3

Programmable Logic Controllers

Contents

3.1 Introduction

- A manufacturing system consists of a group of machine along with material handling, storage, and control devices. To automate the system, two factor must be considered: the control of the equipment and the flow of information.
- Today, the word automation usually implies a system controlled by computers. However, this is not the only form of automation used in modern industry. Along with sophisticated computer controls, there are conventional control devices, such as mechanical controllers with cam and linkages, relay panels, NC controllers, and programmable logic controllers

3.2 Relay Device Component

- PLCs were primarily intended to replace relay devices, so it is important to become familiar with the components used in relay devices. A relay device consists of a front display panel with switches, relay, timers and counters. Each of these is discussed briefly in the following sections.

3.2.1 Switches (Contact)

- A switch is a device that either open or closes a circuit. Although there are numerous type and styles of switches, they can be classified into the following categories
  1. Locking and Non locking
  2. Normally open and Normally closed
  3. Single throw and multiple throw
  4. Single pole and Multiple pole
  5. Break-before make (interrupt transfer) and Make-before break (continuity transfer)
- The first category of switches is easy to understand. A non-locking switch simply returns to its initial state.
- In the second category a normally open switch contact is made by physically depressing the switch ("make contact"). Normally closed switches operate in the opposite manner, Contact is actively interrupted (broken).
- In the third category a single throw switch ha two states, on and off. There are some switches that have three states a release and two operating positions.
- In this case it can select either a neutral circuit or connect to one of two circuits. This kind of switch is called a double throw or multiple throw switch.
- In the fourth category a multiple throw switch has several states. These switches all have a single pole (moving part) and subsequently are called single pole switches. In order to close (or break) two or more contacts at the same time, multiple pole switches are necessary. The most widely used multiple pole switch is the double pole switch.
- The last category is more complex. For some circuit contact can be made or broken several times in succession.
- There are two types of transfer contacts in which "makes" and "breaks" can be combined. A "break-before make," or interrupt transfer, contact does as the name suggests it break one contact before another is made. When the switch is operated, there is a certain amount of time when the common spring is in contact with neither contact.
- Thus a break-before make results. A "make-before –break," or continuity transfer, contact provide the same function as a transfer contact. However, continuity always exists for one or the other contact.

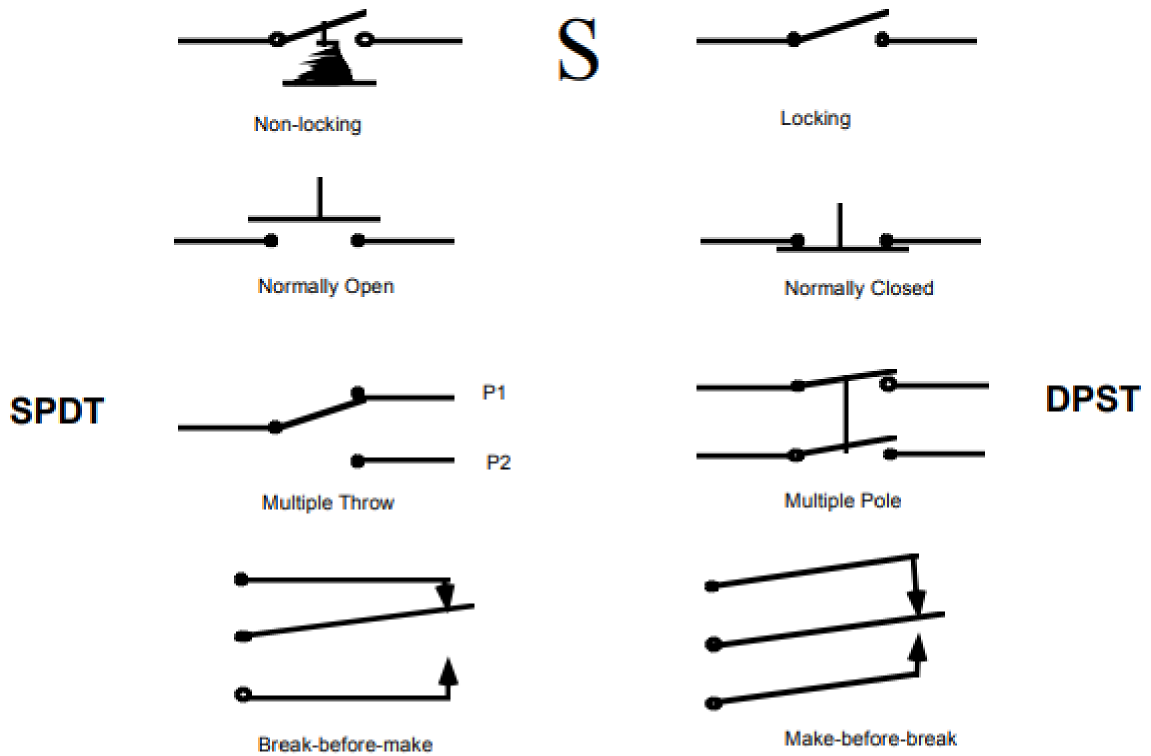

Fig.3.1 – Types of Switches

3.2.2 Relays

- A switch whose operation is activated by an electromagnet is called a relay. The contact and symbology for relay is usually the same as for switches.
- A small current passes through the magnet, causing the pole to switch. Usually the magnet is rated between 3 to 100 volts and a few hundred milliamps.
- Therefore it is operated at very low power (current and voltage). A circuit carrying a much heavier rating can be switched using a relay, however the two circuit are totally separated.

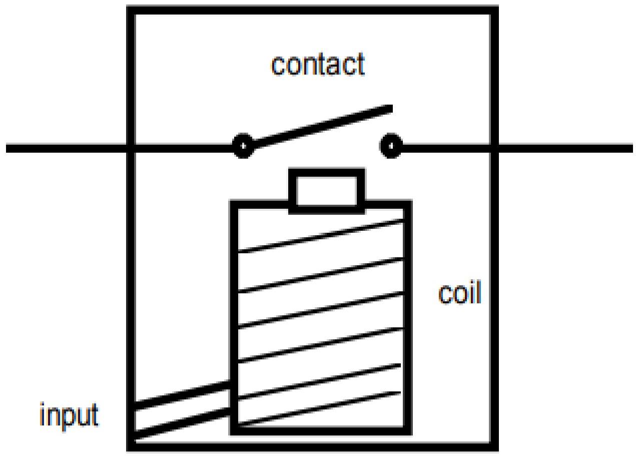

Fig.3.2 – Relay

- When a relay operates, the contacts do not all open or close instantaneously. There may be a delay of several milliseconds between the operations of two contacts of the same relay.
- In the design of a relay circuit, this delay must always be taken into account.

- On the basis of the preceding discussion, it is clear that a relay is really a magnet operated contact switch. The contact switch inside a relay also can be classified by the number of poles and throws. Although most relays are single throw, it is very common to have multiple-pole relays.

3.2.3 Counters

- On the basis of their structure, counters can be classified as mechanical or digital. Mechanical counters, such as an odometer, usually give readings as their output.
- Because mechanical counters are generally not used in a relay panel circuit. Digital counters output in the form of a relay contact when a preassigned count value is reached.
- A digital counter consists of a count register, an accumulator, and a relay contact. The count register holds the preassigned count value.

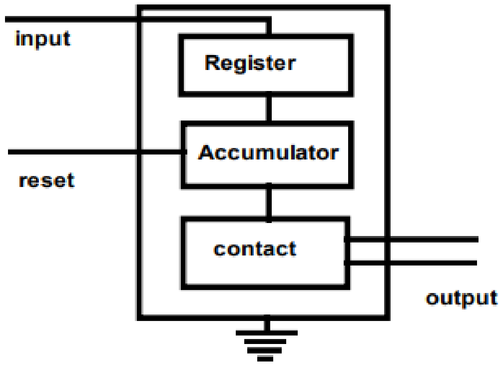

Fig.3.3 – Counter

3.2.4 Timers

- A timer, as its name implies, is used for some timing purpose. It consists of an internal clock, a count value register and an accumulator.
- In process control, a significant number of operations must be timed. For example, in a chemical process, the curing of certain products, and the mixing of chemicals and so on all require a certain period of time to complete.
- In process control, synchronization of operations is also essential. There are two ways to synchronize operations, namely event triggered synch and time controlled synch. Even triggered synch can be achieved by using sensors and switches to detect the event.
- For time-controlled synch, each operation is given a fixed time period to finish therefore, a clock or timer is necessary

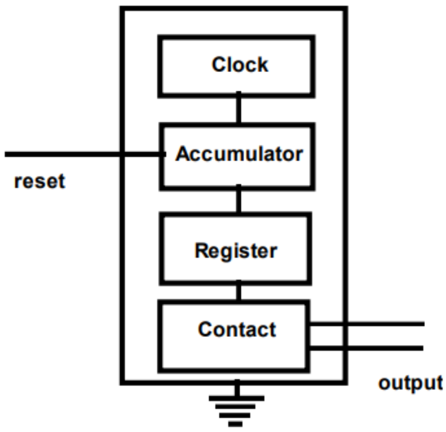

Fig.3.4 – Timer

3.3 Programmable Controller Architecture

- Programmable logic controllers replace most of the wiring by software programming. Therefore the task is made much easier, because the wires and the moving mechanical components are mostly replaced by software, the system is much more reliable.
- Like a general purpose computer a programmable controller consists of five major parts are the CPU (processor), memory, input/output, power supply and peripherals.

3.3.1 The Processor

- Although early PLCs used special purpose logic circuits, most current PLCs are micro-processor based systems. The processor scan the status of the input peripherals, examines the control logic to see what action to take and then executes the appropriate output responses.
- The microprocessor based PLC has significantly increased the logical and control capacities of programmable logic controllers. High end PLC system allows the user to perform arithmetic and logic operations, move memory blocks, and interface with computers, a local area network, and function and so on.

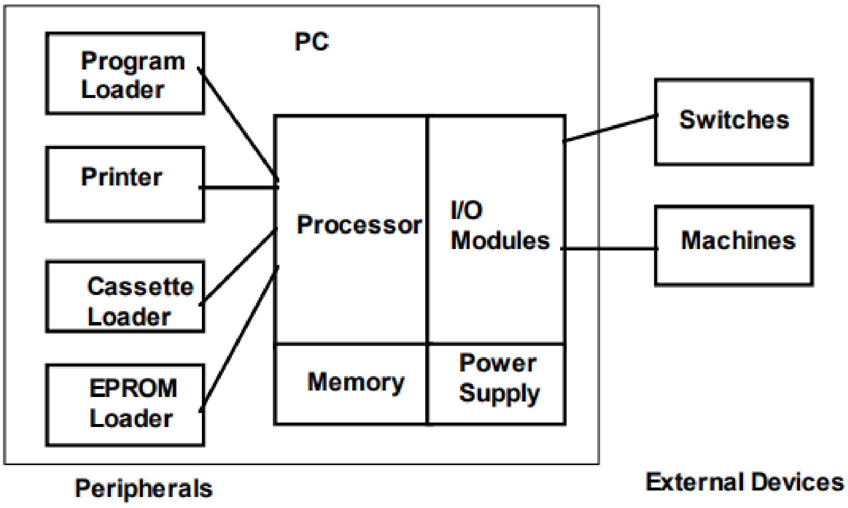

Fig.3.5 – Programmable logic controller system structure

3.3.2 Memory

- The memory of the PLC is important because the control program and the peripheral status are stored there. Memory size in a PLC is measured in either bits, bytes or words.
- Because many words of memory are required, it is usually measured in “k” increments (where 1k = 1024).
- Although several types of memory are used in modern PLCs, memory can be classified into two basic categories volatile and non-volatile. Volatile memory loses state when power is remove.
- This may seem perfectly appropriate. However, you must remember that the program is stored in memory, and if the power fails, the program must be rekeyed or reread into memory, a potentially time consuming activity.
- Non-volatile memory, on the other hand, maintains the information in memory even if the power is interrupted.

3.3.3 Input and Output

- The input and output (I/O) for a PLC is normally a set of modular plug-in peripherals (notice the difference between this definition and the one used in computer I/0s). The I/O modules allow the PLC to accept signals from a variety of external devices, for example, limit switches, optical sensors, and proximity switches.
- The signals (two state signals for the devices mentioned, open or closed) are converted from an external voltage (115 VAC, 230 VAC, 24 VDC) to a TTL signal of ±5 VDC.
- The PLC Processor then uses these signals to determine the appropriate output response. A 5 VDC signalis transmitted to the appropriate output module, which converts the signal to the appropriate response domain (115 VAC, 230 VAC, 24 VDC).
- Normally, a peripheral interface adapter is used to transfer the status of the input peripherals to some prespecified memory location. The user defines the location of the peripheral on the I/O housing in the program.
- Each I/O location is assigned to a specific memory location. This makes accessing input by the CPU a task of loading the content of a specific memory into a storage register. Output changes are equally easy for the CPU to perform.
- The content of a particular memory location are then altered. Due to the electrical difference between the CPU and the external I/O peripheral, the I/O points and the internal memory are actually electrically isolated. In a more advanced design, a separate I/O processor is used to bring the external I/O status to an internal memory location
- I/O module are typically housed in a rack separate from the PLC. Light indicators are usually included in the I/O module to provide the current state. In addition, each module is normally fused and isolated from the processor.

3.3.4 Power Supply

- The power supply operates on AC power to provide the DC power required for the controller's internal operation. It is design to take either 115 or 220 VAC. Some power supplies can take either voltage with a jumper switch for selection. The operation of I/O modules is also supported by the PLCs' power supply. However, separate power source are required in order to close the circuit of switches, motors and external devices.

3.3.5 Peripherals

- A number of peripheral devices are available. They are used to program the PLC, prepare the program listing, back up the program and display the system status. Old PLCs may still have handheld programmers and CRT programmers, today they have been replaced by a PC-based software programming environment. Following is a partial list of peripherals.
  1. Operator console
  2. Printer
  3. Simulator
  4. EPROM loader
  5. Network Communication Interface
  6. PC-based programming software

3.4 Progarmmable Logic Controlle

- Programmable logic controllers were initially developed to replace relay devices. The programming language used was similar to that used by electrical technicians to design electric circuits—the ladder diagram.

- However, as PLCs grew more powerful and flexible, the limitations of the ladder diagram soon became apparent.
- Not only does the ladder diagram have no easy way to represent data manipulation, but it is also extremely difficult to write and debug a large and complex ladder diagram. In recent years, many high-end PLCs began to introduce high level languages.

3.4.1 Ladder diagram

- ladder diagram is a means of graphically representing the logic required in a relay logic system. Ladder diagrams have long preceded the PLC and still represent the basic logic required by a relay device or PLC.
- The fundamental ladder diagram consists of a series of input, timers, and counters. Most simply the ladder diagram represents the action required as a function of a series of inputs that are either on or off. Each ladder-diagram element is represented using some standard symbols.
- A ladder diagrams consists of two rails of the ladder and various control circuits or rungs. Each rung starts from the left rail and ends at the right rail.
- We can consider that the left rail is the power wire and the right rail is the ground wire. Power flows from the left rail to the right rail, and each rung must have an output to prevent a short. The output is connected to physical devices, such as motors, lights, and solenoids.
- To control the output, some switches are used on the rung to from the AND and OR logic. Different rungs are not connected except through the rails. Each rung can contain only one output.
- Functionally, the components in a ladder diagram consists of those used internally to construct the logic, such as some relays, timers, and counters, and those used to connect to the physical devices, such as switches and motors.
- The internal components are the ones replaced by a programmable logic controller.

3.4.2 Logic

- By using serial and parallel connections, various types of logic can be represented in a ladder diagram. The logic states of a component are either on or off. The ladder diagram takes the input state from the input module and output results to the output module.
  1. Basic logic
     a. AND logic
     b. OR logic
     c. Combined AND and OR logic
  2. Relays
  3. Timers and counters

3.4.3 Structured text programming

- Structured text is a high-level language that can be used to express the behaviour of functions, function blocks, and programs. In the IEC 1131-1 standard, structured text has a syntax very similar to PASCAL. In this section, a brief introduction to structured text programming is presented.
- Structured text is a strongly typed language. That means that all variables used in the program have to be declared before they can be used. The language also provides the following functionalities:
  1. Assignments
  2. Expressions
  3. Statements
  4. Operators
  5. Function calls

6. Flow control, such as conditional statements and iteration statements.

3.4.4 Function block programming

- In the IEC 1131-3 standard, a functional block is a well-packaged element of software that can be refused in different parts of an application or even in different projects.
- Functional blocks are the basic building blocks of a control system and can have algorithms written in any of the IEC languages.
- A function block type contains two parts: (1) data declarations, and (2) an algorithm expressed using a structured text, a function block diagram, a ladder diagram, an instruction list, or a sequential function chart. A functional block also can be used directly in a ladder diagram.

3.4.5 Instruction list

- The instruction list is a low-level language that has a structure similar to an assembly language. Because it is simple, it is easy to learn and ideal for small handheld programming devices.
- The instruction list has a simple syntax. Each line of code can be divided into four fields: label, operator, operand, and comment. Label and comment fields are optional.

3.4.6 Sequential function chart

- The sequential function chart is a graphics language used for depicting sequential behaviour. The IEC standard grew out of the French standard, Grafcet, which in turn is based on petri-net.
- An SFC is depicted as a series of steps shown as rectangular boxes connected by vertical lines. Each step represents as a state of the system being controlled.
- A horizontal bar indicates a condition; it can be a switch state, a timer, and so on. A condition statements is associated with each condition bar.
- Each step can also can have a set of actions. The action qualifier causes the action to behave in certain ways. The indicator variable is optional; it is for annotation purposes. The action can be described as part of the SFC.

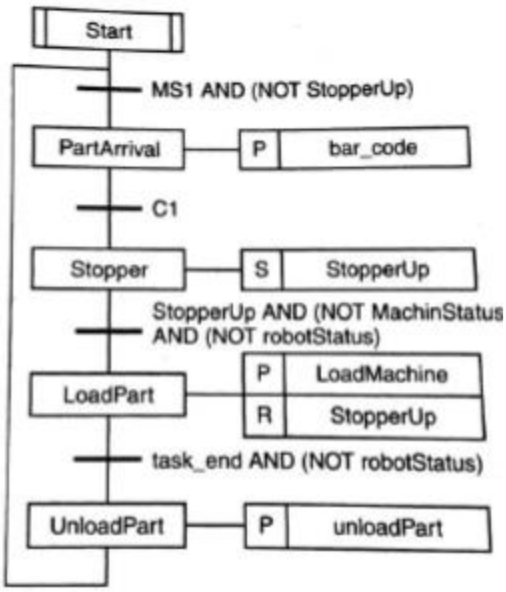

Fig.3.6 – SFC for the material handling example

3.5 Tools For PLC Logic Design

- In this section, two analytical tools for PLC logic design are introduced. The PLC logic design problem takes the description of a control problem and converts it into a PLC program.
- However, the solution is not always obvious. Foe very simple problems, the problem description can be translated directly into a ladder diagram or other PLC programs. When problems are more complex, this translation is either very difficult or produces, inefficient program.
- The two tools introduced in this section can help organize the problem description and convert the description and convert the description into logic statements. Since there is a one-to-one correspondence between logic statements and ladder diagrams, PLC programs can be written easily.
  1. Design using a truth table
  2. Control using a state diagram

3.6 References

Tien-Chien Chang, Richard A. Wysk, Hsu-Pin Wang "Computer Aided Manufacturing" 3rd Edition by Pearson Education