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ABSTRACT

Without actuation, robots are just immobile piles of metal, or plastic. Motors breathe in life into the mechanisms: some drive them around, others rotate their joints or enable end effectors, e.g., to lift objects. Therefore, choosing the right robot motor is of primary importance to their success, whether as functional machines or commercial products.

Robotic applications require precise movements. This report presents an efficient, accurate and versatile motor for use in robotic applications. A stepper motor is suitable for robotic applications because its movement comprises of discrete steps. The software and the hardware circuits of the stepper motor drive is designed and tested for different types of movements of the stepper motor. The drive system allows the movement of the stepper motor to be controlled by selecting options of half or full step, forward or reverse movement and the speed in RPM or the fixed number of steps that it should move.

CHAPTER 1

INTRODUCTION

In this era of industrial automation, robots are used for handling various processes for precise and better quality of production. Choosing ideal motor for perfect robot is always a tough task while designing the robot especially for industries. Proper selection of electrical motors in industrial robots requires several parameters to take account for arm control, position, angular and linear movements.

Electric motor is the electro-mechanical machine which converts the electrical energy into mechanical energy. An electric motor plays a vital role in every sector of the industry, and also in a wide range of applications. There are a variety of types of electric motors are available in the market. The selection of these motors can be done based on the operation and voltage and applications. Every motor has two essential parts namely the field winding and the armature winding. The main function of field winding is to produce the fixed magnetic field, whereas the armature winding looks like a conductor which is arranged within the magnetic field, because of the magnetic field, the armature winding uses energy to generate an adequate torque to make the motor shaft turn..

For a robot, motors of the synchronous and asynchronous variety are a rare choice because of their impressive dimensions. A stepper motor is suitable for robotic applications because its movement comprises of discrete steps. It moves by a discrete angle called the step angle in each step. Stepper motors are the best motors for Robotics applications because of their high reliability, efficient drive system, low cost, high torque at low speeds and a simple construction that operates in almost every environment.

CHAPTER 2

DIFFERENT TYPES OF MOTOR

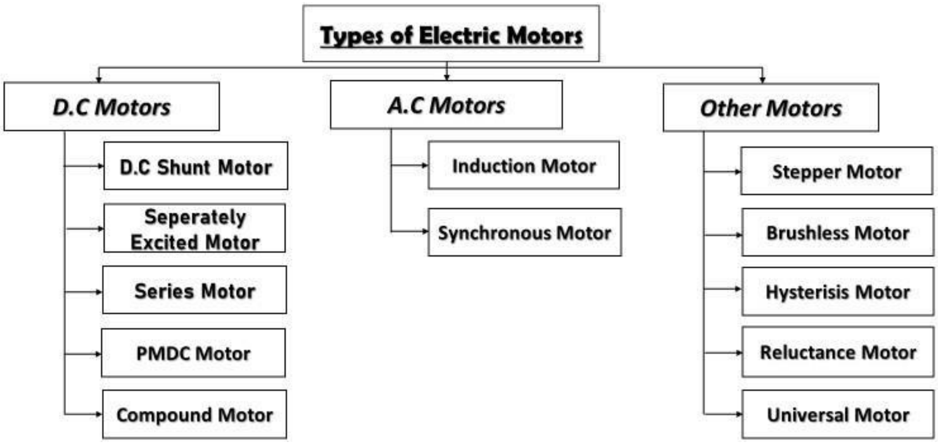


Figure 2.1: Different Types of Motors

2.1 : DC MOTOR

A DC Motor is defined as a class of electrical motors that converts Direct current electrical energy into Mechanical energy.

- **Types Of DC Motor :**
  1. DC Shunt Motor.
  2. Separately Excited Motor.
  3. Series Motor.
  4. PMDC Motor.
  5. Compound Motor.

2.1.1 DC Shunt Motor:

DC shunt motor works on direct current and the windings of this electric motor like the armature windings and field windings are linked in parallel which is known as a shunt. This kind of motor is also called as shunt wound DC motor, where the winding type is known as a shunt winding.

Figure. 2.2: DC Shunt motor

In electrical motors, series circuits and parallel circuits are commonly known as series and shunt. Therefore, in DC motors the connections of the field windings, as well as the armature winding, can be done parallel which is known as DC shunt motor. The main difference between DC series motor as well as DC shunt motor mainly includes the construction, operation, and speed characteristics. This motor gives features like easy reversing control, speed regulation, and starting torque is low. Thus, this motor can be used for belt-driven applications within automotive as well as industrial applications,

- **Construction and Working Principle:**
  - The DC shunt motor construction is the same as any type of DC motor. This motor can be constructed with basic parts like field windings (stator), a commutator, and an armature (rotor).
  - The working principle of a DC Shunt Motor is, whenever a DC motor is turned ON, then direct current flows throughout the stator as well as the rotor. This current flow will generate two fields namely the pole as well as the armature.
  - In the air gap between armature and field shoes, there are two magnetic fields, and they will respond with each other for revolving the armature.
  - The commutator overturns the armature current flow direction at ordinary gaps. So the armature field is repelled with pole field for all time, it keeps revolving the armature within an equal direction

- **DC Shunt Motor Circuit Diagram :**

The DC shunt motor circuit diagram is shown in Figure 2.3, and the flow of current and voltage being supplied to the motor from the supply can be given by I_{total} and E. In case of the shunt wound DC motor, this current supply will divide into two ways like I_a and I_{sh}, where I_a will supply throughout the Ra. In the same way, I_{sh} will supply through the R_{sh}.

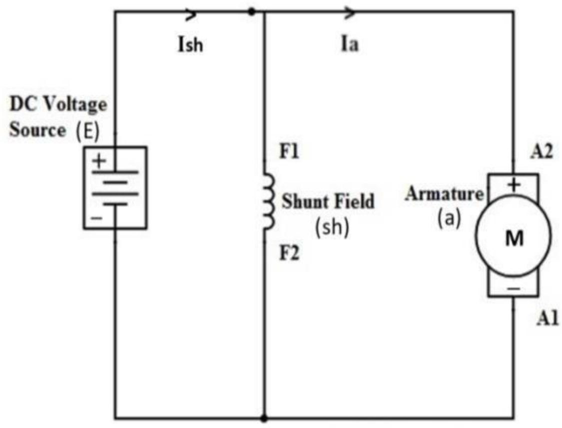


Figure. 2.3: DC Shunt Motor Circuit Diagram

- E – DC Voltage Supplied.
- Ish – Current in Shunt Field.
- Rsh – Resistance in Shunt Field.
- Ia – Current in Armature.
- Ra – Resistance in Armature.
- Itotal – Total current in circuit.

Formulas related to DC Shunt Motor :

- $Itotal = Ia + Ish$.
- $Ish = E \,/\, Rsh$.
- $Ia = Itotal – Ish = E \,/\, Ra$.
- Generally, when the DC motor is in a running state and the voltage supply voltage is stable and the shunt field current given by $Ish = E/Rsh$
- But we know that the armature current is proportional to the field flux $(Ish \propto \Phi)$. Thus the Φ remains more otherwise less stable, due to this reason; a shunt wound DC motor can be named as a constant flux motor.

Back E.M.F in DC Shunt Motor :

Whenever the DC shunt motor's armature winding rotates within the magnetic field which is generated by the field winding. Thus an E.M.F can be stimulated within the armature winding based on the Faradays law (electromagnetic induction). Although, according to Lenz's law, the induced E.M.F can act within reverse direction toward the armature voltage supply. Thus, this E.M.F is named as the Back E.M.F, and it is represented with Eb.

Mathematically this can be expressed as, $Eb = (P\varphi NZ) \,/\, 60A\ V$

Where,

P = Number of poles

Φ = Flux for each pole within Wb

A = Number of parallel lanes

N = Motor’s speed in revolutions per minute

Z = Number of armature conductors.

- **Characteristics of DC Shunt Motor :**
    - This DC motor works at a fixed speed once the voltage supply is set.
    - This DC motor is upturned by the turn around the motor connections like a series motor.
    - In this type of DC motor, by a rising motor current, torque can be improved without reducing in speed.

- **Motor Applications on DC Shunt Motor :**
  - These motors are used wherever stable speed is required.
  - This kind of DC motor can be used in Centrifugal Pump, Lifts, Weaving Machine, Lathe Machines, Blowers, Fans, Conveyors, Spinning machines, etc.

2.1.2 Separately Excited Motor:

In separately excited motor, the connection of stator and rotor can be done using a different power supply. So that the motor can be controlled from the shunt and the armatures winding can be strengthened to generate flux. Like other DC motors, these motors also have both stator and rotor. Stator refers to the static part of motor, which consists of the field windings. And the Rotor is the moving armature which contains armature windings or coils.

Figure. 2.4: Separately Excited Motor

Separately excited dc motor has field coils similar to that of shunt wound dc motor. The name suggests the construction of this type of motor. The field of them does not need any separate excitation. But, in separately excited DC motor, separate supply provided for excitation of both field coil and armature coil.

- **Circuit Diagram :**

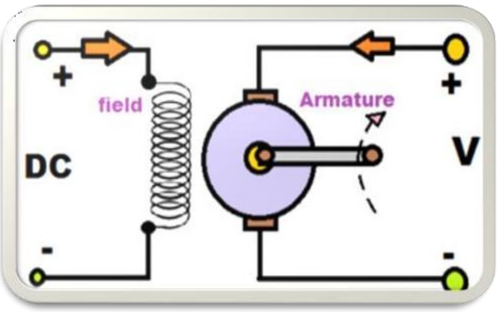


Figure 2.5: Separately Excited Motor Circuit Diagram

The field coil is energized from a separate DC Voltage source and the armature coil is also energized from another source. Armature voltage source may be variable but, independent constant DC voltage is used for energizing the field coil. So, those coils are electrically isolated from each other, and this connection is the specialty of this type of DC motor.

- **Equations Of Voltage, current and power for Separately Excited Motor:**

  In a separately excited motor, armature and field windings are excited form two different DC supply voltages.

  - $Ia = IL = I$
  - $Eb = (V - I) * Ra$
  - $P = V * I$
  - Pm = Power input to armature – Power loss in armature

Where,

I = Current
Ia = Armature current
IL = Line current
Eb = Back E.M.F
V = Voltage
Ra = Armature resistance
P = Power, Pm = Mechanical Power

- **Characteristics of Separately Excited Motor :**

Both in shunt wound DC motor and separately excited DC motor, field is supplied from constant voltage so that the field current is constant. Therefore these two motors have similar speed-armature current and torque-armature current characteristics. In this type of motor flux is assumed to be constant.

1. Speed-armature current (N – Ia) characteristics: We know that speed of DC motor is proportional to Back E.M.F / flux, i.e $Eb\ /\ \varphi$. When load is increased Back E.M.F Eb and φ flux decrease due to armature resistance drop and armature reaction respectively. However Back E.M.F decreases more than φ so that the speed of the motor slightly decreases with load.
2. Torque – armature current (τ – Ia) characteristics: Here torque is proportional to the flux and armature current. Neglecting armature reaction, flux φ is constant and torque is proportional to the armature current Ia.
3. (τ – Ia) characteristics is a straight line passing through the origin. From the curve we can see that huge current is needed to start heavy loads. So this type of motor do not starts on heavy loads.

- **Applications Of Separately Excited Motor :**
  - Separately excited DC motors have industrial applications.
  - They are often used as actuators.
  - This type of motors is used in trains and for automatic traction purposes.

2.1.3 DC SERIES MOTOR:

In DC series motor, rotor windings are connected in series. The operation principle of this electric motor mainly depends on a simple electromagnetic law. This law states that "Whenever a magnetic field can be formed around conductor and interacts with an external field to generate the rotational motion".

Figure 2.6: DC Series Motor

The DC Series Motor is similar to any other motor because the main function of this motor is to convert electrical energy to mechanical energy. The operation of this motor mainly depends on the electromagnetic principle.

⭘ Components used and Construction of DC Series Motor :

- The components of this motor mainly include the rotor (the armature), commutator, stator, axle, field windings, and brushes. The fixed component of the motor is the stator, and it is built with two otherwise more electromagnet pole parts. The rotor includes the armature and the windings on the core allied to the commutator. The power source can be connected toward the armature windings throughout a brush array allied to the commutator.
- The rotor includes a central axle for rotating, and the field winding must be able to hold high current due to the larger quantity of current throughout the winding, the larger will be the torque produced with the motor.
- Therefore the motor winding can be fabricated with solid gauge wire. This wire does not permit a huge number of twists. The winding can be fabricated with solid copper bars because it assists in simple as well as efficient heat dissipation generated accordingly by a large amount of current flow during winding.

⭘ Circuit diagram DC Series Motor :

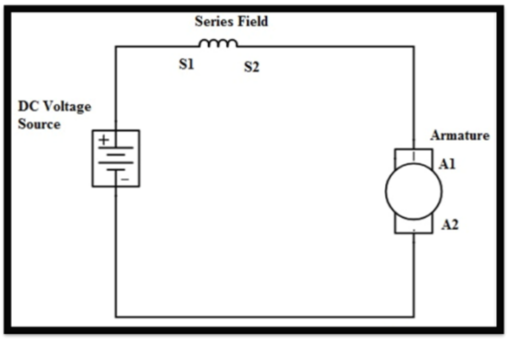


Figure 2.7: Circuit diagram DC Series Motor

In this motor, fields, as well as stator windings, are coupled in series by each other. Accordingly the armature and field current are equivalent huge current supply straightly from the supply toward the field windings. The huge current can be carried by field windings because these windings have few turns as well as very thick. Generally, copper bars form stator windings. These thick copper bars dissipate heat generated by theheavy flow of current very effectively. Note that the stator field windings S1 - S2 are in series with the rotating armature A1-A2.

⭘ Working of DC Series Motor :

- In a series motor electric power is supplied between one end of the series field windings and one end of the armature.
- When voltage is applied, current flows from power supply terminals through the series winding and armature winding.
- The large conductors present in the armature and field windings provide the only resistance to the flow of this current. Since these conductors are so large, their resistance is very low. This causes the motor to draw a large amount of current from the power supply.
- When the large current begins to flow through the field and armature windings, the coils reach saturation that results in the production of the strongest magnetic field possible.
- The strength of these magnetic fields provides the armature shafts with the greatest amount of torque possible.
- The large torque causes the armature to begin to spin with the maximum amount of power and the armature starts to rotate.

Torque, Speed, Back E.M.F equations :

- Torque = Square of Armature current [$T = Ia\hat{}2$]
- Speed is directly proportional to Back E.M.F [$N \propto Eb/\phi$]
- $Eb = (P\phi NZ) \,/\, 60A$ Where,

  P = Number of poles

  Φ = Flux for each pole within Wb

  A = Number of parallel lanes

  N = Motor's speed in revolutions per minute

  Z = Number of armature conductors

Advantages of DC Series Motor :

- Vast starting torque.
- Easy assembly and simple design.
- Protection is easy.
- Cost-effective.

Disadvantages of DC Series Motor :

- The motor speed regulation is fairly poor. When the load speed increases then the machine speed will decrease.

- When the speed is increased, then the DC series motor’s torque will be decreased sharply.
- This motor always needs the load before running the motor. So these motors are not suitable for where the motor’s load is totally removed.

Applications :

- These motors can produce enormous rotating force and the torque from its inactive state.
- This feature will make the series motor fit for mobile electric equipment, tiny electrical appliances, winches, hoists, etc.

2.1.4 PMDC Motor :

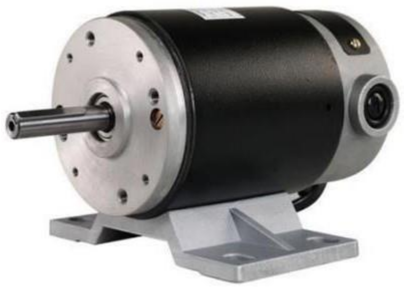


Figure 2.8: PMDC Motor

The term PMDC stands for “Permanent Magnet DC motor”. It is one kind of DC motor which can be inbuilt with a permanent magnet to make the magnetic field necessary for the electric motor operation. The magnetic field strength of a permanent magnet is fixed it cannot be controlled externally; field control of this type of DC motor cannot be possible. Thus permanent magnet DC motor is used where there is no need to control the speed of the motor (which is usually done by controlling the magnetic field). Small fractional and sub-fractional KW motors are often constructed using a permanent magnet.

Construction of PMDC Motor :

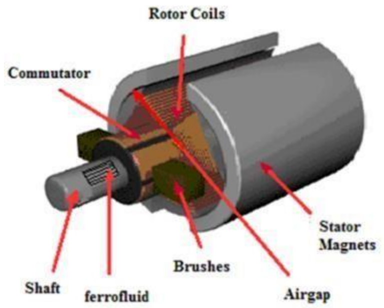


Figure 2.9: Construction of PMDC Motor

The PMDC motor's permanent magnets are maintained with a cylindrical – steel stator and these supplies like a return lane for the magnetic flux. The rotor supplies like an armature, and it includes commutator segments winding slots, and brushes like in conventional dc machines. The permanent magnets used in this motor are classified into three namely Alnico magnets, Ceramic (ferrite) magnets, and Rareearth magnets.

- Alnico magnets are used within motors which have the ratings in the range of 1kW - 150kW.
- Ferrite or Ceramic magnets are much cheap within fractional kW (kilowatt) motors.
- Rare-earth magnets are made with samarium cobalt as well as neodymium iron cobalt.

Operation of PMDC Motor :

- In this motor, a permanent magnetic field can be generated with the permanent magnets which communicate by the perpendicular field stimulated by the flow of currents within the rotor windings; therefore a mechanical torque can be created.
- When the rotor rotates in response to the created torque, then the position among the stator as well as rotor fields can be reduced, and the torque would be reversed in a 90-degree rotation. To maintain the torque performing on the rotor, PMDC motors include a commutator, set to the rotor shaft.
- The commutator activates the current supply toward the stator thus as to continue a steady angle = 90, among two fields. As the flow of current is frequently activated among windings like the rotor twists, then the current within every stator winding is truly exchanging at a frequency comparative to the number of motor magnetic poles as well as the speed.

Circuit Diagram of PMDC Motor:

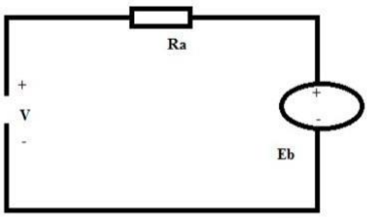


Figure 2.10: Circuit Diagram of PMDC Motor

The circuit diagram of the PMDC motor is shown below. As in permanent magnet DC motor the field can be generated with the permanent magnet, then there is no requirement of drawing field coils within the PMDC motor equivalent circuit. The voltage supply toward the armature will contain fall of armature resistance as well as break of the voltage supply can be countered with the motor's back E.M.F. Therefore the voltage equation of the motor is given by, $V = I * Ra + Eb$

Where,

I = Armature current

Ra = Armature resistance

Eb = Back E.M.F

V = Supply voltage.

- **Advantages of the PMDC Motor :**
  - The size of these motors is smaller.
  - These motors are cheaper.
  - These motors do not need field windings, and they don't have the copper losses in the field circuit.

- **Disadvantages of the PMDC Motor :**
  - The major drawback of this motor is, the generating capacity of working flux within the air gap is limited. But, due to the expansion of some latest magnetic material such as Samarium Cobalt and Neodymium Iron Boron, this trouble has been determined to some level.

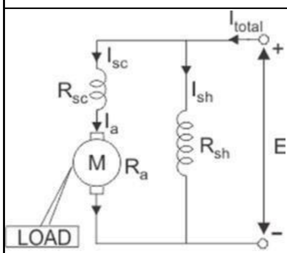
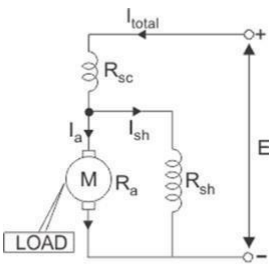
- **Applications of the PMDC Motor :**
  - These motors are in several applications varying from fractions to numerous horsepower. These are designed with 200 kW to use in various industries.
  - These are applicable in automobiles for operating windshield wipers as well as washers, to move up the lower windows, to drive blowers for air conditioners as well as heaters.
  - These are used in computer drives, toy industries.
  - These motors are applicable in food mixers, electric toothbrushes, and moveable vacuum cleaners.

2.1.5 Compound Motor :

Compound DC motor is a compound of both series and shunt motor. It is a self - excited motor. It consists of a Series field coil, which is connected in series with the armature field winding, and a shunt field coil winding, which is connected in parallel with the armature field winding. Presence of both the field windings that is series field winding and shunt field winding gave this motor the name of compound DC motor

Figure 2.11 : Compound Motor

- **Types of Compound Wound DC Motor :**

Long Shunt Compound Wound DC Motor	Short Shunt Compound Wound DC Motor
 In case of long shunt compound wound DC motor, the shunt field winding is connected in parallel across the series combination of both the armature and series field coil, as shown in the diagram below. • Current equation, $Itotal = Ise + Ish$ • Voltage equation, $E = Eb + Ia\ (Ra + Rse)$	 In case of short shunt compound wound DC moto, the shunt field winding is connected in parallel across the armature winding only. And series field coil is exposed to the entire supply current, before being split up into armature and shunt field current as shown in the diagram below. • Current equation, $Itotal = Ia + Ish$ • Voltage equation, $E = Eb + IaRa + (ItotalRse)$

- **Cumulative Compounding of DC Motor :**

A compound wound DC motor is said to becumulatively compounded when the shunt field flux produced by the shunt winding assists orenhances the effect of main field flux, produced by the series winding.

$$\phi total = \phi series + \phi shunt$$

○ Differential Compounding of DC Motor :

A compound wound DC motor is said to be deferentially compounded when the flux due to the shunt field winding diminishes the effect of the main series winding. This particular trait is not really desirable, and hence does not find much of a practical application.

$$\phi total = \phi series + \phi shunt$$

○ Applications of DC compound motor :

- Compound motors due to their ability to perform better on heavy load changes are used in elevators.
- Due to their high starting torque and better speed control for pressure variations, they are used in shears and punches.
- This kind of motors because of the high starting torque and heavy-duty load is used in steel rolling mills.
- Again due to the capacity of driving heavy loads, they are used in the printing press and cutting machines.
- Their good speed control and high starting torque make them a great choice to be used in mixers.

2.2 AC MOTOR *:*

A AC Motor is defined as a class of electrical motors that converts Alternating current electrical energy into Mechanical energy.

○ There are 2 types of A.C Motors:

- Induction Motor
- Synchronous Motor

2.2.1 : Induction Motor:

The electric motor which runs asynchronous speed is known as Induction motor, and an alternate name of this motor is the asynchronous motor. Induction motor mainly uses electromagnetic induction for changing the energy from electric to mechanical. Based on the rotor construction, these motors are classified into two types namely squirrel cage & phase wound.

Figure 2.12: Induction Motor

An induction motor is the most modest electrical machine from the construction point of view, in the majority of the cases. Induction machines are by far the most common type of motor used in industrial, commercial, or residential settings.

- **Types of Induction Motor :**

- Single Phase Induction Motor: The single - phase induction motor is not selfstarting. When the motor is connected to a single -phase power supply, the main winding carries an alternating current. In these types of motors, the start winding can have a series capacitor and/or a centrifugal switch. The angle between the two windings is sufficient to phase difference to provide a rotating magnitude field to produce a starting torque. At the point when the motor reaches 70% to 80% of synchronous speed, a centrifugal switch on the motor shaft opens and disconnects the starting winding.
- Three Phase Induction Motor: These motors are self-starting and use no capacitor, start winding, centrifugal switch, or another starting device. These are of two types, squirrel cage, and slip ring motors. Squirrel cage motors are widely used due to their rugged construction and simple design. Slip ring motors require external resistors to have high starting torque. Induction motors are used in industrial and domestic appliances because these are rugged in construction requiring hardly any maintenance, that they are comparatively cheap, and require supply only to the stator

- **Working Principle :**

The induction motor working principle is, the AC in the rotor of the motor is required to generate torque that is gained through electromagnetic induction which results from the stator winding's rotary magnetic field.

- **Applications of Induction Motor :**

- Single Phase Induction Motor: Pumps, Compressors, Small fans, Mixers, Toys, High-speed vacuum cleaners, Electric shavers, Drilling machines.
- Three Phase Induction Motor:Lifts, Cranes, Hoists, Large capacity exhaust fans, Driving lathe machines, Crushers, Oil extracting mills, Textile.

Advantages of Induction Motor :

- Low Cost & Low Maintenance Cost, Easy of Operation & Speed Variation.
- High Starting Torque, Durability.

Disadvantages of Induction Motor :

- Throughout the light load situation, the power factor is extremely less and it draws a huge current. So, the copper loss can be high which decreases the efficiency throughout the light load situation.
- The squirrel cage induction motor's initial torque is not low.
- This is an invariable speed motor and this motor is not applicable where uneven speed needs.
- This motor speed control is not easy.
- This motor includes a high starting inrush current which will cause a reduction within voltage at the beginning of time.

2.2.2 : Synchronous Motor*:*

An AC Motor in which at steady state, rotation of the shaft is in sync with the frequency of applied current. The synchronous motor works as AC motor but here the total number of rotations made by the shaft is equal to the integer multiple of the frequency of the applied current.

Figure 2.13: Synchronous Motor

The synchronous motor doesn't rely on induction current for working. In these motors, unlike induction motor, multiphase AC electromagnets are present on the stator, which produces a rotating magnetic field. Here rotor is of a permanent magnet which gets synced with the rotating magnetic field and rotates in synchronous to the frequency of current applied to it.

Stator and rotor are the main components of the synchronous motor. Here stator frame has wrapper plate to which key bars and circumferential ribs are attached. Footings, Frame mounts are used to support the machine. To excite field windings with DC, slip rings and brushes are used, Cylindrical and round rotors are used for 6 pole application, salient pole rotor are used when a larger quantity of poles is required, and Construction of the synchronous motor and synchronous alternator are similar.

- **Synchronous Motor Working Principle :**
  - Working of synchronous motors depends on the interaction of the magnetic field of the stator with the magnetic field of the rotor. The stator contains 3 phase windings and is supplied with 3 phase power. Thus, stator winding produces a 3 phased rotating Magnetic Field. DC supply is given to the rotor.
  - The rotor enters into the rotating Magnetic Field produced by the stator winding and rotates in synchronization. Now, the speed of the motor depends on the frequency of the supplied current.
  - Speed of the synchronous motor is controlled by the frequency of the applied current. The speed of a synchronous motor can be calculated as, $Ns = 60f/P = 120f/p$. Where, f = frequency of the AC current (Hz). p = total number of poles per phase. P = total pair number of poles per phase.
  - If the load greater than breakdown load is applied, the motor gets desynchronized. The 3phase stator winding gives the advantage of determining the direction of rotation. In case of single-phase winding, it is not possible to derive the direction of rotation and the motor can start in either of the direction. To control the direction of rotation in these synchronous motors, starting arrangements are needed.

- **Advantages of Synchronous Motors :**
  - The speed is constant and independent of load.
  - These motors usually operate at higher efficiency.
  - Electromagnetic power varies linearly with the voltage.
  - These motors can be constructed with wider air gaps than induction motors, which make them better mechanically.

- **Disadvantages of Synchronous Motors :**
  - It cannot be started under load.
  - It requires dc excitation which must be supplied from external source.
  - It has a tendency to hunt.
  - It cannot be used for variable speed jobs as there is no possibility of speed adjustment.
  - Collector rings and brushes are required.

- **Applications of Synchronous Motors :**
  - Synchronous motors are used for applications where precise and constant speed is required. Low power applications of these motors include positioning machines. These are also applied in robot actuators. Ball mills, clocks, record player, turntables also make use of synchronous motors.
  - These motors are available in a fractional horseshoe size range to high power industrial size range.

2.3 Special Purpose Motors:

The special purpose motors mainly include servo motor, stepper motor, linear induction motor, etc.

2.3.1 Brushless DC Motors:

The brushless DC motors were first developed for achieving superior performance within a lesser space than brushed DC motors. These motors are lesser when compared with AC models. A controller is embedded into the electric motor to facilitate the process within the lack of a commutator and a slip ring.

- **Advantages**
  - Better speed versus torque characteristics
  - High dynamic response
  - High efficiency
  - Long operating life due to a lack of electrical and friction losses
  - Noiseless operation
  - Higher speed ranges

- **Applications:**

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

2.3.2 Hysteresis Motor:

The operation of the hysteresis motor is extremely unique. The rotor of this motor can be induced hysteresis and eddy current to generate the required task. The motor working can depend on the construction, 1-phase supply otherwise 3-phase supply. These motors give a very smooth process with stable speed, similar to other synchronous motors. The noise level of this motor is quite small, due to this reason they are applicable in numerous complicated applications wherever the soundproof motor is used such as sound player, audio recorder, etc.

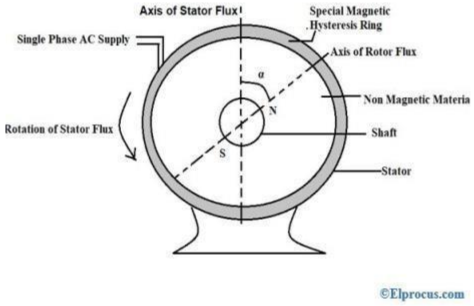


Figure 2.14: Hysteresis Motor

- **Advantages of Hysteresis Motor**:

  - As no teeth and no winding in the rotor, no mechanical vibrations take place during its operation.
  - Its operation is quiet and noiseless as there is no vibration.
  - It is suitable to accelerate inertia loads.
  - The multi-speed operation can be achieved by employing a gear train

2.3.3 Reluctance Motor:

Basically, reluctance motor is a 1-phase synchronous motor & this motor construction is quite same with induction motor like cage type. The rotor in the motor is like squirrel cage type & the stator of the motor include sets of windings such as auxiliary and main winding. The auxiliary winding is very useful at the beginning time of the motor. As they offer a level operation at a stable speed. These motors are commonly used in synchronization applications which include signal generators, recorders, etc.

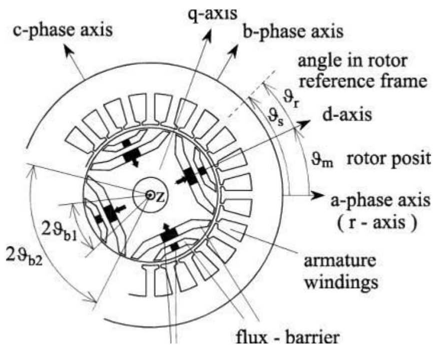


Figure 2.15: Reluctance Motor

- **Advantages of Reluctance Motor:**

- Any change in loads like under load or overloads will be overcome by synchronizing torque. The speed will be maintained in all respects.
- Due to the reluctance principle, it does not need any starting method like in a synchronous motor that needs starting methods and not self-starting.
- The self-starting aspect of the machine makes it more robust.
- Due to a less complicated structure, it requires less maintenance.

2.3.4: Universal Motor:

This is a special kind of motor and this motor works on single AC supply otherwise DC supply. Universal motors are series wound where the field and armature windings are connected in series and thus generates high starting torque. These motors are mainly designed for operating at high-speed above 3500 rpm. They utilize AC supply at low-speed and DC supply of similar voltage.

Thus, this is all about types of electric motors. At present, there are different and flexible. The purpose of the motor is whenever a motion control is required, this is the best choice. The motor must support the use and overall act of the system.

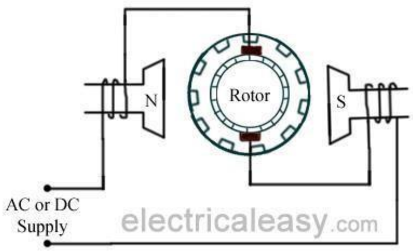


Figure 2.16: Universal Motors

Universal motors are less costly due to their simple construction and no requirement for permanent magnets. Universal motors provide good torque at low speeds. They can rotate at high speed due to the connection of armature windings and field windings in series. Due to its small size and less weight of the universal motor, it is most preferable in many applications. Eddy current losses are reduced due to the presence of an electromagnetic field and heating is avoided. Universal motors require low power input to run the motor. These motors have the capability to run at any given availability speed.

CHAPTER 3

CONTROLLING TECHNIQUES TO CONTROL MOTORS

3.1 Controlling Techniques of DC motor

3.1.1 Armature Resistance Control Method:

The armature resistance control is based on the principle that the speed of the motor is directly proportional to the back EMF. So, if the supply voltage V and the armature resistance Ra are kept at a constant value, the speed of the motor will be directly proportional to the armature current Ia. Thus, if we add the resistance in series with the armature, I_a decreases and hence speed also decreases.

3.1.2 Pulse Width Modulation (PWM):

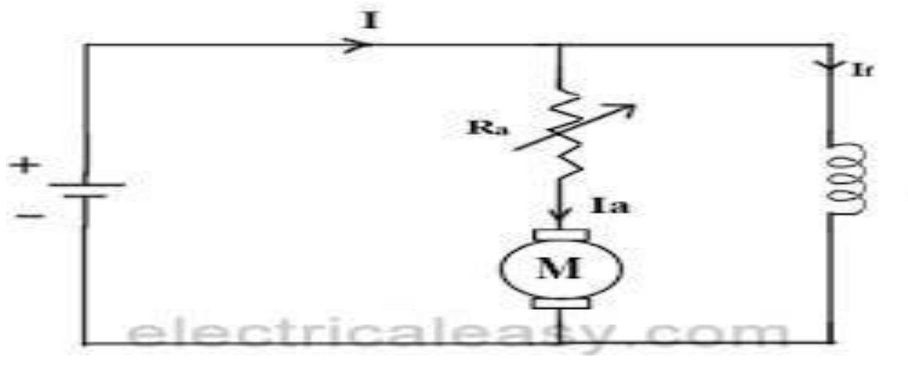
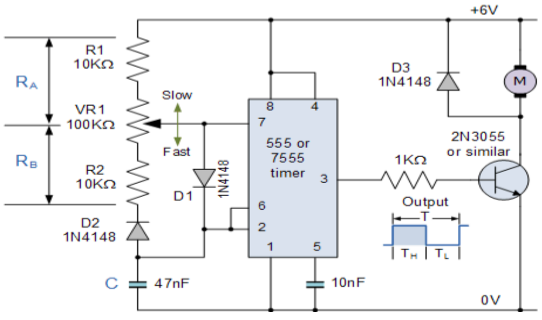


Figure 3.1: Armature Resistance Control Method



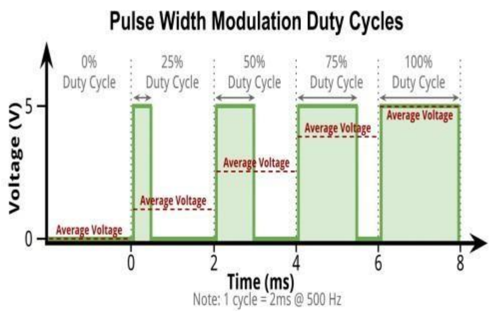


Figure 3.2: Pulse Width Modulation Figure 3.3: Pulse Width Modulation Circuit Duty cycles

It takes a constant steady state DC voltage and produces a train of fixed amplitude ON/OFF pulse. Its switching speed has to be high enough not to affect the load.Here power loss in switching speed is very low. PWMs are commonly used in DC motor control in robotics and other application.

3.1.3 Flux control method:

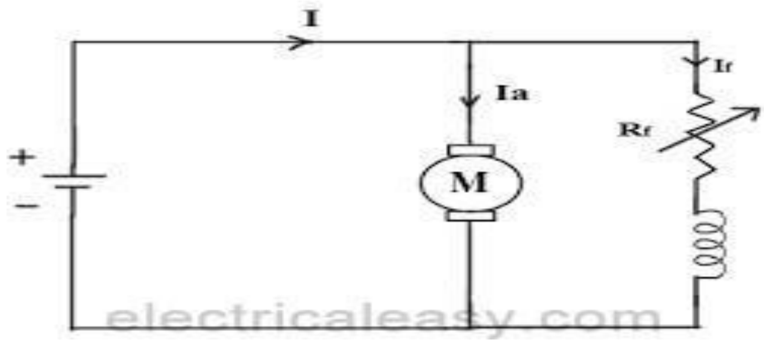


Figure 3.4: Flux Control Method

It is seen that the speed of the motor is inversely proportional to the flux. Thus by decreasing the flux, speed can be increased and vice versa. To control the flux, a rheostat is added in series with the field winding as shown in figure 3.4. Adding more resistance in series with field winding will increase the speed as it will decrease the flux.

3.2 Controlling Techniques of AC Motor:

3.2.1 Pulse width modulator :

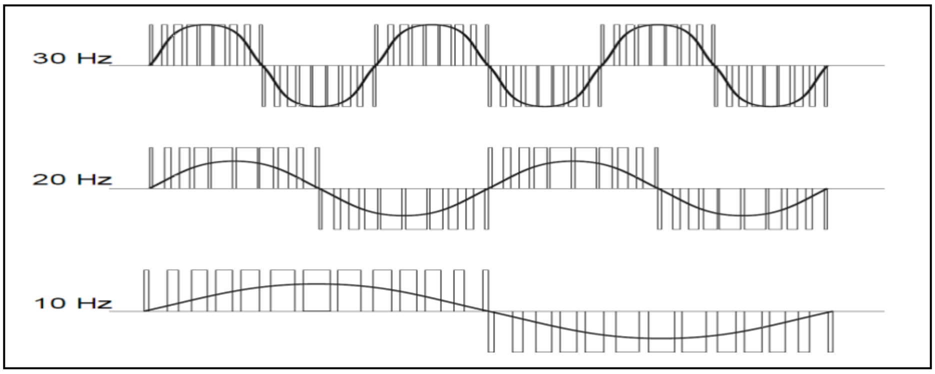


Figure 3.5: Pulse Width Modulator Circuit

Pulse width modulator circuits, or PWMs, are a popular method to simulate AC oscillations. They often provide more precise control than variable voltage inverters. They do so by rapidly switching the current (or “pulsing” it) to match the area under the curve of the true sine wave.Recalling from calculus that the integrals of any two continuous graphs are equal if their areas under their curves are equal

CHAPTER 4

STEPPER MOTOR AND ITS CONTROLLING TECHNIQUES

AC motors are rugged, robust and low cost. AC (alternating current) motors are rarely used in mobile robots because most of the robots are powered with direct current (DC) coming from batteries also since electronic components use DC, it is more convenient to have the same type of power supply for the actuators as well. AC motors are mainly used in industrial environments where very high torque is required, or where the motors are connected to the mains / wall outlet.

The angular speed of asynchronous AC motors may be controlled using variable frequency of AC power supply. The solution requires a very expensive electronics, overcoming the price of motor itself. In general, there are many constructions of AC motors and some are not faster in reaction as compared with other motors.AC motors can be further subdivided into asynchronous and synchronous types. For example, an induction AC motor is an asynchronous type unit that is essentially comprised of a wire-wound stator and a rotor. Power is connected to the wire and AC current flowing through it induces an electromagnetic (EM) field in the coiled wire, with a strong-enough field providing the force for rotor motion. Synchronous motors are constant-speed motors that operate in synchronism with AC line frequency and are commonly used where precise constant speed is required.

Overall,

- The starting torque of this motor is very less.
- At low speeds, it won't operate.
- Poor positioning control limited speed through the frequency supply.
- There are some problems that could arise like eddy current loss is high, less power factor, sparking within the brushes and there is a chance for an increase within armature & field winding reactance drop.

DC motors have certain capabilities that make them a desirable choice, but still they have some disadvantages.

- They generally require separate cooling.
- They require frequent maintenance, and periodically require expensive reconditioning.
- They are no longer common, and replacements often have long delivery times.
- Repair is very expensive .DC motors cost more because the armature must be wound and all the windings soldered to the commutator.
- DC motors require more maintenance. Periodically brushes must be replaced and the commutator turned down and the mica undercut. On large well designed motors, this must be done every few thousand hours. On very small motors it must generally be done more often. DC motors have a very high starting current and must have a control system to limit the starting current to an acceptable value.

Therefore DC motors are usually more expensive and sometimes less reliable in robotics applications overall.

4.1 Stepper Motors in Robotics:

Every motor converts electricity into motion, the stepper motor or step motor is named so because it converts the electricity into discrete step motion. These steps help you to choose a particular type of motion to perform.

The main benefits of stepper motors are their excellent speed control, precise positioning, and repeatability. Furthermore, stepper motors are highly reliable since they do not have contact brushes. In this way, mechanical failure is minimized and the motor's lifespan is maximized.

- Stepper motors can respond and accelerate quickly. They have low rotor inertia that can get up to speed quickly. For this reason step motors are ideal for short, quick moves.
- It provides with highly controlled movement. The Stepper motors have very long life, only if you don't break it by an accident.
- It is an excellent repeater device it can repeat its movements very accurately.
- Stepper motor is also very cheap as compared to other motion controlling devices.
- One of the main features of stepper motor is that it can't be damaged by overloading.

Electric motors are used in the vast majority of robots. Portable robots are powered by repeated brushed DC motors, while industrial robots are powered by AC motors. In systems with lighter loads, these motors are preferred, as they are more efficient and have a rotating motion. The stepper motor can rotate in both directions at the same time. – It can hold a holding torque at zero speed for a long time. It is possible to directly interface the stepper motor with a digital circuit. Applications for lowpower position control utilize this technology.

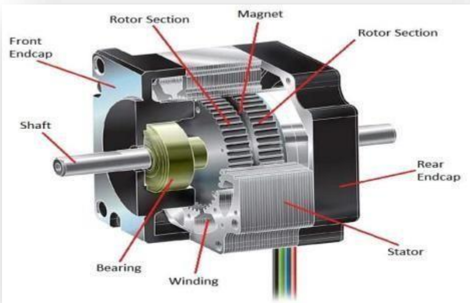


Figure 4.1: Stepper Motor Breakdown

Normal DC motors tend to rotate at their speed as soon as the power supply is connected. Their motion is continuous and without any interruptions. Hence, to use these motors for joints in a robot will require a lot of timing on the part of the controller to make then stop at a precise angle or position as is required/ desired. Whereas stepper motors do not have the same rotation speed as DC motors do. They tend to rotate by a certain degree with each rotation and tend to have small jerks in their motion. This helps the controller of the robot to stop the motor easily at the desired position. Servo motors can also be used, But they are more costly and their operation varies as compared to stepper motors which are relatively easy to control.

4.2 Construction & Working Principle of a Stepper Motor:

The construction of a stepper motor is fairly related to a DC motor. It includes a permanent magnet like Rotor which is in the middle & it will turn once force acts on it. This rotor is enclosed through a no. of the stator which is wound through a magnetic coil all over it. The stator is arranged near to rotor so that magnetic fields within the stators can control the movement of the rotor. The stepper motor working principle is Electro-Magnetism. It includes a rotor which is made with a permanent magnet whereas a stator is with electromagnets. Once the supply is provided to the winding of the stator then the magnetic field will be developed within the stator. Now rotor in the motor will start to move with the rotating magnetic field of the stator. So this is the fundamental working principle of this motor. In this motor, there is a soft iron that is enclosed through the electromagnetic stators. The poles of the stator as well as the rotor don't depend on the kind of stepper. Once the stators of this motor are energized then the rotor will rotate to line up itself with the stator otherwise turns to have the least gap through the stator. In this way, the stators are activated in a series to revolve the stepper motor.

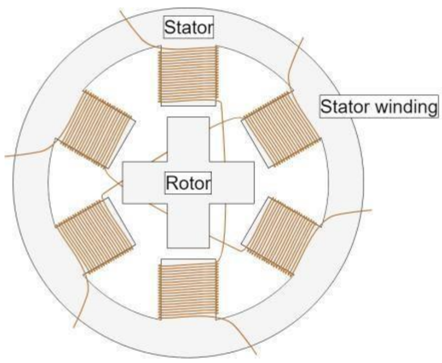


Figure 4.2: Cross section of a Stepper Motor

4.3 Controlling techniques of a stepper motor :

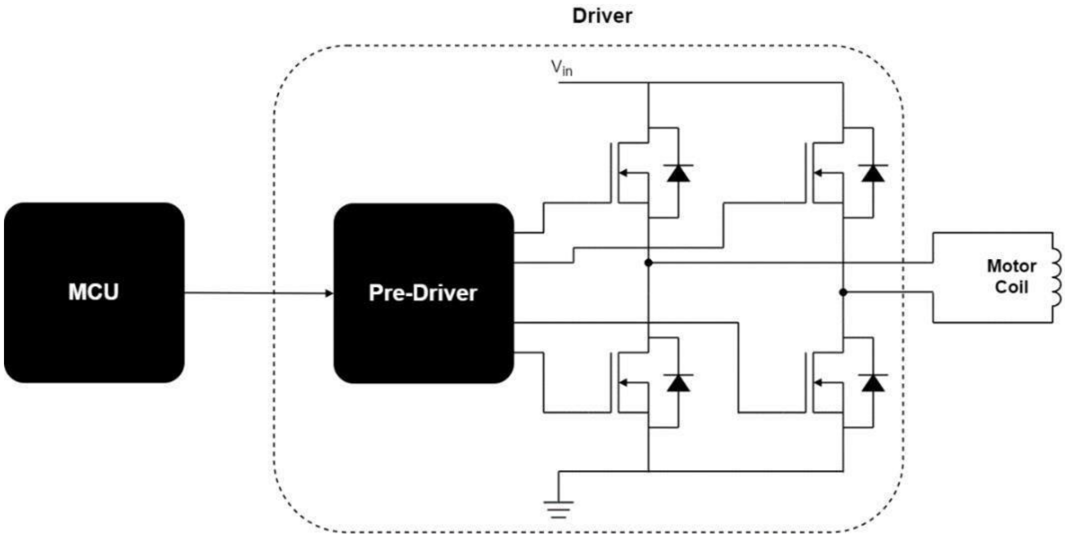


Figure 4.3: Basic Scheme of Motor Control

Stepper motors are controlled by a driver, which sends the pulses into the motor causing it to turn. The number of pulses the motor turns is equal to the number of pulses fed into the driver. The motor will spin at a rate that is equal to the frequency of those same pulses.

Stepper motors are very easy to control. Stepper motors can respond and accelerate quickly. They have low rotor inertia that can get up to speed quickly. For this reason stepper motors are ideal for short, quick moves. The motor coils need to be energized, in a specific sequence, to generate the magnetic field with which the rotor is going to align. Several devices are used to supply the necessary voltage to the coils, and thus allow the motor to function properly. Starting from the devices that are closer to the motor, we have:

- A transistor bridge is the device physically controlling the electrical connection of the motor coils. Transistors can be seen as electrically controlled interrupters, which, when closed allow the connection of a coil to the electrical supply and thus the flow of current in the coil. One transistor bridge is needed for each motor phase.
- A pre-driver is a device that controls the activation of the transistors, providing the required voltage and current, it is in turn controlled by an MCU.
- An MCU is a microcontroller unit, which is usually programmed by the motor user and generates specific signals for the pre-driver to obtain the desired motor behavior.

Overall, stepper motor control is pretty simple. The motor does need a driver, but does not need complex calculations or tuning to work properly. In general, the control effort is lower compared to other motors. With micro stepping, high position accuracy obtained up to approximately 0.007°.

CONCLUSION

Due to their properties, stepper motors are used in many Robotics applications where a simple position control and the ability to hold a position. A stepper motor is suitable for robotic applications because its movement comprises of discrete steps. It moves by a discrete angle called the step angle in each step. Stepper motors are used in commercial and industrial applications because of their high reliability, low cost, high torque at low speeds and a simple construction that operates in almost every environment. Therefore Stepper motors are the most suitable and reliable for Robotics applications

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