Sudan University of Science & Technology

College of Graduate Studies

Design and Implementation of Automated Painting Line Using Programmable Logic Controller

تصميم وتنفيذ أتمتة خط طلاء باستخدام المتحكم المنطقي المبرمج

A Thesis Submitted in Partial Fulfillment for The Requirement of M.Sc.in Mechatronics Engineering

Prepared by: Jamal Magdei Ahmed Abuzeid

Supervised by: Dr/ FathElrahman Ismael khalifa

April/2021

Dedication

To my family for the lifelong encouragement, support and love

&

To my wife and my child Ziad

&

To my friend for all the good times

Acknowledgment

Thanks to god firstly and I would like to thank my family for their unconditional love and support, not only throughout the making of this dissertation, but also throughout my whole academic course. Without their help, I would not have achieved any of this, I sincerely hope I can make them proud, thanks to my wife for everything she does for me.

I would also like to thank my supervisor Dr. Fath Elrahman for his guidance and help throughout the most significant steps of the thesis, all thanks and appreciation to the teachers of my country.

A special thanks to my colleagues: E. Abdullah, E. Hassan for their advice and helpful contributions to the thesis.

Lastly, I would like to thank (and apologize) to anyone unfairly forgotten.

This thesis is dedicated to all of them.

Abstract

In the late sixties of the last century the American company general electric developed the programmable logic controllers (PLC) as an alternative to the complex relay control system in order to use it in its car production lines. These controllers showed very high efficiency in control systems and higher reliability in protecting the components being controlled. In addition to this, the latter improved characteristics made PLCs the most control system used in production Processes.
The aim of this project is to illustrate the usage of PLC in automation of production lines and the utilization of its high capabilities to process input signals from several sensors. This is done by implementing a control system to paint the product through production line as an application in YARMOUK industry complex. Here several processes work in a sequential fashion, in this stage PLCs are used to maintain this sequence. Where a device was used by the Siemens company for logical controllers and was programmed by ladder programming language for the implementation of orders where this controller controls a set of motors in addition to an antenna system in a sequence which adds to the system efficiency, reliability and high production speed and these three interlocutors are considered one of the most important reasons that led to automation This production line in addition to the causes of health damage to which the worker is exposed during manual painting on a daily basis. This automation led to increase in quantity of products exceed 100% and reducing the number of worker to 30% and led to higher quality product.

المستخلص

في أواخر الستينيات من القرن الماضي استحدثت شركة جنرال الأمريكية المتحكمات المنطقية القابلة للبرمجة كبديل لنظام تحكم المرحلات المعقد وذلك للاستفادة منها في التحكم بخطوط إنتاج مصانع السيارات الخاصة بالشركة. أبرزت هذه المتحكمات كفاءة عالية جدا في نظام التحكم و موثوقية عالية في حماية الأنظمة المتحكم بها، بالإضافة للميزات الاخري التي تم استحداثها بعد ذلك، الشي الذي جعل منها أكثر أنظمة التحكم استخداما في عمليات الإنتاج.

يهدف هذا المشروع إلي توضيح استخدام المتحكمات المنطقية القابلة للبرمجة في أتمتة خطوط الإنتاج والاستفادة من قدرتها العالية في معالجة الإشارات الداخلة عبر الحساسات المختلفة المتعددة الاستخدامات وذلك بتنفيذ نظام تحكم في طلاء المنتج من خلال خط إنتاج للطلاء كتطبيق لهذا الاستخدام بمجمع اليرموك الصناعي، حيث يتم عمل عدة عمليات بشكل تسلسلي لإنتاج منتجات مطلية، في هذه المرحلة تتم الاستفادة من المتحكمات المنطقية القابلة للبرمجة في حفظ هذا التسلسل لهذه العملية حسب تزامن معين، حيث تم استخدام جهاز من شركة سيمنز للمتحكمات المنطقية وتمت برمجته بلغت التدرج السلمي لتنفيذ الأوامر حيث يقوم هذا المتحكم بالتحكم في مجموعه من الموتورات بالإضافة إلي نظام هوائي بصورة تسلسلية مما يضيف للنظام كفاءة وموثوقية وسرعة إنتاجية عالية وهذه الثلاثة محاورة تعتبر من أهم الأسباب التي أدت إلي أتمتة هذا الخط الإنتاجي بالإضافة لأسباب الأضرار الصحية التي بتعرض لها العامل إثناء الطلاء بالطرق اليدوية بصورة يومية. أدت هذه الأتمتة إلي زيادة كمية المنتجات بنسبة تتجاوز ١٠٠% وتقليل عدد العمال إلي ٣٠% كما أدت إلي إنتاج منتج بجودة اعلي.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

ANN	Artificial Neural Network
CPU	Center Process Unit
DCS	Distributed Control System
FBD	Function Block Diagram
FRL	Filter Regulator Lubrication Unit
HMI	Human Machine Interface
IEC	International Electro Technical Commission
IL	Instruction List
LAD	Ladder Diagram
PAC	Programmable Automation Controller
PC	Personal Computer
PLC	Programmable Logic Controller
RLL	Relay Ladder Logic
SCADA	Supervisory Control and Data Acquisition
SFC	Sequence Flow Chart
ST	Structure Text

Chapter one

Introduction

1.1 Preface

Industrial automation is the use of robotic devices to complete manufacturing tasks. In this day and age of computers, industrial automation is becoming increasingly important in the manufacturing process because computerized or robotic machines are capable of handling repetitive tasks quickly and efficiently. Machines used in industrial automation are also capable of completing mundane tasks that are not desirable to workers. In addition, the company can save money because it does not need to pay for expensive benefits for this specialized machinery. There are both advantages and disadvantages for a company when it comes to industrial automation. Automation technology, if used wisely and effectively, can yield substantial opportunities for the future. There is an opportunity to relieve humans from repetitive, hazardous, and unpleasant labor in all forms. And there is an opportunity for future automation technologies to provide a growing social and economic environment in which humans can enjoy a higher standard of living and a better way of life.

1.2 Automation Tools

Different types of automation tools exist: ANN – Artificial neural network, DCS Distributed Control System, HMI- Human Machine Interface, SCADA Supervisory Control and Data Acquisition, PLC – Programmable Logic Controller PAC – Programmable Automation Controller, Instrumentation, Motion control and Robotics.

PLC's or programmable logic controllers are one of the most widely used industrial control systems used today to enhance the functionality of a production line or machine functions. Their flexibility in controlling a wide range of inputs and outputs and changing their operation based on requirements have made them a favorite control system in recent times. The typical PLC system is like any other computer system that consists of various hardware components such as the CPU programming devices as well as external hardware components Input/Outputs (I/O) and power supply.

The CPU system is microprocessor based that allows all arithmetic operations as well as logic operations, blocks memory moves, handles the computer interface etc. Typical systems have 4 buses: a data bus to share information between different elements, address bus for the respective addresses, control bus for internal actions that need to be monitored and lastly a system bus which allows the communication between the various ports and Input/output unit. [1] Inputs are usually sensors or switches that control outputs such as motors and electric pumps etc.

Thus, similar to other computerized devices, the PLC unit has a memory storage as well as power supply thus making it a very small integrated unit that can be used in various industries for a wide variety of applications.

1.3 Problem Statement

Paint the products by manual methods exposes the operator to the inhalation of compressed paint atoms by the air which affects the health and cause him diseases in addition to the manual paint process has lost time.

1.4 Proposed Solution

The proposed solution in this thesis is to design and implement fully automated system for paint line using PLC (Siemens s7-200) and pneumatic system.

1.5 Aim and Objectives

The general aim of this research works is to design, simulation and implement a system capable of the detailed objectives include: -

- reduce the health effects of the coating process.
- Increase production capacity.
- Benefit of the time lost as a result of the busy operator for any reason
- Reduce employment if needed.
- Getting regular layers of paint and comparing it with manual paint layers
- comparison of the performance of the automatic line and manual line.

1.6 Methodology

In the beginning study was made of the feasibility of line automation in terms of health for workers, productivity, product quality, and possibility of implementation, and then looking at an estimated amount of practical papers books and references related to automation systems, etc. Then study the mechanical components, their design and electrical components, their programming, linking them and their installation, and then start experiments to ensure the readiness of the project until reaching the last results, all those practical stages were interspersed with the stages of writing the pages of this thesis.

1.7 Thesis Outline

The thesis composed of five chapters, their outlines are as follows: chapter one is an introduction.

Chapter two This chapter details the background information that is related to PLCs and provides a literature review.

Chapter three overview of system, Siemens s7-200, explain for mechanical and electrical components. Simulation.

Chapter four implementation system, Result and discussion.

Chapter five Conclusion and recommendations.

Chapter Two

Literature Review

2.1 Overview of PLCs

Automation is the use of various automatic control equipments, machinery, devices in a process or in a manufacturing firm. Automation has changed the face of industries all over the world. In a layman's language automation means 'doing things automatically in a systematic way'. Introduction of automation in industries have increased the efficiency of the plants and also helped in reducing human errors. Thus helped to improve the quality of the products. Another benefit of automation is that it also saves labor therefore increasing the precision, accuracy and efficiency. Industrial Automation mainly deals with automation of manufacturing, material handling and quality control. It uses various programmed robots to perform activities in an industry. Various sensors, controllers, indicators valves are used in the process. Programmable logic controllers are used to control various instruments used. Computers are used to display the whole process and any fault anywhere in the system is displayed on the screen. The fault can be cleared using the computer itself. PLC has evolved as a main controller in industries nowadays. This is because of the simplicity and robustness of the PLC.A programmable logic controller is a digital, industrial computer which is made up of integrated circuits. PLCs can store instructions like counting, timing, arithmetic manipulations and communication to machines and different control instruments. PLCs have many input and output ports therefore many instructions can be followed at a time with great accuracy. PLC's have replaced automated systems consisting of hundreds of sensors, timers, counters, etc. Its ability to redesign and reform the programming allowed flexibility in performing different processes also in different ways. Various domains like motion control, networking, sequential relay control, distributed control systems have been adjoined in PLC functioning since its inception. The abilities of storage, processing speeds and communication possibilities have made the modern PLC's complement to the desktop computers.

Basic parts of a PLC are (a) CPU(processor), (b) Memory, (c) Input Devices (d) Output Devices, (e) Programming Unit and (f) Power Supply. [4]

Programmable logic controllers also called programmable controllers or PLCs, are solid-state members of the computer family, using integrated circuits instead of electromechanical devices to implement control functions.

They are capable of storing instructions, such as sequencing, timing, counting arithmetic, data manipulation, and communication, to control industrial machines and processes. However, PLCs can be thought of in simple terms as industrial computers with specially designed architecture in both their central units (the PLC itself) and their interfacing circuitry to field devices (input/output connections to the real world). [1]

Figure 2.1: Symbols of PLC Units

2.2 A Historical Background of PLCs

The Hydromantic Division of the General Motors Corporation specified the design criteria for the first programmable controller in 1968. Their primary goal was to eliminate the high costs associated with inflexible, relay controlled systems.

The specifications required a solid-state system with computer flexibility able to

(1) survive in an industrial environment,

(2) be easily programmed and maintained by plant engineers and technicians, and

(3) be reusable. Such a control system would reduce machine downtime and provide expandability for the future.

Some of the initial specifications included the following:

• The new control system had to be price competitive with the use of relay systems.

• The system had to be capable of sustaining an industrial environment.

• The input and output interfaces had to be easily replaceable.

• The controller had to be designed in modular form, so that subassemblies could be removed easily for replacement or repair.

• The control system needed the capability to pass data collection to a central system.

• The system had to be reusable.

• The method used to program the controller had to be simple, so that it could be easily understood by plant personnel.

The product implementation to satisfy Hydrometrics' specifications was underway in 1968 and by 1969, the programmable controller had its first product off springs. These early controllers met the original specifications and opened the door to the development of a new control technology.

The first PLCs offered relay functionality, thus replacing the original hardwired relay logic, which used electrically operated devices to mechanically switch electrical circuits. They met the requirements of modularity, expandability programmability, and ease of use in an industrial environment. These controllers were easily installed, used less space, and were reusable. The controller programming, although a little tedious, had a recognizable plant standard the ladder diagram format in a short period, programmable controller use started to spread to other industries. By 1971, PLCs were being used to provide relay replacement as the first steps toward control automation in other industries, such as food and beverage, metals, manufacturing, pulp and paper. [1]

2.3 PLC Programming Devices

A programming device is used to enter the desired program into the memory of the processor. The program can be entered using relay ladder logic, which is one of the most popular programming languages. Instead of words, ladder logic programming language uses graphic symbols that show their intended outcome. A program in ladder logic is similar to a schematic for a relay control circuit. It is a special language written to make it easy for people familiar with relay logic control to program the PLC. Hand-held programming devices are sometimes used to program small PLCs because they are inexpensive and easy to use. Once plugged into the PLC, they can be used to enter and monitor programs. Both compact hand-held units and laptop computers are frequently used on the factory floor for troubleshooting equipment, modifying programs, and transferring programs to multiple machines. [2]

A personal computer (PC) is the most commonly used programming device. Most brands of PLCs have software available so that a PC can be used as the programming device. This software allows users to create, edit, document, store, and troubleshoot ladder logic programs.

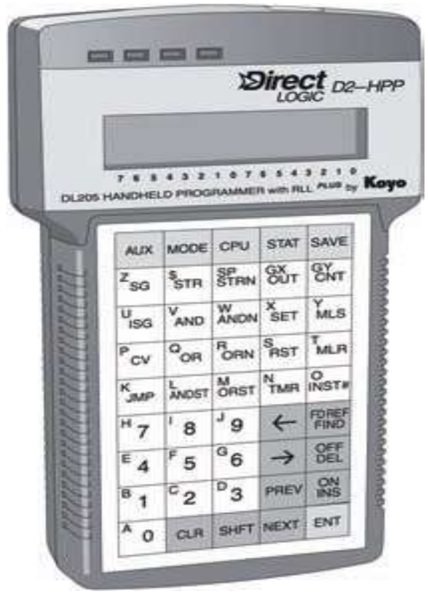


Figure 2.2: Hand-Held Programming Device

The computer monitor is able to display more logic on the screen than can hand-held types, thus simplifying the interpretation of the program. The personal computer communicates with the PLC processor via a serial or parallel data communications link, or Ethernet. If the programming unit is not in use, it may be unplugged and removed. Removing the programming unit will not affect the operation of the user program.

A program is a user developed series of instructions that directs the PLC to execute actions. A programming language provides rules for combining the instructions so that they produce the desired actions. Relay ladder logic (RLL)is the standard programming language used [2].

2.4 PLC Programming Languages

Communication Protocols introduction to the IEC 1131 The International Electro technical Commission (IEC) SC65B-WG7 committee developed the IEC 1131 standard in an effort to standardize programmable controllers. One of the committee’s objectives was to create a common set of PLC instructions that could be used in all PLCs. Although the IEC 1131 standard reached the status of international standard in August 1992, the effort to create a global PLC standard has been a very difficult task to accomplish due to the diversity of PLC manufacturers and the problem of program incompatibility among PLC brands. However, the inroads that have been made so far have had a tremendous impact on the way PLCs will be programmed in the future. The IEC 1131 standard for programmable controllers consists of five parts: general information, equipment and test requirements, programming languages, user guidelines and messaging services (communications). Although there are five parts in the IEC 1131 standard the third part programming languages provides all of the information about instructions and programming standards. The other four sections describe the different guidelines to be used for the testing and communication of language instructions, as well as the methodology that must be employed by the programmable controller user [1].

The IEC 1131 programming language standard is referred to as the IEC 1131-3 programming standard, since part 3 of the standard deals with programming languages hence the dash three (-3), we will refer to the actual programming language as the IEC 1131-3 standard and to the overall standard as the IEC 1131.
The IEC 61131 defined the standards for PLC programming languages:
Ladder diagrams (LAD), instruction list (IL), sequential function charts (SFC), structured text (ST) and function block diagrams(FBD).
Various styles of the above mentioned programming language will be discussed below.

2.4.1 Ladder Diagrams Programming Method

The simplest of all programming method in PLCs is writing logic in ladder diagrams. Writing a program consists of drawing a switching circuit. The ladder diagram has two vertical lines representing the power rails. Circuits are connected as horizontal lines, that is, the rungs of the ladder, between these two verticals Conventions to be followed while programming are as follows.

1. The vertical lines of the diagram depicts the power rails between which circuits are connected. The power flow is taken to be from the left-hand vertical across a rung.

2. Each rung on the ladder defines one operation in the control process.

3. Each rung must start with an input or inputs and must end with at least one output. The term input is a control action, such as closing the contacts of a switch. The term output is a device connected to the output of a PLC, such as a motor or so on. In figure (2.3) symbols are used in IEC 61131-3 for input and output devices.

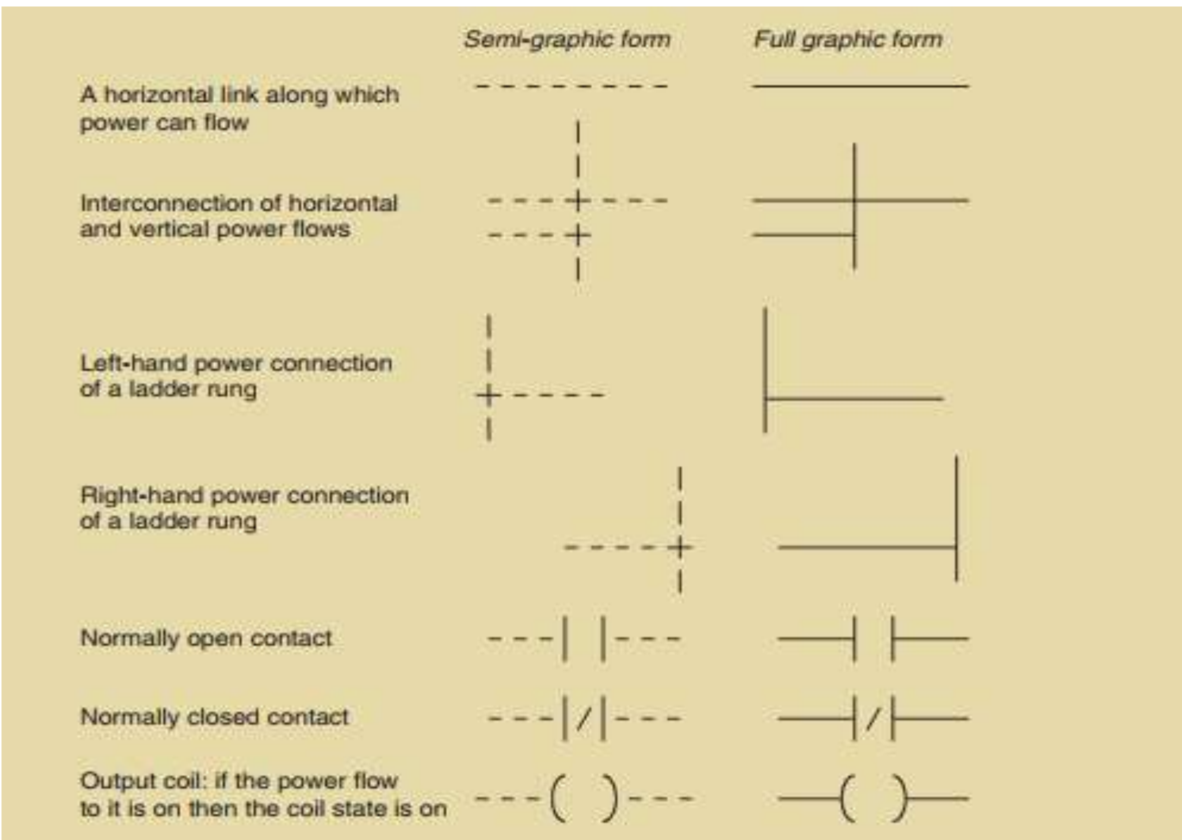


Figure 2.3: Basic Symbols in IEC 61131-3

A typical ladder diagram with an input and an output shown in figure below

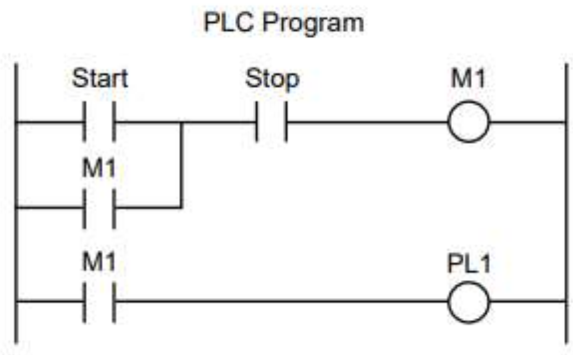


Figure 2.4: Symbol of Ladder Diagram

2.4.2 Function Blocks Diagram (FBD)

The function block diagram (FBD) in PLC programs are described in terms of graphical blocks. It is a graphical language for depicting signal and data flows through blocks, which are reusable software elements. A function block is a program instruction unit that when executed, yields one or more output values. Thus a block is represented in the manner shown in with the function name written in the box. [3] Most of the function blocks has an inbuilt function and can be loaded or called in the program from the respective libraries of the PLC software in our case being B&R Automation Studio 4.2.

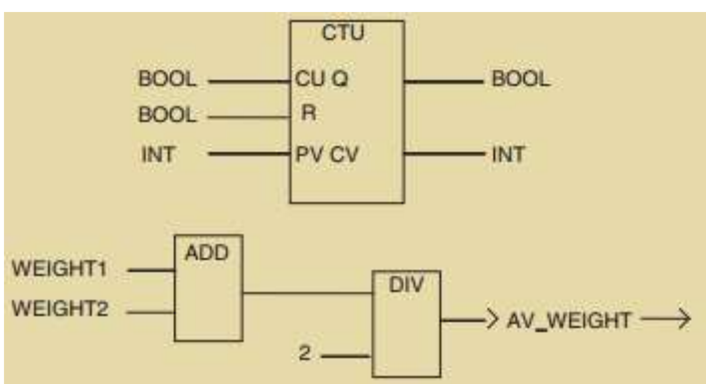


Figure 2.5: Symbol of Function Blocks

2.4.3 Instruction List (IL)

The Instructions list programming method is similar to ladder diagram. But the difference lies in the way it is executed, as this one uses the text format, each rung in ladder corresponds to a rung in Instructions list. For example, we consider the following

LD A

ST B

It implicates that the operand A is loaded in the memory. It is equivalent to rung operation with open contact for input A and the output is passed on to B. table (2.1) is shown The various mnemonic standard codes used by IEC 61131-3 are as

Table 2.1: Instruction List Mnemonics

IEC 61131-3	**Operation**
LD	Load the operand in result register
LDN	Load negative operand into result register
AND	Boolean AND
ANDN	Boolean AND with negative operand
OR	Boolean OR
ORN	Boolean OR with negative operand
ST	Stores the result register into operand

2.4.4 Sequential Flow Chart (SFC)

SFC method of executing a program is used when one wants to describe a sequence of states functions in the form of a flow chart. Following features of SFC are listed below.

1. The operations are described with individual sequentially connected states or steps that are represented by rectangular boxes, each representing a particular state of the system being controlled.

2. Each connecting line between states has a horizontal bar representing the transition condition that has to be realized before the system can move from one state to the next. Two steps can never be directly connected; they must always be separated by a transition. Two transitions can never directly follow from one to another, they must always be separated by a step.

3. When the transfer conditions are met the next step in SFC are executed in a program.

4. The process thus continues from one step to the next until the complete machine cycle is completed.

5. Outputs/actions at any state are represented by horizontally linked boxes and occur when that state has been realized. [3]

2.4.5 Structured Text (ST)

It is a programming language that is similar to C or Pascal. It is written with series of statements separated by semicolons. The subroutines to change variable, calling a well defined function from the library to cut short long programs is what makes it unique, flexible and easy to use. Most of the tasks in this thesis project has been done using this style. Additionally, it also offers the flexibility of using loops and conditional statements. [3]

```
FUNCTION_BLOCK TEST_VOLTAGE
VAR_INPUT
VOLTS1, VOLTS2, VOLTS3 ;
END_VAR
VAR_OUTPUT
OVERVOLTS : BOOL;
END_VAR
IF VOLTS1 > 12 THEN
OVERVOLTS :=TRUE; RETURN;
```

```
END_IF;
IF VOLTS2 > 12 THEN
OVERVOLTS :=TRUE; RETURN;
END_IF;
IF VOLTS3 > 12 THEN
OVERVOLTS := TRUE;
END_IF;
END_FUNCTION_BLOCK;
```

The simple example above is a function block which can be called in many other program to check the voltage level. It just tests the VOLTS1,VOLTS2,VOLTS3 and indicate the output OVERVOLTS to be true , the return statement terminates the execution of block. [3]

2.5 PLC Applications

Since its inception, the PLC has been successfully applied in virtually every segment of industry, PLCs perform a great variety of control tasks, from repetitive ON/OFF control of simple machines to sophisticated manufacturing and process control, Table (2-2) lists a few of the major industries that use programmable controllers.

Table 2.2: Major Industries That Use PLC

Chemical/ Petrochemical	Mixing, Water/Waste treatment,…
Manufacturing/ Machining	Painting, Welding , Material Conveyors,…
Glass/ Film	Cullet weighing, Packaging ,…
Food/ Beverage	Blending, Filling, Product handling,…
Metals	Continuous casting, Rolling mills ,…
Power	Burner control, Sorting, Woodworking ,…
Lumber/ Pulp/ Paper	Coating, Batch digesters,…

Mining	Water/Waste management, Loading/Unloading, …[1]

2.6 Program Scan

The basic function of a programmable controller is to read all of the field input devices and then execute the control program, which according to the logic programmed, will turn the field output devices ON or OFF. In reality, this last process of turning the output devices ON or OFF occurs in two steps. First, as the processor executes the internal programmed logic, it will turn each of its programmed internal output coils ON or OFF. The energizing or de energizing of these internal outputs will not, however, turn the output devices ON or OFF. Next when the processor has finished evaluating all of the control logic program that turns the internal coils ON or OFF, it will perform update to the output interface modules, thereby turning the field devices connected to each interface terminal ON or OFF. This process of reading the inputs, executing the program, and updating the outputs is known as the scan. [1]

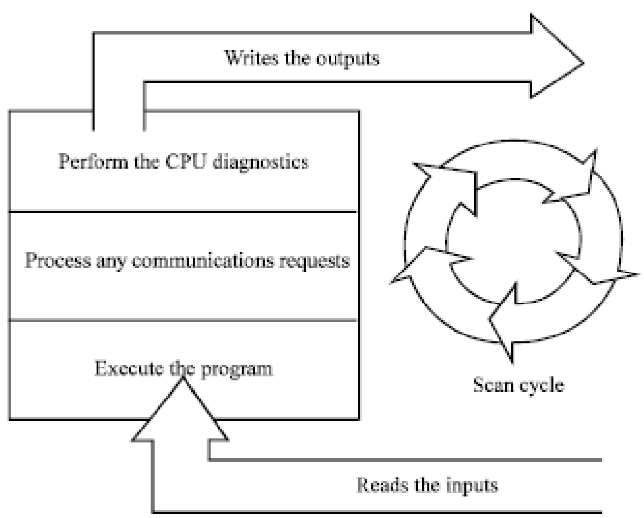


Figure 2.6: Program Scan

The time it takes to complete a scan cycle is called the scan cycle time and indicates how fast the controller can react to changes in inputs. The time required to make a single scan can vary from about 1 millisecond to 20 milliseconds. If a controller has to react to an input signal that changes states twice during the scan time, it is possible that the PLC will never be able to detect this change. For example, if it takes 8 ms for the CPU to scan a program, and an input contact is opening and closing every 4 ms, the program may not respond to the contact changing state. The CPU will detect a change if it occurs during the update of the input image table file, but the CPU will not respond to every change. The scan time is a function of the following:

- The speed of the processor module
- The length of the ladder program
- The type of instructions executed
- The actual ladder true/false conditions. [2]

2.7 Operation Principle of PLC

To illustrate the basic operating mode of a PLC a simple setup can be assumed consisting of a CPU (Central Processing Unit) and an I/O (Input/ Output) interface as shown below. The CPU includes a processor for signal processing, a memory for storing data and a power supply to provide

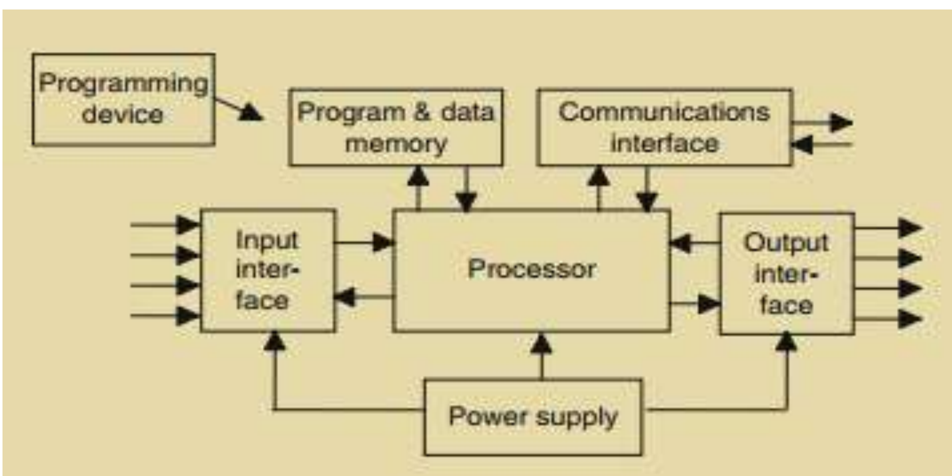


Figure 2.7: Operation Principle of PLC

The necessary voltage for operation. In one cycle the CPU first reads data from the I/O in a second step executes actions depending on those I/O signals and finally writes the updated values back via the output interface. [1]

Currently, there are many PLC manufacturers in the market. Table below shows a list of PLC manufacturers in the global market. They produce many types of PLCs depending on size, cost, and functions to satisfy different requirements of different system speciation's. [6]

Table 2.3: PLC Manufacturers

No	**Manufacturer**	No	**Manufacturer**
1	Siemens	8	Bosch Rexroth
2	ABB	9	Toshiba
3	Schneider	10	Panasonic
4	Mitsubishi	11	Idec
5	GE-Fanuc	12	Fuji
6	Omron	13	Keyence
7	Koyo	14	Rockwell

2.8 Pneumatic Control Overview

2.8.1 Pneumatic

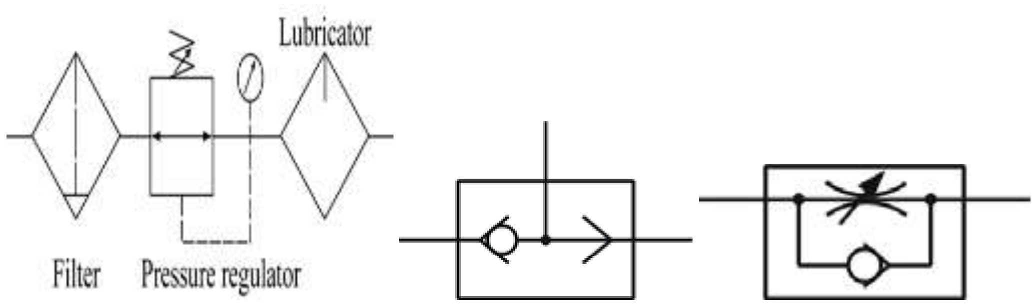
Pneumatic systems are very common, and have much in common with hydraulic systems with a few key differences. The reservoir is eliminated as there is no need to collect and store the air between uses in the system. Also because air is a gas it is compressible and regulators are not needed to recirculation flow. But, the compressibility also means that the systems are not as stiff or strong. Pneumatic systems respond very quickly, and are commonly used for low force applications in many locations on the factory floor.

Some basic characteristics of pneumatic systems are:

- stroke from a few millimeters to meters in length (longer strokes have more Springiness).
- the actuators will give a bit – they are springy.
- pressures are typically up to 85psi above normal atmosphere.
- the weight of cylinders can be quite low.
- additional equipment is required for a pressurized air supply- linear and rotator actuators are available.
- dampers can be used to cushion impact at ends of cylinder travel.

When designing pneumatic systems care must be taken to verify the operating location. In particular, the elevation above sea level will result in a dramatically different air pressure. For example, at sea level the air pressure is about 14.7 psi but at a height of 7,800 ft (Mexico City) the air pressure is 11.1 psi. Other operating environments, such as in submersibles, the air pressure might be higher than at sea level.

Some symbols for pneumatic systems are shown in (Figure 2.8). The flow control valve is used to restrict the flow, typically to slow motions. The shuttle valve allows flow in one direction, but blocks it in the other. The receiver tank allows pressurized air to be accumulated. The dryer and filter help remove dust and moisture from the air, prolonging the life of the valves and cylinders.



(a) (b) (c)

Figure 2.8: (a)Symbol Dryer and Filter (b) Symbol Flow Control Valve (c)Symbol Shuttle Valve

Pneumatic has long since played an important role as a technology in the performance of mechanical work. It is also used in the development of automation solutions. In the majority of applications compressors air is used for one or more of the following:

- To determine the status of processors (sensor).
- Information processing.
- Switching of actuator by means of final control elements.
- Carrying out work (actuators).

To be able to control machinery and installations necessitates the construction of a generally logic interconnection of statuses and switching conditions. This occurs as a result of the interaction of sensors, processors, control elements and actuators in pneumatic or party pneumatic systems

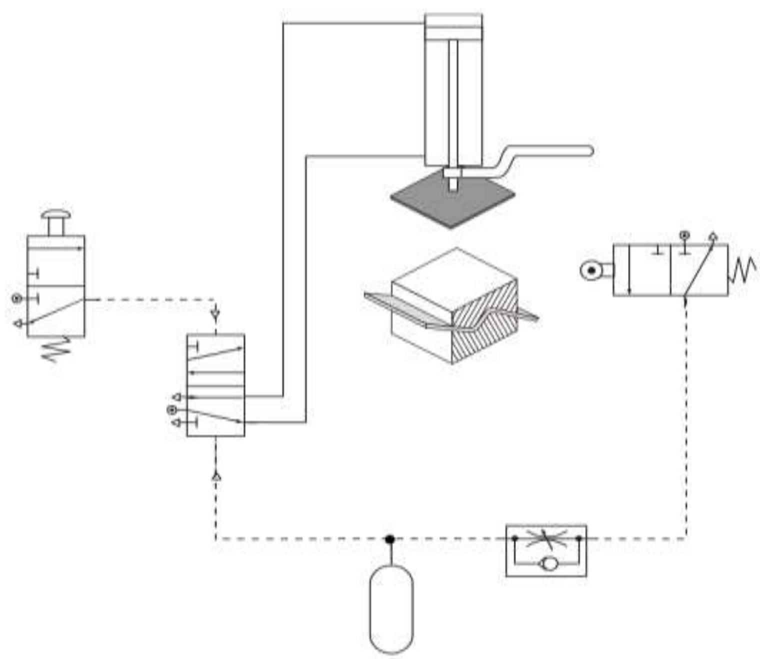


Figure 2.9: Example of Pneumatic Circuit

The technological process made in material, design and production processes has further improved the quality and diversity of pneumatic components and thereby contributed to their widely spread use in automation. [5]

The pneumatic cylinder has a signification role as a linear drive unit, due to its:

- Relativity low cost
- Ease of installation
- Simple and robust construction
- Ready availability in various sizes and stroke lengths

The pneumatic cylinder has the following general characteristics:

- Diameters, stroke lengths, available force, piston speed

Pneumatic components can perform the following types of motion:

- Linear, swivel, rotary

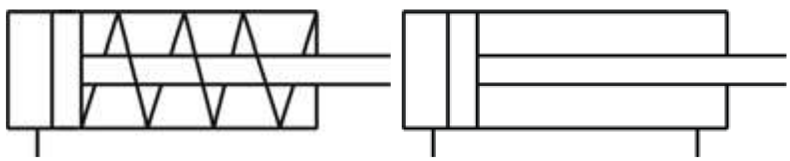
Some industrial applications employing pneumatics are listed below:

- Packaging, sorting, filling, locking, stacking of components … etc. [5]

2.8.2 Pneumatic Cylinders

A cylinder uses pressurized fluid or air to create a linear force/motion. In the figure a fluid is pumped into one side of the cylinder under pressure, causing that side of the cylinder to expand, and advancing the piston. The fluid on the other side of the piston must be allowed to escape freely if the incompressible fluid was trapped the cylinder could not advance. The force the cylinder can exert is proportional to the cross sectional area of the cylinder.

A pneumatic cylinder is a device with two chambers separated by a sliding bore. The air pressure in each chamber is controlled by valve which can connect the chamber to one of two ports: the supply port connects the chamber to a compressor and the exhaust port connects the chamber to room pressure. In some setups a single valve with two output ports is connected to both chambers of a cylinder allowing high pressure in either chamber, but not both. Where the chamber pressures can be controlled independently to allow for the stiffness that results from high pressure on both sides. [12]



(a) (b)

Figure 2.10: (a) Symbol of Single Acting Cylinder (b) Symbol of a Double Acting Cylinder

2.8.3 Solenoids

Solenoids are the most common actuator components. The basic principle of operation is there is a moving ferrous core (a piston) that will move inside wire coil. Normally the piston is held outside the coil by a spring. When a voltage is applied to the coil and current flows, the coil builds up a magnetic field that attracts the piston and pulls it into the center of the coil. The piston can be used to supply a linear force. Well known applications of these include pneumatic values and car door openers. As mentioned before, inductive devices can create voltage spikes and may need supplier، although most industrial applications have low enough voltage and current ratings they can be connected directly to the PLC outputs. Most industrial solenoids will be powered by 24Vdc and draw a few hundred mA.

2.8.4 Pneumatic Valves

The flow of fluids and air can be controlled with solenoid controlled valves. An example of a solenoid controlled valve is shown in Figure 3.10. The solenoid is mounted on the side. When actuated it will drive the central spool left. The top of the valve body has two ports that will be connected to a device such as a hydraulic cylinder. The bottom of the valve body has a single pressure line in the center with two exhausts to the side. In the top drawing the power flows in through the center to the right hand cylinder port. The left hand cylinder port is allowed to exit through an exhaust port. In the bottom drawing the solenoid is in a new position and the pressure is now applied to the left hand port on the top, and the right hand port can exhaust. The symbols to the left of the figure show the schematic equivalent of the actual valve positions. Valves are also available that allow the valves to be blocked when unused.

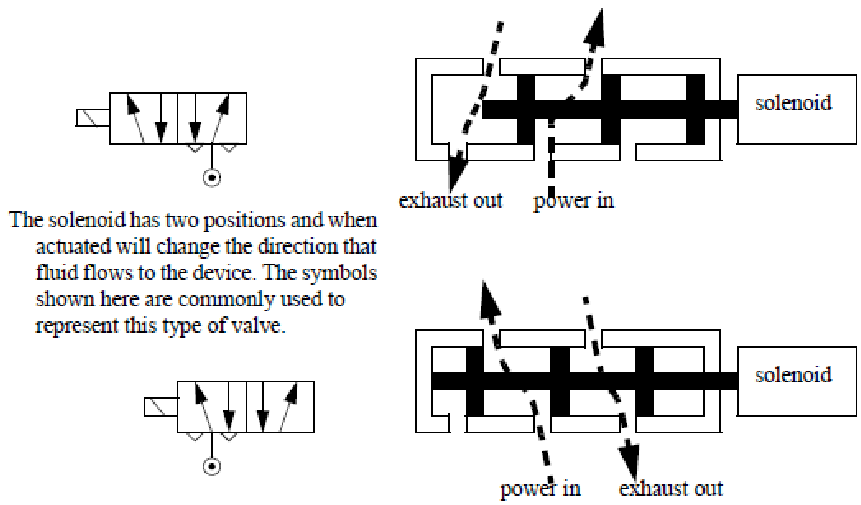


Figure 2.11: A Solenoid Controlled 5 Ported, 4 Way 2 Position Valve

Valve types are listed below. In the standard terminology, the 'n-way' designates the number of connections for inlets and outlets. In some cases, there are redundant ports for exhausts. The normally open/closed designation indicates the valve condition when power is off. All of the valves listed are two position valve, but three position valves are also available.

- 2-way normally closed – these have one inlet, and one outlet. When unenergized the valve is closed. When energized, the valve will open allowing flow. These are used to permit flows.
- 2-way normally open – these have one inlet, and one outlet. When unenergized the valve is open, allowing flow. When energized, the valve will close. These are used to stop flows. When system power is off, flow will be allowed.
- 3-way normally closed – these have inlet, outlet, and exhaust ports. When unenergized the outlet port is connected to the exhaust port. When energized the inlet is connected to the outlet port. These are used for single acting cylinders.
- 3-way normally open – these have inlet, outlet and exhaust ports. When unenergized the inlet is connected to the outlet. Energizing the valve connects the outlet to the exhaust. These are used for single acting cylinders
- 3-way universal – these have three ports. One of the ports acts as an inlet or outlet, and is connected to one of the other two, when energized/unenergized. These can be used to divert flows, or select alternating sources.
- 4-way – These valves have four ports, two inlets and two outlets. Energizing the valve causes connection between the inlets and outlets to be reversed. These are used for double acting cylinders.

Some of the ISO symbols for valves are shown in Figure 5.3. When using the symbols in drawings the connections are shown for the unenergized state. The arrows show the flow paths in different positions. The small triangles indicate an exhaust port. [9]

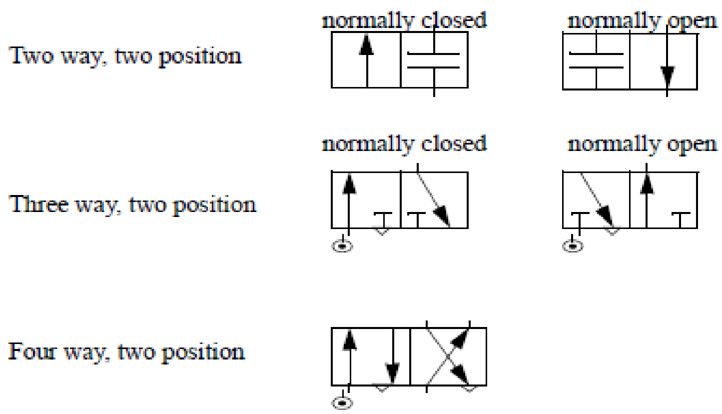


Figure 2.12: ISO Valve Symbols

2.9 Relays

A relay is an electrically operated switch it consists of a set of input terminals for a single or multiple control signals, and a set of operating contact terminals. The switch may have any number of contact in multiple contact forms, such as make contacts, break contact, or combinations thereof. Relays are used where it is necessary to control a circuit by an independent low power signal, or where several circuits must be controlled by one signal the traditional form of a relay uses an electromagnet to close or open the contact, but other operating principles have been invented, such as in solid state relays which use semiconductor properties for control without relying on moving parts. [13,14]

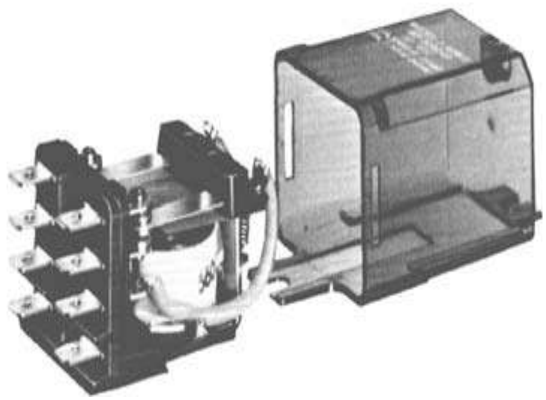


Figure 2.13: Relay

2.10 Sensors

A sensor is a device that converts a physical phenomenon into an electrical signal. As such, sensors represent part of the interface between the physical world and the world of electrical devices, such as computers. The other part of this interface is represented by actuators, which convert electrical signals into physical phenomena A sensor is a device that receives a stimulus and responds with an electrical signal. [10]

2.10.1 Sensor Classification

Sensor classification schemes range from very simple to the complex. Depending on the classification purpose, different classification criteria may be selected. Here we offer several practical ways to look at the sensors.

All sensors may be of two kinds: passive and active. A passive sensor does not need any additional energy source and directly generates an electric signal in response to an external stimulus; that is, the input stimulus energy is converted by the sensor into the output signal. The examples are a thermocouple, a photodiode, and a piezoelectric sensor. Most of passive sensors are direct sensors as we defined them earlier. The active sensors require external power for their operation, which is called an excitation signal. That signal is modified by the sensor to produce the output signal. The active sensors sometimes are called parametric because their own properties change in response to an external effect and these properties can be subsequently converted into electric signals. It can be stated that a sensor's parameter modulates the excitation signal and that modulation carries information of the measured value. For example, a thermostat is a temperature-sensitive resistor. It does not generate any electric signal, but by passing an electric current through it (excitation signal), its resistance can be measured by detecting variations in current and/or voltage across the thermostat. These variations (presented in ohms) directly relate to temperature through a known function. Another example of an active sensor is a resistive strain gauge in which electrical resistance relates to a strain. To measure the resistance of a sensor, electric current must be applied to it from an external power source. Depending on the selected reference, sensors can be classified into absolute and relative. An absolute sensor detects a stimulus in reference to an absolute physical scale that is independent on the measurement conditions, whereas a relative sensor produces a signal that relates to some special case. An example of an absolute sensor is a thermostat: a temperature sensitive resistor. Its electrical resistance directly relates to the absolute temperature scale of Kelvin Another very popular temperature sensor; a thermocouple is a relative sensor. It produces an electric voltage that is function of a temperature gradient across the thermocouple wires. Thus, a thermocouple output signal cannot be related to any particular temperature without referencing to a known baseline. Another example of the absolute and relative sensors is a pressure sensor.

An absolute-pressure sensor produces signal in reference to vacuum an absolute zero on a pressure scale. A relative-pressure sensor produces signal with respect to a selected baseline that is not zero pressure (e.g. to the atmospheric pressure).

Another way to look at a sensor is to consider all of its properties, such as what it measures (stimulus), what its specifications are what physical phenomenon it is sensitive to, what conversion mechanism is employed, what material it is fabricated from, and what its field of application is. [11]

2.10.2 Specifications of sensors

Table 2.4: Specifications of Sensors

Sensitivity	**Stimulus range (span)**
Stability (short and long term)	Resolution
Accuracy	Selectivity

Speed of response	Environmental conditions
Overload characteristics	Linearity
Hysteresis	Dead band
Operating life	Output format
Cost, Size, Weight	Other

Table 2.5: Sensor Material

Inorganic	**Organic**
Conductor	Insulator
Semiconductor	Liquid, Gas, or Plasma
Biological substance	Other

2.11 Related Works

In [4] designed and implemented an Automatic Bottle filling machine to fill bottle with liquid. Filing is the method carried out by a machine that package liquid such as water, cold drink and various types of liquid into a bottle. The method of bottle filling embroiled placing bottle onto a conveyor belt and filling only one bottle at a time. By this method, production of goods is increased and economic growth is also increased.

Described the whole method of filling system. The whole system is controlled by PLC (Programmable Logic Controller) using ladder logic process. It includes user defined volume selection at the wished for level. In a conveyor system, gear motor is used. In this system less number of sensors is used so it is less expensive. In the overall system, PLC is the heart and sensor is the eye. Both play important roles in the whole system. The filling is done by using time operation. The whole system is flexible, time saving and user friendly as well. The finished machine will not be autonomous, but will rely on a human operator The production of goods is being increased by automation system The cost of machine installation is not cheap and it is a time consuming work. But it can run for a long period of time. The performance of this machine is depending on the cost of installation. This machine has been implemented successfully. In this machine, PLC has been used to control the overall system by using ladder logic

The author in [17] explained stages of operation involved in the conversion of a manually operated boiler towards a fully automated boiler. Over the years the demand for high quality, greater efficiency and automated machines has increased in this globalized world where the work focused on passing the inputs to the boiler at a required temperature, so as to constantly maintain a particular temperature in the boiler. The Air preheated and Economizer helps in this process and focused on level, pressure and flow control at the various stages of the boiler plant where controlled of all parameters done by using PLC and monitoring SCADA The most important aspect of any power plant is the boiler control. Several techniques can be implemented to control the boiler in power plant. The method that has to be used relies on varied objectives like superior quality, increased efficiency, high profit and other such points depending upon the purpose of the company that implies it. With the prime objective of catering to these necessities and the needs of the industrial sector, significance has been given here to automation.

The author in [18] make sorting system to sort product according to height of product, used in this system PLC to control in DC motor and some sensors work in conveyor, the product will be coming thought the conveyor system to sensing part based on height, industrial automation mainly focuses on developing and make systems use friendly as possible .The study is Concluded to the sorting process will be very usefully in the industries, the sorting process is an important process by which can easily differentiate an object.

Chapter Three

System Overview

3.1 Block Diagram of System

This block diagram shows the sequence of work of the system where the PLC s7-200 receives the inputs and begins to implement them according to the ladder program and sends signals to the pneumatic system and other electrical parts until it performs the required operation and after completion the PLC s7-200receives the output signals in order to start a new cycle.

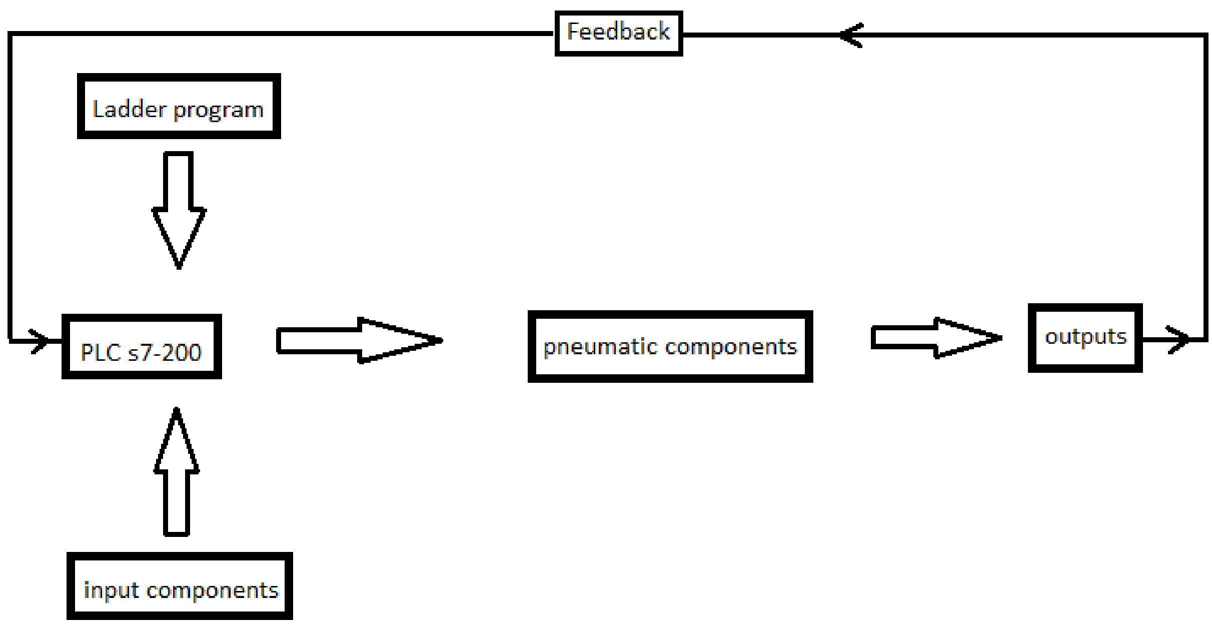


Figure 3.1: Block Diagram

3.2 The Siemens S7-200 PLC

The S7-200 is referred to as a micro PLC because of its small size. The S7-200 has a brick design which means that the power supply and I/O are on-board. The S7-200 can be used on smaller, standalone applications such as elevators, car washes or mixing machines. It can also be used on more complex industrial applications such as bottling and packaging machines.

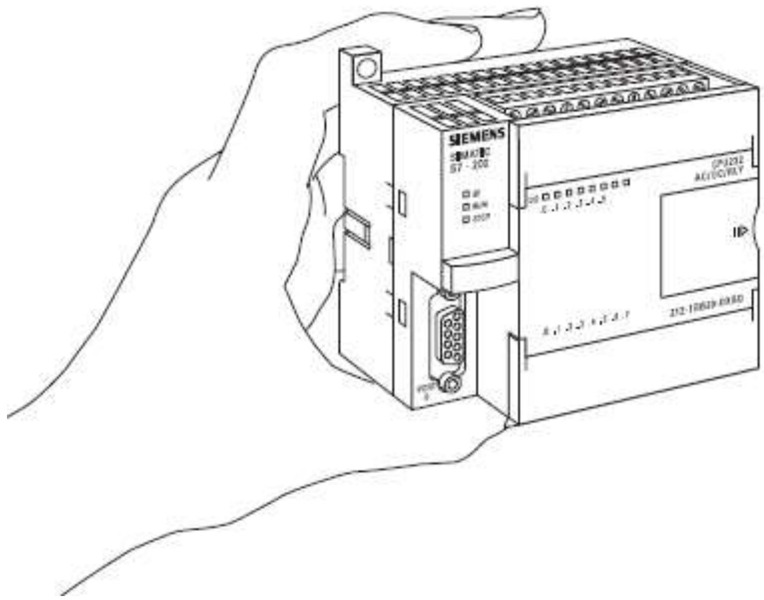


Figure 3.2: PLC Siemens S7-200

3.2.1 S7-200 CPU

The S7-200 CPU combines a microprocessor, an integrated power supply, input circuits, and output circuits in a compact housing to create a powerful Micro PLC. After you have downloaded your program, the S7-200 contains the logic required to monitor and control the input and output devices in your application Siemens provides different S7-200 CPU models with a diversity of features and capabilities that help to create effective solutions for your varied applications.

3.2.2 S7-200 Expansion Modules

To better solve your application requirements, the S7-200 family includes a wide variety of expansion modules. You can use these expansion modules to add additional functionality to the S7-200 CPU. Table 3.1 provides a list of the expansion modules that are currently available.

Table 3.1: List of The Expansion Modules

Expansion Modules	Types
Discrete modules	
Input	8 x DC In 8 x AC In 16 x DC In
Output	4 x DC 4 x Relays
	8 x DC Out 8 x AC Out 8 x Relay
Combination	4 x DC In / 4 x DC Out 8 x DC In / 8 x DC Out 16 x DC In/16 x DC Out
	4 x DC In / 4 x Relay 8 x DC In / 8 x Relay 16 x DC In/16 x Relay
Analog modules	
Input	4 x Analog In 4 x Thermocouple In 2 x RTD In
Output	2 x Analog Out
	4 x Analog In / 1 Analog Out
Combination	
Intelligent modules	Position Modem PROFIBUS-DP Ethernet Internet
Other modules	AS—Interface

3.2.3 Step 7-Micro/Win Programming Package

The Step 7-Micro/Win programming package provides a user-friendly environment to develop, edit, and monitor the logic needed to control your application. Step 7- Micro/Win provides three program editors for convenience and efficiency in developing the control program for your application.

To help you find the information you need, Step 7-Micro/Win provides an extensive online help system and a documentation CD that contains an electronic version of this manual, application tips, and other useful information.

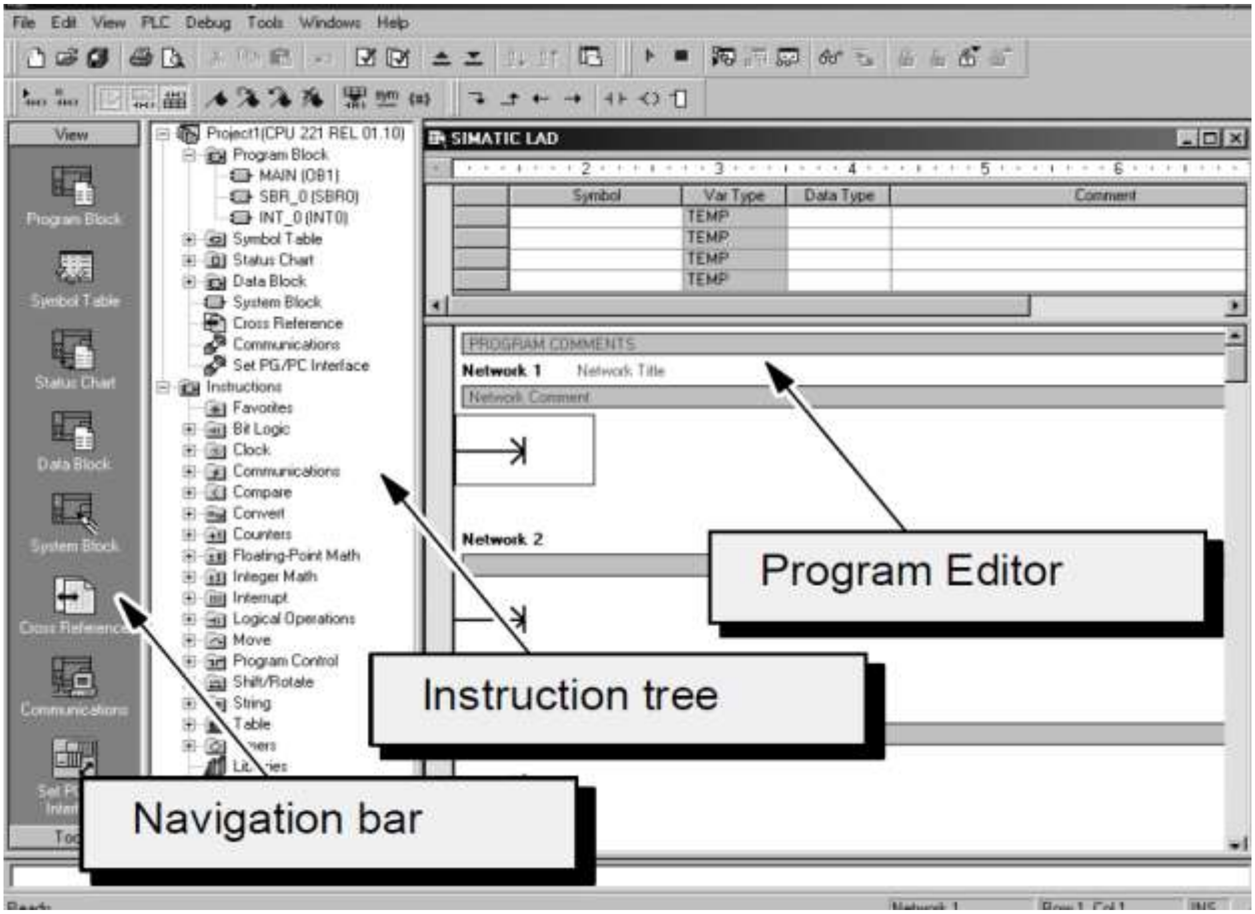


Figure 3.3: Step 7-Micro/Win Programming

3.2.4 Computer Requirements

Step 7-Micro/Win runs on either a personal computer or a Siemens programming device, such as a PG 760.

Your computer or programming device should meet the following minimum requirements:

- Operating system: Windows 2000, Windows XP (Professional or Home).
- At least 100M bytes of free hard disk space.
- Mouse (recommended).

3.2.5 Starting Step 7-Micro/Win

Click on the Step 7-Micro/Win icon to open a new project. Figure below shows a new project. Notice the navigation bar.

You can use the icons on the navigation bar to open elements of the Step 7-Micro/Win project.

Click on the Communications icon in the navigation bar to display the Communications dialog box. You use this dialog box to set up the communications for Step 7-Micro/Win

3.2.6 Verifying the Communications Parameters for Step 7-Micro/Win

The example project uses the default settings for Step 7-Micro/Win and the RS-232/PPI Multi-Master cable. To verify these settings:

1. Verify that the address of the PC/PPI cable in the Communications dialog box is set to 0.
2. Verify that the interface for the network parameter is set for PC/PPI cable (COM1).
3. Verify that the transmission rate is set to 9.6 kbps.

If you need to change your communications parameter settings.

3.2.7 Establishing Communications with The S7-200

Use the Communications dialog box to connect with your S7-200 CPU:

1. Double-click the refresh icon in the Communications dialog box. Step 7-Micro/Win searches for the S7-200 station and displays a CPU icon for the connected S7-200 station.
2. Select the S7-200 and click OK.

If Step 7--Micro/Win does not find your S7-200 CPU, check the settings for the communications parameters and repeat these steps. After you have established communications with the S7-200, you are ready to create and download the example program.

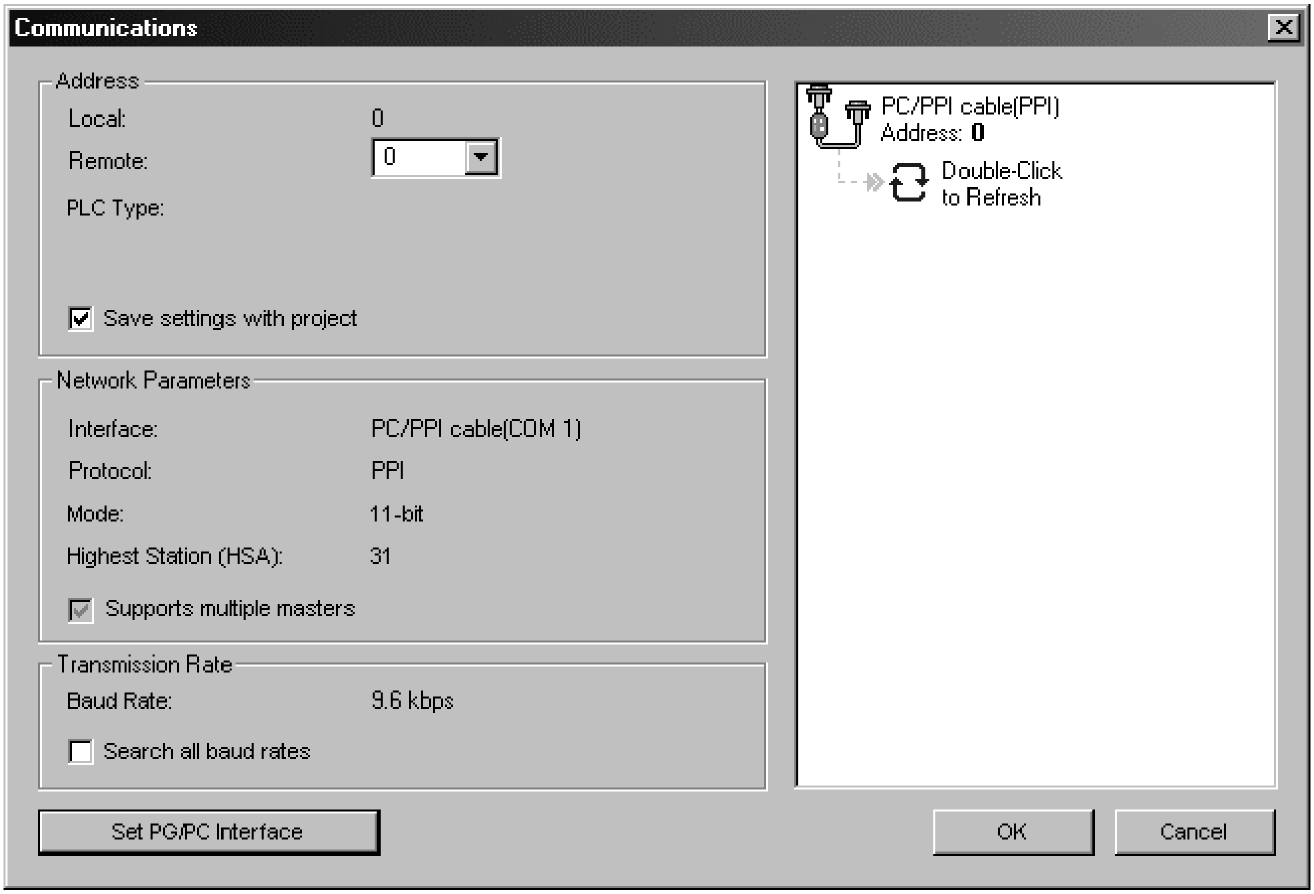


Figure 3.4: Communications Window

3.2.8 Opening the Program Editor

Click on the Program Block icon to open the program editor. See Figure (3.3) Notice the instruction tree and the program editor. You use the instruction tree to insert the LAD instructions into the networks of the program editor by dragging and dropping the instructions from the instruction tree to the networks, the toolbar icons provide shortcuts to the menu commands. After you enter and save the program, you can download the program to the S7-200.

3.2.9 Saving the Sample Project

After entering the three networks of instructions, you have finished entering the program.

When you save the program, you create a project that includes the S7-200 CPU type and other parameters. To save the project:

1. Select the File > Save As menu command from the menu bar.
2. Enter a name for the project in the Save As dialog box.
3. Click OK to save the project.

After saving the project, you can download the program to the S7-200.

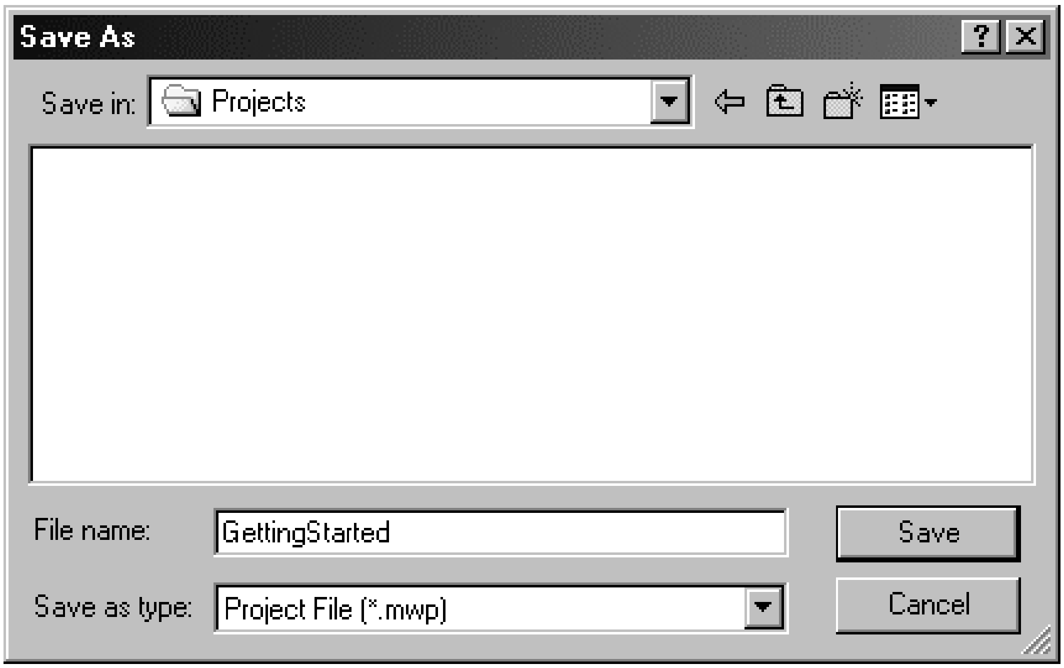


Figure 3.5: Save as Window

3.2.10 Downloading the Sample Program

1. Click the Download icon on the toolbar or select the File > Download menu command to download the program. See Figure 3.6.
2. Click OK to download the elements of the program to the S7-200.

If your S7-200 is in RUN mode, a dialog box prompts you to place the S7-200 in STOP mode. Click Yes to place the S7-200 into STOP mode.

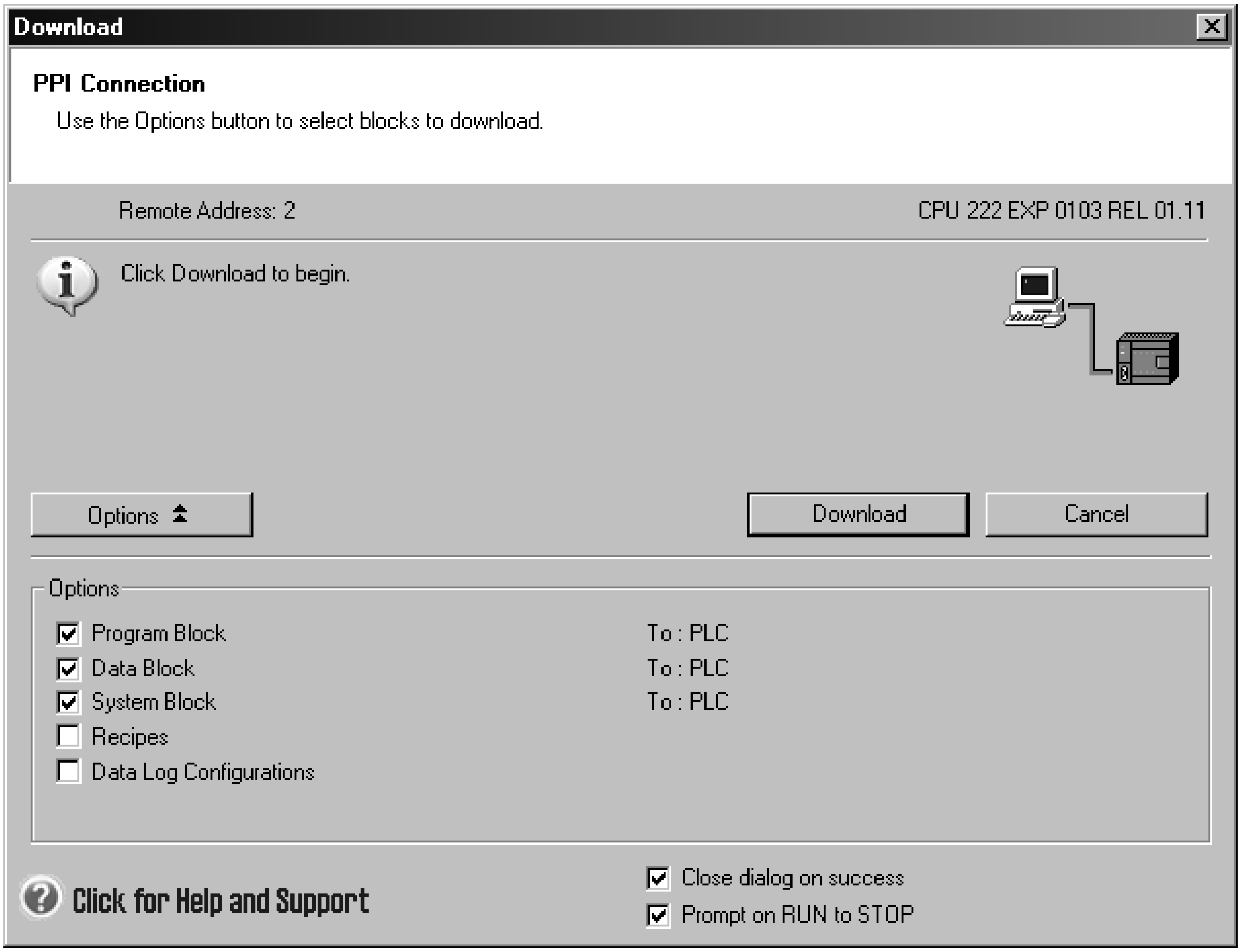


Figure 3.6: Download Program to PLC

3.2.11 Placing the S7-200 in RUN Mode

For Step 7--Micro/Win to place the S7-200 CPU in RUN mode, the mode switch of the S7-200 must be set to TERM or RUN. When you place the S7-200 in RUN mode, the S7-200 executes the program:

1. Click the RUN icon on the toolbar or select the PLC > RUN menu command.
2. Click OK to change the operating mode of the S7-200.

When the S7-200 goes to RUN mode, the output for Q0.0 turns on and off as the S7-200 executes the program. [7]

3.2.12 Ladder Logic for S7-200

Ladder logic (LAD) is one programming language used with PLCs. Ladder logic uses components that resemble elements used in a line diagram format to describe hard-wired control.

The left vertical line of a ladder logic diagram (figure (3.7)) represents the power or energized conductor.

The output element or instruction represents the neutral or return path of the circuit. The right vertical line, which represents the return path on a hard-wired Control line diagram, is omitted. Ladder logic diagrams are read from left-to-right, top-to-bottom. Rungs are sometimes referred to as networks. A network may have several control elements, but only one output coil.

In the example program shown example I0.0, I0.1 and Q0.0 represent the first instruction combination. If inputs I0.0 and I0.1 are energized, output relay Q0.0 energizes. The inputs could be switches, pushbuttons, or contact closures. I0.4, I0.5, and Q1.1 represent the second instruction combination. If either input I0.4 or I0.5 is energized, output relay Q0.1 energizes

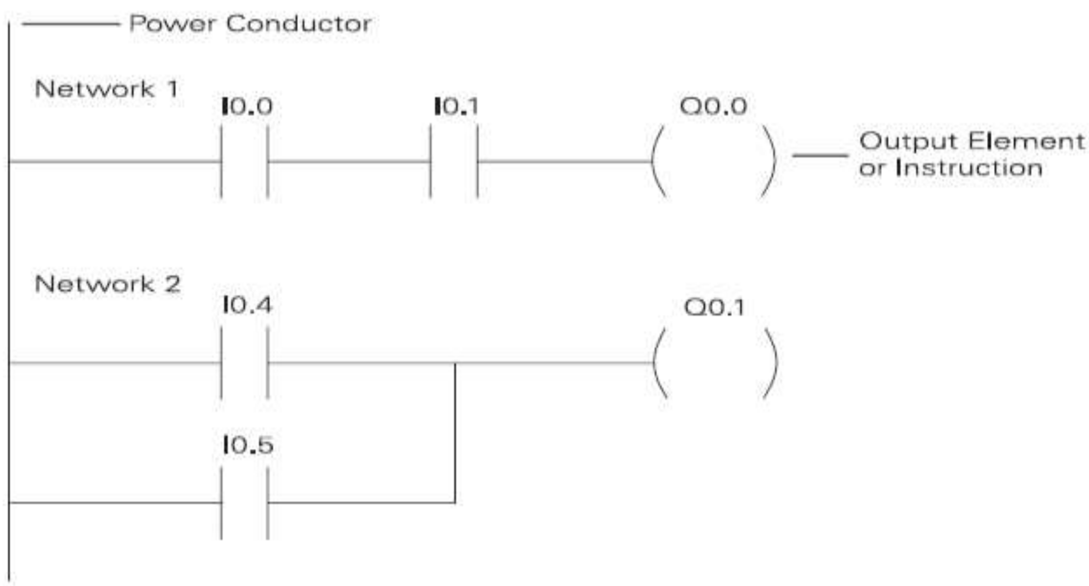


Figure 3.7: Ladder Diagram

3.2.13 PLC Scan for S7-200

The S7-200 executes a series of tasks repetitively. This cyclical execution of tasks is called the scan cycle. the S7-200 performs most or all of the following tasks during a scan cycle: -

- Reading the inputs:

The S7-200 copies the state of the physical inputs to the process-image input register.

- Executing the control logic in the program:

The S7-200 executes the instructions of the program and stores the values in the various memory areas.

- Processing any communications requests:

The S7-200 performs any tasks required for communications.

- Executing the CPU self-test diagnostics:

The S7-200 ensures that the firmware, the program memory, and any expansion modules are working properly.

- Writing to the outputs:

The values are stored in the process-image output register are written to the physical outputs. [8]

3.3 Electrical Components

3.3.1 PLC Siemens

In this system used PLC Siemens S7-200 (DC / DC / DC, cpu224xp cn) 220 v as power supply because it is available and it suitable for our needs (number of inputs and outputs). Where it works on receive the signals and process it to action thrown the relays (see figure 3.8).

Figure 3.8: PLC Unit & Wiring

3.3.2 Sensors of System

The system is containing 4 proximity sensors NPN (8 mm), two of which are used to control the cylinder stroke according to the product length and two to control the main motor movement, these sensors work as inputs for the PLC.

Figure 3.9: Inductive Proximity Sensor

3.3.3 Relay of System

In the system used5 relays 24 VDC using to control in valves, motors and pump, it works as output form PLC.

Figure 3.10: Relay 24VDC

3.4 Mechanical Design

3.4.1 Pneumatic Circuit of System

The circuit views all components in the pneumatic system where shows type of valves are use, cylinder and position of sensors, in the next figures will explain any item and why it used.

3.4.2 Cylinder of System

In system they used double acting pneumatic cylinder where use the force of air to move in both extend and retract strokes (up and down), they have two ports to allow air in, one for out stroke where give the down movement and one for in stroke that for up movement, the type of this cylinder is (FESTO (DNT – 63-500) p.max 10bar).

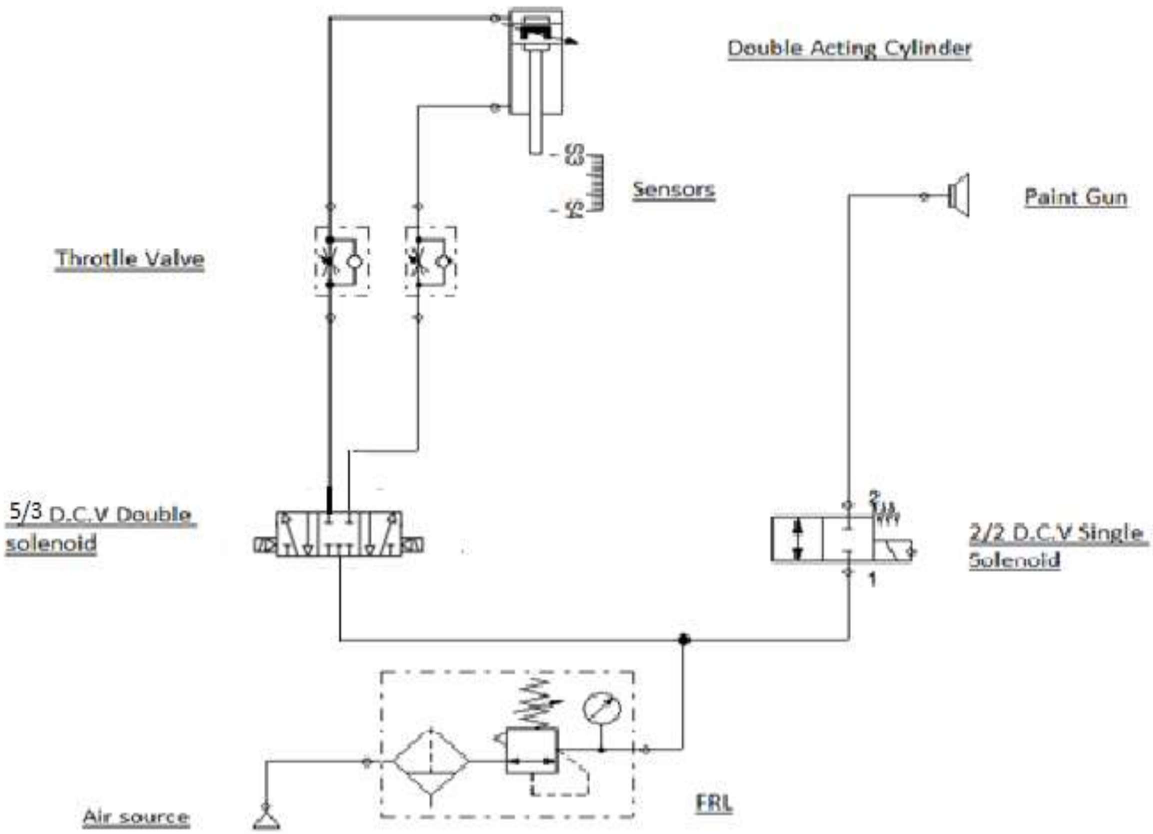


Figure 3.11: Pneumatic Circle of System

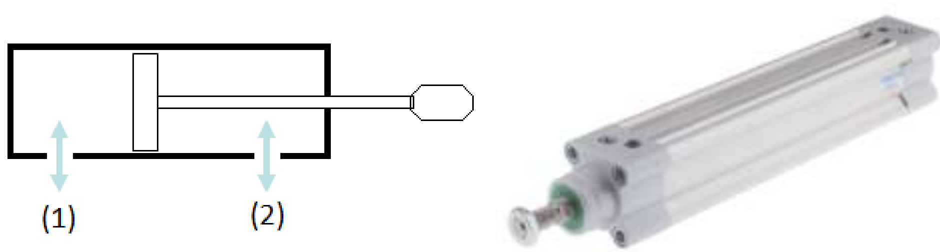


Figure 3.12: Cylinder Symbol of System

3.4.3 Valves of System

According to pneumatic circuit they have three types of valve any one for this valve it using for action in the system, double solenoid valve for control in direction of cylinder, single solenoid pneumatic valve to gun another for control in speed of motion (Throttle valve).

3.4.3.1 5/3 Double Solenoid Valve

The 5/3 double solenoid valve is an electrical valve with three states (5/3 means the valve has 5 ports and 3 states of air flow; the state with no air flow doesn't count as a state, in this naming convention):

State (1) occurs when the left contact of the valve is electrically powered (with 24V DC). The air flow is represented in the left side the air goes into the valve through port 1 and is expelled through port 5. This air flow pushes the cylinder forward.

State (2) occurs when both contacts of the valve are electrically powered, or when both contacts are OFF. The air flow is represented in the center, all ports are closed, and so there is no air flow. This makes the cylinder remain on its current position or decrease fast, to zero, the moving speed.

State (3) occurs when the right contact of the valve is electrically powered. The air flow is represented in the right side, the air goes into the valve through port 1 and is expelled through port 3. This flow pulls the cylinder back. [12]

Figure 3.13: 5/3 D.C.V Double Solenoid

3.4.3.2 2/2 Single Solenoid Pneumatic Valve

The most common and simplest valve is the 2/2-way valve. It has two ports and two states (open and closed) and is therefore also called shut-off valve. They are used in pneumatic applications where the supply of air must periodically be closed off. 2/2-way valves can be mono-stable or bi-stable. Bi-stable 2/2-way valves usually have one solenoid and are pulse operated to switch state. These valves are also referred to as 'latching'. Mono-stable 2/2-way valves can be normally closed (opens when actuated) or normally open (closes when actuated). The majority of 2/2-way solenoid valves is mono-stable and normally closed. The image below shows the symbol for a normally closed valve. [16]

Figure 3.14: 2/2 Single Solenoid Pneumatic Valve

3.4.3.3 Throttle Valve

Pneumatic speed controller is used for controlling the operation speed of a driving device and the movement of cylinder, the flow rate of air from A side to B side can be control, whereas air entering from B side to A side is not under control. [15]

It is possible to tune them to adjust the cylinder speed in both extension and retraction.

Figure 3.15: Throttle Valve

3.4.4 Filter Regulator Lubrication Unit (FRL)

It is used to treat the air coming out of the compressor where it is hot, dirty and wet, which can damage and shorten the life of equipment, such as valves and cylinder. before this air can be used, it needs to be cleaned and lubricator.

Figure 3.16: FRL Unit

3.5 Wiring Diagram of System

This diagram explains the link between electrical components and mechanical components in the system, where the input elements and the output elements are specified in PLC unit. The input elements connect directly to input channel in PLC as for output elements connect by a mediator with the output channel, such as relays and contactors. That for the purpose of protect and take into account the diversity of the output voltage.

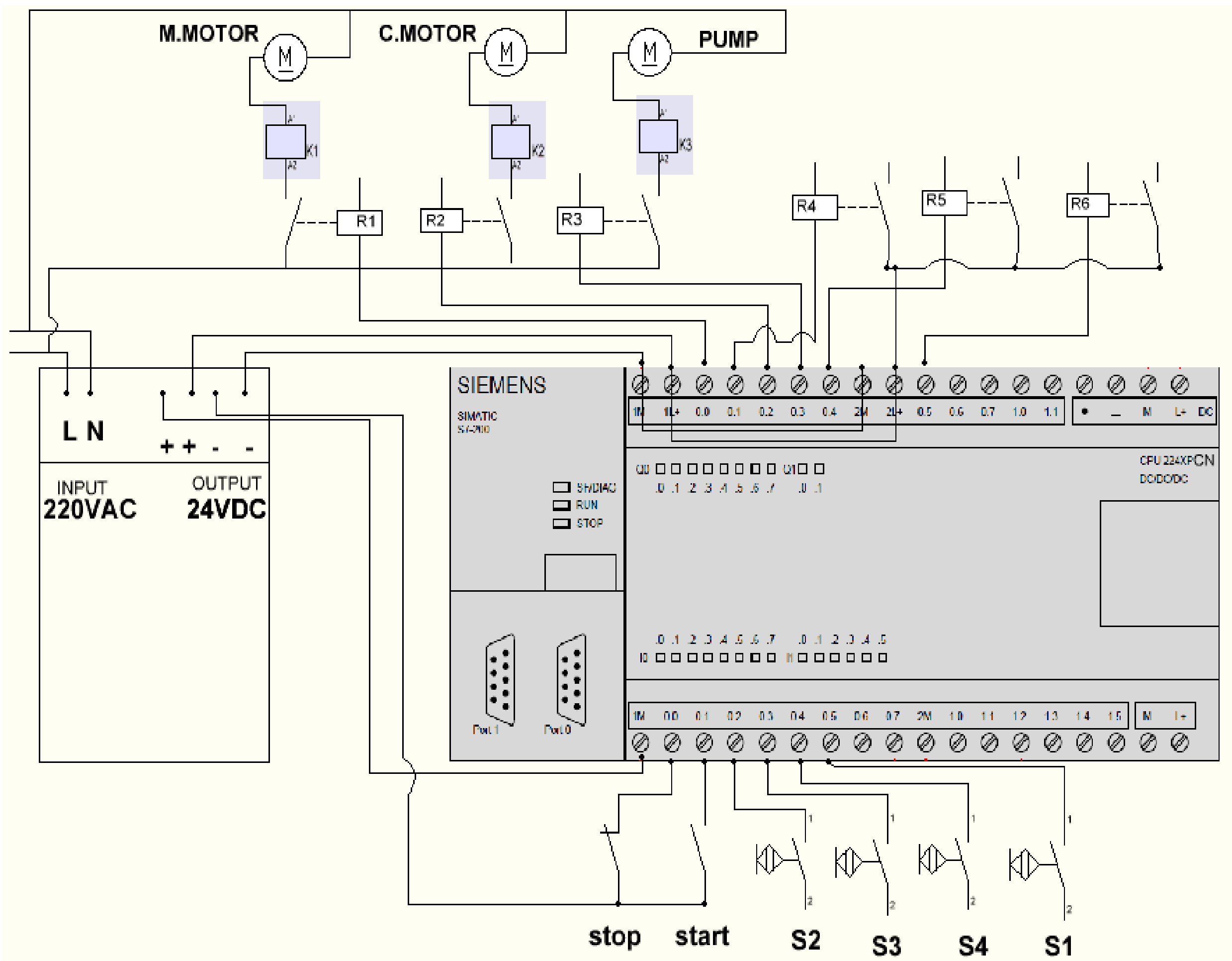


Figure 3.17: Wiring Diagram of System

Chapter Four

Result and Discussion

4.1 Preview

The process of coating in the production line was carried out in the Manual method, the worker is start/stop a main motor and others, he using the paint gun to coating the product by hand, he is exposed to health damage and they have a waste time where the quantitative production processes require high production speed therefore the solution to these problems and other by designed and implementation automation system.

4.2 Method of Operation

The old system has main motor to moving conveyor, circulation motor, suction fan and water pump, by added some sensors, pneumatic unit and plc unit to make a link between components sequentially. Based on a ladder diagram in figure (4.1) will explain how to link these components and the sequence of operations.

When operate the system the main motor moving the conveyor when the product arrive the paint point the system stop the motor and send signal to pneumatic system to begin work.

The pneumatic system has a two section, moving and painting. the moving does by cylinder and double solenoid valve to gives forward and retract and the painting action do by coating gun and single solenoid valve.

‘’used these components specifically because they are available and commonly but can use another component provided they perform same propose ‘’

4.3 Ladder Diagram of System

The diagram explains number of network they are used and show that steps to implement the system with show the details of any codes and where its work, the ladder language is the easiest and clearest programming languages (see appendix A) for more details of the system

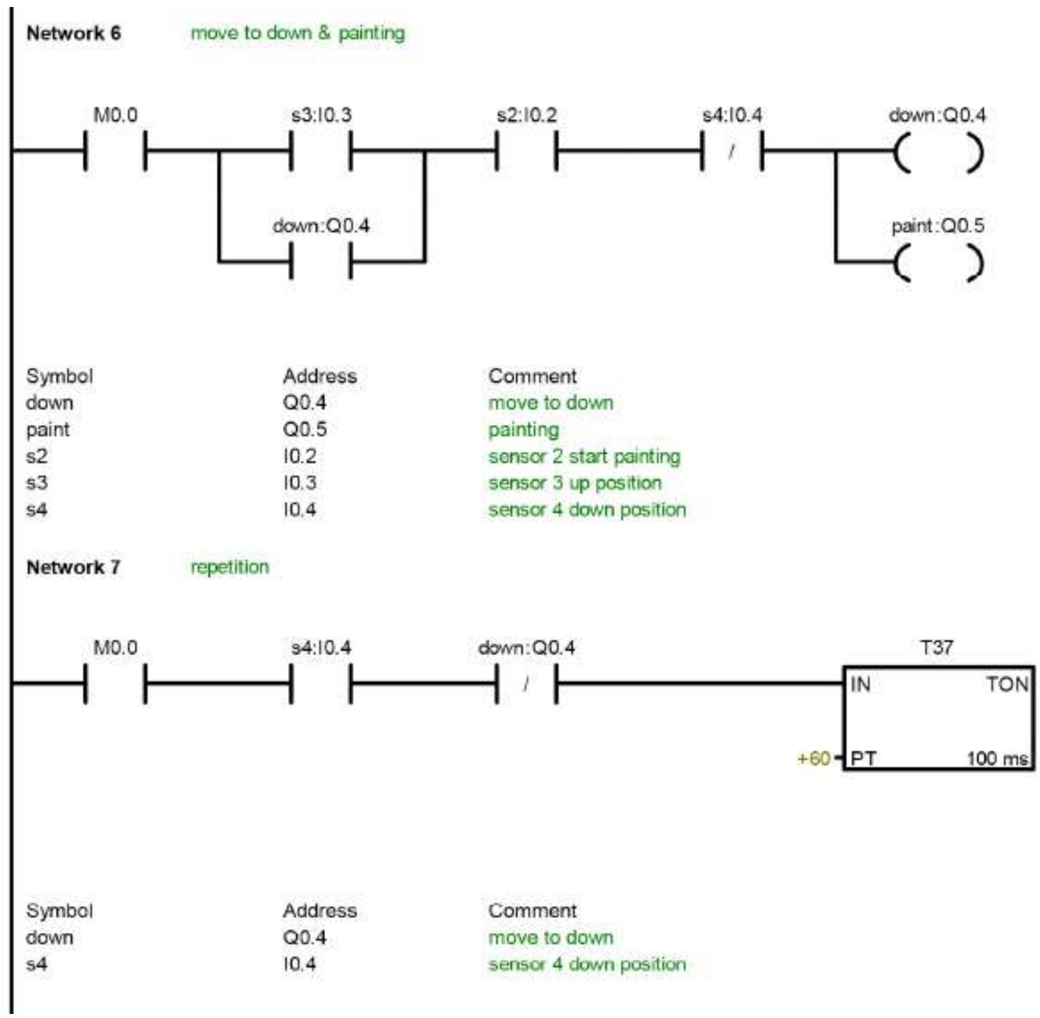


Figure 4.1: Sample of Ladder Program

4.4 Operation of System

When push the pushbutton to start system the signal through to operate the main motor (Q 0.0), circulation motor(Q 0.2), fan(0.6) and water pump (Q0.3), the main motor moving a conveyor until the target arrive to sensor one (I 0.5) see (figure4.2) when the target arrived sensor one the PLC receive signal from sensor and send output by relay to stop main motor, after stopped main motor the conveyor still moving by gravity until the target arrive to sensor two see figure4.3 in this position the product is be in alignment with paint gun inside the paint room.

Figure 4.2: Main Motor & Conveyor

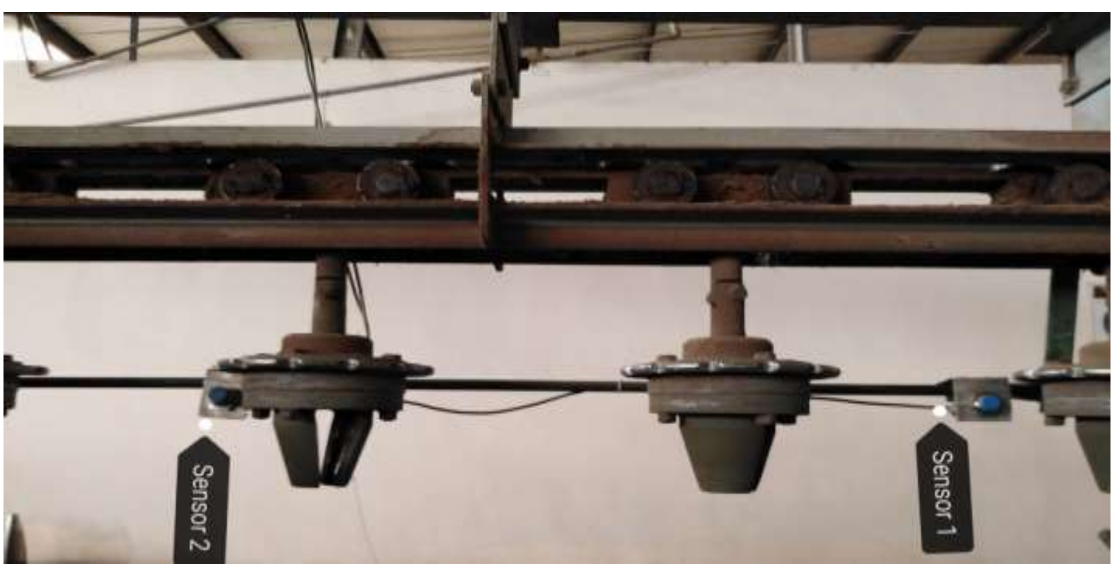


Figure 4.3: Conveyor & Sensors

4.4.1 Extend of Cylinder

When the target arrive sensor two (I o.2), the PLC receive this signal and send output to other relay to activate solenoid of direction control valve (Q0.4) to move the piston rod from up to down from sensor three (I 0.3) to sensor four (I 0.4) according to speed that is adjusted by throttle valve, the paint gun is installed on end of piston rod to move together, the PLC also send signal to on/off valve (Q0.5) where the air passes in paint gun.

Figure 4.4: Position of Start Painting

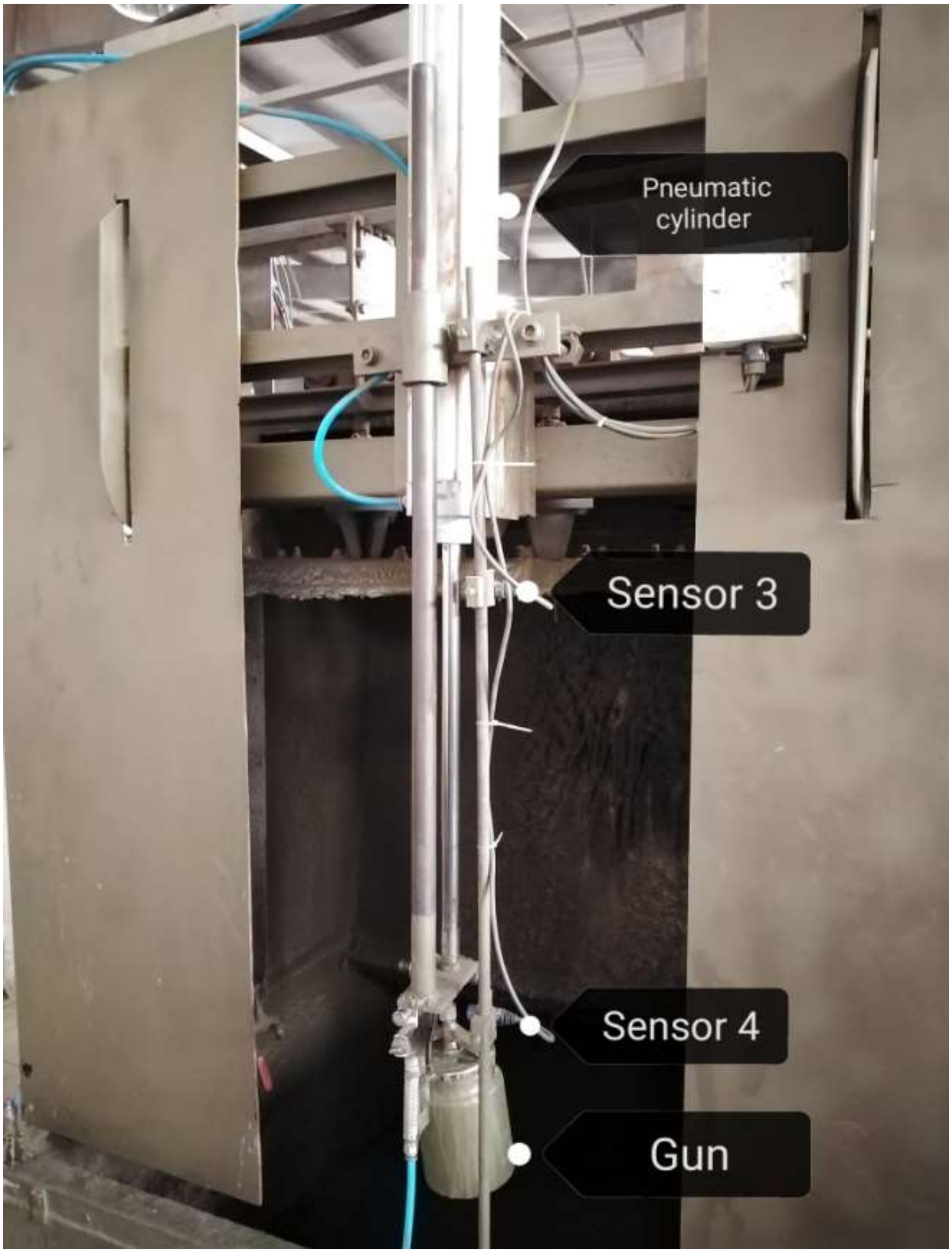


Figure 4.5: Moving Between Sensors

4.4.2 Retract of Cylinder

When the piston rod arrives to sensor four (I 0.4) the plc receive signal from sensor and send output to relays for stop moving to down and stop painting in this moment the plc also send signal to return piston rod to up until arrive sensor three and to main motor to begin start a new cycle by this sequence.

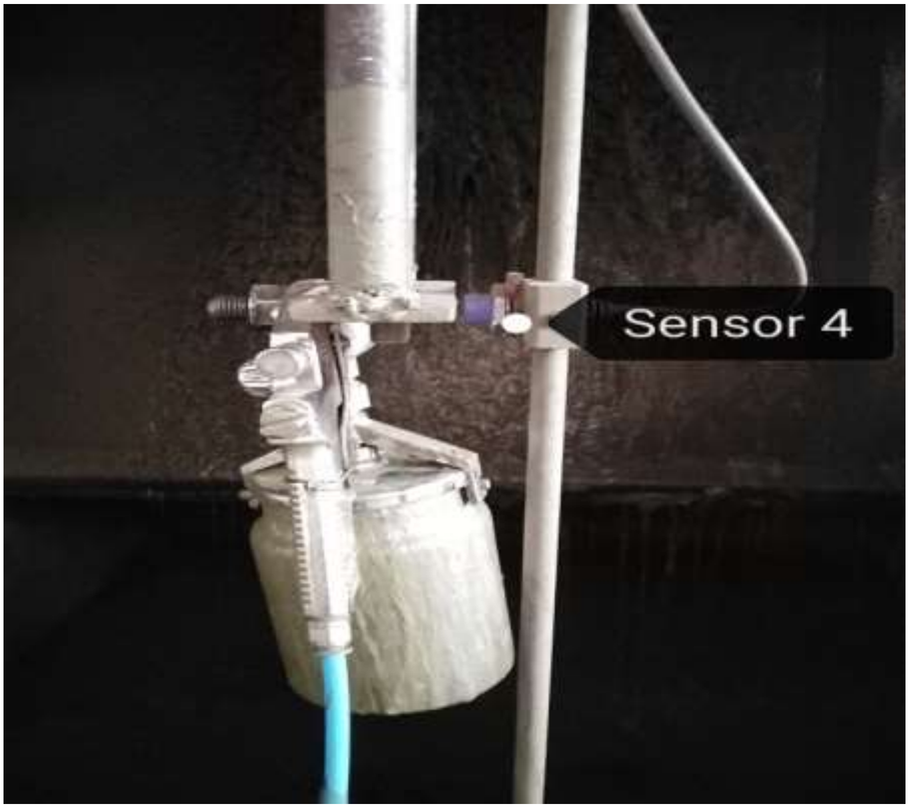


Figure 4.6: position of sensor four

4.5 Discussion

When installed all components in the system experimented system in real mode to ensure the effectiveness of system, as it became excellent and sequential according to the data shown previously, where the automated system a great improvement in terms of amount of production and the provision of lost time, the product became higher quality and also led to a decrease the number of workers, as a very few workers have accomplished the task.

The system has been operating for more than six months until now by high efficient, however the system has some shortcomings and caps that can be areas for research and development in the future, as it can’t distinguish between whether there are a products inside the paint room or not, where the sensors take a signal from conveyor directly not from the product attached on it, secondly this system working at limits products according to stroke of cylinder (500 mm) any product taller than 500mm can’t paint it.

Figure 4.7: Position of Conveyor Sensors

Chapter five

Conclusion and Recommendations

5.1 Conclusion

This thesis explains the details of automation of a product coating line where the coating system has been converted from the manual system to a fully automatic system and this has been done by integration between the PLC system and the pneumatic system where this merging reflects the core of mechatronic engineering. This is by using PLC S7-200 from Siemens and some the components of the pneumatic systems that were clarified in the thesis chapters, which are five chapters, the details of which are as follows: - chapter one is introduction, Problem Statement and proposed solution. In Chapter two, the role of automation in the development of industrial processes and an overview of plc, its history, types tools and languages programming, also the role of pneumatic system it plays an important role in automation processes. In chapter three in this system we use plc Siemens S7-200 we show it, CPU, Expansion Modules types and how program it and so on, a detailed explanting of the pneumatic components and system they used. In chapter four show implementation of system and discussion about the pros and cons of system, the method of operation and photo of the electrical and mechanical components during work. About the objective of the thesis the project achieved all the objectives described in chapter one.

This automation led to increase in quantity of products exceed 100% and reducing the number of worker to 30% and led to higher quality product.

Below is a comparison of the performance between automatic line and manual line in order to know the feasibility of implementing this project and shows the results obtained after the automation process.

Table 5.1: Comparison

NO	**Comparison**	**Manual Line**	**Automatic Line**
1	production capacity	150 product	320 product
2	Number of workers	3	1
3	Quality of production	poor	Good
4	Work hours / day	6 hr	8 hr
5	Running cost	high	Low

5.2 Recommendations

After finishing this research works there are still some open issues can be considered for future research; this include: -

The project considered only part of the production line (one cabinet) this production line contains three cabinets, thus it is extendable, much more future work can be done to complete the whole production line. for example

Add a new pneumatic system to one of other cabinets and combine it with the existing control system or make a new complete system.
Add a monitor (sensor) to check whether there is a product in the production line the system now depends on sensing the sensors (1,2) to the product holder and accordingly the operations are carried out, but in the case of a product holder that

doesn’t have a product, there is no mechanism to monitor the product and thus the process is carried out coating in an empty, so we see that the opportunity for improvement is to monitor the product specifically by sensor or any other mechanism.

References

1/ L.A. Bryan, E.A. Bryan, Programmable Controllers Theory and Implementation Second Edition, Industrial Text Company, 1997.

2/ frankd .petruzella, Programmable Logic Controllers Fourth Edition, McGraw-Hill,2005.

3/ W. Bolton, Programmable Logic Controllers, 5th Edition. 2009

4/ Md. Abdulla Al Nakib, Md. Rana Ahmmad, Shahruk Osman, Design And Implementation Of Plc Based Automatic Bottle Filling, International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 05 Issue: 01 | Jan-2018

5/ peter croser , frank ebel pneumatic basic level,Library of Congress Cataloging, 2002.

6/ M. D. Schwartz, J. Mulder, J. Trent, and W. D. Atkins, \Control system devices: Architectures and supply channels overview," Technical Report SAND2010-5183, Sandia National Laboratories, 2010

7/ Siemens, S7-200 Programmable Controller System Manual, 2005

8/ Ahmed Omer, industrial production line automation using plc systems, 2009

9/ hugh jack, automation manufacturing system with plcs, vision 5, Free Software Foundation, 2007.

10/ Jon S.Wilson, Sensor Technology Handbook, Library of Congress Cataloging, 2005,

11/ Jacob Fraden, Handbook of Modern Sensors Physics, Designs, AND Applications Third Edition,2004

12/ Y. Tassa, T. Wu, J. Movellan, and E. Todorov, “Modeling and identification of pneumatic actuators,” in Mechatronics and Automation (ICMA), 2013 IEEE International Conference on. IEEE, 2013

13/ https://en.m.wikipedia.org/wiki/relay ,10/2/2020

14/ Vladimir Gurevich, Electric RelaysPrinciples and Applications, Taylor & Francis Group, LLC, 2006

15/ https://www.xpneumatic.com/portfolio-items/pneumatic-throtlle-valve/ 2/2020

16/ https://tameson.com/solenoid-valves-for-pneumatic-system.html 2/2020

17/ K. Gowri Shankar Control of Boiler Operation using PLC – SCADA Proceedings of the International MultiConference of Engineers and Computer Scientists 2008 Vol IIIMECS 2008, 19-21 March, 2008, Hong Kong

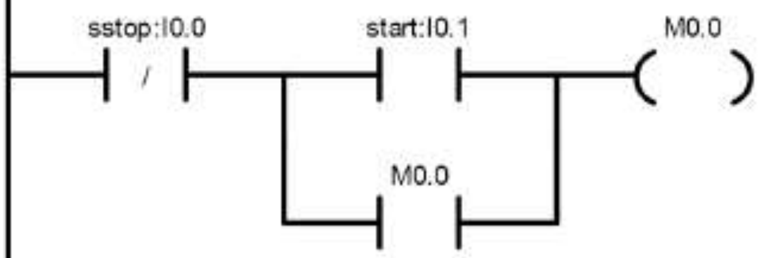
18/ P.Thirumurugan, automatic sorting in process industries using PLC,GlobalResearch and Development Journal for Engineering | Volume 3 | Issue 3 | February 2018

Appendix A – Ladder Diagram of System

painting project

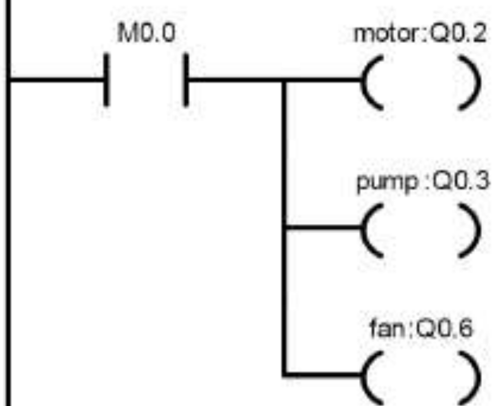
Network 1 start/stop

Network Comment



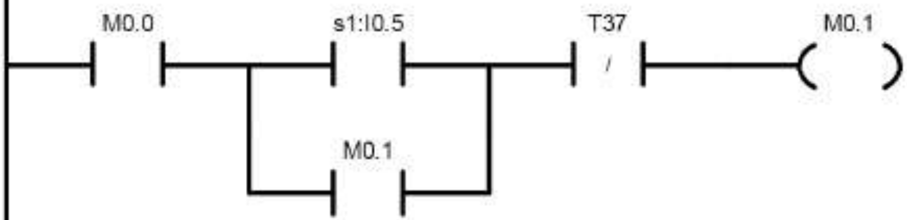
Symbol	Address	Comment
sstop	I0.0	stop
start	I0.1	start

Network 2



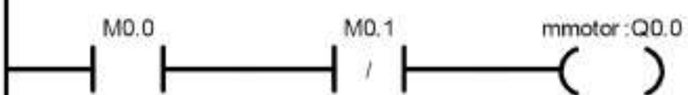
Symbol	Address	Comment
fan	Q0.6	fan
motor	Q0.2	circulation motor
pump	Q0.3	water pump

Network 3 stop main motor



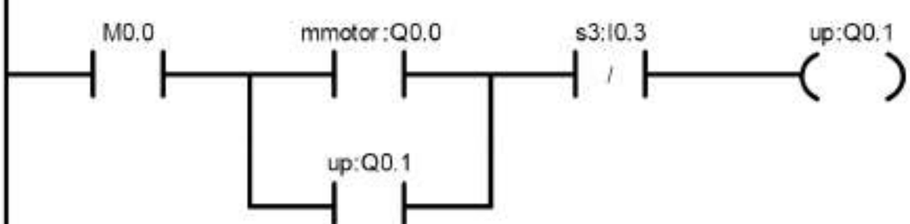
Symbol	Address	Comment
s1	I0.5	sensor 1 to stop m.motor

Network 4



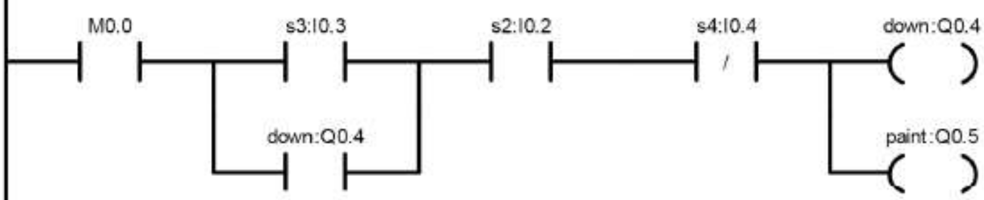
Symbol	Address	Comment
mmotor	Q0.0	main motor

Network 5 move to up



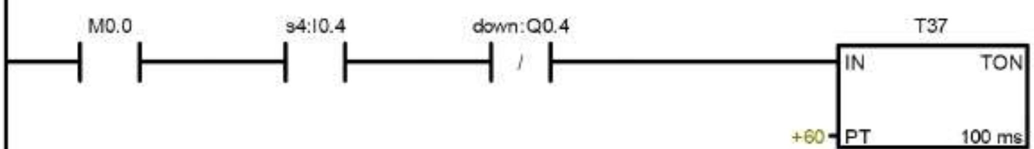
Symbol	Address	Comment
mmotor	Q0.0	main motor
s3	I0.3	sensor 3 up position
up	Q0.1	move to up

Network 6 move to down & painting



Symbol	Address	Comment
down	Q0.4	move to down
paint	Q0.5	painting
s2	I0.2	sensor 2 start painting
s3	I0.3	sensor 3 up position
s4	I0.4	sensor 4 down position

Network 7 repetition



Symbol	Address	Comment
down	Q0.4	move to down
s4	I0.4	sensor 4 down position