CHAPTER 1

INTRODUCTION

1.1 General

In the fast growing face of automation electric machinery has become the integral part of the industry. Automating the routing tasks in the industries increases the productivity and reduces the probability of error in the system. Traditional industrial tasks involve manual operation of machineries and also tasks are dependent on manual intervention, which can cause error in the process. Also it is time consuming and expensive. Automation of operations reduces time and error and quality of products is improved.

Mixing of liquid has wide application in the field of paint industry, medical industry, chemical industry, pharmaceutical industry etc. The most important step in mixing the liquid is defining the accurate proportion of its liquid element, which can be effectively and accurately performed with the help of machinery without manual intervention.

The current system is designed for automated level control, liquid mixing and filling of bottles. The system is designed for filling the mixture of two liquids in equal proportion. It consists of three sub system namely level controller, liquid mixer and bottle filler. The entire process is controlled and automated with the help of Programmable Logic Controller.

1.2 Programmable Logic Controller (PLC)

A PLC is a Programmable Logic Controller that consist of input, output and a CPU which contains memory, timer etc. it is widely used in automation industry and the process control systems like controlling machinery or factory set line of operations. PLCs were invented as replacements for automated systems that would use hundreds or thousands of relays, cam timers, and drum sequencer. Often, a single PLC can be programmed to replace thousands of relays. PLCs have multiple inputs and outputs, operate under extended temperature ranges, have immunity to electrical noise, and have resistance to vibration and impact. Programs to operate sequence of operation or controlling a machine operation are written in the software firstly, then it will be loaded to the battery backed or the non-volatile memory.

Block diagram of a PLC is shown as in the following fig. 1.1

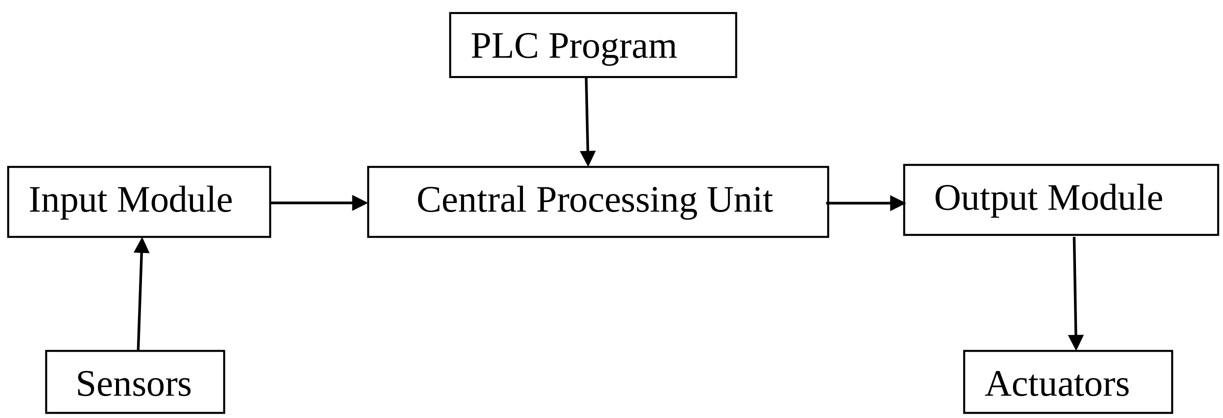


Fig. 1.1 A Block Diagram of PLC

PLCs are made to work in industrial environments, means it can work well in industrial environments like dust, humidity, temperature, cold etc. These PLCs have multiple input/output (I/O) terminals. I/O terminals connect the actual PLC to sensors as well as actuators. PLC works well with various analog signals like heat, force, flow, pressure etc. PLCs output can operate power engines, pneumatic or hydraulic cylinders, relays or solenoids, as well as analog results. Input/outputs can be made in different types of PLCs that can be a small PLC or a fixed wired PLC or a modular PLC. External I/O web template modules are attached on a new bottom or perhaps chassis. Through Ethernet communications any computer can be put straight into most of the PLCs.

Input module is connected with the sensors such as Resistance Temperature Detector (RTD), Thermocouple, Linear variable Differential Transformer (LVDT) etc. which update the inputs status whenever any signal from the sensor is detected. Input signal can be digital such as either 0 or 1 and can be in the analog form such as 0-10V or 4-20mA.Similarly output module of a PLC is used to output the status of level indicators, alarms etc.

1.3 Automated Level Controller

Liquid level controller is designed to automate, monitor and control liquid level in the tank. Reducing human intervention along with reducing cost and preventing industrial accidents by overflowing of a tank is the major objective of the system. Level controllers are used in different industries as well as domestic household purpose in order to automatically control the operation of motor as well as to avoid wastage of liquid.

1.4 Automated Liquid Mixer

Liquid mixer performs mixing of different liquid (chemical, paint etc) in equal proportion using PLC. This task of mixing is performed continuously in a tank and further the mixer is filled in the bottles. To accurately mix specific amount of liquid components, automatic liquid mixture is used. For example in the paint industry as we know different color shades are generated from basic colors. Liquid mixer is used to mix different colors in specific amount to generate different color shades.

1.5 Automated Bottle Filler

The mixer generated by liquid mixer is filled in the bottle placed on a conveyor belt whose movement is controlled by a DC motor, a sensor is used to sense the bottle. As soon as the sensor senses the bottle on the conveyor belt it stops the conveyor belt motor and send signal to PLC, which in tern send signal to open the solenoid valve for filling the bottle. For example, in beverage or paint industries to fill the bottles or containers of specific volume, a timer is set for the specific duration based on the volume.

1.6 Project Objective

The proposed system is designed to automate, monitor and mix different liquids in the tank along with controlling the level of liquids automatically. The mixer in the tank is further required to transfer to the bottles which are also performed in an automated manner.

Automated level controller maintains the level of two different liquids by switching ON and OFF two different motors provided with each tank. The different liquids are mixed in the overhead tank using a mixer which is rotated in the tank using a DC motor. For filling the mixture in the bottles, bottles are placed on a conveyor belt which is moved with the help of a DC motor. As soon as the bottle reaches below the solenoid valve connected to the tank, the IR sensor senses the bottle. Once the bottle is sensed the conveyor belt stops moving this is carried by switching OFF the motor controlling the conveyor belt through PLC. The bottle is filled with the mixture in the time span of 30 seconds and further the belt resumes its motion and this process is continuously carried out.

1.7 Organization of Thesis

The contents of the thesis have been divided into following chapters:

Chapter-1 Introduction

The basic details of automated level controller, mixing and automated bottle filling are discussed in brief. The idea regarding automation of the system has been also discussed in brief using PLC and its components.

Chapter-2 Literature survey

This chapter describes elaborately the literature survey of automatic level control, mixing of liquids and automatic bottle filling industries processes. It also covers the use of PLC and its application in various automated systems.

Chapter-3 PLC and ladder logic

This chapter describes the history and evolution of PLC. The architecture and operation of PLC is explained in this chapter.

Chapter-4 System components

This chapter includes the components of the present system. The description of different hardware and software components along with their working is described.

Chapter-5 Design and Implementation

In this chapter the architecture of present system is explained. The different settings of PLC for implementation of the system are described.

Chapter-6 Operation and Results

This chapter explains the complete operation of the system for automatic level control and bottle filling of the liquid mixture.

Chapter-7 Conclusion and future scope

This chapter contains the conclusion and future scope of the system.

1.7 Conclusion

This chapter described the various sub-system designed for automatic level control, mixing and bottle filling of the liquid mixture. The objective of the automated bottle filling system is also discussed chapter wise organization of thesis is summarized.

CHAPTER 2

LITERATURE REVIEW

2.1 General

A brief description of work carried on industrial automation using through PLC has been described in this chapter. A properly designed PLC based system proves to be more beneficial in terms of saving money and time and providing qualitative and reliable control. A lot of focus, attention and motivation are needed to enhance the quality, production and to reduce the operating cost. The PLC based control schemes used in controlling several field devices have also been discussed.

Automation is a key through which the efficiency of the any system can be increased drastically. PLC and its application is the best option for achieving the goal of saving energy, enhance the production and minimizing the overall cost.

2.2 Literature Review

Greg P. Zimmerman [1] analyzed the concept, working principle, advantage of programmable logic controllers. Knowledge of its practical application and its comparisons with other control system is also provided. How PLC used to control and monitor system parameter is also given.

Petruzella, Mc Graw Hill [2] focused on the working principle of Programmable Logic Controllers and provided a practical approach about the installation, programming and maintenance of PLC system. Information about how Programmable Logic Controllers are used for the replacement of relay logic is discussed. A vast knowledge of practical application of PLCs and its extent of working is also provided.

W Bolton, Newnes [3] explained the application and fundamentals of programmable logic controllers in real time system, identification of input/output devices and its characteristics.

The processing of input and output devices and its communication links, protocols and networking method is also provided. Introduction to mechatronics devices such as valve, actuators is also presented in this book.

Z. Tianxia, D. Feng, Y. Hao [4] The control of each subsection of beer filling production line needs to be optimized to make the operation automatic and efficient. Microprocessor is the core of PLC i.e. an industrial control device. In beer filling line the use of PLC can improve the production efficiency and significantly increase automation level. To improve the system efficiency as the system go to the different operation, timely adjustments are tuned. The system faults are determined by the design of the program and monitoring of the operational status is supervised. An intelligent, secure and efficient functioning on the arranging bottle process can be achieved by making the appropriate control treatments. PLC technology is applied to realize the automatic control. PLC technological advancement eradicates the large manual job, decreases the production expenses, enhances the production efficiency and lifts the automation level to guarantee the stability and security.

David W Pessen, John Wiley & sons [5] describes the measures taken to tackle industrial problem, provides an approach to select appropriate control application method for a given system and also provides information about circuit design. It also deals with cost reduction policies. Information about improvement in existing system is also provided.

Johnson, C.D. [6] presented some information about the concept of element of control system and its operation and design. The author tried to emphasis on the practical approach of design of control system, use of sensor, signal conditioning element, final control elements for the purpose to work with measurement and instrumentation and automation devices like PLC.

Boleslaw F. Boczkaj [7] presented an approach to fill the gap between mathematical or experimental principles of system and case studies which describes instances of some specific application in practice. The main objective of the author is to organize a PLC program to generate a library of code for specific actuator, sensors, robots, axis of motion arrangement and work cell configuration.

Jaykumar Patel, Prof. Alpeshkumar Patel, Mr. Raviprakash Singh [8] this paper describes a process loop useful for bottle washer machine. The process loop can be used in oil and chemical industries. In the bottle washer machine, three parameters level, flow and pressure are to be controlled. These parameters have strong interaction. PLC is used to control pressure and flow for better washing. PLC increases efficiency and response time. This loop can be used for bottle filler by modification in the hardware. Bottle filler requires a valve outside for safety. PLC controls different sensors and valves by the program. Valves are controlled by PLC by generating signals. Along with PLC, Human Machine Interface (HMI) is used for facilitating the user to directly set the values.

Gerardo Gonzalez-Filgueria [9] Industry is looking forward for suitable ways of process automation. This work presents algorithm of process control for packing liquid product using PLC. Along with process control, it is targeted to reduce the process time. This paper includes a comparative study of time required in the process of filling water and detergent. For checking the proper running of automatic process SCADA system is used.

CosminaIlles, Gabriel NicolaePopa and Ioan Filip [10] A water level control system has been described using SIEMENS LOGO, 24RL Programmable Logic Controller, converters and RTX-MID-3V transceivers. A pump has also been used in the system which is controlled by electrical motor. Low power control system is very simple and it is based on a specialized sensor. But pumps power must be taken into consideration. There are different types of water level control system that can be used. The cost of the system devices must also be considered. Finally a low cost method has been presented for water level control with a wireless solution.

LaurentiuSchiop, Marian Gaiceanu [12] The mixing process is an intrinsically non-linear plant and multivariable. For the mathematical model of the tank, flow dynamics of a simple holding tank has been considered. The output of such tank is determined by the inside pressure of the tank. To design an adequate control (PI controllers), a mathematical model is made for the mixing color was considered. A nonlinear mathematical model and a linear model were compared. STEP7 Programming Software for Siemens SIMATIC PLC was used for the control of the process. Matlab-Simulink environment has been used for the implementation of entire process. On-line implementation of controlled process has been done using specific language (FBD – functional block diagram) for STEP7. Additionally, an intuitively HMI (human machine interface) in WinCC has been created to use in industry by an operator.

K. Uttekar, R. Gosavi, S. Lad, J. Kamat [13] traditional wired field bus networks are now days getting obsolete and wireless sensory networks are in more demand because of their cheaper and faster communication. That is why they are gaining acceptance in numerous industrial segments. A novel approach by implementing smart sensor network has been presented to improve performance efficiency of a bottle processing assembly station. A wireless sensor network has been created and implemented for a bottle capping plant assembly station. The data have been collected using smart wireless sensors and then transmitted to DSCD. Physical damage to the system has been prevented by providing an interlocking mechanism. Efficiency can be improved and installation period can be reduced with the use of smart sensors. Current network capacity can easily be expanded by implementing the smart sensor network. Identification of the fault sensors can be done by implementing concept of wire break sensing.

Paul Priba [14] presented the capability of Programmable Logic Controllers for data acquisition, monitoring and data display about the status of machines and large motors in an industrial plant. The author is concerned with the application of a programmable logic controller for acquiring data from solid state motor and protective and to display all these information using SCADA in a control room, a distance away. Basic of PLC and its programming knowledge is also presented.

Gerardo Gonzalez-Filgueria [15] Plant profitability can always be improved by choosing process control. Using the latest scalable control and optimization technologies, this goal can be reached. More suitable systems are precise to be automated by the Small to Medium Enterprises (SMEs).The right running of automatic process has been checked by using SCADA system. PLC's were used for the control.

V Rajeswari, DrLPadma Suresh, ProfY.Rajeshwari [16] A consistent and stable supply of quality controlled water is essential for pharmaceutical production. Related to water different parameters play a vital role in pharmaceutical industries. If these parameters are not maintained properly then the water will not be fit for the usage in plant. Once water has been obtained for pharmaceutical use, Water must be stored and then distributed to the points of use. If the water is not stored and distributed properly then there is no point of producing quality water. For the proliferation of micro-organisms and minimization of possible contamination of the water, this stage is very important. Continuous recirculation must be used to seal the systems and they must have a sanitization system.

Marco Colla [17] describes problems faced by automation engineers during software design and its implementation, their transportation and implementation. An effort has been made by the author to solve these problems by a survey. Some information about the need of automation in industries and plant, and requirement of their fast design and customization as it is increasing rapidly is also provided. The control techniques and device used for automation is also provided.

Hassaan Th. H. Thabet 1, Ma Ysara A. Qasim [18] The food industry plays an important role in the economy of the country. Developing countries always try to catch up with the already developed countries. These countries need to increase their interest in this type of industries. Automation is very important part of the developing policy of any industry. Automation of a food production process has been the main focus and it can be achieved by designing the automated system based on technologies of the PLC.

S. T. Sanamdikar and Vartak C [19] Various stages of operation have been outlined those are involved when a manually operated color plant is converted into a fully automated color making plant. The demand for high quality and greater efficiency has increased over the years for various colors, in this globalized world. Passing inputs of the color mixing and making process with the various components have been the main focus. All the colors coming from process can be mixed in required proportion with help of the mixing tanks. For monitoring of the system SCADA has been used. Internal storage of instruction was done using PLC. Systems are used to control and monitor a plant in an industry. A sincere attempt has been taken to explain the advantages of automation.

Xiaoling Yang, Q. Zhu, H. Xu [20] describes the operation of 2 nine storey elevator running in parallel with the use of PLC. Earlier the same these 2 elevators were running in non parallel mode so the average waiting time and maximum waiting time during the peak hours was very high after the reform the average waiting time and maximum waiting time is reduced. Overall, the control system after the reform has enhanced reliability and better performance.

Gabor A. Biacs, M. S. Adzic [21] describes the solution of rotating iron press for textiles using PLC. With the use of PLC device gives simple solution for sequence control for rotating iron press. Using the PLC a considerable flexibility is achieved other than that great conformity of input and change of parameter are achieved due to built-in display and keyboard. Overall result is improved machine performance and good precision of positioning of the press.

Gediminas Danileviius [22] suggested a methodology for synthesis of control program for a certain process plan that is concerned with development in the planning, production and enhanced Programmable Logic Controllers specific information. A general approach to build control algorithms and automated control programs is presented. Use of signal coding and plc templates for Programmable Logic Controllers is provided.

Masao Ogawa, Y. Henmi [23] presents a combination of PC+PLC based control system. For automation of processing plant of beer brewery process. The developed production control system proves to be cost effective and flexible. The major role of PLC in the entire system is to integrate the PLC system to the PID control loop function as well as development of control and monitoring system for tank selection. Hence it will increase the speed of manufacturing and helps in production quality.

Hiroo Kanamaru [24] presented the concept of safety PLC techniques for industries and factories for minimize the ill effect of accidents along with its installation, configuration, operation and maintenance. The guidelines are provided for programming of these software applications how this technique will be used actually in the factories.

Zhao Futao, D. Wei, X. Yiheng, H. Zhiren [25] presents the use of PLC in main feed water process of Qinshan nuclear power plant. Result obtain from implementation of this scheme indicate that the PLC control system improve the performance of both steam generators water level regulation and disturbance rejection. Steam generators levels are kept well within the limit under 75% plant power trip test. The control system proves to be economically beneficial and is applicable to the control of steam generators and the boilers of the other power plants.

2.3 Conclusion

This chapter described an extensive literature review on PLC and its applications in various industrial processes.

CHAPTER 3
PLC AND LADDER LOGIC

3.1 General

PLC is a programmable sequential processing device with input/output (I/O) interfaces that controls machines and processes. It constitutes built in CPU, memory, I/O units and network modules along with the power supply unit. It uses a programmable memory to store and execute instructions for specific functions that include ON/OFF control, counting, sequencing, timing, architecture operations and data holding is also gives an easy access to various virtual devices like ON-Delay timer, DOWN-Counter, UP-Counter, OFF-delay timer, normally open Switch, normally close switch, Relay coil, etc. The programs developed can be validated before downloading it to PLC controller. The software provides a fully-integrated environment in which every tool and editor works efficiently with each other. Proficy Machine Edition in short offers a complete solution for the development of automation applications under one roof.

3.2 History

The PLC was invented as the need arises from the American automotive industry. Before the invention of the PLC control, sequencing, and safety interlock logic for manufacturing automobiles was accomplished using relays, timers and dedicated closed-loop controllers. The process for updating these facilities due to change of different models which comes yearly was very expensive and very time consuming. As the relay systems needed to be rewired by skilled electricians. In 1968 GM Hydramatic (the automatic transmission division of General Motors) issued a request for proposal for an electronic replacement for hard-wired relay systems.

This proposal came from an American company Bedford Associates of Bedford, Massachusetts. The first PLC is called as 084 because it was this American company Bedford Associates eighty-fourth project. After that this company started a new company dedicated for developing, manufacturing, selling, and servicing of this new product which is called as MODICON, which stood for “Modular Digital Controllers”. One of the people who worked on that project was Dick Morley, who is considered to be the "father" of the PLC. The MODICON brand was sold in 1977 to Gould Electronics, and later acquired by German Company AEG and then by French Schneider Electric, the current owner.

The automotive industry is still one of the largest users of PLCs, and MODICON is one among them. After that different manufactures of the PLCs came into the market. PLCs are used in many different automated industries and machines such as packaging and semiconductor machines. Well known PLC brands are Siemens, Allen-Bradley, Honeywell, ABB, Mitsubishi, Omron, and General Electric.

3.3 Programmable Logic Controller (PLC)

The PLC consist of inputs, a processing unit (CPU), a memory and the output. The Series 90-30 PLCs are a family of controllers, I/O systems designed to meet the demand for versatile industrial solutions. These PLCs have a single overall control architecture and have modular design. the Series 90-30 has been the PLC of record in over 200,000 applications, such as high speed packaging, material handling, complex motion control, water treatment, continuous emissions monitoring, mining, food processing, elevator control, injection molding, etc. the reason behind series 90-30 PLCs is they have large variety of discrete and analog I/O modules. GE Intelligent Platforms also offers a wide range of high-level communication options, from a simple serial connection to a high-speed Ethernet interface and some bus modules.

Fig. 3.1 shows the various connectivity options available for development and monitoring of efficient control systems. The hardware consisting of a PLC 90-30 series, HMI Quick Panel and AC Drives are all connected to the Ethernet bus which is then shared by the software utilities to control and operate upon them. The software utilities such as Proficy Machine Edition, Proficy HMI/SCADA – simplicity, etc. provide a powerful user interface and a rich set of development tools for programming, configuration and monitoring of these hardware devices.

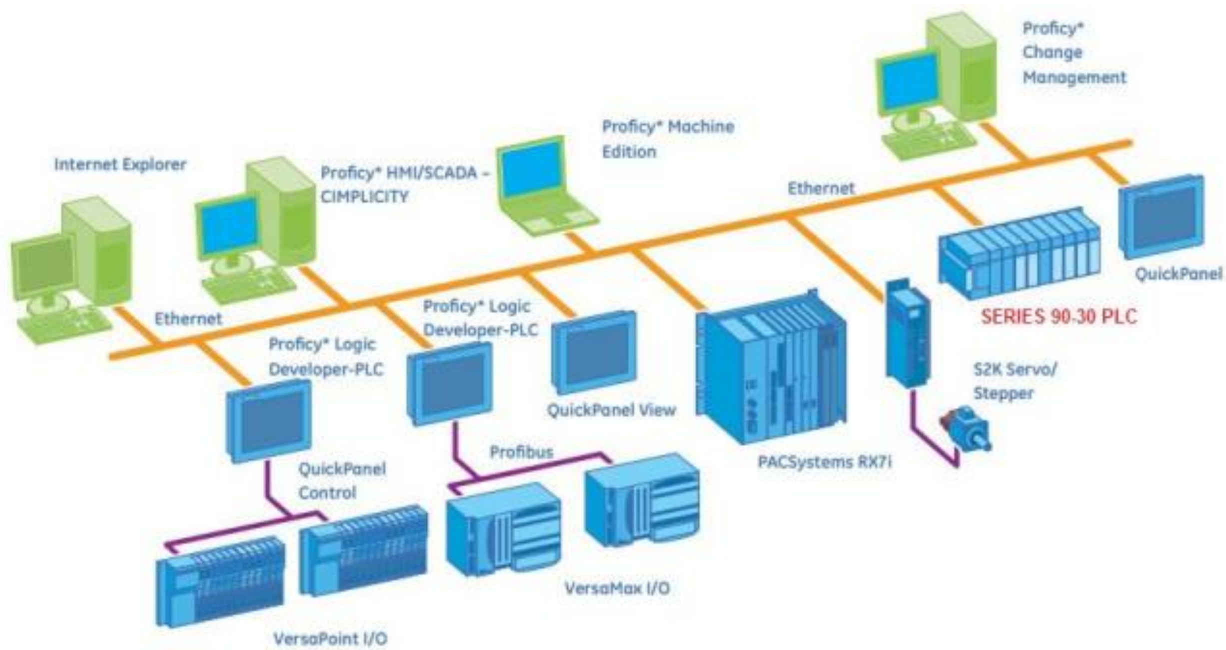


Fig. 3.1 GE Fanuc PLC 90-30 Series and the Connectivity Options

The main reason for using Ethernet communication protocol is the speed at which it communicates which is much faster than the serial communication.

3.3.1 Architecture

PLC is a micro-logic controller, which has some basic parts as shown in Fig. 3.2 below: 1) Central Processing Unit. 2) Input/output interface system (I/O). 3) Memory. 4) Network module. 5) Power supply. The CPU governs all PLC activities. Connection between the CPU, inputs and outputs is provided by the I/O interfaces.

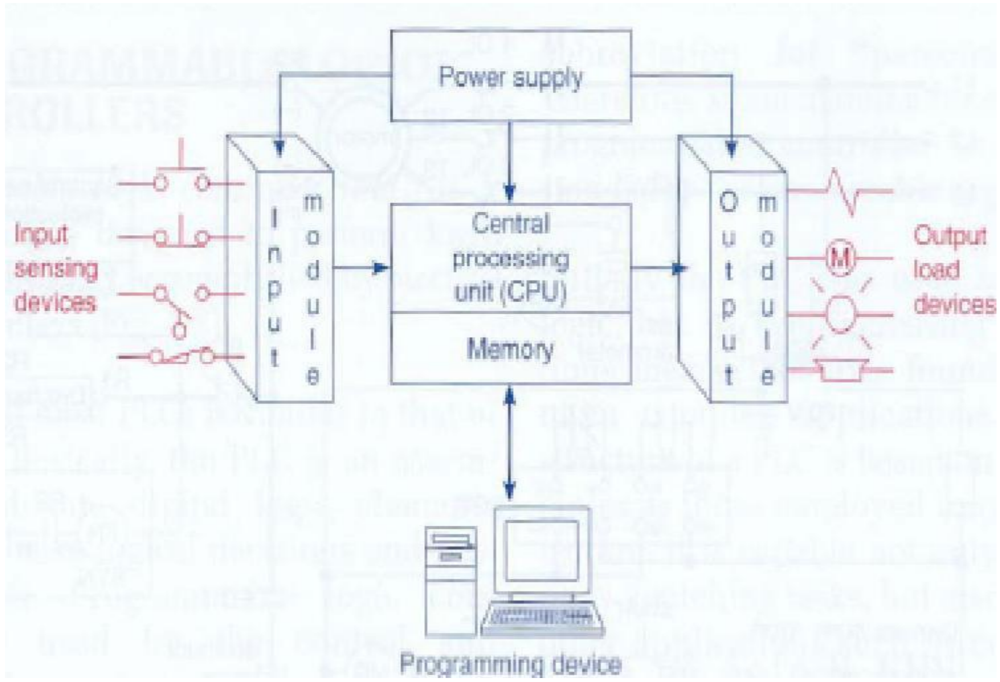


Fig. 3.2 Architecture of PLC

The operation of a programmable logic controller is quite simple. During the execution of the operation, the CPU has to complete three different processes:

a) It reads / accepts the input data from field devices via input interfaces.

b) It executes control program stored in the memory system and

c) It updates or writes the output devices via output interfaces.

The field devices are interfaced with the I/O system that is connected to the controller. These I/O systems are physically connected to the field devices which are controlling the process. These field devices may be analog or discrete I/O devices, such as limit switches, push buttons, motor starters, pressure transducers, solenoids, etc. The main purpose of interface is to condition the various signals sent to or received from external field devices. Incoming signal from sensors like analog sensors, push buttons, limit switches, selector switches, etc. are wired to terminals on input interfaces. Devices like motor starters, valves, pilot solenoids, lights, etc. that are to be controlled, are connected to the terminals of output. The system power supply provides the voltages required for a proper operation of various central processing unit sections. The PLC system in itself consists of several modules, shown below in Table 3.1, with the provision of expansion.

Table 3.1 Hardware descriptions of 90-30 GE Fanuc make PLC

Power Module	CPU Module	Input Module	Output Module	Output Module	Communication Module
Standard power supply Input-100-240VAC Output-24 VDC	CPU-374	Input module 24 VDC Pos/Neg logic 16-pin	Output module 12/24 VDC Pos logic 16-pin	Output module 12/24 VDC Pos logic 16-pin	Profibus DP master

The 90-30 GE fanuc PLC uses the CPU 374. In this processor speed is 133 MHz. Its I/Os limit to 2048. This CPU has a scan speed of 0.15ms per 1000 logic. The standard power supply it uses is 230V AC for input and gives output voltage of 24V DC. Input modules consist of 16 pin and output module consist of 32 pins. For the communication to the third party Profibus DP master is available. The most important advantage that makes PLC a versatile device is that it can be easily configured with any

device such as servo-drive, variable frequency drives, HMI and SCADA. With this additional feature PLC can be accessed in any local network as well as in web based control systems. Communication and networking modules are enhancements for the present day PLC's, and make PLC reliable for a wide range of applications through which programmer or supervisor can access PLC from any place in a described network. In addition to the above mentioned advantages, PLC also possesses certain advantages such as ease of programming and maintenance. It can be used in diagnosing the process faults by LED indicators on its modules. It can be quickly installed and is adaptable to changes, as is required in a particular application, giving it high flexibility. PLC has given automation new heights.

3.3.2 Input/ Output Devices

Input Devices which can be used in conjugation with a PLC are:

- Photoelectric Sensors
- Proximity Sensors
- Sensing Devices
- Limit Switches
- Level Switches
- Temperature Switches
- Condition Sensors
- Encoders Pressure Switches
- Vacuum Switches
- Float Switches

Output Devices which can be used in conjugation with a PLC are:

- Solenoids
- Actuators Horns

- Valves
- Motor Starters
- Alarms
- Stack lights
- Pumps
- Control Relays
- Counter
- Printers
- Fans

3.3.3 Communication and Networking of PLC

Communication and networking as already mentioned are added features to the modern PLCs. As a matter of fact PLC is the main device used, which helps in communication and interfacing with other devices as well as in control of field devices like motor drive, alarms, solenoid valves. The PLC output module runs and controls motor as per the specified ladder logic program (user-logic). Into the PLC the program is downloaded from personal computer through RS-232 serial communication preferably (or sometimes even through Ethernet for high speed communication). These features i.e., communication and networking add to flexibility of PLC making control of devices connected to PLC much easier and at the same time increase the possibility to control these devices remotely through SCADA and HMI. HMI (Human Machine Interface), through a touch pad screen, is being employed for manual control of field devices while SCADA terminal is used for remotely controlling these devices.

3.3.4 PLC Used- GE Fanuc Series 90-30

In the present work, GE Fanuc series 90-30 PLC is used. It has CPU, digital input, digital output, network module and power supply. The digital input module is used to read ON/OFF position of different contacts used in the automated system. The digital input modules operate at 24V DC with 16 points. There are two digital output modules with 32 point operated at 24V DC. This module is used to output the alarms based on the decision made by the control strategy which is written in Ladder Logic.

Fig. 3.3 series 90-30 PLC

The hardware components in a PLC are:

1. **Base-plates:** These are the foundation of a PLC system because most other components are mounting on them. Many systems require a lot more modules and can be mounted on a single base-plate, so there are Expansion and Remote base-plates also that connect together.

2. **Power Supply Modules:** Each base-plate must have its personal power supply. The power supply should always be mounted in a base-plate’s left-most slot. Each power supply module having 230V AC as input and 24 V DC.

3. **CPUs:** It uses the instructions in its application program and firmware to monitor the system and direct the PLC’s operation to make sure there is no basic fault. Some of the Series 90-30 CPUs are built into the base-plates. In some cases, CPU resides in a personal

Computer using Personal Computer Interface Card which interfaces to Series 90-30 Input, Option modules and Output. Processor speed is 133 MHZ and scan rate is 0.15ms per 1000 logic. This CPU limits discrete input and output points to 2048.

4. **Input and Output (I/O) Modules:** I/O modules enable the PLCs to interface with input and output field devices like sensors, switches, solenoids and relays. Modules are available in both discrete and analog types. In present system input to PLC coming from low level, high level, emergency level and IR sensor and output going to 12 V DC motor, solenoid valve, water pump for system operation.

5. **Option Modules:** The CPU module can take upto 8 no. of base plates. In which one is for CPU interfacing and 7 others are available for extensions of I/O module. They can extend the capability of the PLC beyond basic functions and also provide things as communications and temperature control, networking options, motion control etc.

6. **Cables:** Cables connect the PLC components to other systems or together.
They are mainly used to:

- Connect a programmer to an option module or to the CPU
- Interconnect base-plates
- Connect option modules to the field devices or other systems.

On-line diagnostics and monitoring of system performance

- Ethernet connectivity
- Window-based programming software
- Removable terminal strips on I/O modules
- Intel-based CPUs with math capabilities, including floating point math
- Wide variety of I/O modules
- Expandability to over 4,000 I/O points

It can be used for wide varieties of applications such as high speed packaging, Monitoring, food processing, elevator control, mining, injection molding and more.

3.4 PLC Operation

There are four basic steps involved in the operation of all PLCs; Input Scan, Program Scan, Housekeeping and Output Scan. All these steps take place in a repeating loop.

Steps In the PLC Operations:

- Input Scan: It detects the state of all the input devices that are connected to PLC
- Program scan: It executes user created program logic
- Housekeeping: In this step communications with the programming terminals, internal diagnostics, etc take place.
- Output scan: It energizes or de-energizes all the output devices that are connected to PLC.

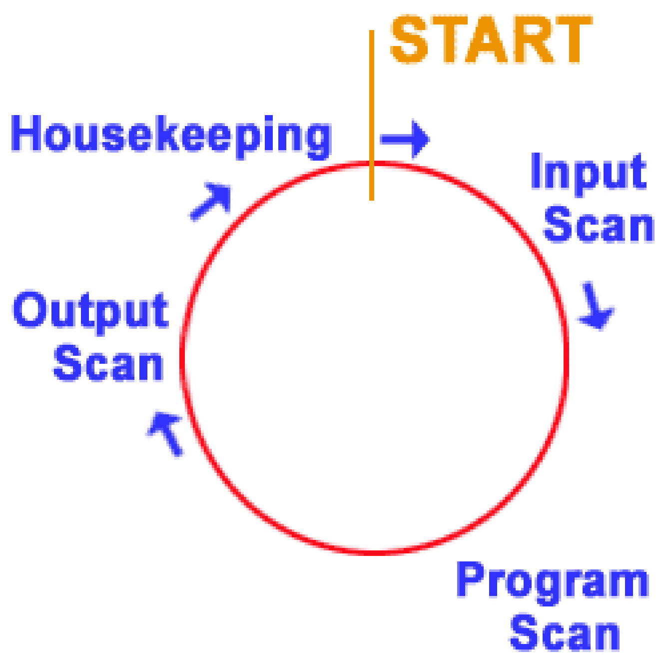


Fig. 3.4 operation of PLC

3.5 Characteristics

The PLCs have added advantage over other computers as they are robust and having unaffected from the severe conditions like dust, moisture, heat ,cold etc type of industrial environments and have the facility for extensive input/output (I/O) arrangements. The output of the PLC is connected to different sensors and actuators. PLCs can be used to drive different analog signals as well as can be used to drive the digital signals as well like operating a electric motors, pneumatic or hydraulic cylinders .PLCs read limit switches, analog process variables (such as temperature and pressure), and the positions of complex positioning systems. The input/output arrangements may be built into a simple PLC, or the PLC may have external I/O modules attached to a computer network that plugs into the PLC.

In earlier PLCs the output of the PLC or the decision making logic was quiet simple in nature which is similar to an electrical schematic diagrams. The electricians were quite able to trace out circuit problems with schematic diagrams using ladder logic. This program notation was chosen to reduce training demands for the existing technicians.

The uses of PLCs are enhancing day by day in automatic industrial environment. The uses of the PLC has evolved over the years which is now a days include sequential relay control, motion control, process control, distributed control systems and networking. The data handling, storage, processing power and communication capabilities of some modern PLCs are approximately equivalent to desktop computers. PLC-like programming combined with remote I/O hardware, allow a general-purpose desktop computer to overlap some PLCs in certain applications.

3.6 System Scale

Generally in a small PLC, only fixed number of inputs and outputs are available. But the expansions are available if the base model does not have enough I/O.

Modular PLCs are quite complex in nature, they consist of a chassis (also called a rack) in which modules are placed with different functions. The processor and selection of I/O modules is customized for the particular application. With this several racks can be administered by a single processor, and may have thousands of inputs and outputs. A special high speed serial I/O link is used so that racks can be distributed away from the processor, reducing the wiring costs for large plants.

PLCs used in industrial automation having larger I/O systems may have peer-to-peer (P2P) communication between processors. This will allow the complex part of the process to have individual control while allowing the subsystems to co-ordinate over the communication link. These communication links are also often used for HMI (Human-Machine Interface) devices such as keypads or PC-type workstations. Now a day's PLCs are quite robust and they can communicate over a wide range of media including RS-232, Coaxial, and even Ethernet for I/O control at network speeds up to 100 Mbps.

3.7 PLC Applications

- PLC is mainly used in the automation industry, because it will reduce the time for products to reach to the customer and reduces other costs as well.
- PLC application includes in Beverage Industry, Improving Production Flexibility and Agility
- It is used in Entertainment Industry, in Increasing the Safety, Reliability and Profitability of Your Venue
- It is also used in Marine Industry for Optimize Equipment Performance and Improve Reliability
- It increases the Accuracy in Packaging Industry and Deliver Greater Speed to Meet Urgent Demands for their customers.

3.8 PLC Programming Language

A Program is a user-developed chain of commands or instructions. Programming languages provide rules for combining these commands. Early PLCs, up to the mid of 1980s, were programmed using programming panels (special purpose programming terminals), which had dedicated function keys representing different logical elements of PLC program. All the programs were saved on cassette tape cartridges. Facilities for documentation and printing were very minimal due to deficiency of memory capacity. Recently, PLC programs are usually written in a special application on a PC, and then downloaded by a connection cable or over a network to PLC. The oldest PLCs had used non-volatile magnetic core memory and now the program is stored in battery-backed-up RAM or some other non-volatile flash memory that is present in PLC processor. Initially PLCs were programmed only in ladder logic, which resembles a schematic diagram of relay logic. The purpose of this was to directly replace electromechanical relays as logic elements, substituting as an alternative for solid-state digital computer with stored program, able to follow the interconnection of various relays to perform certain logical tasks. A PLC has so many "input" terminals, by which it interprets "low" and "high" logical states from switches and sensors. It has many output terminals also, through which it outputs "low" and "high" signals to contactors, small motors, solenoids, and other devices lending themselves to the on/off control. The programming language of PLCs was designed to be similar to ladder logic diagrams to make them easy to program. Modern PLC can be programmed in a number of ways, from ladder logic to some more traditional programming languages like BASIC and C. Another method for this is state logic, a high level programming language designed to program the modern PLCs based on the state transition diagrams. In recent times, the international standard IEC 61131-3 has defined 5 programming languages for the programmable control system which includes Structured text (ST), Ladder diagram (LD), Function block diagram (FBD), Sequential function chart (SFC), and Instruction list (IL, which is similar to assembly language). These techniques give emphasis to logical organization of operations.

Structured Text (ST)

A high level text language that encourages structured programming. It has a language structure (syntax) that strongly resembles PASCAL and supports a wide range of standard functions and operators. For example;

// AND logic
Motor: = switch-1 AND switch-2

Switch-1 and switch-2 both pressed to start the motor.

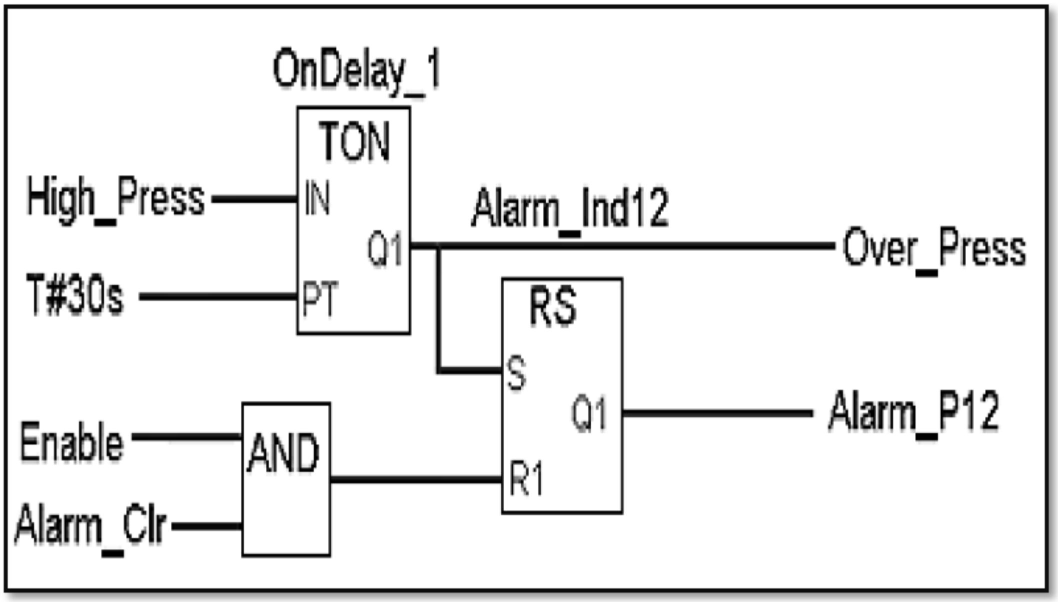
Instruction List (IL)

A low level "assembler like" language that is based on similar instructions list languages found in a wide range of today's PLCs.

Mnemonic	name	function
LD	load	Initial logical operation contact type normally open (NO)
ANB	AND block	Serial connection of multiple parallel circuit
ORB	OR block	Parallel connection of multiple parallel circuit
SET	set	Set bit device latch ON
RESET	reset	Reset bit device OFF

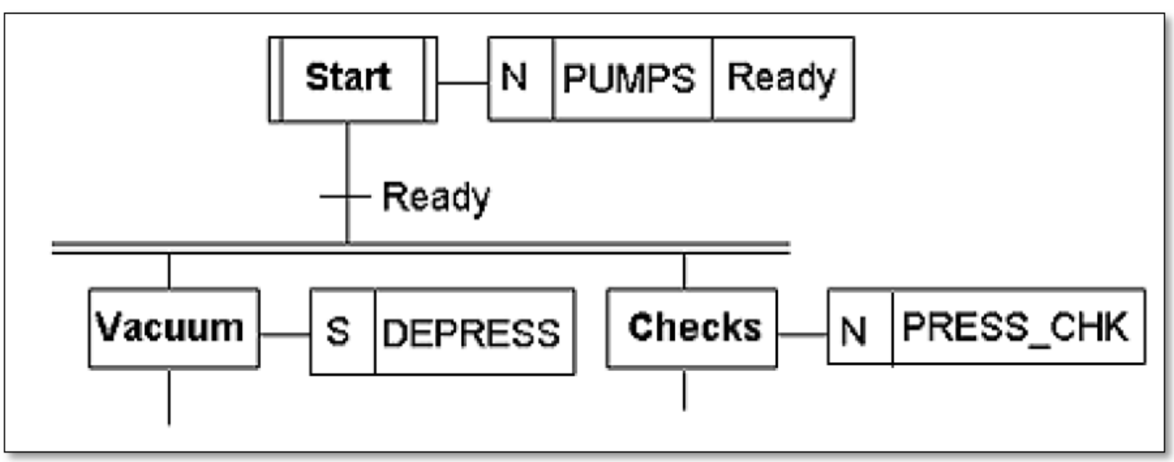
Function Block Diagram (FBD)

A graphical language for depicting signal and data flows through re-usable function blocks. FBD is very useful for expressing the interconnection of control system algorithms and logic.



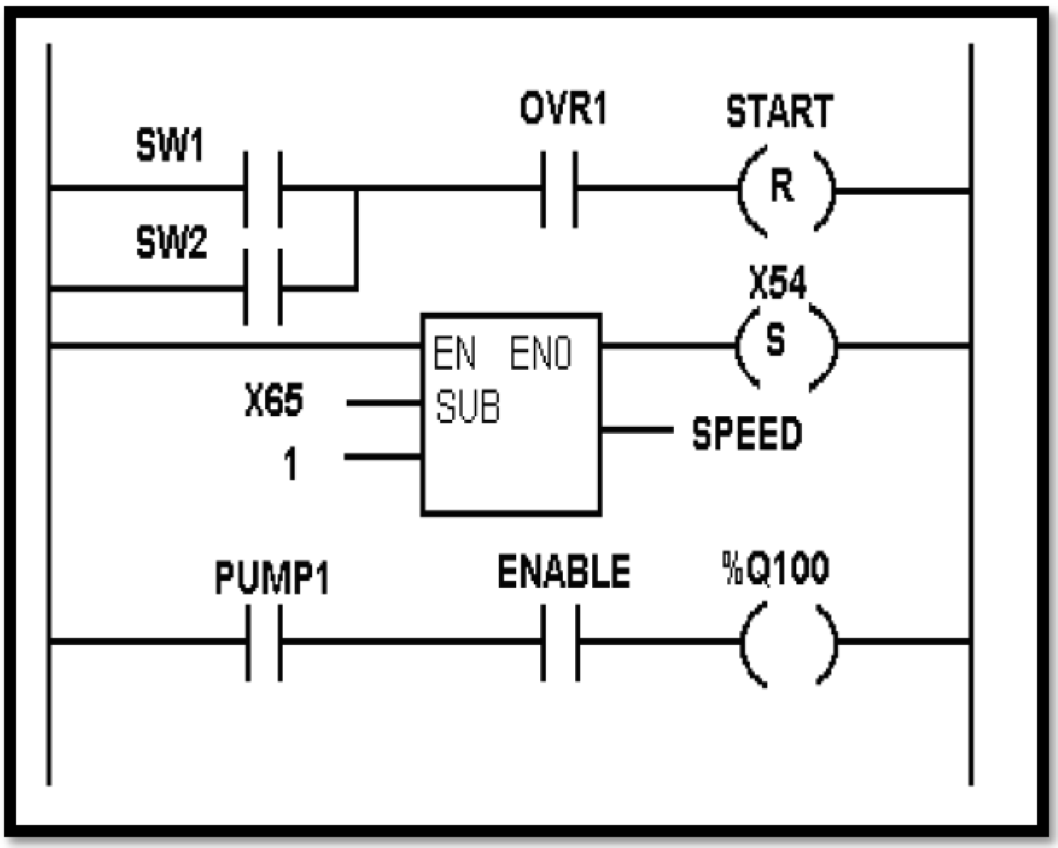
Sequential Function Chart (SFC)

A method of programming complex control systems at a more highly structured level. A SFC program is an overview of the control system, in which the basic building blocks are entire program files. Each program file is created using one of the other types of programming languages. The SFC approach coordinates large, complicated programming tasks into smaller, more manageable tasks.



Ladder Diagram (LD)

Traditional ladder logic is graphical programming language. Initially programmed with simple contacts that simulated the opening and closing of relays, Ladder Logic programming has been expanded to include such functions as counters, timers, shift registers, and math operations



3.9 Ladder Logic

Ladder logic is the programming language used in this project. A ladder logic program is represented by graphical diagrams which represent the interconnection of the virtual devices needed to control field devices and it is based on the circuit diagrams of the relay-based logic hardware, also known as ladder diagram. This name is based on the observation that programs in the language resemble ladders, with two vertical rails and a chain of horizontal rungs between them. The logic used in a ladder diagram normally flows from left to right. Each rung typically consists of an arrangement of input instructions. These input instructions lead to one single output instruction. Each input or output instruction has assigned an address representing the location in PLC memory where the state of that particular instruction is stored. Fig.3.5 shows a view of ladder logic program in which start button, relay coil and output Q1 are represented by normally open switches and emergency stop by a normally closed switch. As soon as the start switch is ON, relay is activated, which activates latched relay coil and an on-delay timer simultaneously. After 100 seconds, Q1 is ON which makes the motor to run. By switching ON emergency stop switch, motor can be stopped at any moment as required.

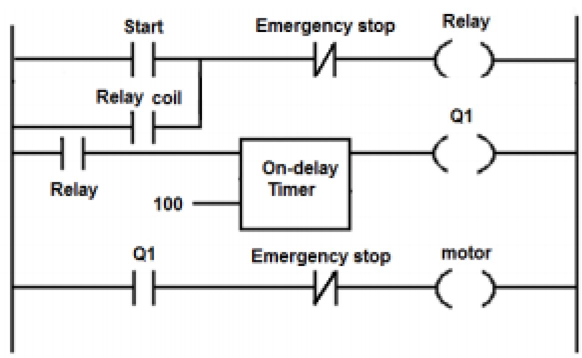


Fig. 3.5 PLC sample ladder logic program

3.9.1 Types of Instructions

Ladder logic programming allows PLC to complete different tasks, including timing, counting, Boolean logic, arithmetic and some special functions. Including these instructions, most PLCs support so many extended instructions to act upon some more complicated tasks.

a) Boolean logic: It is actually what PLCs and all relay based system perform. The real operations in Boolean logic include OR AND and NOT operations. The AND operation means that all inputs must be ON for the output to be ON; which is similar to relay contacts being connected in a series. The OR operation simply means that the output is ON if at least one of all the inputs is ON; which is similar to relay contacts being connected in parallels. The NOT operation simply means that the output will be OFF if and only if the input is ON and vice-versa; which is similar to normally closed relay contact. PLC performs Boolean logic using the basic relay instructions. Common input instructions are used which include normally open contact and the normally closed contact.

b) Timing instructions: The fundamental timing instructions include OFF-delay and ON-delay instructions. With ON-delay timers, output related to the timing instruction is turned ON after some specified time after the input is ON, but it turns OFF instantly when input is turned OFF. In OFF-delay timers, output is turned ON instantly when the input is turned ON. However, it remains ON for some specified period of time after the input has been already turned OFF, and then it turns OFF. Timing instructions are typically connected like relay coil instructions in a ladder diagram, so any set of input conditions can be further programmed to trigger them. When a timing instruction is produced in a PLC program, memory space is set aside for timer running value and preset value that is the value at which the timer will be tripping.

c) Counting instruction: The fundamental counting instructions provide for up-counter and down-counter functions. The up-counter instruction increases the value of a counter by one each time an upward transition (OFF to ON) is detected in the input. Down-counter instructions do the opposite i.e., lessening the count value by one on each upward transition of input. When value of the count exceeds or reaches a preset number, output is then turned ON. The reset instructions reset the value of count to 0 or to a predestined reset value. Like in case of timing instructions, the counting instructions are also usually connected as relay coil instructions in a ladder diagram.

d) Arithmetic instructions: Nearly all PLCs have simple ladder diagram instructions to multiply, divide, add and subtract two numbers. Ladder rung for an instruction used to perform arithmetic operation usually has three parts. First is the input conditions that should be true in order to computation to take place. Second is the locations of two numbers to be operated upon; these locations are similar to examine instructions, which tell the program that where to find numbers in the memory. The third and last part is the output location; that usually entered as address assigned to actual arithmetic instruction (add, subtract, multiply or divide), which is similar to a relay coil instruction. A group of arithmetic instructions is compare instructions, which determines if a number is less than, equal to or greater than the other number. They are programmed like the same way arithmetic operations are. The Proficy Machine Edition 5.9 Software provides a wide variety of options and instructions including the above mentioned instructions. This software provides significant flexibility and versatility in terms of instruction options available.

3.9.2 Ethernet Communication in PLC

Ethernet is a family unit of frame-based computer network technologies for the local area networks (LANs). This name came from physical concept of ether. It defines some of signaling and wiring standards for the physical layer (PL) of Open System Interconnection (OSI) networking model, through means of network access at the Media Access Control (MAC)/Data Link Layer with common addressing format. Ethernet is standardized as per standard IEEE 802.3. Nowadays the combination of the twisted pair versions of Ethernet for the connection of end systems to the network with the fiber optic version for site backbones is the most common wired LAN technology among all. Most of the manufacturers who offer Ethernet compatibility to apply supervisory functions over apparatus controlling plant floor functions use transmission control protocol/ internet protocol (TCP/IP) for layer 3 and 4 of the OSI model. The TCP/IP was originally developed for Arpanet, a computer network formed in the 1970s in the United States. The U.S. Department of Defense established this protocol to correspond information in a trustworthy manner from one computer to the other over the Arpanet network. Nowadays, the TCP/IP protocol is used in Internet data networks.

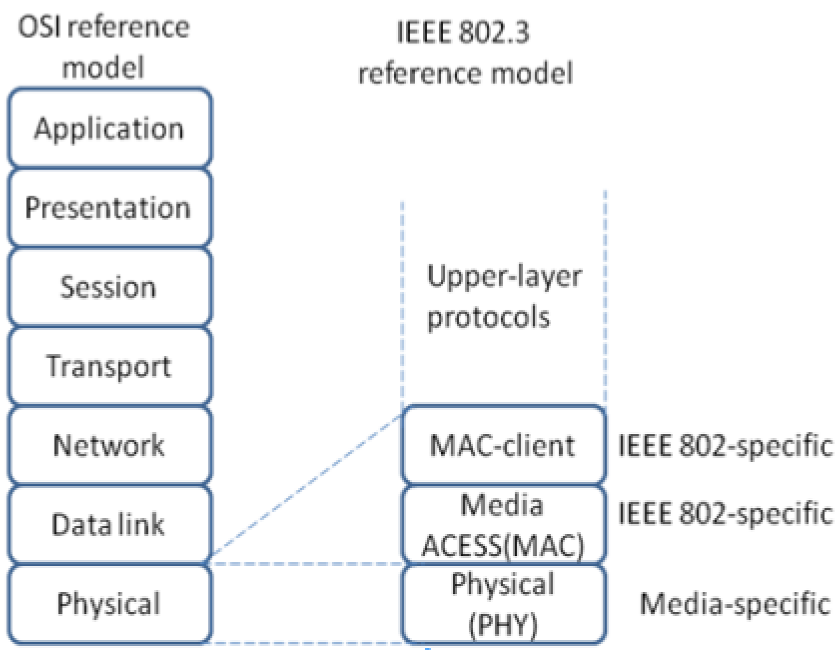


Fig. 3.6 Ethernet and OSI Model

Ethernet supports the data link and physical layers, with TCP/IP as its protocol. To support the data link layer, Ethernet uses Carrier Sense Multiple Access (CSMA)/Collision Detection (CD). The CSMA/CD checks media for the other devices before transmitting, for managing and reducing the number of data collisions. The Ethernet uses (TCP)/(IP) to provide for the layers of OSI model. The seven layers of the OSI can loosely be fitted by the 4 layers of the TCP/IP. The Internet layer of TCP/IP model corresponded by the Network layer. The IP helps this layer for moving the data to various devices in the network. Host-to-Host layer from TCP/IP model corresponded by the Transport layer. Majority of the devices on a TCP/IP network are considered to be hosts and this layer communicates data host-to-host (or peer-to-peer). The Presentation, Application and Session layers of the OSI model correspond to the Application/Process layer of TCP/IP model and all these layers provide user with network services.

In this project, PLC programs are written in Proficy Machine Edition 5.9, GE Fanuc and are communicated to PLC through RS-232 serial communication (or through Ethernet).

Ethernet is networking interconnect system which allows multiple communication paths to exit simultaneously. It provides comparatively high speed communication. RS232 normally used as direct electrical connection from computer to the computer numerical control (CNC). This has some major problems like limited cable length, ground loop noise sensitivity and can easily get damaged from electrical fault. The working cable length is inversely proportional to the cable length. Today RS-232 is mainly found in the applications where cost is more important than the performance. It has almost disappeared from the industrial and some other specialized applications.

In the present system the different operation of level controlling and automatic bottle filling are controlled by PLC. The ON/OFF control of motors used for filling the tank and the motor used for rotating the mixer and conveyor belt are controlled by PLC. The opening and closing of solenoid valve for filling the bottle is also controlled by PLC.

3.10 Conclusion

This chapter gives complete description of PLC and Ladder Logic. Architecture characteristics and operation of PLC is extensively described. GE Fanuc PLC 90-30 series used in the design of present system is explained in detail.

CHAPTER 4

SYSTEM COMPONENTS

4.1 General

Proposed device consists of a PLC (GE FANUC SERIES 90-30), 220V AC Relay, IR Module sensor, Solenoid valve, conveyer belt, 12 V DC motors, water pumps, NPN transistor. IR sensor, transistor are used as input devices and solenoid valve, 12 V DC motor water pumps are used as output devices in the present system.

A Solenoid device is usually an electromagnetically handled device. The device is actually controlled by simply an electric current present through a magnetic solenoid. In this case the valve operation is just on and off. In case of the three-port device, output can be switched between any two outlet ports.

The basic concept of an IR module is simple. There is an emitter that produces infrared (IR) light. These IR light are detected by way of a detector. This concept is employed to produce proximity sensor (to verify when anything prevents the path or not etc), contrast sensors are generally used to find contrast change involving different colors, etc.

Conveyor belt normally involves two or more pulleys, one end is connected to the shaft of the DC motor, while at the other end other pulley is connected by the conveyor belt. One or each of the pulleys are powered, moving the belt and the stuff on the belt ahead. The particular powered pulley is known as drive pulley while the unpowered pulley is known as idler.

4.2 Hardware Components

Hardware components of the project consist of a PLC (GE FANUC SERIES 90-30), IR sensor, solenoid valve, a 12v DC motor, 230v AC relay, a water pump.

4.2.1 Solenoid Operated Valve

A Solenoid device is usually an electromagnetically handled device. The device is actually controlled by simply an electric current present through a magnetic solenoid. In the two-port solenoid valve, the valve operation is just like a switch, it means just ON and OFF while in the case of three-port device, output can be switched between any two outlet ports.

Solenoid operated valves are used in most of the automated industries now a days due to the fact that their operation is reliable and safe. Now most of the bigger automated industries are using it through barrier. There operation is limited to basically ON/OFF control of the fluid valves or to select one of output from the many of the outputs available. Solenoids operated valves are generally low powered i.e., 24V dc or 230V ac, as per requirements but their switching action is fast and reliable and cheap as well.

4.2.1.1 Principle of Operation

General valves contain only two ports inlet and outlet ports depending on the state of the solenoid. The fluid flows from inlet to outlet port. If the valve is normally open (NO) the fluid flow is continuous as long as the solenoid is not energized. And if the solenoid is energized the valve will be closed and there is no flow. Similarly there is normally closed solenoid as well, in which if the solenoid is energized the valve will be open and the flow regularizes otherwise there is no flow from the input to output port.

4.2.1.2 Different Parts of a Solenoid Operated Valve

A commonly used solenoid valve is shown below:

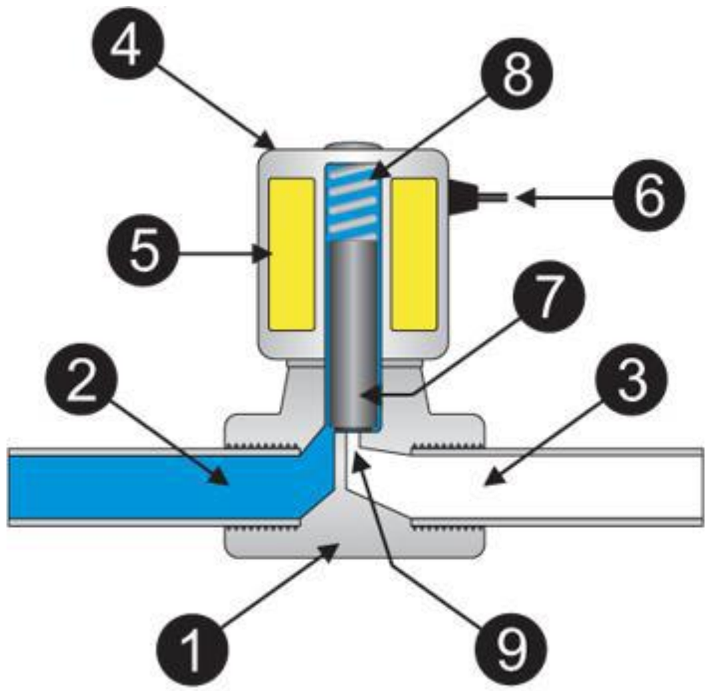


Fig. 4.1 Solenoid valve

1. Valve Body
2. Inlet Port
3. Outlet Port
4. Coil / Solenoid
5. Coil Windings
6. Lead Wires
7. Plunger
8. Spring
9. Orifice

Fig 4.1 shown above is normally closed solenoid valve, in which it will be in closed position when it is not energized. This is normally used in the industry because of its safe and reliable operation. It is direct acting (normally NC) mode. The other type of solenoid valve is normally open.

4.2.1.3 Working of a Solenoid Valve

Fig 4.1 shows a normally closed (NC) solenoid valve. The medium (air, liquid) is controlled by the solenoid valve entering through the inlet port (2). The medium (air, liquid) will be flowing through the orifice (9) before going through outlet port (3). The orifice is generally in closed position and opened through the operation of the plunger (7). Normally-closed valves have a spring (8) which raises the pressure to the plunger tip against the opening of the orifice. The material which is used for sealing at the tip of the plunger keeps medium away from entering through the orifice. Once the solenoid is energized and electromagnetic field is made, the plunger will be lifted up and the medium (air, liquid) will pass through the output port.

4.2.2 Infra Red (IR) Sensor Module

Fig 4.2 IR sensor

Fig. 4.2 shows a general Infra Red (IR) sensor that is readily available in the market. The working of this infra red sensor very simple, there is an emitter that emits the infrared rays. These rays are detected by the IR detector. This phenomenon of sensing is generally used in proximity sensor (capacitive, inductive and optical) or a contrast sensor (which identifies the contrast color i.e. black and white and are generally used in line following robot). So this concept is widely used in the industry for different applications.

4.2.2.1 Working Mechanism

An IR sensor is basically a device which consists of a pair of an IR LED and a photodiode which are collectively called a photo-coupler or an opto-coupler. The IR LED emits IR radiation, reception and/or intensity of reception of which by the photodiode dictates the output of the sensor. Now, there are so many ways by which the radiation may or may not be able to reach the photodiode. Let's discuss a few.

- **Direct Incidence**

Hold the IR LED directly in front of the photodiode, such that almost all the radiation emitted, reaches the photodiode. This creates an invisible line of IR radiation between the IR LED and the photodiode. Now, if an opaque object is placed obstructing this line, the radiation will not reach the photodiode and will get either reflected or absorbed by the obstructing object. This mechanism is used in object counters and burglar alarms.

- **Indirect Incidence**

High school physics taught us that black color absorbs all radiation, and the color white reflects all radiation. This very knowledge is used to build IR sensor. If this IR LED and the photodiode are placed side by side, close together, the radiation from the IR LED will get emitted straight in the direction to which the IR LED is pointing towards, and so is the photodiode, and hence there will be no incidence of the radiation on the photodiode but in the case of opaque object, there will be two cases:

- **Reflective Surface**

If the object is reflective, (White or some other light color), then most of the radiation will get reflected by it, and will get incident on the photodiode. Operation of the IR sensor is also shown in fig 4.3.

- **Non-reflective Surface**

If the object is non-reflective, (Black or some other dark color), then most of the radiation will get absorbed by it, and will not become incident on the photo diode. It is similar to the condition that there is no surface (object) at all, for the sensor, as in both the cases, it does not receive any radiation.

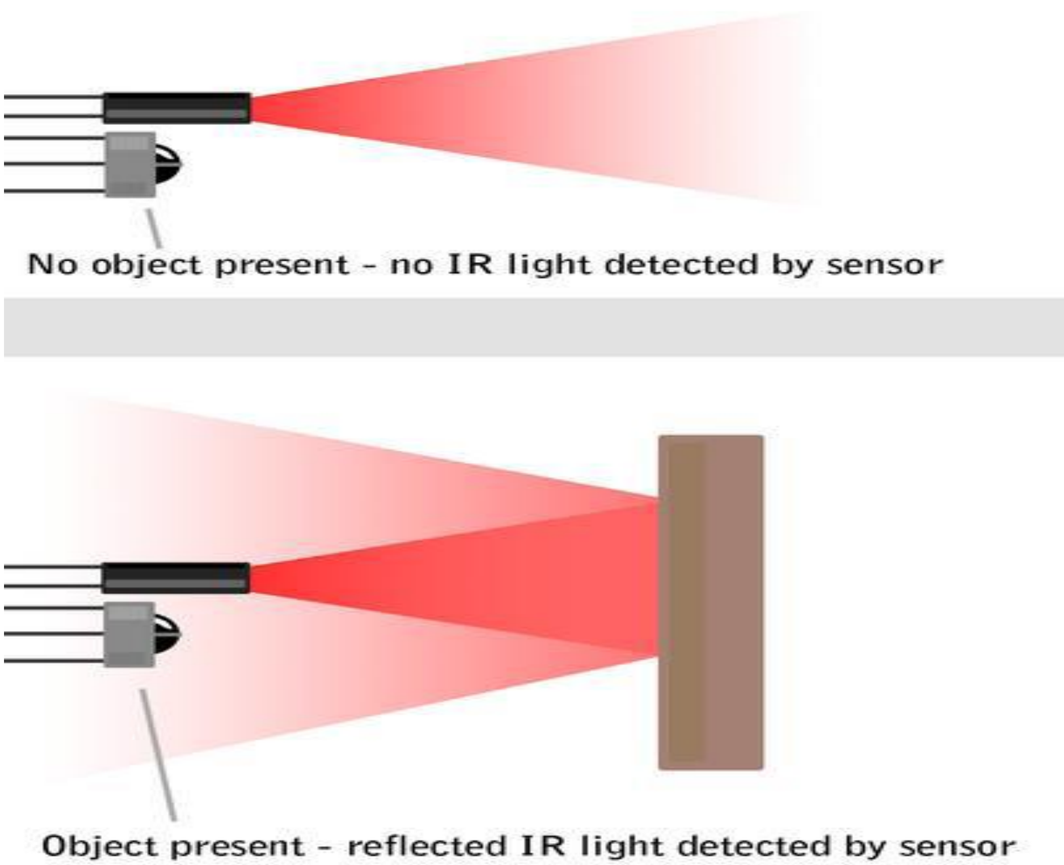


Fig. 4.3 Operation of IR sensor

4.2.2.2 Use as a Proximity Sensor

Proximity sensors are widely used in the automation industry. In the IR type of sensor the IR emitter will emits the IR rays and the detector will detect the proximity to the IR rays. According to distance from the detector the radiation will be converted into voltage .the higher the intensity of rays the higher will be the voltage obtained. Intensity will be calibrated with the distance. Proximity sensors are now readily available in the market. The different types of proximity sensors are of inductive, capacitive and optical.

Proximity sensors are widely used in mobiles phones. All smart phones have inductive or capacitive proximity sensors. The capacitive sensors are having greater sensitivity than the inductive sensor. These sensors are used in automatic doors operation, escalators operation and there are thousands of operations in the industry today.

4.2.3 Programmable Logic Controller (PLC)

A PLC is a device or the logic controller that continuously monitors the state of input and output devices in the real time mode and makes the decision as per the programmed logic to change the status of the output.

PLC is using a sequential mode of operation which is programmed in the software for operating different types of PLC. In automation industry all sequentially operating system it may be bottle filling system, a robot machine operation, a CNC machine all can operate through a PLC control system. The biggest benefit in the PLC is that sequence of operation can be changed by the operator as and when require.

The PLC generally find in market as fixed system and modular system. In which a operator can use the inputs and outputs of the devices to any way they want to use. This facility was not available in the other systems without changing any hardware.

4.2.4 DC Motor (12V)

In this project, 12V DC motor is used for shaft movement, the shaft is connected to a conveyor belt. The operation of the motor is controlled by the PLC program, which is written in ladder logic. The DC motor used is a shunt motor with 150 rpm. These types of DC motors find wide applications in conveyor belt operation due to their constant speed operation.

4.2.5 Water Pump

In this project, two water pumps are used for transferring the liquids from two reservoir tanks to the overhead tank. This motor is works with 230VAC, 50Hz. The maximum flow rate that can be achieved is 1000 liter/hour.

4.3 Software Components

PLC gives an easy access to various virtual devices like ON-Delay timer, UP-Counter, OFF-delay timer, DOWN-Counter; normally open Switch, Relay coil, etc. The program developed is validated before downloading it to PLC controller. The software provides a fully-integrated environment in which every tool and editor works efficiently with each other. Proficy Machine Edition in short offers a complete solution for the development of automation applications under one roof.

There are five main programming languages for programmable control systems namely function block diagram (FBD), sequential function chart (SFC), instruction list (IL; similar to assembly language), ladder diagram (LD) instruction list (IL; similar to assembly language) and structured text (ST; similar to the Pascal programming language). These techniques emphasize logical organization of operations. In the present work Ladder Diagram (LD) is designed using PROFICY MACHINE EDITION 5.9. The program is so designed as to ensure an interface between the PLC and all the hard-ware parts associated with the bottle filling plant.

4.3.1 Ladder Logic

A Relay Ladder Logic (RLL) diagram, also referred to as a Ladder diagram is a visual and logical method of displaying the control logic which, based on the inputs determine the outputs of the program. Ladder logic was originally invented to describe logic made from relays. The ladder is made up of a series of “rungs” of logical expressions expressed graphically as series and parallel circuits of relay logic elements such as contacts, timers etc. Each rung consist of a set of inputs on the left end of the rung and a single output at the right end of each rung.

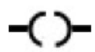
An argument that aided the initial adoption of ladder logic was that a wide variety of engineers and technicians would be able to understand and use it without much additional training, because of the resemblance to familiar hardware systems. This argument has become less relevant given that most ladder logic programmers have a software background in more conventional programming languages, and in practice implementations of ladder logic have characteristics, such as sequential execution and support for control flow features, that make the analogy to hardware somewhat inaccurate.

Ladder logic is widely used to program PLCs, where sequential control of a process or manufacturing operation is required. Ladder logic is useful for simple but critical control systems or for reworking old hardwired relay circuits. As programmable logic controllers became more sophisticated it has also been used in very complex automation systems. Often the ladder logic program is used in conjunction with an HMI program operating on a computer workstation. Each rung consist of a set of inputs on the left end of the rung and a single output at the right end of each rung.

There are many logic symbols available in Ladder Logic - including timers, counters, math, and data moves such that any logical condition or control loop can be represented in ladder logic. With just a handful of basic symbols such as a normally open contact, normally closed contact, normally open coil, normally closed coil, timer and counter most logical conditions can be represented.

Normally Open Contact: 

This can be used to represent any input to the control logic such as a switch or sensor, a contact from an output, or an internal output. When solved the referenced input is examined for a true (logical 1) condition. If it is true, the contact will close and allow logic to flow from left to right. If the status is FALSE (logical 0), the contact is open and logic will NOT flow from left to right.

Normally Open Coil: 

This can be used to represent any discrete output from the control logic. When "solved" if the logic to the left of the coil is TRUE, the referenced output is TRUE (logical 1).

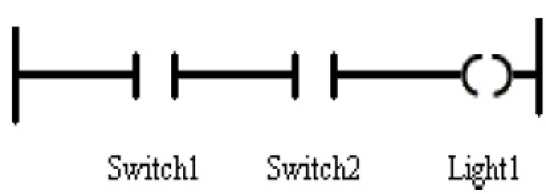
Normally Closed Contact: 

When solved the referenced input is examined for an OFF condition. If the status is OFF (logical 0) power (logic) will flow from left to right. If the status is ON, power will not flow.

Normally Closed Coil: 

When "solved" if the coil is a logical 0, power will be turned on to the device. If the device is logical 1, power will be OFF.

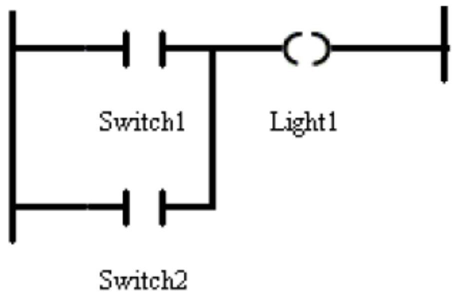
Basic AND & OR Gates: The AND is a basic fundamental logic condition that is easy to directly represent in Ladder Logic. Figure below shows a simplified AND “gate” on a ladder rung.



Simplified AND logic

In order for Light1 to turn TRUE, Switch1 must be TRUE, AND Switch2 must be TRUE. If Switch1 is FALSE, logic (not power) flows from the left rail, but stops at Switch1. Light1 will be TRUE regardless of the state of Switch2. If Switch1 is TRUE, logic makes it to Switch2. If Switch2 is TRUE, power cannot flow any further to the right, and Light1 is FALSE. If Switch1 is TRUE, AND Switch2 is TRUE - logic flows to Light1 solving its state to TRUE.

The OR is a logical condition that is easy to represent in Ladder Logic. Figure below shows a simple OR gate. Notice the differences in logic between the OR and AND gates.



Simplified OR gate

If Switch1 is TRUE, logic flows to Light1 turning it to TRUE. If Switch2 is TRUE, logic flows through the Switch2 contact, and up the rail to Light1 turning it to TRUE. If Switch1 AND Switch 2 are TRUE Light1 is TRUE. The only way Light1 is FALSE is if Switch1 AND Switch2 are FALSE. In other words, Light1 is TRUE if Switch1 OR Switch2 is TRUE.

4.4 Conclusion

The specification and operation of different hardware components used in the system is described in details. Ladder logic which is the software component used for programming the PLC is also described.

CHAPTER 5

DESIGN AND IMPLEMENTATION

5.1 General

This chapter describes the design and implementation of automated bottle filling system which includes the operation of level controlling, mixing and bottle filling. The organization of different components is explained. The complete settings for programming of the PLC are also explained in detail.

5.2 System Architecture

Figure 5.1 shows the system architecture of the automated bottle filling system. This System consists of two reservoir tanks, reservoir Tank A (6) and reservoir Tank B (15) which contain different liquids which are to be transferred and mixed in the overhead tank. Reservoir Tank A is connected to a motor water pump (7) and reservoir Tank B is connected to motor water pump (16) for transferring the liquids to the overhead tank (10). The overhead tank contains sensors to sense the water level i.e. low level (3), high level (2) and the emergency level(1) which is connected to an emergency alarm. The overhead tank contains a mixing fan (9) for mixing the liquids, which is connected to a DC motor (8) (12VDC). There is a IR sensor (13) which senses the empty bottle (4) which is kept in conveyor belt which is connected to the shaft of a DC motor (5) [12V DC ,150 RPM] and at the other end another pulley (14) is connected to the conveyor belt for rotation. Once the IR sensor senses the bottle it sends signal to the PLC (input) and it opens the outlet of solenoid valve (11) and PLC intern makes the motor OFF (5)(output) in order to stop the conveyor belt. It fills the bottle for 30 seconds and after the time finishes the solenoid valve closes until the next bottle arrive. The PLC output will change according to the level (input to the PLC) in the overhead tank. The output of the PLC is connected to two motors associated with the reservoir A and B respectively. It also operates the ON/OFF control of the third motor, which is used for the operation of conveyor belt. PLC will also give an emergency alarm output when the level in the overhead tank exceeds the high level. This will only happen when the high level sensor becomes faulty.

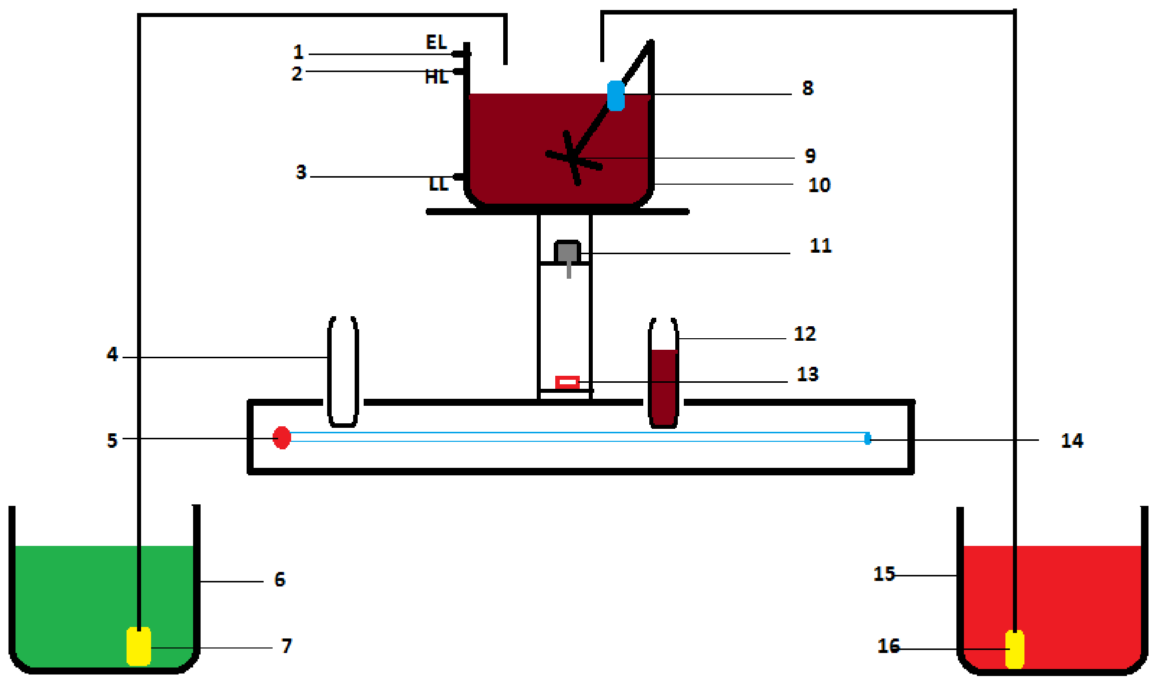


Fig. 5.1 System Architecture

1. Emergency level
2. High level
3. Low level
4. Empty bottle
5. 12 V DC Motor (M4)
6. Reservoir tank A
7. Water pump of tank A (M1)
8. DC motor for mixer (M3)
9. Mixing fan
10. Overhead tank

11. Solenoid valve
12. Filled bottle
13. IR sensor
14. Pulley
15. Reservoir tank B
16. Water pump of tank B (M2)

Picture of the actual system shown in figure 5.2, 5.3 and figure 5.4 respectively.

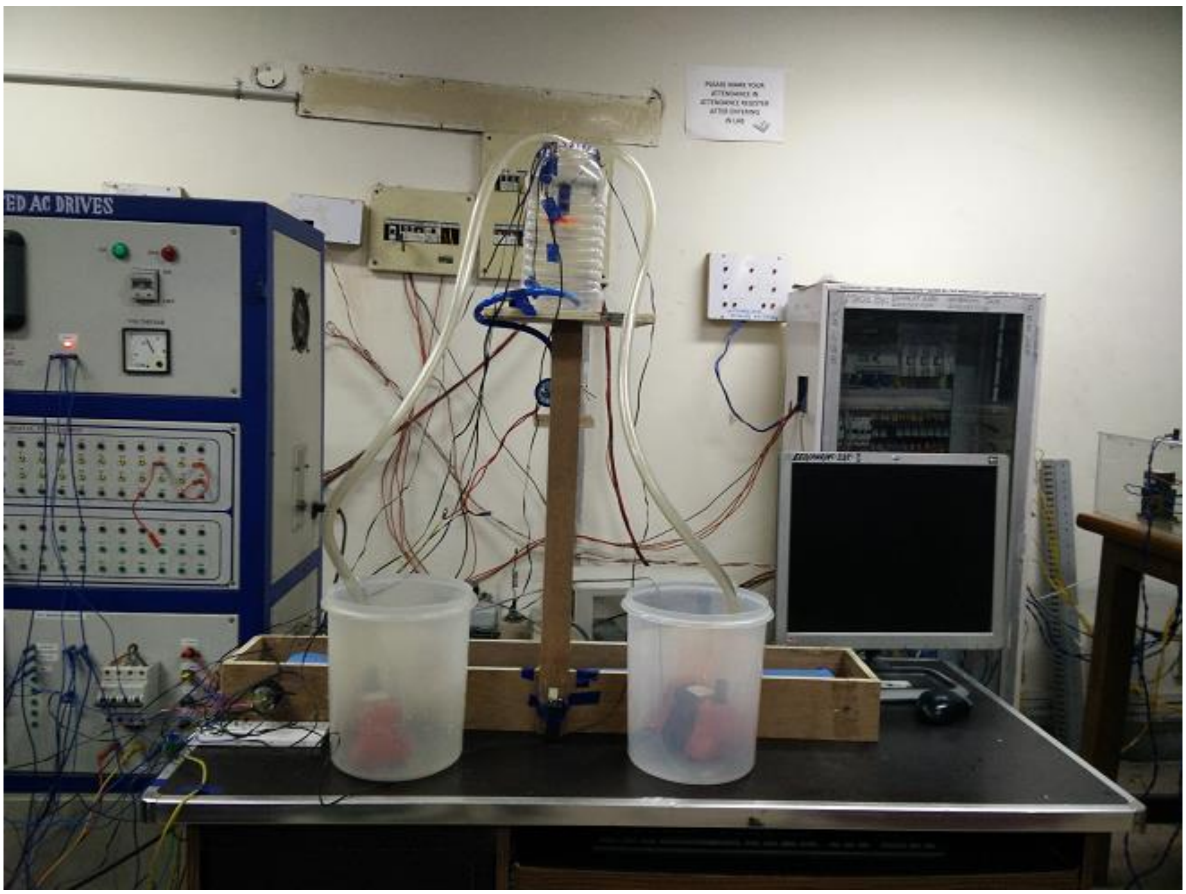


Fig. 5.2 Front view of Hardware Architecture

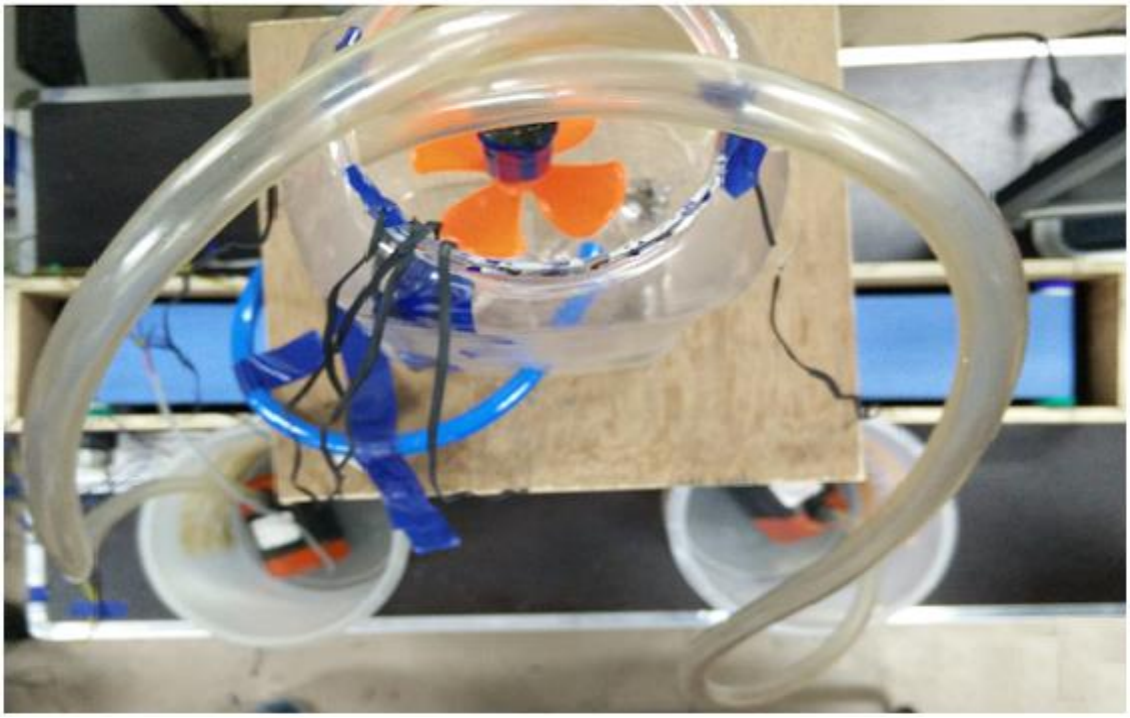


Fig.5.3 Top-view of Hardware Architecture

Fig.5.4 Side view of Hardware Architecture

5.3 Implementation

For the implementation of the automated filling system, PLC programming, its interface with different input and output devices are important. The GE-Fanuc PLC used in the present work, supports all features required for the development of automated filling system. The important features supported by Proficy Machine Edition software of PLC is described below.

The detailed procedure for the development of Ladder Logic along with hardware configuration setup is also explained in detail.

5.3.1 Products and Features Supported by Proficy

a) Proficy View

An HMI specifically designed for the full range of machine-level operator interface/ HMI applications. Proficy view can be used to create graphical panels, write scripts, configure alarm and logging schemes, and eventually launch the project in View Runtime.

b) Proficy Logic Developer-PLC

PLC programming language which configures all GE Intelligent platform, programmable automation controller (PAC) system controllers and remote I/O.

c) Proficy Motion Developer

It is a machine that allows us to develop the programming related to motion control for GE intelligent platforms S2K series motion controllers quickly and efficiently.

d) Proficy Logic Developer-PC

PC Control software combines ease of use and functionality for fast application development. Includes support for the following Runtime options: • Quick Panel Control (Windows CE-based) • Windows 2000/XP/NT

All user-defined logic programs are contained in the Logic folder. Which include the following:

- Sequential Function Chart (SFC) editor
- Ladder Program

- Instruction List Blocks
- Structured Text Blocks
- Function Block Diagram

The following run-time elements are also included with the Logic Developer-

- Logic Developer - PC Web Access
- Control I/O Drivers
- PC Logic Controller

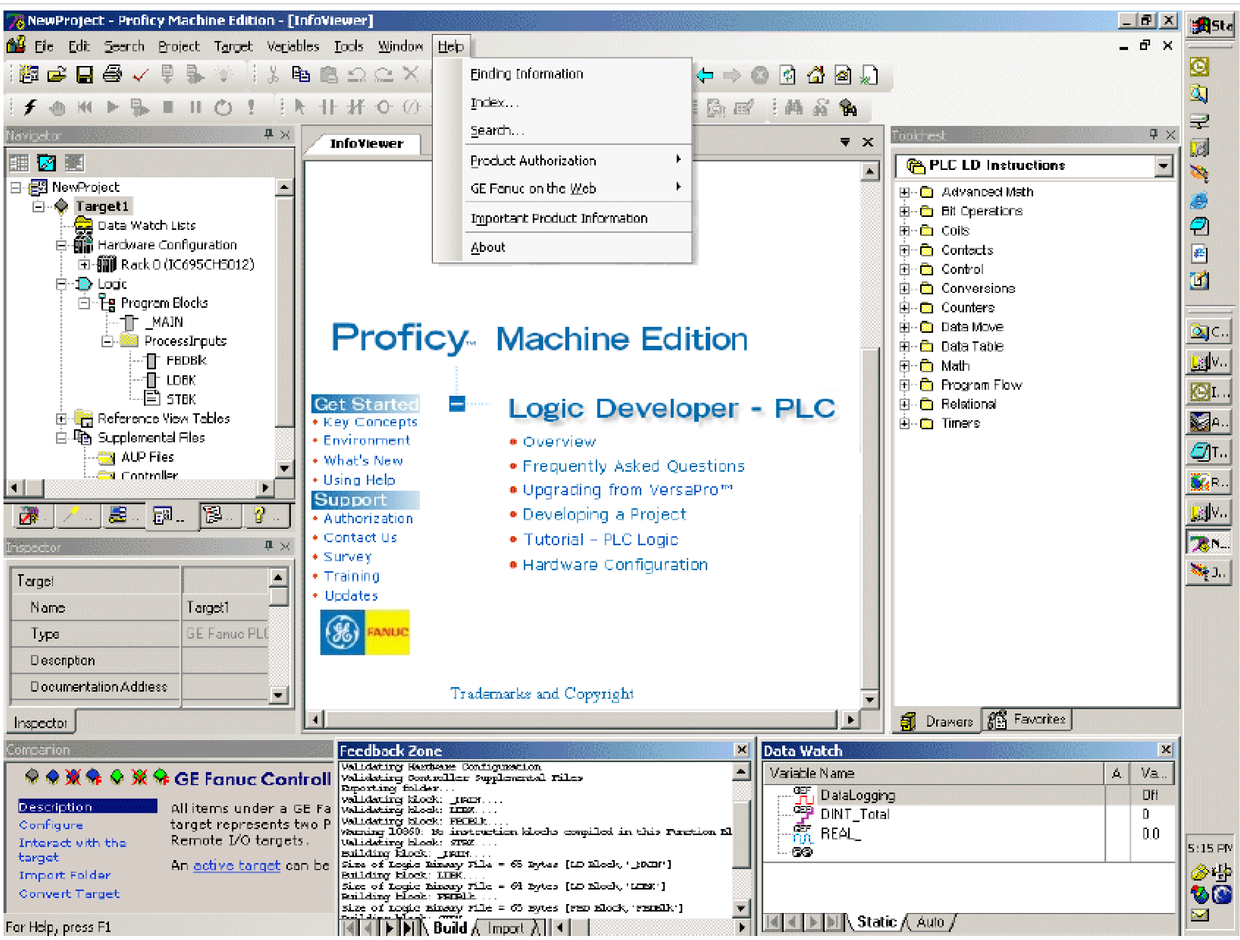


Fig. 5.5 Proficy Machine Edition 5.9 Screenshot

5.3.2 Creating a New Program in Proficy Machine Edition

Proficy Machine Edition 5.9 was used to develop and validate Ladder Logic programs before downloading them to PLC controller. The detailed procedure for development of PLC program is described below:

a) To create a new project, right click on ―My Computer in the left side of window and select option ―New.

b) Give an appropriate name to the project say ― PROFICY on the dialog box that appears in front and select project template as GE Fanuc Series 90-30 type PLC, which is shows in fig. 5.6. Click OK to proceed further. The software by itself configures settings for series 90-30 type PLC and apparently other screen overlays itself on the previous window screen.

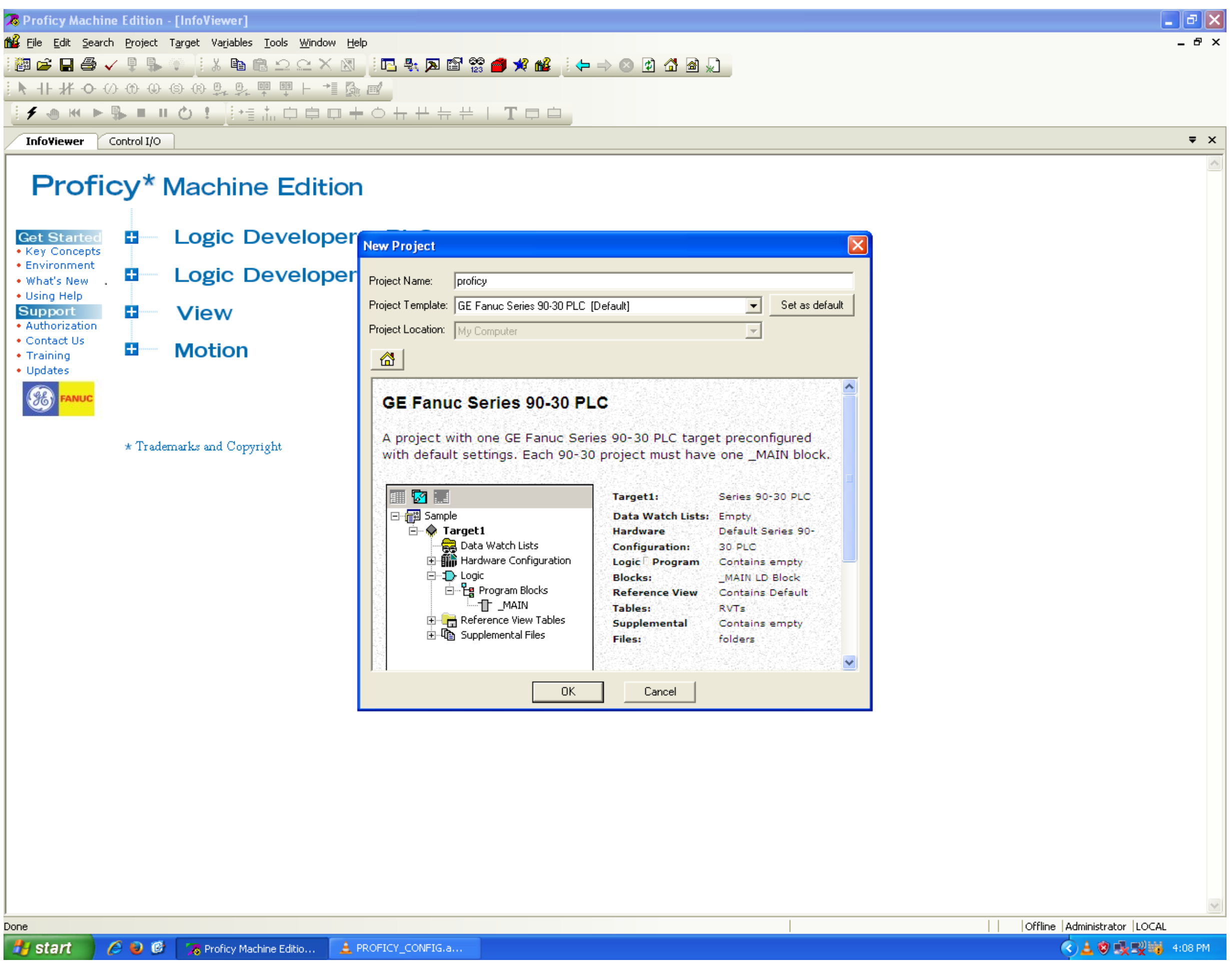


Fig. 5.6 Creating a new project

c) In the ―NEW PROJECT window, right click on the PROFICY. Select -Add target‖ and then in the GE Fanuc Controller option, select ―Series 90-30 PLC. Next change the hardware configuration to the one installed in the setup. For the present setup add Power supply module (IC693PWR330), CPU type (IC693CPU374) shows in fig. 5.7, Digital Input module (IC693MDL645) shows in fig. 5.8, Digital Output module (IC693MDL740) and Bus controller module (IC693PBM200). Since the experimental setup involves two output modules, therefore, select two slots for output while adding hardware configuration to the project.

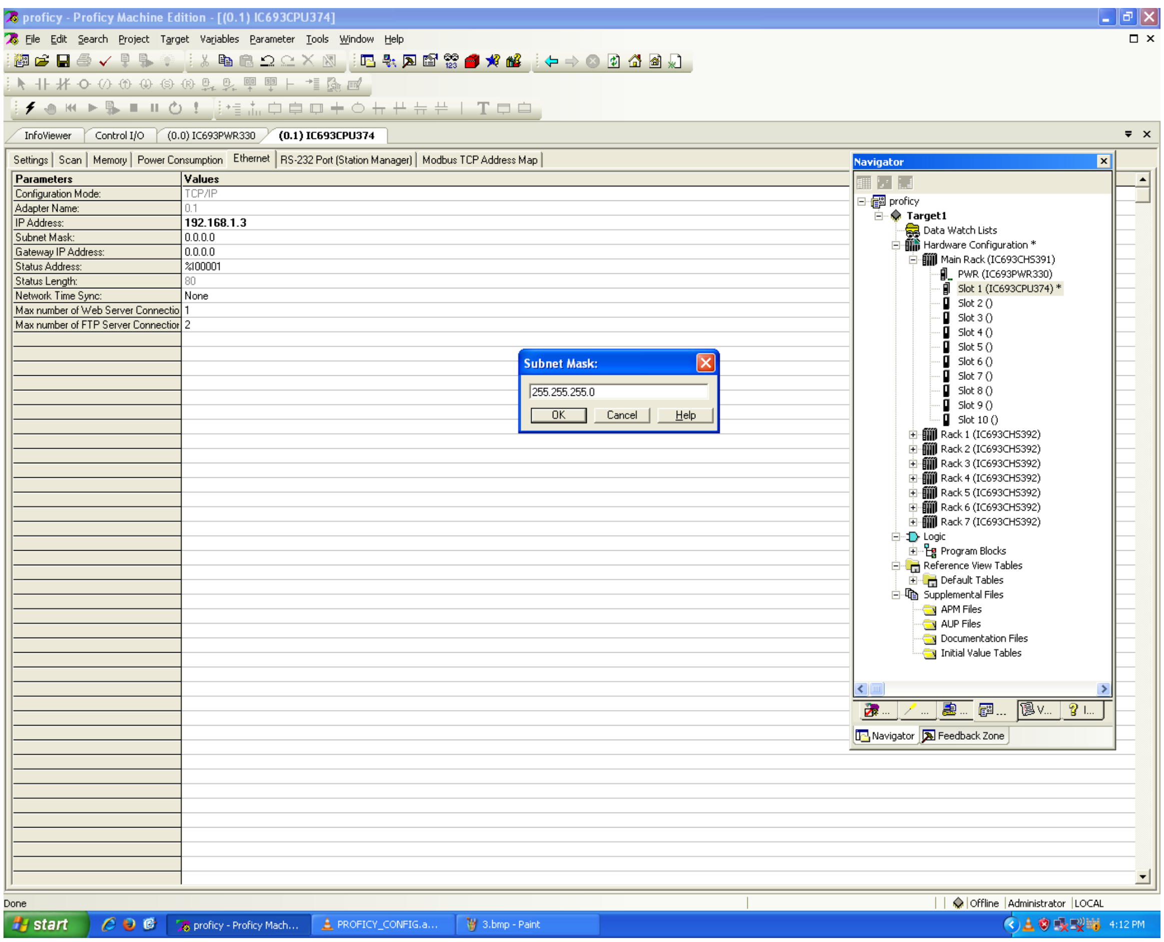


Fig. 5.7 Setting of IP address and subnet mask

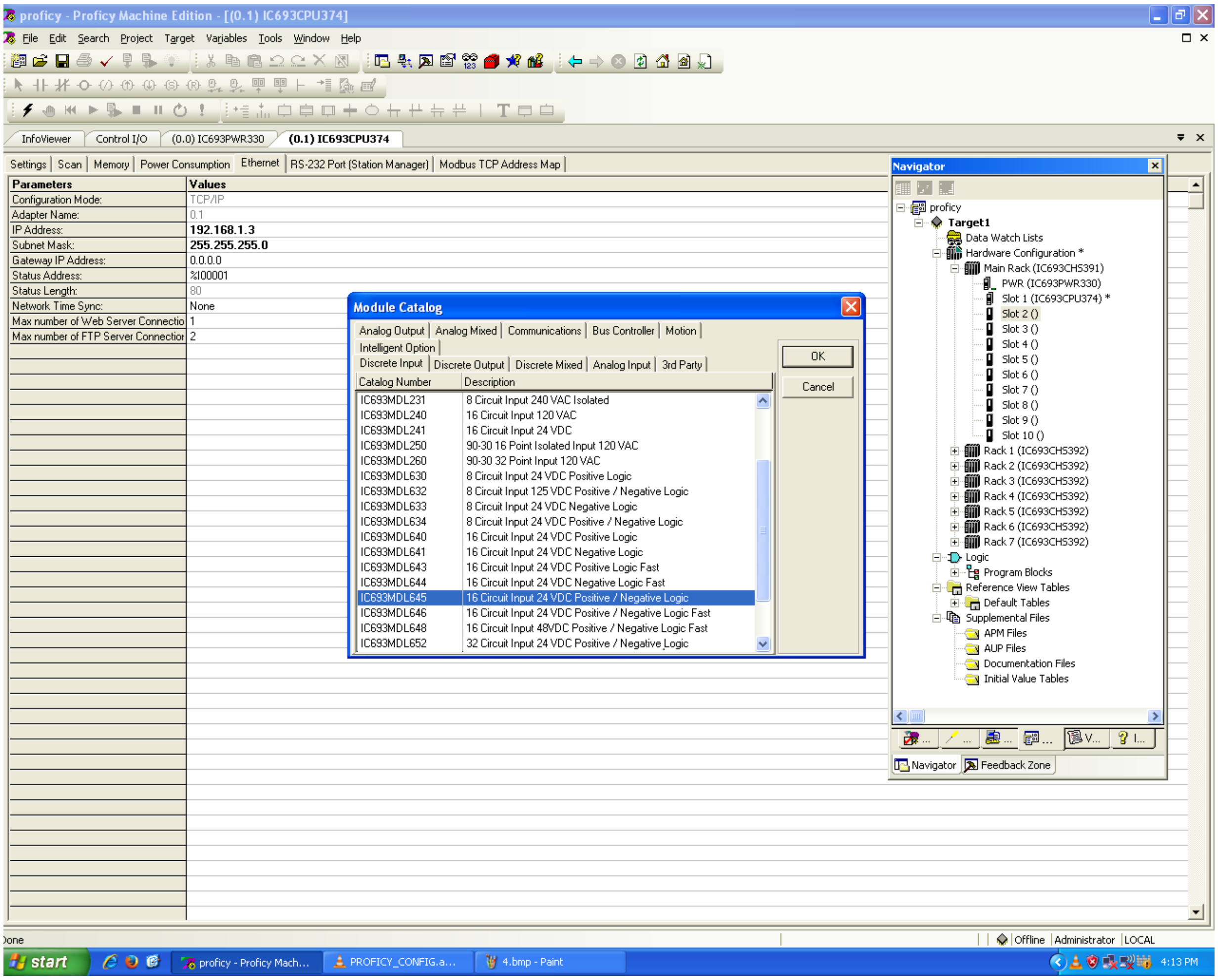


Fig 5.8 Setting of discrete input

d) Create a new ladder diagram by selecting ―MAIN in program blocks present in logic folder given on left side of the programming window. The figure basically represents programming window in offline mode with two vertical rails having provision for addition of rungs so as to develop ladder logic program on it which is the ultimate goal of Proficy Machine Edition software.

In Fig. 5.9, 5.10 and 5.11 shows a simple PLC program incorporating various virtual devices that include normally open and normally closed switches, timers and relay coils in OFF line mode of the present system.

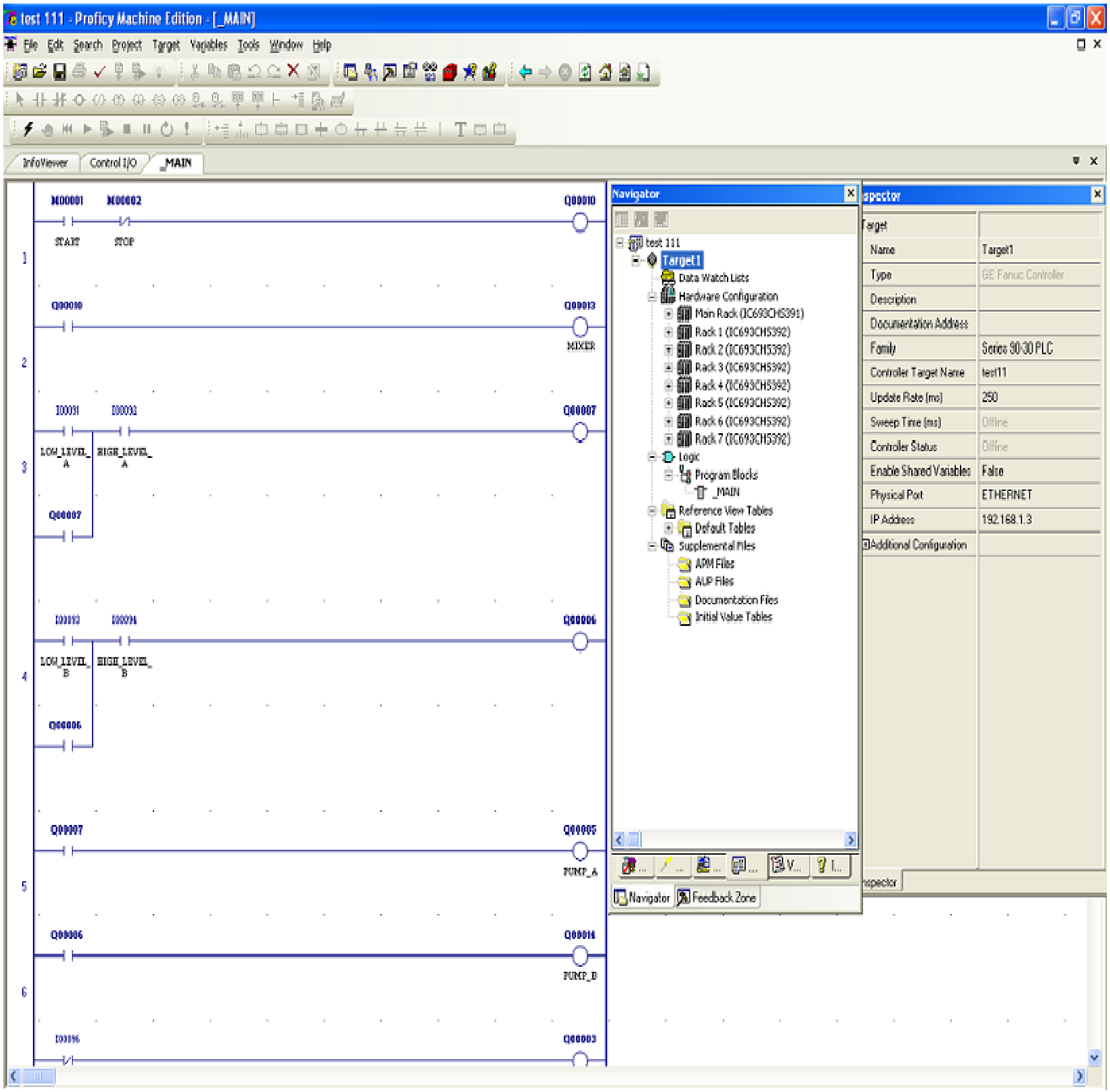


Fig. 5.9 Software window of PLC program in Offline mode 1

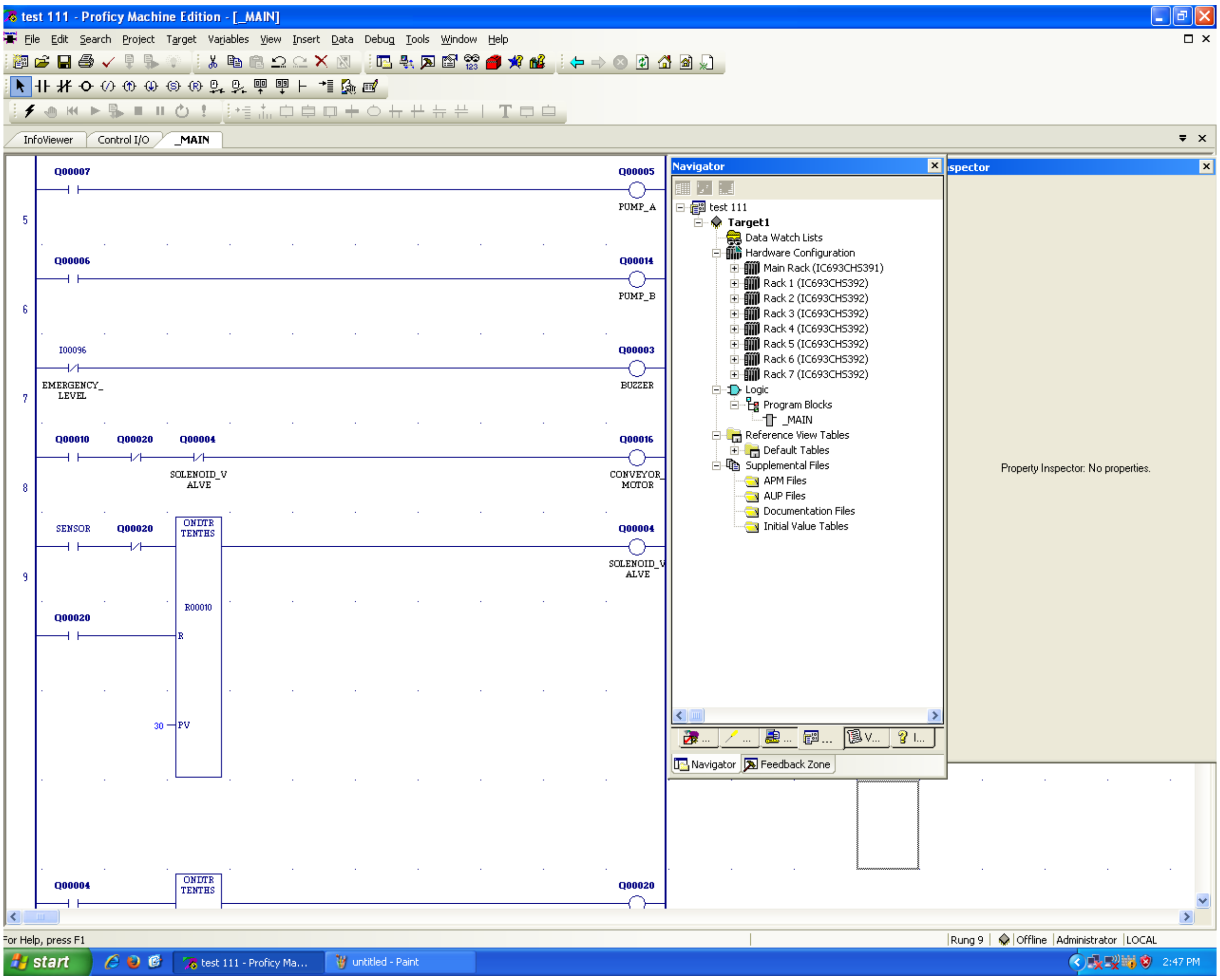


Fig. 5.10 Software window of PLC program in Offline mode 2

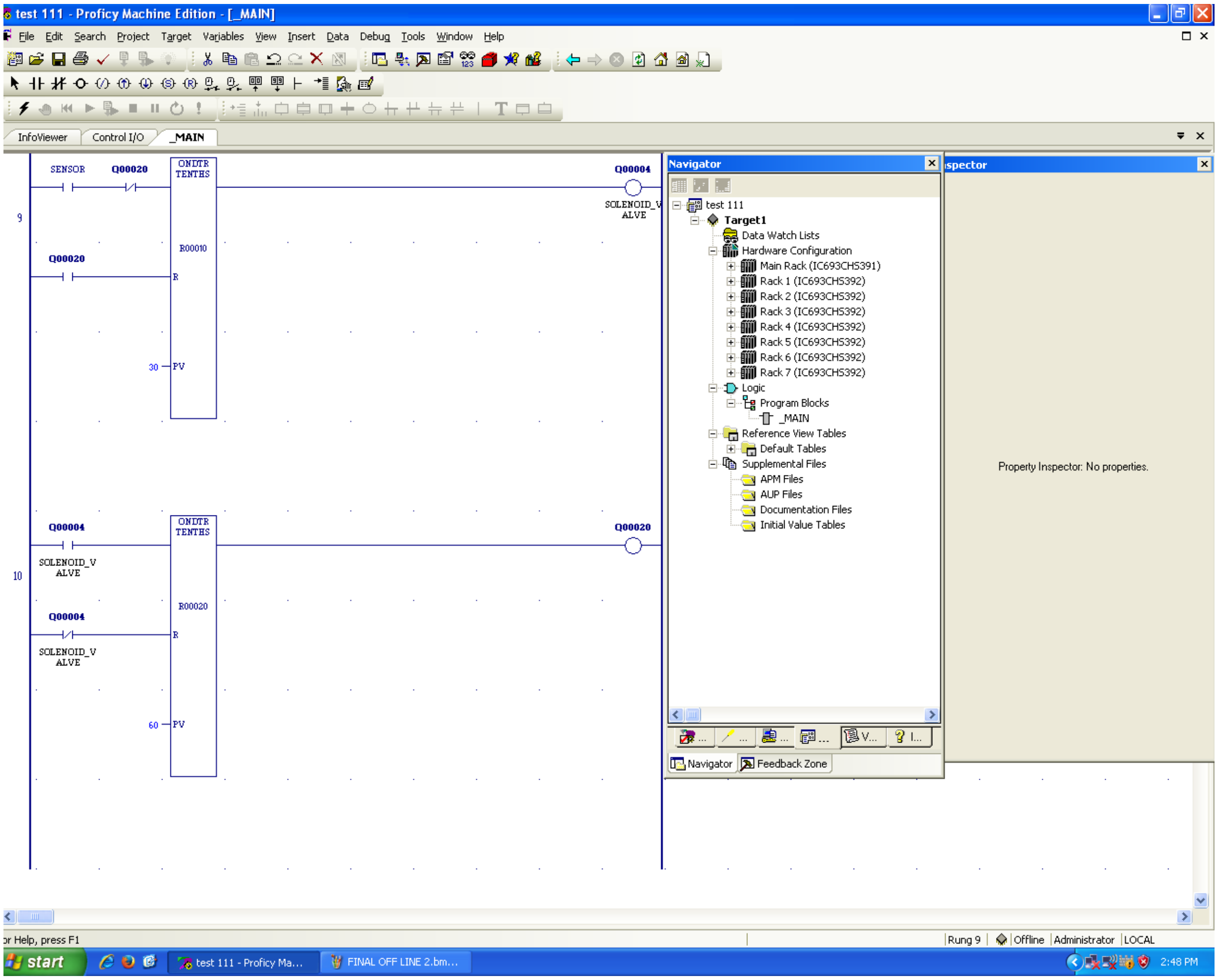


Fig. 5.11 Software window of PLC program in Offline mode 3

e) Save the program and right click on target PLC select ―Go online, if PLC is connected properly through serial communication or through Ethernet it will show ―connected. If it shows ―unable to go online check connections and modules selected. Fig. 5.12 shows downloading of program to PLC.

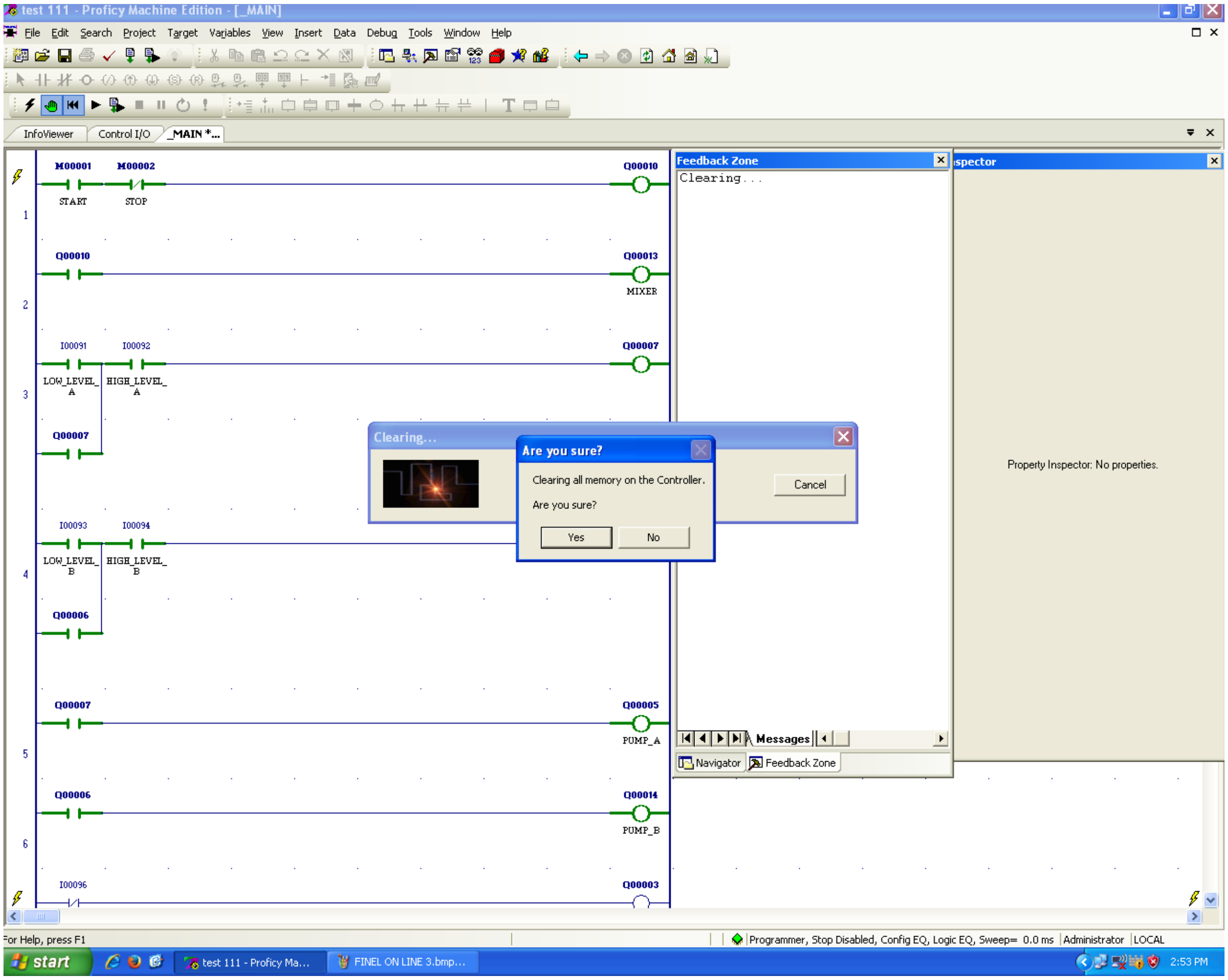


Fig. 5.12 Downloading of program in plc

f) When PLC is online, go to the ―Programmer Model, and select ―Download and Run Program, Machine Edition software will by itself check the program and for a correct program, PLC goes into Run mode indicated by a green LED on PLC board. Fig. 5.13, 5.14 and 5.15 shows PLC in run mode of present system.

Software window of PLC program in Run mode

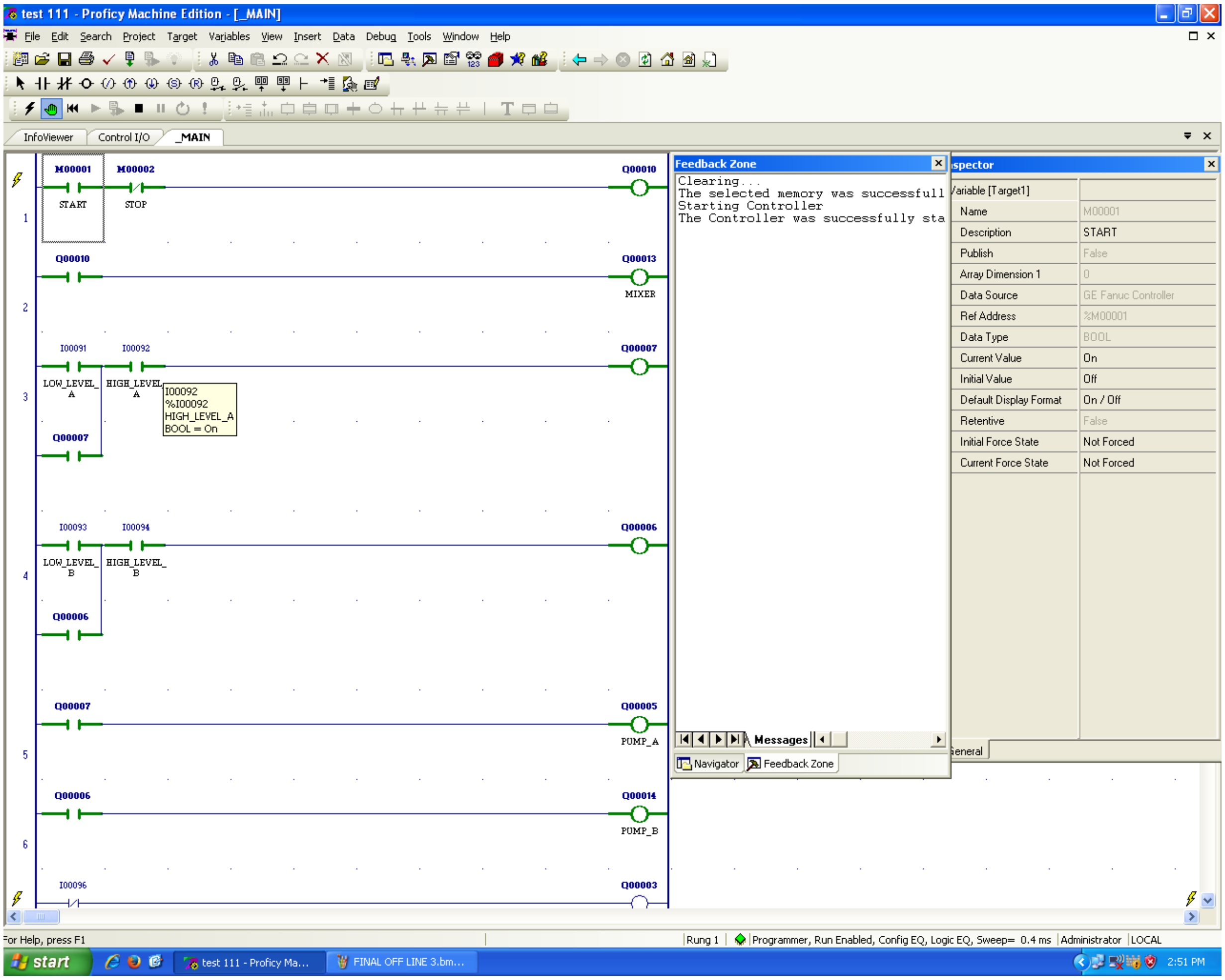


Fig.5.13 Software window of PLC program in Run mode 1

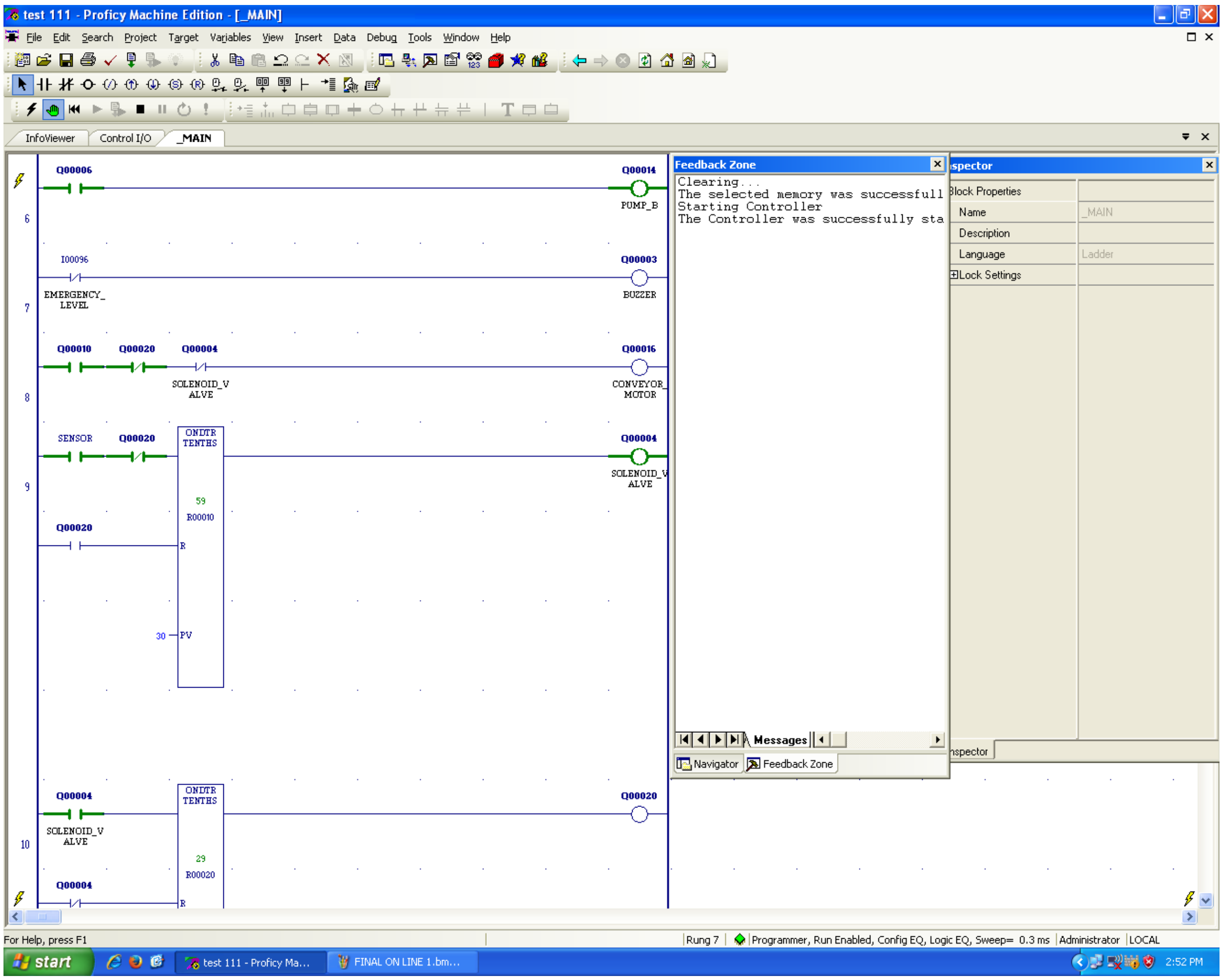


Fig.5.14 Software window of PLC program in Run mode 2

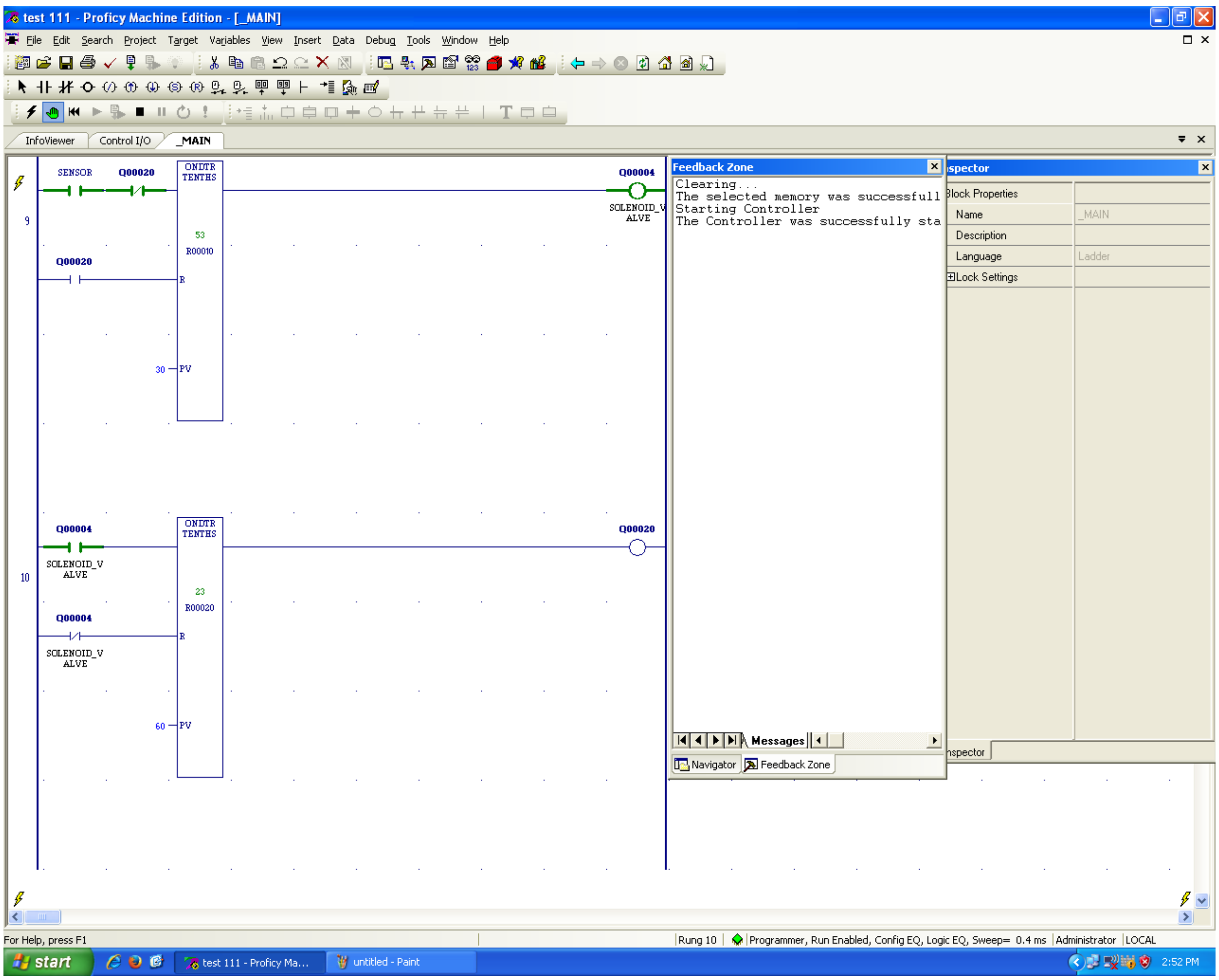


Fig.5.15 Software window of PLC program in Run mode 3

5.4 Conclusion

The complete system architecture is described in details for automating the system operations. The programming of PLC is carried out along with setting the system environment using desired parameters.

CHAPTER 6

OPERATION AND RESULTS

6.1 General

The current system is designed for automated level control, liquid mixing and filling of bottles. The entire process is controlled and automated with the help of Programmable Logic Controller. The system is designed for filling the mixture of two liquids in equal proportion. It consists of three sub system namely level controller, liquid mixer and bottle filler.

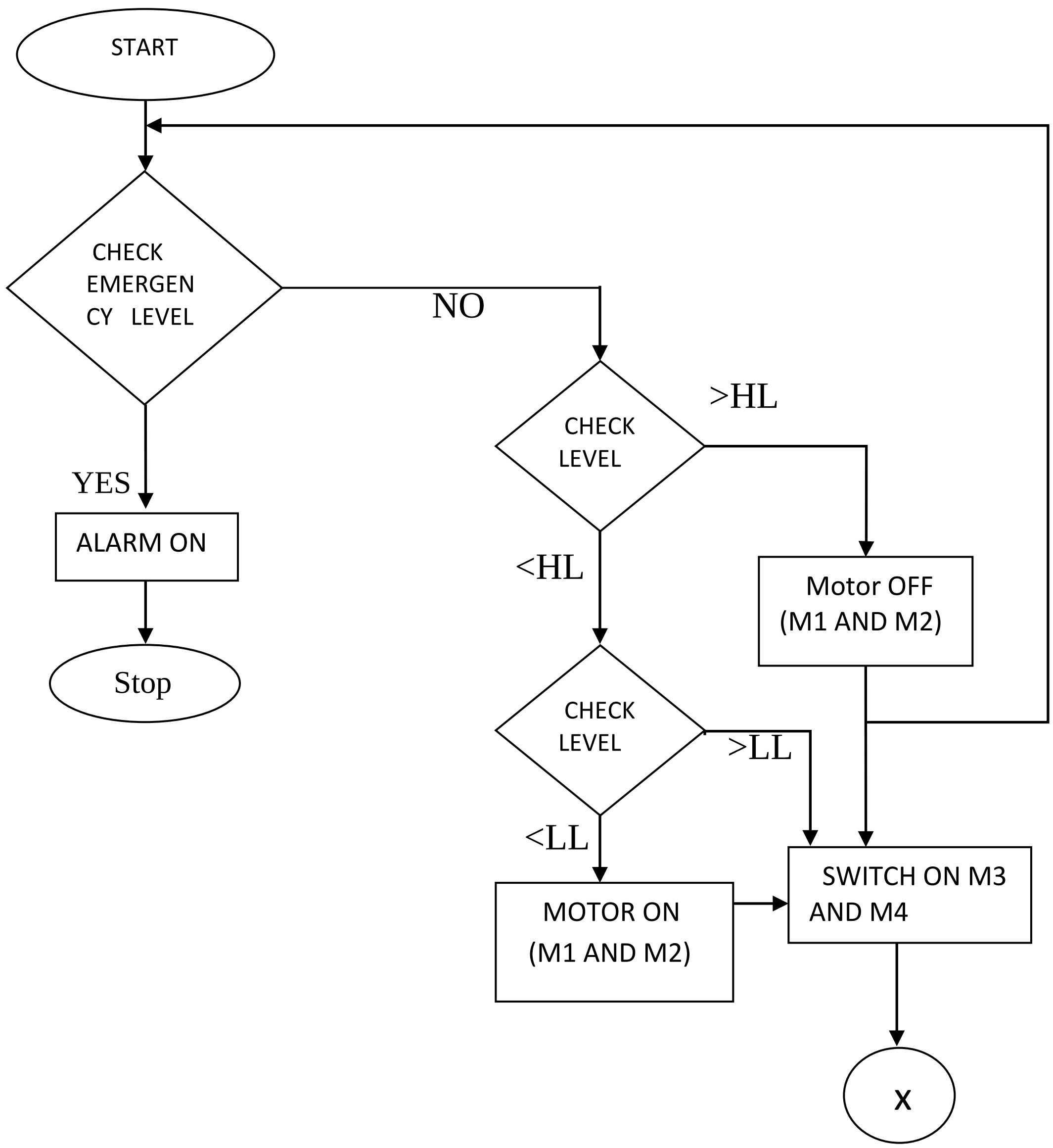
6.2 Sequence of Operation

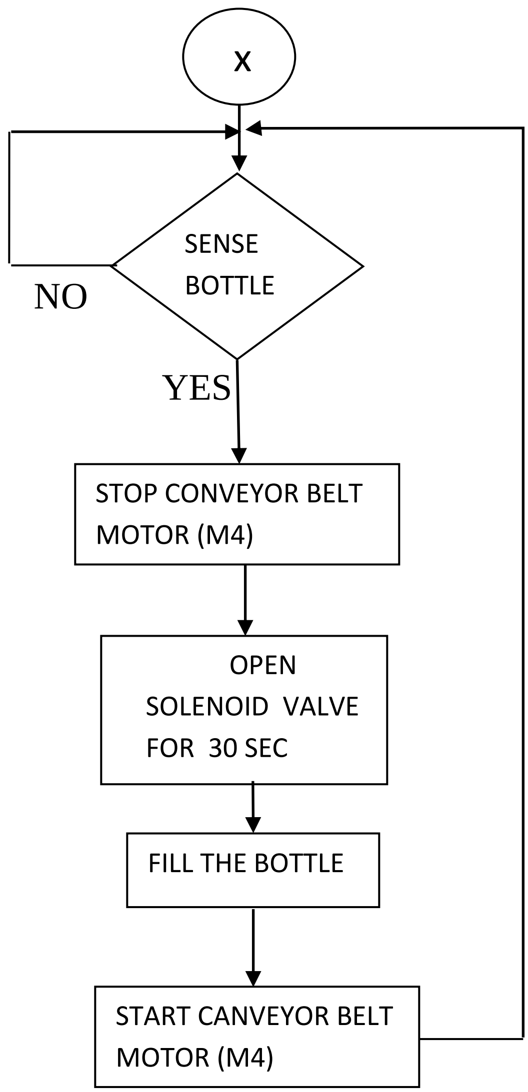
When the system starts PLC sends signal to reservoir motors (M1 and M2), DC motor connected to mixer (M3) and DC motor (M4) connected to conveyor belt. All the above mentioned motors are made ON and the system starts functioning.PLC is programmed using ladder logic.

The liquids start transferring from reservoir tanks to the overhead tank. There are two sensors, low level and high level sensor that detect presence of liquid in tank. According to level, the sensors, low level is fixed at 20% from bottom and high level sensor is fixed at 90% from bottom. Allowable gap between low level and high level sensor is 70%. Another sensor is fixed at 100% from bottom which is named as emergency level. An ON-OFF controller is used to control the level in overhead tank. When the level goes below the low level sensor sends signal to PLC. Which intern send signal to switch ON the motors. Similarly when the liquid level reaches the high level the motors are made OFF through PLC. In case the liquid level reaches emergency level the sensor send signal to PLC which makes the emergency alarm ON.

The overhead tank contains a mixing fan operated by a DC motor for mixing the liquids. This process of mixing is carried out continuously. The generated mixture is filled in the bottles. For filling, the bottles are placed on the conveyor belt which is moving with the help of another DC motor. An IR sensor is placed for sensing the bottle below the solenoid valve. Once the sensor senses the bottle it sends the signal to PLC. PLC sends signal to the conveyor belt motor in order to stop the belt. After a delay PLC sends signal to open the solenoid valve. The bottle is filled with the mixture within the duration of 30 seconds and valve is closed and the PLC send the signal to resume the motion of the belt.

6.3 Flow Chart





1. Water Pump Of Tank A (M1)
2. Water Pump Of Tank B (M2)
3. DC Motor of Mixer (M3)
4. 12 V DC Motor (M4)

6.4 Results

The reservoir tank A contains liquid with red color and tank B contains liquid with green color. These liquids are transfer to the overhead tank and mixed with the help of mixing fan. The resulted mixture is shown below in the fig. 6.1

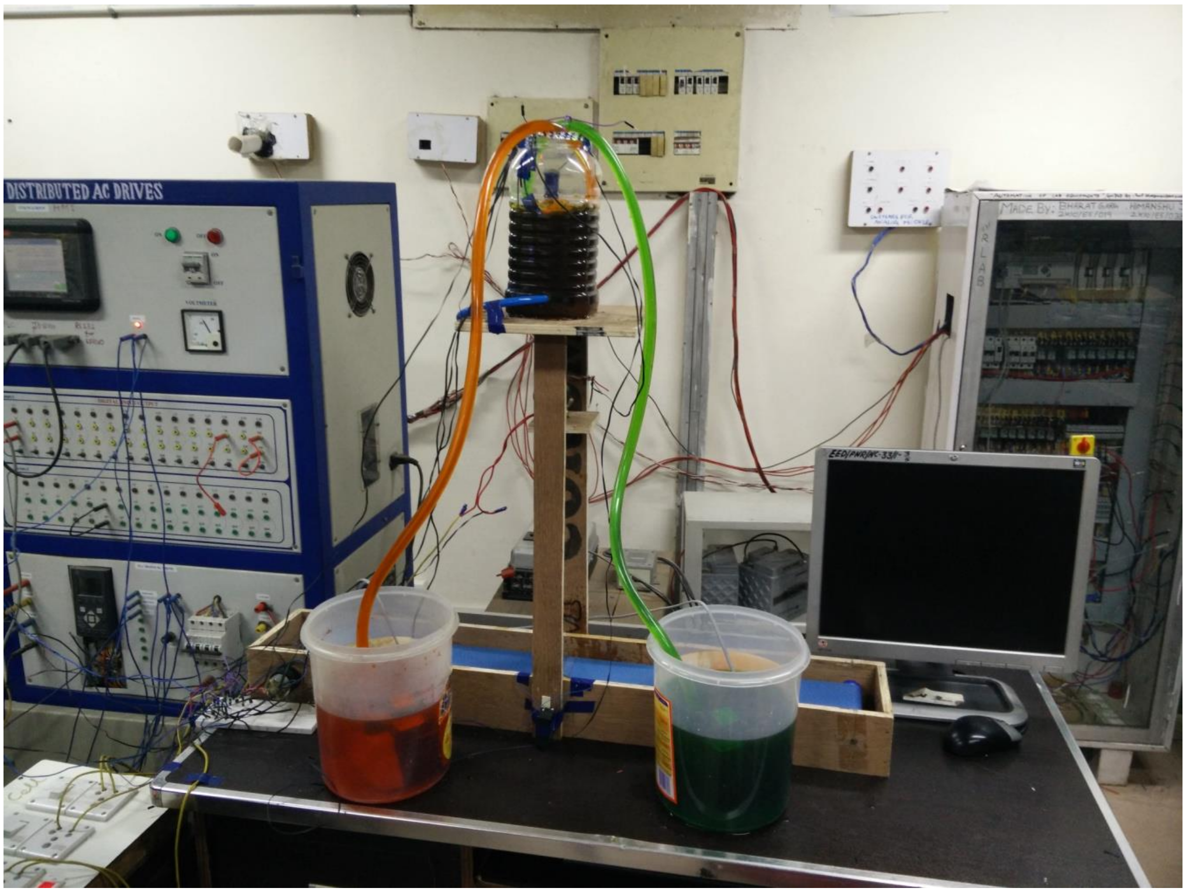


Fig. 6.1 mixing and transfer of liquids to overhead tank

The process of filling the bottle is shown below in fig. 6.2.

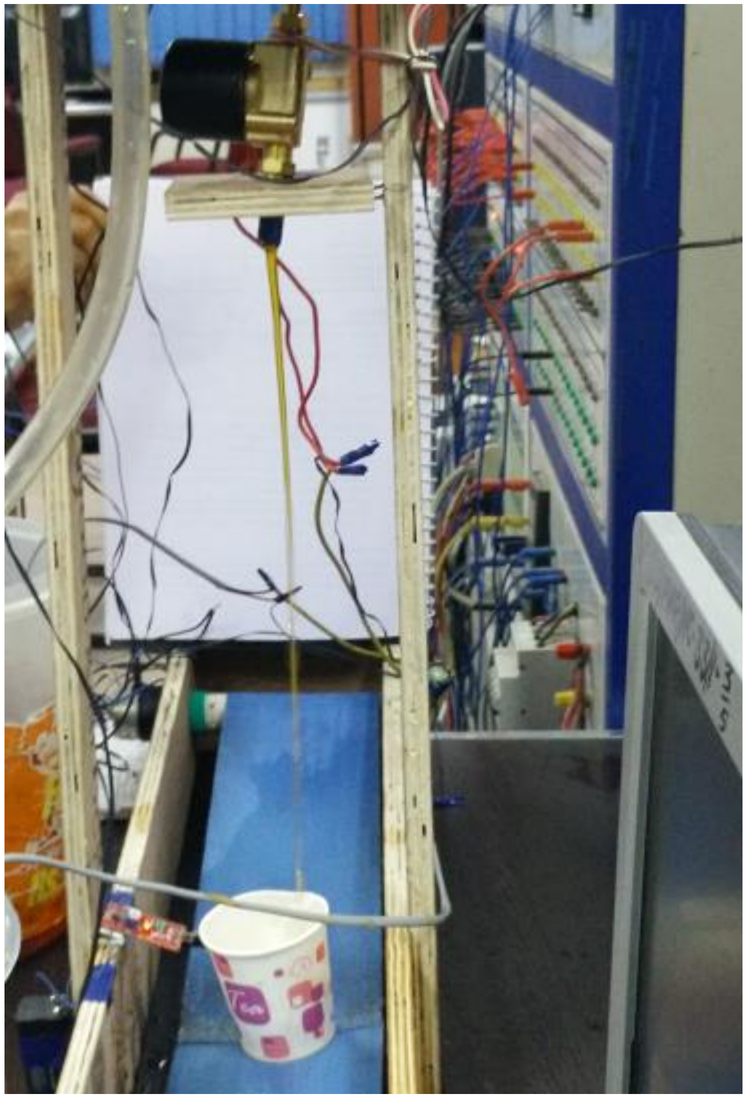


Fig. 6.2 picture of filling of bottle

6.5 Conclusion

The operation of the system is carried out under different system conditions and system is successfully tested for the level control, mixing and bottle filling through PLC automatically.

CHAPTER 7

CONCLUSION AND FUTURE SCOPE

7.1 CONCLUSION

In this project, automated control, mixing and monitoring of a bottle filling plant has been achieved using PLC. The operation of mixing, level control and bottle filling are carried out using different motors smoothly controlled by PLC ladder logic. Ladder logic has been helpful to program the actual PLC in order to intelligently command the particular motors as a way to automate the actual command process as well as minimize manual involvement and cost. Because of its ease of usability and low costing, this system would be adaptable in industrial environment.

Thus the system presents an effective and flexible method for automated control, mixing and bottle filling plant using efficient and advanced PLC technology. This system will facilitate effective and smooth functioning of industrial application with accuracy and increased throughput.

7.2 Future Scope

As the future scope of the project, the following work can be carried out:

1. Counters could be included before and after the filling process to maintain a count of bottles added to the process and those finally filled at the end of the process.
2. Automated capping system using actuator can also be introduced to ensure a holistic industrial process.
3. Automated system for labeling the bottle after capping.
4. Automated packing system at the end of the conveyor belt could also be designed.
5. Automated system for controlling and maintaining temperature and pressure for filling the bottle can be designed.

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