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INDUSTRIAL AUTOMATION WITH PLC

INDUSTRIAL AUTOMATION

Due to the rapid advances in technology, all industrial processing systems, factories, machinery, test facilities, etc. turned from mechanization to automation. A mechanization system needs human intervention to operate the manual operated machinery. As new and efficient control technologies evolved, computerized automation control is being driven by the need for high accuracy, quality, precision, and performance of industrial processes.

Automation is a step beyond mechanization which makes use of high control capability devices for efficient manufacturing or production processes.

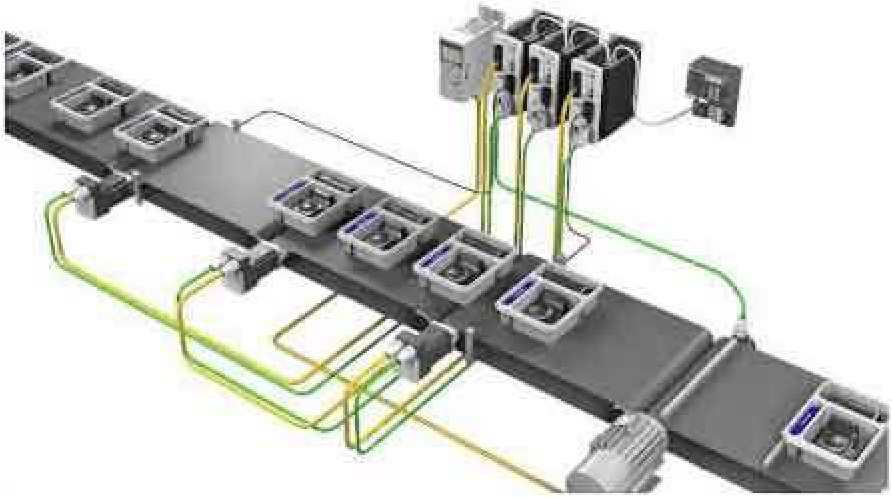
What is Industrial Automation?

Industrial automation is the use of control devices such as PC/PLCs/PACs etc. to control industrial processes and machinery by removing as much labour intervention as possible, and replacing dangerous assembly operations with automated ones. Industrial automation is closely linked to control engineering.

Automation is a broad term applied to any mechanism that moves by itself or is self-dictated. The word ‘automation’ is derived from ancient Greek words Auto (means ‘*self*’) Matos (means ‘*moving*’). As compared with manual systems, automation systems provide superior performance in terms of precision, power, and speed of operation.

In industrial automation control, a wide number of process variables such as temperature, flow, pressure, distance, and liquid levels can be sensed simultaneously. All these variables are acquired, processed, and controlled by complex microprocessor systems or PC based data processing controllers.

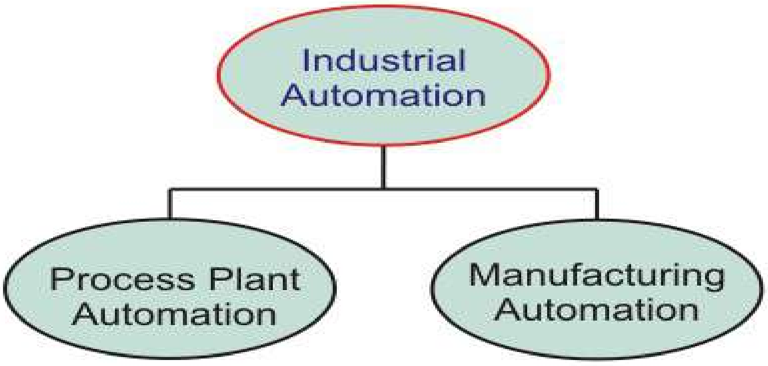
Control systems are an essential part of an automation system. The various types of closed-loop control techniques ensure the process variables to follow the set points. In addition to this basic function, the automation system employs different other functions such as computing set points for control systems, plant start up or shut down, monitoring system performance, equipment scheduling, etc. The control systems combined with monitoring adapted to the operating environment in the industry allow for a flexible, efficient, and reliable production system.



The automated system needs special dedicated hardware and software products for implementing control and monitoring systems. In recent years, a number of such products have been developed from various vendors which providing their specializing software and hardware products. Some of these vendors are Siemens, ABB, AB, National Instruments, Omron, and so on.

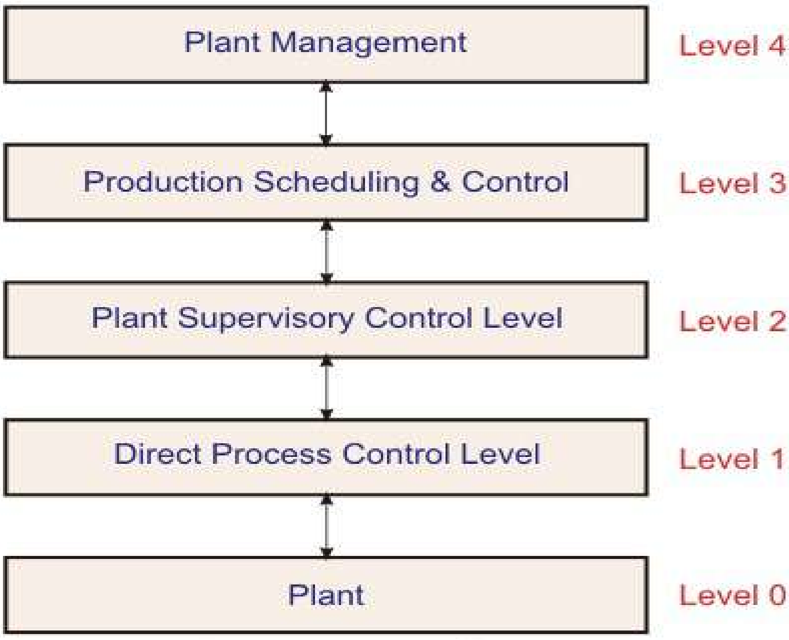
Types of Industrial Automation:

Industrial automation is the use of computer and machinery aided systems to operate the various industrial operations in a well-controlled manner. Depends on the operations involved, the industrial automation systems are majorly classified into two types, namely process plant automation and manufacturing automation.



Process Plant Automation:

In process industries, the product results from many chemical processes based on some raw materials. Some of the industries are pharmaceuticals, petrochemical, cement industry, paper industry, etc. Thus the overall process plant is automated to produce the high quality, more productive, high reliable control of the physical process variables.



Process Plant Automation System Hierarchy

The above figure shows the process automation system hierarchy. It consists of various layers representing widespread components in a process plant.

Level 0 or Plant: This level consists of machines that are closest to processes. In this, sensors and actuators are used to translate the signals from the machines and physical variables for the purpose of analysis and to produce the control signals.

Direct Process Control: In this level, automatic controllers and monitoring systems acquire the process information from sensors and correspondingly drives the actuator systems. Some of the tasks of this level are-

- Data acquisition
- Plant monitoring
- Dara checking
- Open and closed-loop control
- Reporting

Plant Supervisory Control: This level commands the automatic controllers by setting the targets or set points. It looks after the control equipment for optimal process control. Some of the tasks of this level are:

- Plant monitoring performance
- Optimal process control
- Plant coordination
- Failure detection, etc.

Production Scheduling and Control: This level solves the decision-making problems like resource allocation, production target, maintenance management, and so on. Tasks of this level include:

- Production dispatch
- Inventory control
- Production supervision, production reporting, etc.

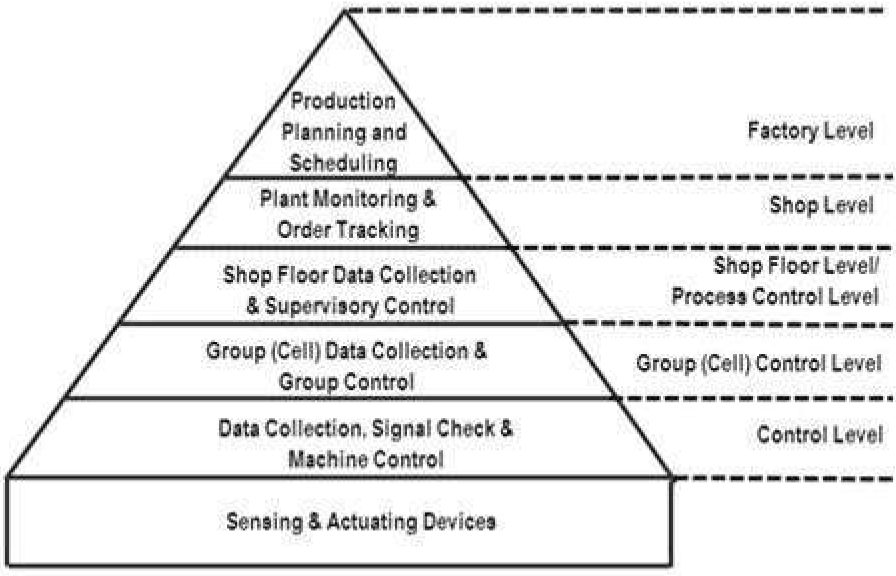
Plant Management: This is the higher level of the process plant automation. It deals more with commercial activities than technical activities. Tasks of this level include-

- Market and Customer analysis
- Orders and sale statistics
- Production planning
- Capacity and order balance, etc.

Manufacturing Automation System:

The manufacturing industries make the product out of materials using machines/robotics. Some of these manufacturing industries include textile and clothing, glass and ceramic, food and beverages, paper making, etc. New trends in manufacturing systems have been using automation systems at every stage such as material handling, machining, assembling, inspection, and packaging. With computer-aided control and industrial robotic systems, manufacturing automation becomes very flexible and efficient.

The figure below shows the manufacturing automation system hierarchy in which all functional levels are automated by using different automation tools.



Manufacturing Automation System Hierarchy

Below is an explanation of each level in the manufacturing automation system hierarchy:

Machinery Level: In this level various sensing and actuating devices controls the manufacturing process. It is an instrumentation level of machine control. Tasks of this level include data collection, signal check, and machine control.

Cell or Group Level: This is another automation level at which the operation of a group of machines within manufacturing cells are co-ordinated. Various automated controllers like PLCs are employed for such control of machines.

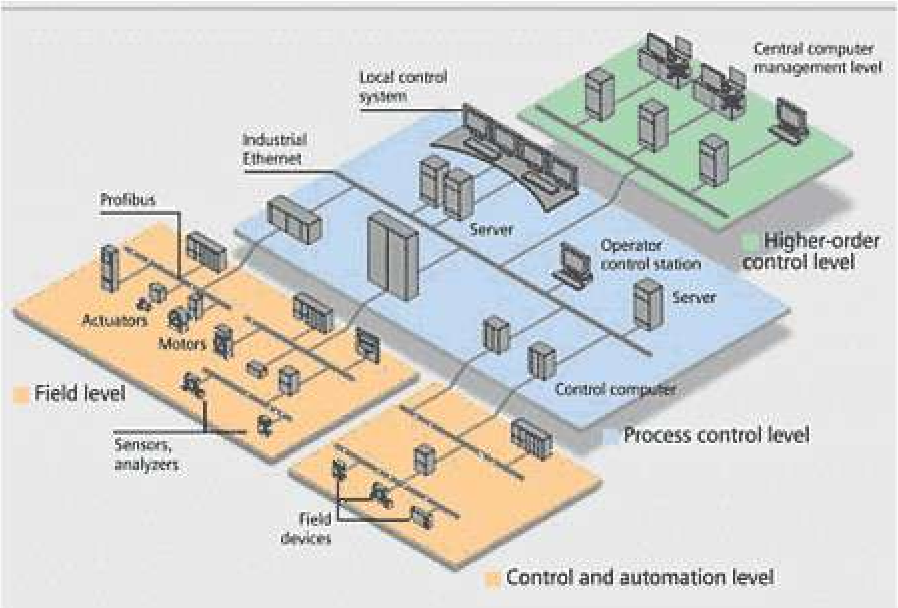
Shop Floor Level: It is a supervisory automated level where supervision and coordination of several manufacturing cells are carried out.

Plant Level: This automation level performs the activities of production monitoring, control, and scheduling, etc. HMIs employed at this level facilitate control of all the manufacturing process variables remotely.

Enterprise Level: This level does all the management related activities such as production planning and scheduling, etc.

Industrial Automation Equipment:

Industrial automation (IA) is an integrated, flexible, and low-cost system platform that consists of various equipment and elements which perform a wide variety of functions like sensing, control, supervision, and monitoring related to industrial processes. The figure below shows the structure of industrial automation which describes the various functional elements of IA.



Sensing and Actuating Elements:

The_sensors or sensing elements convert the physical process variables such as flow, pressure, temperature, etc. into electrical or pneumatic form. Various sensors include thermocouples, Resistor Temperature Detectors (RTDs),_strain gauges, etc. The signals from these sensors are used for processing, analysing, and decisions in order to produce the control output. The various control techniques are implemented to produce the required output by comparing the current sensed process variable with set values. Finally, the controllers produce the computed outputs and are applied as electrical or pneumatic signal inputs to the actuating elements. Actuators convert the electrical or pneumatic signals to the physical process variables. Some of the actuators include control valves, relays, motors, etc.

A special category of the instruments is smart instruments which are integrated systems of sensing or actuating elements with the capability of communicating with field buses. These smart devices consist of a signal conditioning circuit internally and facilitate connecting directly to the communication link in the industrial bus system.

Control System Elements:

These are the microprocessor-based electronic controllers or simply industrial computers that accept the signals from various sensors as well as command signals from supervisory systems or from human operators. These controllers can be continuous control systems or sequential/logic control depends on the structure of control nature. The controller processes the sensing values and supervisory values and depends on the control structure, it produces the control output to various actuating devices.

A modern type of control device used in automation systems is the Programmable Logic Controller (PLC). PLCs come with dedicated software so that these are capable of being programmed to perform corresponding control operations. PLCs have rugged CPU, digital I/O, analog I/O, and communication modules such that they can operate at industry environment conditions to control the various process parameters.

Human Machine Interface or operator interface is a graphical interface for the operators which displays the process information such as process variable status, logging results to the database, generating alarm signals, etc. SCADA is one of the graphical user interfaces which remotely controls industrial operations. Also, Distributed control systems (DCS) provide their own HMI for the graphical display of various industrial parameters.

Supervisory Control Elements:

Supervisory control performs higher-level control over the automatic controllers which further controls the smaller subsystems. The major elements of this level process station PCs, and Human Machine Interfaces. These process station PCs are responsible for functions like setpoint computations, performance monitoring, diagnostics, start-up, shutdown, and other emergency operations.

Human Machine Interface or operator interface is a graphical interface for the operators which displays the process information such as process variable status, logging results to the database, generating alarm signals, etc. SCADA is one of the graphical user interfaces which remotely controls industrial operations. Also, Distributed control systems (DCS) provide their own HMI for the graphical display of various industrial parameters.

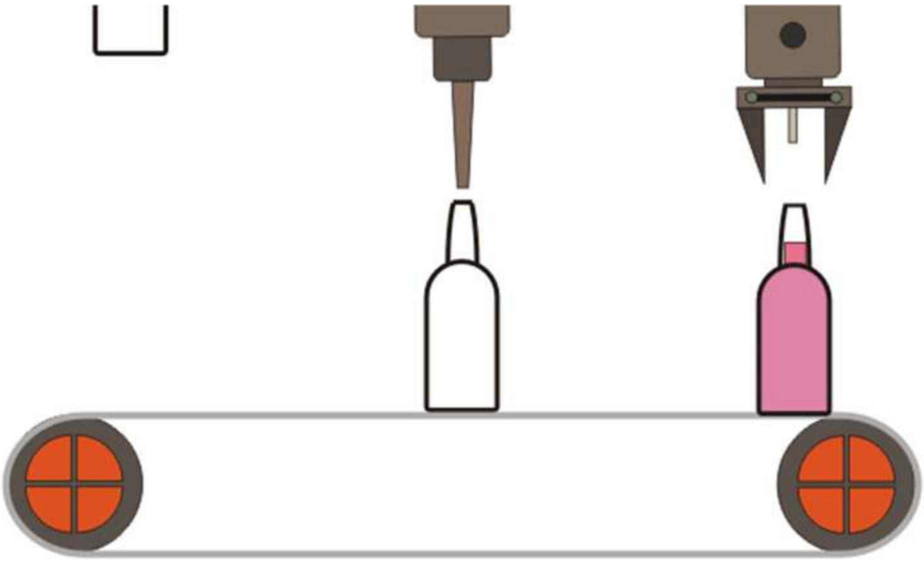
Advantages of Industrial Automation:

Manufacturers face many challenges in today's globally competitive business landscape. Some of these challenges include harsh manufacturing environments (*in a world which is increasingly focused on safety – and rightly so*), increasingly complex supply chains, meeting the latest energy efficient standards, and competing with companies with very small marginal costs. Many of these reasons drive manufacturers towards industrial automation. The advantages of Industrial Automation include:

- Increased labor productivity
- Improved product quality
- Reduced labor or production cost
- Reduced routine manual tasks
- Improved safety
- Assisted remote monitoring

Increased Labor Productivity:

Automation increases the production rate by producing greater output for given labor input. It is not possible for human workers to work for long hours without losing accuracy. On the other hand, without compromising on accuracy, automated control systems able to work for long hours. Hence increased productivity and efficiency per hour of labor input.



Improved Product Quality:

One of the chief benefits of automation is that the reduction of the fraction defect rate. With the manual operation of the manufacturing process, there may be a compromise on the quality specifications of the product. But the automation system performs operations with greater conformity and uniformity to the quality specifications. By using the automation systems, industrial processes are controlled and monitored at all stages in order to produce a qualitative end product.

Reduced Labor or Production Cost:

The automated systems help the industries to save a great deal in the long term by substituting automated machinery in place of human labor so that unit production cost is reduced. Automation equipment running smoothly or uniformly 24 × 7 not only increases productivity but also consequently results in an excellent return on investment by saving salaries, workforce costs, pensions, and costs with employees. The automated system also reduces the labor shortage by substituting automated operations in place of labor.

Reduced Routine Manual Tasks:

In many industrial applications, process variables like temperature, liquid level, pressure, etc. are to be periodically monitored as a routine task to maintain their set levels. Thus an automation system creates the automatic working condition by employing closed-loop control systems.

Improved Safety:

By implementing an automated system, work is made safer by transferring the worker from an active participation location in the process to the supervising role. The automated machines are able to work in hazardous environments and other extreme environments. Also, these systems make use of industrial robots in place of human workers, especially in life-threatening conditions (chemical and high-temperature conditions). Thus an industrial automation system prevents accidents and injuries to the workers.

Assist Remote Monitoring:

Most of the industrial operations have to be controlled remotely for convenient and long-distance monitor and control of process variables. For such cases, automated systems provide a communication link between the process area and supervising (monitor and control) area, thereby allowing operators to control and monitor the industrial processes from a remote location. The best example of this remote control is the automated electric power grid control.

An Overview of Programmable Logic Controllers (PLC)

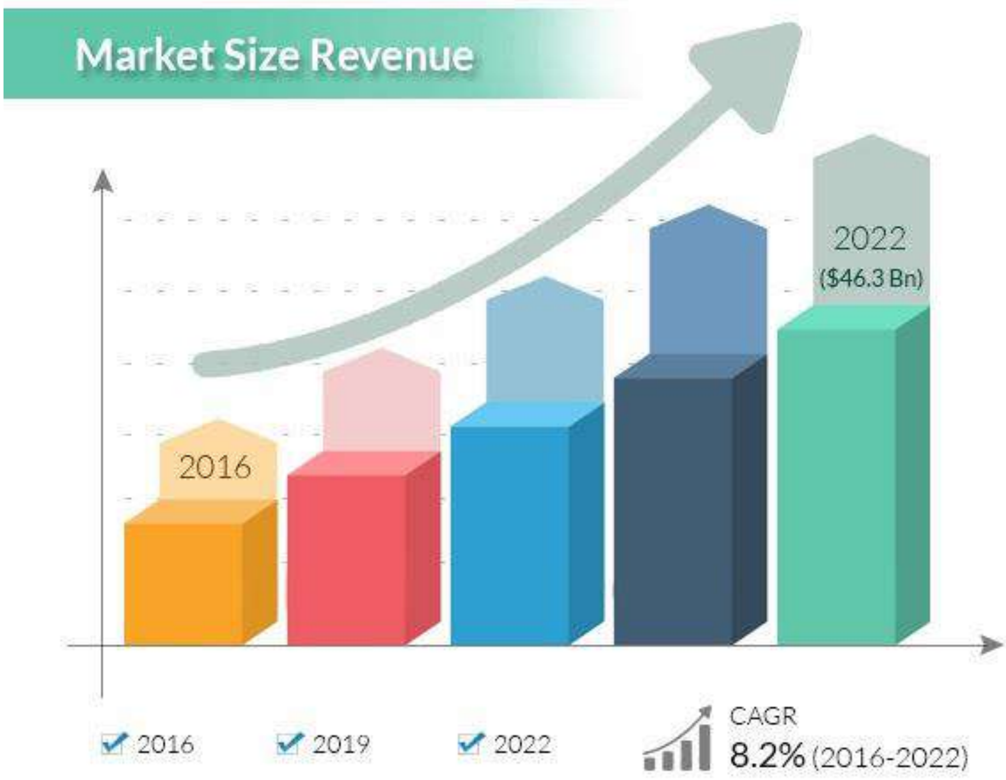
Programmable Logic Controllers (PLCs) have been used in the automation market for more than 40 years. Still, the global PLC market is showcasing remarkable growth since 2016.

In addition, the latest advancements in PLCs have greatly increased their capabilities in industrial automation solutions. Due to its advanced automation handling capabilities, the introduction of PLCs has been aiding the market in terms of better operability.

PLC Market – Overview

The changing industrial landscape of emerging economies such as India, Brazil, Indonesia, and Mexico is stimulating the adoption of PLCs. The increasing demand for industrial control systems in the automation, manufacturing and construction industries will fuel the demand in the global market.

On the other hand, the PLC market (programmable logic controllers market) is projected to reach revenues of more than $46 billion by 2022 and is estimated to grow at a CAGR of over 8% during the forecast period.



PLC Market – Dynamics

The growing prominence of PAC (Programmable Automation Controllers) and PLC-based PACs is attributing to the growth of the PLC market. According to Technavio's market research report, the demand for PLCs will grow at a steady rate and the growing need, the popularity of customized PLCs will drive the growth prospects.

In the manufacturing industries, there is an increasing demand for customized PLC programming solutions that help industries design their own controller package for small, medium, or large machines. On the other hand, customized PLCs provide solutions for demanding industrial environment, and process complexity and also offer automation solutions such as system reliability, system stability, and interoperability, which will fuel the adoption of PLCs in the coming years.

Introduction to PLC (Programmable Logic Controller):

The **National Electrical Manufacturers Association (NEMA)** defines PLC as a

"Digitally operating electronic apparatus which uses a programmable memory for the internal storage of instructions by implementing specific functions, such as logic, sequencing, timing, counting, and arithmetic to control through digital or analog I/O modules various types of machines or processes."

Programmable Logic Controller (PLC) is a ruggedized digital computer that is used for industrial automation to carry out typical industrial electromechanical processes such as control of machinery on factory assembly lines, amusement rides, or light fixtures. These controllers help to automate a specific process, machine function, or even an entire production line.

They are specifically designed for multiple arrangements of digital, analog inputs and outputs, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. The major purpose of PLCs is to monitor crucial process parameters and adjust process operations accordingly. PLCs are extensively used as they are easy to set up a program, and they are ruggedized.

Components in a PLC system

- CPU module, containing the processor and memory.
- Input and output modules, to allow the PLC to read sensors and control actuators
  - A wide variety of types are available.
- Power supply for the PLC, and often sensors and low power actuators connected to I/O modules.
- A rack or bus so the PLC can exchange data with I/O modules.
- A Programming unit is used to create; edit and download a user program to the PLC
- Additional components can include:
  - Network interfaces: to allow PLCs to function in a networked environment.
  - Communication adapters for remote I/O devices: so I/O devices do not have to be physically close to the CPU module.
  - Operator interface devices: allow monitoring and/or data entry by operators.

Working of PLC:

The PLC obtains information from connected sensors/input devices and then processes the data, and triggers outputs based on pre-programmed parameters. PLC can monitor and record run-time data such as machine productivity or operating temperature, depending on the inputs and outputs.

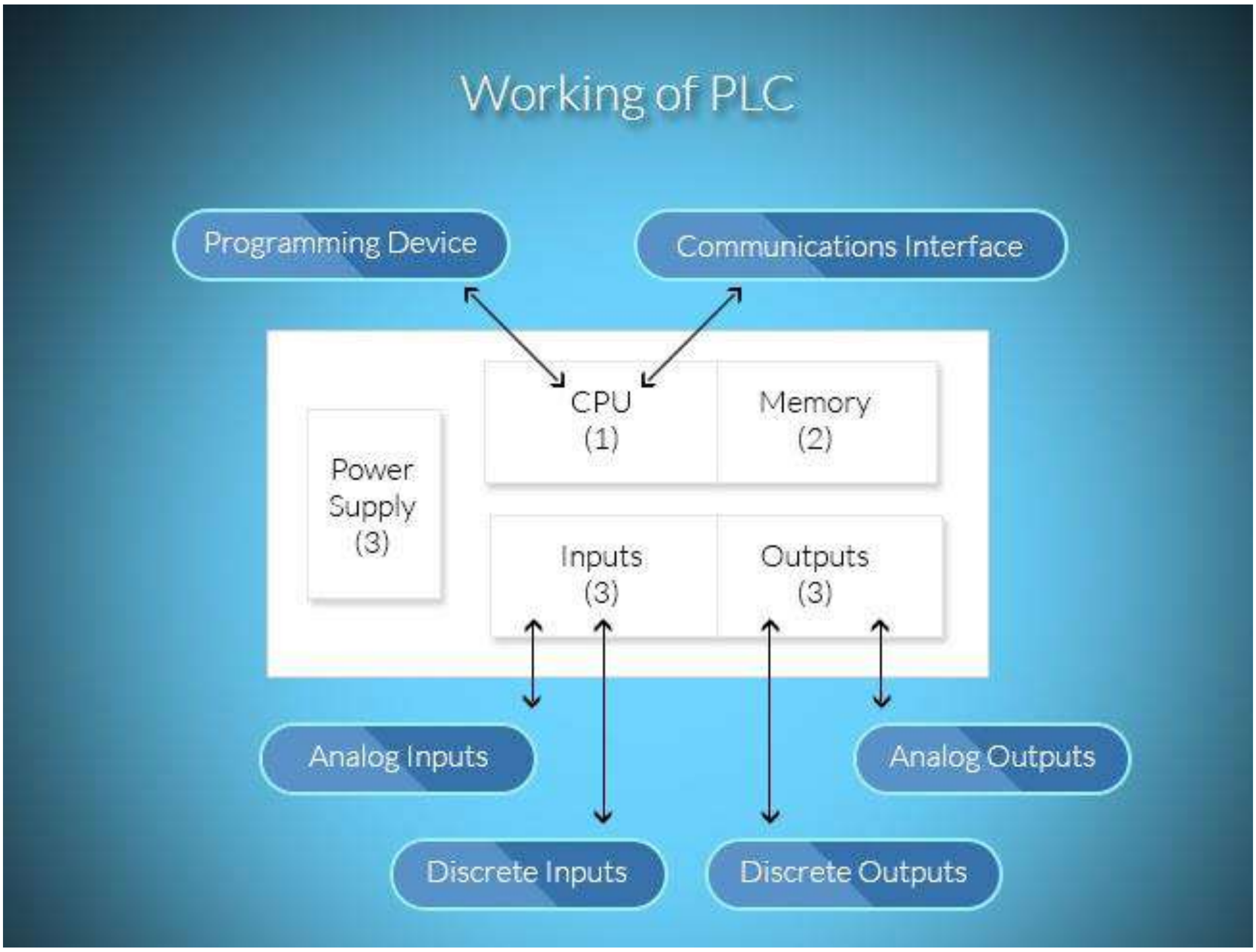


Figure: Block Diagram of PLC

It starts and stops processes automatically and generates alarms if a machine malfunctions. Programmable Logic Controllers are a flexible and robust control solution that is adaptable to almost any application.

The components that make a PLC to work efficiently can be divided into three core areas.

- The power supply and rack
- The central processing unit (CPU)
- The input/output (I/O) section

The working of PLC includes sequential relay control, motion control, process control, distributed control systems, and networking. The most basic function of a programmable logic controller is to follow the functions of electromechanical relays. Separate inputs are given a unique address, and a PLC instruction is tested whether the input state is 'on' or 'off'.

In automation, TRUE or FALSE conditions can be considered as ON or OFF, CLOSED or OPEN. In the PLC, we will consider the binary system (0 or 1).

Typically, having a bit ON represents a TRUE condition while OFF is FALSE.

Applications of PLC:

PLCs are used in various places of automation because of its flexibility. As humans feel tedious to carry out all the tasks, relays were used to perform those activities. However, a relay can be used only for a specific and limited operation which makes their use bulky and uneconomic.

PLCs can be used in various applications:

- The robotic arm in car manufacturing
- Air compressors
- Airport runway lighting control
- Traffic signal control
- Smoke alarm control
- Process valve control
- Textile equipment
- Vacuum pump system

Advantages/Disadvantages of PLC: Advantages of PLC are:

Flexibility: It can easily run many machines.

Corrects Errors: 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: We can generate more & more contacts, coils, timers, counters, sequences etc. and 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 thousands.

Testing: A Programmable Logic Control program can be tested and evaluated in a lab. The program can be tested, validated and corrected saving very valuable time.

Easier Troubleshooting: Troubleshooting a circuit is really quick, easy and simple.

Disadvantages of PLC are:

- It is difficult to find errors and requires a skilful work-force to operate.
- When a problem occurs, hold-up time is indefinite, usually long.
- There will be too much work required in connecting wires
- There will be a difficulty with changes or replacements

Types of PLC:

PLCs are integrated as either single or modular units. The types of PLCs are:

1. An integrated or Compact PLC
2. A modular PLC
3. Small PLC

4. Medium-sized PLC
5. Large PLCs

Integrated or Compact PLC:

It is built with several modules within a single case. Therefore, the I/O capabilities are decided by the manufacturer. Some of the integrated PLCs allow connecting additional I/Os to make them somewhat modular.

Figure: Integrated or Compact PLC

Modular PLC:

Modular PLC is built with several components that are plugged into a common rack or bus with extendable I/O capabilities. It contains a power supply module, CPU and other I/O modules that are plugged together in the same rack. These modular PLCs come in different sizes with variable power supply, computing capabilities, I/O connectivity, etc.

Figure: Modular PLC

Modular PLCs are further divided into small, medium and large PLCs based on the program memory size and the number of I/O features.

Small PLC:

It is a mini-sized PLC that is designed as a compact and robust unit mounted or placed beside the equipment to be controlled. It can be used for replacing hard-wired relay logic, counters, timers, etc. It uses a logic instruction list or relay language as the programming language.

Medium-sized PLC:

Medium-sized PLC is mostly used PLC in industries as it allows may plug-in modules that are mounted on the black plane of the system. Communication module facilities, input/outputs are provided by adding additional I/O cards.

Large PLCs:

Large PLCs are used when complex process control functions are required. These PLCs' capacities are quite higher than the medium PLCs in terms of memory, programming languages, I/O points, and communication modules, and so on.

These PLCs are used in supervisory control and data acquisition (SCADA) systems, larger plants, distributed control systems, etc.

Interlocking in PLC:

Programming in PLC is done using Ladder logic or other formats. There are various terms that are used in programming to identify how they will interact with another system:

These terms include:-

- Permissives
- Protections
- Interlocks

Permissives: They are minimum perquisites that are required for the drive or system to operate. Like lubrication system should be on before a drive starts etc.

Protections: They prevent a drive/logic from a harmful condition and stop the system to prevent human or mechanical damage.

Interlocks: They are codes or conditions that are executed when another action happens and change how the drive/code was working to provide a smooth-running process.

In other words, Interlocks are often used to start auxiliary equipment, standby drives, or to prevent the starting of systems for smooth operations.

Example: If two mortars (say motor A & Motor B). Say, if one motor is used generally but necessary 24 X 7. Then adding an interlock in the logic of motor A because if the other motor B turns off due to error then start to drive A.

A keynote is that Interlocks will require permissives to be followed, i.e. only interlock is not sufficient, permissives are also to be met. Interlocks provide some ease in operation and reduce human errors.

Interlocking:

In the PLC program, it is an action to control the process when certain conditions occur i.e. temperature exceeding its limit, flow below requirement, or any parameter exceeding beyond its safe operating limits.

Importance of PLC: The importance of PLC in automation is:

1. PLC is used in fully automated industries. The actual processes handled and controlled by the controllers mean that PLC plays a very important role in the automation section.
2. PLCs constantly monitor the state of the systems through input devices and generate the control actions according to the logic given in the user program.
3. It is the heart of control systems, PLC monitors the state of the system through field input devices, feedback signals and based on the feedback signal PLC determine the type of action to be carried out at field output devices.
4. It provides logic/sequence control.

Overall, PLC has a great impact on the automation industry in controlling the devices and programming logically. It is mainly designed for multiple inputs and output arrangements and it can withstand extreme temperatures with resistance to vibration and impact.