**UNIT-I**

**INTRODUCTION TO PLC**

**What is the Programmable Logic Controller [PLC]?**

PLC is a solid-state control device or computerized industrial controller that performs discrete or sequential logic in the factory or automation environment.

Basically, PLC is a combination of software and hardware. It acts as the brain of the machine or system for automation control systems.

**Technical Definition of PLC:**
The digital electronic device that uses programmable memory to store instructions and implement specific function such as programming logic, sequence, timing, counting and arithmetic operations to control electronic machines and technical process.

Schematic figure of the PLC (Compact/Mini PLC)

**Building Blocks of PLC**
The block diagram of PLC consists of different components. Each component has associated specific functions and operations in the PLC. The list of basic components are-

- Input and Output Modules
- Power Supply
- Control Processing Unit (CPU)
- Memory System
- Programming

Functions of various blocks of PLC

1. Input and Output (I/O) Modules:

The input/output modules in PLC are of two types. It can be either digital or analog. Just like any other device or machine, we have to provide input to the PLC controller. It yields output. For example, when the user presses a button, the motor starts. Here the switch button is input. The motor is an output device. In PLC, to take the input and to return the output, there are an I/O modules. The input modules are used for providing an interface for input devices like different types of switches (push button switch, selector switch, limited switch), sensors, etc. The output modules are used for providing an interface for output devices like motor, fan, relay, light, lamp, electric heater, solenoid valve, buzzer, etc.
2. Power Supply:

For PLC, we need an electrical power supply. The power supply provides power to all other components to operate. It provides power to the input/output modules, memory system, and processor. The function of the power supply is to provide the DC or AC power to operate the PLC. Most of the PLCs work at 220VAC or 24VDC.

3. Central Processing Unit (CPU):

Central Processing Unit is the heart of the PLC system. The function of the CPU is to store and run the PLC software programs. It helps to perform the basic arithmetic, logic, controlling, and input/output operations specified by the instructions. It consists of the three subparts as memory, processor and power supply.

4. Memory System:

A memory system is responsible for storing and retrieving data and information.

5. Programming Device:

It is the platform where the program or the control logic is written. It can be a handheld device or a laptop or a computer itself.

What is a Compact PLC?

It is also called as Integrated PLC or Fixed PLC. The compact PLC has a fixed number of input/output modules along with power supply and CPU.

![Block Diagram of Compact PLC](DipsLab.com)
**What is a Modular PLC?**

It consists of a variable number of inputs and outputs. Inputs and outputs can be added to the modular PLC systems by the user.

If you look at the below PLC designing structure, it looks more like a rack. So, it is also called as rack-mounted PLC.

Advantages of PLCs over Electromagnetic Relays

The PLC replaces electromechanical relays due to their following advantages

1) PLCs are more reliable and faster in operation.
2) They are compact and can be expanded easily.
3) They require less electrical power.
4) They are less expensive when compared to Hardwired systems of same number of control functions.
5) Hard-wired electromechanical relays lack flexibility.
6) For example, when system operation requirement change, then the relays have to be rewired.
7) PLCs have very few hardware failures when compared to electro-mechanical relays.
8) Special functions such as time-delay actions and counters, can be easily performed using PLCs.

Different Types of PLC Programming Languages

Based on the “International Electrotechnical Commission (IEC)” standard, PLC programming languages are classified into five main standards.
1. **Ladder diagram (LD)**
   
   Ladder diagram (LD) is also known as “Ladder Logic“. It is used with programmable logic controllers. Generally, Ladder diagram is most popular all over the world (including India). This language is easy to learn. If you look at the ladder diagram, it looks similar to the electrical circuit diagram.

   **Advantages of LD:**
   
   • LD is simple logic construction and more reliable than an electronic circuit controller.

   • Easy to learn and read the program.
• Every programming symbol performs specific actions.
• It having good representation for discrete logic
• Easy to troubleshoot
• Shut down the power without the switch (i.e. hardware devices)

2. Instruction List (IL)

Instruction List (IL) is another type of PLC programming language. It uses the mnemonic code. So the syntax of this programming language is easy to remember. In general, AB PLC brand works on the Instruction List (IL) programming language.

Advantages of IL:
• It has a high execution speed.
• It takes less memory as compared to other programming languages.

3. Structured Text (ST)

The “ST” and “STX” are also other abbreviations used for Structured Text PLC language. It uses high-level programming language syntax. The syntax of ST is similar to the syntax of a high-level programming language with loops, variables, conditions, and operators.

Advantages of ST:
• ST is very easier to understand for both novice and experienced programmers.
• Because of its standard coding format, it is easy to edit and modify program written in ST language.

4. Function Block Diagram (FBD)

Function block diagram (FBD) is a popular and easy way to write a program like a Ladder Diagram. FBD is represented like box which consists of a number of lines of code for putting different programming functions. It is a graphical language for programming logic controller. So, it makes your job easy to describe a system.

5. Sequential Function Charts (SFC)
Sequential function charts (SFC) is also a graphical programming language. It is not a text base. It has become a popular method of accurately specifying sequential control requirements. The benefit of SFC is easy to understand. Because you can visualize what is happening and when it is happening in the procedure of the code. The main function of SFC is only the active parts of the code are executed. Due to this, it makes easier to troubleshoot and to change the code if problems occur.

**List of PLC manufacturer:**

- ABB
- Allen Bradley
- Siemens
- Mitsubishi
- Honeywell
- Motorola
- Hitachi
- General Electric
- Modicon
- Schneider Electric
- Panasonic
- Alstom
- Bosch
- Delta
- Devolo
- Echelon
- Omron
- ON Semiconductor
- Qualcomm Atheros
- SiConnect
UNIT-II

WORKING OF PLC

PLC Architecture:

PLC Internal Architecture

A basic PLC system consists of the following sections:

- **Input/ Output Section**: The input section or input module consists of devices like sensors, switches and many other real world input sources. The input from the sources is connected to the PLC through the input connector rails. The output section or output module can be a motor or a solenoid or a lamp or a heater, whose functioning is controlled by varying the input signals.

- **CPU or Central Processing Unit**: It is the brain of the PLC. It can be a hexagonal or an octal microprocessor. It carries out all the processing related to the input signals in order to control the output signals based on the control program.

- **Programming Device**: It is the platform where the program or the control logic is written. It can be a handheld device or a laptop or a computer itself.

- **Power Supply**: It generally works on a power supply of about 24 V, used to power input and output devices.

- **Memory**: The memory is divided into two parts- The data memory and the program memory. The program information or the control logic is stored in the user memory or the program memory from where the CPU fetches the program instructions. The input and output signals and the timer and counter signals are stored in the input and output external image memory respectively.
**Working of the Programmable Logic Controller**

The most important working principle is- the PLC is operated by continuously scanning programs. Scanning happens every time per millisecond. So, it is called as the Scan Cycle.

For this scan cycle, PLC required a little amount of time in the range of milliseconds or ms.

The cycle consists of the following three steps.

1. **Read the inputs**
2. **Execute the program by the CPU**
3. **Update the output**

**Step 1: Read / Sense the input**

Firstly, PLC reads the on/off status of the external input signals. After scanning the input, it gets stored in the input memory. This input included switches, pushbuttons, proximity sensors, limit switches, pressure switches, etc.

**Step 2: Execute the logic by the processor**

This scanned input gets transferred to the CPU for processing from input memory. The processor executes the programming instructions based on the input. After the execution, the result (on/off) will be stored in the device memory.

**Step 3: Update / write the output:**

When the program executes the last instruction, it will send the on/off status to the output device memory. The outputs include solenoids, valves, motors, actuators, and pumps. All three steps get completed under the scan time. The amount of time is taken by the processor to read/sense the first input and execute the last output called the Scan time. PLC is so fast as it can easily scan and execute the program in few milliseconds i.e. 10-15 milliseconds.
Memory Structure of PLC

It consists of different sections like user program, system data, memory-mapped for input and output and operating system.

<table>
<thead>
<tr>
<th>Memory Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating System</td>
<td>The operating system of a PLC operates in one of two modes: the Programming mode and the Run mode. In the Programming mode it communicates with the programming device (hand-held terminal, programming console or PC) to download the user’s program in the user's program space. In the Run mode it executes the instructions stored in the user's program area.</td>
</tr>
<tr>
<td>Memory Mapped</td>
<td>Memory area that holds an image of the state of the inputs as well as the values to be output.</td>
</tr>
<tr>
<td>Input/Output</td>
<td>Memory area used by the operating system to store system data.</td>
</tr>
<tr>
<td>System Data</td>
<td>Memory area that holds the instructions of the user’s program.</td>
</tr>
<tr>
<td>User’s Program Space</td>
<td></td>
</tr>
</tbody>
</table>

Input and Output Module in PLC

Multiple inputs (I) and output (O) modules are used in the PLC system. They provide an interface between the central processing unit (CPU) and programmable devices.

What is Input Module?
The module which interacts with the input signal is called as Input Module. It is required to connect input devices like different types of switches.

What is the Output Module?
The module which interacts with the output signal is called as Output Module. The output module is required to connect output devices like electric applications.
The input device provides a signal to an input module. This input module is connected with the CPU for the initial automated processes. CPU processes all the input data.

After processing by CPU, it gives output data to the output module. The output module provides a signal to the output device. The singles can be anything like activating or deactivating output devices.

And the main function of the programming device is to change or monitor the PLC programming.

There are two types of PLCs- Compact PLC and Modular PLC.
- In Compact PLC, the capability of the I/O module is fixed.
- In Modular PLC, the capability of the I/O module is not fixed.

**Classification of PLC Input and Output Modules**

The classification of input and output (I/O) modules of PLC is based on the types of signals. Basically, there are two types of signals- Discrete signals and analog signals. Based on the signals, I/O modules are classified into two main parts.
Classifications of the PLC Input Output Modules

1. Digital I/O Module

The digital module is also called Discrete Module. In this module, the I/O signal work on the binary system i.e. only 0 or 1 value. For the digital input module, only the 1-bit signal is used. It is useful in the ON or OFF condition. Based on Input and Output, the digital module is of two types.

   - Digital Input Module
   - Digital Output Module

The digital I/O signal gives status in the different form like –

1. High/Low, True/False and 1/0 for General Status
2. ON/OFF for Load Condition
3. Activated/Deactivated for Switching Mechanism
4. Close/ Open for the Switching Contact Status

Examples: Push switch, Toggle switch, Rocker switch, Selector switch, Proximity switch, Limit switch and etc are the example of the Digital Input Signal. Examples: Lamp, Coil, Buzzer, Relay, Motor, Fan, Heater, Actuator, Solenoid Valve and etc are the example of the Digital Output Signal.

2. Analog I/O Module

The analog module is called a Continuous Module. Usually, the voltage or current is given to the input module in the form of an analog signal. For the analog input module, 12-bit or 13-bit signal is used.
Generally, analog input signals operate in the range of 4-20 mA, 0-20 mA, 1-5 V, etc. This analog signal provides any intermittent value between the two extreme limits (initial to final range) for the analog input module. Again, analog I/O modules are also of two types.

- Analog Input Module
- Analog Output Module

**Examples:** Temperature detection switch, Pressure detection switch, Flow detection switch, Level detection switch, Limit detection switch, Position detection switch, PH Level detec
tion switch are the best example of the Analog Input Signal.

**Examples:** Temperature Transmitter, Thermocouples, Pressure Transmitter, Flow Transmitter, Level Transmitter, etc., are the example of the Analog Output Signal.

**MODULE ADDRESSING**

The PLC has to be able to identify each particular input and output. It does this by allocating addresses to each input and output. With a small PLC this is likely to be just a number, prefixed by a letter to indicate whether it is an input or an output. Thus for the Mitsubishi PLC we might have inputs with addresses X400, X401, X402, and so on and outputs with addresses Y430, Y431, Y432, and so on, the X indicating an input and the Y an output. Toshiba uses a similar system.

With larger PLCs that have several racks of input and output channels, the racks are numbered. With the Allen-Bradley PLC-5, the rack containing the processor is given the number 0 and the addresses of the other racks are numbered 1, 2, 3, and so on, according to how setup switches are set. Each rack can have a number of modules, and each one deals with a number of inputs and/or outputs. Thus addresses can be of the form shown in Figure. For example, we might have an input with address I:012/03. This would indicate an input, rack 01, module 2, and terminal 03.
With the Siemens SIMATIC S5, the inputs and outputs are arranged in groups of eight. Each such group is termed a byte, and each input or output within a group of eight is termed a bit.

The inputs and outputs thus have their addresses in terms of the byte and bit numbers, effectively giving a module number followed by a terminal number, a full stop (.) separating the two numbers. Figure shows the system. Thus I0.1 is an input at bit 1 in byte 0, and Q2.0 is an output at bit 0 in byte 2.

The GEM-80 PLC assigns inputs and output addresses in terms of the module number and terminal number within that module. The letter A is used to designate inputs, and B outputs. Thus A3.02 is an input at terminal 02 in module 3, and B5.12 is an output at terminal 12 in module 5.

In addition to using addresses to identify inputs and outputs, PLCs also use their addressing systems to identify internal, software-created devices, such as relays, timers, and counters.

**SOURCING AND SINKING INPUTS/OUTPUTS**

The terms “sourcing” and “sinking” refer to the direction of current (as denoted by conventional flow notation) into or out of a device’s control wire.
A device sending (conventional flow) current out of its control terminal to some other device(s) is said to be sourcing current, while a device accepting (conventional flow) current into its control terminal is said to be **sinking current**.

Note 2: By “control wire,” I mean the single conductor connecting the I/O card channel to the field device, as opposed to conductors directly common with either the positive or negative lead of the voltage source. If you focus your attention on this one wire, noting the direction of conventional-flow current through it, the task of determining whether a device is sourcing or sinking current becomes much simpler. To illustrate, the following illustration shows a PLC output channel is sourcing current to an indicator lamp, which is sinking current to ground:

![PLC discrete output channel](image)

These terms really only make sense when electric current is viewed from the perspective of conventional flow, where the positive terminal of the **DC power supply** is envisioned to be the “source” of the current, with current finding its way “down” to ground (the negative terminal of the DC power supply).

In every circuit formed by the output channel of a PLC driving a discrete control device, or by a discrete sensing device driving an input channel on a PLC, one element in the circuit must be sourcing current while the other is sinking current.

A device that sinks current “sucks” current from the other device. If the discrete device connecting to the PLC is not polarity-sensitive, either type of PLC I/O module will suffice.

For example, the following diagrams show a mechanical limit switch connecting to a sinking PLC input and to a sourcing PLC input:
Note the differences in polarity and labeling between the sinking card’s common terminal and the sourcing card’s common terminal.

On the “sinking” card, the input channel terminal is positive while the common (“Com”) terminal is negative.

and on the “sourcing” card, the input channel terminal is negative while the common (“VDC”) terminal is positive.

Some discrete sensing devices are polarity-sensitive, such as electronic proximity sensors containing transistor outputs. A “sourcing” proximity switch can only interface with a “sinking” PLC input channel, and vice-versa:
In all cases, the “sourcing” device sends current out of its signal terminal while the “sinking” device takes current into its signal terminal.