UNIT II BUILDING BLOCKS OF A ROBOT

Electrical Drive

An electrical drive can be defined as an electromechanical device for converting electrical energy into mechanical energy to impart motion to different machines and mechanisms for various kinds of process control.

2.1 VARIOUS TYPES OF MOTORS

Stepper motor

A stepper motor is a pulse-driven motor that changes the angular position of the rotor in steps. Due to this nature of a stepper motor, it is widely used in low cost, open loop position control systems.

2.1.1 Variable Reluctance Motor

Figure 2.1 shows the construction of Variable Reluctance motor. The cylindrical rotor is made of soft steel and has four poles as shown in Fig.2.1. It has four rotor teeth, 90° apart and six stator poles, 60° apart. Electromagnetic field is produced by activating the stator coils in sequence. It attracts the metal rotor. When the windings are energized in a reoccurring sequence of 2, 3, 1, and so on, the motor will rotate in a 30° step angle. In the non-energized condition, there is no magnetic flux in the air gap, as the stator is an electromagnet and the rotor is a piece of soft iron; hence, there is no detent torque. This type of stepper motor is called a variable reluctance stepper.

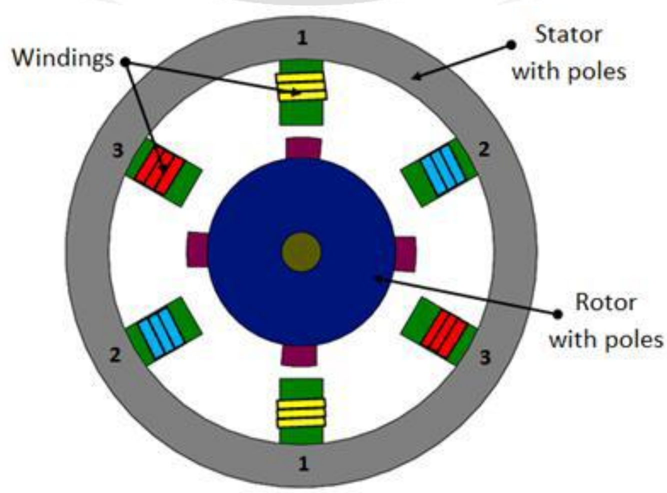

Fig. 2.1 Variable reluctance stepper motor

2.1.2 Permanent magnet (PM) stepper motor

In this type of motor, the rotor is a permanent magnet. Unlike the other stepping motors, the PM motor rotor has no teeth and is designed to be magnetized at a right angle to its axis. Figure 2.2 shows a simple, 90^0 PM motor with four phases (A-D). Applying current to each phase in sequence will cause the rotor to rotate by adjusting to the changing magnetic fields. Although it operates at fairly low speed, the PM motor has a relatively high torque characteristic. These are low cost motors with typical step angle ranging between 7.5^0 to 15^0.

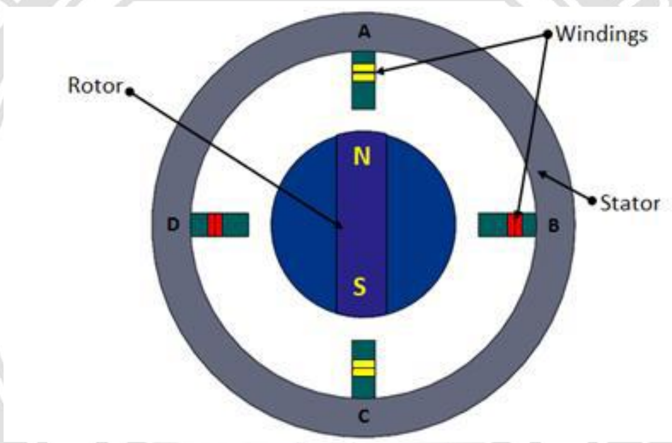

Fig. 2.2 Permanent magnet stepper

2.1.3 Hybrid stepper motor

Hybrid stepping motors combine a permanent magnet and a rotor with metal teeth to provide features of the variable reluctance and permanent magnet motors together. The number of rotor pole pairs is equal to the number of teeth on one of the rotor's parts. The hybrid motor stator has teeth creating more poles than the main poles windings (Fig. 2.3).

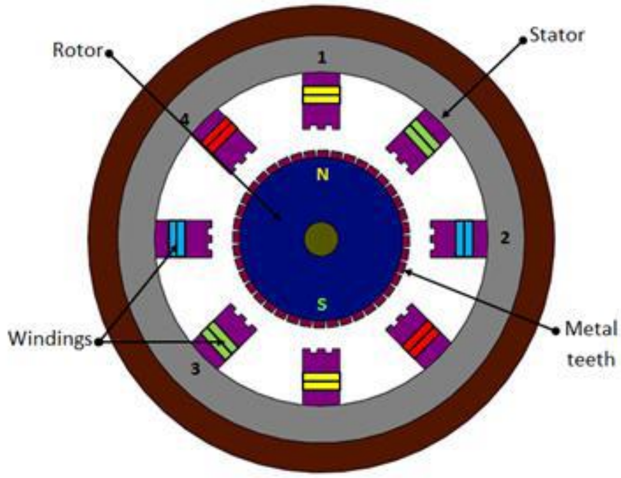

Fig. 2.3 Hybrid stepper

Rotation of a hybrid stepping motor is produced in the similar fashion as a permanent magnet stepping motor, by energizing individual windings in a positive or negative direction. When a winding is energized, north and south poles are created, depending on the polarity of the current flowing. These generated poles attract the permanent poles of the rotor and also the finer metal teeth present on rotor. The rotor moves one step to align the offset magnetized rotor teeth to the corresponding energized windings. Hybrid motors are more expensive than motors with permanent magnets, but they use smaller steps, have greater torque and maximum speed.

Step angle of a stepper motor is given by

$$\text{Step angle} = \frac{360^\circ}{\text{Number of poles}}$$

Advantages of stepper motors:

- Low cost
- Ruggedness
- Simplicity of construction
- Low maintenance
- Less likely to stall or slip
- Will work in any environment
- Excellent start-stop and reversing responses

Disadvantages of stepper motors:

- Low torque capacity compared to DC motors
- Limited speed

- During overloading, the synchronization will be broken. Vibration and noise occur when running at high speed.

2.2 Servomotor

Servomotors are special electromechanical devices that produce precise degrees of rotation. A servo motor is a DC or AC or brushless DC motor combined with a position sensing device. Servomotors are also called control motors as they are involved in controlling a mechanical system. The servomotors are used in a closed-loop servo system as shown in Figure 4.2.4. A reference input is sent to the servo amplifier, which controls the speed of the servomotor. A feedback device is mounted on the machine, which is either an encoder or resolver. This device changes mechanical motion into electrical signals and is used as a feedback. This feedback is sent to the error detector, which compares the actual operation with that of the reference input. If there is an error, that error is fed directly to the amplifier, which will be used to make necessary corrections in control action. In many servo systems, both velocity and position are monitored. Servomotors provide accurate speed, torque, and have ability of direction control.

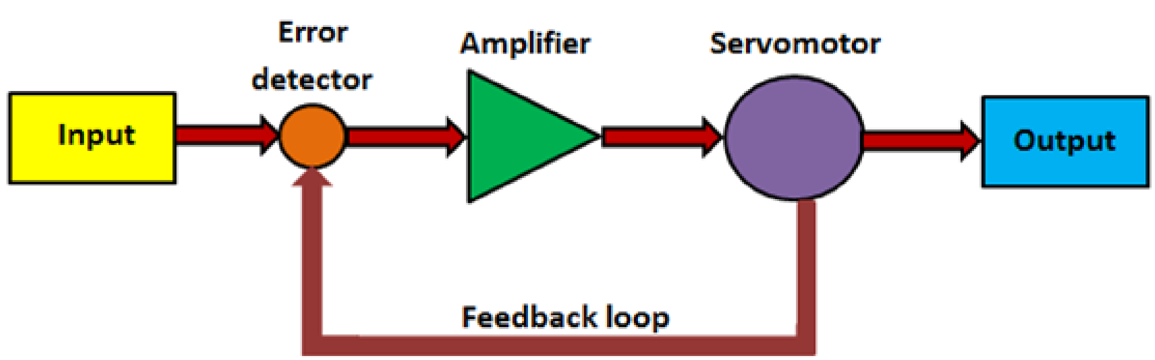

Fig. 2.4 Servo system block diagram

2.3 DC servomotors

DC operated servomotors are usually respond to error signal abruptly and accelerate the load quickly. A DC servo motor is actually an assembly of four separate components, namely:

- DC motor
- gear assembly
- position-sensing device
- control circuit

2.4 AC servo motor

In this type of motor, t he magnetic force is generated by a permanent magnet and current which further produce the torque. It has no brushes so there is little noise/vibration. This motor provides high precision control with the help of high resolution encoder. The stator is composed of a core and a winding. The rotor part comprises of shaft, rotor core and a permanent magnet. Digital encoder can be of optical or magnetic type. It gives digital signals, which are in proportion of rotation of the shaft.

Advantages of servo motors

- Provides high intermittent torque, high torque to inertia ratio, and high speeds
- Work well for velocity control
- Available in all sizes
- Quiet in operation
- Smoother rotation at lower speeds

Disadvantages of servo motors

- More expensive than stepper motors
- Require tuning of control loop parameters
- Not suitable for ha zardous environments or in vacuum
- Excessive current can result in partial demagnetization of DC type servo motor

2.5. DC Motor

DC Motors are electromechanical devices which use the interaction of magnetic fields and conductors to convert the electrical energy into rotary mechanical energy Electrical DC Motors are continuous actuators that convert electrical energy into mechanical energy. The DC motor achieves this by producing a continuous angular rotation that can be used to rotate pumps, fans, compressors, wheels, etc. As well as conventional rotary DC motors, linear motors are also available which are capable of producing a continuous liner movement.

Fig. 2.5 A Typical Small DC Motor

DC Motor or **Direct Current Motor** to give it its full title, is the most commonly used actuator for producing continuous movement and whose speed of rotation can easily be controlled, making them ideal for use in applications were speed control, servo type control, and/or positioning is required. A DC motor consists of two parts, a "Stator" which is the stationary part and a "Rotor" which is the rotating part. The result is that there are basically three types of DC Motor available.

- **Brushed Motor** – This type of motor produces a magnetic field in a wound rotor (the part that rotates) by passing an electrical current through a commutator and carbon brush assembly, hence the term "Brushed". The stators (the stationary part) magnetic field is produced by using either a wound stator field winding or by permanent magnets.Generally brushed DC motors are cheap, small and easily controlled.
- **Brushless Motor** – This type of motor produce a magnetic field in the rotor by using permanent magnets attached to it and commutation is achieved electronically. They are generally smaller but more expensive than conventional brushed type DC motors because they use "Hall effect" switches in the stator to produce the required stator field rotational sequence but they have better torque/speed characteristics, are more efficient and have a longer operating life than equivalent brushed types.
- **Servo Motor** – This type of motor is basically a brushed DC motor with some form of positional feedback control connected to the rotor shaft. They are connected to and controlled by a PWM type controller and are mainly used in positional control systems and radio controlled models.

Normal DC motors have almost linear characteristics with their speed of rotation being determined by the applied DC voltage and their output torque being determined by the current flowing through the motor windings. The speed of rotation of any DC motor can be varied from a few revolutions per minute (rpm) to many thousands of revolutions per minute making them suitable for electronic, automotive or robotic applications. By connecting them to gearboxes or gear-trains their output speed can be decreased while at the same time increasing the torque output of the motor at a high speed.

The "Brushed" DC Motor

A conventional brushed DC Motor consist basically of two parts, the stationary body of the motor called the **Stator** and the inner part which rotates producing the movement called the **Rotor** or **"Armature"** for DC machines.

The motors wound stator is an electromagnet circuit which consists of electrical coils connected together in a circular configuration to produce the required North-pole then a South-pole then a North-pole etc, type stationary magnetic field system for rotation, unlike AC machines whose stator field continually rotates with the applied frequency. The current which flows within these field coils is known as the motor field current. These electromagnetic coils which form the stator field can be electrically connected in series, parallel or both together (compound) with the motors armature. A series wound DC motor has its stator field windings connected in *series* with the armature. Likewise, a shunt wound DC motor has its stator field windings connected in *parallel* with the armature.

Conventional (Brushed) DC Motor

The Permanent magnet (PMDC) brushed DC motor is generally much smaller and cheaper than its equivalent wound stator type DC motor cousins as they have no field winding. In permanent magnet DC (PMDC) motors these field coils are replaced with strong rare earth (i.e. Samarium Cobolt, or Neodymium Iron Boron) type magnets which have very high magnetic energy fields.

The use of permanent magnets gives the DC motor a much better linear speed/torque characteristic than the equivalent wound motors because of the permanent and sometimes very strong magnetic field, making them more suitable for use in models, robotics and servos.

Although DC brushed motors are very efficient and cheap, problems associated with the brushed DC motor is that sparking occurs under heavy load conditions between the two surfaces of the commutator and carbon brushes resulting in self generating heat, short life span and electrical noise due to sparking, which can damage any semiconductor switching device such as a

MOSFET or transistor. To overcome these disadvantages, **Brushless DC Motors** were developed.

The "Brushless" DC Motor

The brushless DC motor (BDCM) is very similar to a permanent magnet DC motor, but does not have any brushes to replace or wear out due to commutator sparking. Therefore, little heat is generated in the rotor increasing the motors life. The design of the brushless motor eliminates the need for brushes by using a more complex drive circuit were the rotor magnetic field is a permanent magnet which is always in synchronisation with the stator field allows for a more precise speed and torque control.

Then the construction of a brushless DC motor is very similar to the AC motor making it a true synchronous motor but one disadvantage is that it is more expensive than an equivalent "brushed" motor design.

The control of the brushless DC motors is very different from the normal brushed DC motor, in that it this type of motor incorporates some means to detect the rotors angular position (or magnetic poles) required to produce the feedback signals required to control the semiconductor switching devices. The most common position/pole sensor is the "Hall Effect Sensor", but some motors also use optical sensors.

Using Hall effect sensors, the polarity of the electromagnets is switched by the motor control drive circuitry. Then the motor can be easily synchronized to a digital clock signal, providing precise speed control. Brushless DC motors can be constructed to have, an external permanent magnet rotor and an internal electromagnet stator or an internal permanent magnet rotor and an external electromagnet stator.

Advantages of the **Brushless DC Motor** compared to its "brushed" cousin is higher efficiencies, high reliability, low electrical noise, good speed control and more importantly, no brushes or commutator to wear out producing a much higher speed. However, their disadvantage is that they are more expensive and more complicated to control.

2.6 SELECTION CRITERIAN FOR ACTUATORS

Selection Criteria

The selection of the proper actuator is more complicated than selection of the sensors, primarily due to their effect on the dynamic behaviour of the overall system. Furthermore, the selection of the actuator dominates the power needs and the coupling mechanisms of the entire system.

The coupling mechanism can sometimes be completely avoided if the actuator provides the output that can be directly interfaced to the physical system. For example, choosing a linear motor in place of a rotary motor can eliminate the need of a coupling mechanism to convert rotary motion to linear motion.

In general, the following performance parameters must be addressed before choosing an actuator for a specific need:

1. Continuous power output—the maximum force/torque attainable continuously without exceeding the temperature limits

2. Range of motion—the range of linear/rotary motion

3. Resolution—the minimum increment of force/torque attainable

4. Accuracy—Linearity of the relationship between the input and output

5. Peak force/torque—the force/torque at which the actuator stalls

6. Heat dissipation—Maximum wattage of heat dissipation in continuous operation

7. Speed characteristics—Force/torque versus speed relationship

8. No load speed—typical operating speed/velocity with no external load

9. Frequency response—the range of frequency over which the output follows the input faithfully, applicable to linear actuators

10. Power requirement—Type of power (AC or DC), number of phases, voltage level, and current capacity In addition to the above-referred criteria, many other factors become important depending upon the type of power and the coupling mechanism required.

For example, if a rack- and-pinion coupling mechanism is chosen, the backlash and friction will affect the resolution of the actuating unit