Sudan University of Science and Technology

College of Graduate Studies

Design and Simulation of an Automatic Filling Line for Different Sizes using Programmable Logic Controllers

تصميم ومحاكاة خط تعبئة أوتوماتيكى لاحجام مختلفة بإستخدام المتحكمات المنطقية القابلة للبرمجه

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of M.Sc in Mechatronics Engineering

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الآيــة

قال الله تعالى :

أعوذُ بالله من الشيطان الرجيم

(قَـالُـواْ سُبْحَانَـكَ لاَ عِلْمَ لَـنَـا إِلاَّ مَـا عَلَّمْتَـنَـا إِنَّـكَ أَنـتَ الْـعَلِـيمُ الْـحَكِـيمُ)

صدق الله العظيم

سورة البقرة الآية ٣٢

الإهـــــداء

إلى كل من أضاء بعلمه عقل غيره

وهدى بالجواب الصحيح حيرة سائليه

فاظهر بسماحته تواضع العلماء

وبرحابته سماحة العارفين

أهدى هذا العمل المتواضع إلى أبى الذي لم يبخل على يوماً بشئ

والى أمي التي زودتنى بالحنان والمحبة

وأقول لهم انتم وهبتموني الحياة والأمل ..

والى أخوتي وأسرتي جميعاً.

ثم إلى كل من علمني حرفاً أصبح سنا برقه يضئ الطريق أمامي ..

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Abstract

Filling is a task, which carried out by a machine that packages liquid products such as cold drinks or water. Traditional methods of bottle filling involved placing bottles into a conveyor and filling only one bottle at a time. This method is time consuming and expensive. The present work represents the design procedures and the simulation of an automatic filling line of different bottle sizes by using Programmable Logic Control (PLC). The system works automatically by filling liquid products into the bottles of different heights and is fully controlled by the PLC, which acts as the heart of the system. The system sequence of operation is designed by using ladder diagram technique, and the PLC programming software. The input signal that has been sent from the sensor to the PLC has being made as a reference signal. Farther more this reference signal used to determine the output signal, which is exactly is the same with the PLC programming language signal. The entire system is more flexible and time saving.

المستخلص

التعبئة هي مهمة تقوم بها آلة تقوم بتعبئة المنتجات السائلة مثل المشروبات الباردة أو الماء. الطرق التقليدية للتعبئة تشمل وضع العبوات في ناقل وملء عبوة واحدة فقط في كل مرة. هذه الطريقة تستغرق وقتا طويلا ومكلفة. في هذا البحث تم تصميم ومحكاة عمل منظومة لتعبئة السوائل اتوماتيكياً في عبوات ذات ارتفاعات مختلفة وتم التحكم في هذه المنظومة بواسطة المتحكمات المنطقية القابلة للبرمجة (PLC) والذي تعتبر بمثابة القلب للنظام. برنامج تشغيل المنظومه تم تصميمه بأستخدام لغه المخطط السلمي وبرمجيات التحكم المنطقي القابل للبرمجة. في هذه المنظومة يلعب جهاز المحساس دوراً حيوياً ويقوم بدور ناقل إشارة الإدخال لجهاز التحكم المنطقي القابل للبرمجة في النظام. أُستخدم جهاز المحساس خلال هذا المشروع للكشف عن موقع العبوة التي تتحرك عبر السير الناقل بسرعة منخفضة أثناء دوران الآلة. إشارة الإدخال التي تم إرسالها من جهاز المحساس إلى جهاز التحكم المنطقي القابل للبرمجة استخدمت كإشارة مرجعية لتحديد إشارة الإخراج التي تماثل بالضبط لغة برمجة جهاز التحكم المنطقي القابل للبرمجة استناداً على متطلبات المستخدم. يعد هذا الجهاز أو النظام أكثر مرونة وادخاراً للوقت.

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CHAPTER ONE

INTRODUCTION

1.1 Over view:

The field of automation has had a notable impact in a wide range of industries beyond manufacturing. Automation is the use of control systems and information technologies to reduce the need for human work in the production of goods and services. In the scope of industrialization, automation is a step beyond mechanization. Whereas mechanization provides human operators with machinery to assist them with the muscular requirements of work, automation greatly decreases the need for human sensory and mental requirements as well. Automation plays an increasingly important role in the world economy , one of the important applications of automation is in the soft drink and other beverage industries, where a particular liquid has to be filled continuously for these kinds of applications. The trend is moving away from the individual device or machine toward continuous automation solutions. Totally Integrated Automation puts this continuity into consistent practice.

Totally Integrated Automation covers the complete production line, from receipt of goods, the production process, filling and packaging to shipment of goods [1].

In the past humans was the main method for controlling a system, if we compare a job being done by human and by automation, the physical part of the job s replaced by use of a machine, whereas the mental capabilities of the human are replaced by automation. The human sensory organs are replaced with electrical, mechanical or electronic sensors to enable the automation system to perform the job [2].

More recently electricity has been used for control and early electrical control was based on relays. These relays allow power to be switched on and off without a mechanical switch. It is common to use relays to make simple logical control decisions.

The Programmable Logic Controller (PLC) was used to replace relay logic; PLC was invented in the 60/70's for the automotive manufacturing industry. Since this time, they have developed into one of the most versatile tools used for industrial automation, programmable logic controller or PLC is the hub of many manufacturing processes. These micro processor based units are used in processes as simple as boxing machines or bagging equipment to controlling and tacking sophisticated manufacturing processes. They are in virtually all new manufacturing, processing and package equipment in one form or another. Because of their population in industry [3].

PLCs have been gaining popularity on the factory floor and will probably remain predominant for some time. This is because of the advantages they offer:

- Eliminates much of the hard wiring that was associated with conventional relay control circuits.
- Communications Capability, PLC can communicate with other controllers or computer equipment.
- The same PLC can be reprogrammed (using only software) to perform another task or control another process.
- Reliable components make these likely to operate for years before failure.
- Cost effective for controlling complex systems.
- Faster Response Time, PLCs operate in real-time which means that an event taking place in the field will result in an operation or output taking place.

- Easier to Troubleshoot, PLCs have resident diagnostic and override functions allowing users to easily trace and correct software and hardware problems [4].

This project is an application of automation we have developed an automatic filling line of different size , the various processes are controlled using a PLC.

Being a usual part of an assembly line system, filling machine is a vital component of a bottling process. This type of filling machine is present on facilities that produce liquid based products such as beverages, chemicals and household cleaners. The bottling process includes filling, labeling and packing equipment. This equipment is incorporated with a bottle conveying system which is responsible in transporting bottles to go through the different processes. The bottle conveyor will make sure that the bottles are held securely to keep them aligned with the filling machine.

1.2 Problem description:

The problems that are existing in the present machines are that it can fill only a particular type of containers of certain height and the filling amount is as set by the operator. If the machine has to fill different type (size) of container then again the operator has to set the filling amount for each container.

Time taken for filling will become more in such conditions. Sometimes in special environments which are dangerous and not conductive for human operation, the operator cannot go and set the filling amount. By this the rate of production was affected due to the use of manual inspection systems. Sometimes in special environments which are dangerous and not conductive for human operation.

1.3 Objective:

The main objectives of the project are to:

- design an Automatic filling machine for filling liquid products using bottles of different height with PLC Integration.
- develop a control program for the system using PLC ladder logic diagram.
- simulate the process of filling different sizes of containers on the bases of height.

1.4 Methodology:

Bottles are kept in position over a conveyor belt , there are three Capacitive sensors used for sensing the bottles, the sensors are fixed in the solenoid valve area. Depending on the output of the sensors the corresponding valve switches on and filling operation takes place.

If the particular bottle is not present then the valve in that position is switched off, thereby avoiding wastage of the liquid. The filling process is done based on timing. Depending on the present value of the timer the valve is switched on for that particular period of time and the filling is done.

1.5 Outlines:

- In this project, five chapters will be briefly discussed. Chapter one: the introduction of the filling line system using PLC will mainly discussed about the project objectives and scope in order to achieve the desired goal.
- Chapter two: literature review will cover all explanation about the history of PLC ,main component of PLC and the PLC operation.
- Chapter three, methodology will describe about the overall project that has been testified and successfully operate.

- Chapter four, project design, will discuss about the system components, ladder diagram and the electrical wiring of the system.
- Finally chapter five there will be conclusion and recommendation.

Chapter Two

CHAPTER TWO

PREVIUOS STUDIES

This chapter will explain and discuss about some of Literature review about the filling machine project, also contained the theory of the components of the programmable logic controller (PLC) that is used in the project.

2.1 PLC base automatic bottle filling:

This project was designed by Jaymin Patel Department of Physics and electronics, North Gujarat University. Patan.India to develop an automatic bottle, filling and capping system with a deduction mechanism using sensors.

Automatic filling process for all the bottles simultaneously with a user defined selection for volume to be filled.

Bottles are kept in position in a carton over a conveyor belt; they are sensed to detect their presence. Proximity sensors are used for sensing the bottles. Depending on the output of the sensor the corresponding pumps switch on and filling operation takes place. If the bottle is not present then the pump in that position is switched off, thereby avoiding wastage of the liquid. The filling operation is accompanied with a user-defined volume selection menu which enables the user to choose the volume of liquid to be filled.

The filling process is done based on timing. Depending on the present value of the timer the pump is switched on for that particular period of time and the filling is done [5].

2.2 Design &implementation of automated filling and capping machine using PLC:

This project was designed by a student from Malaysia technical university, to Design and implementation of automated filling and capping machine using PLC.

This machine is divided into four sections; the loading section, the conveyor section, filling section, capping section.

The Machine was controlled by Omron CQM1-H PLC and use pneumatic System for loading part and capping part.

1. **Loading Section:**

The loading section was designed to store the empty bottle before the process was started. Use pneumatic system and cylinder was use as stopper. The slider is designed lean about 40 degrees so that the bottle will slide down according to gravity principle after the cylinder return to its initial position. The loading magazine can store up to 5 bottles of 125mL at one time.

2. **Filling Section**

The filling tank was design on top of the bottle while filling process because the liquid easily flow through to the bottom according to gravity principle. The measurement of the tank was 9cm height, 20cm wide and 6cm deep which will cover the capacity 1080mL of water. With this amount of water, it can full up to 8 bottles of 125mL. The total time for the valve to open and full one bottle of 125mL was 6 minutes and 10 seconds. This section use feed valve to flow the water into bottle.

3. **Capping Section**

The capping section use pneumatic system and cylinder as a pusher to push cap to bottle.

4. **Conveyor**

The conveyor part, it will use dc motor to move the conveyor forward. It will stop according to the sensor or the limit switch position.

2.3 PLC Controlled Automatic Bottle Filling System

This project developed a hardware model of a liquid filling system, and the process is controlled using a PLC. It is an automatic process where empty bottles are first placed on the conveyor belt. As an empty bottle is brought to the filling station, the belt stops to let the bottle fill-up with a fixed amount of liquid. The liquid is kept at an overhead tank near the filling station. After the bottle is filled-up, the belt starts again to move away the filled-up bottle and to bring another empty bottle to the filling station.

The whole process consists of three tasks:

- Filling bottles one after another with the desired level of liquid.
- Timely refilling the overhead tank to continue smooth operation.
- Controlling of the liquid flow from the reservoir to overhead tank.

Features of the Proposed System:

- Detection of the presence of a bottle using sensor
- Timer based automatic bottle filling
- Control of the liquid level of the overhead tank

2.4 Definition of PLC:

A PLC (Programmable Logic Controller) is a hardware that was invented to replace the conventional relay logic circuits for machine and process control. This hardware can accept the real world inputs and can send the outputs command through its input/output modules.

The PLC operates by sensing its inputs and depending upon their conditions, the outputs are activated. The user writes a program as per the application, usually via software, which when loaded and run in the PLC, produces the desired results.

PLC's are used in many "Real World" applications, in any industry, in this modern World of automation there is a need of a PLC. Particularly in the field of machining, packaging, material handling, automated assembly or countless other Industries the application that needs some type of electrical control has a need for a PLC.

In any process, if there are number of operations to be taken place simultaneously, involving large number of relays, timers, counters, etc. the involvement of a PLC will ensure a reliable and cost effective management in performing the desired system operation. So it is well understood that larger a control system is, it is evident that a PLC is used.

PLC's vary in size and sophistication. When PLC's were first introduced, they typically used a dedicated programming device for entering and monitoring the PLC program. The programming device could not only be used for programming a specific brand of PLC. These dedicated programmers, although user friendly, were very expensive and could not be used for anything designed that allowed a personal computer to program a PLC. Although dedicated programming devices still are available, the most common programming device used today is a personal computer running, i.e. windows based programming software.

Many engineers and/or technicians seem apprehensive about PLC's and their application in industry. One of the purposes of this manual is to explain PLC basis in a plain, easy-to understand approach so that engineers and technicians with no PLC experience will be more comfortable with their first exposure to Programmable Logic Controller.

2.5 History of PLC:

In the late 1960's PLCs were first introduced. The primary reason for designing such a device was eliminating the large cost involved in replacing the complicated relay based machine control systems. Bedford Associates (Bedford, MA) proposed something called a Modular Digital

Controller (MODICON) to a major US car manufacturer. Other companies at the time proposed computer based schemes, one of which was based upon the PDP-8. The MODICON 084 brought the world's first PLC into commercial production.

When production requirements changed so did the control system. This becomes very expensive when the change is frequent. Since relays are mechanical devices they also have a limited lifetime which required strict adhesion to maintenance schedules. Troubleshooting was also quite tedious when so many relays are involved. Now picture a machine control panel that included many, possibly hundreds or thousands, of individual relays. The size could be mind boggling. How about the complicated initial wiring of so many individual devices! These relays would be individually wired together in a manner that would yield the desired outcome. As can be seen, there were many problems with this relay based design [3].

These "new controllers" also had to be easily programmed by maintenance and plant engineers. The lifetime had to be long and programming changes easily performed. They also had to survive the harsh industrial environment. That's a lot to ask! The answers were to use a programming technique most people were already familiar with and replace mechanical parts with solid-state ones.

In the mid70's the dominant PLC technologies were sequencer state-machines and the bit-slice based CPU. The AMD 2901 and 2903 were quite popular in Modicum and A-B PLCs. Conventional microprocessors lacked the power to quickly solve PLC logic in all but the smallest PLCs. As conventional microprocessors evolved, larger and larger PLCs were being based upon them. However, even today some are still based upon the 2903. (Ref A-B's PLC-3) Modicum has yet to build a faster PLC than their 984A/B/X which was based upon the 2901.6

Communications abilities began to appear in approximately 1973. The first such system was Modicum's Mudbugs. The PLC could now talk to other PLCs and they could be far away from the actual machine they were controlling. They could also now be used to send and receive varying voltages to allow them to enter the analog world. Unfortunately, the lack of standardization coupled with continually changing technology has made PLC communications a nightmare of incompatible protocols and physical networks. Still, it was a great decade for the PLC.

The 80's saw an attempt to standardize communications with General Motor's manufacturing automation protocol (MAP). It was also a time for reducing the size of the PLC and making them software programmable through symbolic programming on personal computers instead of dedicated programming terminals or handheld programmers. Today the world's smallest PLC is about the size of a single control relay. The 90's have seen a gradual reduction in the introduction of new protocols, and the modernization of the physical layers of some of the more popular protocols that survived the 1980's. The latest standard (IEC 1131-3) has tried to merge PLC programming languages under one international standard. We now have PLCs that are programmable in function block diagrams, instruction lists, C and structured text all at the same time! PC's are also being used to replace PLCs in some applications. The original company who commissioned the MODICON 084 has actually switched to a PC based control system [3].

A. **Advantages of PLC**

- Less wiring.
- Wiring between devices and relay contacts are done in the PLC program.
- Easier and faster to make changes.

- Trouble shooting aids make programming easier and reduce downtime.
- Reliable components make these likely to operate for years before failure.

B. **Disadvantages** :

- PLC was designed for relay logic ladder and has difficulty with some smart devices.
- To maximize, PLC performance and flexibility, a number of option modulus must be added.

C. **Applications of PLC:**

- It is used in process automation
- It is used to optimize the process.
- It is used to integrate the different processing level s.
- By using PLCs quality of production is possible.
- System accuracy is increased by using PLCs.
- Automatic traffic control system is possible.
- It is used in twisting machines, automatic suspension of rotary system
- Numerous applications are possible by using PLCs in the industry [3].

2.6 PLC compared with other control system:

PLCs are well adapted to a range of automation tasks. These are typically industrial processes in manufacturing where the cost of developing and maintaining the automation system is high relative to the total cost of the automation, and where changes to the system would be expected during its operational life. PLCs contain input and output devices compatible with industrial pilot devices and controls; little electrical design is required, and the design problem centers on expressing the desired sequence of operations. PLC applications are typically highly customized systems, so the cost of a packaged PLC is low compared to the cost of a specific custom-built controller design. On the other hand, in the case of mass-produced goods, customized control systems are economical. This is due to the lower cost of the components, which can be optimally chosen instead of a "generic" solution, and where the non-recurring engineering charges are spread over thousands or millions of units.

For high volume or very simple fixed automation tasks, different techniques are used. For example, a consumer dishwasher would be controlled by an electromechanical cam timer costing only a few dollars in production quantities.

A microcontroller-based design would be appropriate where hundreds or thousands of units will be produced and so the development cost (design of power supplies, input/output hardware and necessary testing and certification) can be spread over many sales, and where the end-user would not need to alter the control. Automotive applications are an example; millions of units are built each year, and very few end-users alter the programming of these controllers. However, some specialty vehicles such as transit buses economically use PLCs instead of custom-designed controls, because the volumes are low and the development cost would be uneconomical.

Very complex process control, such as used in the chemical industry, may require algorithms and performance beyond the capability of even high-performance PLCs. Very high-speed or precision controls may also require customized solutions; for example, aircraft flight controls. Single-board computers using semi-customized or fully proprietary hardware may be chosen for very demanding control applications where the high development and maintenance cost can be supported. "Soft PLCs" running on desktop-type computers can interface with industrial I/O hardware while executing programs within a version of commercial operating systems adapted for process control needs.

Programmable controllers are widely used in motion control, positioning control and torque control. Some manufacturers produce motion control units to be integrated with PLC so that G-code (involving a CNC machine) can be used to instruct machine movements.

PLCs may include logic for single-variable feedback analog control loop, a proportional, integral, derivative (PID) controller. A PID loop could be used to control the temperature of a manufacturing process, for example. Historically PLCs were usually configured with only a few analog control loops; where processes required hundreds or thousands of loops, a distributed control system (DCS) would instead be used. As PLCs have become more powerful, the boundary between DCS and PLC applications has become less distinct.

PLCs have similar functionality as remote terminal units (RTU). An RTU, however, usually does not support control algorithms or control loops. As hardware rapidly becomes more powerful and cheaper, RTUs, PLCs and DCSs are increasingly beginning to overlap in responsibilities, and many vendors sell RTUs with PLC-like features and vice versa. The industry has standardized on the IEC 61131-3 functional block language for creating programs to run on RTUs and PLCs, although nearly all vendors also offer proprietary alternatives and associated development environments.

In recent years "safety" PLCs have started to become popular, either as standalone models or as functionality and safety-rated hardware added to existing controller architectures (Allen Bradley Guard logic, Siemens F-series etc.). These differ from conventional PLC types as being suitable for use in safety-critical applications for which PLCs have traditionally been supplemented with hard-wired safety relays. For example, a safety PLC might be used to control access to a robot cell with trapped-key access, or perhaps to manage the shutdown response to an emergency stop on a conveyor production line. Such PLCs typically have a restricted regular instruction set augmented with safety-specific instructions designed to interface with emergency stops, light screens and so forth. The flexibility that such systems offer has resulted in rapid growth of demand for these controllers [3].

2.7The Internal Configuration of PLC:

The PLC is programmed interface between the input field element and output field elements and it is consist of:

- Main Rack
- Power Supply
- CPU
- Digital Input/output cards
- Analog Input/output cards
- Special Features Cards

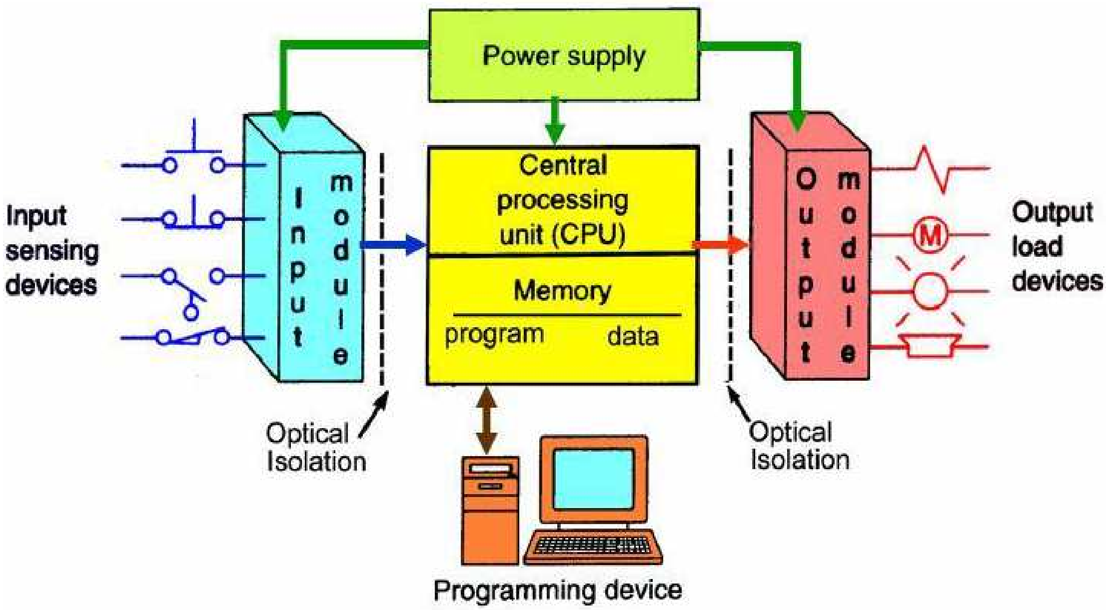


Figure 2.1: block diagram of PLC

a) Main Rack:

This is where the rest of the elements are connected or plugged in. It is normally screwed to the electric cabinet mounting plate. It can get a certain number of cards depending on the manufacturer and to be connected to other racks through a communication cable, being called in this auxiliary rack.

b) Power Supply:

Converts the input power of 110 or 220 V AC to 24 V DC and necessary current to supply the CPU and IN/OUT cards as well as auxiliary equipment if needed

c) CPU:

This is the brain of the PLC. With one or more microprocessors (depending on the manufacturer)it is programmed with a special software. Most of them are using a standard programming language like instructions, contacts, functions, sequential etc. They work with logic 1-0, this is two different states for the same bit. Normally use 16 bits word as memory basis although some new ones work on a 32 bits words basis. Depending on the CPU models, are able to manage more memory and calculation functions as well as microprocessor speed.

Nowadays the calculation power of these devices is very high and usual to work with floating point numbers thus giving mathematical precision more than needed. It is normal to have 10 msec. scan cycle for typical digital application and about 40 m sec, for an analogue one, much faster than any process transmitter or valve actuator. The application program is made in a special language , it has beginning and an end. The time between them is called scan cycle and there is timer inside the PLC's CPU unit that looks for the program to be executed from the beginning to the end before that timer ends. This is the WATCHDOG timer. If this timer ends before the scan cycle, the PLC will go to the STOP status [4].

d) Digital Input/output Cards:

They are connected to the main or auxiliary rack and communicate with the CPU across related connection. In case of digital inputs these ones transmit the 0 or 1 status of the process signals (pressure switches, limit switches proximity sensors, switches etc.) to the CPU. In case of digital outputs, the CPU will set or reset them following the program instructions. 24 DC V for inputs and outputs are normally used, but 110 or 230 V AC inputs/outputs as well. The number of input/outputs per card can be from 8, 16 or 32 points etc.

e) Analog Input/output Cards:

They are connected the same way than the previous ones but in some PLC's have to be as close to the CPU as possible. These cards receive an analogue value from filed and internally convert it to a digital value to be processed by the CPU. This conversion is made by Analogue to Digital converters located in the analogue card and distributed to one for the whole card or one per channel depending on the card model (this is the fastest one). They are made of 2.4.8 or 16 input /outputs called each one "channel" and referred from 0 to (Max-1), for example, the first channel of a 4 analogue outputs card is named 0 and the last one ids named 3.

Inputs and output ranges varies between 4-20 mA (milliamps), 0 to 10 VDC, etc.

The most important thing to be considered when designing a control using analogue input cards is that is desirable to be isolated, otherwise will have problems with the value readings.

f) **Program memory**:

The program memory is classified into three types

a. System memory

b. Load memory

c. Work memory

a. System memory:

In system memory contain all hardware configuration details

b. Load memory:

Each CPU has an internal load memory. The size of this internal load memory depends on the CPU used.

This internal load memory can be replaced by using external memory cards. If there is no memory card inserted, the CPU uses the internal load memory; if a memory card is inserted, the CPU uses the memory card as load memory. The size of the usable external load memory cannot, however, be greater than the internal load memory even if the inserted SD card has more free space.

c. Work memory

Work memory is a non-retentive memory area for storing elements of the user program that are relevant for program execution. The user program is executed exclusively in work memory and system memory.

It divided into two

I. Run mode

II. Stop mode

Is the working area of the PLC consisting of data regarding the status of input and output, mathematics, calculations, timer and counter values [3].

g) Programming Device:

A personal computer (PC) is the most commonly used programming device, the software allows users to create, edit, document, store and troubleshoot programs, The personal computer communicates with the PLC processor via a serial or parallel data communications link.

h) Special Features Cards:

Connected in the same way than previous ones are normally used to control or monitories special process variables like rotation speed, position, frequency, etc. They normally have an independent processor that makes the work and discharge of it to the PLC's CPU. The following are some examples of Special cards:

- Fast counting cards
- Motors positioning cards
- Regulation cards…etc.

The PLC mainly consists of a CPU, memory areas and appropriate circuits to receive input/output data. We can actually consider the PLC to be a box full of hundreds or thousands of separate relays, counters, timers and data storage locations. Do these counters, timers etc. really exist? No they don't physically exist but rather they are simulated and can be considered software counters, timers etc. These internal relays are simulated through bit locations in registers [4].

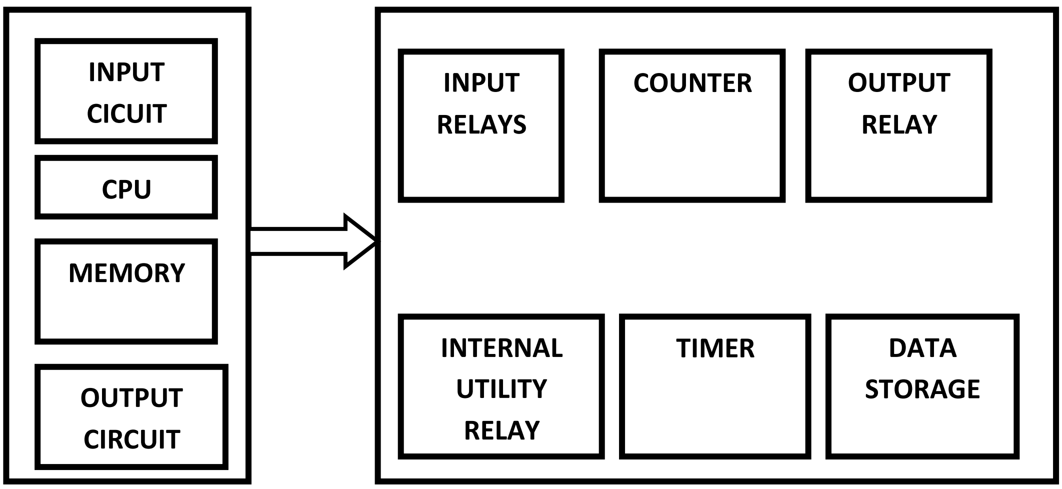


Figure 2.2: PLC internal registers

2.8 Each PLC internal part in detailed:

a) Input Relays (contacts):

These are connected to the outside world. They physically exist and receive signals from switches, sensors, etc. Typically they are not relays but rather they are transistors [1].

b) Internal Utility Relays (contacts):

These do not receive signals from the outside world nor do they physically exist. They are simulated relays and are what enables a PLC to eliminate external relays. There are also some special relays that are dedicated to performing only one task. Some are always on while some are always off. Some are on only once during power-on and are typically used for initializing data that was stored.

c) Counters:

These again do not physically exist. They are simulated counters and they can be programmed to count pulses. Typically these counters can count up, down or both up and down. Since they are simulated they are limited in their counting speed. Some manufacturers also include high-speed counters that are hardware based. We can think of these as physically existing. Most times these counters can count up, down or up and down.

d) Timers:

These also do not physically exist. They come in many varieties and increments. The most common type is an on-delay type. Others include off-delay and both retentive and non-retentive types. Increments vary from 1ms through 1s.

e) Outputs relay (coils):

These are connected to the outside world. They physically exist and send on/off signals to solenoids, lights, etc. They can be transistors, relays, or traces depending upon the model chosen.

f) Data storage:

Typically there are registers assigned to simply store data. They are usually used as temporary storage for math or data manipulation. They can also typically be used to store data when power is removed from the PLC. Upon power-up they will still have the same contents as before power was removed.

2.9 PLC memory organization:

Memory can be categorized into volatile and non volatile memory. Volatile memory will lose its stored information if all operating power is lost (or) removed. Volatile memory is easily altered and quite suitable for most applications when supported by battery backup. Non volatile memory can retain stored information when power is removed accidentally or intentionally. Plc makes use of many different types of volatile and non volatile memory devices [3].

Common memory types description:

1. RAM: Random access memory (RAM) is designed so that information can be written into (or) read from the memory today's controllers use the CMOS-RAM with battery support for user program memory. RAM provides an excellent means for easily creating and altering a problem.

2. ROM: Read- only memory (ROM) is designed so that information stored in memory can be read and cannot be changed under ordinary circumstances.

3. EPROM: Erasable programmed read only memory (EPROM) is designed so that it can be reprogrammed after being entirely erased with the use of an ultraviolet light source.

4. EEPROM: Electrically erasable programmed read- only memory. (EEPROM) is a non volatile memory that offers the same programmed flexibility as does RAM. It provides permanent storage of the program but can be easily changed using standard programming devices.

2.10 Basics of PLC Operation:

A PLC works by continually scanning a program. We can think of this scan cycle as consisting of 3 important steps. There are typically more than 3 but we can focus on the important parts and not worry about the others. Typically the others are checking the system and updating the current internal counter and timer values [1].

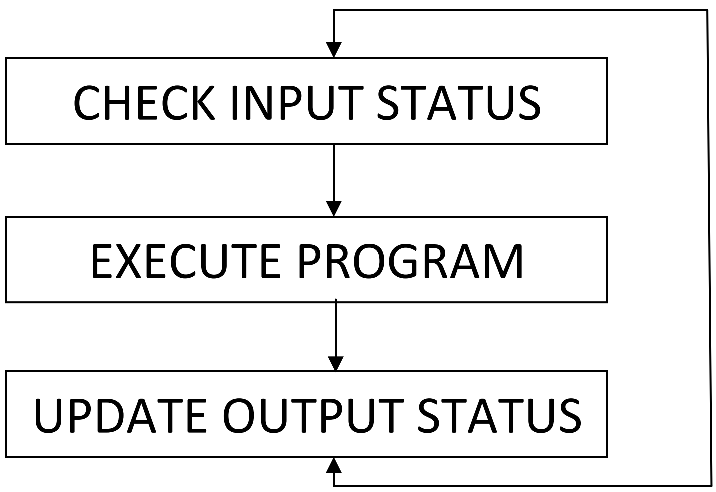


Figure 2.3: PLC operations

<u>**Step1**: Check input status</u>

First the PLC takes a look at each input to determine if it is on or off. In other words, is the sensor connected to the first input on? How about the second Input? How about the third... It records this data into its memory to be used during the next step.

Step 2: Execute program

Next the PLC executes your program one instruction at a time. Maybe your program said that if the first input was on then it should turn on the first output. Since it already knows which inputs are on/off from the previous step it will be able to decide whether the first output should be turned on based on the state of the first input. It will store the execution results for use later during the next step.

Step 3: Update output status

Finally the PLC updates the status of the outputs. It updates the outputs based on which inputs were on during the first step and the results of executing your program during the second step. Based on the example in step 2 it would now.

Turn on the first output because the first input was on and your program said to turn on the first output when this condition is true. After the third step the PLC goes back to step one and repeats the steps continuously. One scan time is defined as the time it takes to execute the 3 steps listed above.

Chapter Three

CHAPTER THREE

METHODOLOGY

3.1 Preface:

This chapter will mainly discuss about the methodology of the project and also the aspect or factors that must be taken into consideration during the development process. All this factors were very important to make sure the project will achieve its objective. Moreover, this chapter will also discuss about the designation stage on this project including electronic design, hardware design and material selection. In this section, it will discuss an overall overview of filling line system Using PLC and the hardware and software component of the system.

3.2 Software and hardware were used in the project:

A. **Hardware:**

1) Programmable logic controller (PLC).
2) Sensors.
3) Solenoid valve.
4) Conveyor belt.
5) Reservoir and over head tanks.
6) Bottle feeding unit.
7) Pump.
8) Motors .
9) Level switches.

B. **Software**

1) PLC Simatic S7-200 .
2) Ladder diagram .

1) PLC Simatic S7-200: In this project, to implement the control logic of the system, we used a PLC. Here we have used SIMATIC S7-200 which is manufactured by Siemens Corporation.

- **Features of PLC Siemens:**

a) It covers 30% of industrial automation

b) Having a very huge instruction set as compare to others

c) Large no. of protocol are supported

d) Wide operating temp. Range (-40c to 70c)

e) Having high data resolution

- **TYPES OF PLC Siemens:**

  According to STEP (Siemens Technical education program), it is a group of engineers decide the standard of plc –Siemens,It is of two type STEP (STEP5& STEP7).

a) **STEP5**: (90U, 100U, 110U, 120U)

1. It is DOS operated.
2. Having 1024 max no of inputs and output.

b) **STEP7** :(S7-200, S7-300, S7-400, S7-1200)

IT support windows operating system .

- TYPES OF PLC siemens:

COMPACT	MODULAR
Input and output	separate
Modules are integrated	input/output
On CPU	modules are provided

2) Ladder diagram:

The ladder language is a symbolic instruction set that is used to create a programmable controller program. It is composed of six categories of instruction that include relay-type, timer/counter, data manipulation, arithmetic, data transfer, and program control. The ladder instruction symbols can be formatted to obtain control logic that is to entered into memory.

The main function of the ladder diagram program is to control outputs based on the input condition. This control is accomplished through the use of what is referred to as a ladder rung.

In general, a rung consists of a set of input conditions represented by relay contact type instruction and an output Instruction at end of the rung represented by the coil symbol. Throughout the section the contact instruction for a rung may be referred to as input conditions or control logic. Coils and contacts are the basic symbols of the ladder diagram instruction set. The contact symbol programmed in a given rung represents conditions to be evaluated in order to determine the control of the output all the format of the rung contacts is dependent on the desired control logic. Contacts may be placed in any configuration such as series parallel or series parallel that is required to control a given output for an output to be activated or energized at least one left-to –right path of contacts must be closed. A complete closed path is referred to as having logic continuity. When logic continuity exists in at least one path, it is said that the rang condition is TRUE. The rung condition is FALSE. If no path has continuity. In the early year, the standard ladder instruction set was limited to performing only relay equivalent functions, using the basic relay-type contact and coil symbols similar to those illustrates in

A need for greater flexibility coupled with developments in technology, led to extended ladder diagram instructions that perform data manipulation, arithmetic and program flow control.

3.3 system component:

1. Reservoir and over head tank.
    - Reservoir tank: use to supply liquid to the over head tank
    - Over head tank: connect to the solenoid valve for liquid filling operation
2. Bottle feeding unit: feeds bottles to conveyor belt.
3. Conveyor belt: carries the bottles for filling section.
4. Electric motors:
    - Motor1: for conveyor belt.
    - Motor 2: for turn table.
5. Motor pump: connected to the reservoir tank for liquid supply.
6. Solenoid valve: use to fill the bottle with liquid.
7. Capacitive proximity sensors:
    - Sensor 1: for minimum bottle size
    - Sensor 2: for medium bottle size
    - Sensor 3: for maximum bottle size
8. liquid level switches:

- L1: indicate the minimum liquid level in the over head tank.
- L2: indicate the maximum liquid level in the over head tank.
- L3: indicate the minimum liquid level in the reservoir tank.

3.4 system description:

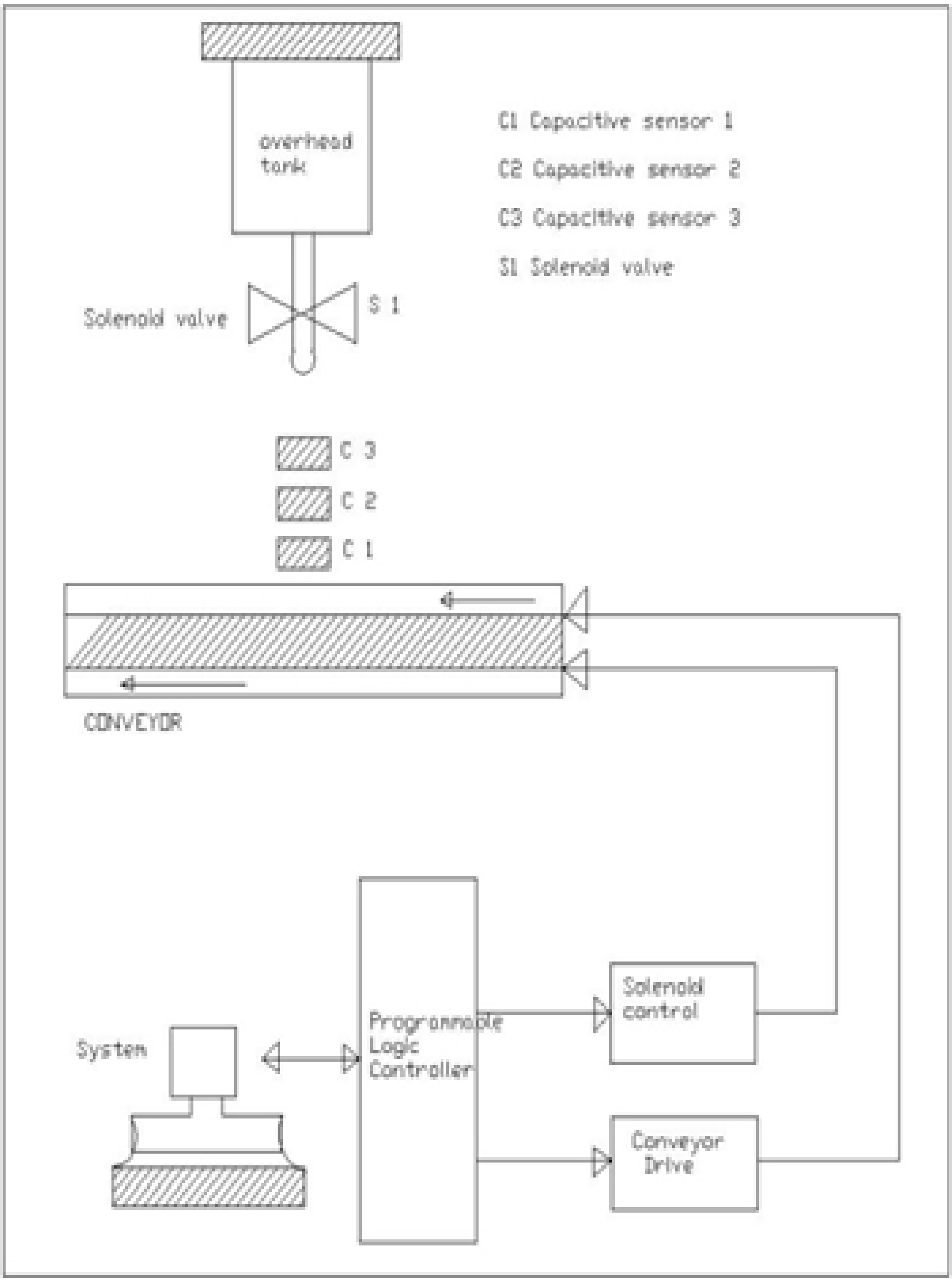


Figure 3.1: Block Diagram of the Process

The filling system consists of inputs modules and output modules.

The input module includes the capacitive sensors, start/stop push button, emergency push button, level liquid switches.

There are three capacitive sensors whose output is given as an input to the PLC , Three capacitive sensors (C1, C2, C3) are used to detect the bottles position and the bottle high, These sensors kept near the filling side.

There are two push button one push button to start the cycle and the other push button to stop the cycle, one emergency stop use in emergency state.

There are three level liquid switches (L1,L2,L3) use in this system, two switches use to detect the maximum and minimum level of the over head tank and the third one is use to detect the minimum level of the Reservoir tank.

The various output devices used in this system are A C synchronous motors, solenoid valve, pump and alarm, These are connected to the output module.

There are two motors (MOTOR 1, MOTOR2) use in this system ,motor1 is used to run the conveyor belt in forward direction and motor2 is used to run the bottle feeding unit . One solenoid valve(Y) is used for the filling process, and is connected to the overhead tank. One pump connect to the Reservoir tank and it is use to supply liquid for the over head tank ,there is alarm light use to alarm if the over head tank is in the minimum level .These are the various output devices used in the filling process.

The system can be divided into several parts:

A: Conveyor Belt Mechanism:

The conveyor belt mechanism consists of a belt and rollers with ac motor. It is coupled with two rollers and runs continuously with the motor When a start button is pressed the conveyor belt run and carries the bottles which come from the bottle feeding unit along the assembly line to be filled up with liquid up to a particular level and then the conveyor belt runs again to take the filled up bottle to the other end to be collected by an attendant.

B: Filling unit Mechanism:

In this unit it consists of overhead liquid tank, capacitive sensors, solenoid valve connected to liquid tank. After inspection done by the inspection unit the container comes below the solenoid valve there are capacitive sensors placed below the valve and when it sense the container the conveyor stops, then the solenoid valve get ON and fills the liquid to the component based on the instruction given by inspection unit(i.e. which size container has to be filled). Liquid will be as soon as the conveyor stops. Solenoid control valves are electromagnetic plunger valves which control flow rates of liquid. The input to solenoid valve is given by PLC. Three different timings are given for three different containers. The timing of solenoid valve and conveyor stopping is set by the timers used in program. We can change the timing based on the Requirement. Conveyor stopping time also varies for three containers. The overhead liquid tank will supply liquid to the solenoid valve. After filling liquid to container the solenoid valve gets OFF and conveyor Starts to run and automatically cycle repeats.

C: Liquid Level Maintaining Mechanism at the Overhead Tank:

Due to continuous filling of the bottles, the amount of liquid at the overhead tank gets depleted. So it is crucial to maintain a minimum level of liquid at the overhead tank to continue the smooth operation of the bottle filling task. On the other hand, while refilling the overhead tank with liquid, care should be taken so that it does not overflow. Therefore, the option for sensing the minimum and maximum liquid levels have been provided. Two level liquid switches, i.e., the upper level and the lower level switches are placed in the over head tank. When liquid level at the overhead tank goes below,

Signal is sensed at the PLC providing the information on inadequate amount of liquid at the overhead tank and consequently a command is sent from the output of the PLC to start a pump to refill the overhead tank from the main reservoir. On the other hand, when the liquid level goes above the upper level switch, a signal is sensed at the PLC, providing the information on overflow of liquid at the overhead tank. Therefore, a command is sent from the output of the PLC to stop the pump.

Also there is one liquid level switches in the reservoir tank use to indicate the minimum level of the tank.

Chapter Four

CHAPTER FOUR

FILLING PRODUCTION LINE DESIGN AND SIMULATION

4.1Preface:

A systematic approach of control system design using programming logic controller is presented in this chapter. The filling machine components will be discussed. Next, the assignment of input and outputs are shown in tables. Then the ladder diagram design using Siemens software is shown. Finally the wiring of the system will be shown.

Figure 4.1 shows the proposed system which was designed by using photo shop.

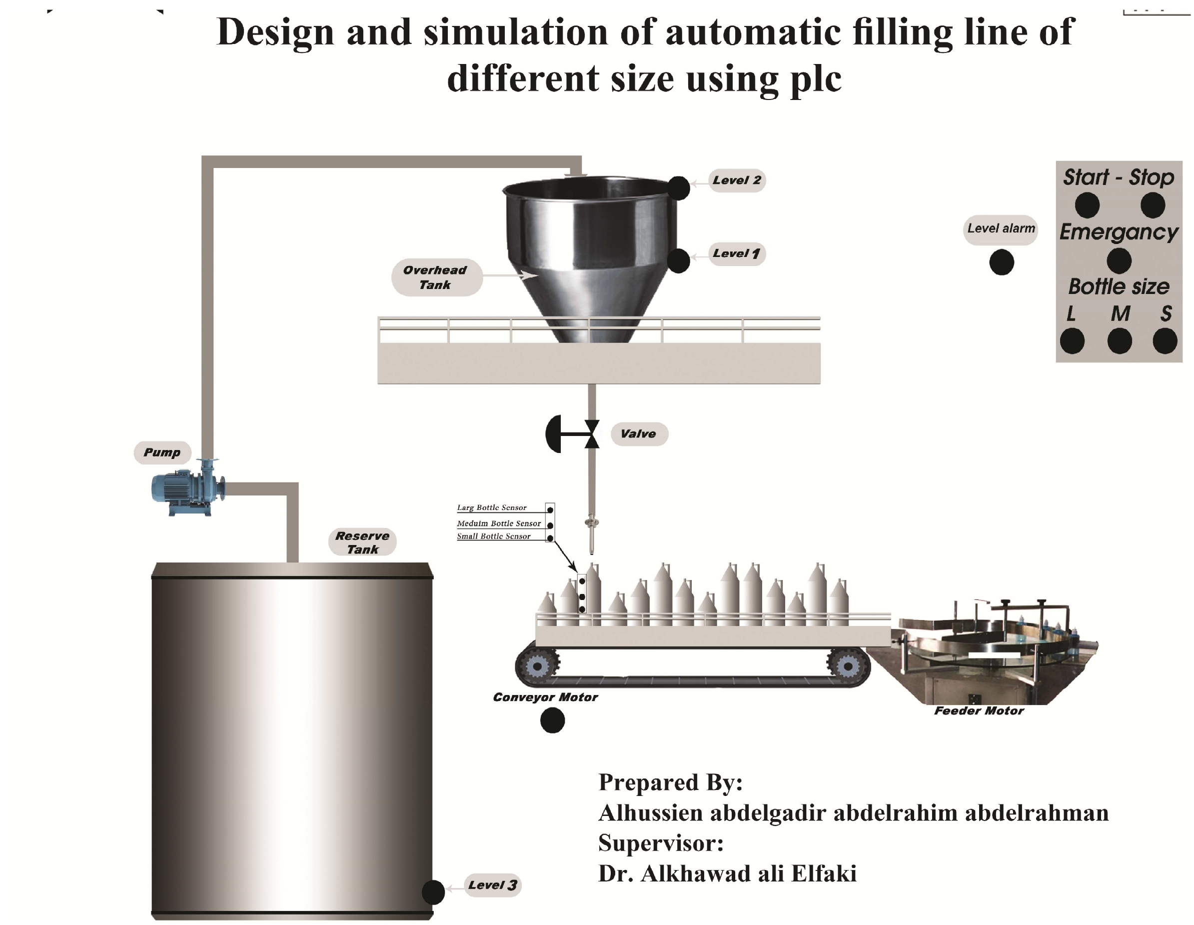


Figure 4.1: Filling Machine layout

4.2 Filling machine components:

1. Reservoir tank &over head tank:

Normally both tank made from stainless steel and com with different size, which depend of the type of production and the capacity.

In this project the reservoir tank capacity is 2000LTR and the over head capacity is 500LTR, this also depend on customer requirement.

Figure 4.2: Over head tank& reservoir tank

2. Bottle feeding unit:

Turntables are used to feed empty bottle to the conveyor belt, the table diameter is 80 cm and the high is 90cm.we use AC motor to run the table in Circular motion.

Figure4.3: Bottle feeding unit

3. Conveyor system:

A conveyor belt is the carrying medium of a belt conveyor system (often shortened to belt conveyor). A belt conveyor system is one of many types of conveyor systems. A belt conveyor system consists of two or more pulleys (sometimes referred to as drums), with an endless loop of carrying medium—the conveyor belt—that rotates about them. One or both of the pulleys are powered, moving the belt and the material on the belt forward. The powered pulley is called the drive pulley while the unpowered pulley is called the idler pulley. There are two main industrial classes of belt conveyors; Those in general material handling such as those moving boxes along inside a factory and bulk material handling such as those used to transport large volumes of resources and agricultural materials, such as grain, salt, coal, ore, sand, overburden and more. Today there are different types of conveyor belts that have been created for conveying different kinds of material available in PVC and rubber materials.

The belt consists of one or more layers of material. Many belts in general material handling have two layers. An under layer of material to provide linear strength and shape called a carcass and an over layer called the cover. The carcass is often a woven fabric having a warp & weft. The most common carcass materials are polyester, nylon and cotton. The cover is often various rubber or plastic compounds specified by use of the belt. Covers can be made from more exotic materials for unusual applications such as silicone for heat or gum rubber when traction is essential.

Figure 4.4: view of conveyor belt

4. Motors:

The motor or an electrical motor is a device that has brought about one of the biggest advancements in the fields of engineering and technology ever Since the invention of electricity. A motor is nothing but an electro-mechanical device that converts electrical energy to mechanical energy. It's because of motors, life is what it is today in the 21st century. Without motor we had still been living in Sir Thomas Edison's Era where the only purpose of electricity would have been to glow bulbs. There are different types of motor have been developed for different specific purposes. In simple words we can say a device that produces rotational force is a motor. The very basic principal of functioning of an electrical motor lies on the fact that force is experienced in the direction perpendicular to magnetic field and the current, when field and current are made to interact with each other[6].

In this project three phase synchronous servo motor will be used for conveyor belt and for the bottle feeding unit (turntable), synchronous servo motors are ideal for conveyors system where the motor needs to be operated continuously in one direction at synchronous speed regardless of load torque, because of many advantages of this type of motors which are:

a. Power Factor Correction:

Synchronous motors can help to reduce electric energy costs and to improve the efficiency of the power system by supplying reactive energy to the grid they are connected. In a few years, the electric energy savings can pay off the amount invested in the motor.

b. Constant Speed

Synchronous motors are capable of maintaining constant speed operation under overload conditions and/or during voltage variations, observing the limits of maximum torque (pull-out).

c. High Torque Capacity

Synchronous motors are designed with high overload capability, maintaining constant speed even in applications with great load variations.

d. High Efficiency

Synchronous motors are designed to provide high efficiency under a large range of operational conditions providing significant savings with energy costs along its lifetime.

e. Greater Stability in the Operation with Frequency Inverters:

Synchronous motors can operate in a wide speed range, while maintaining stability regardless of load variation (e.g.: rolling mill, plastic extruder, among others) [7].

Figure 4.5 Synchronous servo motor

Rated power is the motor parameter always Specified when motors are selected is a function of five components :

a) The power required to run the system.

b) The power required to horizontally move the load.

c) The power required for vertical lift.

d) The power required for friction from additional equipment such as inside travel rollers.

e) The power required for acceleration.

The usual method used to determine total power required is to multiply the sum of all five components by 1.1 and choose the next largest standard size.

In this project the specification of two motor is 2HP, 140 RPM and 415 VOLT.

5. Motor Pump:

Pumps are used in a wide range of industrial and residential applications. Pumping equipment is extremely diverse, varying in type, size, and materials of construction.

a) Classification of pumps:

Pumps are divided into two fundamental types based on the manner in which they transmit energy to the pumped media: kinetic or positive displacement. In kinetic displacement, a centrifugal force of the rotating element, called an impeller, “impels” kinetic energy to the fluid, moving the fluid from pump suction to the discharge. On the other hand, positive displacement uses the reciprocating action of one or several pistons, or a squeezing action of meshing gears, lobes, or other moving bodies, to displace the media from one area into another (i.e., moving the material from suction to discharge). Sometimes the terms ‘inlet’ (for suction) and ‘exit’ or ‘outlet’ (for discharge) are used. The pumped medium is usually liquid; however, many designs can handle solids in the forms of suspension, entrained or dissolved gas, paper pulp, mud, slurries, tars, and other exotic substances, that, at least by appearance, do not resemble liquids. Nevertheless, an overall liquid behavior must be exhibited by the medium in order to be pumped. The HI classifies pumps by type, not by application. The user, however, must ultimately deal with specific applications. Often, based on personal experience, preference for a particular type of pump develops, and this preference is passed on in the particular industry. For example, boiler feed pumps are usually of a multistage diffuser barrel type, especially for the medium and high energy (over 1000 hp) applications, although volute pumps in single or multistage configurations, with radially or axially split casings, also have been applied successfully. Examples of pump types and applications and the reasons behind implicational preferences will follow [6].

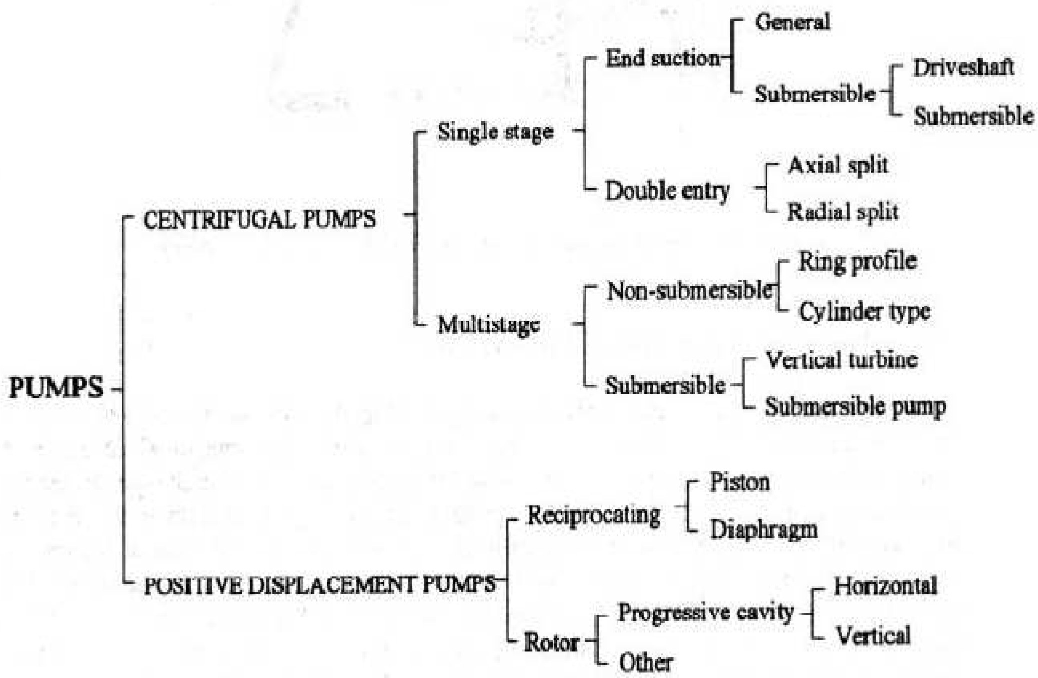


Figure 4.6 Classification of pump

b) selecting a pump for the project:

There is no recipe for the selection of the most suitable pump. Various factors would influence the Selection, but in the end, economics has to be the decisive factor and this would include capital, maintenance, and replacement and energy costs.

In this project a centrifugal pump with 1 HP ac motor will be used to supply the liquid for over head tank.

Centrifugal pumps are a sub-class of dynamic ax symmetric work-absorbing turbo machinery. Centrifugal pumps are used to transport fluids by the conversion of rotational kinetic energy to the hydrodynamic energy of the fluid flow. The rotational energy typically comes from an engine or electric motor. The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radials outward into a diffuser or volute chamber (casing), from where it exits.

Figure 4.7 Ac motor pump

c) Work idea of the centrifugal pump:

Like most pumps, a centrifugal pump converts rotational energy, often from a motor, to energy in a moving fluid. A portion of the energy goes into kinetic energy of the fluid. Fluid enters axially through eye of the casing, is caught up in the impeller blades, and is whirled tangentially and radials out ward until it leaves through all circumferential parts of the impeller into the diffuser part of the casing. The fluid gains both velocity and pressure while passing through the impeller. The doughnut-shaped diffuser, or scroll, section of the casing decelerates the flow and further increases the pressure, figure below show the component of the pump [6].

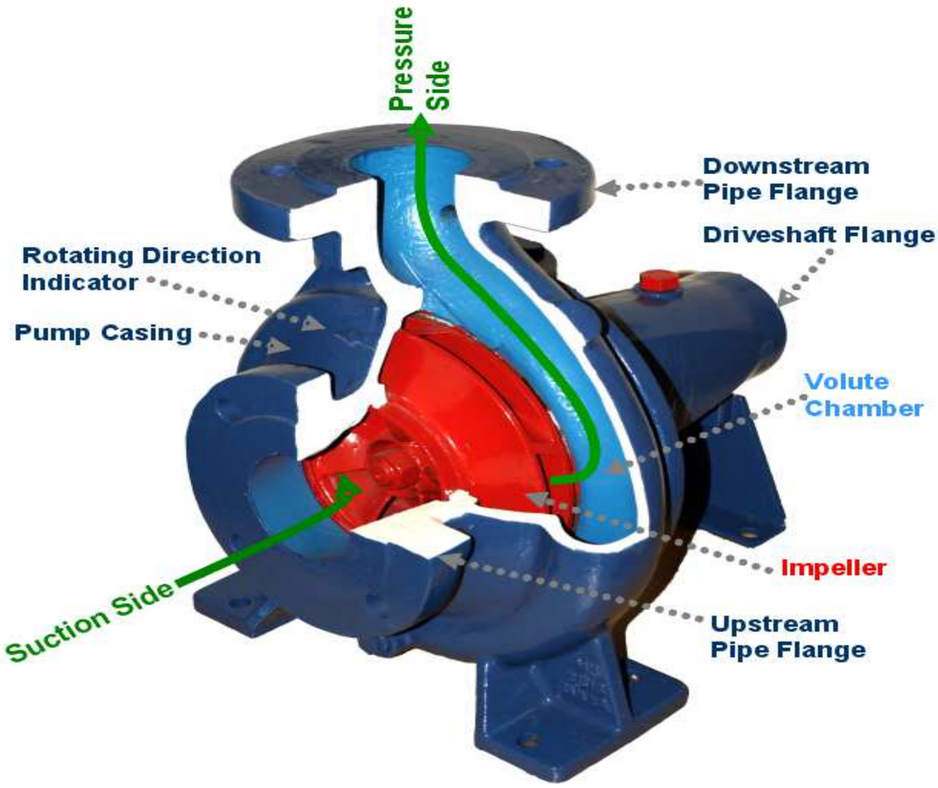


Figure 4.8: Centrifugal pump main component

4.3 Electrical component of the filling line:

1. Relays:

The output of the sensors cannot be given directly to the PLC as the input voltage to the PLC should be 24V. Hence they are given through signal Conditioning circuits which condition the input signals and in turn give it as an input to the PLC. For safety purposes the inputs are not given directly to the PLC. They are given through relay circuits.

A relay is an electrically operated switch. Many relay use an electromagnet to operate a switching mechanism mechanically, but other operating principle are also used relays where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled and circuit), or where several circuits must be controlled by on signal [8].

A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contractor. Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called "protective relays".

Magnetic latching relays require one pulse of coil power to move their contacts in one direction, and another, redirected pulse to move them back. Repeated pulses from the same input have no effect. Magnetic latching relays are useful in applications where interrupted power should not be able to transition the contacts.

Magnetic latching relays can have either single or dual coils. On a single coil device, the relay will operate in one direction when power is applied with one polarity, and will reset when the polarity is reversed. On a dual coil device, when polarized voltage is applied to the reset coil the contacts will transition. AC controlled magnetic latch relays have single coils that employ steering diodes to differentiate between operate and reset commands [8]

Figure4.9: general Relay

Advantages of relays:

- Relays can switch AC and DC.
- Relays can switch high voltages.
- Relays are a better choice for switching large currents (> 5A).
- Relays can switch many contacts at once.

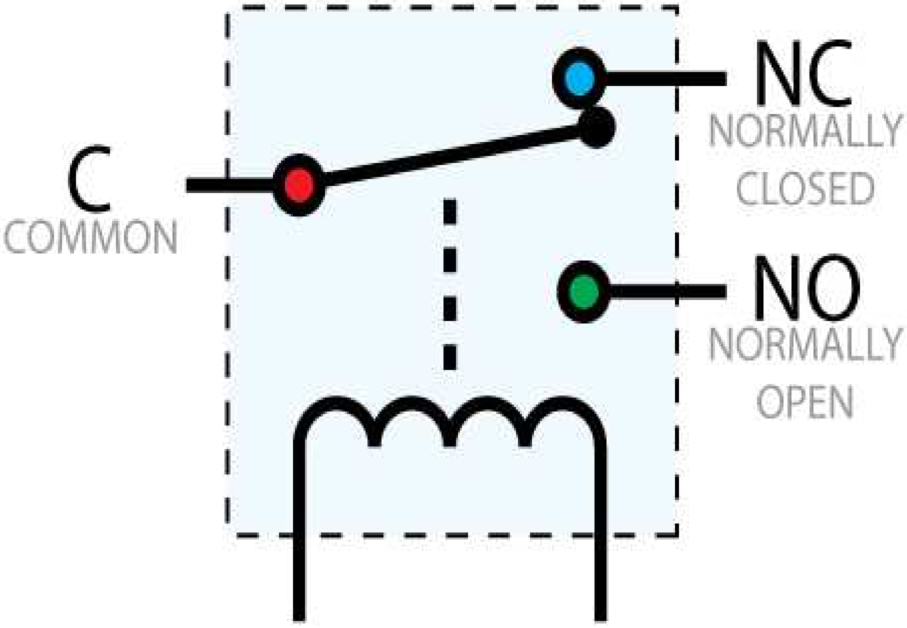


Figure 4.10: RELAY TERNMINALS

The relay's switch connections are usually labeled COM, NC and NO:

- COM = Common, always connect to this; it is the moving part of the switch.
- NC = Normally Closed, COM is connected to this when the relay coil is off.
- NO = Normally Open, COM is connected to this when the relay coil is on.
- Connect to COM and NO if you want the switched circuit to be on when the relay coil is on.
- Connect to COM and NC if you want the switched circuit to be on when the relay coil is off.

How relay works?

The working of a relay can be better understood by explaining the following diagram given below.

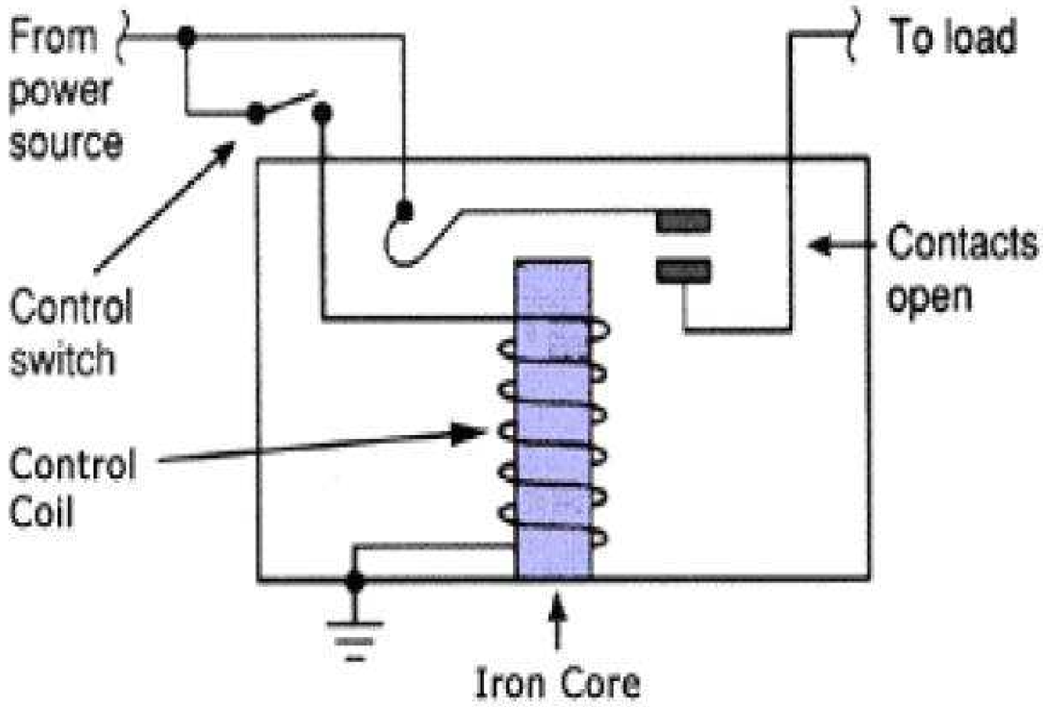


Figure 4.11 Relay design

The diagram shows an inner section diagram of a relay. An iron core is surrounded by a control coil. As shown, the power source is given to the electromagnet through a control switch and through contacts to the load. When current starts flowing through the control coil, the electromagnet starts energizing and thus intensifies the magnetic field. Thus the upper contact arm starts to be attracted to the lower fixed arm and thus closes the contacts causing a short circuit for the power to the load. On the other hand, if the relay was already de-energized when the contacts were closed, then the contact move oppositely and make an open circuit.

As soon as the coil current is off, the movable armature will be returned by a force back to its initial position. This force will be almost equal to half the strength of the magnetic force. This force is mainly provided by two factors. They are the spring and also gravity [8].

2. Solenoid Valve:

A solenoid valve is an electro magnetically controlled mechanical valve used for the ON/OFF (open/closed) or diverting control of liquid or gas media.

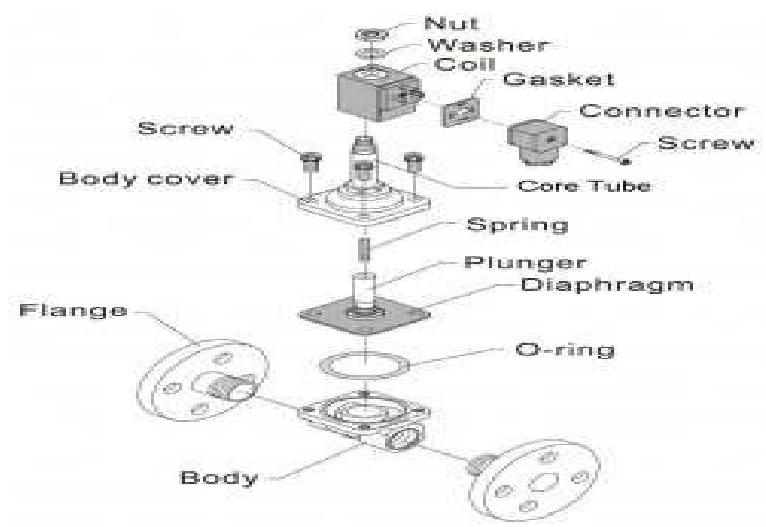


Figure 4.12: Solenoid valve

Most solenoid valves operate on a digital principle. They therefore possess two distinct states, which are (1) when the coil is activated by an electrical current, and (2) when the valve is resting (without electricity).

The solenoid valves may have two functions, normally closed (NC) if there is no Flow across the valve in its resting position (with no current on the Solenoid contacts) and normally open (NO) when it enables fluid to pass in its active position (with current on the solenoid contacts).

The most common solenoid valve is 2/2 solenoid valve or 2 port 2 position solenoid valve with 1 inlet port and 1 outlet port and 3/2 solenoid valve or 3 port 3 position solenoid valve with 1 inlet port ,1 outlet port ,1 exhaust port[9].

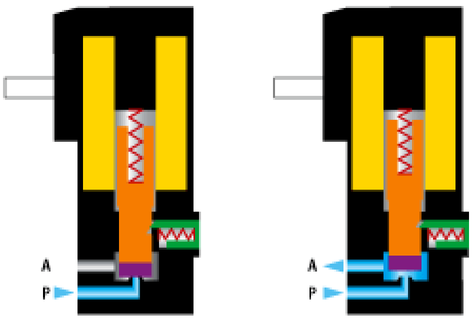


Figure 4.13: 2 way solenoid valve

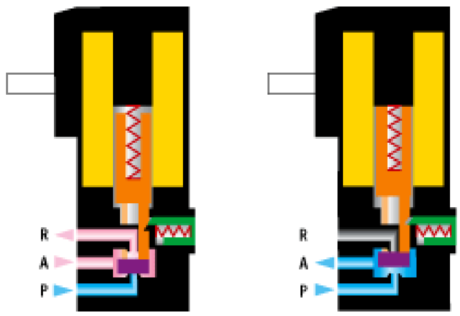


figure 4.14: 3 way solenoid valve

- **Type of operation:**

Solenoid valves can be categorized into different groups of operation.

A. Direct operated:

Direct operated (direct acting) solenoid valves have the most simple working principle. The medium flows through a small orifice which can be closed off by a plunger with a rubber gasket on the bottom. A small spring holds the plunger down to close the valve. The plunger is made of a ferromagnetic material. An electric coil is positioned around the plunger. As soon as the coil is electrical energized, a magnetic field is created which pulls the plunger up towards the centre of the coil. This opens the orifice so that the medium can flow through. This is called a Normally Closed (NC) valve. A Normally Open (NO) valve works the opposite way: it has a different construction so that the orifice is open when the solenoid is not powered. When the solenoid is actuated, the orifice will be closed. The maximum operating pressure and the flow rate are directly related to the orifice diameter and the magnetic force of the solenoid valve. This principle is therefore used for relatively small flow rates. Direct operated solenoid valves require no minimum operating pressure or pressure difference, so they can be used from 0 bar up to the maximum allowable pressure [10].

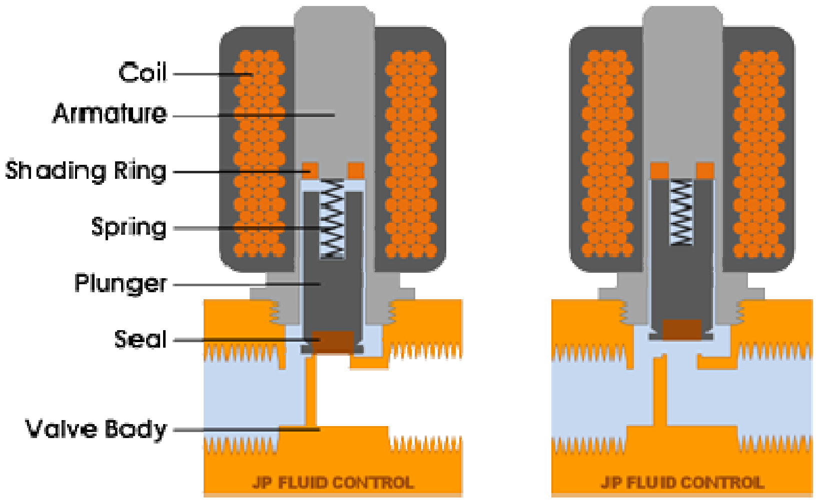


Figure 4.15: direct operated solenoid valve (2/2-way, normally closed)

B. Indirect operated (servo or pilot operated):

Indirect operated solenoid valves (also called servo operated, or pilot operated) use the differential pressure of the medium over the valve ports to open and close. Usually these valves need a minimum pressure differential of around 0.5 bar. The inlet and outlet are separated by a rubber membrane, also called diaphragm. The membrane has a small hole so that the medium can flow to the upper compartment. The pressure and supporting spring above the membrane will ensure that the valve remains closed. The chamber above the membrane is connected by a small channel to the low pressure port. This connection is blocked in the closed position by a solenoid. The diameter of this "pilot" orifice is larger than the diameter of the hole in the membrane. When the solenoid is energized, the pilot orifice is opened, which causes the pressure above the membrane to drop. Because of the pressure difference on both sides of the membrane, the membrane will be lifted and the medium can flow from inlet port to outlet port. The extra pressure chamber above the membrane acts like an amplifier, so with a small solenoid still a large flow rate can be controlled. Indirect solenoid valves can be used only for one flow direction. Indirect operated solenoid valves are used in applications with a sufficient pressure differential and a high desired flow rate, such as for example irrigation systems, showers or car wash systems. Indirect valves are also known as servo controlled valves [10].

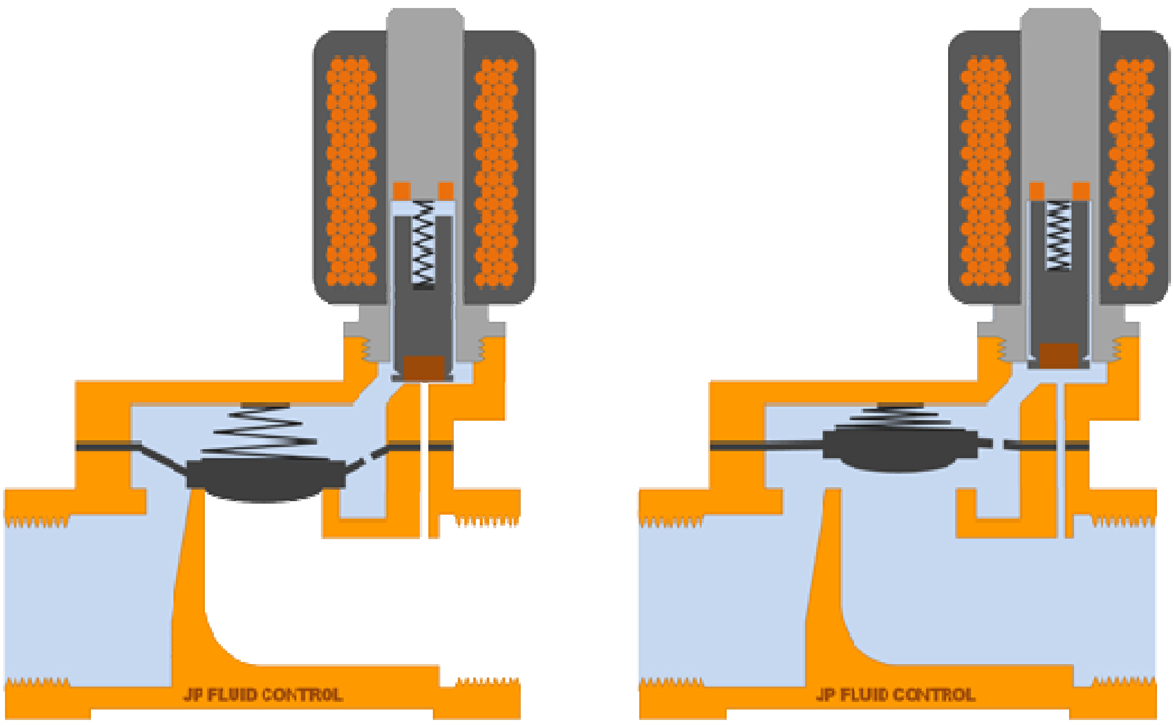


Figure 4.16 indirect operated solenoid valve (2/2-way, normally closed)

C. Semi-direct operated:

Semi-direct operated solenoid valves combine the properties of direct and indirect valves. This allows them to work from zero bar, but still they can handle a high flow rate. They look somewhat like indirect valves and also feature a movable membrane with a small orifice and pressure chambers on both sides. The difference is that the solenoid plunger is directly connected to the membrane. When the plunger is lifted, it directly lifts the membrane to open the valve. At the same time, a second orifice is opened by the plunger that has a slightly larger diameter than the first orifice in the membrane. This causes the pressure in the chamber above the membrane to drop. As a result, the membrane is lifted not only by the plunger, but also by the pressure difference. This combination results in a valve that operates from zero bar, and can control relatively large flow rates. Often, semi-direct operated valves have more powerful coils than indirect operated valves. Semi-direct operated valves are sometimes called assisted-lift solenoid valves [10].

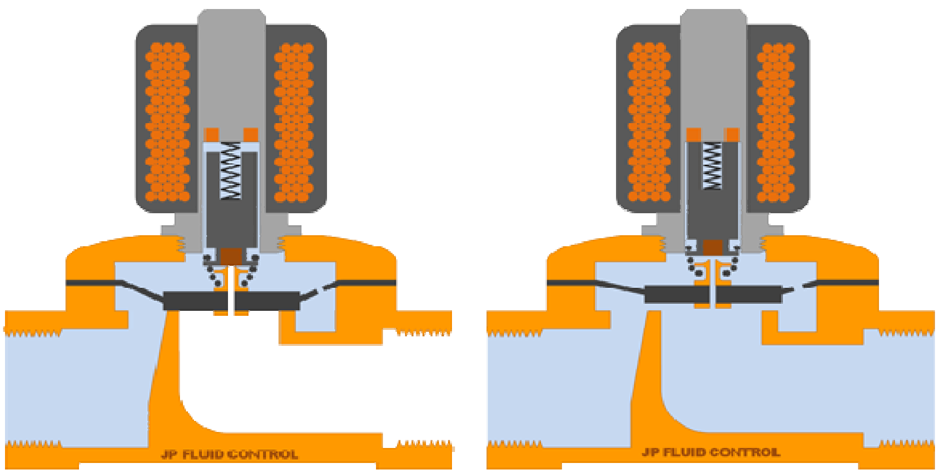
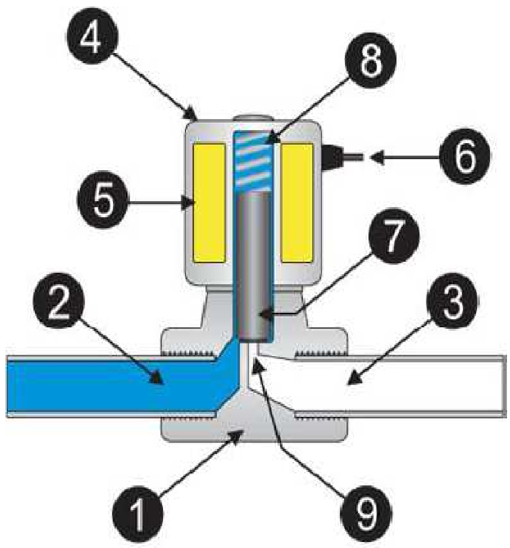


Figure 4.17 semi-direct operated solenoid valve (2/2-way, normally closed)

How does a solenoid valve work?



1. Valve Body
2. Inlet port
3. Outlet port
4. Coil/solenoid
5. Coil windings
6. Lead wire
7. Plunger
8. Spring
9. Orifice

Figure 4.18 working principle of solenoid valve

The media controlled by the solenoid valve enters the valve through the inlet (Part 2 in the illustration above). The media must flow through the orifice (9) before continuing into the outlet port (3). The orifice is closed and opened by the plunger (7).

The valve pictured above is a normally-closed solenoid valve. Normally-closed valves use a spring (8) which presses the plunger tip against the opening of the orifice. The sealing material at the tip of the plunger keeps the media from entering the orifice, until the plunger is lifted up by an electromagnetic field created by the coil.

In this project direct operation solenoid valve with 20mL/S flow rate will be used.

3. Sensors:

A sensor is a device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena. The output is generally a signal that is converted to human-readable display at the sensor location or transmitted electronically over a network for reading or further processing [11].

One type of feedback frequently needed by industrial-control systems is the position of one or more components of the operation being controlled. Sensors are devices used to provide information on the presence or absence of an object.

A. Classification of the sensors:

There are many type of sensor we can use to detect the present of the bottles such as: limit switches, photoelectric, inductive, capacitive, and ultrasonic sensors, the following table show the compare between some types of sensors [12]:

Table 4.1comparing the sensors type

Sensor	Advantages	Disadvantages	Application
Limit Switch	•High Current Capability •Low Cost •Familiar "Low-Tech" Sensing	•Requires Physical Contact with Target •Very Slow Response	•Interlocking •Basic End-of-Travel Sensing
Photoelectric	•Senses all Kinds of Materials •Long Life •Longest Sensing Range •Very Fast Response Time	•Lens Subject to Contamination •Sensing Range Affected by Color and Reflectivity of Target	•Packaging •Material Handling •Parts Detection
Inductive	•Resistant to Harsh Environments •Very Predictable •Long Life •Easy to Install	•Distance Limitations	•Industrial and Machines •Machine Tool •Senses Metal-Only Targets
Capacitive	•Detects Through Some Containers •Can Detect Non-Metallic Targets	•Very Sensitive to Extreme Environmental Changes	•Level Sensing
Ultrasonic	•Senses all Materials	•Resolution •Repeatability •Sensitive to Temperature Change	•Anti-Collision •Doors •Web Brake •Level Control

In this project capacitive proximity sensor will be used.

Figure 4.19: proximity sensor

Capacitive proximity sensors are similar to inductive proximity sensors. The main difference between the two types is that capacitive proximity sensors produce an electrostatic field instead of an electromagnetic field. Capacitive proximity switches will sense metal as well as nonmetallic materials such as paper, glass, liquids, and cloth, Because capacitive sensing involves charging plates, it is somewhat slower than inductive sensing ... ranging from 10 to 50 Hz, with a sensing scope from 3 to 60 mm. Many housing styles are available; common diameters range from 12 to 60 mm in shielded and unshielded mounting versions. Housing (usually metal or PBT plastic) is rugged to allow mounting very close to the monitored process. If the sensor has normally-open and normally-closed options, it is said to have a complimentary output. Due to their ability to detect most types of materials, capacitive sensors must be kept away from non-target materials to avoid false triggering. For this reason, if the intended target contains a ferrous material, an inductive sensor is a more reliable option.

B. Working principle:-

The figure below show how the capacitive sensor works, the sensing surface of a capacitive sensor is formed by two concentrically shaped metal electrodes of an unwound capacitor. When an object nears the sensing surface it enters the electrostatic field of the electrodes and changes the capacitance in an oscillator circuit. As a result, the oscillator begins oscillating. The trigger circuit reads the oscillator's amplitude and when it reaches a specific level the output state of the sensor changes. As the target moves away from the sensor the oscillator's amplitude decreases, switching the sensor output back to its original state [13].

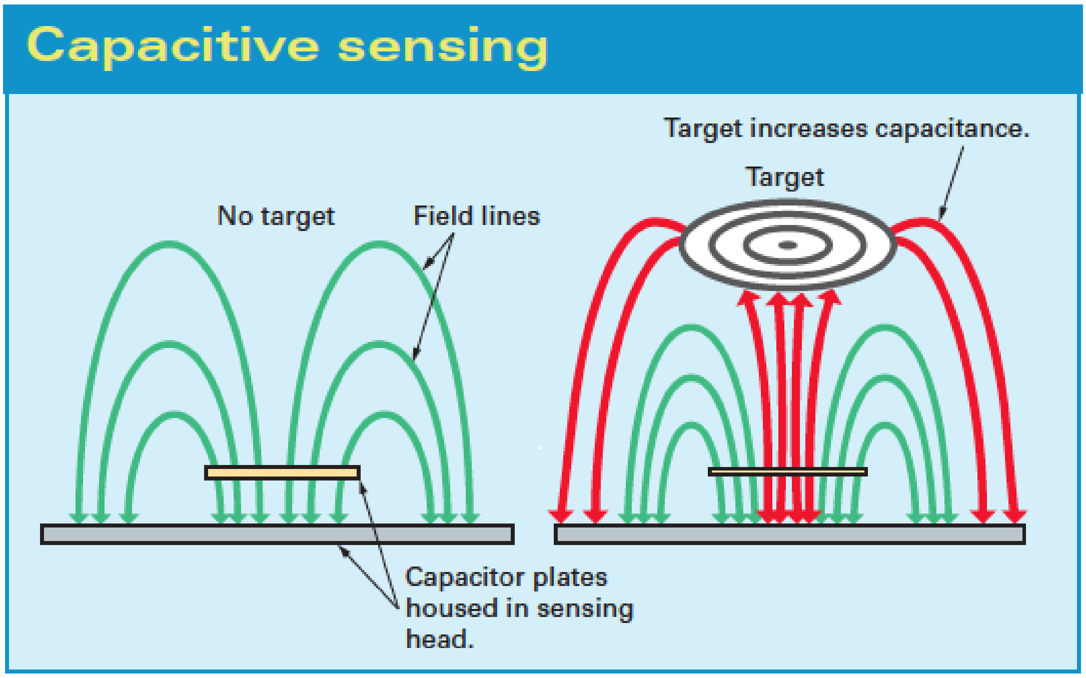


Figure 4.20 capacitive sensor principle of work

C. Wiring of sensor:

This sensor is PNP type, it has three wires first wire vcc is connected to the DC 24v, and Enable wire is output of the sensor, it is connected to the input of PLC and the third wire is ground.

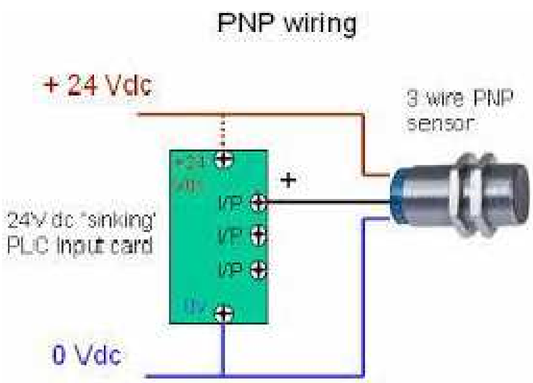


FIG 4.21 Wiring connection of Sensor to PLC

4. Liquid level switches:

Liquid level switches detect liquid levels or interfaces between liquids such as oil and water, or liquid and solid interfaces. Liquid level switches are used in a number of liquid container monitoring applications including flow line monitoring, heaters and furnaces, as well as other household appliances, automotive applications, and control technology [14].

Figure 4.22 liquid level switch

In order to select the proper liquid level switch, it is important to understand the various factors of a liquid level management system. The switch is a critical element in the system and when selecting a switch it is important to consider the type of measurement, the switch type, the configuration, and the pole and throw specifications [14].

In this project Electromechanical switches will be used, it has mechanical contacts or relays. These types of switches can control a wider range of current and voltage options. They are not affected by dirt, mist, magnetic fields or temperature ranges from near absolute zero to 1000°.

Electric circuit requires a normally open and normally closed switch, which show in figure 3.23:

- Normally open (NO) switches do not allow current to pass through in the free position. They need to "make" a contact to be activated, so we use it to indicate the maximum liquid level in the over head tank.
- Normally closed (NC) switches allow current to pass through in the free position and need to "break" contact (open) to be activated, so we use it to indicate the minimum liquid in the over head tank and reservoir tank

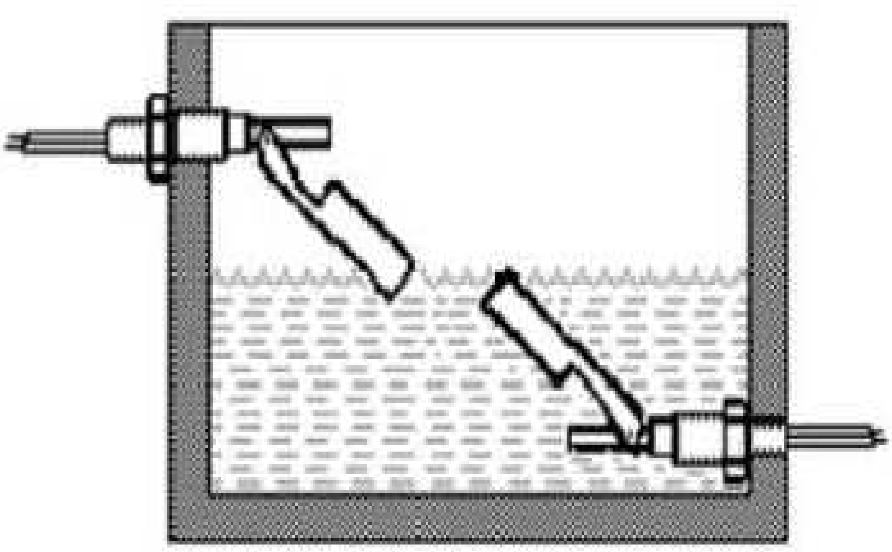


Figure 4.23 operation of the level switches

4.4 Assignments of inputs and outputs:

All external input and output devices connected to the PLC must be determined and assigned the number corresponding to the input and output number. Tables 4.2 , 4.3 and 4.4 shows the assignment of inputs, outputs and instructions.

Table 4.2 Assignment of the input

Name	**Address**
Start push button	I0.0
stop push button	I0.1
Emergency push button	I0.2
Level liquid switch(L1)	I0.3
Level liquid switch(L2)	I0.4
Level liquid switch(L3)	I0.5
Sensor 1 for minimum size	I0.6
Sensor 2 for medium size	I0.7
Sensor 3 for maximum size	I1.0

Table 4.3 Assignment of the output

Name	**Address**
Pump 1	Q0.0
Motor 1	Q0.1
Motor 2	Q0.2
Solenoid valve	Q0.3
Alarm	Q0.4

Table 4.4 instruction

Name	Address
Main relay	M0.0
Minimum bottle size relay	M0.1
Medium bottle size relay	M0.2
Maximum bottle size relay	M0.3
Filling timer	T5

4.5 Process flow chart:

The general flow chart of the sequences of operation is shown in Figure 4.24 and figure 4.25.

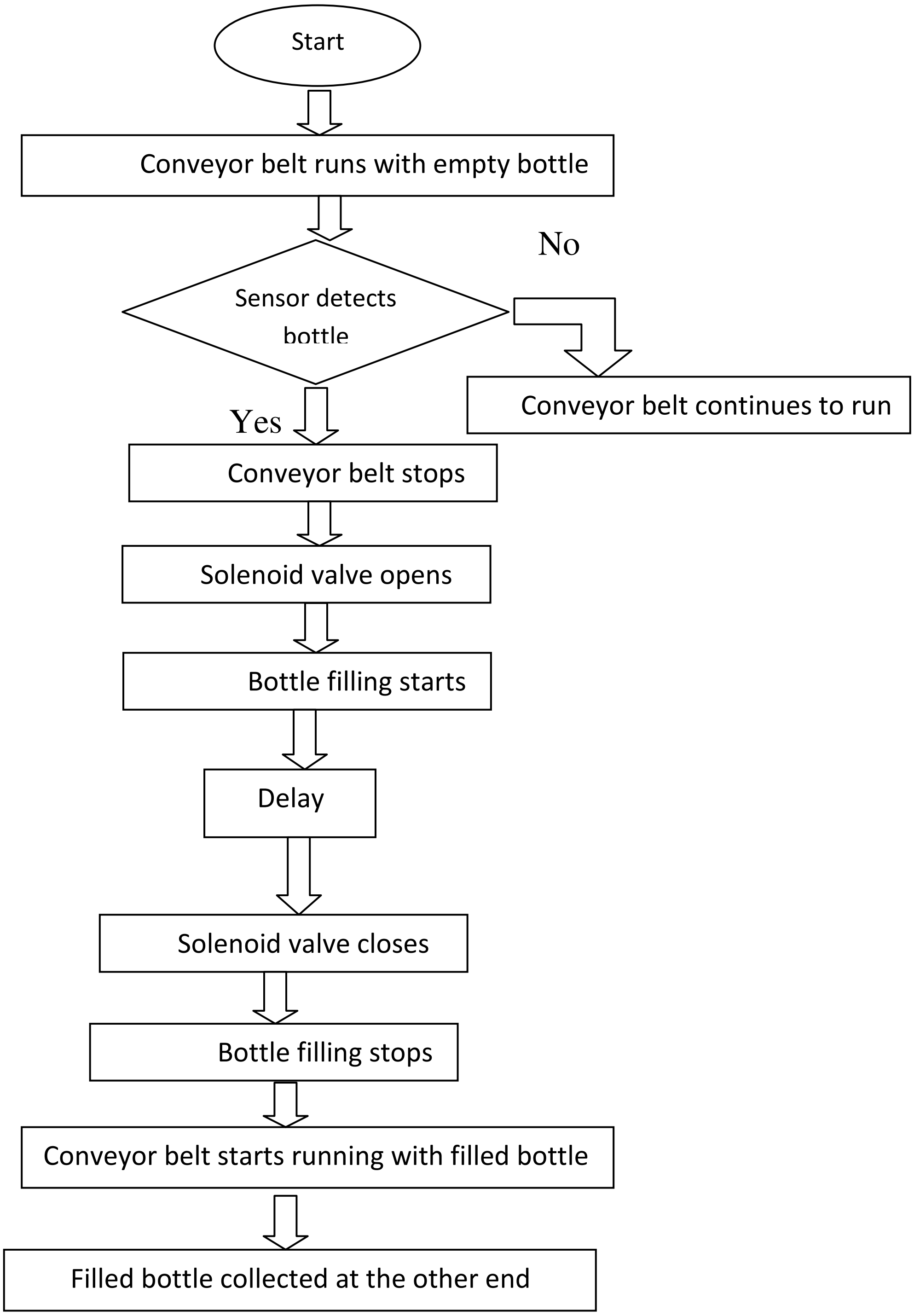


Figure 4.24: Flow chart for bottle sensing and filling system

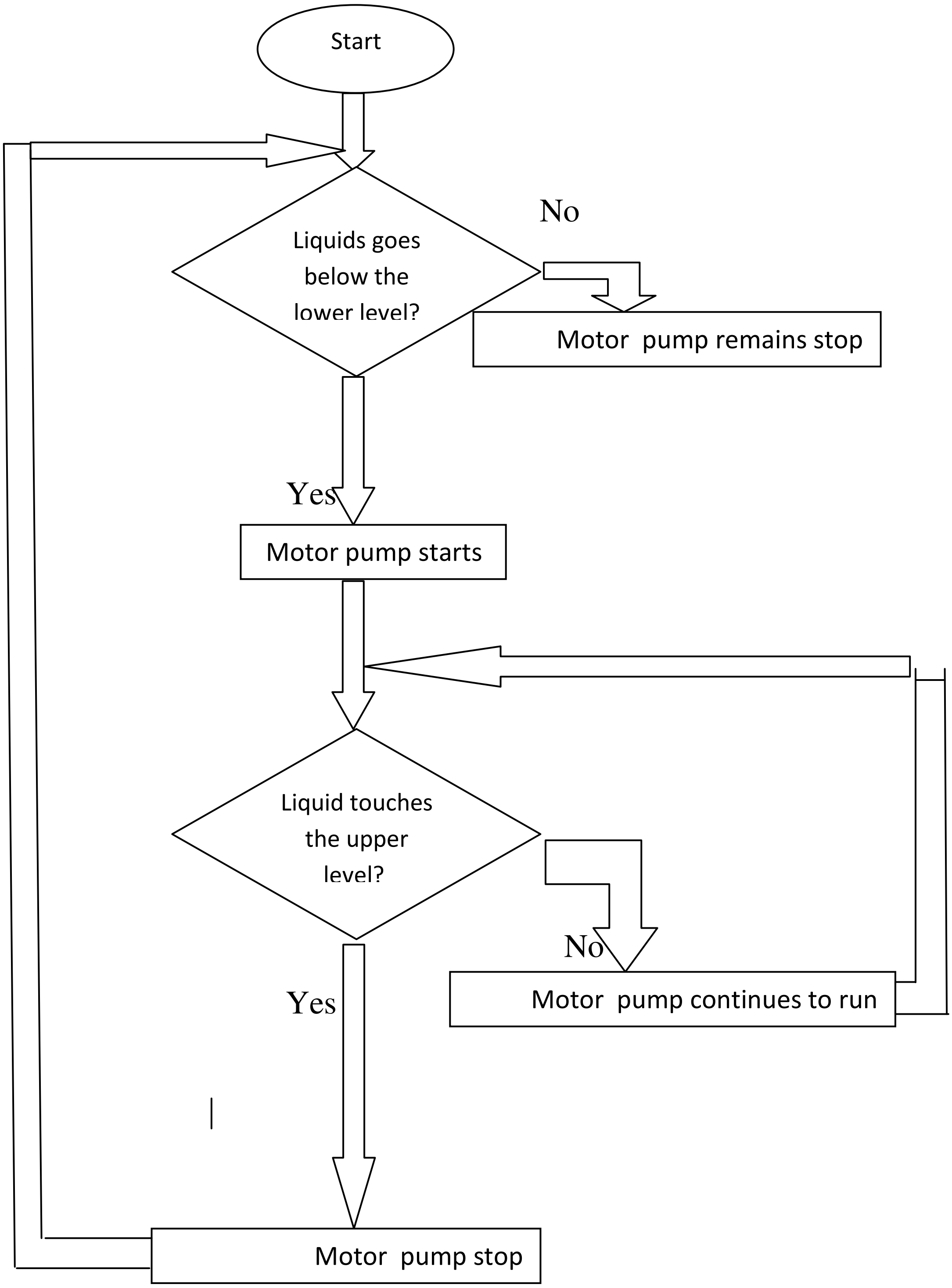


Figure 4.25: Flow chart for maintain liquid level at the overhead tank.

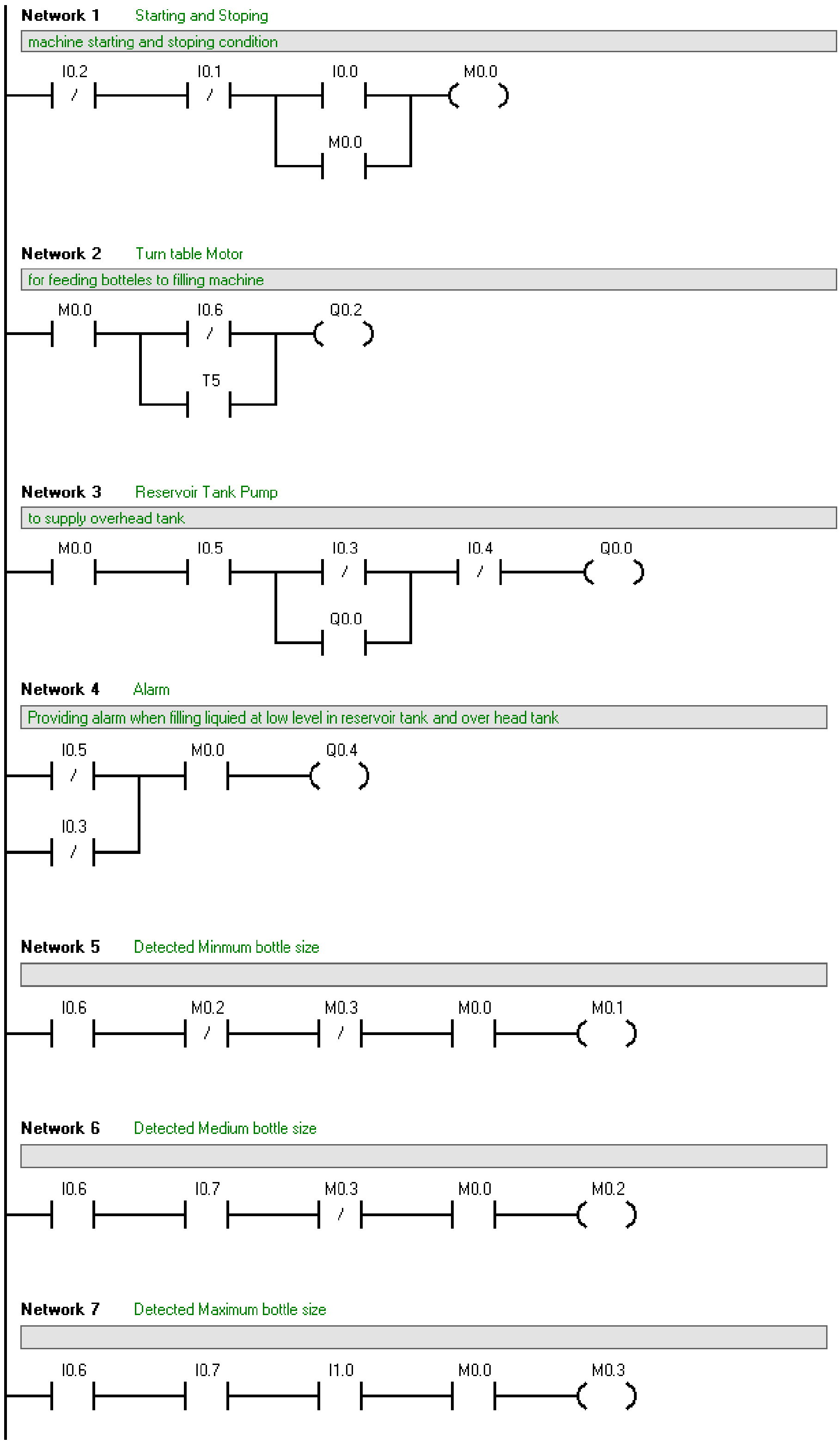
Figure 4.24 shows the flow chart of the bottle sensing and filling system. When the system is powered on, the conveyor belt starts running. The conveyor belt keeps running if the capacitive sensors do not detect the presence of any bottle in front of it. If the sensor detects any bottle then the conveyor belt stops, solenoid valve opens and bottle filling starts. We control the amount of liquid filling with a timer. Depending on the size of the bottle (minimum, medium or maximum) timer's time duration, the opening of the valve is decided. The solenoid valve then closes and conveyor belt starts again with the filled bottle and carries the bottle to the other end where the bottle is collected by an attendant.

Figure 4.25 shows the flow chart of liquid level control at the overhead tank. As we need to control the liquid level at the overhead tank, leveling switches are used. When the liquid goes below lower level, the motor pump starts pumping liquid from the main reservoir to the overhead tank. When the liquid touches upper level, motor pump stops to prevent overflow of liquid at the overhead tank. If the liquid doesn't touch the upper level, the motor pump remains on.

4.6 ladder diagram of the system:

Every PLC manufacturer provides their own software interface to program the PLCs. The software provided by Siemens Corporation is named 'Simatic Step7- 200'. This software will be used in this project.

Normally Open and Normally Close type LAD contacts will be used which correspond to the physical contact signals from different sensors and level switches of the project and are directly wired to the "*I*" (input) terminals on the PLC. Several LAD output coils have also been used, which contain the memory identifier "*Q*". The output signals for the motors, pump and valve are wired to the "*Q*" terminals of the S7-200. In RUN mode, the CPU system continuously scans the input signals, processes the input states according to the program logic, and then reacts by setting new output state values in the process output register. Moreover, we needed to use “timer (T5)” as well as “On-delay timer (TON)” to create programmed time delays. The pulse timer generates a pulse with a preset width time and the On-delay timer output is set to ON after a preset time delay.



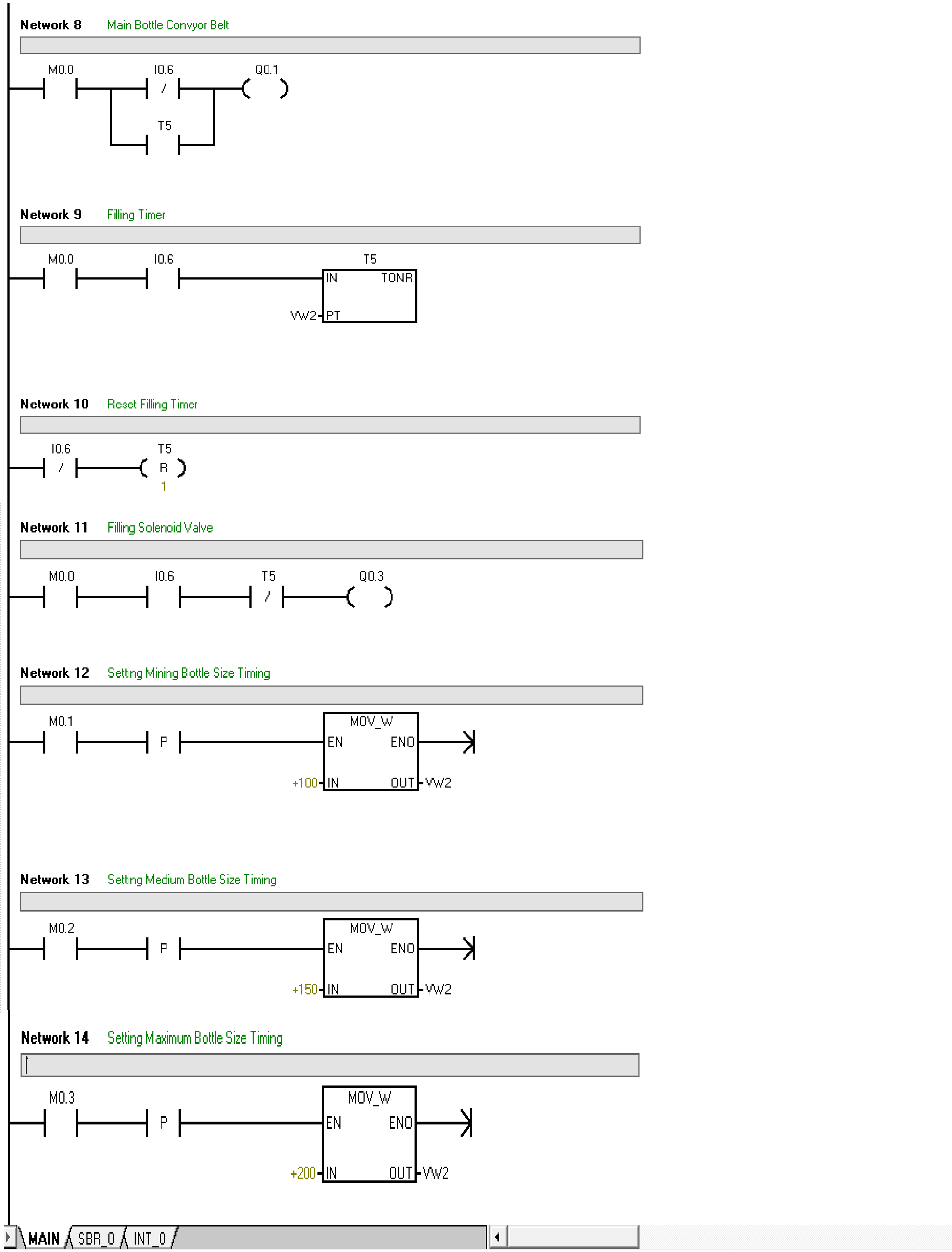


Figure 4.26: ladder diagram

Figure 4.26 shows the ladder diagram of the program. The control logic implemented through each of the rungs of the ladder diagram has been explained below:

- The net work (1) and net work (2) indicate the control logic to start the system, the system continues to run as long as the proximity sensors and solenoid valve status stored at the bit address "I0.6" , "I0.7" , "I1.0" and "Q0.3" is low, that means there is no bottle in the filling section.
- The lower and upper liquid level switches outputs are connected to the input ports of the PLC with addresses I0.3, I0.4 and I0.5 respectively. The net work (3) of the ladder diagram indicates that both " I0.3" and "I0.4" LAD contacts are normally closed type that enables the motor pump(Q0.0) to operate as long as the upper level sensor does not come in contact with liquid. When the liquid level in the overhead tank crosses the upper level sensor the LAD contact addressed " I0.4" *breaks* and this cause to stop the pump. Also the level liquid switch in the reservoir tank "I0.5" lad contact is normally open this make the pump not run if there is no liquid in the reservoir tank , this for pump safety.
- In The net work (4) both "I0.5" and "I0.3" lad contact addresses are normally closed and this to indicate the minimum level of the liquid in the over head and reservoir tank and when the level of the liquid riche to its lower level this cause of alarm.
- The minimum ,medium and maximum bottle size capacitive sensors outputs are connected to the input ports of the PLC with addresses "I0.6" ,"I0.7",and "I1.0" respectively .The net work (5) detect the minimum bottle size, the "I0.6" lad contact is normally open . Net work (6) detect the medium size of the bottle there for "I0.6" and "I0.7" are normally open.Net work (7) detect the maximum size of the bottle there for "I0.6" ,"I0.7" and "I1.0" are normally open.

- The net work (8) indicates the control logic to stop the conveyor belt. The conveyor belt continues to run as long as the capacitive sensor output status stored at the bit addresses "I0.6 is low. If the bit logics in this address becomes high the conveyor belt stops. This situation occurs if the capacitive sensor detects the presence of the bottle.
- Net work (9) for the filling timer (T5), the timer uses a structure stored in a data block to maintain timer data..Net work (10) for timer reset and this happen when the "I0.6" is change its status whish indicate that the filling operation complete and there is no bottle in filling section.
- The net work (11) shows the control logic to open or close the solenoid valve. The solenoid valve opens on the condition that the capacitive sensor with address "I0.6" is detecting bottle and it remains open for few seconds which set by the T5 timer.
- The net work (12) for the minimum bottle size time which is take 10sec to fill bottle with 200mL , net work (13) for the medium bottle size time which take 15 sec to fill bottle with 300mLand net work (14) for the maximum bottle size time which take 20 sec to fill bottle with400mL.the filling time is stored in a variable word address (VW2) which use by the timer (T5) to execute the process.

4.7 Wiring of the system:

One of the many advantages to using a PLC/PAC is the simplicity of the I/O wiring.

I/O devices are wired to I/O points on a fixed I/O unit and to I/O modules in a modular unit. Input devices such as switches, pushbuttons and sensors are wired to input module points and output devices such as indicator lights, solenoids and motor starter coils are wired to output module points. I/O modules can accept Acv, DCV or a combination of ACV and DCV. Most modern automation systems use DCV I/O.

Figure 4.2 shows the warring of the project, the output power of the PLC is just 24V DC but we have to operate AC motor which requires 380V AC, in order to supply it, we are using the relays. It operates at 24V DC, the common of the relay is connected to phase of supply and motor is connected to NO in series with neutral. the input device include one push button to start the system ,one push button to stop the system ,emergency stop push button, three level liquid switches (level liquid switch1, level liquid switch2, level liquid switch3) and three capacitive sensor (sensor1, sensor2, sensor3) these are connected to the input modules of the PLC .

The various output devices used in the system are motor pump, motor 1 for conveyor belt, motor 2 for turn table, alarm and solenoid valve.

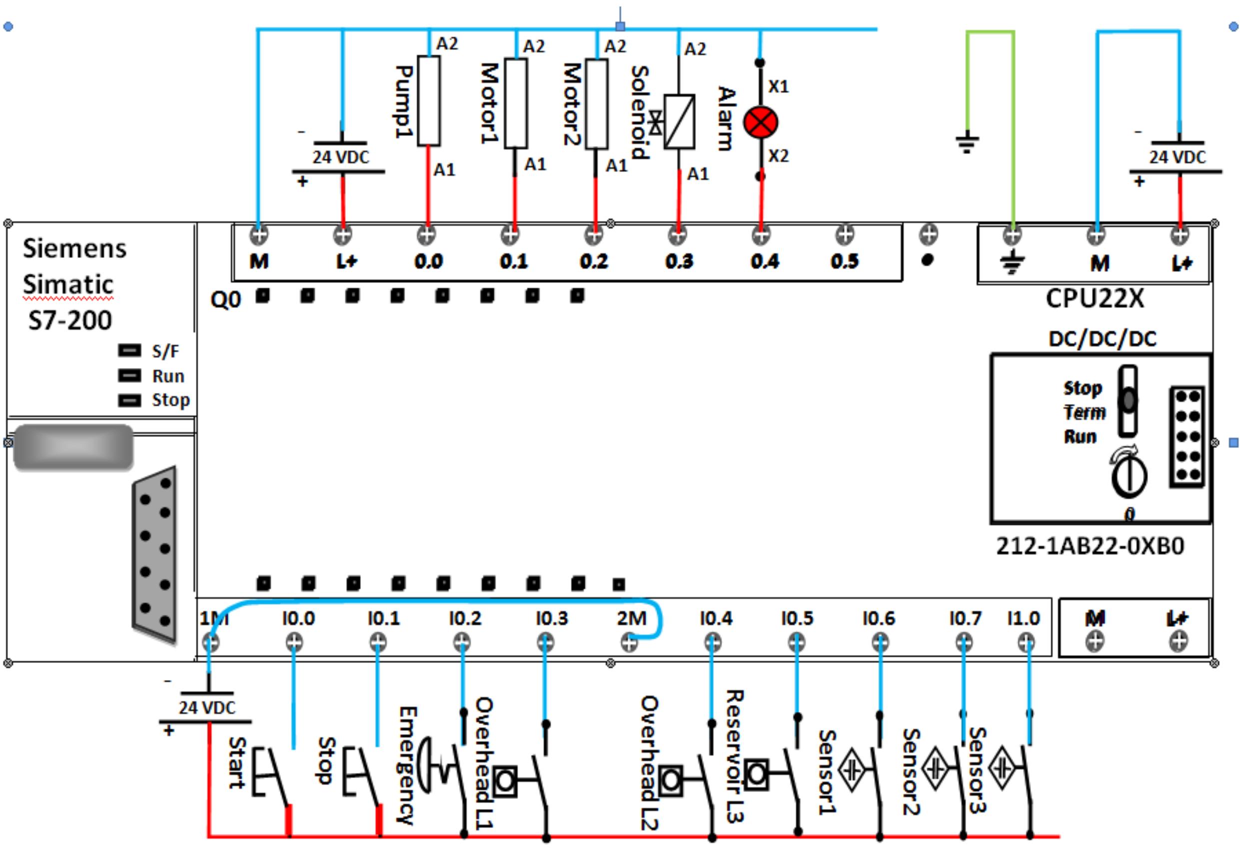


Figure 4.27: wiring diagram

Chapter Five

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusions:

An Automatic filling line of different size system using PLC has been successfully designed and simulated by applying all the concept of control system at this project.

The present system will provides a great deal of applications in the field of automation, especially in mass production industries where there are large number of components to be processed and handled in a short period of time and there's need for increased production. The programming to this system developed is flexible, quickly and easily. This will increase the total production output; this increase in production can yield significant financial benefits and savings. This concept can be used in beverage and food industries, milk industries, medicine industries, mineral water, chemical product industries and manufacturing industries.

5.2Recommendation:

This project depend on the high of bottle to determine the filling time so in the future studies can be kept in mind the width, shape and weight of the bottle, also can be increased the number of filling nozzles to Increase production. Two moving handle can be added to the system in the filling section ,one before the solenoid valve and the other after the solenoid valve to control the movement of bottles during the filling process to make sure that the bottle exactly in the filling section under the solenoid valve on the filling process start to avoid any wastage in liquid.

This project involves the filling process of liquid, overhead tank system and the water pump system. But these are only a part of the total system. There are additional operations like bottle capping system, automatic packaging or labeling system, monitoring system etc.

- Bottle capping system: This system facilitates the bottle capping after the liquid is filled. A stepper motor operated capper can be used for bottle capping depend of the bottle size.
- Robotic arm system: This system can be used to move and place a bottle to a required position. It can be used in both placing the bottle on the conveyor belt and removing from the conveyor belt to the packaging system, the selection of the bottle depending of the bottle size.
- Packaging system: To box a particular number of bottles the packaging system can be used. This system can be facilitated by the help of robotic hand.
- Monitoring system: Several monitoring systems can be placed in this project to monitor the number and sensing of bottle, quantity of liquid in the bottle etc.
- Today design in the third world and the Middle East are based on the current technology which is used the microcontrollers only in robotics applications not widely used in the harsh factory floor, but in counters like Japan and Canada and USA, a new technology is taken place, by using a special technique to make the microcontrollers fit in a harsh industrial environment by cover the microcontroller with a shield to isolate it from the electrical noise, to make sure it well perform perfectly .so can Use the microcontrollers as a heart of the automation systems instead of PLCS .

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