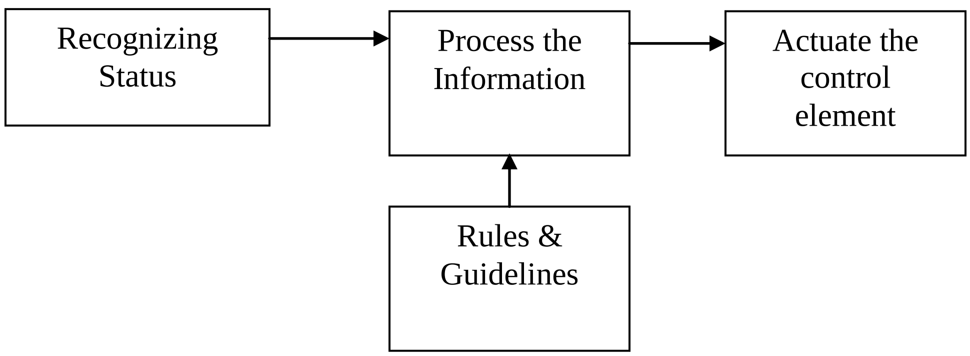
Session – I

1. Introduction to PLC

1.1 Process Control

The process of recognizing the state of the processes at all times, process the information according to the set of rules and guidelines and accordingly actuate the control elements is referred to as ***process control***.

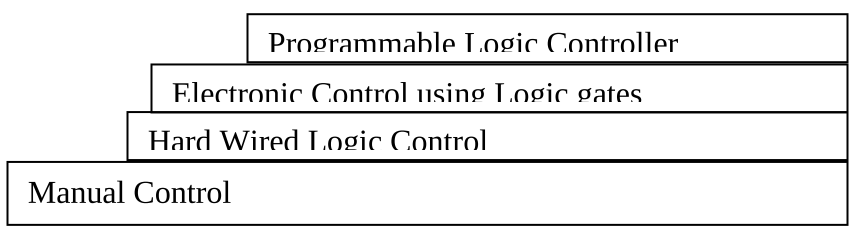
In the control of processes, all these actions can be taken manually with human involvement or in a semi-automatic or fully automatic manner.



1.2 Automation:

Automation is basically the delegation of human control functions to technical equipment aimed towards achieving higher productivity, superior quality of end product, efficient usage of energy and raw materials and improved safety in working conditions

1.3 History of Process Control & Automation



- In **manual control**, all the actions related to process control and automation are taken by the operators. There is possibility of human errors and its effect on quality of final product.

- In **hard wired logic control**, the contactors and relays together with timers and counters were used in achieving the desired level of automation It has following limitations:
  - Bulky & complex wiring
  - Involves lot of rework to implement changes in control logic
  - The work can be started only when the task is fully defined and this leads to longer project time.

- In **electronic control using logic gates**, the digital logic gates started replacing the relays and auxiliary contactors in the control circuits. We got benefits of reduced space requirements, energy saving, less maintenance and greater reliability.

- PLC – With the coming of microprocessor and associated peripheral chips, the whole process of control and automation underwent a radical change. The desired logic control is achieved through a program or software.

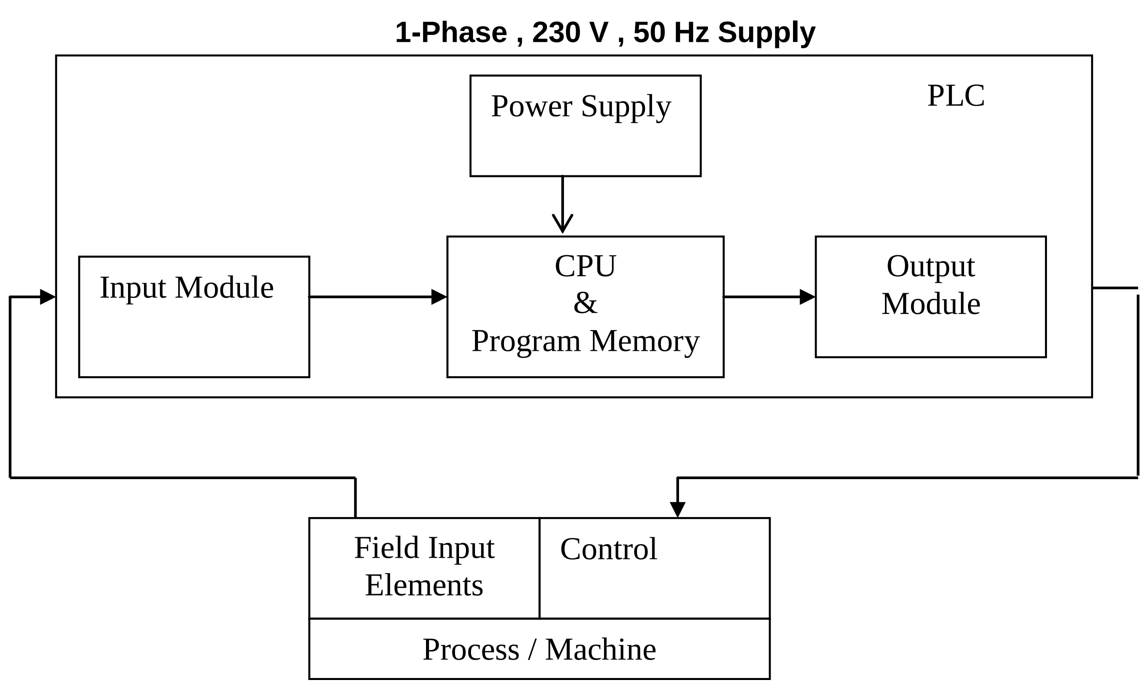
1.4 Why do we use PLCs?

In industry, there are many production tasks that are highly repetitive in nature which need careful attention of operator to ensure good quality of final product. Many a times, close supervision of processes cause high fatigue on operator resulting in loss of track of process control. Some times it is hazardous also as in the case of potentially explosive chemical processes. Under such conditions we can use PLCs effectively, in totally eliminating the possibilities of human error. Some of the capabilities of PLC are as follows:

- Logic Control
- PID Control
- Coordination & Communication
- Operator Control
- Signaling & listing
- Reduced space requirements
- Energy Saving
- Less maintenance and greater reliability

In short wherever, sequential logic control and automation is desired the PLCs are the best suited to meet the task. It includes simple interlocking functions to complicated analog signal processing to PID control action in closed loop control etc.

1.5 What Constitutes a PLC? (Block Diagram)



Block Schematic of a PLC in a minimum System

The PLC is basically a programmed interface between the field input elements like limit switches, sensors, transducers, push-buttons etc. and the final control elements like actuators, solenoid valves, dampers, drives, LEDs, hooters etc. this interface called as programmable logic controller consists of the following:

- Input Modules (Signal modules)
- CPU with processor and program memory
- Output modules (Signal Modules)
- Bus system
- Power Supply

1.6 PLC HARDWARE

The most essential components of a PLC are:

Power Supply - This can be built into the PLC or be an external unit. Common voltage levels required by the PLC (with and without the power supply) are 24V DC, 110V AC, 220VAC.

INTRODUCTION

Many PLC configurations are available, even from a single vendor. But, in each of these there are common components and concepts. The most essential components are:

Power Supply - This can be built into the PLC or be an external unit. Common voltage levels required by the PLC (with and without the power supply) are 24V DC, 110V AC, 220VAC.

CPU (Central Processing Unit): The heart of the CPU is the microprocessor / micro controller chip. It is fully controlled by the instructions / programs stored in user program memory. User Program directs and controls the CPU's working. The user, based on the control logic required for the control and automation task prepares the program. ***This is a computer where ladder logic is stored and processed.***

Input Module: It acts as an interface between the field control inputs and the CPU. The V/ I signals generated by the **sensors, transducers, limit switches, push buttons** etc. are applied to the terminals of the input module. The main functions are:

- It converts the field signal into a standard control signal for processing by PLC which could be 5V, 9V whereas the field signal received by it could be 24V DC or 230V AC.
- If required, it isolates the field signal from the CPU
- It sends one input at a time to CPU by multiplexing action

Depending upon the nature of input signal coming from the field, the input module could be analog or digital. The typical analog inputs are 4-20mA, 0 to 20mA, 0 to 50mV, 0 to 10V etc. The typical digital input modules are 24V DC, 115V AC, 230V AC.

Output Module: It acts as a link between the CPU and the output devices located in the field. It could be relays, contactors, lamps, motorized potentiometers, actuators, solenoid valves etc. These devices control the process. The Output modules converts the output signal delivered by CPU into an appropriate voltage level suitable for the output field devices. The voltage provided by

CPU could be 5V or 9V but the output module converts this voltage level into say 24V DC, 115V AC or 230V AC etc. Like input modules it could be either analog or digital. Typical analog output modules have the ratings of 4-20mA or 0-10V & the digital output modules have 24V DC, 115V AC, 230V AC or relay output.

Additional Modules: In addition to the above , the other frequently used modules are Interface modules , Communication Processor , Intelligent Periphery or Function modules.

Bus System: It is a path for the transactions of signals. In the PLC, it is responsible for the signal exchange between processor and I/O modules. The bus comprises of several signal lines i.e. wires and tracks. There are 3 types of buses in a PLC:

- Address bus that enables the selection of a memory location or a module
- Data bus that carries the data from modules to processor and vice versa

Control bus that transfers control and timing signals for the synchronization of the CPU's activities within the programmable controller.Indicator lights - These indicate the status of the PLC including power on, program running, and a fault. These are essential when diagnosing problems.

Rack - A rack is often large (up to 18" by 30" by 10") and can hold multiple cards. When necessary, multiple racks can be connected together. These tend to be the highest cost, but also the most flexible and easy to maintain.

Mini - These are similar in function to PLC racks, but about half the size.

Micro - These units can be as small as a deck of cards. They tend to have fixed quantities of I/O and limited abilities, but costs will be the lowest.

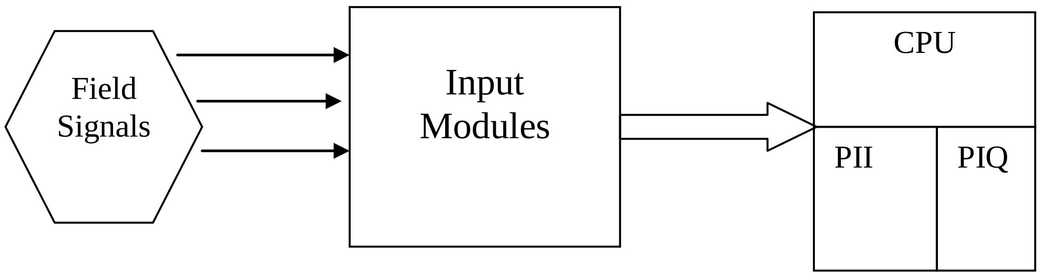
Indicator lights - These indicate the status of the PLC including power on, program running, and a fault. These are essential when diagnosing problems.

Programming Devices: PLCs can be programmed using LAPTOPS and PCs with proprietary interface cards in case of stand-alone systems & also in case of PLCs networked over proprietary networks. Software implementation of each vendor being different, software packages of all the systems must be loaded in the programming unit if more than one make of PLCs are used over the network. Alternatively more than one programming unit can be connected over network. Modern PLC development systems employ GUI running on standard operating systems like Microsoft Windows XP, Windows 2000, and Windows 2003 server. Windows VISTA being the latest operating system offered by Microsoft, programming packages compatible to it are expected to be in market by January 2008 as Microsoft will officially stop supporting Windows XP from June 2008. SIMATIC STEP7 V 5.4 SP1 and RSLogix5000 V16.00.00 are the latest programming tools of SIEMENS & ROCKWELL PLCs respectively. These programming packages are resource intensive and experience has shown that minimum configuration of Laptops & PCs should have :

- Intel P4 3.0 GHz and above
- 1GB RAM preferred (512 MB minimum)
- 40 GB HDD 7200 RPM or SATA preferred
- PCI slots (minimum 2 nos) for add on cards.
- 19 inch monitor in case of desktops for better navigation of screen.
- DVD RW preferred (minimum CD RW) for software backups.
- USB ports, Ethernet NIC

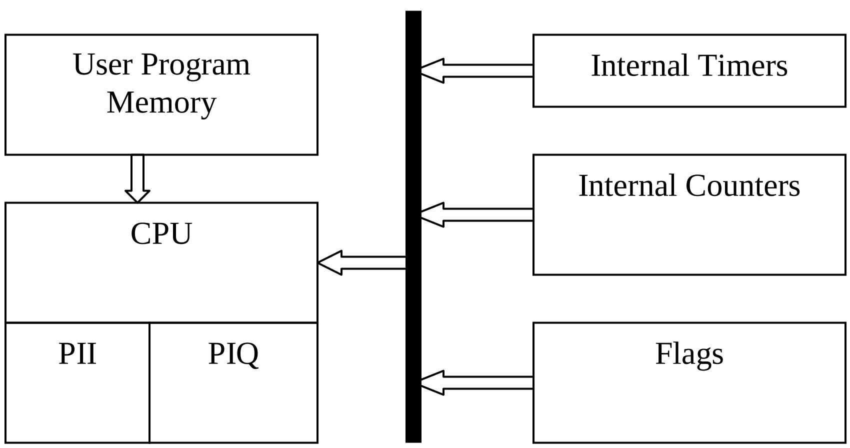
1.7 How PLC Works?

a. Bringing input signal status to the internal memory of CPU



As the field signals are connected to input module, at the output of input module the field status converted into the voltage level required by the CPU is always available. At the beginning of each cycle, the CPU brings in all the field input signals from input module and stores into its internal memory as process image of input signal. This internal memory of CPU is called ***PII (Process Image Input).***

b. Processing of Signals using Program:



Once the field input status is brought into the internal memory of CPU i.e. in PII, the execution of user program, statement by statement, begins. Based on the user program, the CPU performs logical and arithmetic operations on the data from PII. It also processes times and counts as well as flag states.

c. Storing the Results of Processing in the Internal Memory:

The results of the user program scan are then stored in the internal memory of CPU. This internal memory is called ***Process Output Image or PIQ.***

d. Sending Process Output Image to Output Modules:

At the end of the program run (scanning cycle), the CPU transfers the signal states in the PIQ to the output module that finally reaches to the field controls or actuators.

2.1 Programmable Logic Controllers

SIMATIC S7 consists of the following three types of programmable logic controllers classified according to their performance range:

SIMATIC S7-200 is a compact micro programmable logic controller (PLC) designed for applications having the lowest performance range. S7-200 is controlled by its own system-specific software package which is not included in the following comparison of S5 and S7.

SIMATIC S7-300 is a modular mini controller designed for applications having a low performance range.

SIMATIC S7-400 is designed for applications providing an intermediate to high performance range.

For easy reference, S7-300 module names always start with a "3" and S7-400 module names with a "4".

Feature	CPU 312 IFM	CPU 313	CPU 314	CPU 314 IFM	CPU 315	CPU 315-2 DP
Work memory (integrated)	6 Kbytes	12 Kbytes	24 Kbytes	24 Kbytes	48 Kbytes	
Load memory						
• integrated	20 Kbytes RAM; 20 Kbytes EEPROM	20 Kbytes RAM	40 Kbytes RAM	40 Kbytes RAM; 40 Kbytes EEPROM	80 Kbytes RAM	
• expandable with memory card	–	up to 512 Kbytes	up to 512 Kbytes	-	up to 512 Kbytes (in CPU programmable up to 256 Kbytes)	
Process image size, inputs and outputs	32 bytes + 4 on-board	128 bytes	128 bytes	124 bytes + 4 on-board	128 bytes	
I/O address area • digital inputs/outputs	Inputs: 128 + 10 on-board Outputs: 128 + 6 on-board	128	512	Inputs: 496 + 20 on-board Outputs: 496 + 16 on-board	1024	
• analog inputs/outputs	32		64	Inputs: 64 + 4 on-board Outputs: 64 + 1 on-board	128	
Bit memory	1024	2048				
Counters	32	64				
Timers	64	128				
Max. sum of all retentive data	72 bytes		4736 bytes	144 bytes	4736 bytes	
Local data	512 bytes in total; 256 bytes per priority class	1536 bytes in total; 256 bytes per priority class				
Blocks:						
OBs	3	13	13	13	13	14
FBs	32	128	128	128	128	128
FCs	32	128	128	128	128	128
DBs	63	127	127	127	127	127
SFCs	25	44	48	48	48	53
SFBs	2	7	7	14	7	7

Signal Modules in S7-300 PLC

DI (SM 321)	DO (SM 322)	AI (SM 331)	AO (SM 332)
32 x 24 VDC	32 x 24 VDC/0.5 A	8 x 12 bit	2 x 12 bit
16 x 24 VDC	16 x 24 VDC/0.5 A	2 x 12 bit	
16 x 24 VDC with hardware and diagnostic interrupt	8 x 24 VDC/0.5 A with diagnostic interrupt	Ex: 4 x 15 bit	Ex: 4 x 15 bit
16 x 24 VDC M-reading	8 x 24 VDC/2 A	Ex: 12 x 15 bit	
8 x 120/230 VAC	8 x 120/230VAC / 2 A	AI 4/AO 2 X 8/8 bit (SM 334)	
Ex: 4 x 24 VDC	Ex: 4 x 15 VDC/ 20m A		
	Ex: 4 x 24 VDC/ 20m A		

Starting the STEP 7 Software

After starting ***Windows*** you will find the icon for the ***SIMATIC Manager*** on the ***Windows Desktop*** Double-clicking the “SIMATIC Manager” icon is the fastest way to start.

This icon opens the window for the SIMATIC Manager. From here, you can access the standard system, all optional software, and all functions that you have installed.

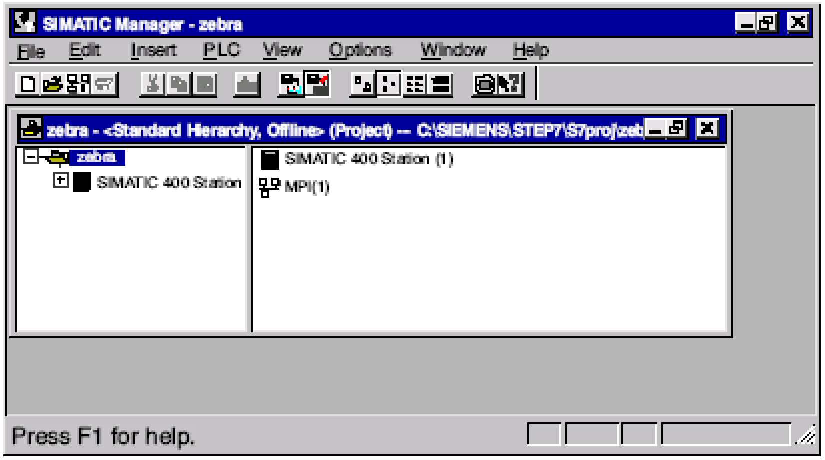
Alternatively, you can also start the SIMATIC Manager by clicking the Start-(All)Programme-Simatic/STEP 7

The SIMATIC Manager is the initial window used for configuring and programming. Here you can do the following:

- Set up projects
- Configure and assign parameters to hardware
- Configure communication connections
- Create programs
- Test programs and start them running

Access to functions is object-oriented, intuitive, and easy to learn.
You can work with the SIMATIC Manager in the following ways:

- Offline (not connected to a controller), or
- Online (connected to a controller)



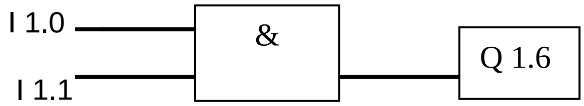
1.8 Programming of PLC: (Software)

- The PLC is a software-driven equipment.The control of machine or process is decided by the user through 'User Program'. Depending upon the process control requirement, the user prepares the program (instructions), which is stored in the **User Memory or Program Memory** in the form of machine code.CPU sequentially reads these instructions and operates the control elements taking into consideration the input status and the program instructions. In this manner the PLC controls the process. The programming language used in programming of Siemens make PLC is **Step-5 or Step-7.**
- Step 7 is the most user friendly, simple to understand and application oriented programming language. For Step 7, a PC is required for loading and programming the Software.
- The programming can be done either on-line or off-line. Off-line programming means writing of instructions in a memory submodule and then simply plugging it into the socket provided on the CPU. In on-line programming , the programming unit is directly connected to the programming port of the CPU and then the instructions are directly written into the user memory of CPU.
- Initial keying in of the program is normally done in the off-line mode (i.e. programming unit is not connected to the programmable controller) and after checking and verifying , the PU is connected to the controller in on-line mode to test the program.
- After commissioning, the program is transferred to the EPROM memory module and the computer can then operate independent of the PU.
- In STEP 7 programming language, the user program can be written in any one of the following forms:

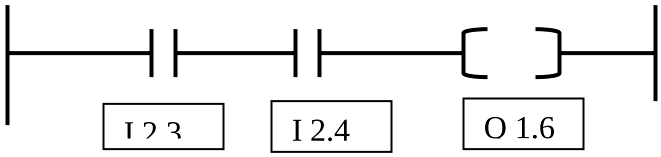
a) Statement List (STL): This method uses mnemonic abbreviations in programming. The statement consists of an **Operation** that specifies what is to be done and an **Operand** that specifies where the operation is to be done . Operand has 2 parts: Operand Identifier and Parameter.

The complete statement is **A I 2.3 –** this conveys AND operation is to be performed with the signal at input I with address 2.3

b) **Function Block Diagram (FBD):** This method uses graphical symbols to formulate the control task . This method is preferred by those who are familiar with the logic symbols / logical machine & process sequence.



c) **Ladder diagram (LAD) :** It uses relay logic symbols to formulate the control task.



1.9 Selection of PLC:

In the market, PLCs with different capacities, capabilities and constructional features are available. They are referred to as lower end, middle or upper end PLCs. Construction wise they could be compact or with modular construction. In selecting the PLC we have to ask the following questions, get the answers and then decide on which PLC to buy:

- How many control signals will be inputted to PLC?
- How many output devices or controlling elements are to be controlled by CPU /PLC?
- What memory capacity is needed to store the user program ?
- What speed of processing and operational capabilities desire?
- What are the communication requirements?

On getting this information we have to check for the specifications of the available PLCs vis-à-vis our requirement and then take the decision.

1.10 Summary :

Originally PLCs were conceived as a replacement for hard wired logic control. However with technological development the PLCs very rapidly evolved far beyond that and are used today in a diverse range of industrial and process control application. PLCs can control production sequences , handle data communication tasks and enable convenient monitoring and controlled manipulation of process.Today the demanda from industry market are :

- Consistently high quality of the final product
- Minimization of Costs
- An extensive communication system to allow exchange of information both between various automation systems and from man to machine and vice versa.

PLCs meet all these requirements and hence today the PLC constitutes the basic building block of an automation system.

2. 1 Make of different PLCS

1. M/S SIEMENS :

1.S5 SERIES
2.S7 SERIES

HMI :COROS, SIFLEX,

2. M/S ROCKWELL AUTOMATION:

1.SLC-5
2.AB 3 SERIES
3.AB 5 SERIES
4.CONTROL LOGIX

HMI : PANEL VIEW,
CONTROL VIEW,
RS VIEW

3. M/S ABB:
1. MP 200 SERIES
2. ADVANT CONTROLLER (AC450)
(BEING PROPOSED)

HMI : MASTER VIEW.

4. M/S L&T :

1.U84
2.R84 H/M
3.QUANTUM

HMI - PANAROMA

5. GE FANUC : 9030 SERIES (VERY FEW)

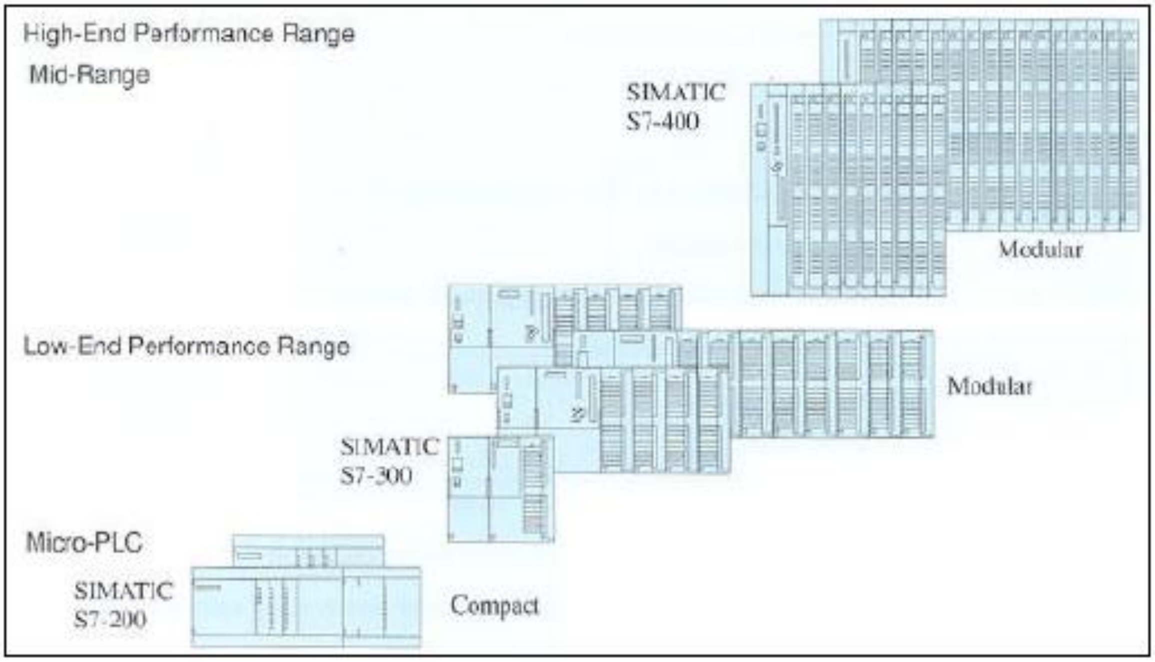
2.2 SIMATIC S7 Programmable Controllers

SIMATIC S7 consists of three programmable controllers graded according to performance**:**

- The compact SIMATIC S7-200 micro PLC for the lowest performance range.
- The modular SIMATIC S7-300 mini PLC system for the low-end performance range.
- The SIMATIC S7-400 PLC for mid to high-end performance range.

Performance Characteristics of the Programmable Controllers

Characteristics	S7-200	S7-300	S7-400
Program memory (max.) for approximate statements	4 Kbytes 2 K	24 Kbytes 8 K	512 Kbytes 170 K
Scan time for 1 K binary statements	0.8 ms	0.3 ms	0.08 ms
Digital inputs/outputs (max.)	64	512	Approx. 11000
Analog input/output (max.)	None	64	5500
Expansions (max.)	5 modules	32 modules	396 modules in 22 racks
Distance between modules	None	30 m	102.25 m
Use of distributed I/O	No	Yes	Yes
Network capability	Yes, over PPI	Yes, over MPI, integral DP & CP	Yes, over MPI, integral DP & CP



S7-200, S7-300 & S7-400 Programmable Controllers

2.3 Hardware Configuration of S7 300 PLC

2.31 Configuring an S7 300 PLC:

It is made up of the following components:

a) **Rail**: It accommodates the S7 300 modules

b) **Power Supply**: It converts the power system voltage (120V / 230V AC) into 24V DC for the PLC and load power supply for 24V DC load circuits

c) **CPU** : It contains memory card , backup battery and front connectors and executes the user program. It provides 5 V supply for the backplane bus and communicates with other nodes in an MPI network(multipoint Interface)

d) **Signal Modules(SM)** : These are digital and analog input / output modules

e) **Function Modules (FM)**: These are used to process signal processing tasks e.g. positioning or closed loop control.

f) **Communication Processor (CP)** : It relieves the CPU of communication tasks for example CP 342-5 DP for connection to PROFIBUS DP.

g) **Interface module (I M)** : It interconnects the individual tiers of an S7 300

h) **PROFIBUS cable with bus connector**: It interconnects stations on an MPI or PROFIBUS subnet.

i) **Programming device Cable** : It connects a CPU to a programming device / PC

j) **RS 485 Repeater** : It amplifies the signals in an MPI or PROFIBUS subnet and for connecting segments in these systems.

k) **Programming device or PC with the STEP 7 software package** : It configures , initializes , programs and tests the S7 300.

Several S7 300s can communicate with each other over PRIFIBUS bus cables .

2.32 **Modular Arrangement for an S7 300 Configuration on one Rack:**

The following rules apply to the arrangement of the modules on one rack:

- No more than eight modules (SM, FM, CP) may be mounted to the right of the CPU
- The number of modules that can be plugged in is limited by the amount of power they draw from the S7 – 300's back plane bus. The total power drawn from the S7 300 backplane bus by all the modules on one rack must not exceed 1.2 A
- The interface module is always located in slot 3 , to the left of the first signal module.
- For mounting S7 300 on several racks, we require interface modules. It connects the S7 300 backplane bus from one rack to the next. CPU is always in rack 0. The following cables are available for connecting IM:

Length	Spec.
1m	6ES 368 – 3BBB01-0AA0
2.5 m	6ES 368 – 3BC51-0AA0
5 m	6ES 368 – 3BF01-0AA0
10m	6ES 368 – 3CB01-0AA0

- S7 300 uses IM 365 for a configuration on 2 racks. The two interface modules are already permanently connected across a 1 m long cable. Signal Modules can be connected only in Rack 1. The total current consumption of the signal modules plugged in both racks must not exceed 1.2 A , the current consumption of rack 1 is limited to 800mA.

2.33 Slot Oriented Addressing for Modules :

In slot-oriented addressing (default addressing) , a module start address is allocated to each slot number. The input and output addresses for I/O modules start from the same module start address. The following table shows the start addresses for the signal modules

Rack	Module Start Addresses	Slot Number										
		1	2	3	4	5	6	7	8	9	10	11
0	Digital Analog	PS	CPU	IM	0 256	4 272	8 288	12 304	16 320	20 336	24 352	28 368
1	Digital Analog			IM	32 384	36 400	40 416	44 432	48 448	52 464	56 480	60 496
2	Digital Analog			IM	64 512	68 528	72 544	76 560	80 576	84 592	88 608	92 624
3	Digital Analog			IM	96 640	100 656	104 672	108 688	112 704	116 720	120 736	124 752

PLC advancements: <u>Programming languages</u>

- **Early PLCs**
  - upto mid 80s, PLCs were programmed using proprietary programming panels or special purpose programming terminals
  - Function keys for various logical elements
  - Program stored on cassette tape cartridge
  - PLC used magnetic core memory
  - PLC programmed in ladder logic

- **Modern PLCs**
  - General purpose PC as programming terminal
  - Program downloaded to PLC
  - PLC uses battery backed RAM or non volatile Flash Memory
  - Programming language supported varies from ladder logic to high level languages such as Basic and ‘C’

PLC simulator software for program development