Introduction to mechatronics

Actuators

By: Mr Qusay Hamid Ali

ACTUATORS

One of the important components of a mechatronic control system is the actuator. Actuators are the devices that accept a control command and produce a change in the physical system by generating **force, motion, heat, flow, etc.** It is a device that makes something to move. Normally, the actuators are used in conjunction with the power supply and a coupling mechanism. The power unit provides either AC or DC power at the rated voltage and current. The coupling mechanism acts as the interface between the actuator and the physical system. Typical mechanisms include rack and pinion, gear drive, belt drive, lead screw and nut, piston, and linkages.

Definition of Actuators :

- Actuators are the device used for converting hydraulic, pneumatic, and electrical energy into mechanical energy.
- The mechanical energy used to get the work done. Actuators perform functions just opposite to that of the pump.
- They can be used for lifting, tilting, clamping opening, closing, metering, mixing and turning, and for many other operations.

Functions of actuation :

1. Transformation of rotary motion into a translating motion as in the case of the cam and follower mechanism where the rotational motion of the cam is changed into the translational movement of the follower.
2. Transformation of rotary motion for a long distance which is not possible by using gears, as in the case of belt drives.
3. Transformation of rotary motion for a medium distance without slipping which is not possible by using belt drives.
4. Transformation of linear motion into rotational motion as in the case of rack and pinion mechanism.
5. Locking of rotating elements as in the case of ratchet and pawl mechanism.

Types of Actuators

1. Electrical actuators
   - Electric motors
     - DC servomotors
     - AC motors
     - Stepper motors
   - Solenoids

1. Hydraulic actuators
   - Use hydraulic fluid to amplify the controlle command signal
1. Pneumatic actuators
   - Use compressed air as the driving force

Types of Actuators :

1.Actuators are basically classified into the following two types based on their movement.

- **Translational**
- **Rotational**

It is possible to convert one form of actuation to another. For example, translational motion is converted into rotational and vice versa by suitably designing the interfacing components around the actuator. Rack and pinion, gears, pulleys, lead screw and nut, and cams can be used as interfacing components.

2. Actuators can be classified into the following types based on the type of energy.

- Electrical
- Electromechanical
- Electromagnetic
- Hydraulic
- Pneumatic

Electrical Actuators :

An actuator obtaining electrical energy from the mechanical system is called electric actuators. Electric actuators are generally referred to ad being those where an electric motor drives the robot links through some mechanical transmission i.e. gears.

Electrical actuators comprise the following :

1. **Drive system:** DC motor, AC motor, Stepper motor

2. **Switching Device:**

a. **Mechanical switch:** Solenoids, Relays

b. **Solid-state switch:** Diodes, Thyristor, Transistors

Advantages of Electrical Actuators :

- Higher power conversion efficiency.
- The widespread availability of power supply.
- No pollution of the working environment.
- The basic drive element in an electric motor is usually lighter than that for fluid power.
- Structural components can be lightweight.
- The drive system is well suited to electronic control.

Disadvantages of Electrical Actuators :

1- A larger and heavier motor must be used which is costly.

2- Poor dynamics response.

3- Compliance and wear problems are causing inaccuracies.

4- Conventional gear-driven creates a backlash.

5- Electric motors are not intrinsically safe. They cannot, therefore, be used in for explosive atmospheres.

Electro-mechanical actuators :

Electromechanical actuators are electrical motors that convert electrical energy into mechanical motion. Motors are the principal means of converting electrical energy into mechanical energy in industry. Broadly, they are classified into DC motors, AC motors, and stepper motors.

Electro-magnetic actuators

An electromagnetic actuator is a device that provides working motion due to an internal electromagnetic field. The solenoid is the most common electromagnetic actuator. A solenoid consists of a static, hollow-centered wire coil and a movable ferrous metal plunger. When the wire coil is energized, a magnetic field establishes that provides the force to push or pull the metal plunger.

Examples of electrical actuators

Relay :

A relay is an electrically operated switch. It is also called as electromagnetic or electromechanical switch. The heart of a relay is an electromagnet: a coil of wire that becomes a temporary magnet when electricity flows through it. Relay consists of four elements, and it is shown in Fig.3.1

1- Electromagnet 2- Movable armature 3- Contacts and 4- Spring

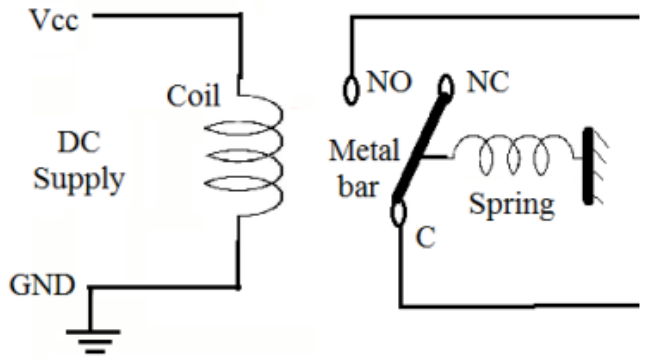

Fig. 3.1 Relay showing its components

Types of Relays

Relays are basically classified into four type as shown in fig. 3.4.

Single Pole Single Through (SPST)

Single Pole Double Through (SPDT)

Double Pole Single Through (DPST)

Single Pole Single Through (DPDT)

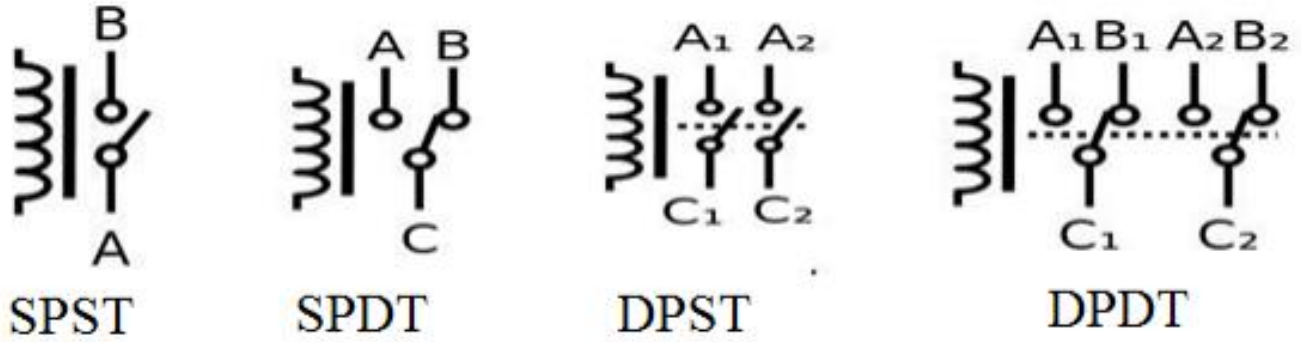

Fig. 3.4 Types of relays

Solenoid

Solenoid is an insulated copper coil is wound around some cylindrical cardboard or plastic tube such that the length of the coils is greater than its diameter, then it becomes like a magnet.

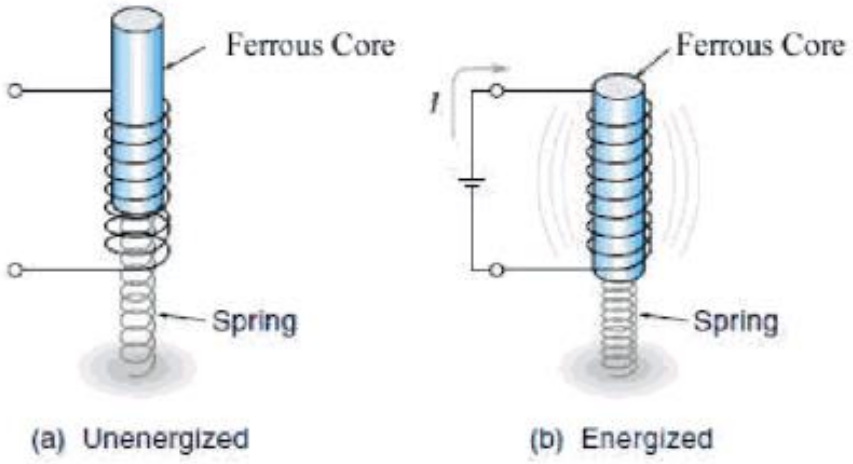

Fig. 3.5 Solenoid working

Hydraulic and Pneumatic Actuators :

Hydraulic and pneumatic actuators are normally either rotary motors or linear pistons/cylinders. They are ideally suited for generating very large force coupled with large motion. Pneumatic actuators use the compressed air that is more suitable for low to medium force, short stroke, and high-speed applications. Hydraulic actuators use oil under pressure which is incompressible. They can produce very large force coupled with large motion in a cost-effective manner. The rotary motors are usually used in applications where low speed and high torque are required. The cylinder/piston actuators are suited for the application of linear motion. A proper selection of actuators and their drive systems for a particular application is of utmost importance in the design of mechatronic systems.

Hydraulic Actuators :

- Hydraulic actuators transform the hydraulic energy stored in a reservoir into mechanical energy by means of suitable pumps.
- Hydraulic actuators are also fluid power device for industrial robots which utilize high-pressure fluid such as oil to transmit forces to the point of application desired.

Advantages of hydraulic actuators :

1- It has the advantage of generating extremely large force from a very compact actuator.

2- It can also provide precise control at low speeds

3- robust.

4- self-lubricating.

5- Due to the presence of an accumulator that acts as a storage device the system can meet sudden demand in power.

6- No mechanical linkages are required.

7- High efficiency and high power to size ratio

Disadvantages of hydraulic actuators :

1- The hydraulic system is required for a large infrastructure is high-pressure pump, tank, distribution lines.

2- Leakage can occur causing a loss in performance.

3- High maintenance.

4- Not suitable for a clean environment.

Pneumatic actuators

- Pneumatic actuators utilize pneumatic energy provided by a compressor and transforms it into mechanical energy by means of a piston or turbines.
- Pressurized air is used to transmit and control power.
- Pneumatic actuators are devices that cause things to move by taking advantage of potential energy.

Advantages of Pneumatic Actuators :

The advantages of Pneumatic actuators are as follows,

1- Control is simple.

2- When the source of compressed air are readily available, as they often are in engineering related facilities, pneumatic actuators may be a good choice.

3- It is the cheapest form of all actuators

4- Pneumatic actuators have very quick action and response time, thus allowing for fast work cycles.

5- No mechanical transmission is usually required.

Disadvantages of Pneumatic Actuators :

- More noise and vibration.
- Since air is compressible, pneumatic cylinders are not typically used for applications requiring accurate motion between two well-defined endpoints.
- Pneumatics are not suitable for heavy loads.
- If mechanical stops are used, resetting the system can be slow.