# APC 3rd Module Notes - PLC and SCADA

## Use of relays in process control

Relay were used during early times in industrial control, before the use of PLCs became popular. They are used to monitor the changes occurring in the process. According to the inputs from the process, the control relay takes one of the two states, that is, energized or de-energized. Relays can be arranged as a sequence to perform some logical operation. This arrangement of relays is known as relay sequencer or relay logic panel.

- In relay based control, each rung of the relay-ladder diagram is evaluated simultaneously.
- The relays are all hardwired to AC power
- When the AC supply is ON, based on the input conditions, indicators at the output change their state. (Check the example in notebook)
- If any change in the logic conditions is to be made, it is required to rewire the relay panel
- Sometimes addition of more relays are required for the new ladder program
- Thus, using relays is difficult and time consuming.
- Nowadays relays have been replaced by computer based Programmable Logic Controllers for industrial control purposes

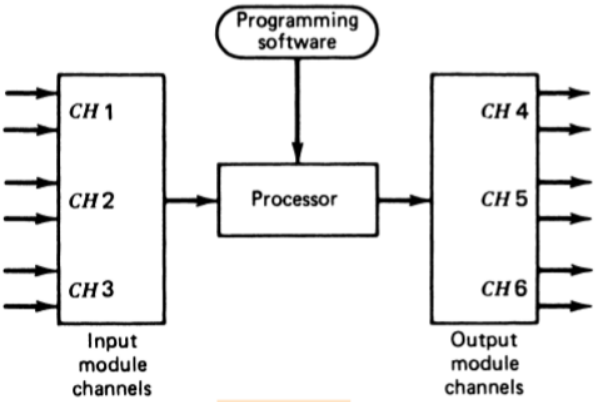
## What are PLCs (Programmable Logic Controllers)?

A Programmable Logic Controller (PLC) is an industrial computer control system that continuously monitors the state of input devices and makes decisions based upon a program to control the state of output devices.

### Advantages of PLCs compared to relays

1. Input and output variables in a process industry are mostly binary type. Hence they are compatible with PLCs since they are computer based (digital signal).
2. The logic conditions are programmed using software. Hence there is no hardwire failure, like that in relays
3. It is easy to make changes in program because rewiring is not required
4. Timers and counters are easy to implement using the software in PLCs
5. There are special power devices to convert the low level commands from a computer/PLC to high power signals, in order to drive the actuators.
6. PLCs are small in size compared to relays, they are reliable and have low cost.

## PLC Block Diagram (Important)



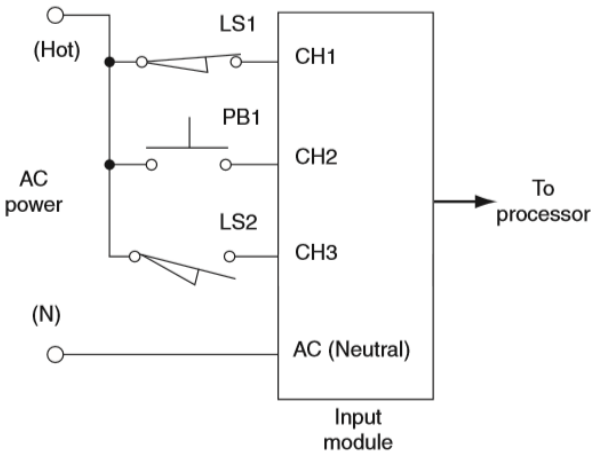
Basic structure of the programmable logic controller (PLC).

The Block diagram of PLC consists of 3 main units. An input Module to accept the input from input devices, a processor which executes a program based on input conditions and an output module, which drives the output devices based on program execution.

### Processor

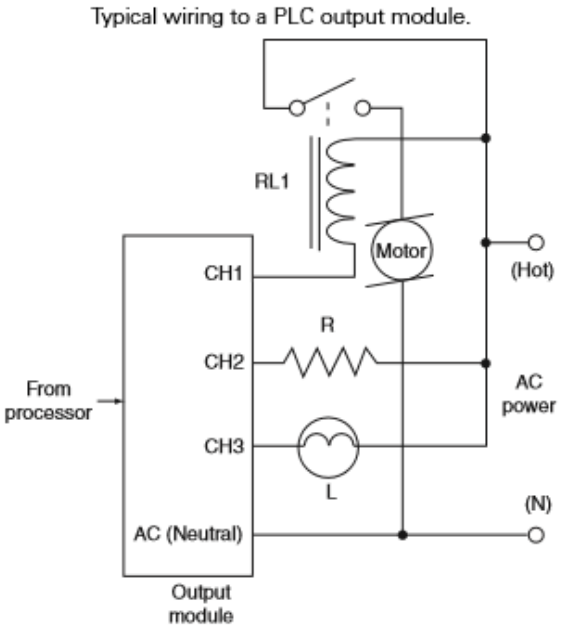
- It executes program to perform operations specified in the ladder diagram
- Performs arithmetic and logical operations on the input data
- Determines the state of output variables based on the program
- It is a serial machine – Can perform only one operation at a time
- It sequentially samples each output, executes the ladder program, provides the output and repeat this process
- Nowadays desktop computers with special data boards are used to run PLC software

### Input Modules




- There are several channels at the input, to which the input devices are connected
- Input modules examine the state of input switches and other input devices
- They provide the state of each device at the input to the PLC processor for evaluation by the ladder diagram
- The AC power is not connected directly to the input devices. The AC neutral is connected to the input module directly.

## Output Modules




- Output module supply external power to output devices such as motor, indicator light, solenoid etc. The output given to the devices will be based on execution of ladder program.
- The outputs from the processor are low level commands. These are used to activate relays, SCRs, Triacs, BJTs etc to increase the power of the output signal.
- Example: A motor requiring high power is not directly connected to the output module. Instead, it is connected through a relay.
- The AC power is not connected directly to the output devices. It is supplied through the output module

## Applications of PLCs

1. They can run machines for years without human intervention
2. They are used in glass manufacturing, for controlling the material ratio
3. They are used to control machines used for paper manufacturing
4. They are used to mix raw materials in the correct quantity, in cement manufacturing industry
5. They are used to control the wind turbines

## Modes of operation of PLC (Important)

There are two modes of operation in a Programmable Logic Controller. One is the **I/O scan mode** and the other is the **execution mode**

### I/O Scan Mode

- This consists of Input scan and output scan
- During Input Scan, the input channels are scanned one at a time (not all the channels together)
- The processor looks at each input channel to see if it is ON or OFF
- The information from the input channels is stored in a data table inside the processor for use in the next step
- Based on the inputs scanned and program execution, output values are stored in a temporary memory inside processor.
- During output scan, outputs are updated using temporary values stored in the memory

### Execution Mode

- This mode evaluates each rung of the ladder diagram program
- The execution is sequential, which means, it happens one after another. It begins from the first rung and ends at the last rung.
- Execution is done using the memory copy of inputs (Stored in the data table during input scan)
- Based on the execution of program, the outputs are either energized or de-energized

This process repeats: Input Scan → Execution → Output Scan

## PLC Scan Time

PLC Scan time is the time required for one complete cycle of I/O Scan and execution.

PLC Scan Time = Input Scan Time + Execution Time + Output Scan Time

- It depends of the number of input and output channels and the length of PLC program
- Maximum PLC scan time is 5-20 ms
- Speed of PLC depends on clock frequency of Processor also. If clock frequency is higher, Processor will be fast and thus PLC Scan time will be less.
- If a limit switch at the input goes ON for less than a scan time, it cannot be detected by the PLC. This results in a miss by the PLC

## PLC Memory Types

The memory used with Programmable Logic Controllers are of different types and are described here:

1. **RAM: Random Access Memory**

- RAM is temporary memory.
- It is used for testing and execution of the ladder diagram program.
- It is read and write memory.
- If any corrections are to be made in the program, it can be done if program is stored in RAM
- If power failure occurs, data stored in the RAM is lost

2. **ROM: Read Only Memory**

- The program after complete debugging (correction of errors in program), is burned onto the ROM
- Data stored in ROM is not affected by power failure
- Once written, the data stored in ROM cannot be edited
- When ROM is plugged into the device, it is ready to be placed into industrial setting

3. **EPROM: Erasable Read Only Memory**

- It is a type of ROM.
- The data stored in EPROM can be erased using UV rays. New data can thus be written and stored on EPROMs

4. **EEPROM: Electrically Erasable Read Only Memory**

- It is a type of ROM
- The data stored in EPROM can be electrically erased. New data can thus be written and stored on EPROMs

5. **Flash EPROM**

- It is the fastest type of ROM. It can be reused many number of times

## Selection criteria of PLC

While selecting a PLC, certain matters needs to be taken care of. This selection criteria of PLC is discussed here:

1. **Application requirements**

This refers to the task to be achieved with the PLC. The task should be such that they can be split into simple understandable elements

2. **System requirements**

The number of input channels or the number of output channels should be specified when selecting the PLC. If there is any special function other than simple ON/OFF, that is to be mentioned

3. **Speed of operation**

This criterion specifies how fast the machine should operate. Some processes are fast and some are slow. Hence PLCs should be selected accordingly.

4. **Electrical requirements**

This specifies the level of incoming power and the level of output voltage or current

5. **Communication requirements**

This criterion specifies how data can be communicated to another computer/monitor in the operator's station

6. **Operator interface**

This selection criterion specifies the type of Push buttons for accepting inputs or the type of LED display for displaying messages about machine status.

7. **Physical environment**

This is specification regarding the environment in which PLC is to be placed. Protection is to be given to the PLC if it is kept in harsh environments. The covering should be such that there is provision for maintenance or reprogramming.

8. **Vendor selection**

Depending upon the vendor (seller), the number of modules, special features, scope for future development and cost effectiveness can change.

## PLC Programming methods

There are different methods to program PLC and is described here:

1. **Ladder Diagram Programming**

- This is the most common PLC methods
- The diagram looks like a ladder. The vertical lines are for power supply and are known as vertical rails. The horizontal lines are known as rung.
- The inputs are arranged on the left side and outputs are arranged on the right side of the ladder diagram.
- Example: I1 and I2 are the two inputs and O1 is the output. This ladder diagram performs logical AND function.

2. **Function Block Diagram**

- It is a pictorial method of programming.
- It consists of blocks for each function to show inputs and outputs.
- Lines drawn between the blocks indicate how outputs change according to inputs.
- Eg: A process in which alarm has to sound when weight measured is too low or too high. Then there will be a line drawn from weight scale block to the alarm horn block.

3. **Sequential Function Chart**

- It is another pictorial method, it is similar to a flow chart.
- There are 2 elements in sequential function chart: actions and transitions
- Actions are individual steps in a process (Weighting an item, sounding an alarm)
- Transitions are change from one step to another.

4. **Structured Text**

- This is text language and is not much used with PLCs
- It is similar to c or c++ languages and is suitable for people familiar with computer programming
- Complex mathematical functions are easy to implement using structured text compared to ladder diagram

5. **Instruction List**

- It is a complicated method and is similar to programming the microcontrollers.
- The language is known as assembly language.
- It is difficult compared to ladder diagram programming

## PLC Instruction Set: (Notes already given in the class)

## SCADA (Supervisory Control And Data Acquisition System)

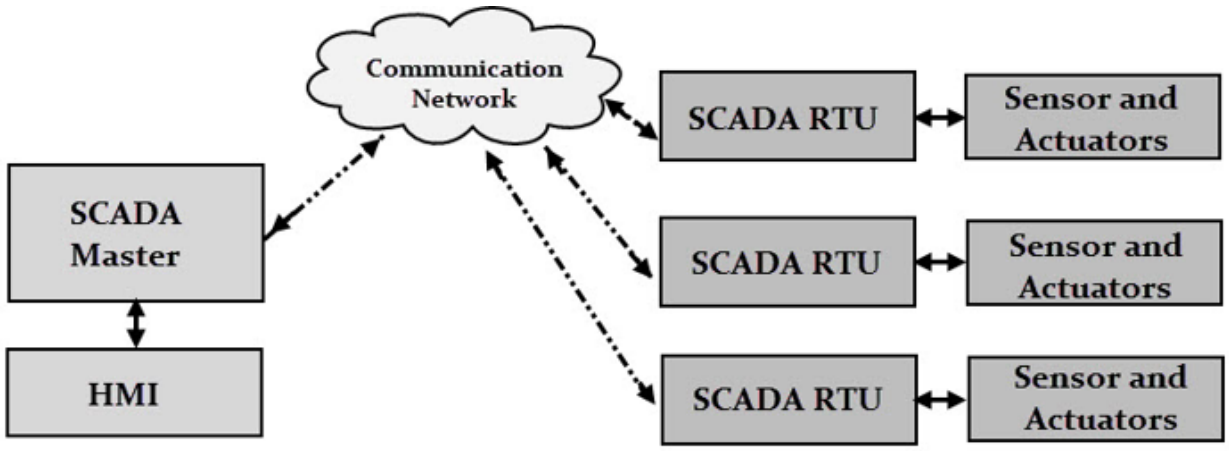
SCADA **(**Supervisory Control and Data Acquisition**)** is a system that collects data from various sensors at a factory, plant, or in other remote locations and sends this data to a central computer that then manages and controls the data. This is used to control geographically distributed processes. It is scattered over 1000s of kms. It has applications in the following areas:

- Mining industries
- Water distribution system
- Waste water treatment
- Oil and gas pipelines
- Electrical Power distribution

In SCADA, data from various remote locations are collected using sensors using RTUs (Remote Terminal Units) and displays the data on HMIs (Human Machine Interfaces) at the Master Station. The data is also recorded on the SCADA database.

SCADA has hardware and software components. The hardware consists of main 3 components.

## Components of SCADA (Block diagram of SCADA)




### Master Station

It is the heart of SCADA system. It has a dedicated computer in a central location. It monitors and controls the RTUs. The master station consists of Engineering work stations, HMI (Human Machine Interface) stations and large databases (for storing data). The master station performs the following functions:

- Collects and processes information from the RTUs.
- Stores collected data on a database
- Provides interface to the operators through HMIs

**Communication equipment**

- Communication is carried out between Master Station and Remote Terminal Units.
- The communication is bidirectional (both to and from).
- It can be wired or wireless. Wired communication can be through twisted pair cables or fiber optic cables or telephone lines. Wireless communication can be using radio signals or satellites

**Remote Terminal Unit (RTUs)**

- These are special units like PLCs which are placed at geographically distributed field sites.
- They are connected with sensors for getting various information like voltage, current, temperature or pressure.
- They are also connected with actuators like pumps, relays or valves
- RTUs collect information from the field and controls the field devices.
- Sometimes they store data in a local data base and waits for instruction from Master Station to send data.

**Features of SCADA**

- Data acquisition is done by the Master Station with the help of RTUs
- Display of information in the form of pictures or text is provided on several HMIs
- The SCADA executes supervisory form of control. Control of equipment which are at remote locations is done from the master station
- Alarm Processing – There is facility to alert the operator by informing the place and time of an event.
- Information storage and reports – Data is stored in a temporary data base for 40 days or 12 months. Later it is shifted to a permanent storage device.