CHAPTER TWO

LITERATURE REVIEW AND THEORETICAL BACKGROUND

2.1 Parking Availability and Gate Control System

Parking availability is always a concern for a closed parking area inside a building. Hence a parking availability system together with the gate control system can be implemented in order to let the drivers aware of the parking area condition. The parking availability system will indicates whether there is any unoccupied parking slot available in the parking area, while the gate control system will allow or disallow drivers enters the parking area depending on the availability of the parking area.

2.1.1 Parking System history

Over the years, car parking systems and the accompanying technologies have increased and diversified. Car parking systems have been around almost since the time cars were invented. In any area where there is a significant amount of traffic, there are car parking systems. Car parking systems were developed in the early 20th century in response to the need for storage space for vehicles.

In the 1920s, forerunners of automated parking systems appeared in U.S.A cities like Los Angeles, Chicago, New York and Cincinnati. Some of these multi-storey structures are still standing, and have been adapted for new uses. One of the Kent Automatic Parking Garages in New York (now known as the Sofia Apartments) is an Art Deco landmark that was converted into luxury condominiums in 1983. A system that is now found all over Japan — the "Ferris-wheel," or paternoster system — was created by the Westinghouse Corporation in 1923 and subsequently built in 1932 on Chicago's Monroe Street.

The Nash Motor Company created the first glass enclosed version of this system for the Chicago Century of Progress Exhibition in 1933, and it was the precursor to a more recent version, the Smart Car Towers in Europe.

Automated (car) parking system APS saw a spurt of interest in the U.S. in the late 1940s and 1950s with the Bowser, Pigeon Hole and Roto Park systems. In 1957, 74 Bowser, Pigeon Hole systems were installed, and some of these systems remain in operation. However, interest in APS in the U.S. waned due to frequent mechanical problems and long waiting times for patrons to retrieve their cars. Interest in APS in the U.S. was renewed in the 1990s, and there are 25 major current and planned APS projects (representing nearly 6,000 parking spaces) in 2012.

While interest in the APS in the U.S. languished until the 1990s, Europe, Asia and Central America had been installing more technically advanced APS since the 1970s. In the early 1990s, nearly 40,000 parking spaces were being built annually using the paternoster APS in Japan. In 2012, there are an estimated 1.6 million APS parking spaces in Japan. The ever-increasing scarcity of available urban land (urbanization) and increase of the number of cars in use (motorization) have combined with sustainability and other quality-of-life issues to renew interest in APS as alternatives to multi-story parking garages, on-street parking and parking lots[3]

2.1.2 Parking system components

A basic parking and gate control system consist of entrance and exit electric gates, parking structure and parking control elements.

2.1.2.1 Entrance and exit electric gates

Electric gates are an easy way to ensure the security of private premises and can be used for all sized properties. The backbone of any electric gate, whether automatic or not, is the electric gate motor, two distinct motor types exist hydraulic, or electromechanical. This is the electric device which actually enables the electric gate to open and close without having to manually push the gate. All types of electric gates and barriers make use of a motor of some kind [4].

2.1.2.2 Parking structure

Many car parks are independent buildings dedicated exclusively to that use. A multi-storey car park is a building designed for car parking and where there are a number of floors or levels on which parking takes place. It is essentially a stacked car park. These parks often have low ceiling clearances, which restrict access by full size vans and other large vehicles. Movement of vehicles between floors can be effected by:

- Interior ramps (the most common).
- Exterior ramps (which may take the form of a circular ramp).
- Vehicle lifts (the least common).
- Automated robot systems (combination of ramp and elevator).

Parking structures are subjected to the heavy and shifting loads of moving cars, and must bear the associated physical stresses [5].

2.1.2.3 Parking and gate control elements

Parking and gate control elements consist of control unit, sensors and wiring.

2.2 programmable logic controllers Overview

Programmable logic controllers, also called programmable controllers or PLCs, are solid-state members of the computer family, using integrated circuits instead of electromechanical devices to implement control functions. They are capable of storing instructions, such as sequencing, timing, counting, arithmetic, data manipulation, and communication, to control industrial machines and processes. Programmable controllers have many definitions. However, PLCs can be thought of in simple terms as industrial computers with specially designed architecture in both their central units (the PLC itself) and their interfacing circuitry to field devices (input/output connections to the real world) [1].

PLCs have the great advantage that the same basic controller can be used with a wide range of control systems. To modify a control system and the rules that are to be used, all that is necessary is for an operator to key in a different set of instructions. There is no need to rewire. The result is a flexible, cost effective, system which can be used with control systems which vary quite widely in their nature and complexity.

PLCs are similar to computers but whereas computers are optimized for calculation and display tasks, PLCs are optimized for control tasks and the industrial environment. Thus PLCs are:

- Rugged and designed to withstand vibrations, temperature, humidity and noise.
- Have interfacing for inputs and outputs already inside the controller

- Are easily programmed and have an easily understood programming language which is primarily concerned with logic and switching operations [6].

2.2.1 Programmable Logic Controllers history

Early machines were controlled by mechanical means using cams, gears, levers and other basic mechanical devices. As the complexity grew, so did the need for a more sophisticated control system. This system contained wired relay and switch control elements. These elements were wired as required to provide the control logic necessary for the particular type of machine operation. This was acceptable for a machine that never needed to be changed or modified, but as manufacturing techniques improved and plant change over to new products became more desirable and necessary, a more versatile means of controlling this equipment had to be developed. Hardwired relay and switch logic was cumbersome and time consuming to modify. Wiring had to be removed and replaced to provide for the new control scheme required. This modification was difficult and time consuming to design and install and any small "bug" in the design could be a major problem to correct since that also required rewiring of the system. A new means to modify control circuitry was needed. The development and testing ground for this new means was the USA. auto industry. The time period was the late 1960's and early 1970's and the result was the programmable logic controller, or PLC. Automotive plants were confronted with a change in manufacturing techniques every time a model changed and, in some cases, for changes on the same model if improvements had to be made during the model year. The PLC provided an easy way to reprogram the wiring rather than actually rewiring the control system.

The PLC that was developed during this time was not very easy to program. The language was cumbersome to write and required highly trained programmers. These early devices were merely relay replacements and could do very little else. The PLC has at first gradually, and in recent years rapidly developed into a sophisticated and highly versatile control system component. Units today are capable of performing complex math functions including numerical integration and differentiation and operate at the fast microprocessor speeds now available. Older PLCs were capable of only handling discrete inputs and outputs (that is, on-off type signals), while today's systems can accept and generate analog voltages and currents as well as a wide range of voltage levels and pulsed signals. PLCs are also designed to be rugged. Unlike their personal computer cousin, they can typically withstand vibration, shock, elevated temperatures, and electrical noise to which manufacturing equipment is exposed.

As more manufacturers become involved in PLC production and development, and PLC capabilities expand, the programming language is also expanding. This is necessary to allow the programming of these advanced capabilities. Also, manufacturers tend to develop their own versions of ladder logic language (the language used to program PLCs).

This complicates learning to program PLC's in general since one language cannot be learned that is applicable to all types. However, as with other computer languages, once the basics of PLC operation and programming in ladder logic are learned, adapting to the various manufacturers’ devices is not a complicated process. [7]

2.2.2 Internal architecture

The basic internal architecture of a PLC consists of a central processing unit (CPU) containing the system microprocessor, memory, and input/output circuitry, as shown in Figure (2.1). The CPU controls and processes all the operations within the PLC. It is supplied with a clock with a frequency of typically between 1 and 8 MHz This frequency determines the operating speed of the PLC and provides the timing and synchronization for all elements in the system. The information within the PLC is carried by means of digital signals. The CPU uses the data bus for sending data between the constituent elements, the address bus to send the addresses of locations for accessing stored data and the control bus for signals relating to internal control actions. The system bus is used for communications between the input/output ports and the input/output unit [6].

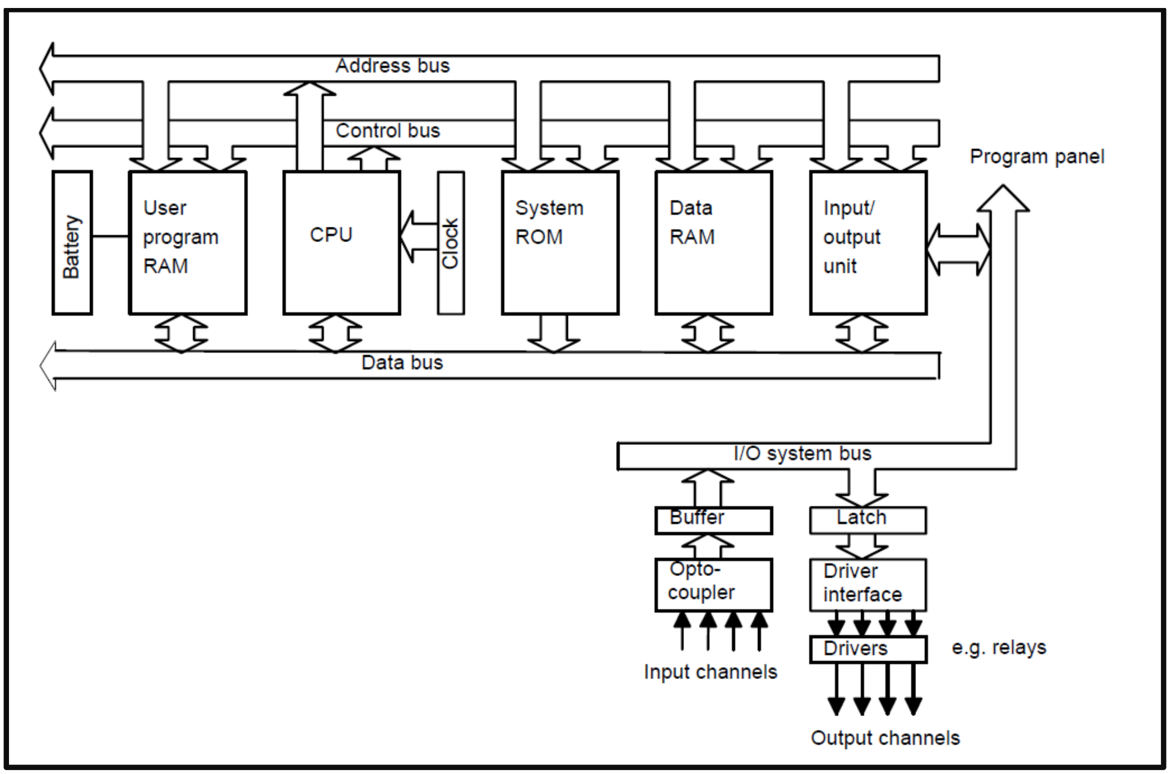

Figure (2.1): PLC internal architecture

The internal architecture of a PLC consists of:

2.2.2.1 The CPU

The internal structure of the CPU depends on the microprocessor concerned. In general they have:

- An arithmetic and logic unit (ALU) which is responsible for data manipulation and carrying out arithmetic operations of addition and subtraction and logic operations of AND, OR, NOT and EXCLUSIVE-OR.
- Memory, termed registers, located within the microprocessor and used to store information involved in program execution.
- A control unit which is used to control the timing of operations [6].

2.2.2.2 The buses

The buses are the paths used for communication within the PLC. The information is transmitted in binary form. Each of the bits is communicated simultaneously along its own parallel wire. The system has four buses:

- The data bus carries the data used in the processing carried out by the CPU. A microprocessor termed as being 8-bit has an internal data bus which can handle 8-bit numbers. It can thus perform operations between 8-bit numbers and deliver results as 8-bit values.
- The address bus is used to carry the addresses of memory locations. So that each word can be located in the memory, every memory location is given a unique address. Each word location is given an address so that data stored at a particular location can be accessed by the CPU. It is the address bus which carries the information indicating which address is to be accessed. If the address bus consists of 8 lines,

the number of 8-bit words, and hence number of distinct addresses, is $2^8 = 256$.

- The control bus carries the signals used by the CPU for control, e.g. to inform memory devices whether they are to receive data from an input or output data and to carry timing signals used to synchronize actions.
- The system bus is used for communications between the input/output ports and the input/output unit [6].

2.2.2.3 The Memory

There are several memory elements in a PLC system:

- System read-only-memory (ROM) to give permanent storage for the operating system and fixed data used by the CPU.
- Random-access memory (RAM) for the user's program.
- Random-access memory (RAM) for data. This is where information is stored on the status of input and output devices and the values of timers and counters and other internal devices.

  The programs and data in RAM can be changed by the user. All PLCs will have some amount of RAM to store programs that have been developed by the user and program data. However, to prevent the loss of programs when the power supply is switched off, a battery is used in the PLC to maintain the RAM contents for a period of time.
- Possibly, as a bolt-on extra module, erasable and programmable read-only-memory (EPROM) for ROMs that can be programmed and then the program made permanent [6].

2.2.2.4 Input/output unit

The input/output unit provides the interface between the system and the outside world, allowing for connections to be made through input/output channels to input devices such as sensors and output devices such as motors and solenoids. It is also through the input/output unit that programs are entered from a program panel. Every input/output point has a unique address which can be used by the CPU. The input/output channels provide isolation and signal conditioning functions so that sensors and actuators can often be directly connected to them without the need for other circuitry.

The digital signal that is generally compatible with the microprocessor in the PLC is 5V DC. However, signal conditioning in the input channel, with isolation, enables a wide range of input signals to be supplied to it. A range of inputs might be available with a larger PLC, e.g. 5 V, 24 V, 110 V and 240 V digital/discrete, as shown on figure (2.2). A small PLC is likely to have just one for of input, e.g. 24 V.

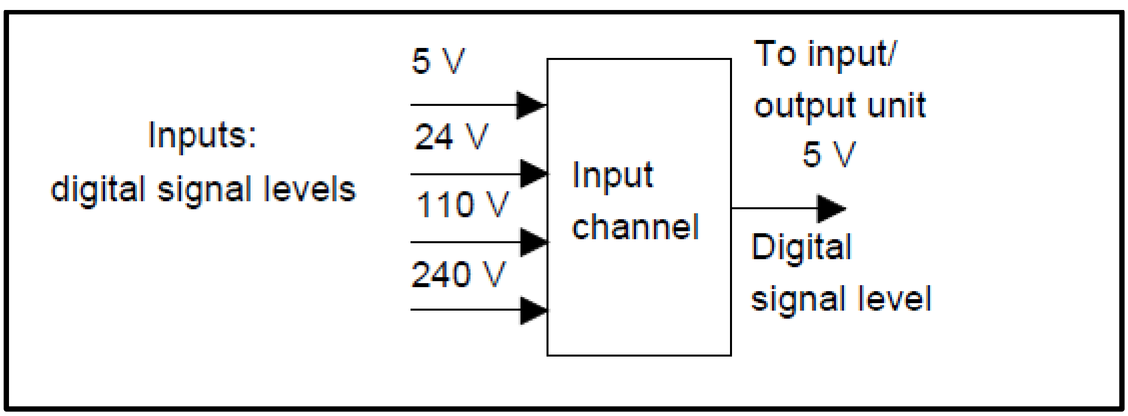

Figure (2.2): PLC input levels

The output from the input/output unit will be digital with a level of 5 V. However, after signal conditioning with relays, transistors or triacs, the output from the output channel might be a 24 V, 100 mA switching signal, a

DC voltage of 110 V, 1 A or perhaps 240 V, 1A AC, or 240 V, 2 A DC, from a triac output channel as shown as figure (2.3) [6].

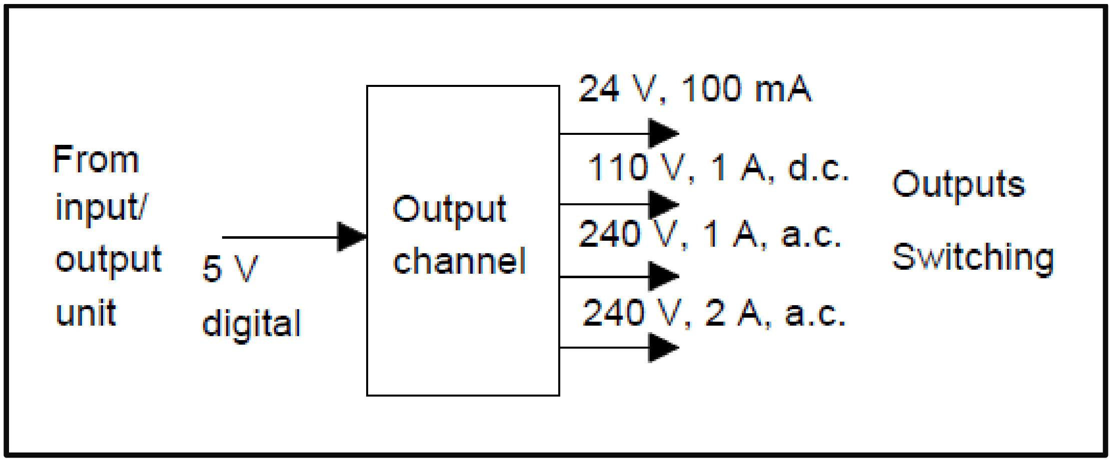

Figure (2.3): PLC output levels

2.2.3 Principles of operation

The input/ output (I/O) system is physically connected to the field devices that are encountered in the machine or that are used in the control of a process. These field devices may be discrete or analog input/output devices, such as limit switches, pressure transducers, push buttons, motor starters, solenoids, etc. The I/O interfaces provide the connection between the CPU and the information providers (inputs) and controllable devices (outputs). During its operation, the CPU completes three processes:

- **Reads** or accepts the input data from the field devices via the input interfaces.
- **Executes** or performs, the control program stored in the memory system.
- **Writes** or updates the output devices via the output interfaces.

This process of sequentially reading the inputs, executing the program in memory, and updating the outputs is known as scanning as shown as figure (2.4) illustrates a graphic representation of a scan [1].

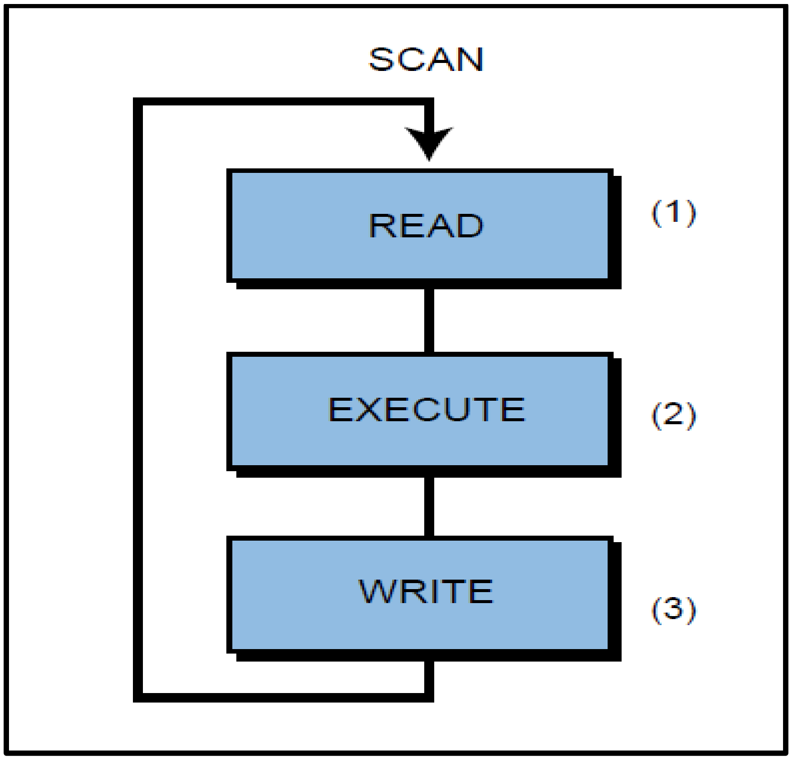

Figure (2.4): Illustration of a scan

The input/output system forms the interface by which field devices are connected to the controller as shown as figure (2.5). The main purpose of the interface is to condition the various signals received from or sent to external field devices. Incoming signals from sensors (e.g., push buttons, limit switches, analog sensors, selector switches, and thumbwheel switches) are wired to terminals on the input interfaces. Devices that will be controlled, like motor starters, solenoid valves, pilot lights, and position valves, are connected to the terminals of the output interfaces. The system power supply provides all the voltages required for the proper operation of the various central processing unit sections [1].

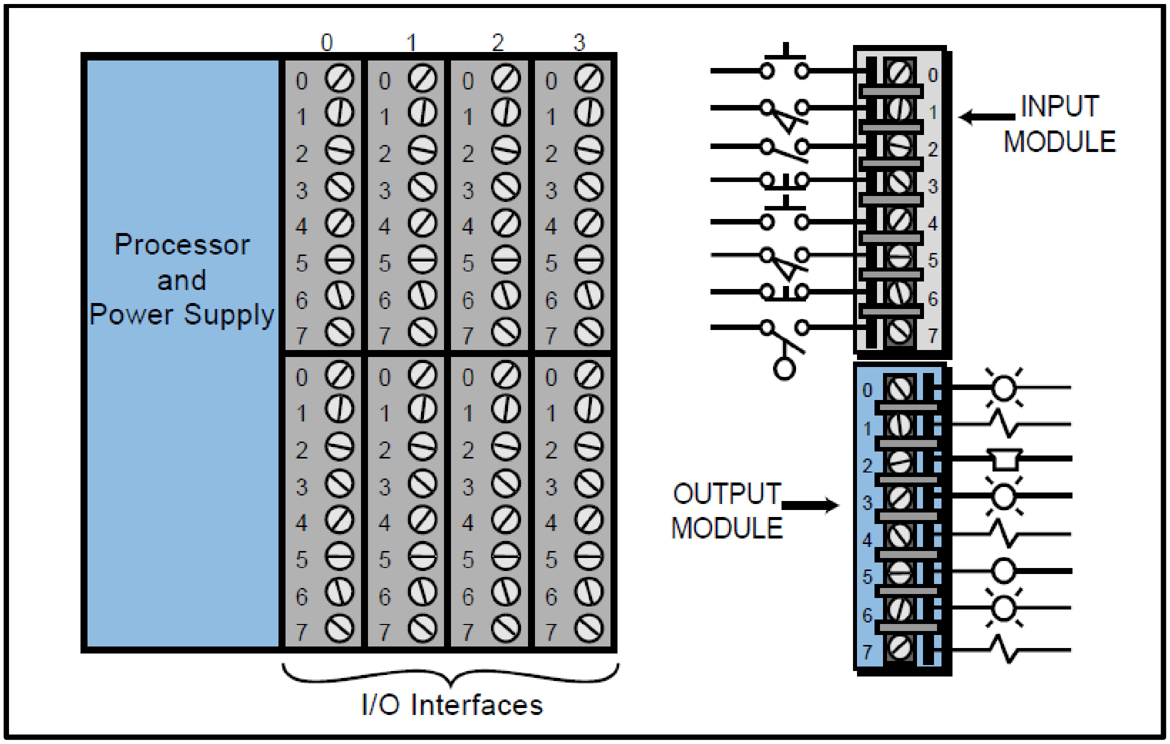

Figure (2.5): Input/output interface

2.2.4 PLC Configurations

Programmable logic controllers are much like personal computers in that the user can be overwhelmed by the vast array of options and configurations available are:

2.2.4.1 Single printed circuit board

Basic PLCs are available on a single printed circuit board as shown in Figure (2.6).They are sometimes called single board PLCs or open frame PLCs. These are totally self-contained (with the exception of a power supply) and, when installed in a system, they are simply mounted inside a controls cabinet on threaded standoffs. Screw terminals on the printed circuit board allow for the connection of the input, output, and power supply wires. These units are generally not expandable, meaning that extra inputs, outputs, and memory cannot be added to the basic unit. However, some of the more sophisticated models can be linked by cable to expansion boards that can provide extra I/O. Therefore, with few exceptions, when using this type of PLC, the system designer must take care to specify a unit that has enough inputs, outputs, and programming capability to handle both the present need of the system and any future modifications that may be required. Single board PLCs are very inexpensive, easy to program, small, and consume little power, but, generally speaking, they do not have a large number of inputs and outputs, and have a somewhat limited instruction set. They are best suited to small, relatively simple control applications [7].

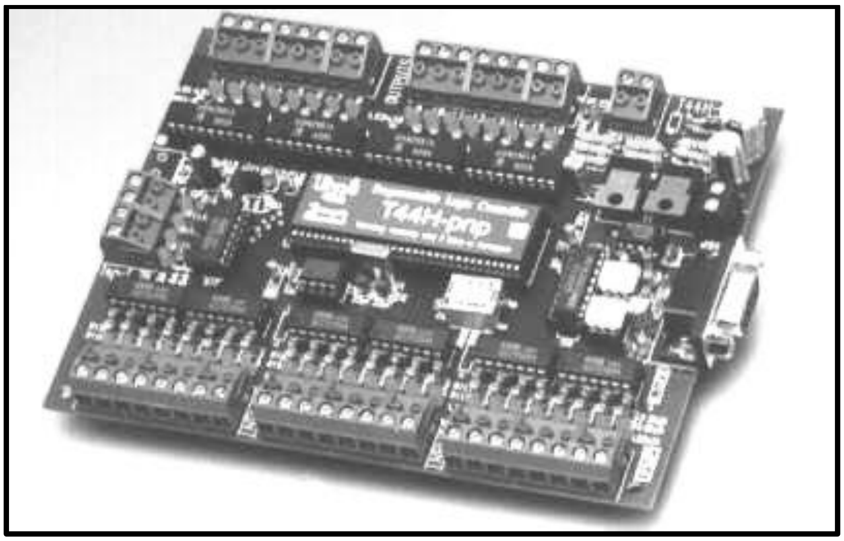

Figure (2.6): Open Frame PLC

2.2.4.2 Single case (box)

PLCs are also available housed in a single case (sometimes referred to as a shoe box) with all input and output, power and control connection points located on the single unit, as shown in Figure (2.7). These are generally chosen according to available program memory and required number and voltage of inputs and outputs to suit the application. These systems generally have an expansion port (an interconnection socket) which will allow the addition of specialized units such as high speed counters and analog input and output units or additional discrete inputs or outputs. These expansion units are either plugged directly into the main case or connected to it with ribbon cable or other suitable cable [7].

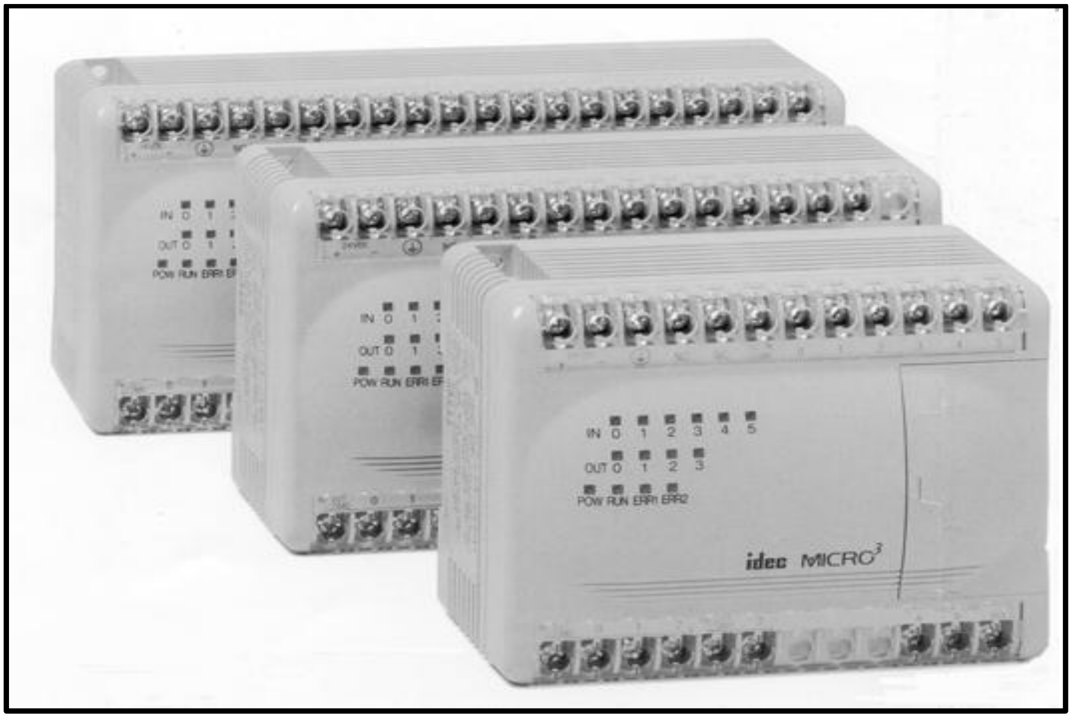

Figure (2.7): Shoebox-Style PLCs

2.2.4.3 Modular/rack types

More sophisticated units, with a wider array of options, are modularized. An example of a modularized PLC is shown in Figure (2.8).

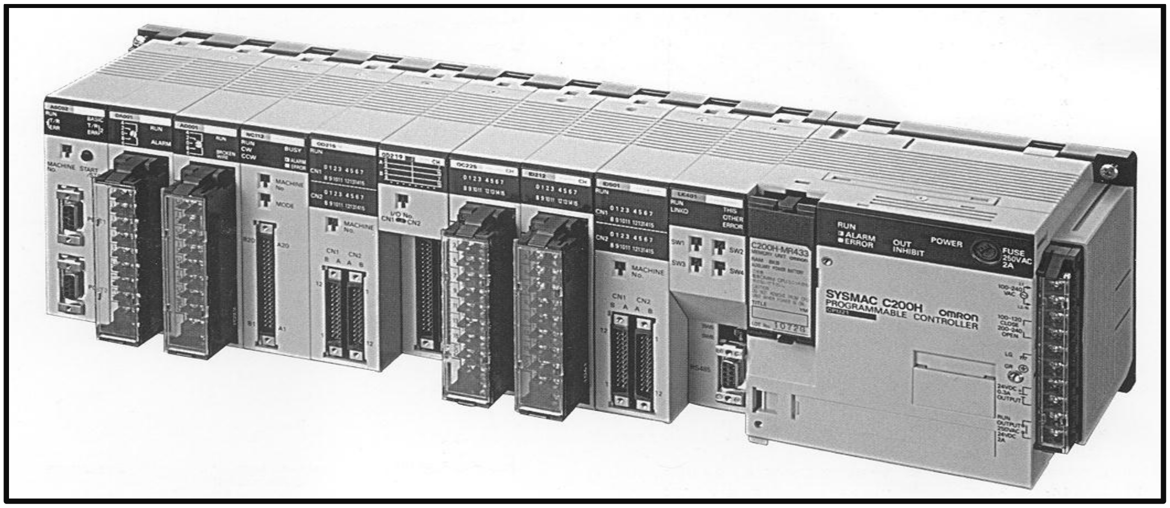

Figure (2.8): Modularized PLC

The typical system components for a modularized PLC are:

Processor: The processor (sometimes call a CPU), as in the self-contained units, is generally specified according to memory required for the program to be implemented. In the modularized versions, capability can also be a factor. This includes features such as higher math functions, PID control loops and optional programming commands. The processor consists of the microprocessor, system memory, serial communication ports for printer, PLC LAN link and external programming device and, in some cases, the system power supply to power the processor and I/O modules.

Mounting rack: This is usually a metal framework with a printed circuit board backplane which provides means for mounting the PLC input/output (I/O) modules and processor. Mounting racks are specified according to the number of modules required to implement the system. The mounting rack provides data and power connections to the processor and modules via the backplane. For CPUs that do not contain a power supply, the rack also holds the modular power supply. There are systems in which the processor is mounted separately and connected by cable to the rack. Mounting racks are cascadable so several may be interconnected to allow a system to accommodate a large number of I/O modules.

Input and output modules: Input and output (I/O) modules are specified according to the input and output signals associated with the particular application. These modules fall into the categories of discrete, analog, high speed counter or register types.

Discrete I/O modules are generally capable of handling 8 or 16 and, in some cases 32, on-off type inputs or outputs per module. Modules are specified as input or output but generally not both although some manufacturers now offer modules that can be configured with both input and output points in the same unit. The module can be specified as AC only, DC only or AC/DC along with the voltage values for which it is designed.

Analog input and output modules are available and are specified according to the desired resolution and voltage or current range. As with discrete modules, these are generally input or output; however some manufacturers provide analog input and output in the same module. Analog modules are also available which can directly accept thermocouple inputs for temperature measurement and monitoring by the PLC.

Pulsed inputs to the PLC can be accepted using a high speed counter module. This module can be capable of measuring the frequency of an input signal from a tachometer or other frequency generating device. These modules can also count the incoming pulses if desired. Generally, both frequency and count are available from the same module at the same time if both are required in the application.

Register input and output modules transfer 8 or 16 bit words of information to and from the PLC.

Power supply: The power supply specified depends upon the manufacturer's PLC being utilized in the application. As stated above, in some cases a power supply capable of delivering all required power for the system is furnished as part of the processor module. If the power supply is a separate module, it must be capable of delivering a current greater than the sum of all the currents needed by the other modules. For systems with the power supply inside the CPU module, there may be some modules in the system which require excessive power not available from the processor either because of voltage or current requirements that can only be achieved through the addition of a second power source. This is generally true if analog or external communication modules are present since these require ± DC supplies which, in the case of analog modules, must be well regulated.

Programming unit: The programming unit allows the engineer or technician to enter and edit the program to be executed. In its simplest form it can be a hand held device with a keypad for program entry and a display device (LED or LCD) for viewing program steps or functions, as shown in Figure (2.9) More advanced systems employ a separate personal computer which allows the programmer to write, view, edit and download the program to the PLC. This is accomplished with proprietary software available from the PLC manufacturer. This software also allows the programmer or engineer to monitor the PLC as it is running the program. With this monitoring system, such things as internal coils, registers, timers and other items not visible externally can be monitored to determine proper operation. Also, internal register data can be altered if required to fine tune program operation. This can be advantageous when debugging the program. Communication with the programmable controller with this system is via a cable connected to a special programming port on the controller. Connection to the personal computer can be through a serial port or from a dedicated card installed in the computer [7].

Figure (2.9): Programmer Connected to PLC

2.2.5 PLC programing

Programs for microprocessor-based systems have to be loaded into them in machine code, this being a sequence of binary code numbers to represent the program instructions. PLCs are intended to be used by engineers without any great knowledge of programming, this is a means of writing programs which can then be converted into machine code by some software for use by the PLC microprocessor, and this method of writing programs became adopted by most PLC manufacturers. The standard, published in 1993, is IEC 1131-3 (International Electrotechnical Commission), the IEC 1131-3 programming languages are ladder diagrams (LAD), instruction list (IL), sequential function charts (SFC), structured text (ST), and function block diagram (FBD), as shown in Figure (2.10) [6].

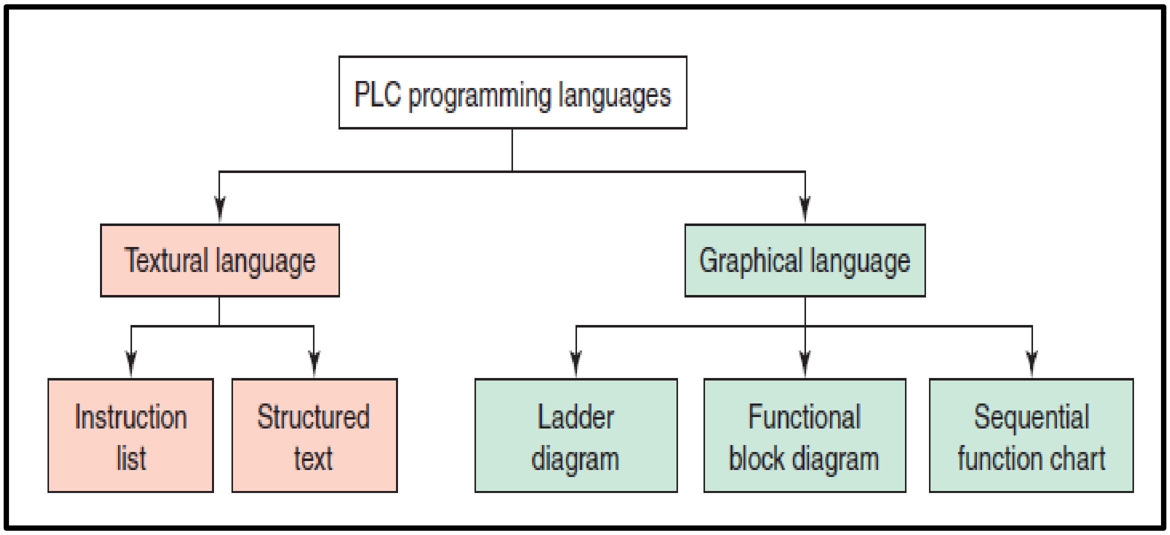

Figure (2.10): Standard IEC 61131 languages associated with PLC programing

Ladder diagrams a very commonly used method of programming PLCs is based on the use of ladder diagrams. Writing a program is then equivalent to drawing a switching circuit. The ladder diagram consists of two vertical lines representing the power rails. Circuits are connected as horizontal lines, i.e. the rungs of the ladder, between these two verticals.

In drawing a ladder diagram, certain conventions are adopted:

- The vertical lines of the diagram represent the power rails between which circuits are connected. The power flow is taken to be from the left-hand vertical across a rung.
- Each rung on the ladder defines one operation in the control process.

- A ladder diagram is read from left to right and from top to bottom, Figure (2.11) showing the scanning motion employed by the PLC. The top rung is read from left to right. Then the second rung down is read from left to right and so on. When the PLC is in its run mode, it goes through the entire ladder program to the end, the end rung of the program being clearly denoted, and then promptly resumes at the start. This procedure of going through all the rungs of the program is termed a cycle. The end rung might be indicated by a block with the word END or RET for return, since the program promptly returns to its beginning.

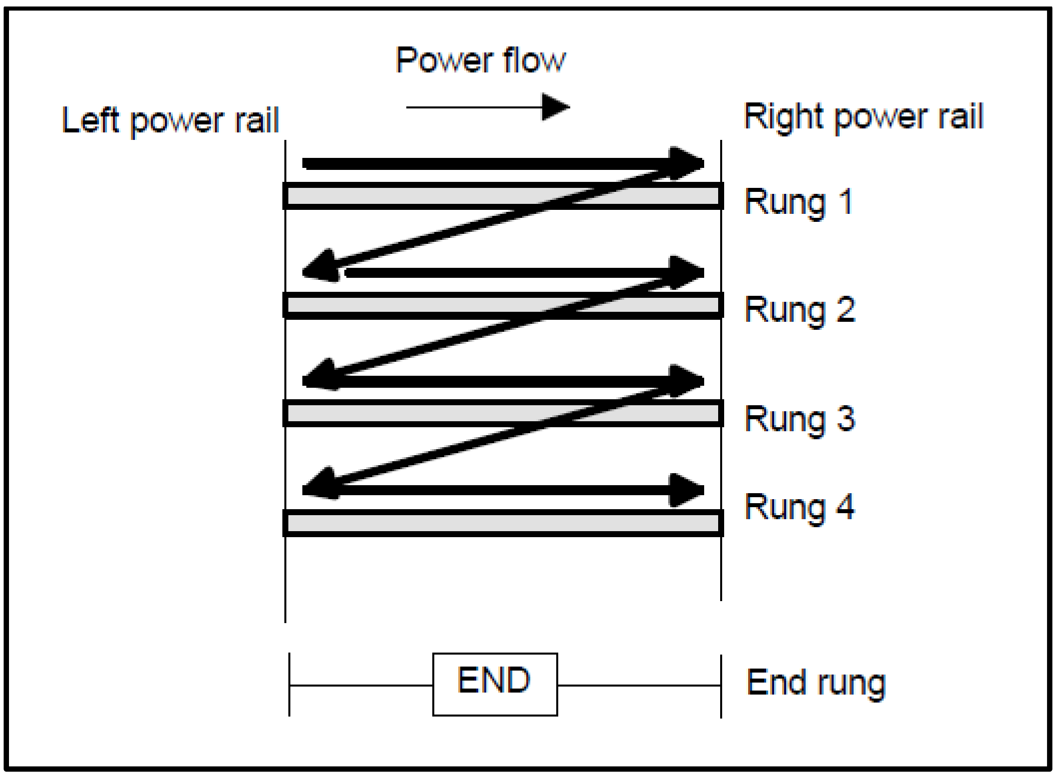

Figure (2.11): Scanning the ladder program

- Each rung must start with an input or inputs and must end with at least one output.

- Electrical devices are shown in their normal condition.
- A particular device can appear in more than one rung of a ladder. The same letters and/or numbers are used to label the device in each situation.
- The inputs and outputs are all identified by their addresses, the notation used depending on the PLC manufacturer. This is the address of the input or output in the memory of the PLC.

Starting with the input, we have the normally open symbol **| |** for the input contacts. There are no other input devices and the line terminates with the output, denoted by the symbol **( )**.When the switch is closed, i.e. there is an input, the output is activated, If there had been a normally closed switch **|/|** with the output, then there would have been an output until that switch was opened as shown in Figure (2.12).

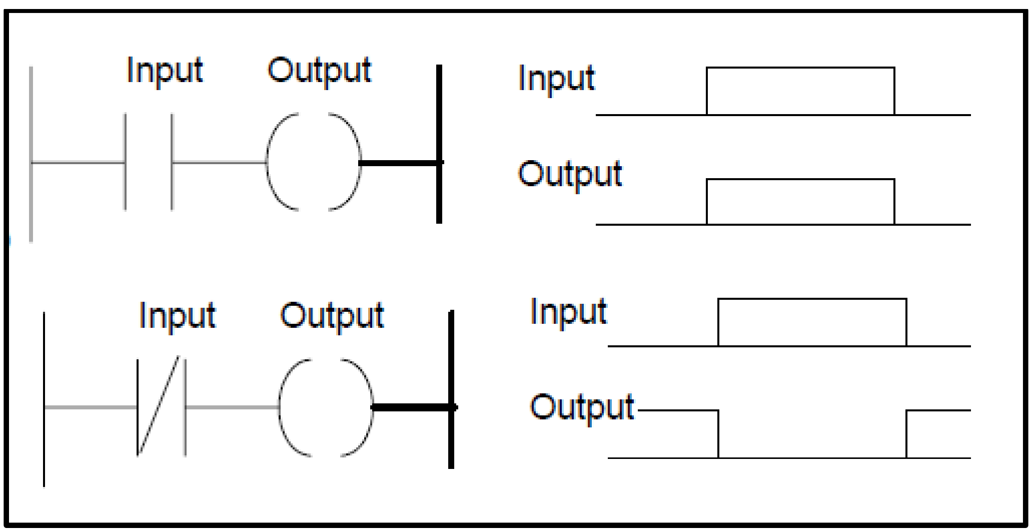

Figure (2.12): A ladder rung

In drawing ladder diagrams the names of the associated variable or addresses of each element are appended to its symbol. Thus Figure (2.13-a) shows how the ladder diagram would appear using Mitsubishi, (2.13-b) Siemens,(2.13-

c) Allen-Bradley, (2.13-d) Telemecanique notations for the addresses. Thus Figure (2.13-a) indicates that this rung of the ladder program has an input from address X400 and an output to address Y430.When wiring up the inputs and outputs to the PLC, the relevant ones must be connected to the input and output terminals with these addresses [6].

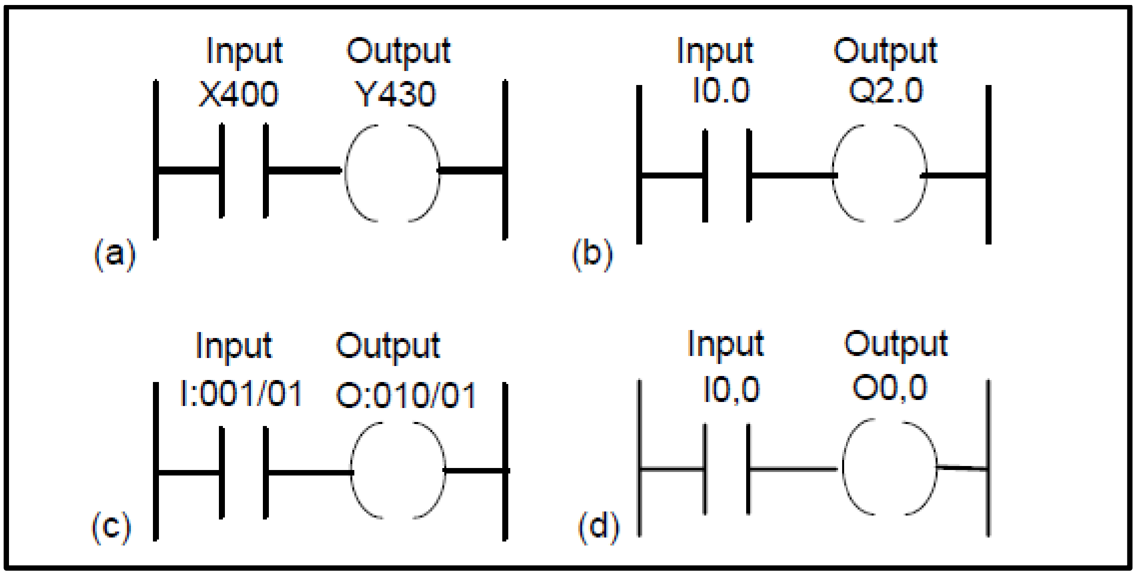

Figure (2.13): Notation: (a) Mitsubishi, (b) Siemens, (c) Allen-Bradley, (d) Telemecanique

2.2.6 PLCs versus computers

PLCs are similar to computers but whereas computers are optimized for calculation and display tasks, PLCs are optimized for control tasks and the industrial environment. Thus PLCs are:

- Rugged and designed to withstand vibrations, temperature, humidity and noise.

- Have interfacing for inputs and outputs already inside the controller.
- Are easily programmed and have an easily understood programming language which is primarily concerned with logic and switching operations [6].

2.2.7 PLC Advantages

- **Flexibility:** One single Programmable Logic Controller can easily run many machines.
- **Correcting Errors:** In old days, with wired relay-type panels, any program alterations required time for rewiring of panels and devices. With PLC control any change in circuit design or sequence is as simple as retyping the logic. Correcting errors in PLC is extremely short and cost effective.
- **Space Efficient:** Today's Programmable Logic Control memory is getting bigger and bigger this means that we can generate more and more contacts, coils, timers, sequencers, counters and so on. We can have thousands of contact timers and counters in a single PLC.
- **Low Cost:** Prices of Programmable Logic Controllers vary from few hundreds to few thousand dollars.
- **Testing:** A Programmable Logic Control program can be tested and evaluated in a lab.
- **Visual observation:** When running a PLC program a visual operation can be seen on the screen. Hence troubleshooting a circuit is really quick, easy and simple [8].

2.3 Human Machine Interface

Human Machine Interface aims at a better Human-machine interaction. Any automation system is said to be blind without HMI. HMI gives the ability to the operator, and the management to view the plant in real time. Add to that the ability to have alarm management that can warn the operator of a problem. It came even log and prints all the alarms in real time, which can help the management to improve the production and efficiency.

Today there are exists many Human Machine Interface software that could be used to monitor, supervise and control process.

The HMI's main functionality is to monitor, supervise, and control processes. This could be used in a variety of industries such as food processing, sawmills, bottling, semiconductors, oil and gas, automotive, chemical, pharmaceutical, pulp and paper, transportation, utilities, and more. HMI software provides the process knowledge and control needed to perfect the products companies make and the processes they manage. It is said that a control without an HMI is a blind control.

Human Machine Interface can display texts, pictures, bar graphs, bitmap and animated pictures. More importantly it can also display system messages, reports, alarms, trends and manipulate string values and calculate Boolean operations and more complex math operations. More and more manufacturing designers are recognizing the benefits of using Human Machine Interface to control and to operate their controls [9].

2.3.1 Typical Applications

- Machine monitoring and control.
- Supervisory Control and Data Acquisition (SCADA).
- Control Center Monitoring, Tracking, and Control.
- Building Automation and Security.
- Electrical Substation Monitoring.
- Pipeline Monitoring and Control.
- Transportation Control Systems.

- Batch Process Monitoring and Control.
- Continuous Process Monitoring and Control.
- Heating, Ventilation, and Air Conditioning.
- Statistical Process Control (SPC).
- Telecommunications.
- Discrete Manufacturing [9].

2.3.2 HMI Advantages

The following is a list of some of the most important features of having Human Machine interface.

- **High quality graphics for realistic representations of machinery and processes:** This will give the operator and the management a very realistic view of the plant. The operator does not need to be close to the equipment to control of monitor.
- **Alarms (Real Time / Historical):** Viewing alarms will help the operator to locate and react faster to any malfunction of any anomalies. Some of the alarms could be of preventive type, for example to create a warning alarm on a hydraulic tank oil level before the oil level really reaches a critical point. Historical Alarm logging is very useful to track problems. It could be used to optimize process, which in turn would increase productivity and reduce lost time.
- **Trends (Real Time / Historical):** Trends are very useful with PID's. You can view the curve used to reach a certain set point. Study of certain values will result in optimizing your process, and it will certainly make it much more efficient.

- **Recipe Manager:** Simple and complex recipe could be controlled with HMI. This is very useful and very effective way to execute recipes.
- **Simulation:** Some of the high quality HMI's will be so flexible that you can simulate a plant in your office. This will help PLC program developers test their program without having single equipment or devices. This kind of simulation is used more and more to reduce startup time.
- **Messaging:** This is a very interesting functionality. You can message, page or fax someone when a certain event happens. For example let's say the oil level in the hydraulic tank has reaching a low level. Then low oil level will be triggered and it will page the person in charge to fill up the tank.

  Animate equipment's and instrument based on operator standards: one picture is better than 100 words. Now this is not only a picture it is an animated one. This will really improve the whole view of the process. Any anomalies will be detected much easier.
- **Reduce the cost of hardware:** An HMI can replace hundreds of push buttons, selectors, Lights and so on. As a result less consoles and panels and definitely less cables all over the plant.

- **Communication:** Today most HMI can communicate with many different brands of PLC's. The most communications used are Serial Port, Data Highway Plus (DH+), Remote I/O and DDE - Dynamic Data Exchange (DDE) [9].

2.4 Sensors

The devices that inform the control system about what is actually occurring are called sensors also known as transducers. For a control system, the designer must ascertain exactly what parameters need to be monitored for example, position, temperature, and pressure and then specify the sensors and data interface circuitry to do the job [10].

2.4.1 Position sensors

Position sensors report the physical position of an object with respect to a reference point. The information can be an angle, as in how many degrees a radar dish has turned, or linear, as in how many inches a robot arm has extended. Position sensors have many types such as linear-motion potentiometers, rotary potentiometers, Absolute optical encoders, incremental optical encoder and linear variable differential transformer (LVDT) [10].

2.4.2 Angular velocity sensors

Angular velocity sensors, or tachometers, are devices that give an output proportional to angular velocity. These sensors find wide application in motor-speed control systems. They are also used in position systems to improve their performance [10].

2.4.3 Proximity sensors

A proximity sensor simply tells the controller whether a moving part is at a certain place. A limit switch is an example of a proximity sensor. A limit switch is a mechanical push-button switch that is mounted in such a way that it is actuated when a mechanical part or lever arm gets to the end of its intended travel. Switches are suitable for many applications, but they have at least two drawbacks:

- Being a mechanical device, they eventually wear out.
- They require a certain amount of physical force to actuate.

Two other types of proximity sensor, which use either optics or magnetics to determine objects [10].

2.4.4 Load sensors

Load sensors measure mechanical force. The forces can be large or small for example, weighing heavy objects or detecting low-force tactile pressures. In most cases, it is the slight deformation caused by the force that the sensor measures, not the force directly.

Typically, this deformation is quite small. Once the amount of tension (stretching) or compression (squeezing) displacement has been measured, the force that must have caused it can be calculated using the mechanical parameters of the system. The ratio of the force to deformation is a constant for each material, as defined [10].

2.4.5 Pressure sensors

Pressure is defined as the force per unit area that one material exerts on another. In SI units, pressure is measured in newton per square meter

(N/m^2), which is called a Pascal (Pa). For a liquid, pressure is exerted on the side walls of the container as well as the bottom.

Pressure sensors usually consist of two parts: The first convert pressure to a force or displacement, and the second converts the force or displacement to an electrical signal. Pressure measurements are made only for gases and liquids. The simplest pressure measurement yields a gauge pressure, which is the difference between the measured pressure and ambient pressure.

A slightly more complicated sensor can measure differential pressure, the difference in pressure between two places where neither pressure is necessarily atmospheric. Pressure sensor measures absolute pressure, which is measured with a differential pressure sensor where one side is referenced at 0 psi (close to a total vacuum) [10].

2.4.6 Temperature sensors

Temperature sensors give an output proportional to temperature. Most temperature sensors have a positive temperature coefficient (desirable), which means that the sensor output goes up as the temperature goes up, but some sensors have a negative temperature coefficient, which means that the output goes down as the temperature goes up. Many control systems require temperature sensors, if only to know how much to compensate other sensors that are temperature-dependent. Some common types are resistance temperature detector (RTD), Thermistors and Thermocouples [10].

2.4. 7 Vision sensors

A vision sensor is a TV camera connected to a computer. Machine vision is being used to perform inspections and to guide machine operations. Alternatively, a vision system might be used to provide guidance to a pickand-place robot for doing such things as unloading boxes from a pallet or inserting components in a circuit board. Vision systems require computing power to process thousands of pixels of information continuously in order to arrive at a go/no-go decision.

Vision-guided systems are now performing operations that before had to be done by hand or with very long and complicated but inflexible multi-sensor systems [10].

2.5 Direct Current Motors

An indispensable component of the control system is the actuator. The actuator is the first system component to actually move, converting electrical energy into mechanical motion. The most common type of actuator is the electric motor. Motors are classified as either DC or AC, depending on the type of power they use. AC motors have some advantages over DC motors. They tend to be smaller, more reliable, and less expensive. However, they generally run at a fixed speed that is determined by the line frequency. DC motors have speed-control capability, which means that speed, torque, and even direction of rotation can be changed at any time to meet new conditions. Also, smaller DC motors commonly operate at lower voltages (for example, a 12-V disk drive motor), which makes them easier to interface with control electronics [10].

2.5.1 Theory of operation

The discovery that led to the invention of the electric motor was simply this: A current carrying conductor will experience a force when placed in a magnetic field. The conductor can be any metal iron, copper, aluminum, and so on. The direction of the force is perpendicular to both the magnetic field and the current. A demonstration of this principle is easy to perform with a strong magnet, flashlight battery, and a wire and is highly recommended. Place the wire between the magnet poles and alternately connect and disconnect the wire from the battery.

An electric motor must harness this force in such a way as to cause a rotary motion. This can be done by forming the wire in a loop and placing it in the magnetic field as shown in Figure (2.14) .The loop (or coil) of wire is allowed to rotate about the axis shown and is called the armature winding. The armature is placed in a magnetic field called the field. The commutator and brushes supply current to the armature while allowing it to rotate [10].

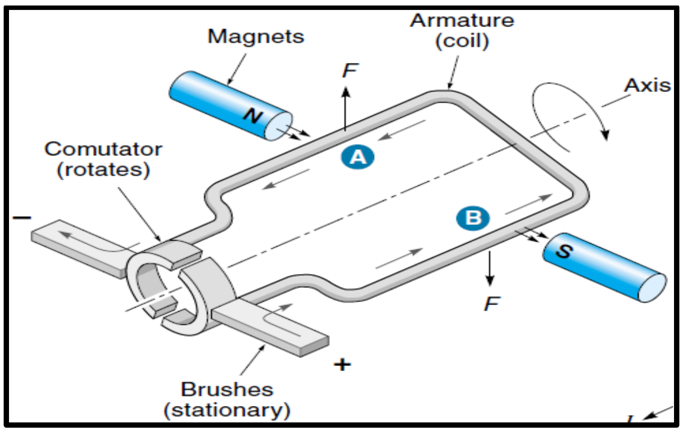

Figure (2.14): Conventional DC motor action

2.5.2 Wound-field dc motors

There are three types of electrical connections between the stator and rotor possible for DC electric motors:

- Series-Wound Motors
- Shunt-Wound Motors
- Compound Motors

2.5.3 permanent-magnet motors

Permanent-magnet (PM) motors use permanent magnets to provide the magnetic flux for the field. Three types of magnets are used:

- The Alnico magnet (iron based alloy) has a high-flux density but loses its magnetization under some conditions such as a strong armature field during stalled operation.
- Ferrite (ceramic) magnets have a low flux density, so they have to be larger, but they are not easily demagnetized.
- The newer, so-called rare-earth magnets, made from samarium-cobalt or neodymium-cobalt, have the combined desirable properties of high-flux density and high resistance to demagnetization.

At the present time, the size of PM motors is limited to a few horsepower or less. Small PM motors are used extensively in office machines such as printers and disk drives, toys, equipment such as cameras (for zoom and autofocus), and many places in industry. Larger PM motors are used in control systems such as industrial robots.

2.5.4 Brushless Dc motors

The weak point in the mechanical design of the DC motor is the brushes rubbing against the rotating commutator (to get current into the armature). Brushes wear out, get dirty, cause dust, and are electrically noisy. The brushless DC motor (BLDC) operates without brushes by taking advantage of modern electronic switching techniques. Although this adds some complexity, the result is a motor that is extremely reliable, very efficient, and easily controlled—all very desirable qualities. The BLDC is becoming increasingly popular, particularly in those cases where the motor must be operated from a DC source such as a battery.