction of cage motors favour them as crane motors.
9. With the advent of thyristors and associated power converters it is possible to have torque control during starting, running and braking.

EV Control schemes

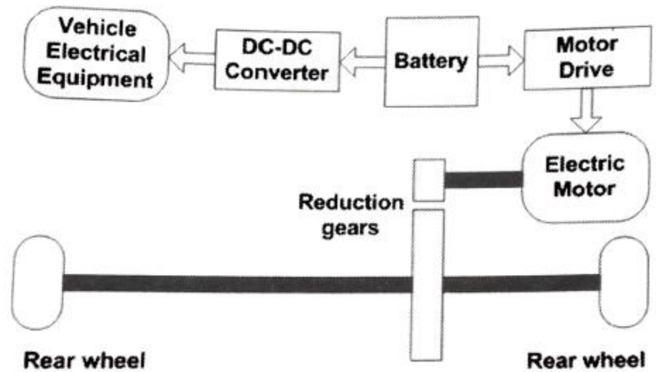


Fig. 3.15 Typical System Systematic of EVs

Selection of the electric motor to fit a particular vehicle is important.

1. The properties of the vehicle such as size, weight, overload and aerodynamics will ultimately determine speed, torque and power requirements of the electricmotor.
2. Driving cycle is to determine the vehicle configuration (series hybrid, parallel hybrid, all electric) and battery pack size and ultimately impact the choice of the powertrain.
3. The targeted maximum speed, gearbox ratios available and rolling radius of the wheel are usedin the calculations to determine the maximum speed the electric motor has to reach in your application.
4. The maximum torque enables the vehicle to start in a given slope. it is possible to calculate the highest torque required by the electric motor considering the differential and gearbox. Maximal weight is also to be taken into consideration.
5. The maximum power enables the vehicle to reach and maintain a constant speed under stringentslope and speed conditions. Select the electric motor to be able to do the worst hill climb conditions with no time constraints.
6. The battery capacity is typically calculated using a simulator to go through a reference cycle typical of the usage of the vehicle. The simulator can output the consumption of the vehicle in kWh/km.
7. The battery voltage is dependent on the size of the vehicle. As the battery voltage increases, thecurrent output is lowered. There are normally two ranges of voltages: 300-450V dc and 500-750Vdc.
8. Cost