SNS COLLEGE OF ENGINEERING

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

19EE602 INDUSTRIAL AUTOMATION

III YEAR / 06 SEMESTER EEE

Unit 1 – INTRODUCTION TO PLC

What is a Programmable Logic Controllers (PLC)

- PLC stands for Programmable Logic Controller which was invented in automobile manufacturing to provide a flexible, rugged, and easily programmable controller to automate a system in the year of 1964 by Dick Morely.
- That's why he is called as father of PLC.
- PLC is a general-purpose computer modified specially to perform control tasks. It is used for industrial automation to automate a specific process, machine function, or even entire production.
- PLCs are developed for electronic replacement for hard-wired relay logic circuit systems for machine control.
- They are designed for industrial use to control many automated processes in industries.

What is a Programmable Logic Controller (PLC)?

- A programmable Logic Controller(PLC) is a specialized digital computer employed in industrial settings for automation and control.
- Acting as the central brain of machinery and processes, PLCs receive input from sensors, process the data through programmed logic, and generate output signals to control devices like motors and valves.
- They use a programming language, often ladder logic, resembling electrical relay diagrams.
- PLCs are ruggedized for harsh industrial environments and play a crucial role in automating tasks and reducing manufacturing and energy.
- Their modular design allows scalability, making them versatile components in modern industrial control systems.

Where Can PLC Be Used?

- PLCs play a pivotal role in industrial automation, efficiently managing machinery and processes.
- They receive data from sensors, execute programmed logic, and control actuators, enhancing precision and reducing manual intervention.
- PLCs find application across diverse industries, from manufacturing to utilities, ensuring streamlined operations, increased productivity, and adaptability to evolving production needs.
- Their robust capabilities make PLCs indispensable in modern industrial settings, facilities with seamless control and automation for improved efficiency and reliability.

Main Components of a PLC

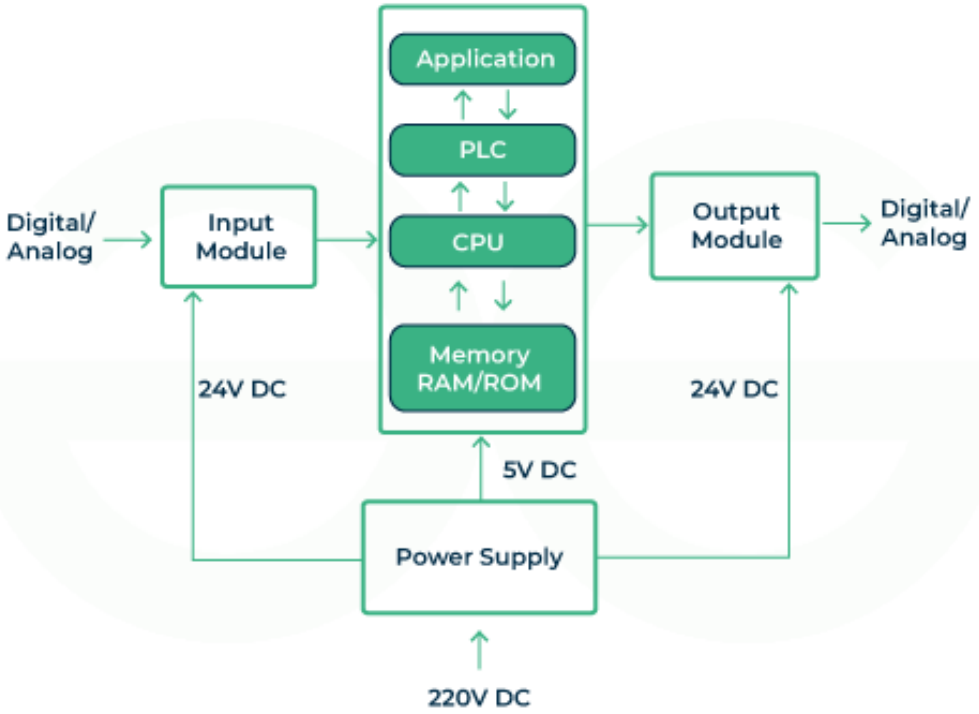
Their are mainly 6 major part of a PLC that are :

- Processor
- Memory(RAM/ ROM)
- Input device
- Output device
- Power supply
- Programming device

Description of each part of a PLC :

- **CPU :** CPU is the brain of a PLC, responsible for executing the control program stored in memory. It performs tasks such as data processing, decision-making and communication with other devices.
- **Memory(RAM/ROM) :** PLCs have main type of memory one is ram and another is rom. RAM is used for storing data and variables temporarily during the execution of the program. ROM is used to store the operating system of a PLC and the user program. The program typically consists of two ladder logic, function block diagrams or other programming languages.
- **Input Device :** This is responsible for interacting with the machine and the instructor which can be external sensors, switches etc. This part helps to take input and send to to the CPU to response accordingly.
- **Output Device :** Output device is responsible for interacting with the end point external device like motor, valve or indicator. It converts control signal from the PLC that these devices can interpret.
- **Power Supply :** PLC requires a stable power supply to run its program and match the voltage levels that needed for a PLC components.
- **Programming Device :** As PLC is mainly a programmable device, so we need a device where we can write code and execute it, just like a monitor and keyboard.

Basic Structure of PLC with Block Diagram



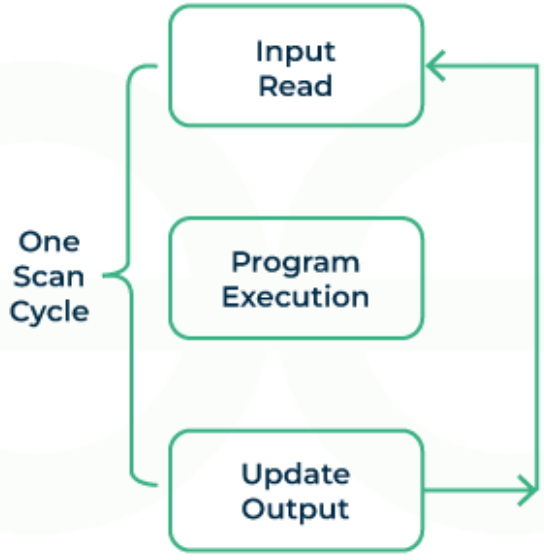
PLC

Working of PLC controller

- Their are main four part of a PLC, input and output module, controller and a power supply.
- First supply current goes to the power supply machine which is 220v AC, later it is divided into three parts and converts it from AC to DC. Both of the two input and output module takes 24v DC current and the main controller part takes 5v DC current.
- Input part takes signal from sensor and other devices, and passes it to the PLC main part.
- The main controller part sends the signal to the CPU, then starts executing its program in compiler from the memory. After that the program creates a instruction signal, which goes to the output module.
- The output module receives type signal and sends it to the external devices like motor, valve etc. which will execute the instruction by controlling the system according to the instruction.

This part can continue in a loop cyclically. For one single cycle this whole process is called scan time of PLC.

Working-of-PLC-Controller



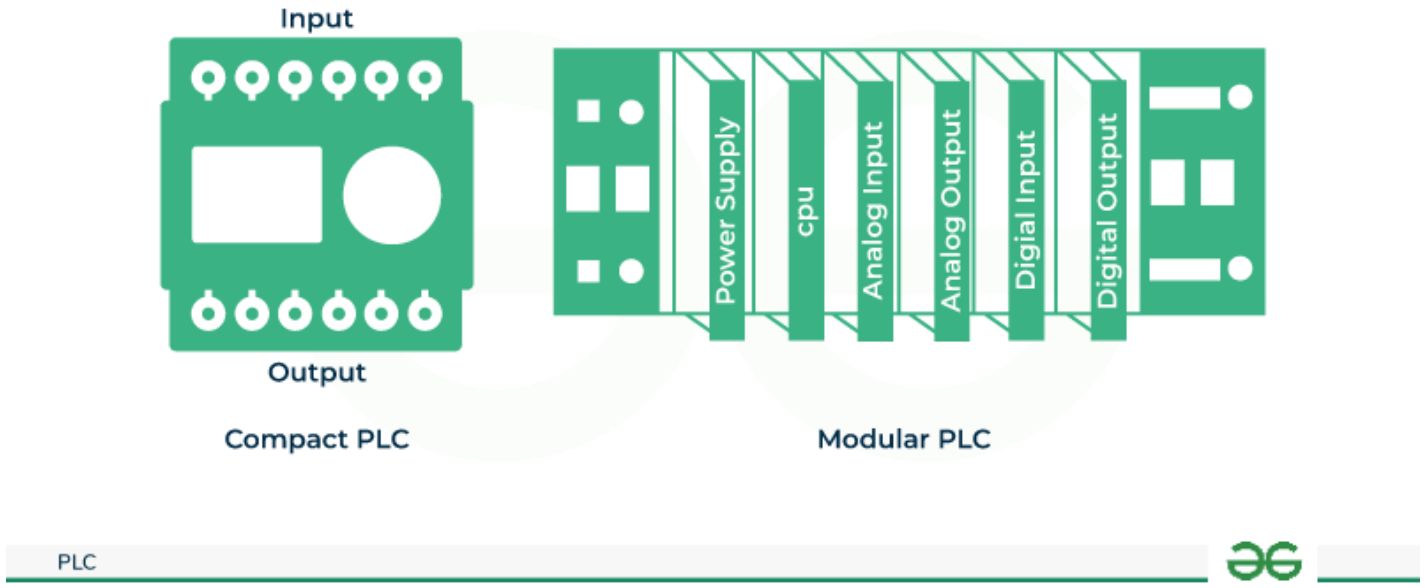
PLC

Types of PLC

PLCs can be classified into three main types based on their capabilities :

- **Compact PLC :**
  - small size and typically have a limited number of I/O points.
  - designed for space is a critical factor, and the control requirements are relatively simple.
  - often used in small-scale control applications where the number of devices to be controlled and monitored is limited.
  - Examples include simple machines, standalone equipment, or processes with minimal complexity.
- **Modular PLC :**
  - designed with s modular architecture, where the CPU, Power supply, and input-output modules are separate components.
  - provides flexibility in system configuration, making it easier to expand or modify the system based on changing requirements.
  - suitable for applications that may grow or change over time.
  - Industries with evolving control needs, such as manufacturing plants that may expand production lines.

- **Rack-Mount PLC :**
  - High end PLC which is specially designed for complex and demanding application.
  - It has maximum number of I/O points also Rack-mount PLCs are modular and can easily expanded by adding additional modules to the rack.



Features of PLC

PLC comes with a wide range of features, which makes it versatile. The features are :-

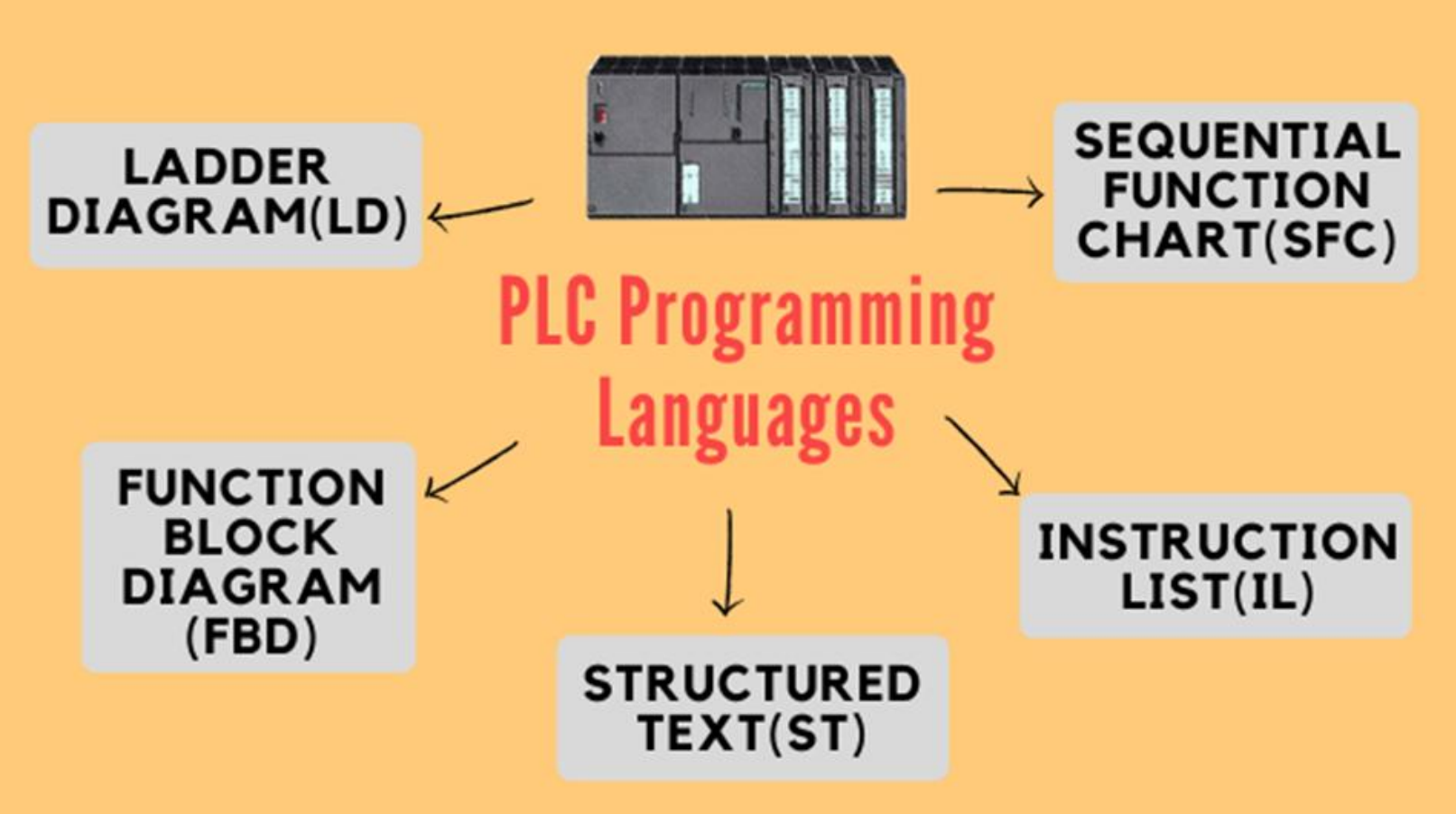
- **Digital and analog I/O :** It can handle both digital and analog signals from the sensor and other input device and allows a wide range of input.
- **Scalability :** Many PLCs offer modulation in their setting by expanding the input/output number or CPUs to accomodate the changing requirements.
- **Communication interfaces :** PLCs support various communication devices and protocol like ethernet, modbus to devices like CPU monitor and control systems.
- **Programming Language :** It allows different programming languages like ladder logic, structured text, function block diagram etc. to the user.
- **Real-Time monitoring :** PLCs operate in real-time by continuously scanning and processing input signals to make rapid decisions and update output devices with minimal delay.
- **Mathematical Functions :** PLCs support mathematical functions and calculations. enabling users to perform computations within the control program.

Applications of PLC

- **Manufacturing Automation:** PLCs are extremely used in manufacturing industries for automating processes such as assembly lines, packaging, and material handling.
- **Process Control :** In industries like chemical, petrochemical, and pharmaceuticals, PLCs play a crucial role in controlling and monitoring complex process.
- **Water treatment and Distributions:** PLCs are employed in water treatment plants to control the purification process, monitor water quality, and manage the distribution of water in a network.
- **Food and Beverage Industry :** PLCs can be used in food processing plants for tasks like mixing, backing packaging, quality control etc.
- **HVAC System :** PLCs play vital role in heating, ventilation, ACs to managing temperature, humidity, air quality etc.

Programmable Logic Controller Programming

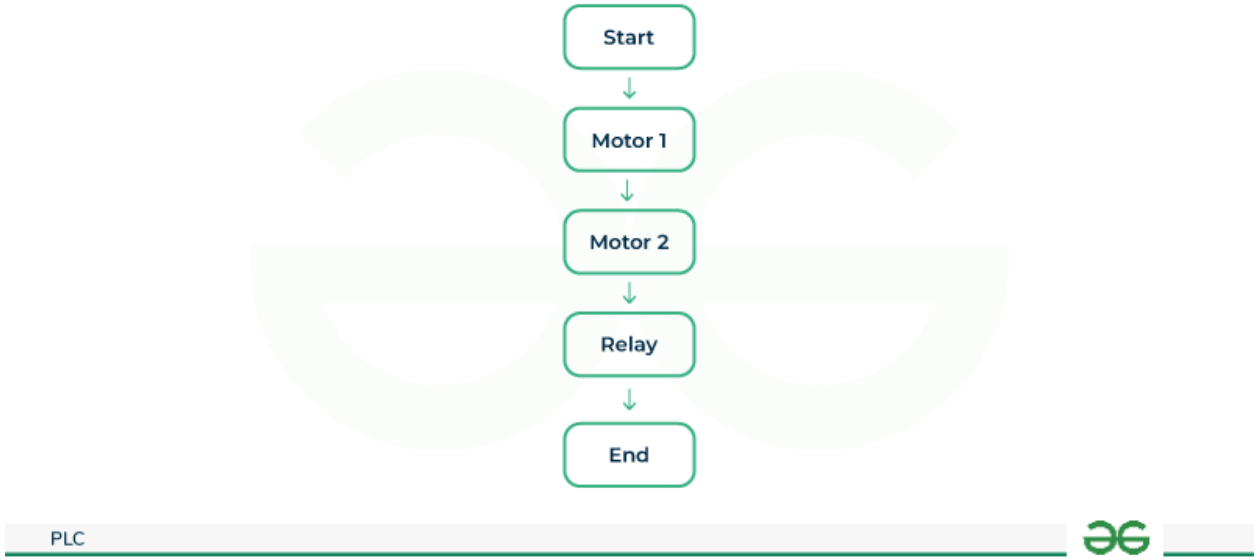
PLC is a programmable controller. Their are several types of programming languages or strategies that can be followed. Some of them are :-



Function Block Diagram

- It is a graphical representation of control logic.
- It uses function blocks to depict operations, such as comparisons or timers, with inputs and outputs conducted by lines.
- Contacts and coils symbolize input conditions and output actions.
- Branches and junctions control logic flow.
- For instance, motor control system FBD might include a start or stop button, a motor and a control relay illustrating the interconnection of these components in a visual and intuitive format for programming complex control algorithms.

Function-Block-Diagram



Advantages

- **Flexibility and Reliability :** PLCs are highly flexible. They can be easily programmed and edited. Manufacturing process of PLCs can be done virtually, without physical presentation. It makes PLC more flexible. They are made for robust condition, which makes it more reliable for industry.
- **Programming :** PLCs are programmable device. Which means it can be edited. The code and the instructions given to it are easily changeable.
- **High Speed Operation :** Because of being a programming device, it can create instant output instruction, which depends on the program complexity and the CPU memory, makes it more efficient.
- **Monitoring system :** PLCs provide inbuilt monitoring tools, make them easier to identify the troubleshoot in the system.

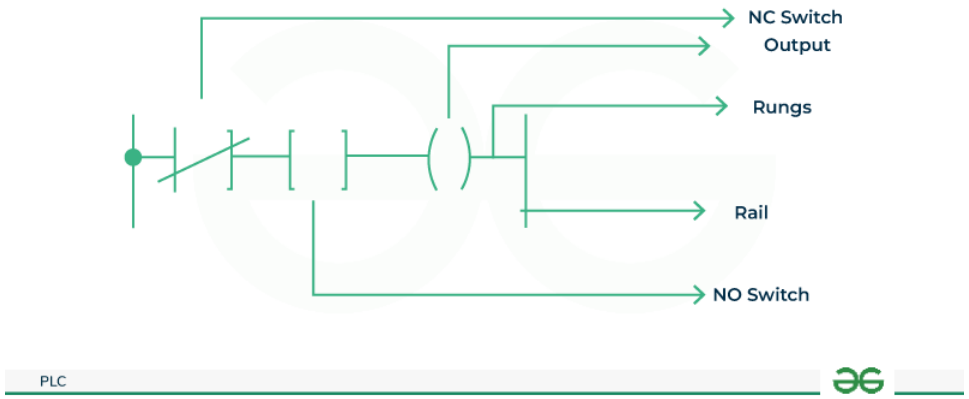
Disadvantages

- **Cost :** Initial investment for installation for a PLCs are costly. Mainly for small business it can be costly.
- **Programming :** Ladder logics are comparatively easy but complex control system may require extensive algorithm and program.
- **Software update :** It is quite challenging to maintain and upgrade when older PLC system become obsolete or when software hardware updates are required.
- **Scalability issue :** Some PLC system may face scalability issues, particularly if the initial design did not account for future expansions or changes in the manufacturing process.

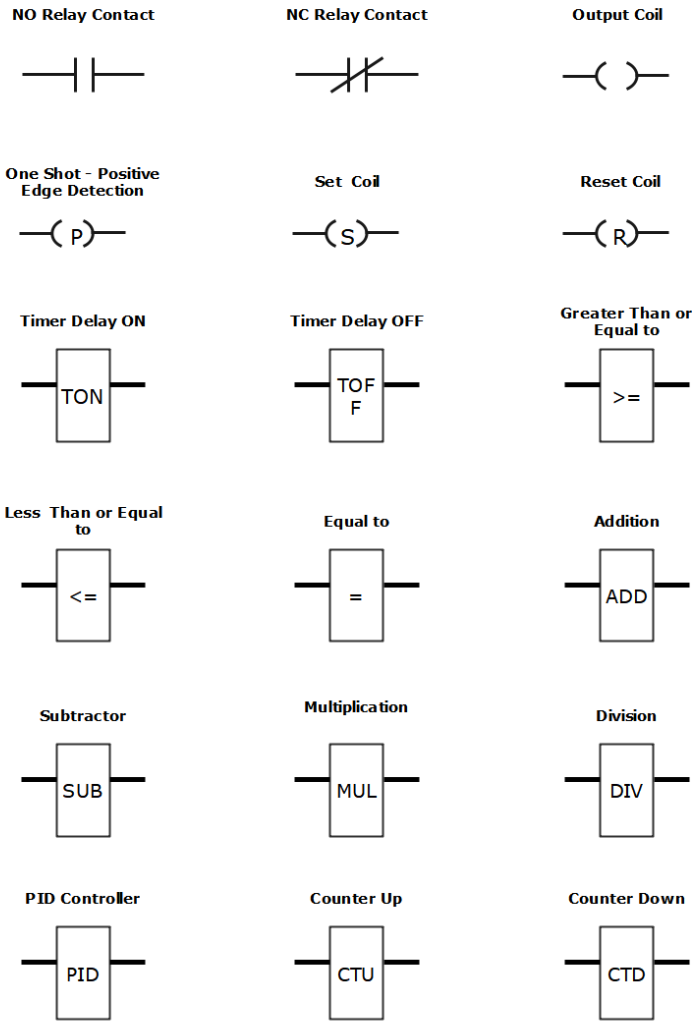
Programmable Logic Controller Programming

Ladder Logic :

- Ladder logic is also known as Ladder diagram.
- It is basically a graphical representation of relay logic circuit, which consists two vertical parallel lines connected by horizontal lines.
- This lines are called rail and rungs.
- the vertical line works to supply power, and the vertical line is responsible for creating logic.



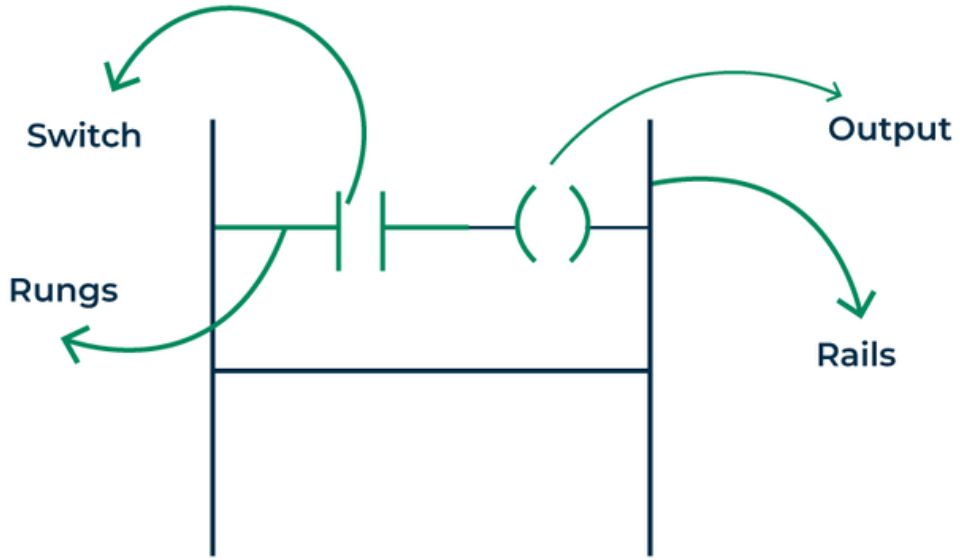
Ladder Diagram Symbols



PLC Programming Ladder Logic

- A PLC or Programmable Logic Controller is a special type of digital computer without a monitor and keyboard.
- This is basically used in industrial automation such as manufacturing, automotive, food and beverage, chemical processing, and more to automate systems.
- This tiny computer receives data through input and sends operating instructions as output.
- As the name suggests, it's a programable device.
- The main languages that are used to program a PLC are 'Ladder Logic' and 'C’.
- Ladder Logic is the most used programming for PLCs.

Ladder Logic Structure



- Ladder logic diagram are graphical programming language which executes through real time input.
- It has two vertical line, which is called as rails, the left rail supplies power to the circuit, then it passes through each rung.
- Each rung has switches and output coil. Switches can perform OR, AND and NOT operation, and through these basic logic operation we can make any programming logic in PLC.

- A ladder logic diagram executes from left to right and top to bottom.
- When all the condition of a rung met the connected output coil get energized.
- then it activate the real world system, such as turning on a motor or turning off a motor.
- This process is continuously scanned and repeated by the PLC and control system to ensure the automation of operating system.

Ladder Logic Components

Rail and Rung

Vertical lines are called rails and the horizontal lines are called rungs.

Concept of NO/NC switch

NO(Normally Open) and NC(Normally Closed) are used to represent the state of current flow or contact in electronics circuit, which is also used is PLC ladder logic programming. These terms define whether the switch is open or closed.

Normally Open

- A normally open switch or contact is open when not actuated.
- It closes the circuit when pressed or activated, allowing current flow.
- In ladder logic diagrams, a normally open contact is shown as an open gap and becomes a solid line when activated.

Normally Closed

- Normally closed switch/contact is closed when not actuated.
- Activation of the switch opens the circuit, stopping current flow.

In ladder logic diagrams, it's represented as a solid line, becoming an open gap when activated.

Output/Coil

Output devices are such as motor, valve, indicator, lights etc. but in LLD it is represented by vertical line with a label representing the output device.

Description and Working of Ladder Logic

- Firstly two rails are taken, and then a rungs. The rails will work here as a supply of source or current supply.
- The left rail is connected to the input switch and the right rail in connected to the output coil. and the switch and coils are connected through a wire.
- Then add input switch, it can be NO or NC depending on the logic to be created. Switches should be placed at the left side rail. The number of switch and placement of it can vary depending on the logic is creating.
- For creating this logic, we create truth table, and according to that, put the switch, if input is '0' , generally NO switch is used, but NC switch can also be used, but in that case we have to make it opened, or false. For '1' input, NC switches are used, but same like previous NO switch can also be used.
- An output coil should be connected to the right side rails.

What Is Interlocking In PLC?

- It is a control method used to ensure safety and operational integrity in industrial processes.
- It prevents undesired states by requiring specific conditions to be met before an action can proceed.
- For instance, an interlock might ensure a machine cannot start if a safety guard is not in place.
- This method enhances safety by preventing dangerous situations and ensuring operations follow the correct sequence.
- Interlocking is essential in processes where precise control and safety are critical, helping maintain smooth and secure operations.
- By using interlocks, industries can prevent accidents and equipment damage, ensuring reliable and safe production.

Types of Interlocking in PLC Systems

Hard Interlocking:
This type involves physical wiring and hardware to enforce interlocks. For example, safety switches and relays can physically prevent machinery from operating under unsafe conditions.

Soft Interlocking:
Implemented through PLC programming, soft interlocks use logical conditions and software commands to manage operations. These are more flexible and easier to modify than hard interlocks.

Process Interlocking:
This type ensures that processes occur in a specific sequence. For instance, a mixing operation will not start unless the previous heating process is completed and verified.

Applications of Interlocking in Industrial Automation

In manufacturing, interlocking ensures that machinery operates within safe parameters, preventing accidents and reducing downtime.
For example, interlocking can control the sequence of operations in an assembly line, ensuring that each step is completed safely before the next one begins.

In the chemical industry, interlocking is critical for preventing dangerous reactions by ensuring that processes occur under controlled conditions.
Similarly, in the energy sector, interlocking can prevent electrical systems from operating in unsafe states, thereby avoiding potential hazards such as short circuits or overloads.

Moreover, interlocking plays a vital role in transportation systems.
For instance, in rail networks, interlocking ensures that signals and switches operate in harmony to prevent collisions and ensure smooth train operations.

Across all these applications, interlocking helps maintain a high level of safety and operational efficiency, protecting both personnel and equipment.

Examples of Interlocking in PLC Programs

Conveyor Belt System: In a packaging plant, interlocking ensures that the conveyor belt stops immediately if a sensor detects an obstacle. This mechanism prevents potential damage to both the products and the machinery. The interlock program is simple yet effective, safeguarding the operation by halting the belt to avoid collisions and jams.

Robotic Arm Operation: In an automotive assembly line, interlocking plays a vital role in coordinating the movements of a robotic arm and a welding machine. The PLC program ensures that the robotic arm remains stationary until the welding process is fully completed. This prevents accidental collisions and enhances safety, reducing the risk of accidents and ensuring smooth operation.

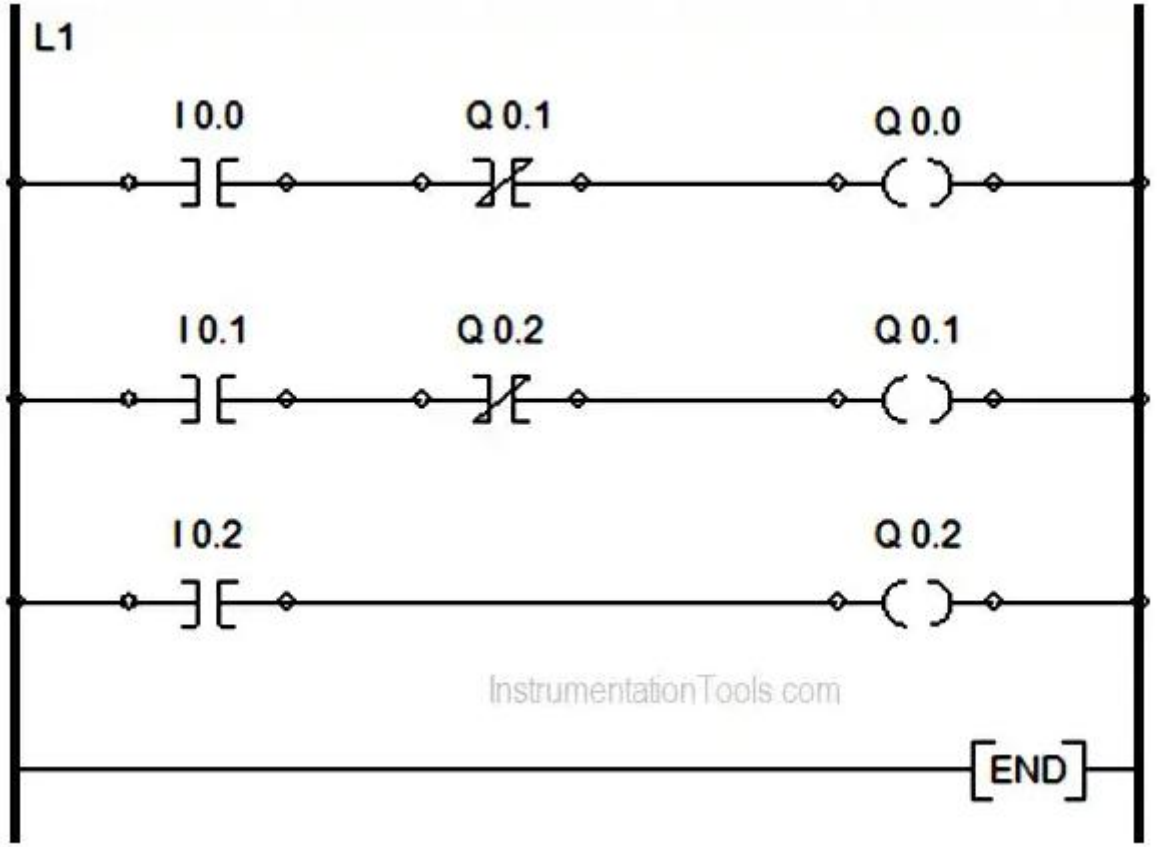
Chemical Mixing Process: In a chemical plant, safety is paramount. Interlocking in PLC programs ensures that a mixing tank's agitator starts only after all safety checks are passed and the lid is securely closed. This prevents spills and ensures safe operation, protecting both the equipment and the personnel.

Design a ladder logic for Go-Down wiring for 3-rooms using plc programming and explain the Concept of **Interlocking in PLC** programs.

- I0.0 , I0.1 , I0.2 : Toggle switches of corresponding rooms 1, 2, 3.
- Q0.0 , Q0.1 , Q0.2 : Output coils (Bulbs) in room 1, 2 ,3.

Interlocking in PLC

Seeing the ladder diagram it can be infered that as soon as the person enters into room 1 and switches ON the toggle switch 1 (I0.0), the bulb of that room glows i.e, coil Q0.0 in rung 1 gets energized.


L1
I 0.0
Q 0.1
Q 0.0
I 0.1
Q 0.2
Q 0.1
I 0.2
Q 0.2
InstrumentationTools.com
END

- Now, the person moves into room 2 without switching OFF the toggle switch of room 1.
- As soon as he/she presses the toggle switch 2 (I0.1), the bulb of that room (Q0.1) starts glowing as its coil gets energized, while the bulb of room 1 itself goes OFF as its circuit is break by the interlock contact Q0.1 in rung 1 which is (N-C) type.
- Similarly, when the goes into room 3 and presses switch 3 (I0.2) , the bulb of room 3 starts glowing and that of room 2 switches OFF keeping the bulb of room 1 already OFF.
- This is what we cover the going down from room 1 to room 2 to room 3.
- Now as soon as the person wants to come back he/she again presses the toggle switch 3 (I0.2) which in turn breaks the circuit in rung 3 and the bulb (Q0.2) goes OFF.
- As soon as the bulb of room 3 goes OFF , the bulb of room 2 starts glowing again because here no longer the interlock contact Q0.0 remains open.
- Similarly, pressing the toggle switch of room 2 (I0.1) switches OFF the bulb Q0.1 and in turn makes interlock contact Q0.l (N-C) from (N-O) and bulb of room 1 again start glowing by making the rung 1 logic TRUE.
- After pressing the toggle switch 1 (I0.0) again the bulb of room 1 i.e, Q0.0 goes OFF.

PLC Latching Function

- A simple example of such a situation is a motor, which is started by pressing a push button switch.
- Though the switch contacts do not remain closed, the motor is required to continue running until a stop push button switch is pressed.
- The term latch circuit is used for the circuit used to carry out such an operation.
- It is a self-maintaining circuit in that, after being energized, it maintains that state until another input is received.
- There are often situations where it is necessary to hold an output energized, even when the input ceases.

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PLC Latching Function

An example of a latch circuit is shown in Figure 1.18. When the input A contacts close, there is an output. However, when there is an output, another set of contacts associated with the output closes.

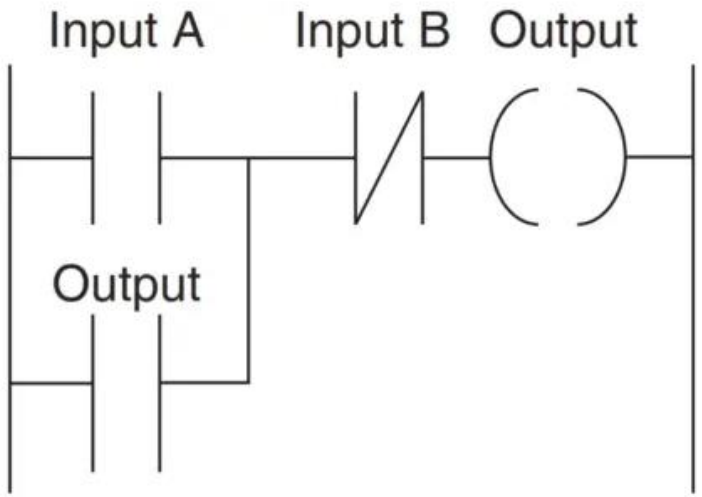

Figure1.18: Latched circuit

These contacts form an OR logic gate system with the input contacts. Thus, even if the input A opens, the circuit will still maintain the output energized. The only way to release the output is by operating the normally closed contact B.

Activity

Find the Ten Difference

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