PLCs & SCADA

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THEORY AND PRACTICE

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CONTENTS

Preface

I find the great thing in this world is not so much where we stand, as in what direction we are moving.

—Oliver Wendell Holmes

Control engineering has evolved overtime. In the past humans were the main methods for controlling a system. More recently electricity has been used for control and early electrical control was based on relays. The development of low cost computer has brought the most recent revolution, the Programmable Logic Controller (PLC). The advent of the PLC began in the 1970s, and has become the most common choice for manufacturing controls.

Since the development of first logic controllers, the capabilities of programmable logic controllers have grown by leaps and bounds. Likewise, the applications of PLCs have grown with them. In fact, in today's increasingly computer controlled environment, it is almost impossible to find a technical industry that does not use programmable controllers in one form or another. This book, provides a comprehensive theoretical, yet practical, look at all aspects of PLCs and their associated devices and systems.

After finishing the book, the student will most likely be employed in a position designing, programming and maintaining systems using PLCs of some brand or model, or even more likely, many machines with many different brands and models of PLC. The authors desire that this text not only be used to learn programmable logic controllers, but also that this text will become part of the student's personal technical reference library.

The organized material that resulted in this book is our attempt at providing a reasonable degree of balance between rigor, clarity of presentation and at the same time keeping the length of book at manageable level. The principal objective of the book is to provide an introduction to various PLC concepts and to develop a foundation that can be used as basis for research and further study in this field.

Organization of this Book

Chapter 1 is on PLC introduction highlighting evolution of PLCs, Advantages of PLC, PLC components, PLC Programming techniques, PLC applications and manufacturers.

Chapter 2 is on Fundamental concepts of Digital electronics incorporating number systems, conversions, Logic gates and Boolean Algebra**.**

Chapter 3 is on Ladder Logic concepts incorporating Basic Control system components and their symbols, Ladder logic input, output and programming concepts,Basic and Advanced Ladder Logic Functions. Relay logic and Boolean logic concepts.

Chapter 4 is on File structure and Addressing Formats, highlighting fundamental concepts of SLC 500 BASED SYSTEM, Addressing formats and elements of output and Input, Timer data, Bit data, Counter data and various other associated files.

Chapter 5 is on PLC Project development, including features of RS Logix 500 and RS Linx software, Various installation steps, Micrologix, SLC 5 /03 driver configurations, Various phases in developing a New Project, followed by LADSIM based simulation.

Chapters 6 and 7 are on Instruction set highlighting operation and significance of various Bit, Timer, Counter, Comparison and sequencing Instructions.

Chapter 8 is on PLC Applications highlighting the use of RS Logix software to program and develop some of PLC applications like Liquid level control, Process control, Drink dispenser.

Chapter 9 is PLC & SCADA interface with emphasis on SCADA software Installation, SCADA Project Development, Basics of PLC interfacing with SCADA working with developed projects.

Chapter 10 is on SCADA animations highlighting various SCADA animations like Visibility animation, text animation, Numeric display, Numeric input and Project creation using memory tags.

Chapter 11 is on Alarming and Data logging highlighting the Use of Alarm, Alarm configurations Procedure for Alarm set up, Alarm start up and operation and Concept of Alarm summary and Data logging.

Chapter 12 is on SCADA Supplements highlighting Various SCADA supplement like Event detection, Derived tags, Tens, OLE, Security and its significance in PLC Control.

The book has been written to position itself within the marketplace midway between a number of texts in this subject area which may be regarded as comprehensive, and a number of other texts which are rather brief and tend to be merely primers. Reference texts can be too detailed and large for a newcomer to the topic and the primer type of text can lack information and be rather bland for many readers. With this in mind the book is written to appeal to two broad ranges of readers:

1. Students of electronics/instrumentation engineering undergraduate and postgraduate courses who are studying Programmable Logic Controllers.
2. Professional engineer who has basic knowledge of operation and control of PLC's and for the new engineer embarking on an exciting career in electronics design and control.

Utmost care was exercised to eliminate errors; Effort has been made, as far as possible, to make each chapter self contained. Suggestions for the improvement of this book shall be gratefully acknowledged.

—Authors

Credit Where Credit is Due

On completing a book of this nature, it becomes clear to the author(s) that the work would not have been possible without the support of others.

Becoming an electronics engineer and, consequently, writing this book was spurred on by our early interest in electronics and computers that was fully supported and encouraged by our families. Whether it was the attic turned into a laboratory, a trip to the electronic supply store, or accompaniment to the science fair, our families have always been behind us. We wish to express gratitude to ***Our loving parents*** for their support and blessings throughout our life.

More directly, several friends and colleagues were kind enough to review the initial draft, provide feedback on the content, and bring to our attention details that required correction and clarification. We are grateful to our friends and colleagues for their suggestions during the course of our work.

We are thankful to our mentors for teaching us the essence of learning and keeping up with emerging technology.

—Authors

1

PROGRAMMABLE LOGIC CONTROLLERS

LEARNING OBJECTIVES

After reading this chapter, you will be able to explain:

1. Evolution of PLCs, programmable logic controller basics, and its advantages
2. PLC architecture and system components
3. PLC programming techniques
4. PLCs application list

1.1 INTRODUCTION

For automation in industries, many manufacturing processes demand a sequence of operations, which are to be performed repetitively. Early automation systems were mechanical in design, timing and sequencing being effected by gears and cams. Slowly these design concepts were replaced by electrical drives, which were controlled by relays. The relay provided many benefits since its operation was well established, it was immune to electrical interference and able to handle typical industrial input and output signals without special interfacing. The electromagnetic relays have provided control mechanism over a long period of time. But the relay does have a number of limitations:

1. It suffers from contact wear and reliability problems.
2. Being single input, multi-output, it is often completely unsuited for controlling sequencing in industrial processes.
3. The relays are hardwired *i.e.*, relays are wired to perform specific functions. When the system needs to be modified the relays have to be rewired. In large systems this would mean replacing complete control panels because it is not economical to rewire the old panels.
4. Hardwired systems are very expensive to produce due to the high labour content and modification is difficult and time consuming.

In order to control ever-increasing configurations of systems, engineers turned to computers. The computer however was not suited to the industrial environment and the use of the computer on the factory floor, was not possible, unless costly interference filtering was used. The other major problem with computers was the need to program it using a high level language. Engineers who understood a process and its control using relay ladder logic could not readily convey this to a computer programmer. So, a system similar to electromechanical relays using logical programming to control the process called PLC found favourable.

1.2 PROGRAMMABLE LOGIC CONTROLLERS

A programmable Logic Controller shown in Fig. 1.1 is a solid-state device, designed to operate in noisy industrial environments and perform all the logic functions previously achieved using electro-mechanical relays, drum switches, mechanical timers and counters. Microprocessor technology now provides a more reliable and maintenance free alternative to the relay. It contains software relays in place of actual relays or conventional relays. Solid-state relays based on silicon technology with no moving parts may be used to switch on the large loads to control a process. Hence, this replaces the electromechanical relays or hardwired solid-state logic blocks.

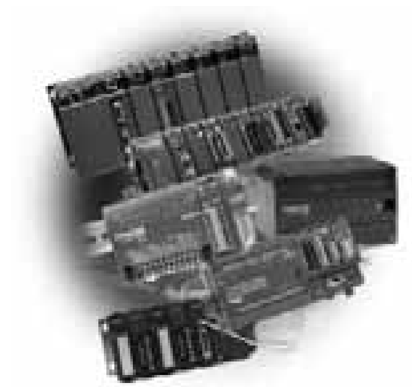

Fig. 1.1 Programmable Logic Controllers

Programmable logic controllers are sometimes also called programmable controllers as it consists of microprocessor based systems. They make technologically advanced control systems having the inherent flexibility and advantages of other programmable controllers, but with an important difference of simplicity. It is a dedicated computer that can be programmed to perform controlling functions in harsh industrial environment.

Today's industrial control problems are much more sophisticated and may need modification in their control strategy from time-to-time. A PLC can easily handle those kinds of problems because it gives required flexibility whereas hardwired devices would be very complicated and provides negligible flexibility towards changes in control strategies. PLCs have replaced old electro-mechanical relay type systems and have provided with noise free reliable control systems. PLCs have many advantages:

1. It uses simple programming language *e.g.*, ladder diagrams. The program can also be transferred to PLC installed on the factory floor by a programming device.
2. The outputs may be a mixture of conventional relays and solid-state relays.
3. They are designed for an electrically noisy environment no extra filtering is required.
4. They are smaller, faster and more reliable than hardwired systems.
5. All devices like drum switches, timers, and counters are implemented using software programs. No such physical devices exist.
6. PLCs have incorporated object-oriented programming tools and multiple languages based on the IEC 1131-3 standard.
7. Small PLCs have been provided with powerful instructions, which extend the area of application for these small controllers.

8. If system requirements call for flexibility or future growth, a programmable controller brings returns that outweigh any initial cost advantage of a relay control system. Even in a case where no flexibility or future expansion is required, a large system can benefit tremendously from the troubleshooting and maintenance aids provided by a PLC.

1.3 BASIC OPERATION

PLC forms the nucleus of control system. It interfaces input devices to capture the data and actuates control through interfaced output devices. Input parameters are acquired after weak signals from sensors which are conditioned and digitized before use with PLCs. The digital outputs can be converted into analog equivalents if required. Figure 1.2 shows the PLC basic operation to control a machine or plant.

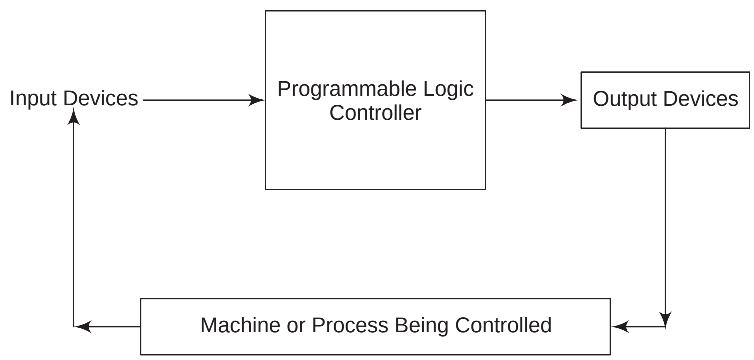

Fig. 1.2 Basic PLC Operation

The input devices are sensors that monitor the machine or the process being controlled. The status of these sensors which can be ON or OFF is fed to the PLC. Depending upon the input status of these sensors the outputs of the PLC may be switched on to energize motors, relays, valves etc. to control the machine or process.

During its operation, the PLC (CPU) completes three processes: (1) it **reads**, or accepts, the input data from the field devices via the input interfaces, (2) it **executes**, or performs, the control program stored in the memory system, and (3) it **writes**, or updates, the output devices via the output interfaces. This process of sequentially reading the inputs, executing the program in memory, and updating the outputs is known as **scanning.** Figure 1.3 illustrates a graphical representation of a scan.

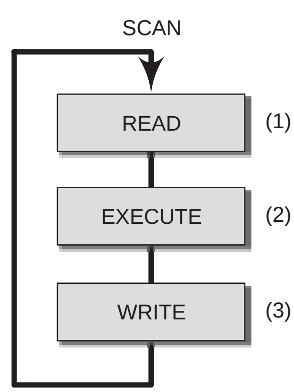

Fig. 1.3 Illustration of a Scan

Although not generally considered a part of the controller, the **programming device**, usually a personal computer or a manufacturer's mini-programmer unit, is required to enter the control program into memory.

1.4 PLC ARCHITECTURE AND COMPONENTS

The PLC, like a computer, employs a microprocessor chip to do the processing and memory chips to store the program. The PLC consists of:

1. A processor
2. Memory
3. Inputs
4. Outputs
5. Programming devices
6. Power supply

The inputs and outputs are connected via proper interfaces. Each input and output has its own address. An interface is a medium where two systems come together and interact or communicate, *i.e.*, communication between the plant being controlled and the PLC. Figure 1.4 shows the basic architecture of a PLC. It contains a processor *e.g.*, a microprocessor chip and memory chips. It also contains all the input and output interfacing. The programming devices can be either handheld or desktop which are remote from the PLC.

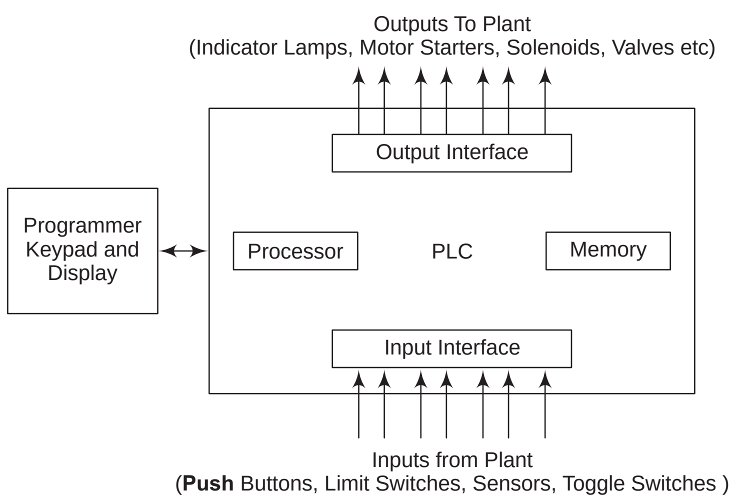

Fig. 1.4 PLC Architecture

1.4.1 Processor

Very small **microprocessors** (or micros)—integrated circuits with tremendous computing and control capability—provide the intelligence of today's programmable controllers. The processor unit contains a microprocessor chip *e.g.*, Zilog Z80, 8085, 8086 or any 16 or 32-bit microprocessor as shown in Fig. 1.5 and necessary circuits to communicate with the devices inside the PLC as well as outside the PLC. This word length affects the speed at which the processor performs most operations. For example, a 32-bit microprocessor can manipulate data faster than a 16-bit microprocessor, since it manipulates twice as much data in one operation. Word length correlates with the capability and degree of sophistication of the controller (*i.e.*, the larger the word length, the more sophisticated the controller). The processor can initiate the operation of counters, sequences, timers and the control relays although no actual physical devices exist. These operations are performed using