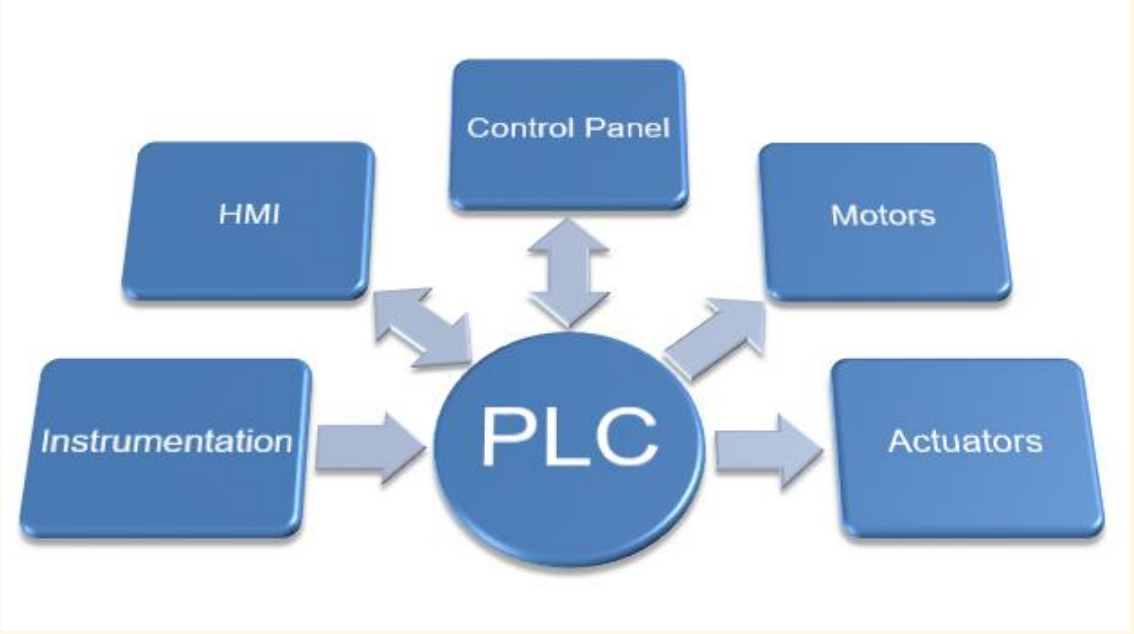
6. Industrial Robotics automation and PLC

Programmable Logic Controller (PLC)

Industrial Robotics, Introduction to PLC

A Programmable Logic Controller (PLC) or Programmable Controller is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines, control of amusement rides, or control of lighting fixtures.



Industrial Robotics, Introduction to PLC

A formal definition Of a PLC comes from the National Electrical Manufacturers Association (NEMA):

"A digitally operating electronic system, designed for use in an industrial environment, which uses a programmable memory for the internal storage of user-oriented instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic, to control, through digital or analogue inputs and outputs, various types of machines or processes. Both the PC and its associated peripherals are designed so that they can be easily integrated into an industrial control system and easily used in all their intended functions."

Programmable Logic Controller (PLC)

Brief history

In 1960s and 1970s, electromachanical relays, timer, counters and sequencers were the standard. Many Control Panels contained hundreds of these electromachanical devices and in some cases, a thousand of meters wires. The programmable controller is a solid state electronic device designed in the early 1970s to **replace electromechanical relays, mechanical timers, counters, and sequencers.**

General Motors was the first to start PLC for their plant.

Programmable Logic Controller (PLC)

Brief history

Richard E Morley is considered as the father of the PLC. Commonly known as Dick Morley, he was an American engineer who was an expert in the field of computer design, artificial intelligence and automation.

The first Programmable Logic Controller was called a Modicon PLC. The name was a shortened version of **mod**ular **di**gital **con**troller. The introduction of the **MODICON** PLC revolutionized industry and how industrial processes and machines where automated.

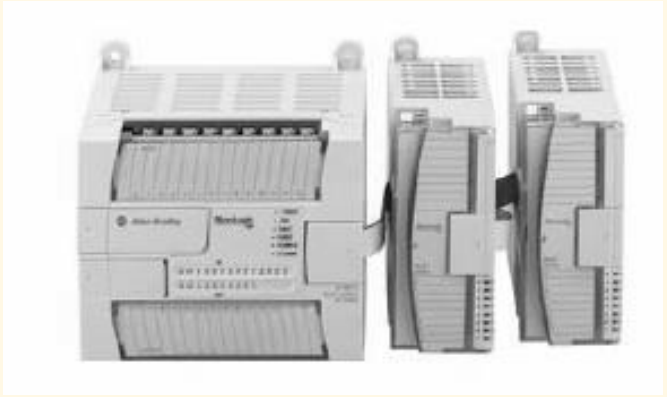
MODICON was the company that created the **MODICON** PLC in 1968. But since then **MODICON** have been owned by Gould, AEG and are presently owned by Schneider.

Types of PLC :-

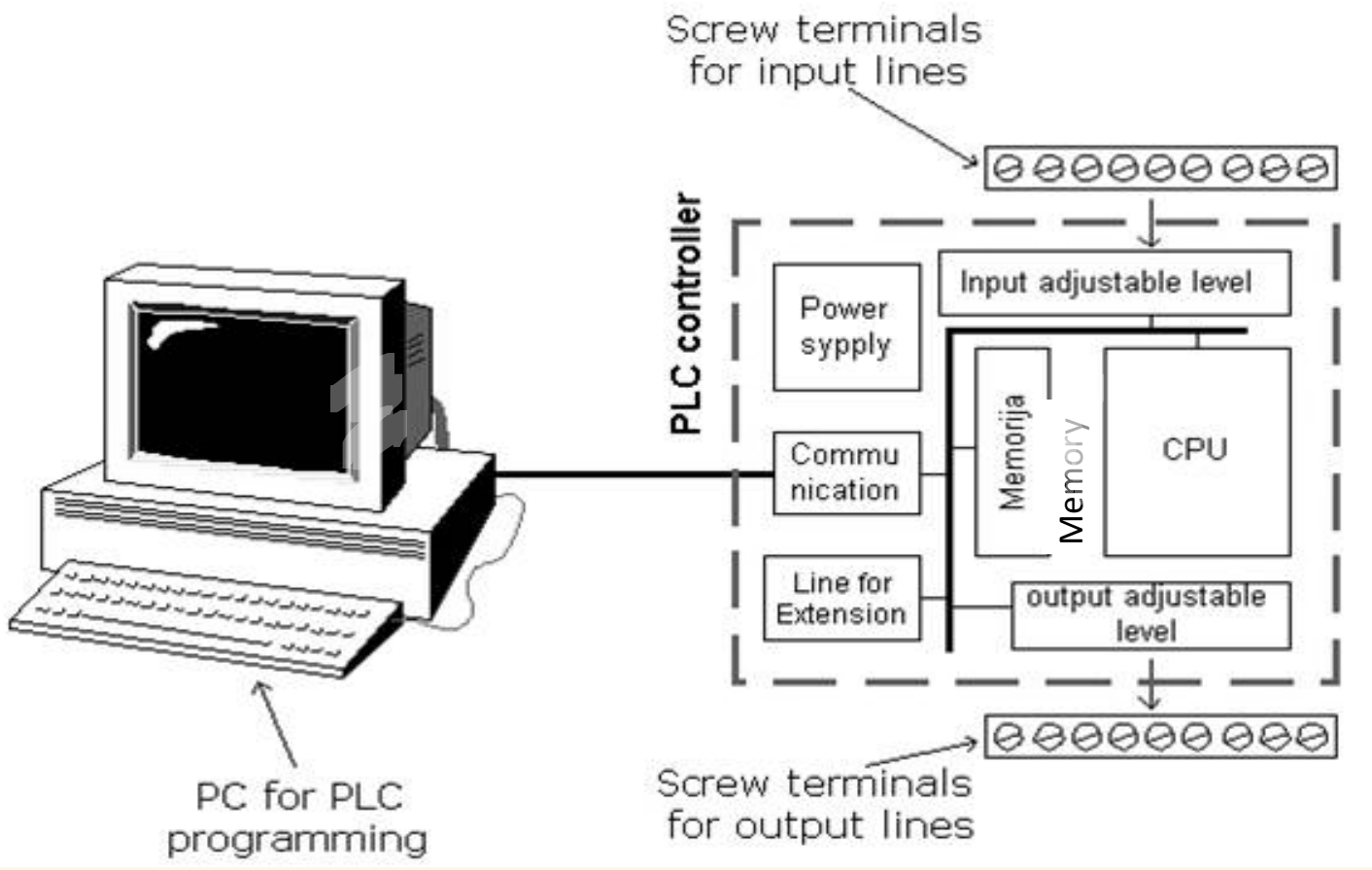
1) Fixed PLCs :- All input and output terminals are built into the PLC package and are fixed, not removable. This style of PLC is also called a Packed Controller.

2) Modular PLCs :-

The modular PLC comes as separate pieces. A modular PLC is one that can be connected with one other piece by piece.



Basic Components of PLC :-




Demo Station: Custom Beer Mug Factory


Top PLC Manufacturers
Allen-Bradley
SIEMENS
ABB
Schneider Electric
HITACHI
Inspire the Next
BECKHOFF
OMRON
MITSUBISHI MOTORS
Fuji Electric
REALPARS

Basic Components of PLC :-

1) Processor (CPU) :-

The Processor consists of one or more standard or custom microprocessors and other integrated circuits that perform the computing and control function of the PLC system.

Basic Components of PLC :-

2) Input/output System :-

Input/output (I/O) system has various input modules to sense and measure physical quantities of the process such as motion, level, temperature, pressure, position, current, and voltage.

Inputs are field devices such as sensors, button, switches and instrumentation which are used to decide when and how the machine will operate. Inputs are wired directly into to the PLC or via input modules.

Outputs are field devices such as relays, motor contactors, solenoid valves, lamps and sirens which cause the machine to operate and provide feedback to the machine operator. Outputs are wired directly out of the PLC or via output modules.

Basic Components of PLC :-

2) Input/output System :-

There are different types of Input/output (I/O) modules:

- Analog I/O Modules,
- Digital I/O Modules,
- AC I/O Modules,
- DC I/O Modules and
- Intelligent I/O Modules.

Basic Components of PLC :-

3) Programming Language & Device :-

The four most common types of languages used in PLC are :

1) Ladder Programming

2) Statement List Programming

3) Function Block Programming

4) Boolean Logic

Basic Components of PLC :-

3) Programming Language & Device :-

Programming devices can be dedicated or personal computers that normally have four basic components: keyboard, visual display, microprocessor, and communication cable.

The programming terminal i.e. a Computer is normally connected only to the programmable logic controller system during programming or during troubleshooting of the control system. Otherwise the programming device is disconnected from the system.

The most common programming terminals are as follows:

1. Hand-held manual programmer (HMI)
2. Industrial programming terminal
3. Personal computer-based programmer(PLC Software)

Basic Components of PLC :-

4) Memory

Memory is used to store control program for the PC System; it is usually located in the same housing as the CPU.

5) Power Supply :-

The power supply converts ac line voltage to dc voltage to power the electronics circuits in a PLC .

These power supplies rectify, filter, and regulate voltages and currents to supply the correct amounts of voltage and current to the system.

The power supply normally converts 240 V ac line voltages into direct voltages into direct current voltages such as + 5 or ± 15 V.

Advantages of PLC :- **Comparison with Microcontroller, PCs etc**

The 4 main types of controllers used in industrial control systems are …..

1) relay logic
2) industrial PCs
3) microcontrollers
4) PLCs

Relays are best suited to automate a hand full of simple automation tasks.

While an **Industrial PC** would be best suited when high degrees of math computation is required, such as a flight simulator.

A **Microcontrollers** is best suited to automate an application with a fixed set of parameters and has potential for mass production, like a washing machine.

A **PLCs** is best suited to automate a large amount of automation tasks, such as a manufacturing plant.

The **difference between a PLC and a microcontroller** lies in the architecture of the units. Both have a microprocessor with inputs and outputs, but ….

A PLC is designed to be expandable, accept and process large amounts of I/O and be able to communicate with other devices.

A microcontroller is usually built for one particular automation task, at lower cost and usually for mass production purposes.

Advantages of PLC :-

1) Compact and robust.
2) Reliability of the PLC
3) Virtually maintenance free.
4) Trouble shooting aids make programming easier and reduce downtime.
5) Easily expandable due to its modular design.
6) Lower power consumption compared to relay systems.
7) Built in communication for remote I/O, instrumentation, other PLCs and SCADA.

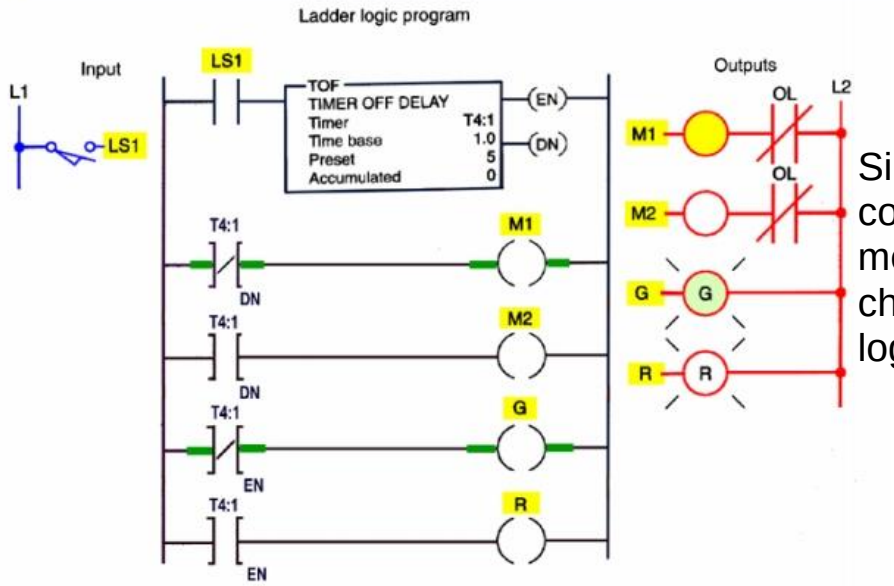
Advantages of PLC :-

7) Can handle a large number of digital inputs and outputs.
8) Able to process analogue input signals and PID loops.
9) Multiple programming languages available.
10) Easy to use programming interface via PC.
11) Control logic modifications easily done via software, no hard wire modifications required.
12) Installation costs greatly reduced as compared to relay systems.
13) Excellent documentation facilities.
14) Increased ability for fault finding and diagnostics.

Advantages of a PLC Control System

Increased Reliability:

Once a program has been written and tested it can be downloaded to other PLCs.

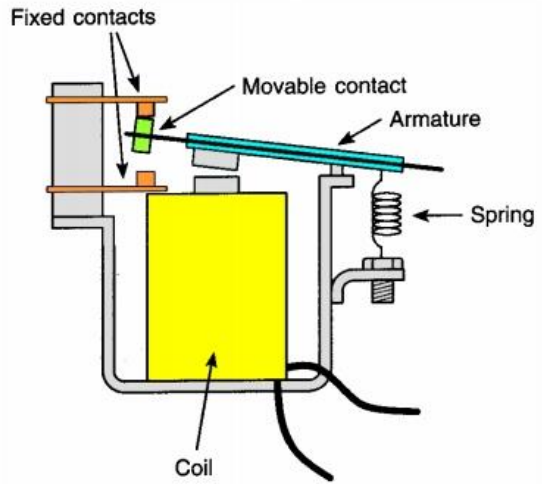


Since all the logic is contained in the PLC's memory, there is no chance of making a logic wiring error.

Advantages of a PLC Control System

Lower Costs:

Originally PLCs were designed to replace relay control logic. The cost savings using PLCs have been so significant that relay control is becoming obsolete, except for power applications.

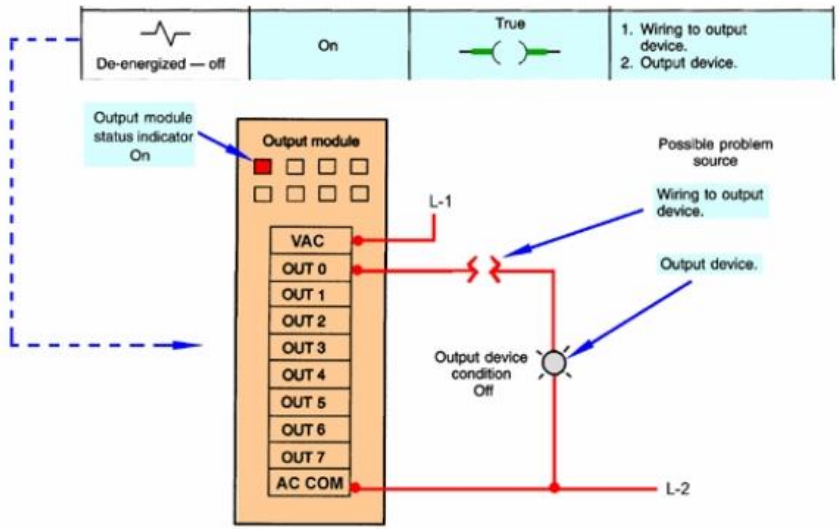


Generally, if an application requires more than about 6 control relays, it will usually be less expensive to install a PLC.

Advantages of a PLC Control System

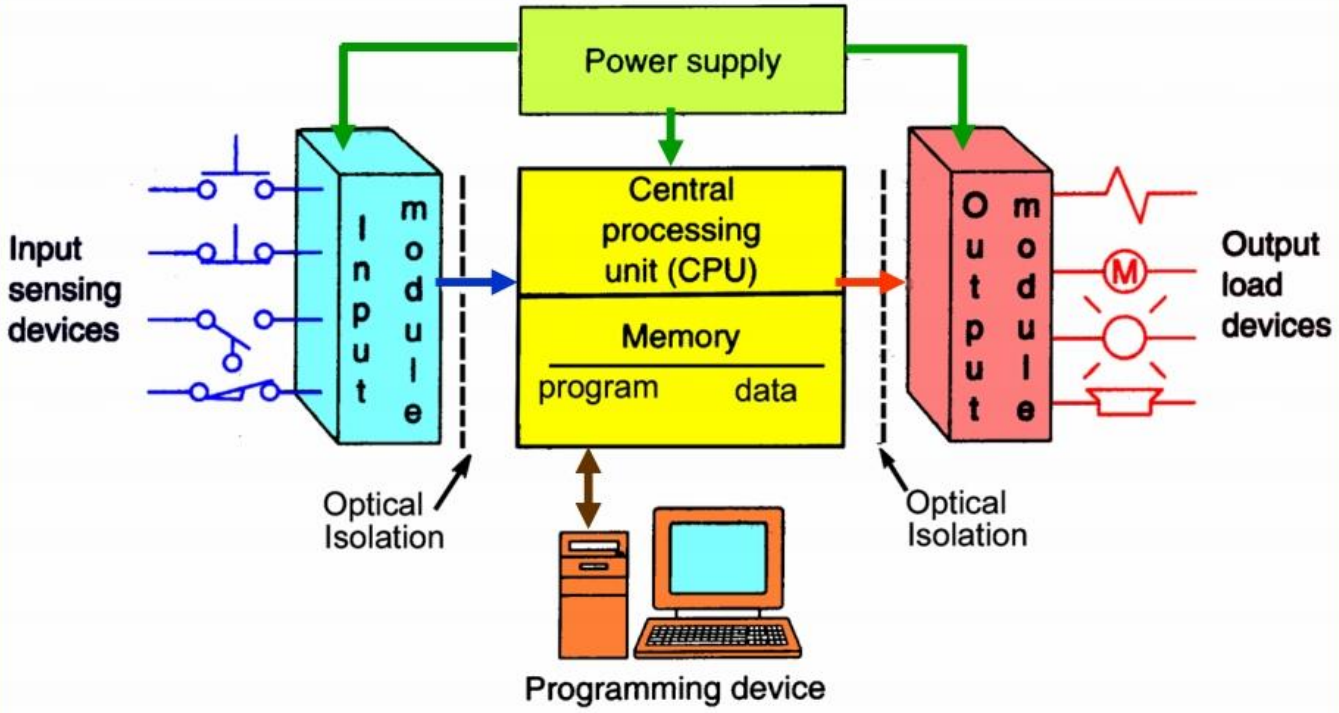
Easier To Troubleshoot:

PLCs have resident diagnostic and override functions allowing users to easily trace and correct software and hardware problems.



The control program can be watched in real-time as it executes to find and fix problems

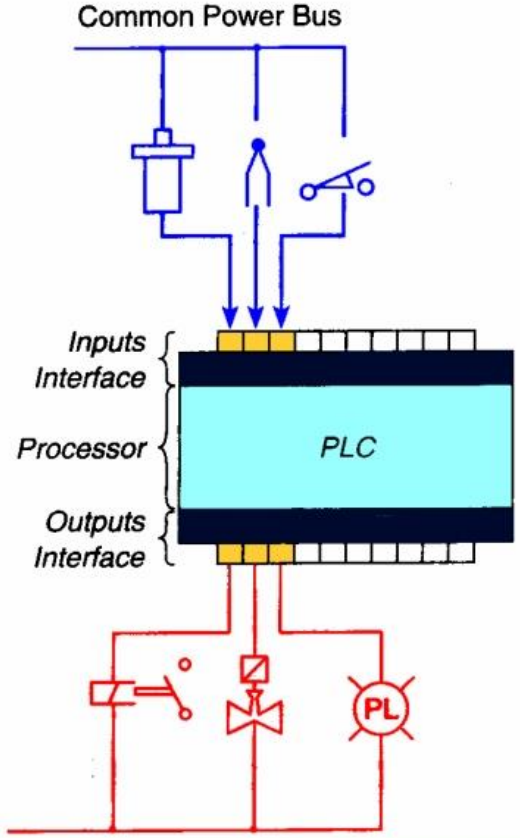
PLC System


Power supply
Central processing unit (CPU)
Memory
program
data
Input module
Output module
Input sensing devices
Output load devices
M
Optical Isolation
Optical Isolation
Programming device

I/O Configurations

Fixed I/O

- Is typical of small PLCs
- Comes in one package, with no separate removable units.
- The processor and I/O are packaged together.
- Lower in cost – but lacks flexibility.

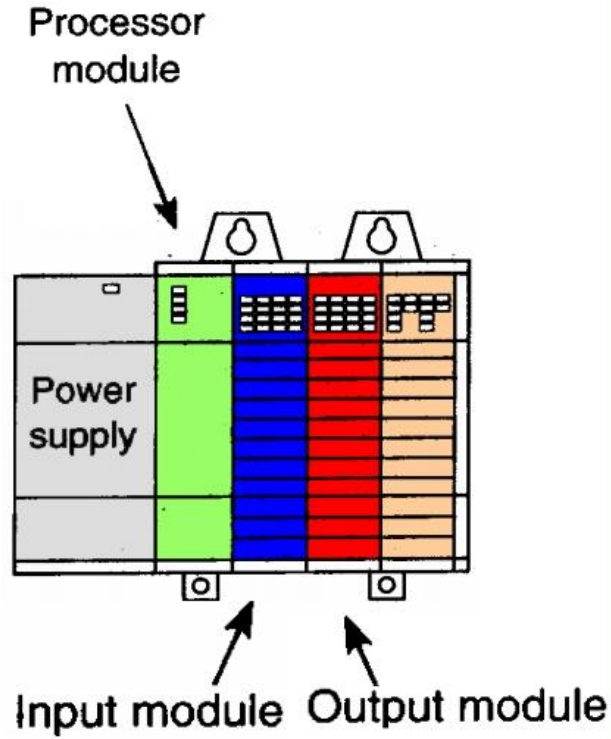


I/O Configurations

Modular I/O

Is divided by compartments into which separate modules can be plugged.

This feature greatly increases your options and the unit's flexibility. You can choose from all the modules available and mix them in any way you desire.



Disadvantages of PLC :-

1) For simple applications where relay logic might suffice, using a PLC might will increase costs due to the need to hire a programmer.
2) Math functions in a PLC are quite advanced, but when it comes to doing large amounts of complex math computations then an industrial PC might be better suited.
3) Certain robotic and positioning applications may require extremely high speed execution which may not be able to be achieved form a PLC.
4) Can be expensive for automating an application with fixed parameters for mass production as compared to a microcontroller.

Ladder diagram of a PLC

1. **Rails** – There are two rails in a ladder diagram which are drawn as vertical lines running down the far most ends of the page. If they were in a relay logic circuit they would represent the active and zero volt connections of the power supply where the power flow goes from the left hand side to the right hand side.
2. **Rungs** – The rungs are drawn as horizontal lines and connect the rails to the logic expressions. If they were in a relay logic circuit they would represent the wires that connect the power supply to the switching and relay components. Each rung is numbered in ascending sequential order.

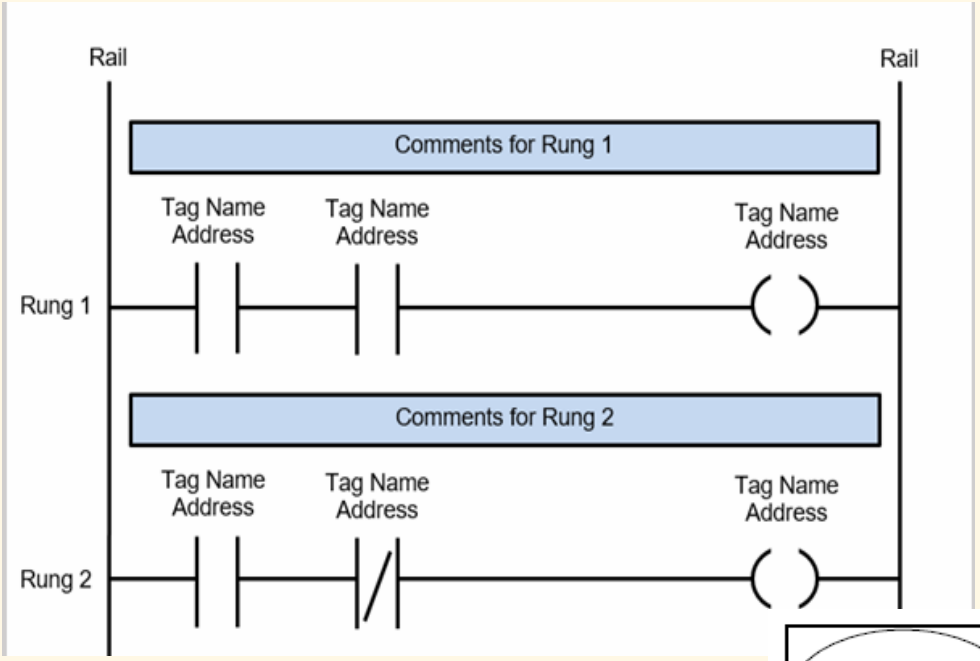
Ladder diagram of a PLC

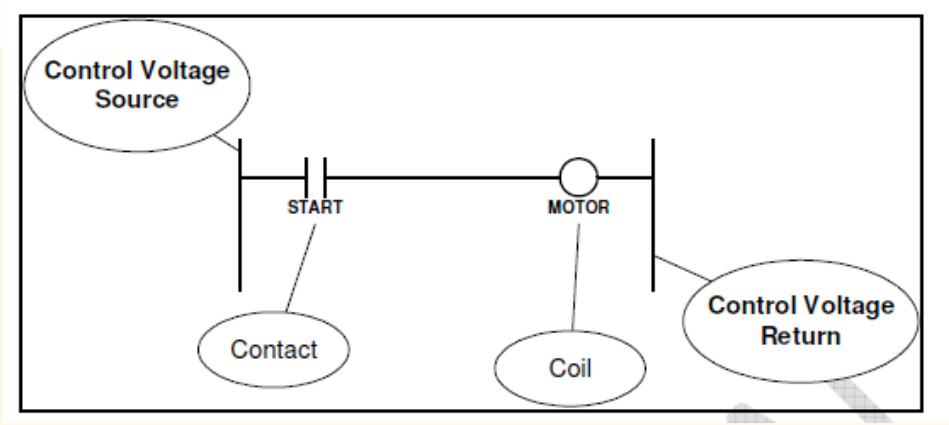
3) **Inputs** – The inputs are external control actions such as a push button being pressed or a limit switch being triggered. The inputs are actually hardwired to the PLC terminals and represented in the ladder diagram by a normally open (NO) or normally closed (NC) contact symbol.
4) **Outputs** – The outputs are external devices that being are turned on and off such as an electric motor or a solenoid valve. The outputs are also hardwired to the PLC terminals and are represented in the ladder diagram by a relay coil symbol.

Ladder diagram of a PLC

5) **Logic Expressions** – The logic expressions are used in combination with the inputs and outputs to formulate the desired control operations.
6) **Address Notation & Tag Names** – The address notation describes the input, output and logic expression memory addressing structure of the PLC. The tag names are the descriptions allocated to the addresses.
7) **Comments** – Last but by not least, the comments are an extremely important part of a ladder diagram. Understanding ladder diagrams is made a lot easier by using comments.

Ladder Logic :-





Ladder Logic :-

Ladder logic has been developed to mimic relay logic. The decision to use the relay logic diagrams was a strategic one. By selecting ladder logic as the main programming method, the amount of retraining needed for engineers and trades people was greatly reduced. Ladder logic input contacts and output coils allow simple logical decisions.
Functions extend basic ladder logic to allow other types of control. For example, the addition of timers and counters allowed event based control.

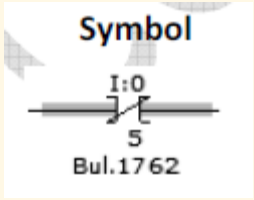
A list of functions is shown below:

- Combinatorial Logic--- relay contacts and coils
- Events--- Timer instructions, counter instructions
- Data Handling -- Moves, Conversions, Numerical Logic, Boolean op.., Comparisons
- Lists--- shift registers/stacks, Sequencers
- Program Control-- branching/looping, Immediate In/Out, fault/interrupt detection
- Input/Output– PID, Communications, high speed counters, ASCII string functions

Ladder Logic :-

2. XIO (Examine if Open) :

Use the XIO (Normally closed) instruction in your ladder program to determine if a bit is 'Off'. When the instruction is executed, if the bit addressed is off (0), then the instruction is evaluated as true. When the instruction is executed, if the bit addressed is on (1), then the instruction is evaluated as false.



Logically similar to NC or normally closed switch (inverter)

Usage:

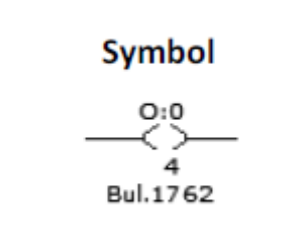
In our program, this instruction is used for giving the input which comes from switches, sensors etc.

For example –To stop a motor by using limit switch for safety in reverse direction.

Ladder Logic :-

3. OTE (Output Energize) :

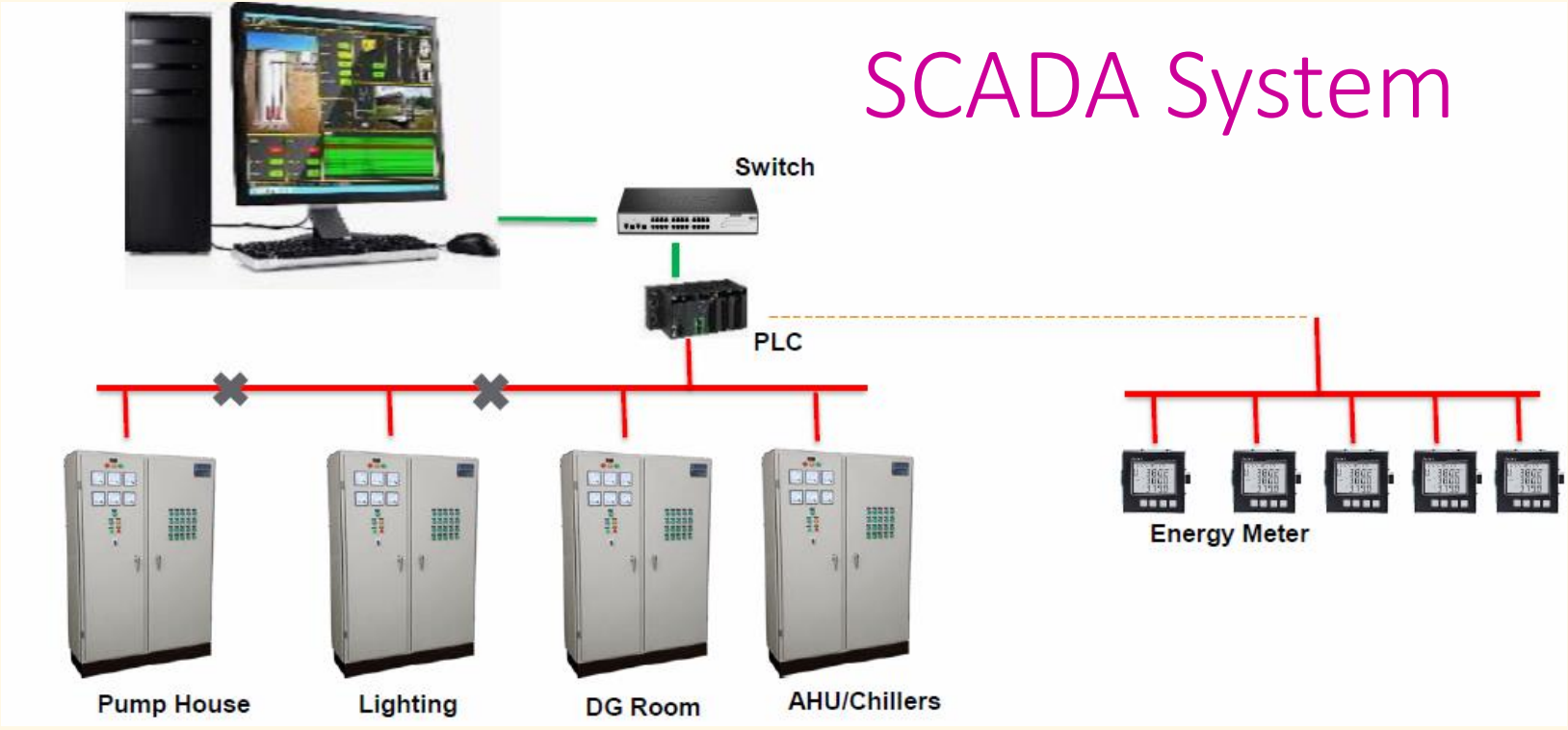
Use the OTE instruction in your ladder program to turn on a bit when rung conditions are evaluated as true.



Usage:

This instruction is used for output i.e. starting the motor, turning ON lamps, buzzers etc.

SCADA System

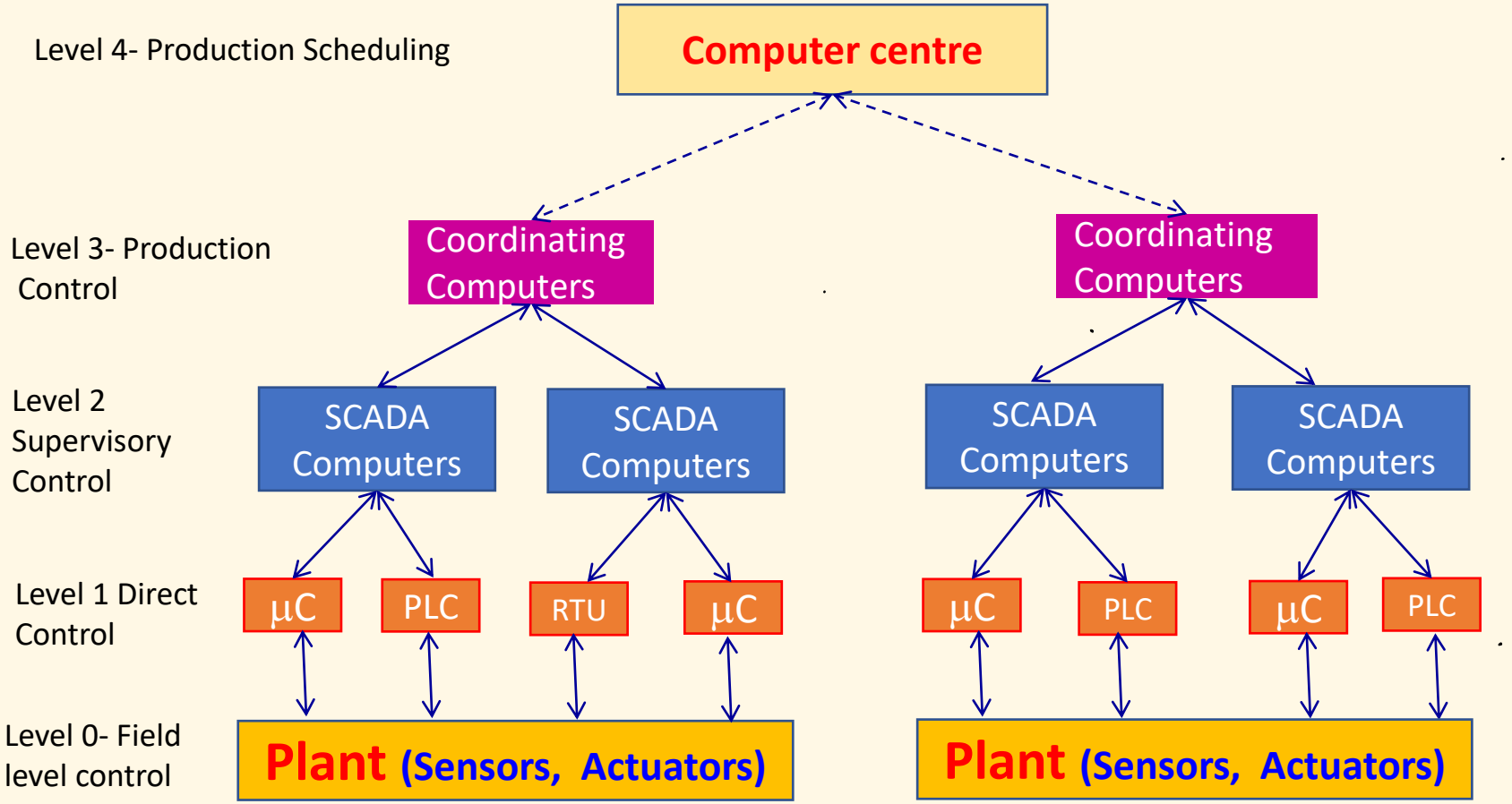


SCADA- Supervisory Control and Data Acquisition

What is SCADA System?

SCADA stands for Supervisory Control and Data Acquisition; it is an industrial computer-based control system employed to gather and analyze the real-time data to keep track, monitor and control industrial equipments in different types of industries.

Automation levels ---Plant



Comparison between PLC and SCADA

PLC	SCADA
The term PLC stands for programmable logic control	The term SCADA stands for Supervisory Control and Data Acquisition
PLC is hardware-based	SCADA is software-based
PLCs are mainly used to control the process of complex systems like motors and running machines.	SCADA is used to observe & run the processes of the plant.
The PLC includes Processor, I/O Modules, a Programming Device & Power Supply	The SCADA system includes three essential components like MTU, RTU, and HMI
There are different types of PLCs like fixed or compact & modular.	The different types of a SCADA system are monolithic, distributed, networked & IOT
The I/P & O/Ps are signified in NO (normal open), NC (normal close) & coil contacts.	The input & outputs of SCADA are represented through images.
In PLC, every component can be defined through an address.	In SCADA, each component can be defined through the name.

SCADA Basics

1. Human-machine Interface (HMI)

It is an input-output device that presents the process data to be controlled by a human operator. It is used by linking to the SCADA system's software programs and databases for providing the management information, including the scheduled maintenance procedures, detailed schematics, logistic information, trending and diagnostic data for a specific sensor or machine. HMI systems facilitate the operating personnel to see the information graphically.

SCADA Basics

2. Supervisory System

Supervisory system is used as server for communicating between the equipment of the SCADA system such as RTUs, PLCs and sensors, etc., and the HMI software used in the control room workstations. Master station or supervisory station comprises a single PC in smaller SCADA systems and, in case of larger SCADA systems, supervisory system comprises distributed software applications, disaster recovery sites and multiple servers. These multiple servers are configured in a hot-standby formation or dual-redundant, which continuously controls and monitors in case of a server failure for increasing the integrity of the system.

SCADA Basics

3. Remote Terminal Units (RTU)

Physical objects in the SCADA systems are interfaced with the microprocessor controlled electronic devices called as Remote Terminal Units (RTUs). These units are used to transmit telemetry data to the supervisory system and receive the messages from the master system for controlling the connected objects.

SCADA Basics

4. Communication Infrastructure

Generally the combination of radio and direct wired connections is used for SCADA systems, but in case of large systems like power stations and railways Synchronous Optical Network (SONET)/ **synchronous digital hierarchy (**SDH) are frequently used.

Disadvantages of SCADA system

The disadvantages of the SCADA system include the following.

1. It is complex in terms of dependent modules & hardware units.
2. It needs analysts, programmers & skilled operators to maintain
3. High installation cost
4. Unemployment rates can be increased

Applications of SCADA system

There are numerous applications of SCADA systems, but a few most frequently used SCADA applications include:

1. Manufacturing Industries
2. Waste Water Treatment and Distribution Plants
3. SCADA in Power System