Sudan University of science and technology
College of post graduate student

Design of an Automatic Batching system for Hyper Glass Cleaner Using Programmable Logic Controller

تصميم منظومة رصف أوتوماتيكيلمنظف الزجاج المفرط بإستخدام المتحكمات المنطقية القابلة للبرمجه

A research submitted in partial fulfillment of the requirements

Of the degree of M.Sc in mechatronic Engineering

Prepared By:

Mohied Mohamed Toum Mohamed

Supervisor:

Dr. Alaa Alden Awouda

February 2016

أ لآيــه

قال الله تعالى :

أعوذُ بالله من الشيطان الرجيم

(قَــالُــوا سُبْـحَـانَـك لاَ عِـلْـمَ لَــنَــا إِلّاَ مَــا عَـلّـمْـتَـنَـا إِنّـكَ أنــتَ الْــعَـلِـيـمُ الْــحَـكِـيـمُ)

صدق الله العظيم

سورة البقره الآيه 32

الإهداء

الى كل من اضاء بعلمه عقل غيره

وهدىبالجواب الصحيح حيرة سائليه

فاظهر بسماحتة تواضع العلماء

وبرحابته سماحة العارفين

اهدى هذا العمل المتواضع الى ابى الذى لم يبخل على يوماً بشئ

والى أمى التى زودتنى بالحنان والمحبة

واقول لهم انتم وهبتمونى الحياة والامل والنشأة على شغف الاطلاع والمعرفة ..

والى اخوتى واسرتى جميعاً.

ثم الى كل من علمنى حرفاً اصبح سنا برقه يضئ الطريق امامى ..

Acknowledgement

All our thanks to our lord. Thanks to the supervisor Dr. Ala EldeenAwouda for anything he gave me, his experience, his grate helps and his motivation, special appreciation for his guidance.

To my family and my friends, those who supported me. To my brothers Mohammed, Hossam, Mojtaba. For their efforts and support.

Finally, and with great love, my thanks to my wife, for putting up with me so many hours.

BSTRACT

Nowadays, the application of Programmable logic controller (PLC) is widely known and used in this digital world. PLC's application is obviously applied at the industrial sector. Normally, the PLC's that have been used at the industrial field is usually to control a mechanical movement either of the machine or heavy machine in order to create an efficient production and accurate signal processing. In this project, a discussion about PLC application will be explained in more details. Whereby, the aim of this project is to install a new Automated batching system using PLC [SIEMENS (step_7)], which acts as the heart of the system. The operations system sequence is designed by ladder diagram and the programmed by using (SIMATIC STEP 7 v5.4 + sp3) software, and for supervisory control and data Acquisition (SCADA) by using SIMATIC WinCC v5.1. Limit switches is widely used in daily activities such as position detection and other purposes. In this project, limit switches is used to detect the position of the automatic valves. There is four control valves in this project, which is used to control the fluids flow, three pumps to deliver the fluids inward and outward the mixer tank and Agitator to make the mixer tank blending for a given time. Besides that, the electronics and electric devices that usually been controlled by the PLC are like indicator light and the others devices.

المستخلص

في العالم المعاصر، اصبحت المتحكمات المنطقية القابلة للبرمجة من اكثر التطبيقات المعروفة والمستخدمة في هذا العالم الرقمي وهو تطبيق يستخدم بالذات في المجالات الصناعية. وفي أغلب الاحيان تستخدم المتحكمات المنطقية القابلة للبرمجة في عالم الصناعة للتحكم في الحركة الميكانيكية للأليات سواء كانت أليات خفيفة او ثقيلة وذلك لتحسين الكفاءة الانتاجية و لضمان الدقة المطلقة في تنفيذ كافة العمليات الانتاجية.

في هذا البحث تم تسليط الضوء علي تطبيق (المتحكمات المنطقية القابلة للبرمجة) وتمت مناقشته بصورة مفصلة ودقيقة، بجانب أن الهدف الاساسي من هذا البحث هو انشاء منظومه تحكم متكامله للتحكم في مصنع بأستخدام احد المتحكمات المنطقية القابله للبرمجه من شركه (سيمنس ستيب7) ، والذي سوف يعمل كقلب لهذه المنظومه، برنامج تشغيل المنظومه سيتم تصميمه بأستخدام لغه المخطط السلمي ، وسوف يكون برنامج التصميم بطبيعه الحال كذلك من شركه سيمنس. وسوف يستخدم كذلك برنامج التحكم الاشرافي وجمع البيانات لزياده وتسهيل امكانيه التحكم في المنظومه اثناء العمليه الانتاجيه ، وذلك ايضا بإستخدام منتج اخر من منتجات شركه سيمنس. ولإكمال بقيه عناصر منظومه التحكم لابد من إستخداممفاتيح الضغط ومفاتيح من النوع الحدي وهي تعمل كعناصر إدخال بالنسبه لهذه المنظومه وتستخدم لتحديد الموقع بالنسبه لبعض الاليات ، وفي هذا البحث تستخدم لتحديد موقع الصمامات الاوتوماتيكيه وهي عباره عن صمامات تستخدم للتحكم في سريان الماء والسوائل الاخري في هذه المنظومه ، وتوجد كذلك طلمبات لتوفير القوة اللازمه لدفع مختلف السوائل في هذه المنظومه من وإلي حوض الخلط الرئيسي ، ويوجد ايضا محرك كهربي متصل بخلاط لضمان خلط الخليط بصوره متجانسه . إلي جانب مختلف الاجهزه الالكترونية والكهربائية التي يتم التحكم بها بواسطه (المتحكمات المنطقية القابلة للبرمجة) ، مثل لمبات البيان وغيرها من الاجهزة.

TABLE OF CONTENTS

ListofTables

List of Figures

List of abbreviations

PLC	:	Programmable Logic Controller
SCADA	:	supervisory and data acquisition
CPU	:	central processing unit
MAP	:	manufacturing automation protocol
STEP	:	Siemens Technical education program
DI/ DO	:	Digital Input, Digital Out But
AI/AO	:	Analog Input/ Analog out Put
PS	:	Power supply
IM	:	Interface Module
PID	:	proportional integral divertive
MPI	:	Multi-Point Interface
Profibus	:	process field bus
Rs	:	Recommended standard
MTBF	:	Mean Time between Failures
HI	:	Hydraulic Institute
ANSI	:	American National Standards Institute
PNP	:	(positive-negative-positive) sourcing
NPN	:	(negative-positive-negative) sinking
LED	:	light emitting diode

CHAPTER ONE

INTRODUCTION

Introduction

1.1 Overview:

Industrial automation is the use of control systems to control machines and processes, reducing the need for human intervention, this made the production rate constant and almost error free.

If we compare a job being done by human and by automation, the physical part of the jobs 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.

Control engineering has evolved over time. In the past humans were the main method for controlling a system. 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 development of low cost computer has brought the most recent revolution, the Programmable Logic Controller (PLC). The advent of the PLC began in the 1970s, and has become the most common choice for manufacturing controls [1].

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:

- Cost effective for controlling complex systems.
- Flexible and can be reapplied to control other systems quickly and easily.
- Computational abilities allow more sophisticated control.

- Troubleshooting aids make programming easier and reduce downtime.
- Reliable components make these likely to operate for years before failure.
- With the invention of PLCs process controlling became easier, and productivity increased noticeably.

This project is based on the water purification. To make water more acceptable for a desired end-use. These can include use for drinking water, industry, medical and many other uses.

The goal of all water treatment process is to remove existing contaminants in the water, or reduce the concentration of such contaminants so the water becomes fit for its desired end-use. One such use is returning water that has been used back into the natural environment without adverse ecological impact.

All the process is described and the ladder logic design based upon these process.

So there is three ingredients water and other two ingredients areadded in specified time to the mixing tank. After all the ingredients have been added to the mixing tank, the mixture is blended by running the agitator for a given time. When the blending time is complete, the finished product is pumped to the filling lines.

There are eight limit switches will have implemented in this project. There are four control valves in this project, which is used to control the fluids flow, three pumps to deliver the fluids inward and outward the mixer tank and Agitator to make the mixer tank blending for a given time.

1.2 Problem Statement:

Manual control system is implemented to control the system. Which defined as the overall actions related to control the processes are taken by operators.

When using manual control systems, we usually confronted with some issues such as:

The production, safety, energy consumption and usage of raw material are all subject to the correctness and accuracy of human action. Likely human errors affect quality of the final product.

A case study considering a water treatment plant for producing hyper glass cleaner. This process is mainly conducted by mixing three ingredients ex. (water, alcohols and glycol ethers…etc.) each one is placed in a separate tank and the final solution is pumped to the filling lines.

This plant is totally manually controlled. Control valves is used to control the flow of the fluids. Three pumps deliver the fluids inward and outward the mixer tank and an agitator to make the mixer tank blending for a given time. So the ingredients (water, other two selective ingredients) are manually added in specified time to the mixing tank. After all the ingredients have been added to the mixing tank, the mixture is blended by running the agitator for a given time. When the blending time is completed the finished product is pumped into the filling lines.

1.3 Project Objective:

The main objective of this project is to apply plc to design automatic mixing system. To drive the main objective there are several supporting goals need to be achieved as listed below:

- To design a closed-loop system which can control adding and mixing the ingredients which are used.
- To make sure that valves does open at the wright time to insure delivery of the ingredients to the mixer.
- Limit switches which insure that the valves do opens or closes.
- To maintain an automatically and continuous flowrate into the filling lines.

1.4 Methodology

Hardware components such as PLC (SIMATIC S7-300), limit switches, valve, pumps and agitator will be used to build the Automatic batching system. Software programs such as (SIMATIC STEP 7 v5.4 + sp3) will be used to write a program (ladder diagram) to direct and control the system and SCADA software by using SIMATIC WinCC v5.1.

1.5 Research Outlines

- In this project, six chapters will be briefly discussed. Chapter one: the introduction of automatically batching system using plc will mainly have discussed about the project objectives and scope in order to achieve the desired goal.

  Chapter two: literature review will cover all explanation about the main type of plc and the type of plc that has been chosen for this project (SIEMENS).

- Chapter three, methodology will describe about the overall project that has been testified and successfully operate. Come along with in this chapter is an explanation about material selection which is including controller, pumps, limit switches, valves. In order to design a project.
- Chapter four, electrical design, will discuss about the electrical component used, and the installation of the electrical components on the system. This chapter also discuss the concept of how the input and output circuit of plc should be understood, the wiring of dc input, ac input, relay output and the transistor outputs are also.
- After that programming development will be discussing in chapter five. Systematic approach of control system design using programmable logic controller. The machine sequences of operation will be discussing, next the assignment of input and output are shown in table, finally the ladder diagram design.
- Finally, chapter six there will be conclusion and recommendation.

CHAPTER TWO

LITERATURE REVIEW

Literature review

2.1 Hyper glass cleaner

This project is based on the water purification. To make water more acceptable for a desired end-use. These can include use for drinking water, industry, medical and many other uses.

The goal of all water treatment process is to remove existing contaminants in the water, or reduce the concentration of such contaminants so the water becomes fit for its desired end-use. One such use is returning water that has been used back into the natural environment without adverse ecological impact.

All the process is described and the ladder logic design based upon these process.

2.2 Household cleaners:

Household cleaners are some of the most widely purchased consumer products. In 1991 sales of household cleaners were more than $1.6 billion in the United States. Nearly a billion units of these products were sold that year. [2]

Manufacturers of household cleaners have always had to keep three sometimes conflicting goals in mind: the performance of the product, the safety of the ingredients for users, and the costs of the ingredients. Recently, due to consumer demands, reducing impacts upon the environment has been added as a fourth goal. Given the diversity of the cleaners, the number of ingredients, and the difficulty in Understanding the entire life cycle of multi-ingredient formulations, it is not surprising that different manufacturers have different definitions of "green" for household cleaners.

In order to classify products by ingredients, information on specific products was requested directly from manufacturers. Additional general information on types of ingredients used in the industry was obtained from manufacturers associations, trade publications, and books.

2.2.1 Classification by Product Use:

The products surveyed included a range of general purpose cleaners, as well as some cleaners for specific purposes, such as glass cleaners, toilet bowl cleaners, carpet cleaners, and spot removers. A few types of cleaners were broken out into subgroups. Scouring cleansers were kept separate from bathroom cleaners, for example. Toilet bowl cleaners were divided into manual and automatic cleaners, since their use and formulations are quite different, but these categories could be combined if desired.

The use classification scheme selected is shown in Table 1. Table 1 includes a working definition of the products included and examples of specific types of products which meet the definition.

Product Use Category	Definition	Examples
General Purpose	Surface cleaners labeled as multi-purpose, or clearly intended for use in a variety of applications in the home.	Multi-purpose spray cleaners, floor or wall cleaners, disinfecting cleaners, cleaner-degreasers, concentrated cleaners.
Bathroom Cleaners	Cleaners intended primarily for use on bathroom surfaces, labeled as bathroom cleaners, or which mention specific bathroom surfaces.	Tub and tile cleaners, mildew stain removers, shower cleaners, disinfecting bathroom cleaners.
Disinfectants (excluding disinfecting cleaners)	Products which claim to disinfect surfaces but not necessarily to clean.	Liquid, spray, or concentrated germicides
Scouring Cleansers	Surface cleaners combining an abrasive.	Scouring powders, scouring pastes or liquids.
Glass Cleaners	Cleaners specifically for glass.	Pump spray, aerosol, or liquid glass cleaners.
Carpet/Upholstery Cleaners	Cleaners specifically designed for use on fabrics which cannot be removed for laundering or drycleaning.	Liquids, foams, or dry powders, including products for use in rental machines.
Spot/Stain Removers	Products designed to remove spots, excluding bleaches.	Cleaning fluids, stain sticks, enzyme spot removers.
Toilet Bowl Cleaners	Products designed specifically to clean the toilet bowl and which have no intended other use.	Liquid or crystal acid-based cleaners, detergent cleaners.
Automatic Toilet Cleaners	Products which are placed in the toilet tank and which drip or dissolve, providing continuous cleaning of the bowl.	Blocks, tablets, controlled release bottles.

Table 2.1: classification of cleaners by product use

2.2.2 Classification by Ingredients:

Ingredient information was obtained for more than 200 specific products in order to classify products by ingredients and to evaluate specific product subclasses.

There are five general types of ingredients found in household cleaners:

Surfactants: or surface active ingredients, are the wetting and foaming agents which form the basis for most aqueous cleaners. Anionic, nonionic, and amphoteric surfactants are used mainly for cleaning. Cationic surfactants are often used as antimicrobials.

Builders: include a range of both organic and inorganic chemicals whose function is to improve the performance of the surfactants. Builders are used to adjust or maintain the pH of the washing solution; soften water by removing calcium and other metal ions; and boost, reduce, or maintain foam height.

Solvents: are added to help dissolve oil and grease. Antimicrobials are pesticides which kill bacteria, fungus, or mildew on surfaces. Sometimes the same materials are used in smaller amounts as preservatives.

All other ingredients: have been placed in the category called miscellaneous. This category includes abrasives, fragrances, dyes, thickeners, hydro topes (substances which keep a mixture from separating), preservatives, and anything else. Substances whose precise function was unknown were also placed under miscellaneous.

2.3 Glass Cleaners:

Gosselin gives typical formulas for glass cleaners. After water, the main ingredients are alcohols and glycol ethers, with surfactants being a very small part of the mixture. The general formula which most closely matches most of the products we found is shown in Table 2.2.

Ingredients	%
butoxy ethanol	3-5%
alcohol	0-15%
wetting agent (surfactant)	0.5-1%
dyes	trace
silicone	trace
water	balance

Table 2.2: typical formula for glass cleaner

Most of the specific brands of glass cleaners we surveyed were liquids dispensed from pump spray bottles. A few were aerosols, propelled by means of propane or other flammable hydrocarbon. A third type of product is a premoistenedtowelette. There was remarkably little variation between the listed ingredients in the glass cleaners we investigated.

The major ingredient in liquid glass cleaners is water. Almost all of the glass cleaners contained glycol ethers, usually ethylene glycol monobutyl ether. Alcohol, such as isopropanol, was also commonly found, as was ammonia. A few products contained vinegar or lemon juice as an alternative to ammonia, however, it is important to note that these products may still contain glycol ethers. One product contained acetone as a solvent.

Aerosol formulations were similar except for the inclusion of a propellant gas, usually propane or isobutane. For the towelettes, the liquid used to moisten them was similar in composition to the usual glass cleaners.

Ingredients found in products making "green" claims included coconut-based surfactants, ethanol, propylene glycol ethers, citrus oil, lemon juice, vinegar, and various plant extracts.

It is interesting to note that in a recent review of glass cleaners, Consumer Reports found that plain water worked as well as half of the products tested. In addition, the most effective cleaner for oily fingerprints was lemon juice and water. [2].

2.4 History of Programmable Logic Controller (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. [3]

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. 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 Central processing unit (CPU). The

AMD 2901 and 2903 were quite popular in Modicon 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) Modicon has yet to build a faster PLC than their 984A/B/X which was based upon the 2901.

Communications abilities began to appear in approximately 1973. The first such system was Modicon's Modbus. 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.

2.5 Programmable Logic Controller definition(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 a 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.

2.6 The Internal Configuration of plc

The main components of a PLC are the following:

- Main Rack
- Power Supply
- Central processing unit (CPU)
- Digital Input/output cards
- Analog Input/output cards
- Special Features Cards

2.6.1 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.

2.6.2 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

2.6.3 Central processing unit (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 one's 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 this 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 look 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. [3]

2.6.4 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.

2.6.5 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.

2.6.6 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 [3].

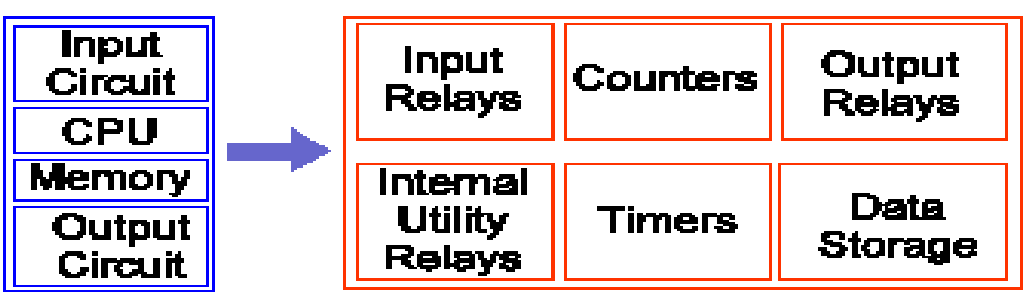


Figure 2.1: PLC internal registers

2.7 Each PLC internal part in detailed:

2.7.1 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 [3].

2.7.2 Internal Utility Relays (contacts):

These do not receive signals from the outsideworld 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.

2.7.3 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.

2.7.4 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.

2.7.5 Outputs relays (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 triacs depending upon the model chosen.

2.7.6 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.

2.8 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. [3]

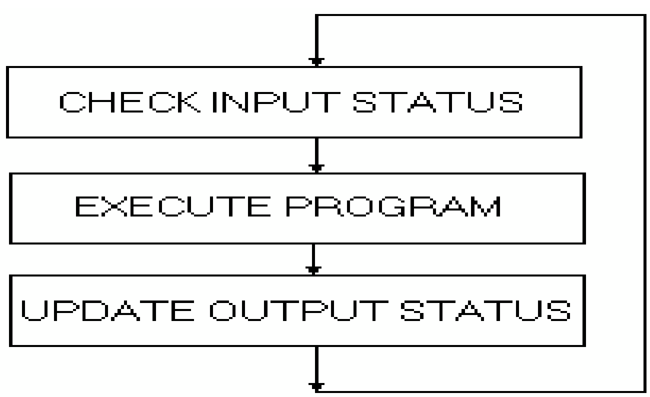


Figure 2.2: PLC operations

Step1: Check input status

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.

2.9 Time response of plc

ThePLC can only see an input turn on/off when it's looking. In other words, it only looks at its inputs during the check input status part of the scan [3].

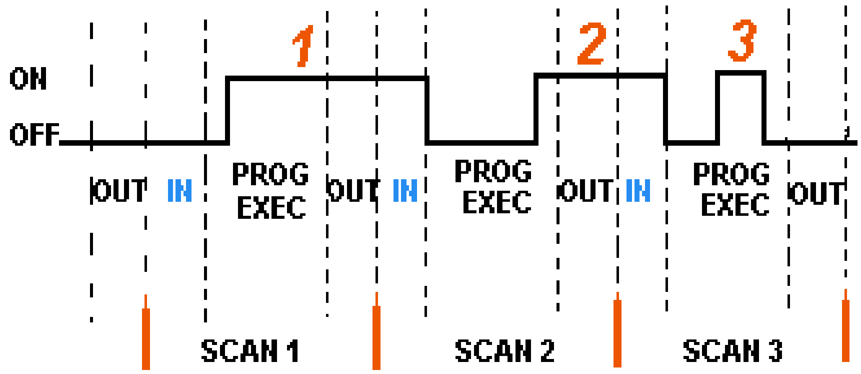


Figure 2.3: scan cycle of PLC

In the diagram, input 1 is not seen until scan 2. This is because when input 1 turned on, scan 1 had already finished looking at the inputs.

Input 2 is not seen until scan 3. This is also because when the input turned on scan 2 had already finished looking at the inputs.

Input 3 is never seen. This is because when scan 3 was looking at the inputs, signal 3 was not on yet. It turns off before scan 4 looks at the inputs. Therefore, signal 3 is never seen by the plc.

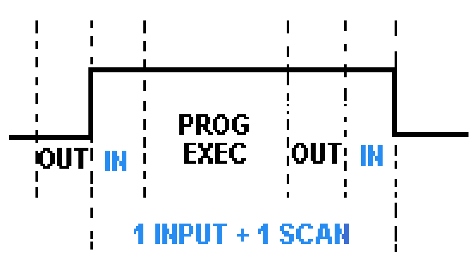


Figure 2.4: Time response of PLC

To avoid this, we say that the input should be on for at least 1
Input delay time + one scan time.

But what if it was not possible for the input to be on this long? Then the plc doesn't see the input turn on. Therefore, it becomes a paper weight! Not true... of course there must be a way to get around this. Actually there are two ways:

2.9.1 Pulse stretch function:

This function extends the length of the input signal until the plc looks at the inputs during the next scan. (I.e. it stretches the duration of the pulse.)

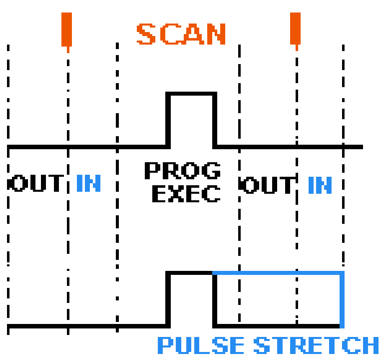


Figure 2.5: Pulse stretch

i. <u>Interrupt function</u>:

This function interrupts the scan to process a special routine that you have written. I.e. As soon as the input turns on, regardless of where the scan currently is, the plc immediately stops what it is doing and executes an interrupt routine. (A routine can be thought of as a mini program outside of the main program.) After it's done executing the interrupt routine, it goes back to the point it left off at and continues on with the normal scan process.

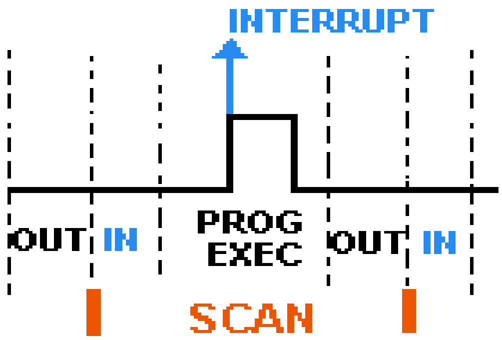


Figure 2.6: Pulse stretch

Now let's consider the longest time for an output to actually turn on. Let's assume that when a switch turns on we need to turn on a load connected to the plc output.

The diagram below shows the longest delay (worst case because the input is not seen until scan 2) for the output to turn on after the input has turned on.

The maximum delay is thus 2 scan cycles - 1 input delay time.

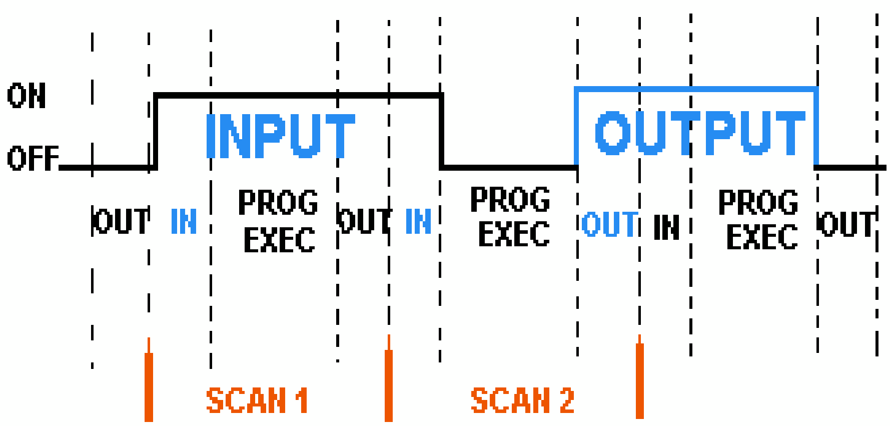


Figure 2.7: Maximum Delay Time

2.10 PLC SIEMENS

2.10.1 Features

- It covers 30% of industrial automation
- Having a very huge instruction set as compare to others
- Large no. of protocol is supported
- Wide operating temp. Range (-40c to 70c)
- Having high data resolution

2.10.2 TYPES OF PLC

- 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)

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

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

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

1. IT support windows operating system [4]

2.10.2.1 TYPES OF PLC:

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

2.10.3 ARCHITECTURE OF SIEMENS

PS	CPU	IM	------	-----	-----	SM	------	-----	------	-----

Table 2.3: architecture of Siemens

- The complete structure is known as rack having 11 slots.
- They are arrange as shown in above figure.

From 3 onwards the signal module covers the slots., which contain DI, DO, DI/DO, AI, AO, AI / AO, interface module,processor,power supply.

2.10.3.1 PS (power supply)

Slot no.1 is always reserved for PS

INPUT= 230volt/120volt ac, single phase 50 to 60 Hertz, 24-volt dc, Output= 24-volt dc external, current 2 amps, 5 amp

2.10.3.2 CPU (central processing unit)

Slots no. 2 is always reserved memory (Load memory, work memory, system memory)

- Load memory**:** this memory is used to store the user program

Capacity -> 64 kb to 256 kb

- Work memory**:** this is the execution memory of Siemens plc.
- System memory**:** called in-built memory used to store the memory of predefined files. Like Input image table, Timer, Counter, Diagnostic buffer

Diagnostic buffer: in it the mode transaction of the plc is stored with time and data

2.10.3.3 IM (INTERFACE MODULE)

It is always used to interconnect the two different racks and this process is known as tier configuration.

2.10.3.4 OTHER MODULES

Signal modules: it contains DI, DI/DO, AI, AO, AI /AO

Function module: it is designed for specific function such as high speed timers, counters, PID controllers etc.

Communication module: for connecting the remote I/O and connected from slot no. 4 to 11. [4]

2.10.4 COMMUNICATION (PROTOCOLS)

2.10.4.1 MPI – It stand for multi-point interface.

Nodes – 32 support

Local - 38400 bps

Network - 187.5kbps

Port - Rs 485

Profibus (process field bus)

- baud rate will go up to 12mbps
- Maximum node can be connected up to 126

Simulation	SIMATIC S7-PLCSIM v5.2 +sp2
PLC Programming	SIMATIC STEP 7 v5.4 + sp3

Table 2.4:PLC Programming&SimulationSoftware

CHAPTER THREE

METHODOLOGY

METHODOLOGY

3.1 Over View:

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 automatically batching system Using PLC project. The introduction to system task will also briefly explain in this chapter. Finally, the entire decision making will be addressed in this section. Basically, software and hardware design will be used in order to implement this project. In addition, there some methods must be executed to keep this project implemented successfully.

This project is based on the water purification. To make water more acceptable for a desired end-use. These can include use for drinking water, industry, medical and many other uses.

The goal of all water treatment process is to remove existing contaminants in the water, or reduce the concentration of such contaminants so the water becomes fit for its desired end-use. One such use is returning water that has been used back into the natural environment without adverse ecological impact.

All the process is described and the ladder logic design based upon these process.

3.2 Software and hardware were used in this project

NO	SOFTWARE	DESCRIPTION
1	Operating System	Microsoft Windows XP Professional Version 2002 Service pack 3
2	PLC Programming	SIMATIC STEP 7 v5.4 + sp3
3	SCADA	SIMATIC WinCC v5.1
4	Simulation	SIMATIC S7-PLCSIM v5.2 +sp2
5	Communication Protocol	PROFIBUS (Process Field Bus)
6	Communication Driver	MPI Adapter
7	Drawing	AutoCAD 2008
8	Documentation	: Microsoft Office 2013
9	Others	- SIMATIC Authorsw v2.4 + Service pack 2 - SIMATIC WinCC Smart tools v 5.1

Table 3.1: Software were used in this project

NO	HARDWARE	DESCRIPTION
1	PC	Intel® Core™i5-2430M CPU 2.40 GHz Intel® Original Motherboard 6GB DDR2 RAM, 64-bit operating system HDD 14” color TFT Monitor
2	PLC	SIMATIC S7-300; CPU 312 312-1AE14-0AB0
3	External DI/DO Module	SM 323 DI8/DO8 x DC 24V; 6ES7 323-1BH01-0AA0 x2
4	External DO Module	SM 322DO8 x DC24V/0.5A
5	PC >> PLC Communication port	MPI Adapter

Table 3.2: Hardware were used in this project

(PLC, External DI/DO Module, External DO Module, PC >> PLC Communication port) SIEMENS Manufacturer SIEMENS

3.3 System Component: -

3.3.1 Valves:

AV-CW: Supplies city water to the mixing tank.

AV-QR: Supplies QR ingredient to the mixing tank.

AV-KM: Supplies KM ingredient to the mixing tank.

AV-MT: Supplies the finished product to the filling lines.

3.3.2 Limit Switches:

LS-CW1: Indicates when valve AV-CW is closed.

LS-CW2: Indicates when valve AV-CW is open.

LS-QR1: Indicates when valve AV-QR is closed.

LS-QR2: Indicates when valve AV-QR is open.

LS-KM1: Indicates when valve AV-KM is closed.

LS-KM2: Indicates when valve AV-KM is open.

LS-MT1: Indicates when valve AV-MT is closed.

LS-MT2: Indicates when valve AV-MT is open.

3.3.3 Pumps:

Pump-QR: Pumps ingredient QR to the mixing tank.

Pump-KM: Pumps ingredient KM to the mixing tank.

Pump-MT: Pumps ingredient MT from the mixing tank.

3.3.4 Motor:

Agitator MTR-MTA: Blends the ingredient in the mixing tank.

3.3.5 Operator Panel Component: -

1) System ready light PL1: Indicates the system is ready for Batch.

2) System fault pilot light PL2: Indicates the system has a fault

3) Start batch pushbutton switch PB1: Start a new batch.

4) Start batch pushbutton switch PB1: Start a new batch.

5) Stop batch pushbutton switch PB2: Stop the batching process.

6) Adding water light PL3: Indicates adding water to the mixing tank.

7) Adding QR light PL4: Indicates adding QR to the mixing tank.

8) Adding KM light PL5: Indicates adding KM to the mixing tank.

9) Blending pilot light PL6: Indicates blending the ingredients.

10) Pumping to lines light PL7: Indicates pumping the ingredients.

11) E-stop Pushbutton PB3: Immediately stops the entire system

3.4 System description:

Three ingredients (City water, QR ingredient, and KM ingredient) are added in specified amounts by weight to the Mixing Tank. After all the ingredients have added to the mixing Tank, the Mixer is blended by running the Agitator for a given time. When the blending time is completed, the finished product is pumped to the Filling Lines for bottling and final Packing.

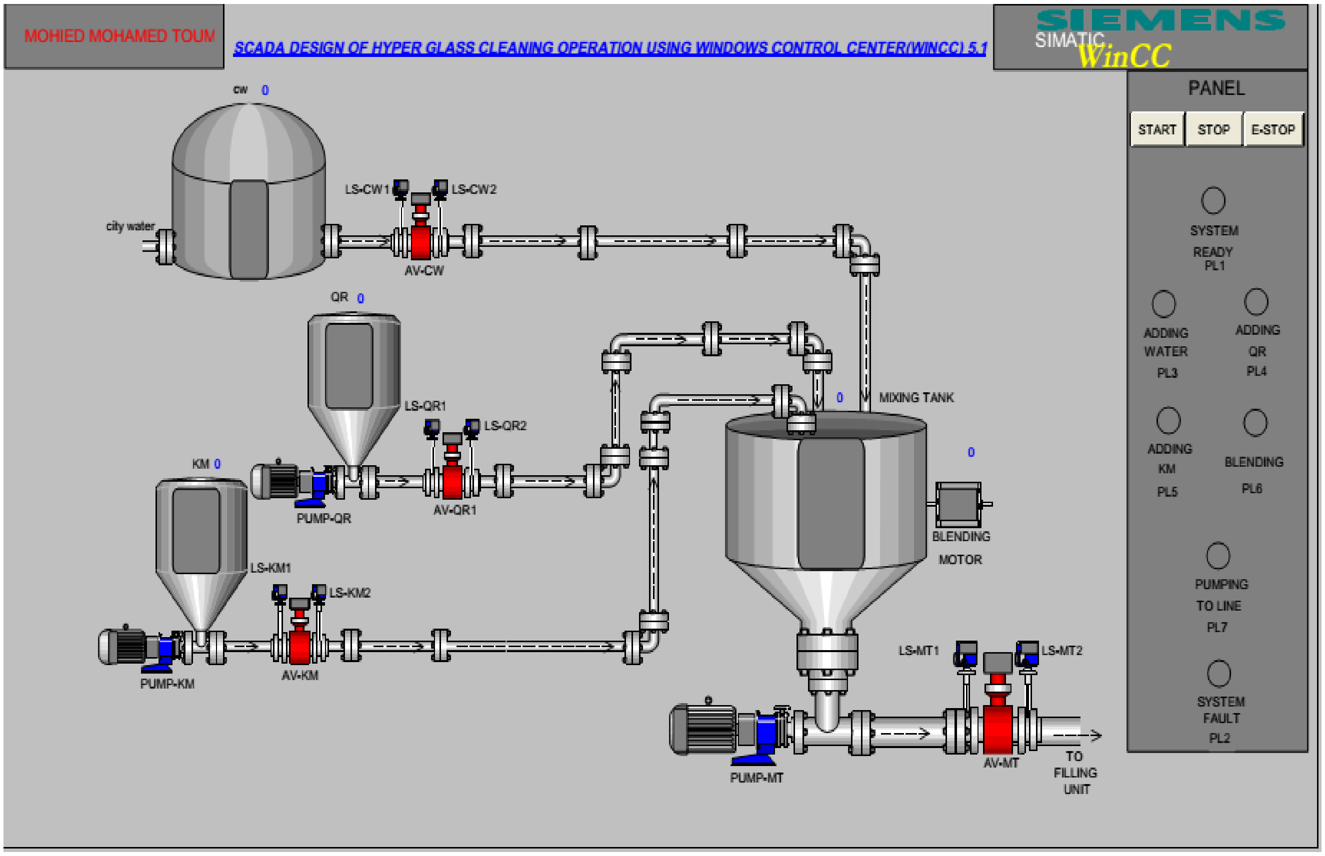


Figure 3.1: SCADA OVERVIEW

To begin a new batch, the operator will verify that the” SYSTEM READY” pilot light is on and that the mixing tank is ready to receive ingredients. The operator will then press the “START BATCH” pushbutton to begin the batching process. No further operator input is required. The pilot” SYSTEM READY” light will turn off. Automatic valve AV-CW will open. The “ADDING WATER” pilot light will illuminate. The state of AV-CW will be verified by limit switch LS-CW2. If LS-CW2 is not made within 2 seconds after the valve was told to open, a fault will be generated and the system will shut down. The pilot light “SYSTEM FAULT” PL2 will illuminate indicating that a fault has occurred. Valve AV-CW will remain open until 1275 lbs.

Of City Water is in the mixing tank valve AV-CW will closed within 2 seconds after the valve was told to close. If the valve closure is not verified within 2 seconds, a fault will be generated, the system will shut down and PL2 will illuminate. All valves and their respective limit switches will work in the manner described above. After the City Water has been added and LS-CW1 indicates that valve AVCW is closed, the pilot “ADDING WATER” light will turn off. Valve AV-QR will be opened. The “ADDING QR” pilot light will illuminate. After the valve position has been verified by LS-QR2, PUMP-QR will pump 390 lbs. of ingredient QR into Mixing Tank. After the ingredient QR has been add to the Mixing Tank, valve AV-QR will close and the “ADDING QR” pilot light will turn off. After LS-QR1 indicates the valve has been closed, valve AV-KM will open. The “ADDING KM” pilot light will illuminate. After the valve position has been verified by LS-KM2, PUMP-KM will pump 173 lbs. of ingredient KM into the Mixing Tank. After ingredient KM has been added to the Mixing Tank, valve AV-KM will close. The “ADDING KM” pilot light will turn off. After LS-KM indicates the valve has been closed, the agitator motor MTRMTA will start. The “BLENDING” pilot light will illuminate. The agitator will run for 3 minutes. After the agitator is finished, the “BLENDING” pilot light will turn off and valve AV-MT will open after LS-MT1 indicates the valve is open, the” PUMPING TO LINES” pilot lamp will illuminate. PUMP-MT will pump the entire the batch to the filling lines, PUMP-MT will turn off after tank empty, valve AV-MT will close and batching cycle is complete the “PUMPING TO LINES” pilot light will turn off and “SYSTEM READY” pilot light will illuminate. During every phase of batching process, the liquid level must be monitored by the PLC. If the level rises to greater than 95% of the mixing tank capacity, the system will generate a fault and batching process must be halted. The operator may press “E-STOP” push button PB3 is used in case an emergency arises especially during fault condition. It helps to safely shut down the system and to reset it at fault condition.

3.4.1 Pumps

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.

There have been significant new developments in the area of pumping equipment since the early 1980s.

There are materials for corrosive applications, modern sealing techniques, improved dry-running capabilities of seal less pumps (that are magnetically driven or canned motor types), and applications of magnetic bearings in multistage high energy pumps. The passage of the Clean Air Act of 1980 by the U.S. Congress, a heightened attention to a safe workplace environment, and users’ demand for greater equipment reliability have all led to improved mean time between failures (MTBF) and scheduled maintenance (MTBSM) [5].

3.4.1.1 Classification of Pumps

One general source of pump terminology, definitions, rules, and standards is the Hydraulic Institute (HI) Standards, approved by the American National Standards Institute (ANSI) as national standards.

A classification of pumps by type:

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 [5].

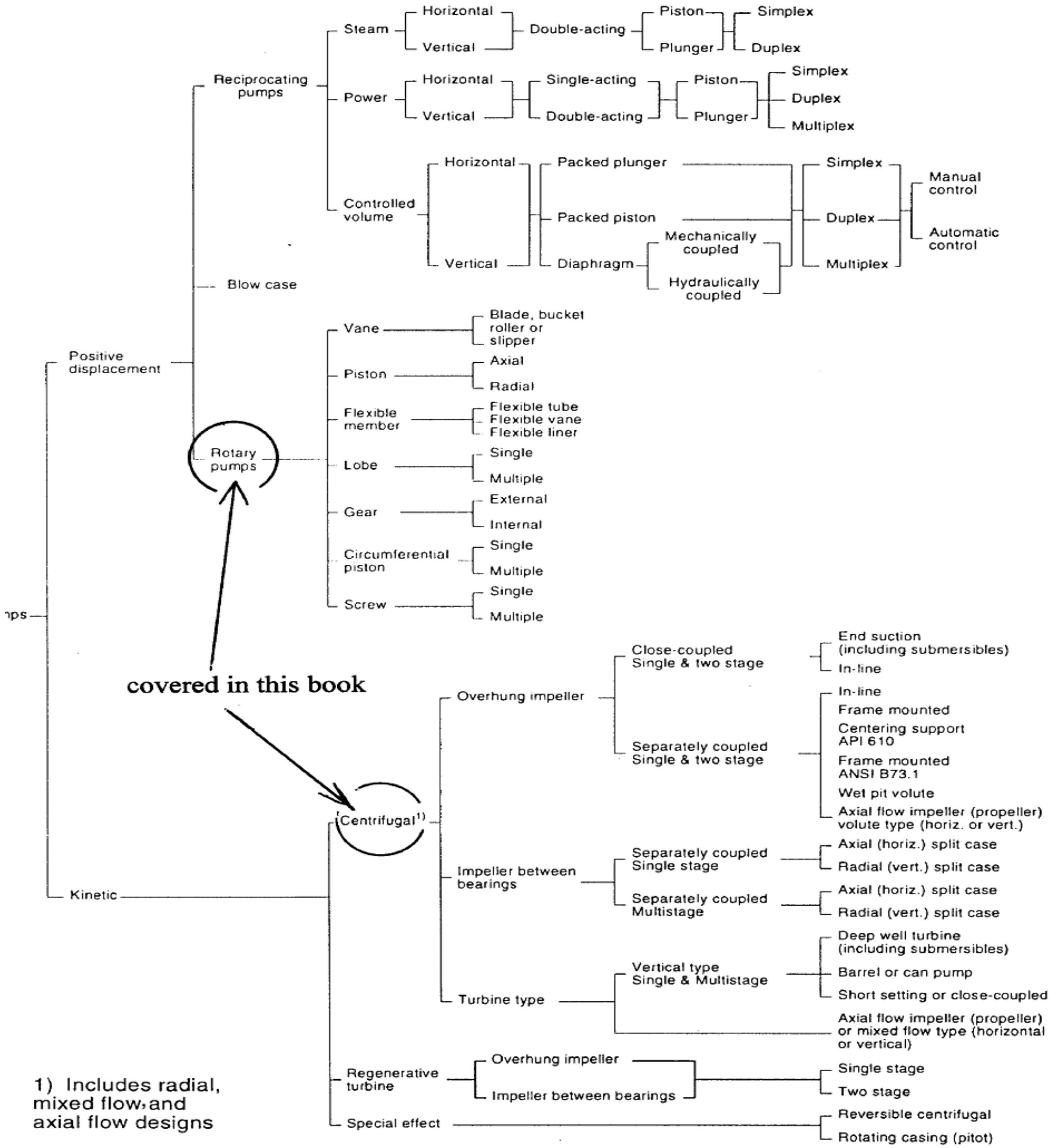


Figure 3.2: Pumps classification

3.4.1.2 Centrifugal pump

A centrifugal pump is one of the simplest pieces of equipment in any processplant. Its purpose is to convert energy of a prime mover (an electric motor or turbine) first into velocity or kinetic energy and then into pressure energy of a fluid that is being pumped. The energy changes occur by virtue of two main parts of the pump, the impeller and the volute or diffuser. The impeller is the rotating part that converts driver energy into the kinetic energy. The volute or diffuser is the stationary part that converts the kinetic energy into pressure energy [6].

The process liquid enters the suction nozzle and then into eye (center) of arevolving device known as an impeller. When the impeller rotates, it spins the liquid sitting in the cavities between the vanes outward and provides centrifugal acceleration.

As liquid leaves the eye of the impeller a low-pressure area is created causing more liquid to flow toward the inlet. Because the impeller blades are curved, the fluid is pushed in a tangential and radial direction by the centrifugal force. This force acting inside the pump is the same one that keeps water inside a bucket that is rotating at the end of a string.

Figure 4.2below depicts a side cross-section of a centrifugal pump indicating themovement of the liquid.

The key idea is that the energy created by the centrifugal force is kinetic energy.The amount of energy given to the liquid is proportional to the velocity at the edge or vane tip of the impeller. The faster the impeller revolves or the bigger the impeller is, then the higher will be the velocity of the liquid at the vane tip and the greater the energy imparted to the liquid.

This kinetic energy of a liquid coming out of an impeller is harnessed by creatinga resistance to the flow. The first resistance is created by the pump volute (casing) that catches the liquid and slows it down. In the discharge nozzle, the liquid further decelerates and its velocity is converted to pressure according to Bernoulli's principle.

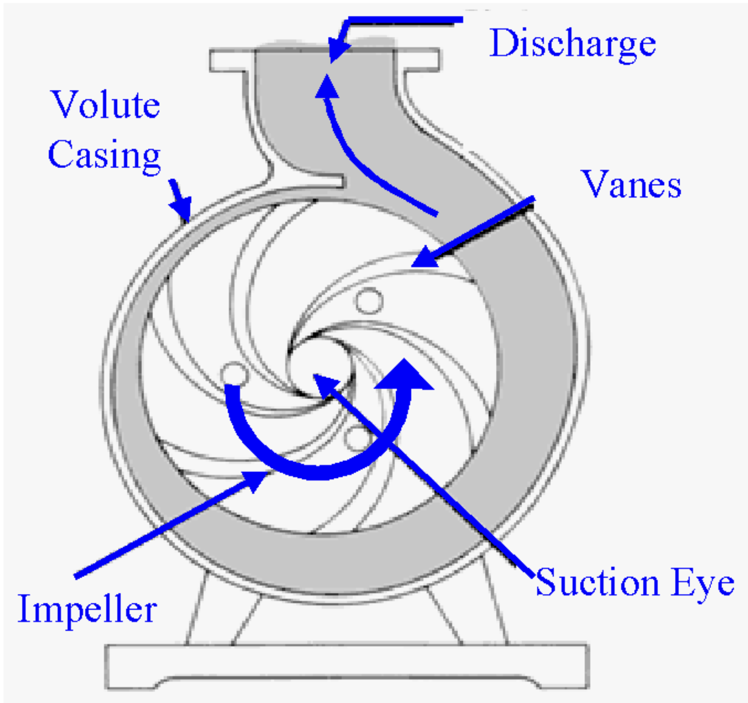


Figure 3.3: Liquid flow path inside a centrifugal pump

A centrifugal pump has two main components:

I. A rotating component comprised of an impeller and a shaft

II. A stationary component comprised of a casing, casing cover, and bearings.

The general components, both stationary and rotary, are depicted in Figure 4.3. Figure 4.4 shows these parts on a photograph of a pump in the field [6].

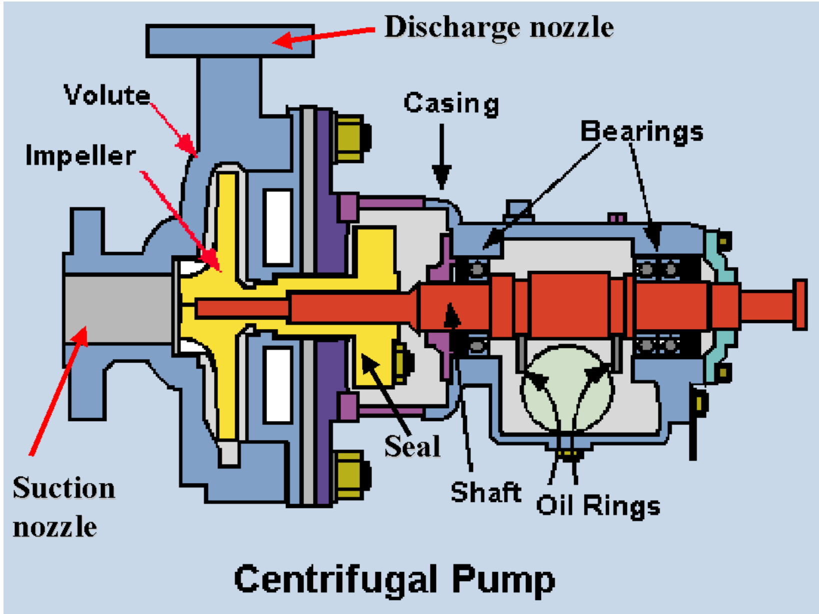


Figure 3.4: General components of a Centrifugal Pump

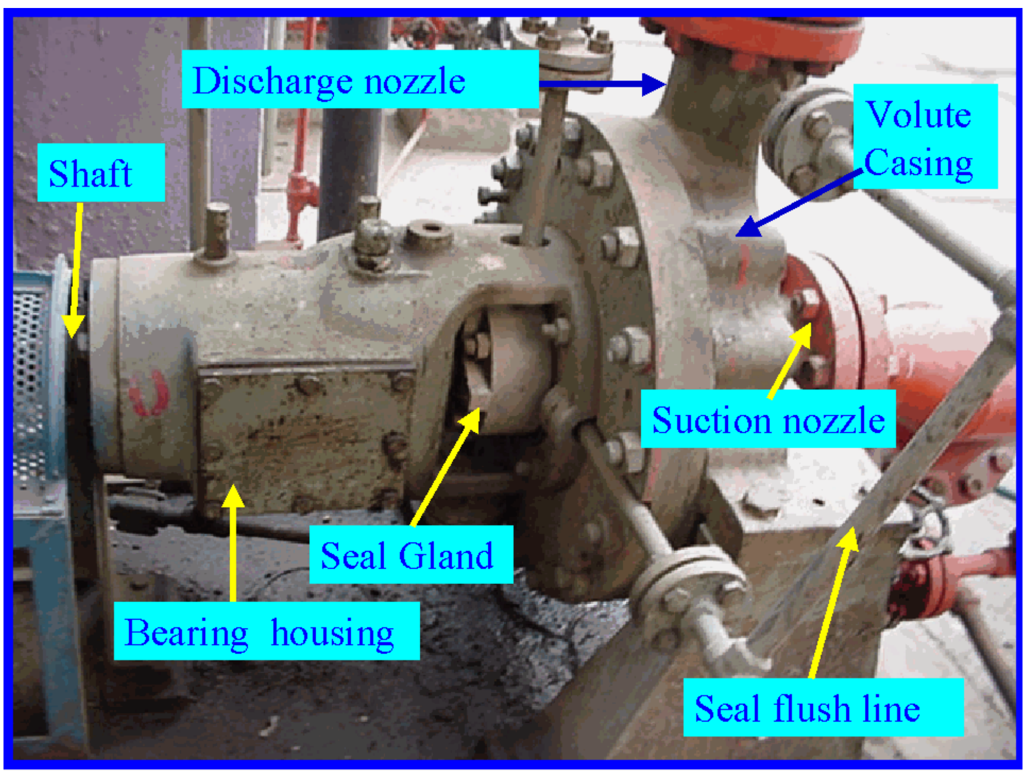


Figure 3.5: General components of a Centrifugal Pump on a field

3.4.2 Control Valves:

A Control Valve is a power-operated device used to modify the fluid flow rate in a process system. Process plants consist of hundreds, or even thousands, of control circuits all networked together to produce a product. Each of these control circuits or loops is designed to maintain the plant in safe operating limits. Each of these control loops is designed to keep some important process variable such as:

Pressure

Flow

Level

Temperature

The control valve assembly typically consists mainly of the valve body, the internal trim parts, and an actuator to provide the motive power to operate the valve. A variety of additional valve accessories, which can include positioners, transducers, supply pressure regulators, manual operators, snobbery, or limit switches are also included to add functionality of various levels and to characterize the particular valve.

Basic Types of control valves: There are two basic types of control valves: rotary and linear. Linear-motion control valves commonly have globe, gate, diaphragm, or pinch - type closures. Rotary-motion valves have ball, butterfly, or plug closures. Each type of valve has its special generic features, which may, in a given application, be either an advantage or a disadvantage [7].

3.4.2.1 Linear Valve Features:

- A low recovery
- The throttling of small flow rates
- Suitability to high-pressure applications
- Be flanged or threaded
- A separable bonnet
- A tortuous flow path

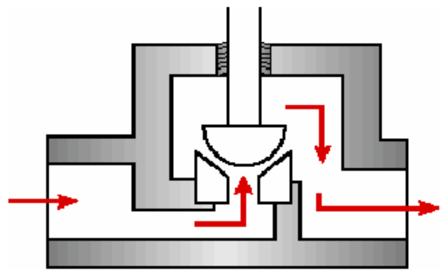


Figure 3.6: Linear valve

3.4.2.2 Rotary Valve Features:

- Streamlined flow path
- High recovery
- More capacity
- Less packing wear
- Flangeless
- High range ability

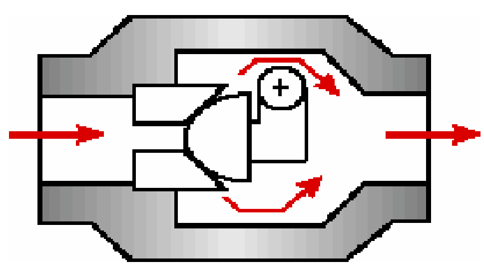


Figure 3.7: Rotary valves

In addition to linear and rotary, control valves are also classified according to their guiding systems and the types of services they are used in.

i) Different Types of Control Valves:

The following types of control valves are commonly used in the Engineering applications: -

- Globe Valves
- Gate Valves
- Butter Fly Valves
- Eccentric Disc Valves
- Ball Valves
- Rotary Plug Valves
- Diaphragm Valves
- Pinch Valves [8]

Figure 3.8: Control Valve

3.4.3 Motor:

Electric motors are so much a part of everyday life that we seldom

An electric motor is an electric machine that converts electrical energy into mechanical energy. In this project three phase induction motor will be used because it can spin 360° continuously [9].

Figure 3.9: Motor

The humble motor, consisting of nothing more than an arrangement of copper coils and steel laminations. Athree phase motor has 2 partsstator and rotor.

The supply is fed to the stator windings.as a result of thata magnetic field is developed on the stator windings which runs at synchronous speed. This magnetic field is induced on the rotor's windings which produces a torque on it and it starts rotating .This is how a three phase motor rotates.

3.4.3.1 AC three-phase motor selection & operation:

Operateon 3-phase power only. Higher starting and breakdown torque, high efficiency, medium starting current, ruggeddesign, long life. For all types of industrial uses. [10]

Mounting:

Solid, rigid or footed: Motor solidly fastened to equipment throughmetal base which is bolted, cast or welded to motor shell or frame.

Resilient: Sometimes called cushion or rubber mount. Motor shell isolated from base by vibration-absorbing material, such as rubber rings on the end shields, to reduce transmission of vibration to the driven equipment.

Face or flange: Drive end has a flat mounting surface, machined to standard dimensions, with holes to allow easy, secure mounting to driven equipment, Used on pumps, oil burners and gear reducers.

Lug: Brackets extending radially from case of small motors used on fans and blowers.

Extended thru bolts: Motor has bolts extending from front or rear, by which it is mounted. Used on small, direct drive fans and blowers or to mount fan guard to motor.

National Electrical Code (NEC): A code for safeguarding persons and property from the hazards arising from the use of electricity. Sponsored by the National Fire Protection Association. Used by insurance inspectors and by many government bodies regulating building codes, etc.

NEMA (National Electrical Manufacturers' Association): This organization establishes certain voluntary industry standards relating to motors;such asoperating characteristics, terminology, basic dimensions, ratings and testing.

Rotation: Direction in which shaft rotates: CW = clockwise; CCW = counter-clockwise; both = reversible, rotation can be changed; ECW - either CW or CCW, connected for CW at factory ; ECCW.=.either CW or CCW, connected for CCW at factory. Unless stated otherwise, rotation specified in this catalog is as viewed facing end of motor opposite shaft extension.

Service Factor: A measure of the overload capacity designed into a motor. A 1.15 SF means the motor can deliver 15% more than the rated horsepower without injurious over-heating. A 1.0 SF motor should not be overloaded beyond its rated horsepower. Service factors will vary for different horsepower motors, and for different speeds.

Temperature Rise: The amount by which a motor, operating under rated conditions, is hotter than its surrounding ambient temperature.

***Thermal Protection**: A protective device, built into the motor, used to sense excessive (overload) temperature rise and/or current. These devices disconnect the motor from its power source or operate through a control circuit.

Basic types:

Automatic-Reset (AUTO or A): After motor cools, this line-interrupting protector automatically restores power. Should not be used where unexpected restarting would be hazardous.

Manual-Reset (MAN or M): This line interrupting protector has an external button which must be pushed to restore power to motor. Use where unexpected restarting would be hazardous, as on saws, conveyors, compressors.

Resistance Temperature Detectors (RTD): Precision-calibrated resistors mounted in the motor, used in conjunction with instrument to detect high temperatures.

Thermostat: Protector, which is temperature sensing only, is mounted on the stator winding. Two leads from the device must be connected to a control circuit which initiates corrective action.

Torque: Twisting or turning force produced by motor.

Starting Torque: The amount of turning force produced by a motor as it begins to turn from standstill and accelerate. (Sometimes called locked rotor torque.)

Full-Load Torque: This is the amount of torque produced by a motor when it is running at rated full-load speed at rated horsepower.

Breakdown Torque: The maximum torque which a motor will develop under increasing load conditions without an abrupt drop in speed and power.

UL (Underwriters Laboratories, Inc.): An independent testing organization that sets safety standards for motors and other electrical equipment.

Voltage (Volts or V): Voltage is a unit of electromotive force which applied to conductors will produce current in the conductors.

Watts (W): A unit of electrical power; 746 watts equal one horsepower.

Electric Motor Terminology: -

Bearings:

Sleeve: Preferred where low noise is important, as on fan and motors. Unless otherwise stated, sleeve bearing motors can be mounted in any position, including shaft-up or shaft-down.

Ball: Used where high shaft load (radial or axial thrust load)

Canadian Standards Association (CSA): Sets safety standards for motors and other electrical equipment used in Canada. Most all motors in this catalog meet CSA standards and the CSA logo is displayed on the nameplate.

Efficiency: A measurement of how effectively a motor turns electrical energy into mechanical energy.

Enclosure: The term used to describe the motor housing. Common types:-

Open (OP): Ventilation openings in end shields and/or shell to permit passage of cooling air over and around the windings. Location of openings not restricted. For use indoors, in fairly clean locations.

Dripproof (DP): Ventilation openings in end shields and shell placed so drops of liquid falling within an angle of 15 degrees from vertical will not affect performance. Normally used indoors, in fairly clean, dry locations.

Totally Enclosed (TE): No openings in the motor housing (but not air-tight). Used in locations which are dirty, damp, oily, etc. Two types are:

Totally enclosed fan cooled (TEFC): Includes anintegral fan to blow cooling air over the motor.

Totally enclosed non-ventilated(TENV): Not equipped with a fan for external cooling. Depends on convection air for cooling.

Explosion-proof (EP): A special enclosed motor designed to standwith an internal explosion of specified gases or vapors, and not allow the internal flame of explosion to escape. Usually available as non-ventilated (EPNV) in smaller ratings (below 1/3 HP) and fan-cooled (EPFC) in larger ratings. Explosion-proof motors are labeled to meet UL and NEC requirements.

3.4.4 Limit Switches:

Limit switches operate discrete inputs to a distributed control system, signal Lights, small solenoid valves, electric relays, or alarms. The cam-operated Type is typically used with two to four individual switches operated by movement of the valve stem.

An assembly that mounts on the side of the actuator houses the switches. Each switch adjusts individually and can be supplied for either alternating current or direct current systems. Other styles of valve-mounted limit switches are also available

Figure 3.10: Limit switches

CHAPTER FOUR

ELECTRICAL DESIGN

ELECTRICAL DESIGN

4.1 Over View:

Electrical design of the Automatic Batching System involves the electrical components used, andthe installation of the electrical components on the system. Before all connection was established allthe input and output devices to PLC, the concept on how the input and outputs circuits of PLC mustbe understood. The wiring of the DC input, AC input, relay output, and the transistor output isdiscussed.

4.1.1 DC Input

Typically, dc input modules are available that will work with 5, 12, 24, and 48V. the connections of the DC input modules is either PNP(sourcing) or NPN(sinking) transistor types devices. For a regular switch (i.e. toggle or pushbutton, etc.), typically no need to worry about whether wire it as NPN or PNP. Most PLCs not allow mix NPN and PNP devices on the same modules.

The difference between the two types is whether the load switched to ground or positive voltages. An NPN type's sensor has the load switches to ground whereas a PNP device has the load switches to positive voltage.

4.1.1.1 Sinking/Sourcingconcept:

Sinking sensors allow current to flow into the sensor to the voltage common, while

Sourcing sensors allow current to flow out of the sensor from a positive source.

When discussing sourcing and sinking we are referring to the output of the sensor

That is acting like a switch. In fact, the output of the sensor is normally a transistor that will act like a switch (with some voltage loss). A PNP transistor is used for the sourcing output, and an NPN transistor is used for the sinking input. When discussing these sensors, the term sourcing is often interchanged with PNP, and sinking with NPN. A simplified example of a sinking output sensor is shown in Figure 4.3. The sensor will have some part that deals with detection, this is on the left. The sensor needs a voltage supply to operate, so a voltage supply is needed for the sensor. If the sensor has detected some phenomenon, then it will trigger the active line. The active line is directly connected to an NPN transistor.

(Note: for an NPN transistor the arrow always points away from the center.) If the voltage to the transistor on the active line is 0V, then the transistor will not allow current to flow into the sensor. If the voltage on the active line becomes larger (say 12V) then the transistor will switch on and allow current to flow into the sensor to the common [1].

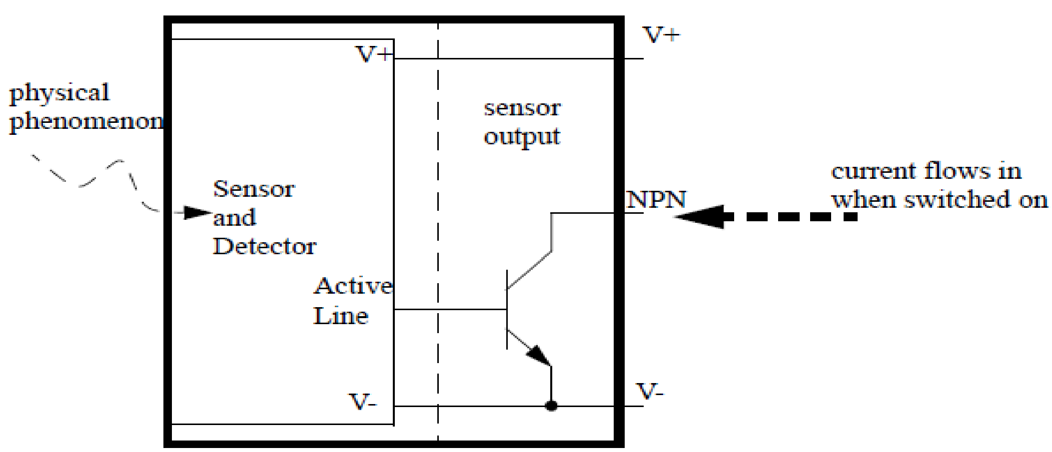


Figure 4.1: A Simplified NPN/Sinking Sensor

Sourcing sensors are the complement to sinking sensors. The sourcing sensors usea PNP transistor, as shown in Figure 4.4. (Note: PNP transistors are always drawn with the arrow pointing to the center.) When the sensor is inactive the active line stays at the V+ value, and the transistor stays switched off. When the sensor becomes active the active line will be made 0V, and the transistor will allow current to flow out of the sensor. [1]

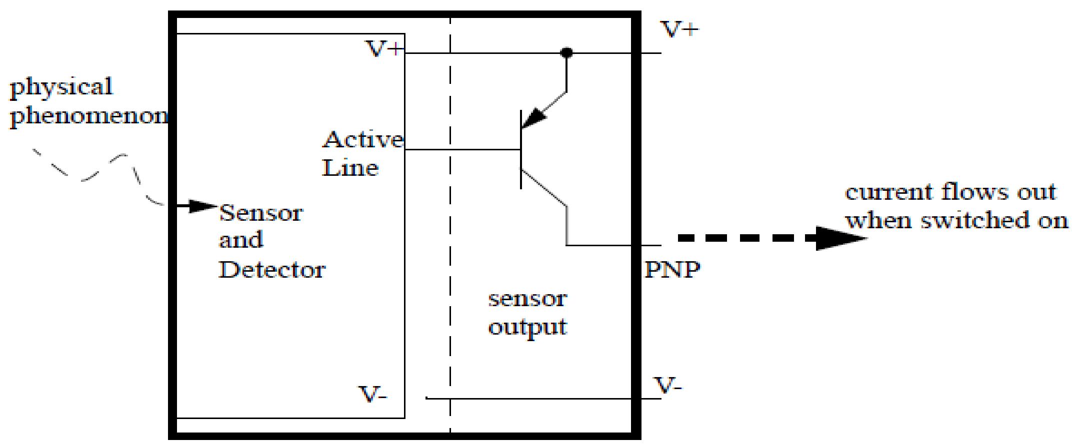


Figure 4.2: A Simplified Sourcing/PNP Sensor

4.1.2 PLC Input Card for Sinking Sensors

When a PLC input card does not have a common but it has a V+ instead, it can be

Used for NPN sensors. In this case the current will flow out of the card (sourcing) and we must switch it to ground.

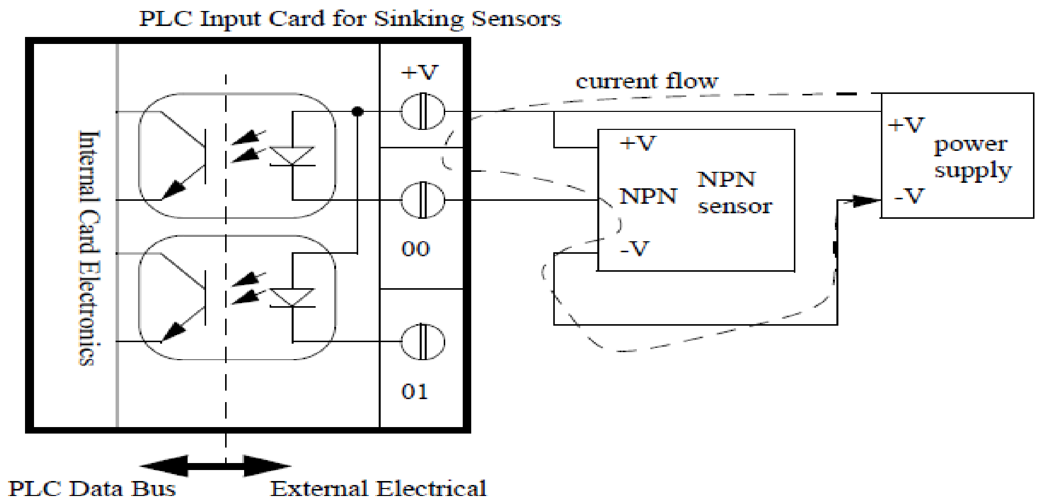


Figure 4.3: A PLC Input Card for Sinking Sensors

This card is shown with 2 optocouplers (one for each output). Inside these devices is an LED and a phototransistor, but no electrical connection. These devices are used to isolate two different electrical systems. In this case they protect the 5V digital levels of the PLC computer from the various external voltages and currents.

The dashed line in the figure represents the circuit, or current flow path when theSensor is active. This path enters the PLC input card first at a V+ terminal (Note: there is no common on this card) and flows through an optocoupler. This current will use light to turn on a phototransistor to tell the computer in the PLC the input current is flowing. The current then leaves the card at input 00 and passes through the sensor to V-. When the sensor is inactive the current will not flow, and the light in the optocoupler will be off. The optocoupler is used to help protect the PLC from electrical problems outside the PLC.

4.1.3 PLC Input Card for Sourcing Sensors

When we have a PLC input card that has a common then we can use PNP sensors. In this case the current will flow into the card and then out the common to the power supply.

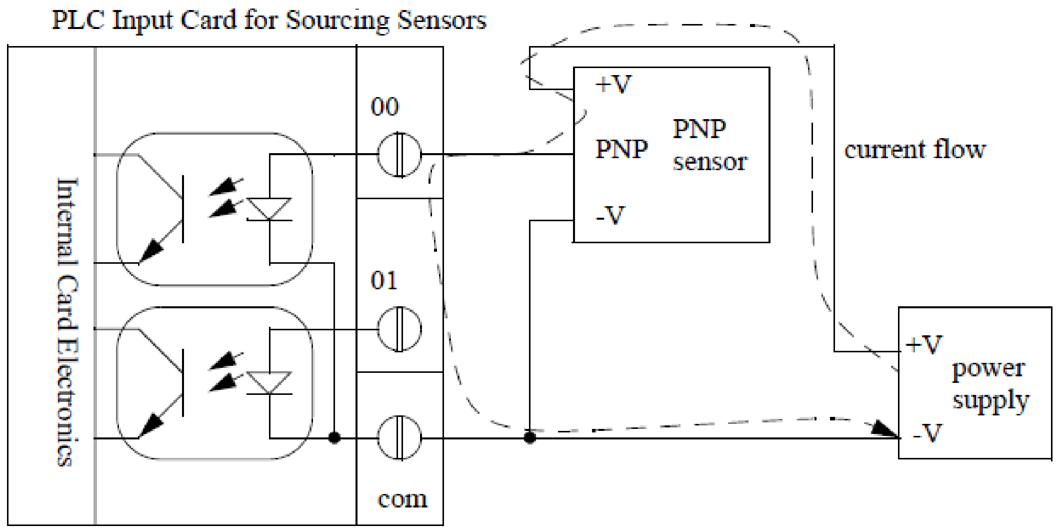


Figure 4.4: PLC Input Card for Sourcing Sensors

The current flow loop for an active sensor is shown with a dashed line. Following the path of the current we see that it begins at the V+, passes through the sensor, in the input 00, through the optocoupler, out the common and to the V-.

Wiring is a major concern with PLC applications, so to reduce the total number of wires, two wire sensors have become popular. But, by integrating three wires worth of function into two, we now couple the power supply and sensing functions into one. Two wire sensors are shown in Figure 4.8.

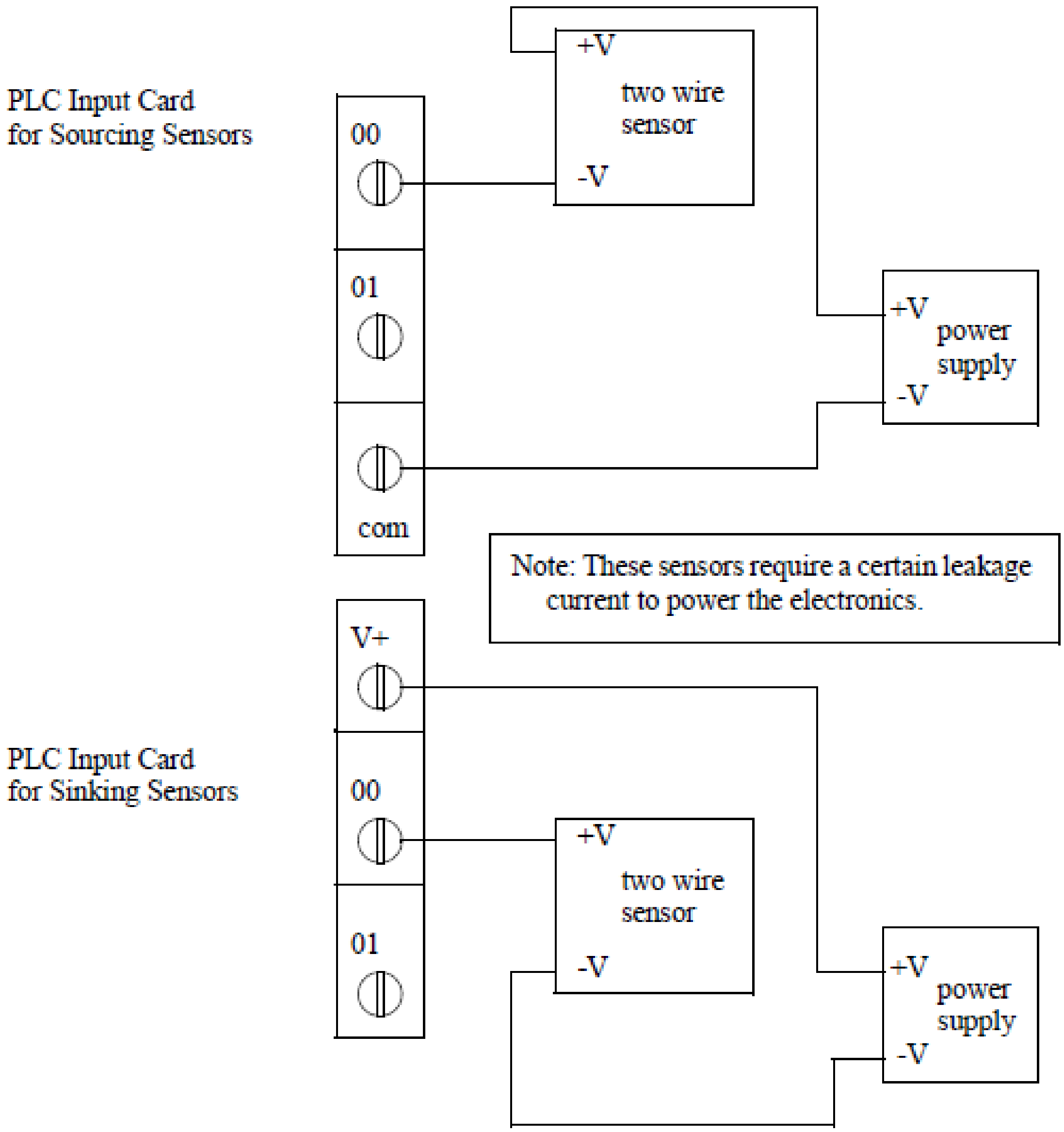


Figure 4.5: Two Wire Sensors

A two wire sensor can be used as either a sourcing or sinking input. In both of these arrangements the sensor will require a small amount of current to power the sensor, but when active it will allow more current to flow. This requires input cards that will allow a small amount of current to flow (called the leakage current), but also be able to detect when the current has exceeded a given value [1].

4.1.4 AC Input

An Ac voltage is non-polarized, means that there is no positive and negative polarity. Typically, ac input modules are available that will work with 24, 48, 110, and 220V an AC device is connected to input PLC as shown in Figure 4.3

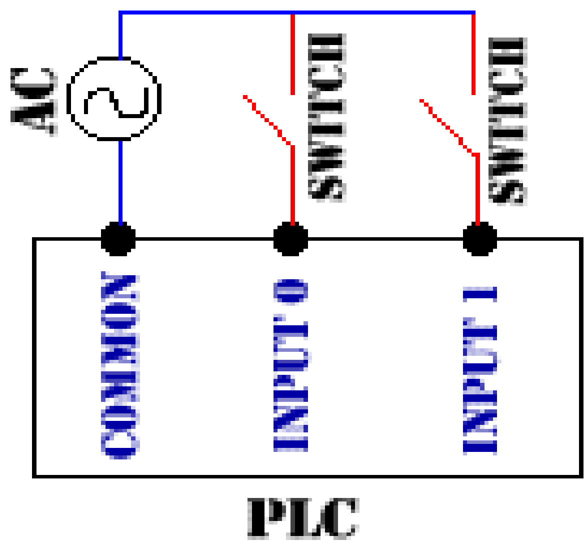


Figure 4.6: Wiring of AC input

Commonly the ac "hot" wire is connected to the switch while the "neutral" goes to the PLC common. The ac ground (3rd wire) should be connected to the frame ground terminal of the PLC. AC connection is typically color code. In US is commonly white (neutral), black (hot), and green (3rd wire ground when applicable). Outside the US it's commonly coded as brown (hot), blue (neutral), And green with yellow stripe (3rd wire ground when applicable). A common switch (i.e. limit switch, pushbutton, toggle, etc.) would be connected to the input terminals directly as shown in Figure 4.4. One side of the switch would be connected directly to PLC input. The other end goes to the ac hot wire. This assumes the common terminal is connected to neutral [3].

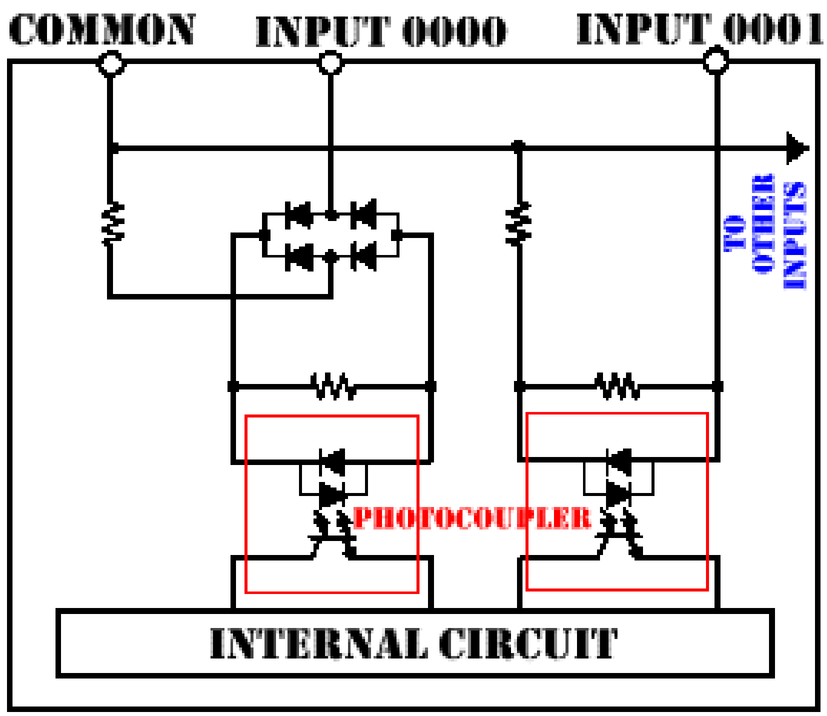


Figure 4.7: Internal input circuit diagram

4.1.5 Relay Output

One of the most common types of outputs available is the relay outputs. A relay can be used with both AC and DC loads. Some forms of a load are a solenoid, buzzer, motor, etc. Always check the specifications of the load before connecting it to the PLC output and make sure that the maximum current it will consume is within the specifications of the PLC outputs. Some types of loads are very deceiving. These deceiving loads are called inductive loads. These have a tendency to deliver a “back current” when they turn on. This back current is like a voltage spike coming through the system. Typically, a diode, resistor, or other snubbed circuit should be used to prevent any damage to the relay.

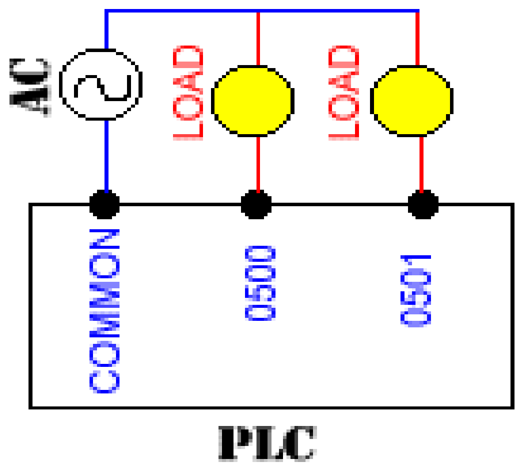


Figure 4.8:Wiring of Relay Output

Figure 4.5 is a typical method of connecting the outputs to the PLC relays. AC Supply or DC supply can be used as well connected to the output. A relay is no polarized and typically it can switch either AC or DC. Here the common is connected to one end of the AC power supply or DC power supply and the other end of the supply is connected to the load. The other half of the load gets connected to the actual PLC outputs.

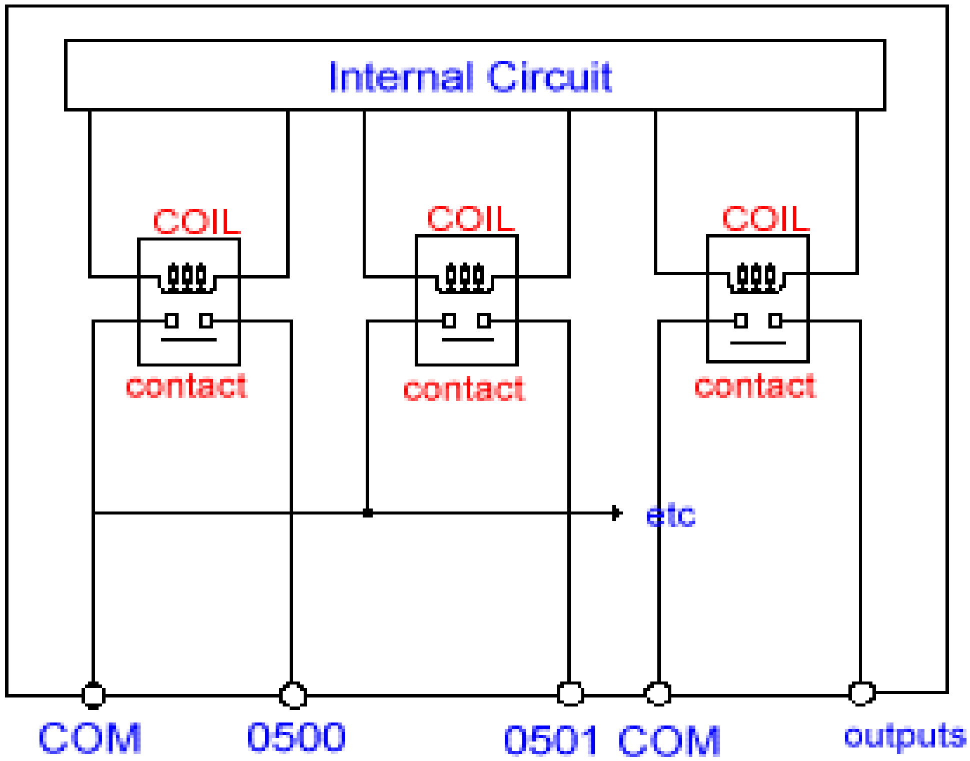


Figure 4.9: circuit diagram

The relay is internal to the PLC. Its circuit diagram is shown in Figure 4.6. When ladder diagram tells the outputs to turn on, the PLC will internally apply a voltage to the relay coil. This voltage will allow the proper contact to close. When the contact close, and external current is allowed to flow through our external circuit. When the ladder diagram tell the PLC to turn off the output, it will simply remove the voltage from the internal circuit thereby enabling the output contact to release the load will than have an open circuit and will therefore be off.

4.1.6 Transistor Output

The next type of outputs is transistor type outputs. Typically a PLC will have either NPN or PNP type outputs. It is important to note that a transistor can only switch a dc current. For this reason it cannot be used with an Ac voltage. A transistor is a solid-state switch or an electrical switch. A small current applied to the transistor base (i.e. input) and switch a much larger current through its outputs. The PLC applies a small current to the transistor base and the transistor output "close". When it's closed, the devices connected to the PLC output will be turn on.

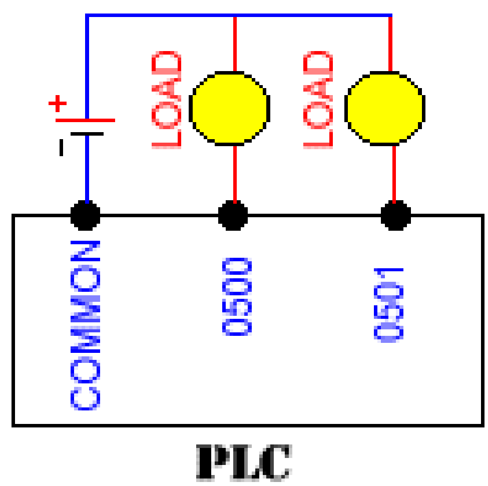


Figure 4.10: Wiring of Transistor for NPN Type

Figure 4.7 shows how to connect the output devices to the transistor output for NPN type transistor. If it were a PNP type, the common terminal is connected to

V+ and V- would connect to one end of the load.

4.2 The Electrical Components

4.2.1 Relay

First of all the general concept of the relay must be understood

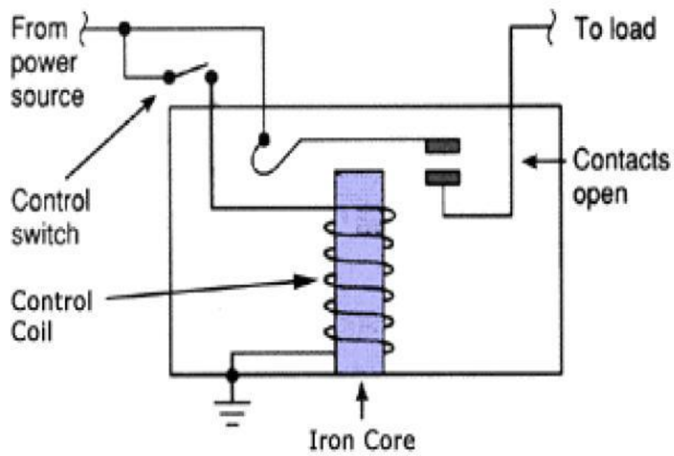


Figure 4.11:Relay concept

4.2.2 General relays

Suitable for DC or AC circuit switching in various automation devices, process control and communication equipment's

Figure 4.12: general Relay

4.2.3 Contactor

It is a spring actuated mechanism having a set of double-breaking power contacts. It also have a set of auxiliary contacts, generally 2 NO & 2NC, which are used for control wiring.

Figure 4.13: contactor

4.2.4 Thermal Overload Relay:

Figure 4.14:Thermal Overload Relay

4.3 The Wiring System:

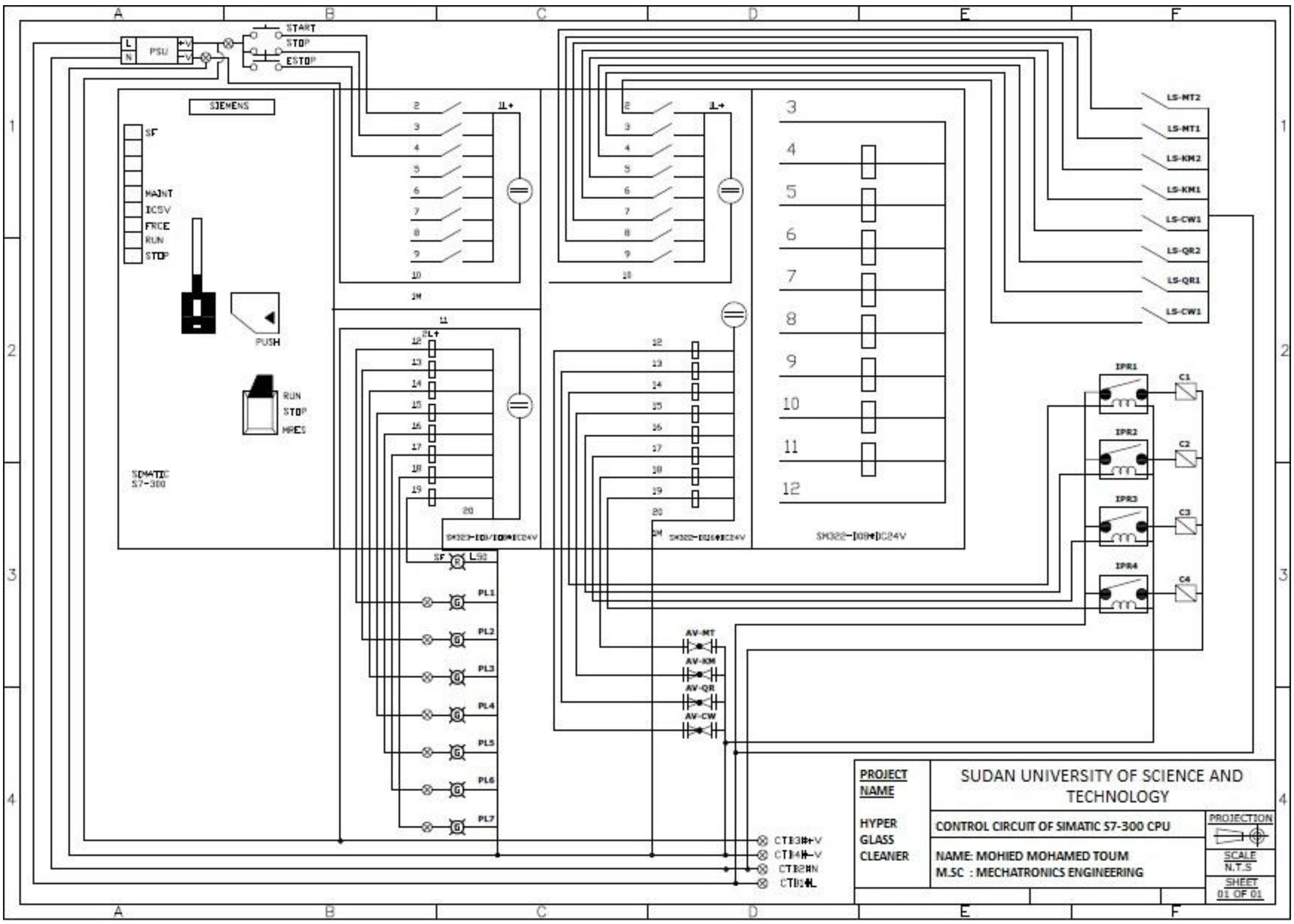


Figure 4.15: Electrical wiring of PLC I/O devices

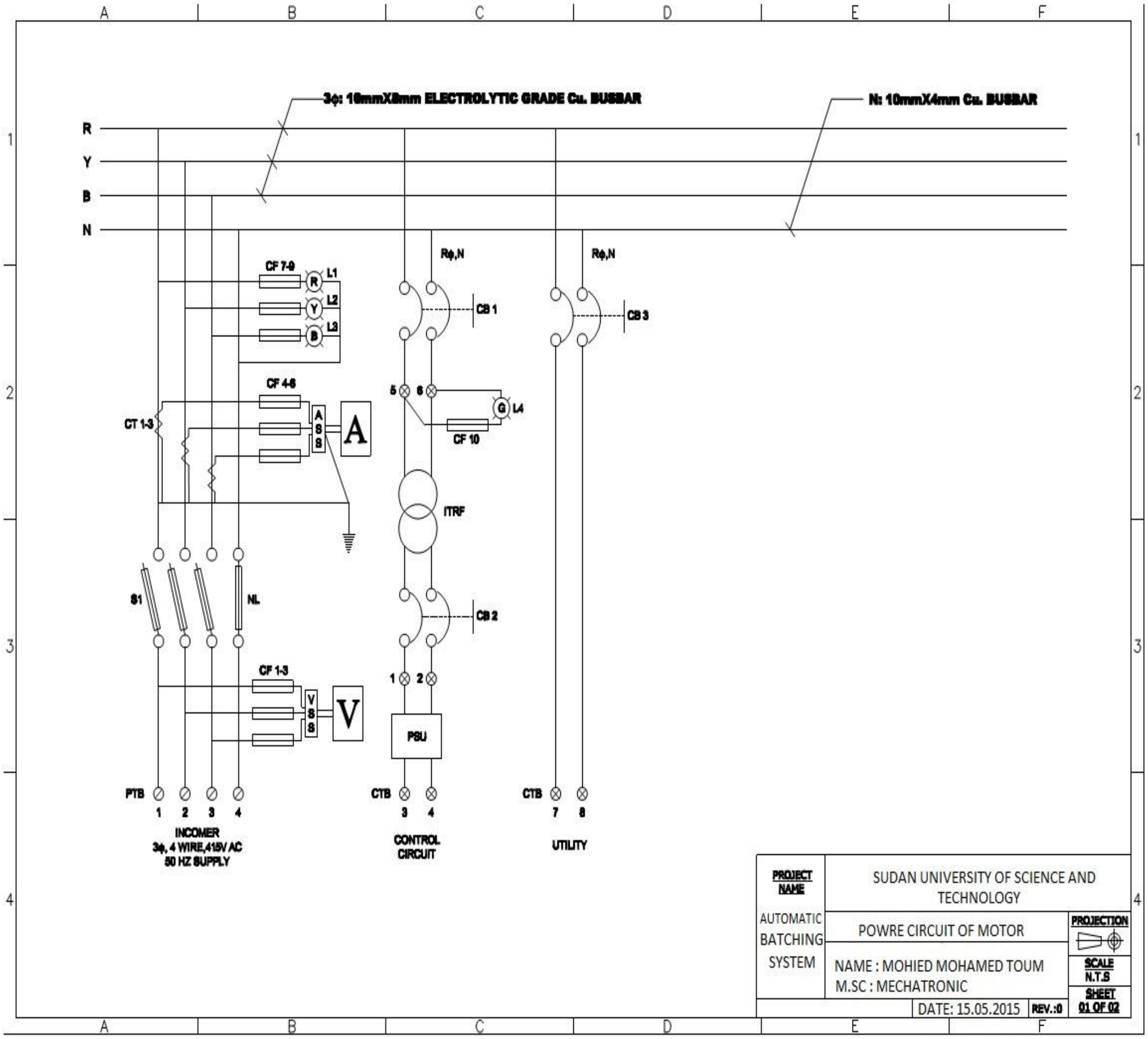


Figure 4.16: Electrical wiring of the power circuit devices

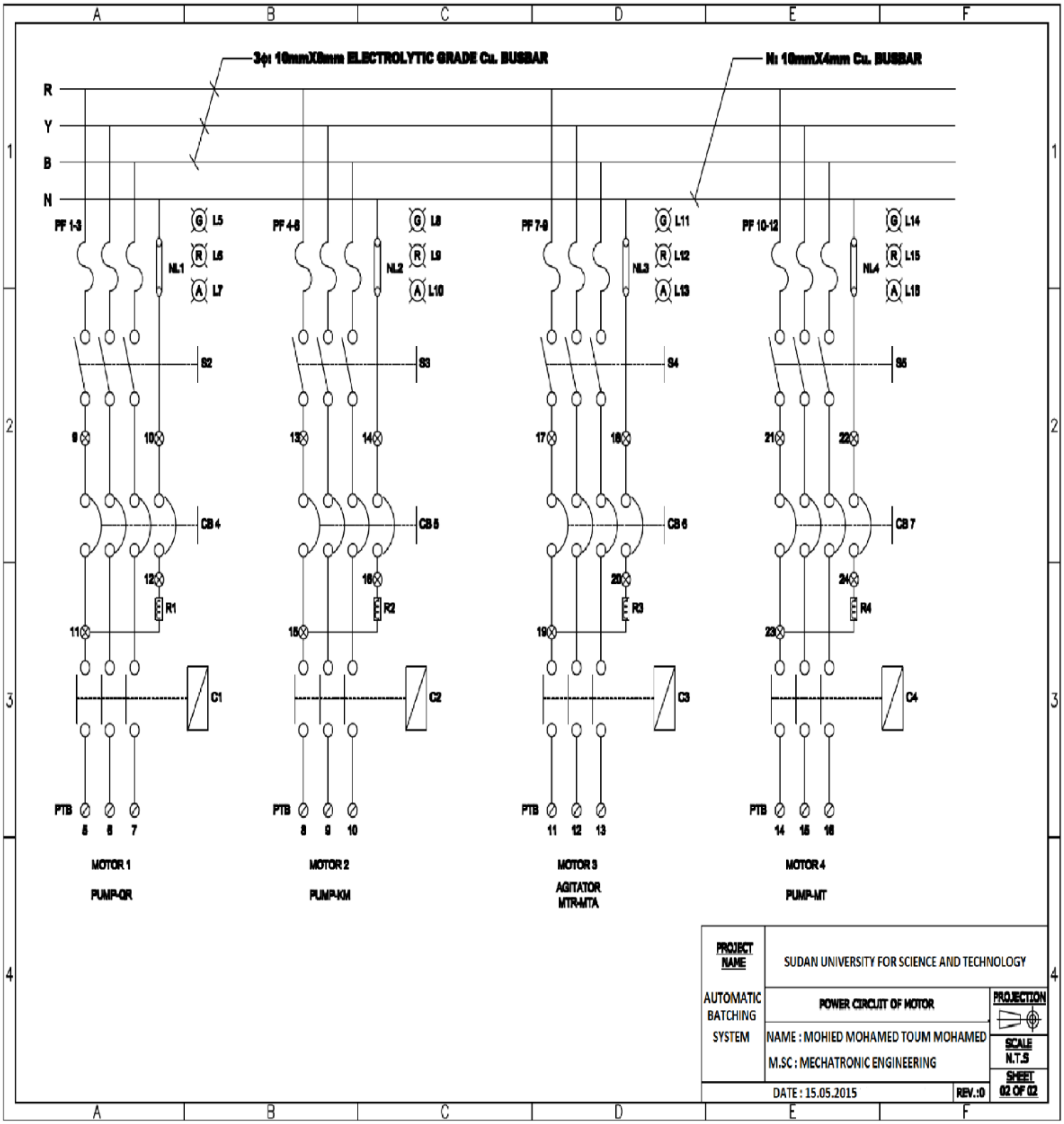


Figure 4.17: Electrical wiring power circuit devices

CHAPTER FIVE

PROGRAMMING DEVELOPMENT& SIMULATION

Programming development and simulation

5.1 Over View:

A systematic approach of control system design using programming logic controller is presented in this chapter. As a rule, the layout of the entire of Automatic Batching System using PLC is designed before implementing programming development process. The machine sequences of operation will be discussed. Next, the assignment of input and outputs are shown in tables. Finally, the ladder diagram design using Siemens software are shown.

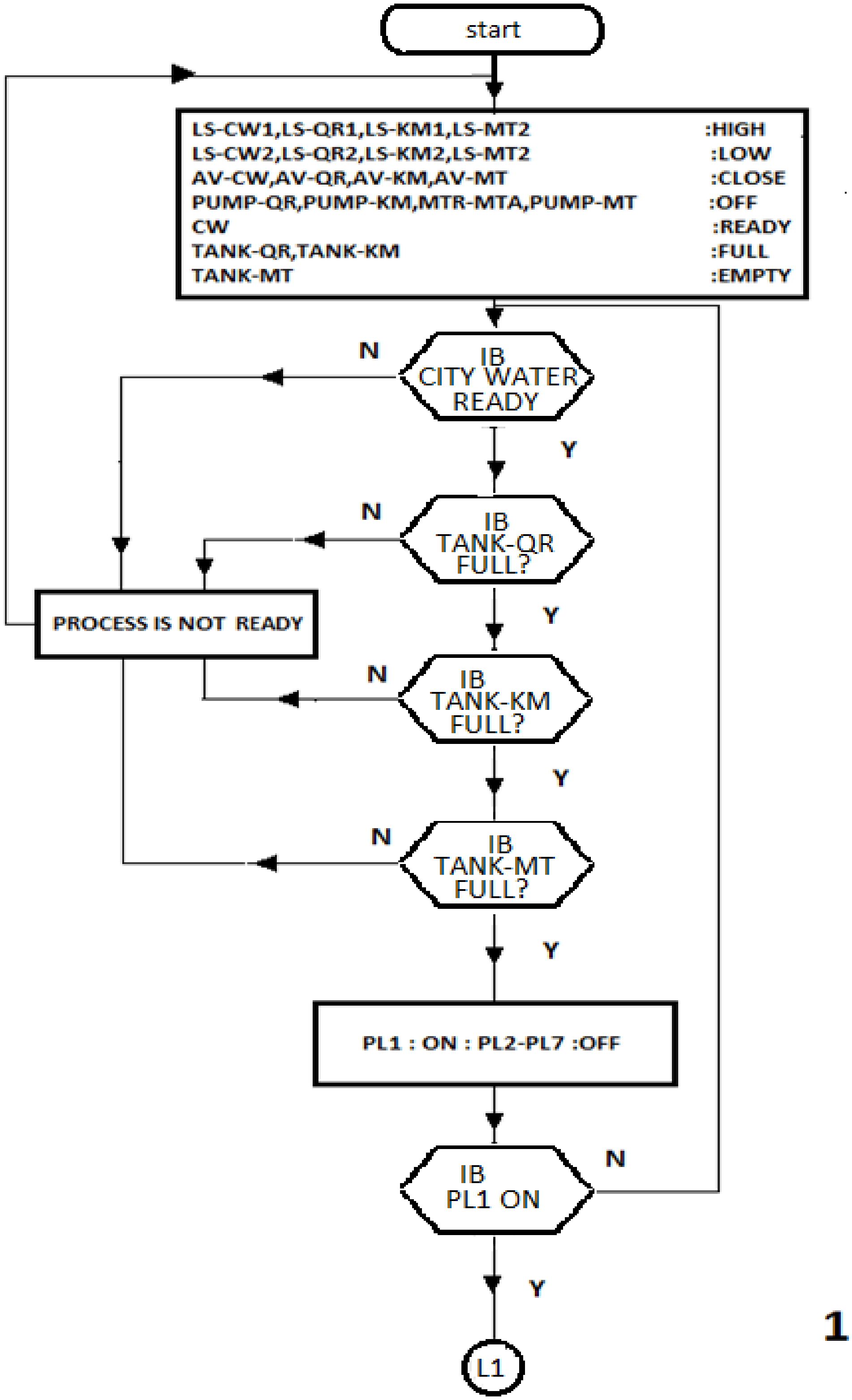
5.2 A Systematic Approach of Control System Design.

In general, a control system is a collection of electronic devices and equipment which are in place to ensure the stability, accuracy and smooth transition of a process or a manufacturing activity. Every single component in a control system plays an important role regardless of size.

Before programming, the concept of controlling a control system is introducing, which is the systematic approach of control system design using a PLC. The operation procedure of the system approach is shown in Figure (13.1).

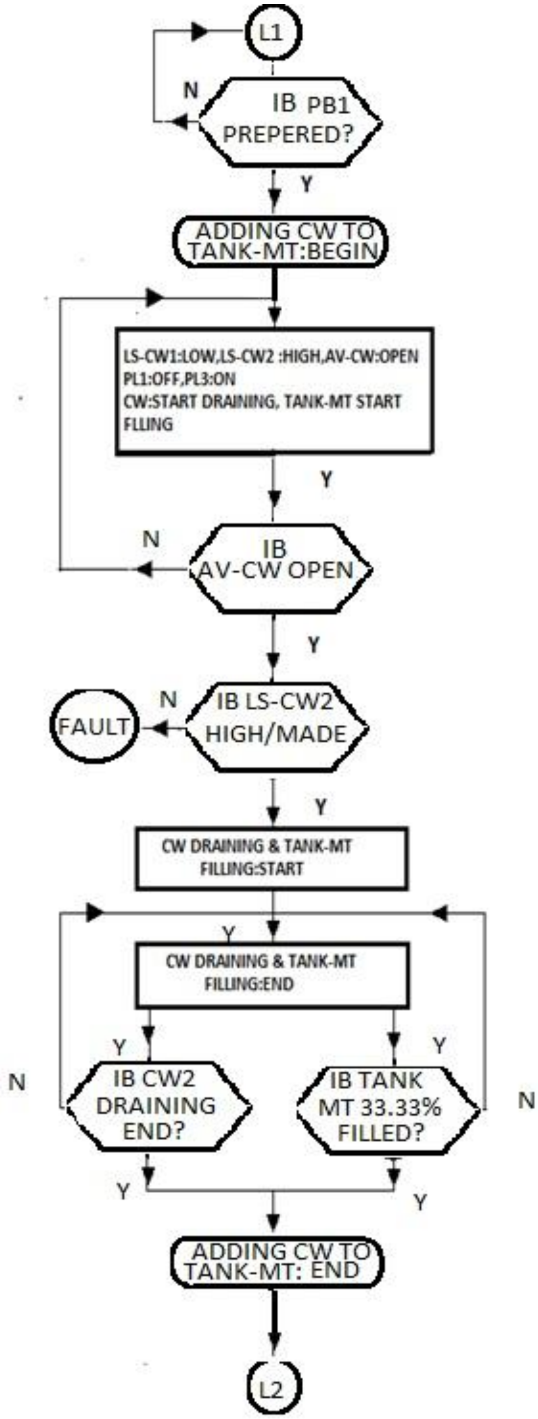
Process flow chart:

The general flow chart of the sequences of operation is shown in Figure 13.1


start
LS-CW1,LS-QR1,LS-KM1,LS-MT2 :HIGH
LS-CW2,LS-QR2,LS-KM2,LS-MT2 :LOW
AV-CW,AV-QR,AV-KM,AV-MT :CLOSE
PUMP-QR,PUMP-KM,MTR-MTA,PUMP-MT :OFF
CW :READY
TANK-QR,TANK-KM :FULL
TANK-MT :EMPTY
IB CITY WATER READY
N
Y
IB TANK-QR FULL?
N
Y
PROCESS IS NOT READY
IB TANK-KM FULL?
N
Y
IB TANK-MT FULL?
N
Y
PL1 : ON : PL2-PL7 :OFF
IB PL1 ON
N
Y
L1

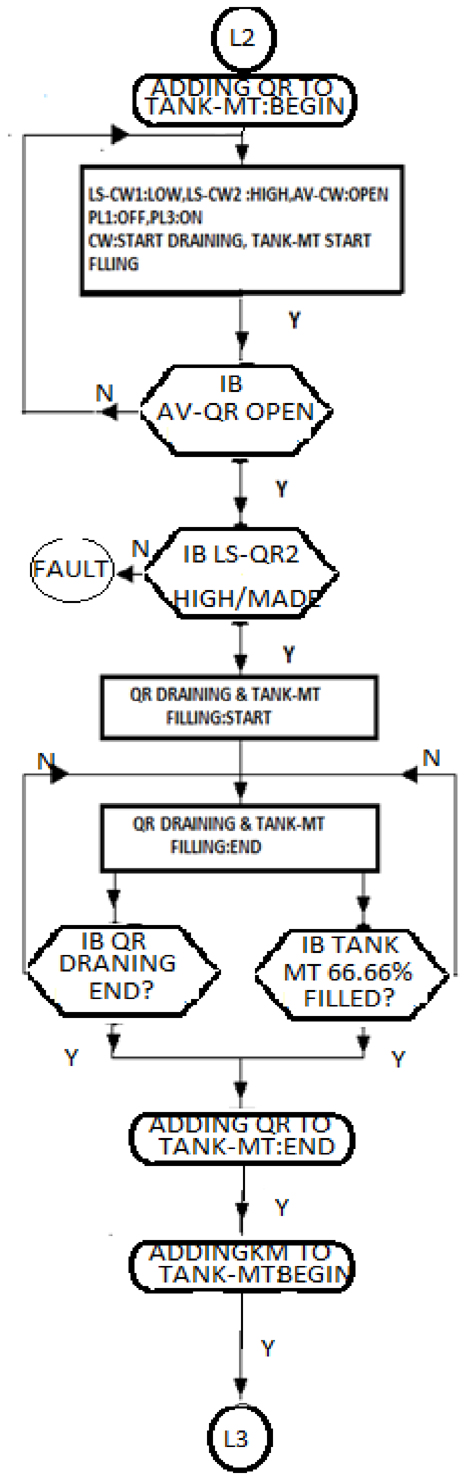
1 OF 6

Figure 5.1.1: Flow chart of the Operation



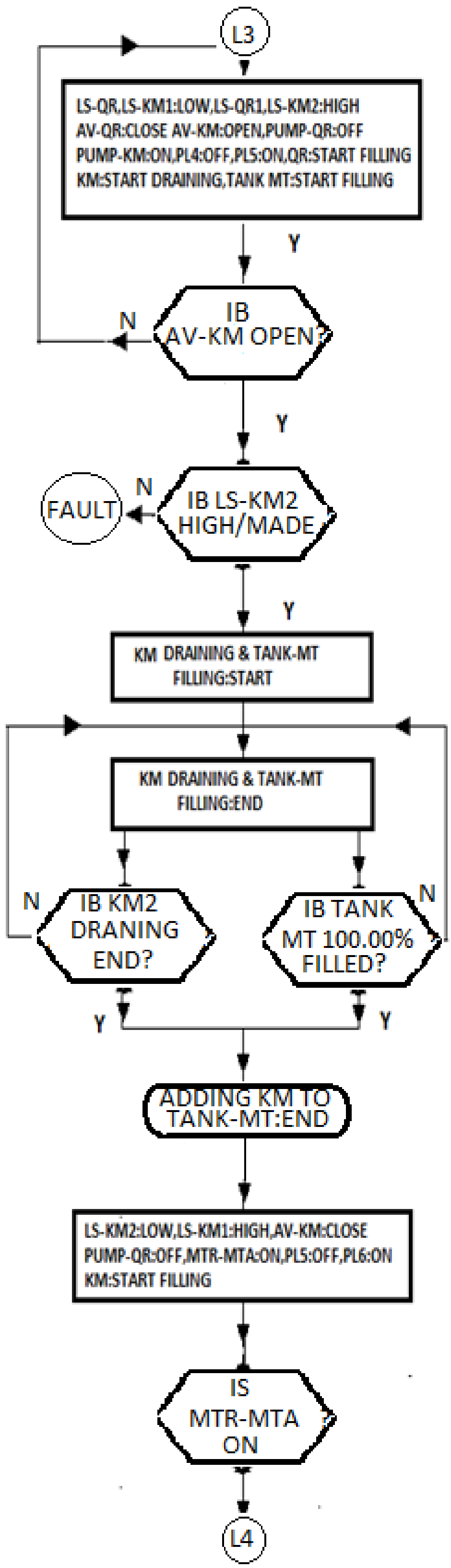
2 OF 6

Figure 5.1.2: Flow chart of the Operation



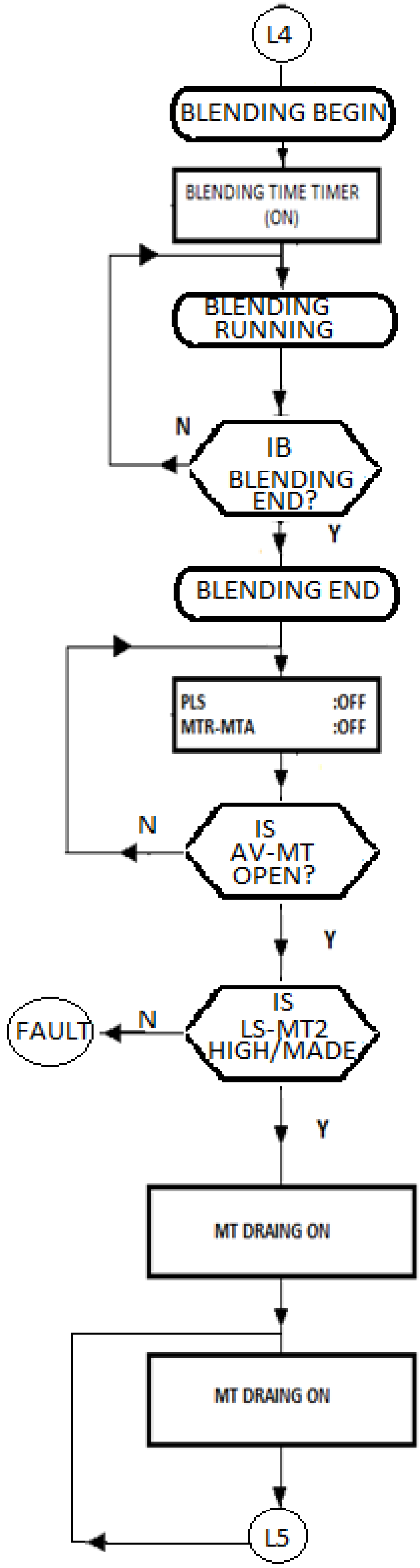
3 OF 6

Figure 5.1.3: Flow chart of the Operation



4 OF 6

Figure 5.1.4: Flow chart of the Operation



5 OF 6

Figure 5.1.5: Flow chart of the Operation

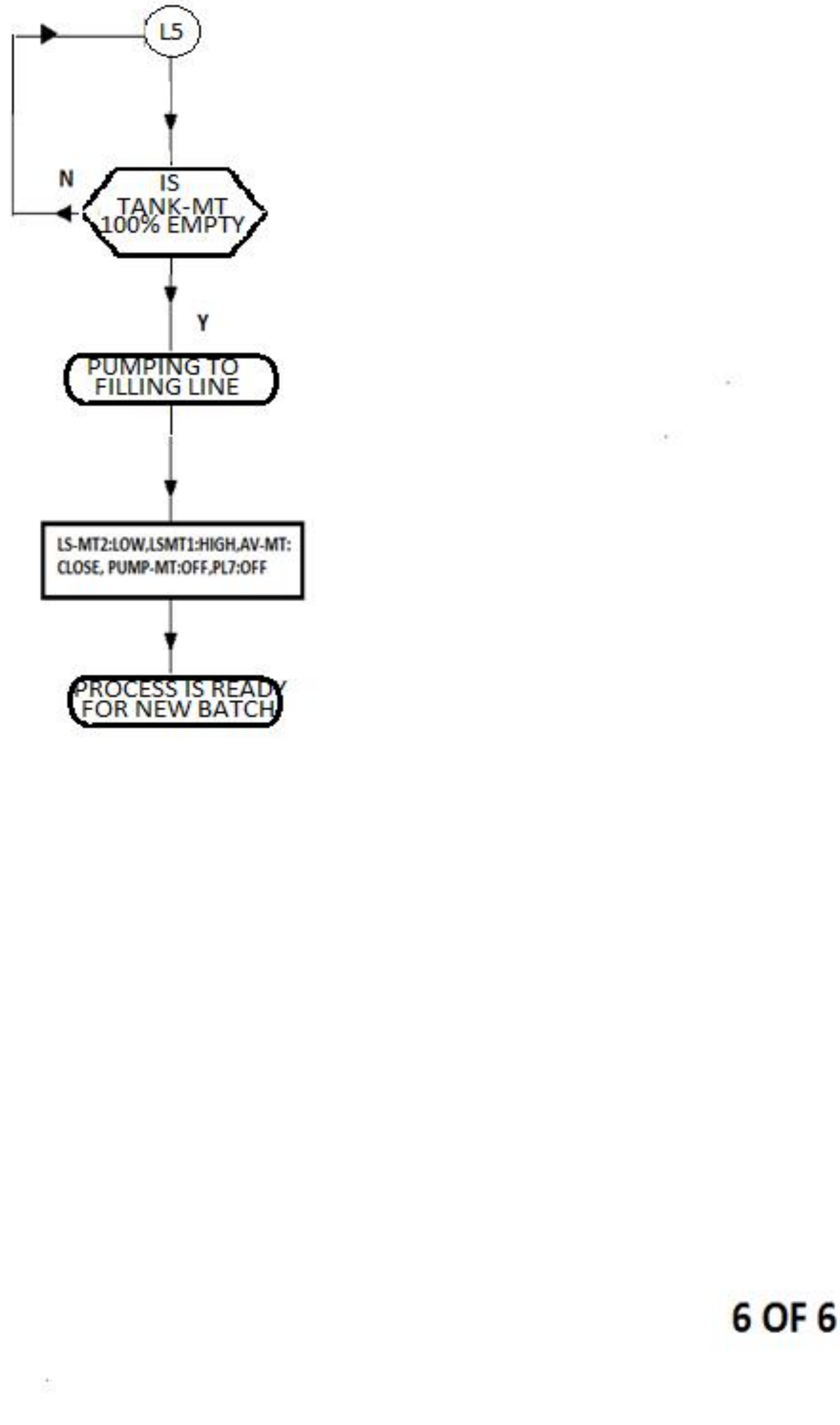


Figure 5.1.6: Flow chart of the Operation

5.3 Assignment of Inputs and Outputs

After the system sequence of operation is determine, all external input and output devices connected to the PLC must be determined and assigned the number corresponding to the input and output number. Table 5.1 and 5.2 shows the assignment of inputs and outputs.

Name	Address	SCADA bits
Start - PB	I 0.0	M 5.0
Stop -PB	I 0.1	M 5.1
E - Stop	I 0.2	M 5.2
LS-CW1	I 4.0	M.0.0
LS-CW2	I 4.1	M.0.1
LS-QR1	I 4.2	M.0.2
LS-QR2	I 4.3	M.0.3
LS-KM1	I 4.4	M.0.4
LS-KM2	I 4.5	M.0.5
LS-MT1	I 4.6	M.0.6
LS-MT2	I 4.7	M.0.7

Table 5.1: Assignment of Inputs

NAME	Address	Comment
PL1	Q 0.0	
PL2	Q 0.1	
PL3	Q 0.2	
PL4	Q 0.3	
PL5	Q 0.4	
PL6	Q 0.5	
PL7	Q 0.6	
AV- CW	Q 4.0	
AV- QR	Q 4.1	
AV- KM	Q 4.2	
AV- MT	Q 4.3	
PUMP- QR	Q 4.4	
PUMP- KM	Q 4.5	
MTR-MT	Q 4.6	
PUMP- MT	Q 4.7	

Table 5.2: Assignment of outputs

5.4 Ladder Diagram

A ladder diagram is produced according to the flow chart of the system and based on the system operations and conditions. Figure 5.3 shows the ladder diagram of the system. The system in the ladder diagram form will be programmed into SIMATIC STEP 7 v5.4 + sp3 PLC software. Once the program has been downloaded into PLC simulator, it can be monitored in the Diagram Workspace during execution. Furthermore, the SIMATIC STEP 7 v5.4 + sp3 software provides on-line editing functions during execution. Note that the on-line editing is possible in the Run mode. All activities occur can be observed using SIMATIC STEP 7 v5.4 + sp3 simulator.

OB1 - <offline>

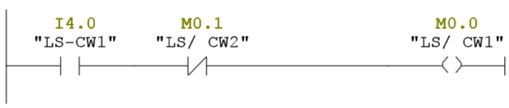
""

Name: **Family:**
Author: **Version:** 0.1
Block version: 2
Time stamp Code: 04/11/2015 06:12:56 PM
Interface: 02/15/1996 04:51:12 PM
Lengths (block/logic/data): 00932 00746 00022

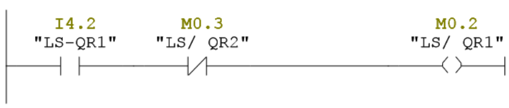
Name	Data Type	Address	Comment
TEMP		0.0	
OB1_EV_CLASS	Byte	0.0	Bits 0-3 = 1 (Coming event), Bits 4-7 = 1 (Event class 1)
OB1_SCAN_1	Byte	1.0	1 (Cold restart scan 1 of OB 1), 3 (Scan 2-n of OB 1)
OB1_PRIORITY	Byte	2.0	Priority of OB Execution
OB1_OB_NUMBR	Byte	3.0	1 (Organization block 1, OB1)
OB1_RESERVED_1	Byte	4.0	Reserved for system
OB1_RESERVED_2	Byte	5.0	Reserved for system
OB1_PREV_CYCLE	Int	6.0	Cycle time of previous OB1 scan (milliseconds)
OB1_MIN_CYCLE	Int	8.0	Minimum cycle time of OB1 (milliseconds)
OB1_MAX_CYCLE	Int	10.0	Maximum cycle time of OB1 (milliseconds)
OB1_DATE_TIME	Date_And_Time	12.0	Date and time OB1 started

Block: OB1 "Main Program Sweep (Cycle)"

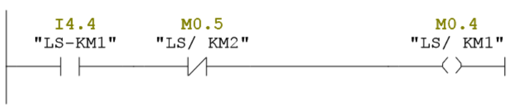
Network: 1



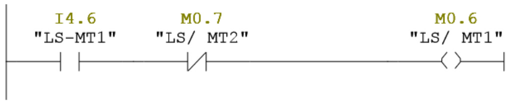
Network: 2



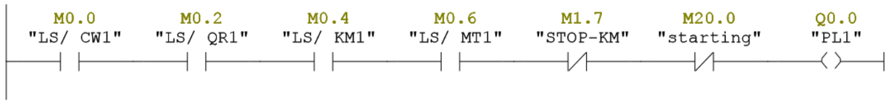
Network: 3



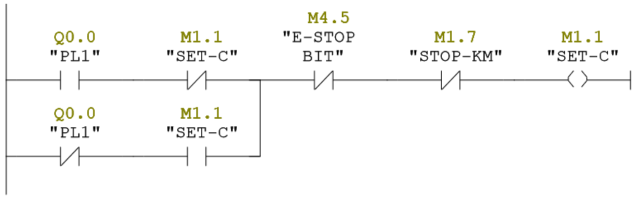
Network: 4



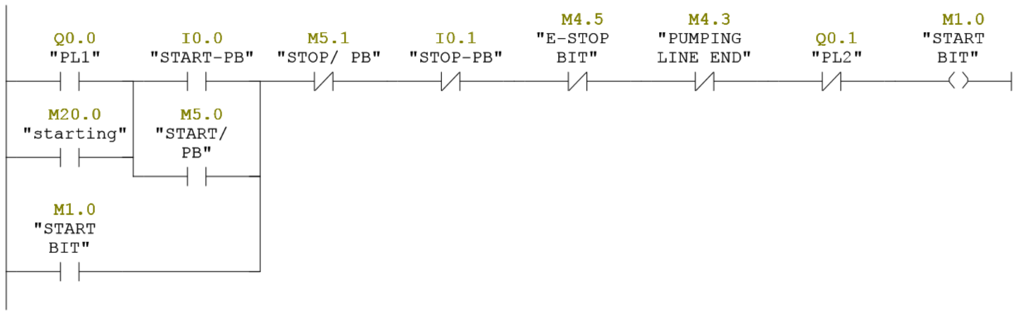
Network: 5



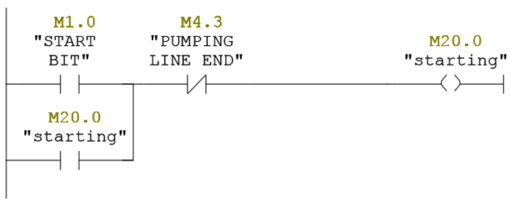
Network: 6



Network: 7

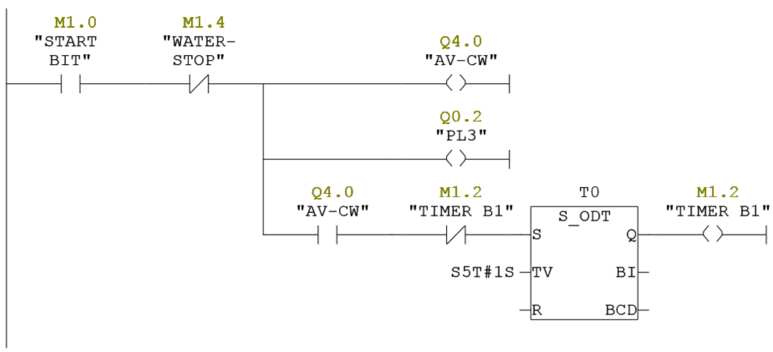


Network: 8



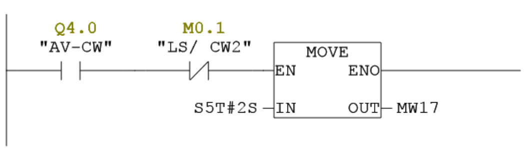
Network: 9

Network: 10

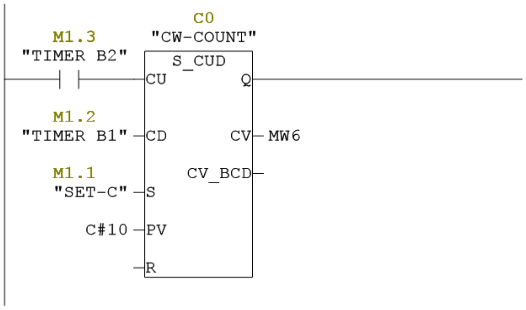


Network: 11

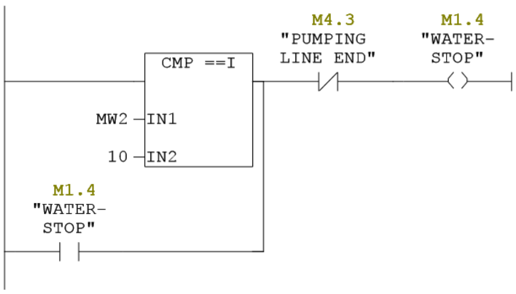
Network: 12



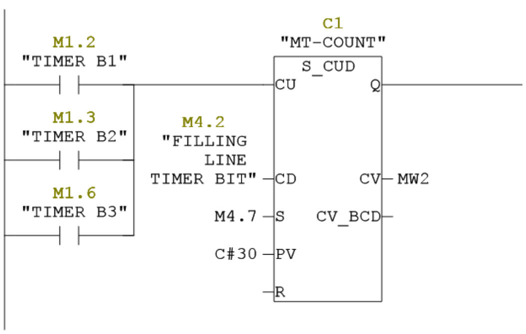
Network: 13



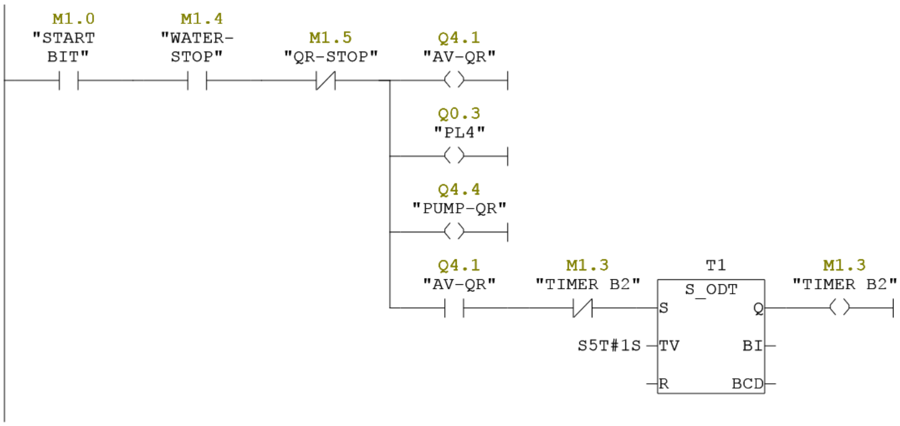
Network: 14



Network: 15

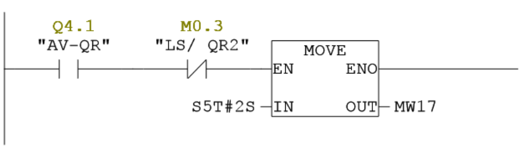


Network: 16

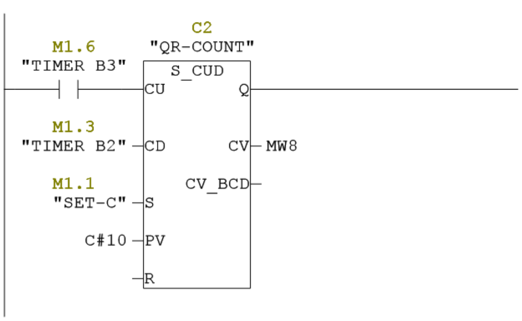


Network: 17

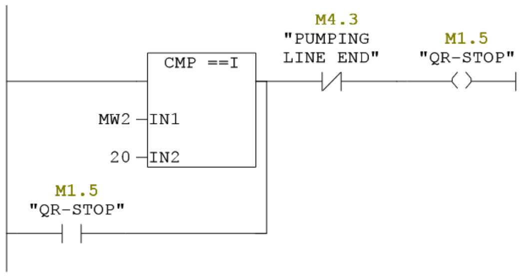
Network: 18



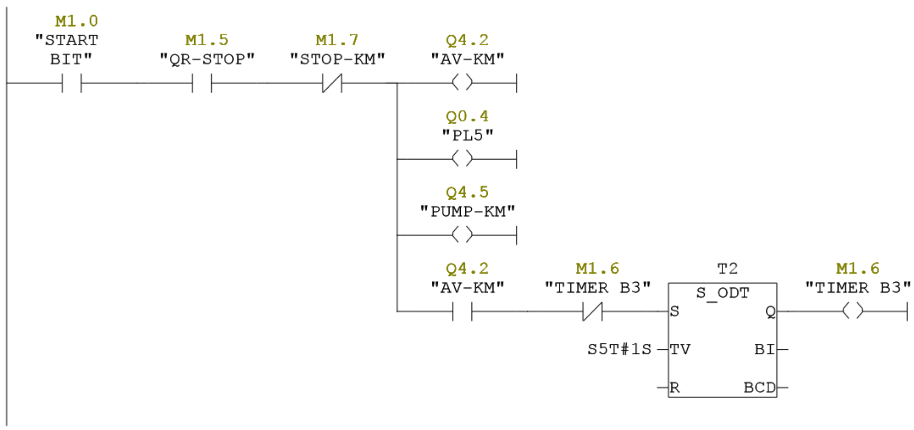
Network: 19



Network: 20

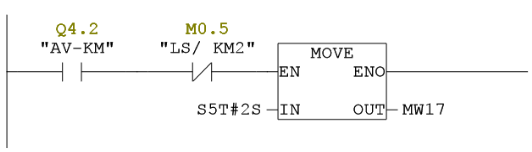


Network: 21

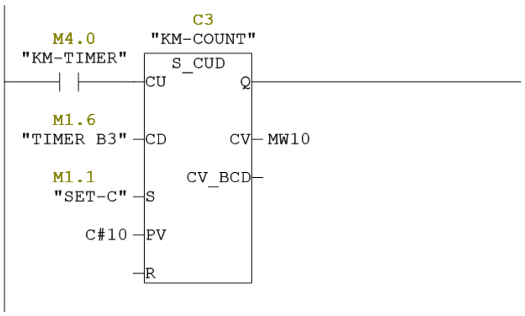


Network: 22

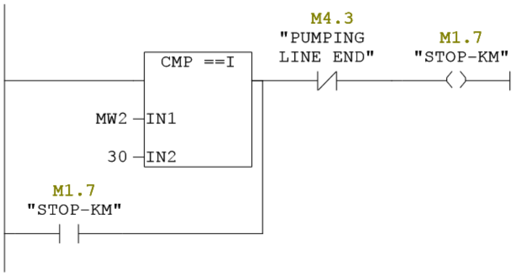
Network: 23



Network: 24

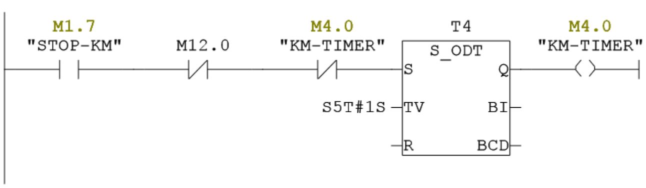


Network: 25

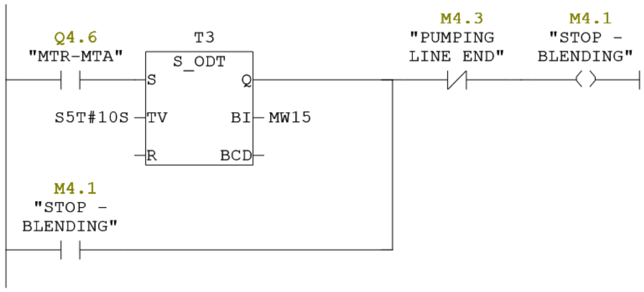


Network: 26

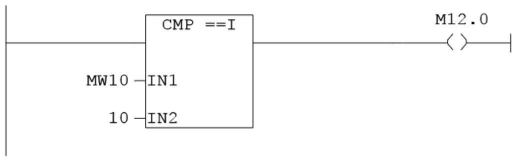
Network: 27



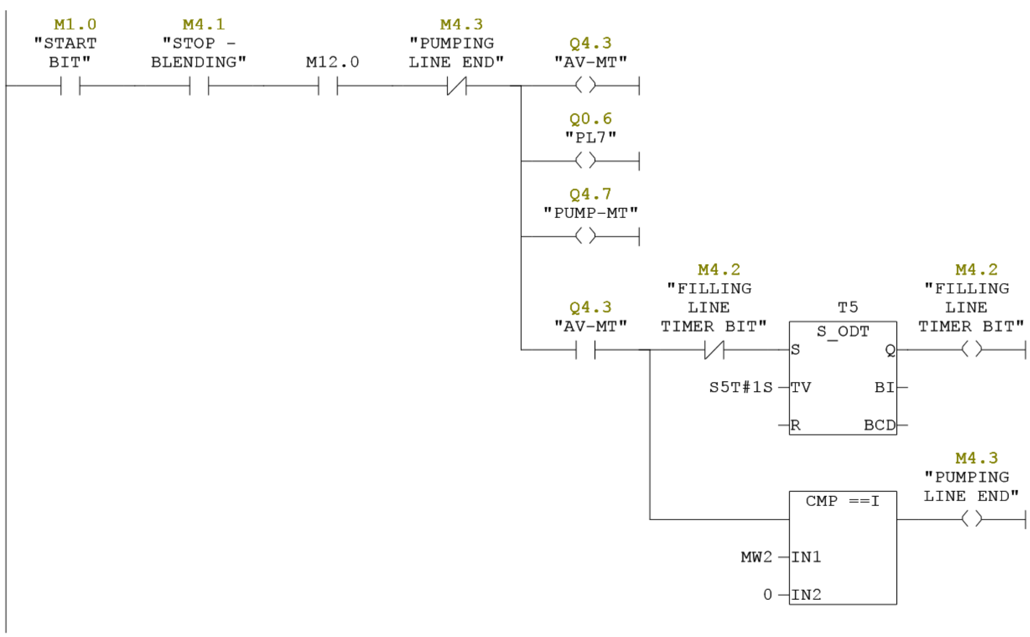
Network: 28



Network: 29

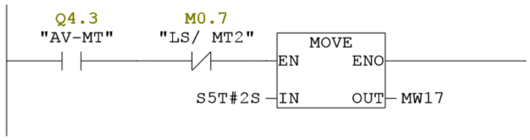


Network: 30

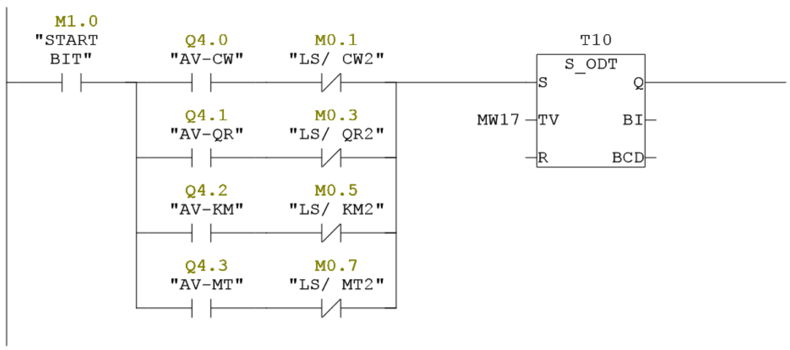


Network: 31

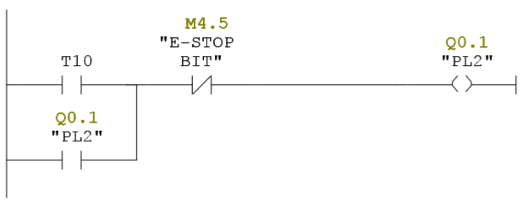
Network: 32



Network: 33



Network: 34



5.5 Run mode

After the program downloaded into the PLC simulator, the sequence of the program in the run mode starts to execute, a detailed explanation is presented below:

5.5.1.1 To begin a new batch, limit switches (LS-CWI, LS-QR1, LS-KM, LS-MT1) must be on to indicate that valves (AV-CW, AV-QR, AV-KM, and AV-MT1) were closed. the operator will verify that the" SYSTEM READY" pilot light is on and that the mixing tank is ready to receive ingredients.

This step is shown in Figure 5.1 & Figure5.2

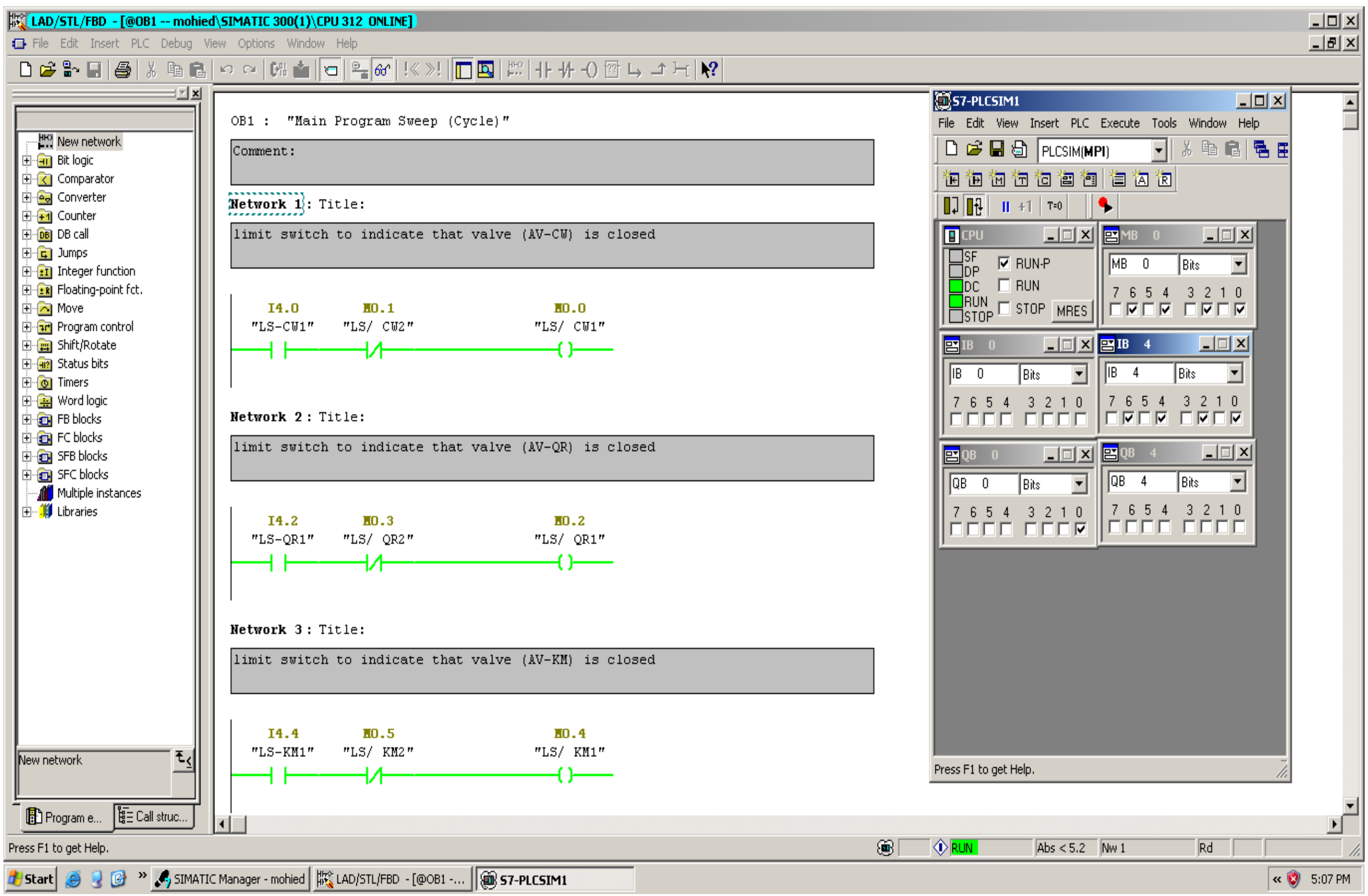


Figure 5.1: system ready

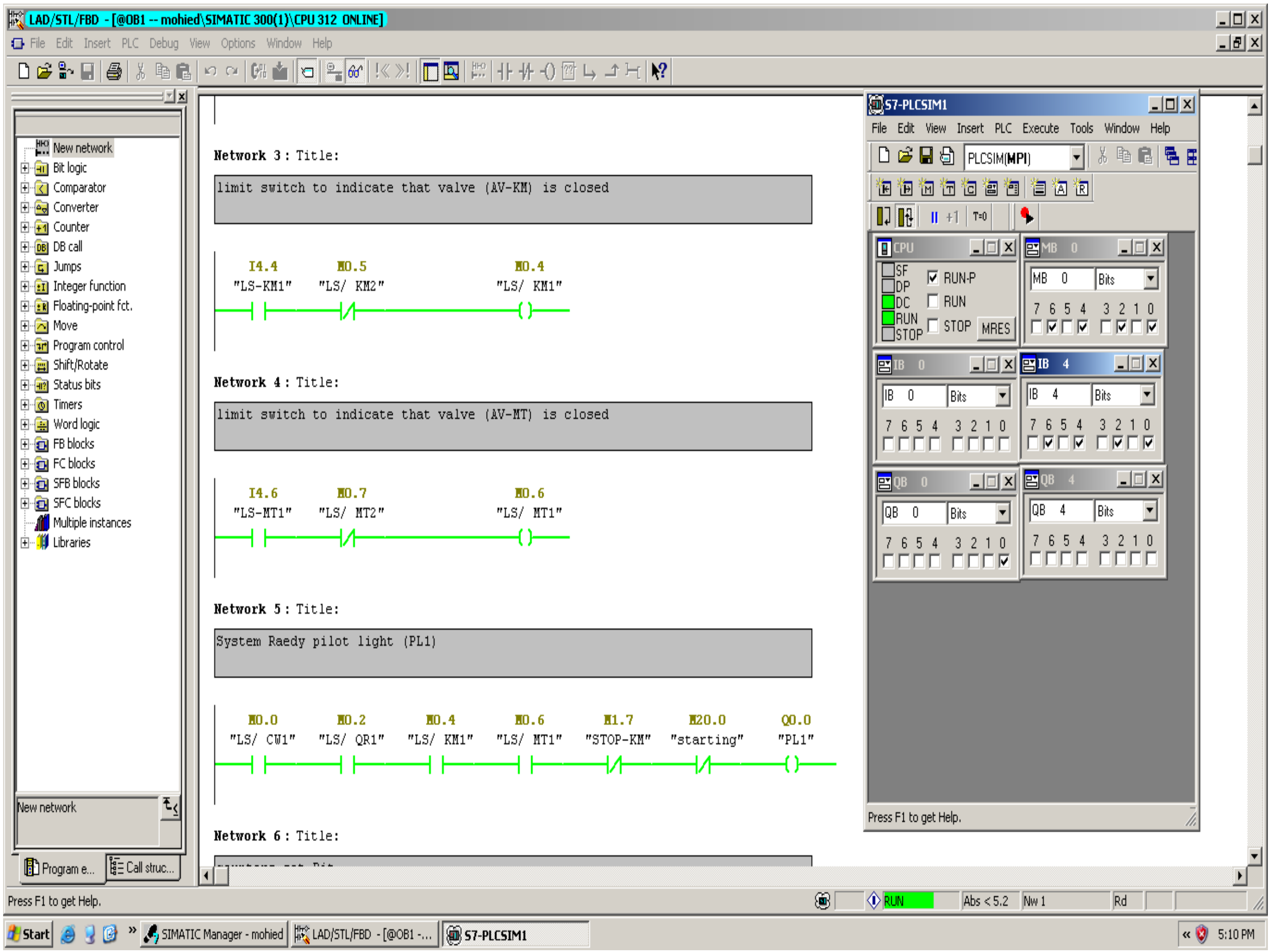


Figure 5.2: system ready

5.5.1.2 The operator will then press the "START BATCH" pushbutton to begin the batching process. No further operator input is required. The pilot" SYSTEM READY" light will turn off

This step is shown in Figure 5.3

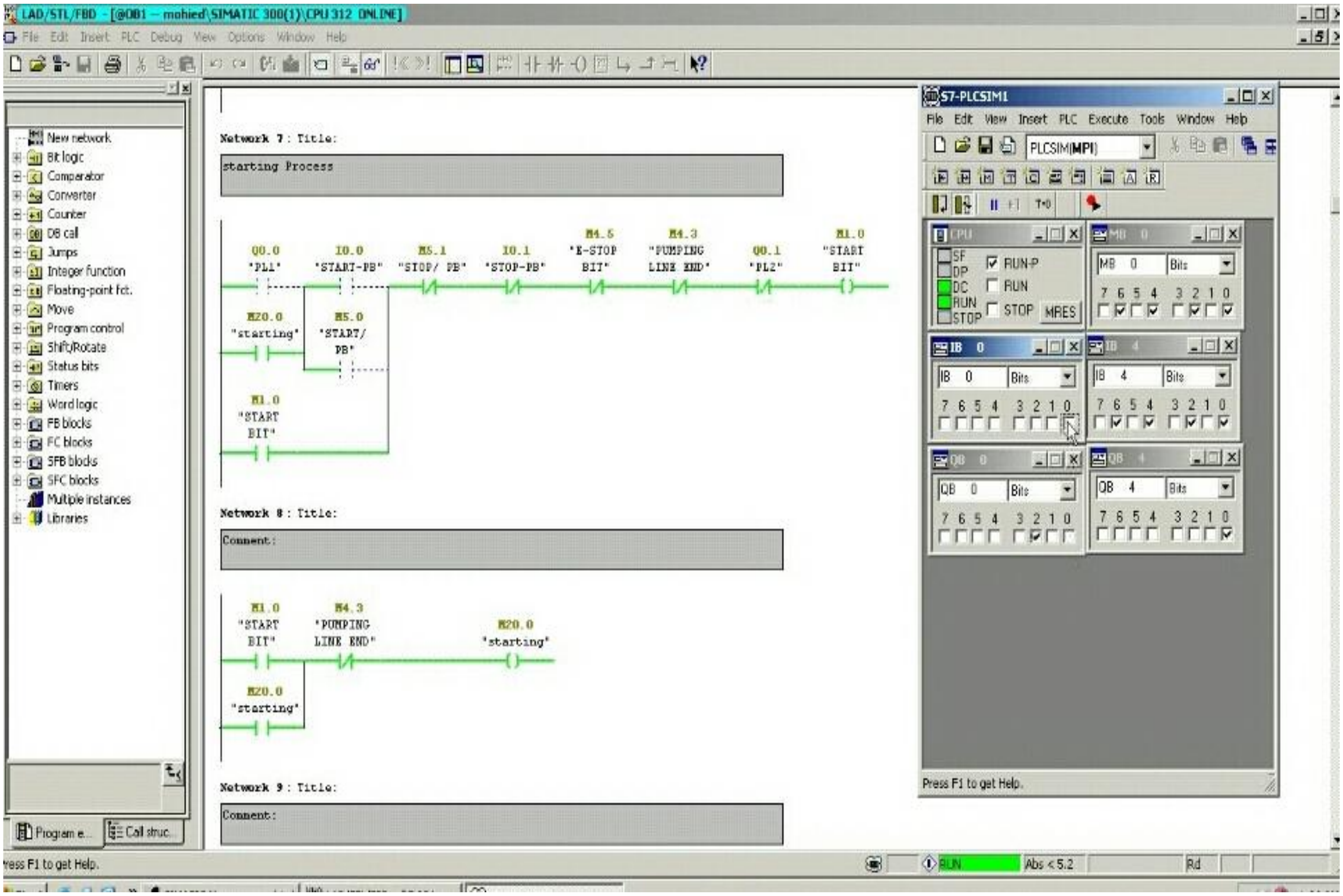


Figure 5.3: starting process

5.5.1.3 Automatic valve AV-CW will open. The “ADDING WATER” pilot light will illuminate. The state of AV-CW will be verified by limit switch LS-CW2. If LS-CW2 is not made within 2 seconds after the valve was told to open, a fault will be generated and the system will shut down. The pilot light “SYSTEM FAULT” PL2 will illuminate indicating that a fault has occurred. Valve AV-CW will remain open until 1275 lbs. Of City Water is in the mixing tank valve AV-CW will closed within 2 seconds after the valve was told to close. If the valve closure is not verified within 2 seconds, a fault will be generated, the system will shut down and PL2 will illuminate. This step is shown in Figure 5.4 & Figure 5.5

Note :- (All valves and their respective limit switches will work in the manner described above)

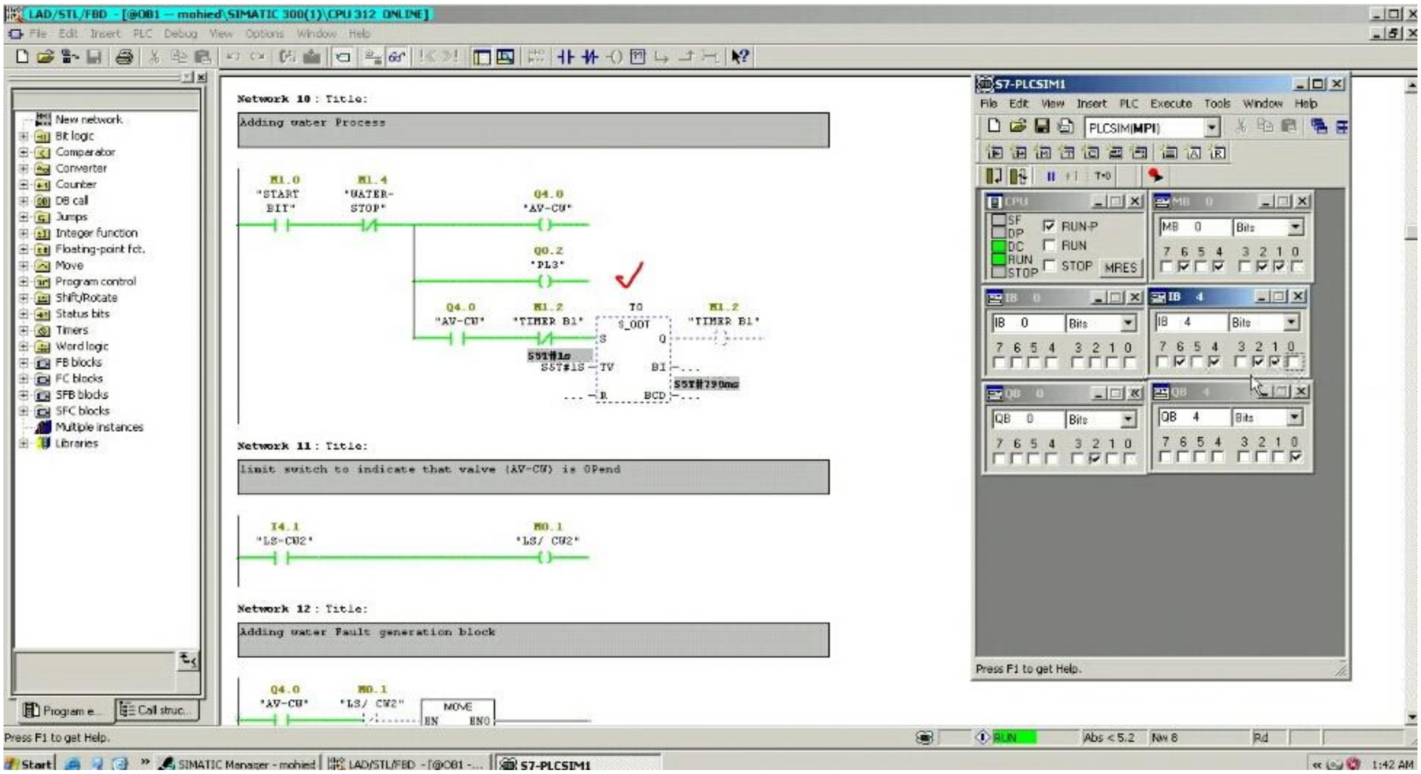


Figure 5.4: adding water

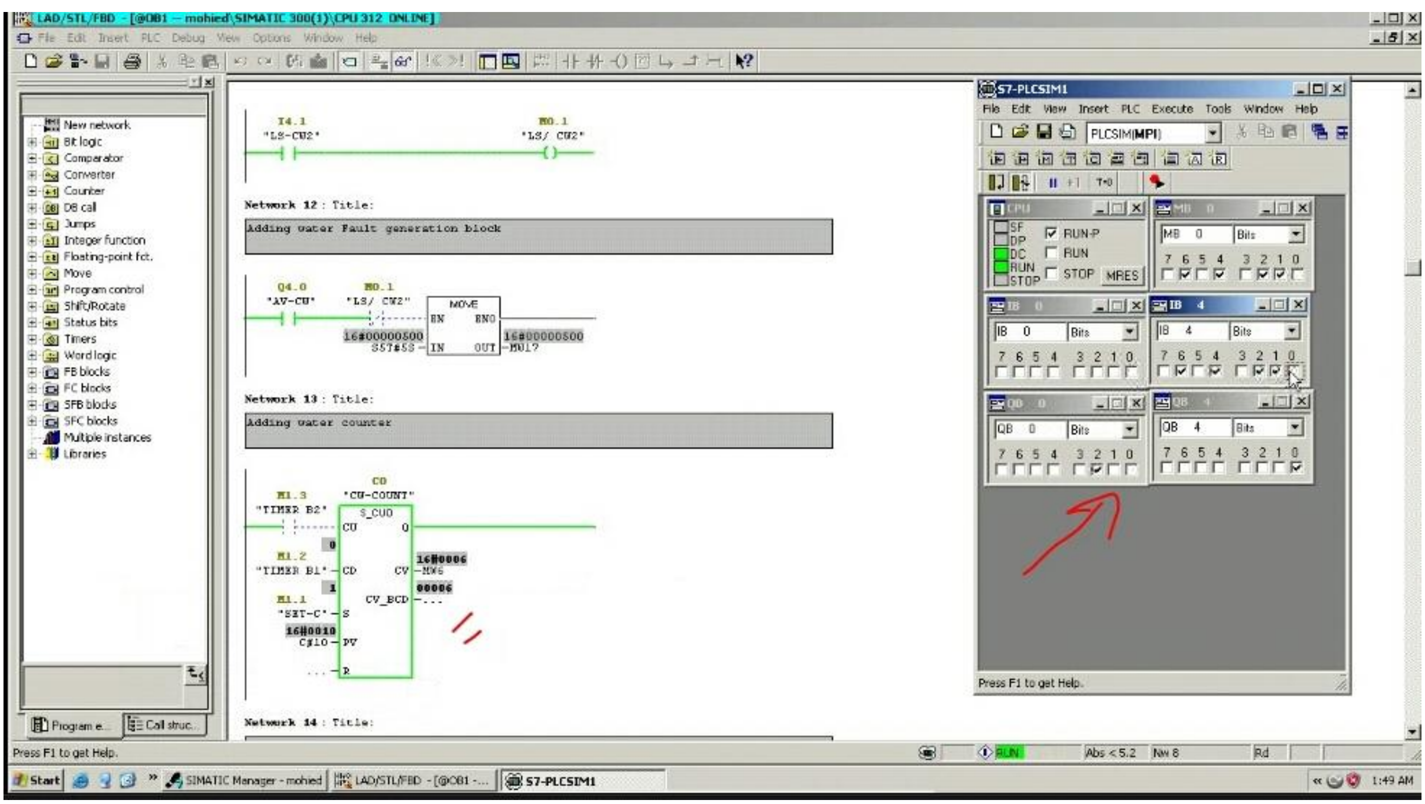


Figure 5.5: adding water Counter

5.5.1.4 After the City Water has been added and LS-CW1 indicates that valve AVCW is closed, the pilot “ADDING WATER” light will turn off. Valve AV-QR will be opened. The “ADDING QR” pilot light will illuminate. After the valve position has been verified by LS-QR2, PUMP-QR will pump 390 lbs. of ingredient QR into Mixing Tank.

This step is shown in Figure 5.6 & Figure 5.7

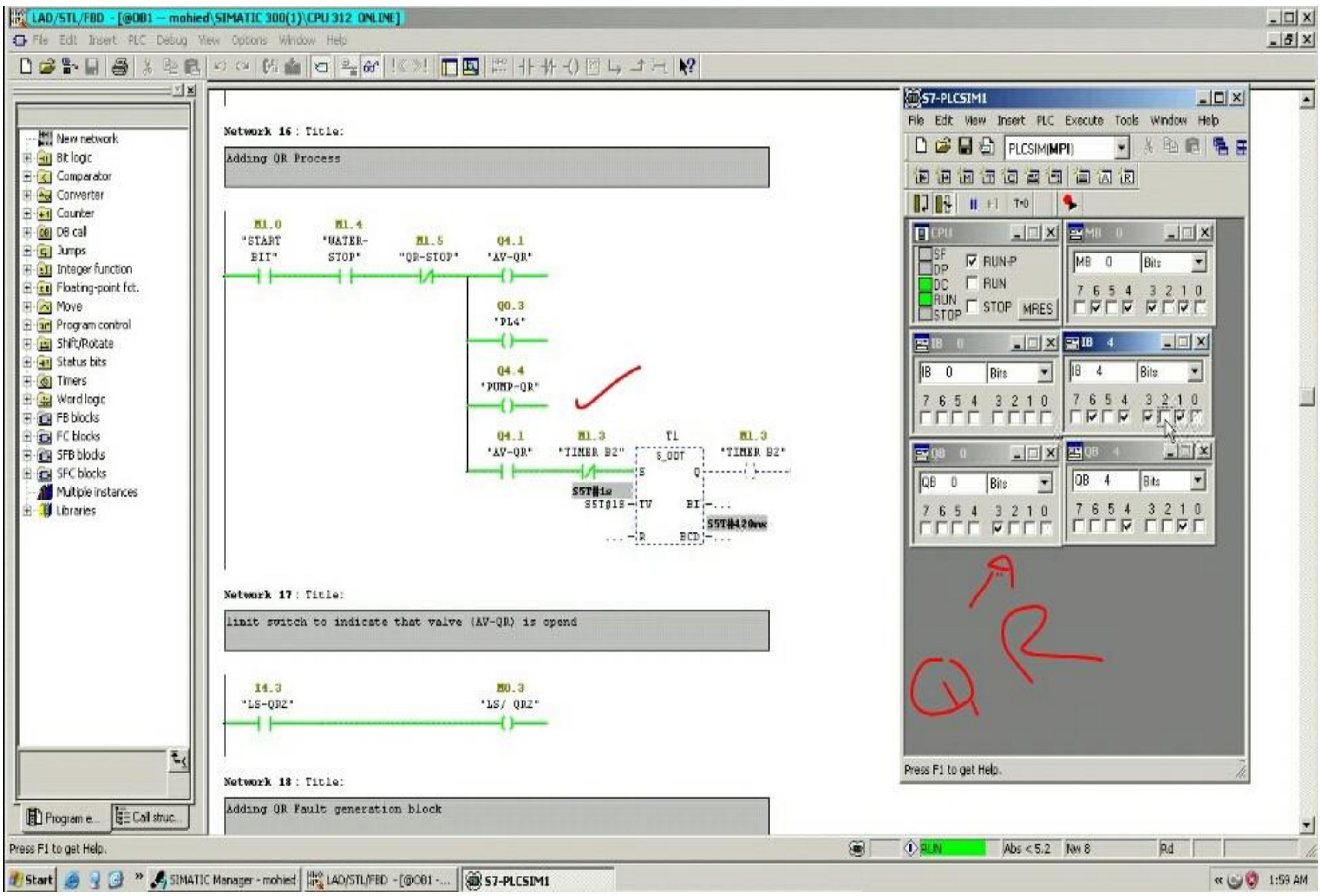


Figure 5.6: adding QR

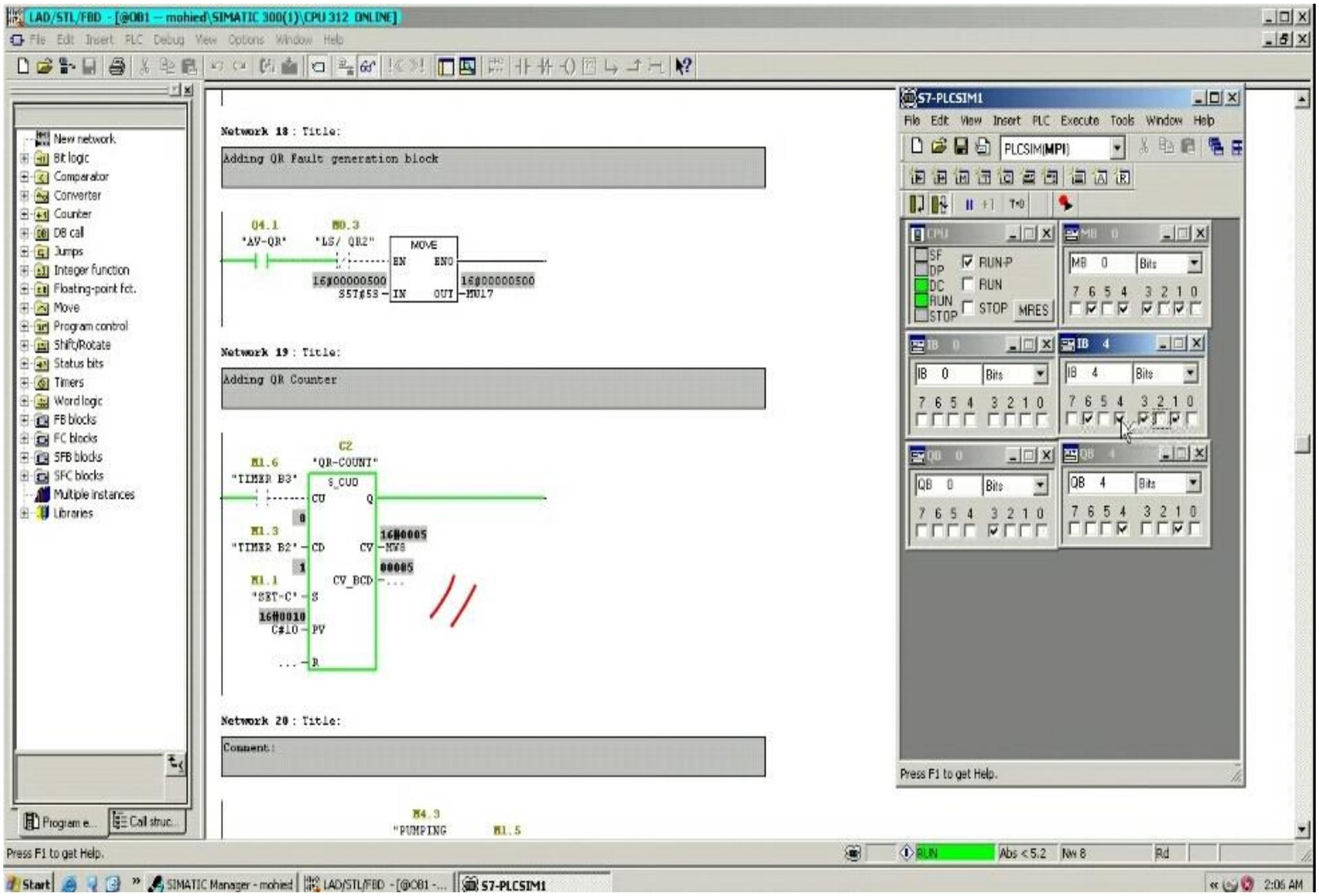


Figure 5.7: adding QR Counter

5.5.1.5 After the ingredient QR has been add to the Mixing Tank, valve AV-QR will close and the "ADDING QR" pilot light will turn off. After LS-QR1 indicates the valve has been closed, valve AV-KM will open. The "ADDING KM" pilot light will illuminate. After the valve position has been verified by LS-KM2, PUMP-KM will pump 173 lbs. of ingredient KM into the Mixing Tank.

This step is shown in Figure 5.8 & Figure 5.9

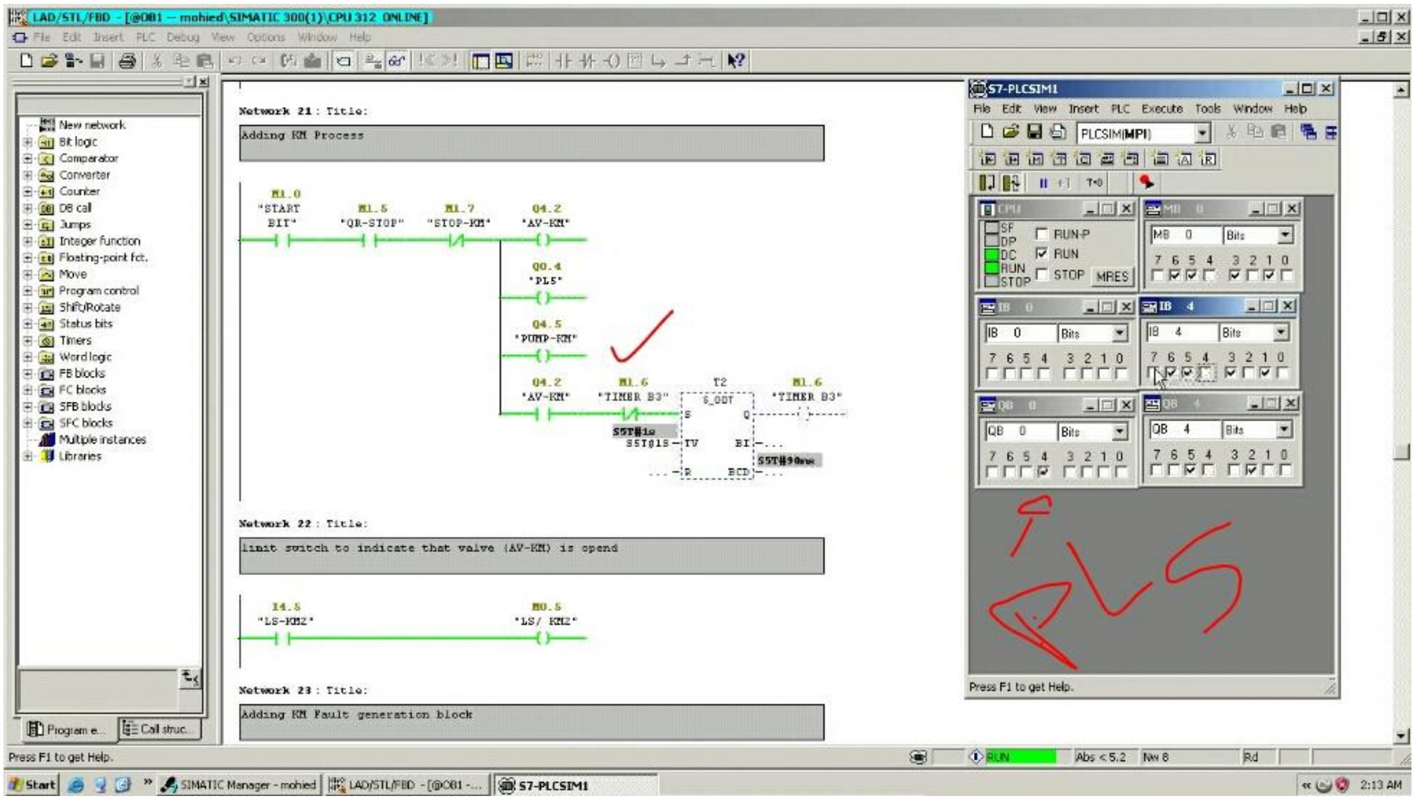


Figure 5.8: adding KM

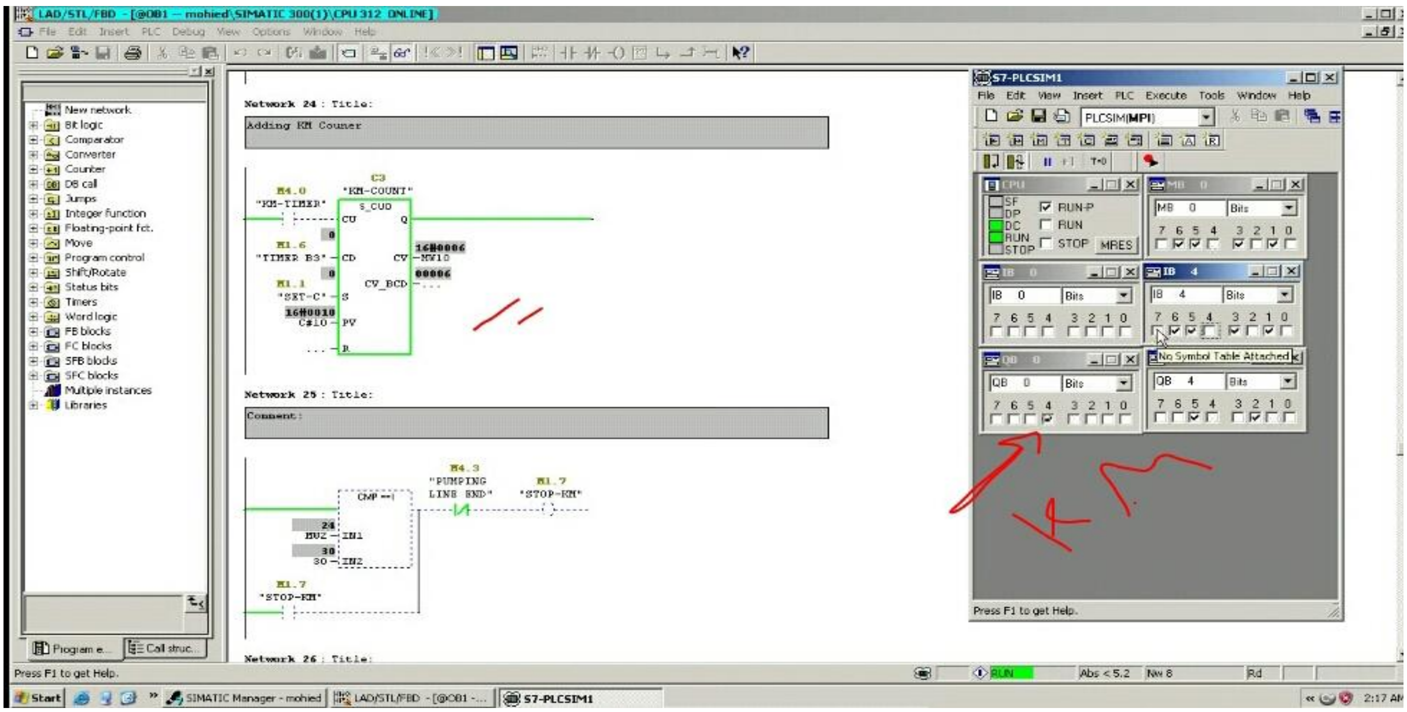


Figure 5.9: adding KM counter

5.5.1.6 After ingredient KM has been added to the Mixing Tank, valve AV-KM will close. The “ADDING KM” pilot light will turn off. After LS-KM indicates the valve has been closed, the agitator motor MTRMTA will start. The “BLENDING” pilot light will illuminate. The agitator will run for 3 minutes. After the agitator is finished

This step is shown in Figure 5.10

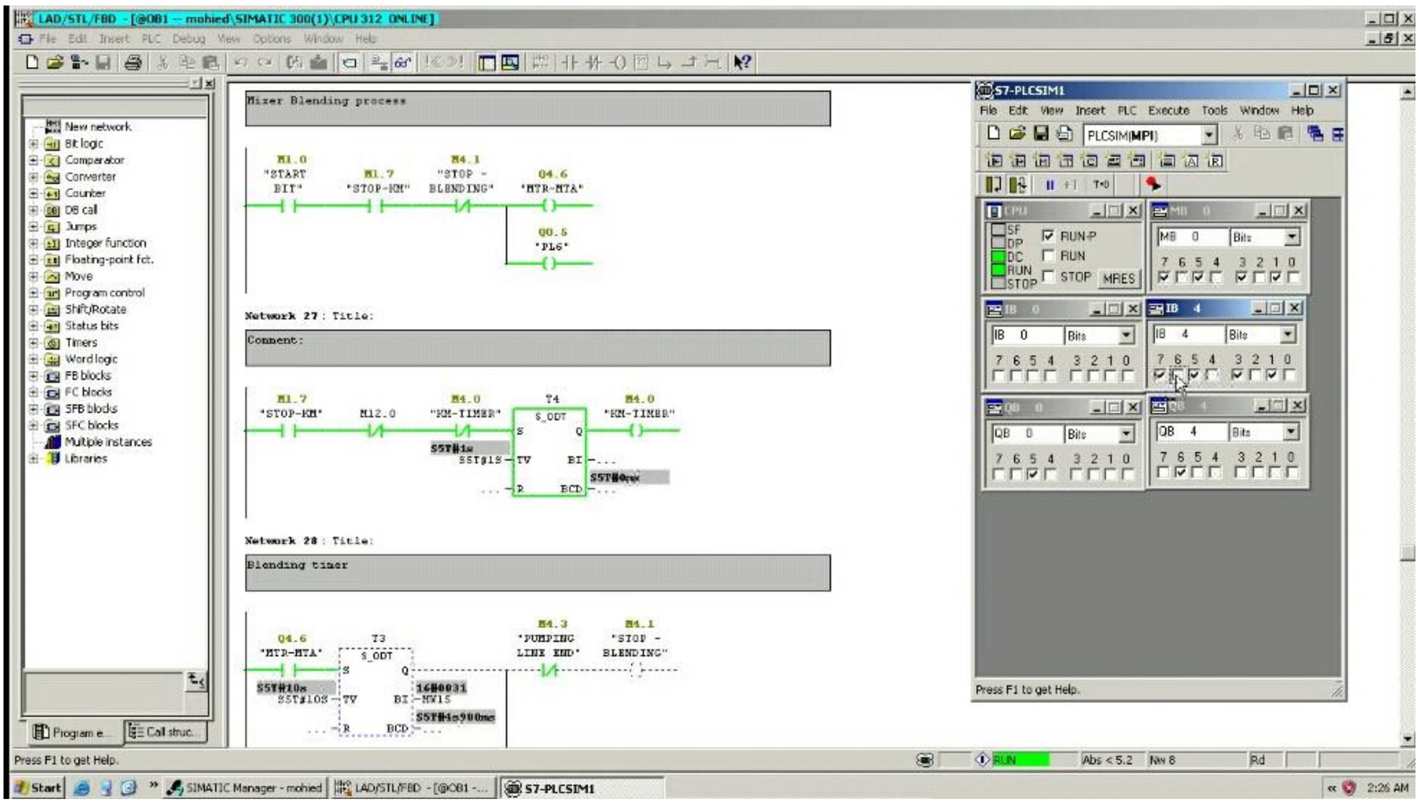


Figure 5.10: blending process

5.5.1.7 After the agitator is finished, the “BLENDING” pilot light will turn off and valve AV-MT will open after LS-MT1 indicates the valve is open, the” PUMPING TO LINES” pilot lamp will illuminate. PUMP-MT will pump the entire the batch to the filling lines, PUMP-MT will turn off after tank empty, valve AV-MT will close and batching cycle is complete

This step is shown in Figure 5.11

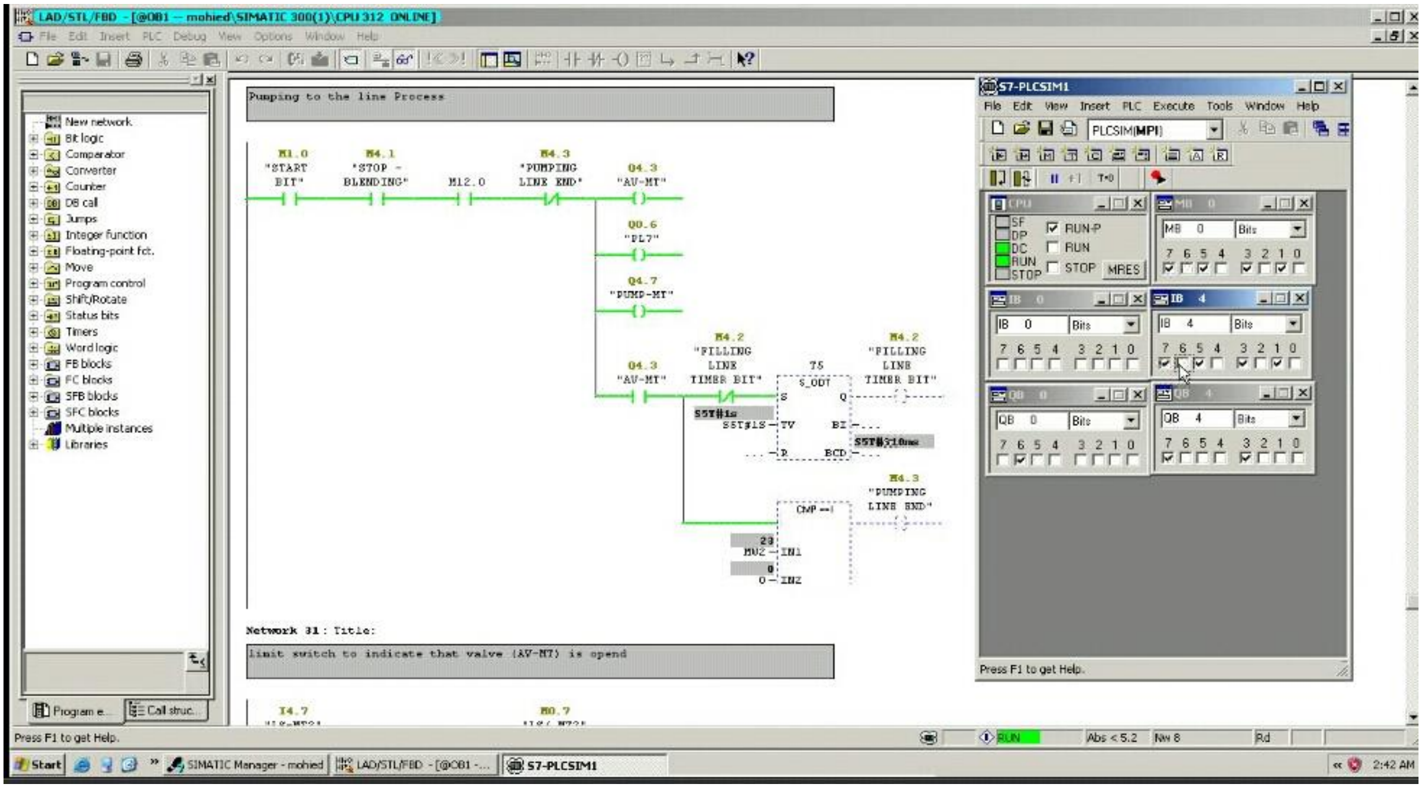


Figure 5.11: pumping to the line process

5.5.2 The mixing tank counter

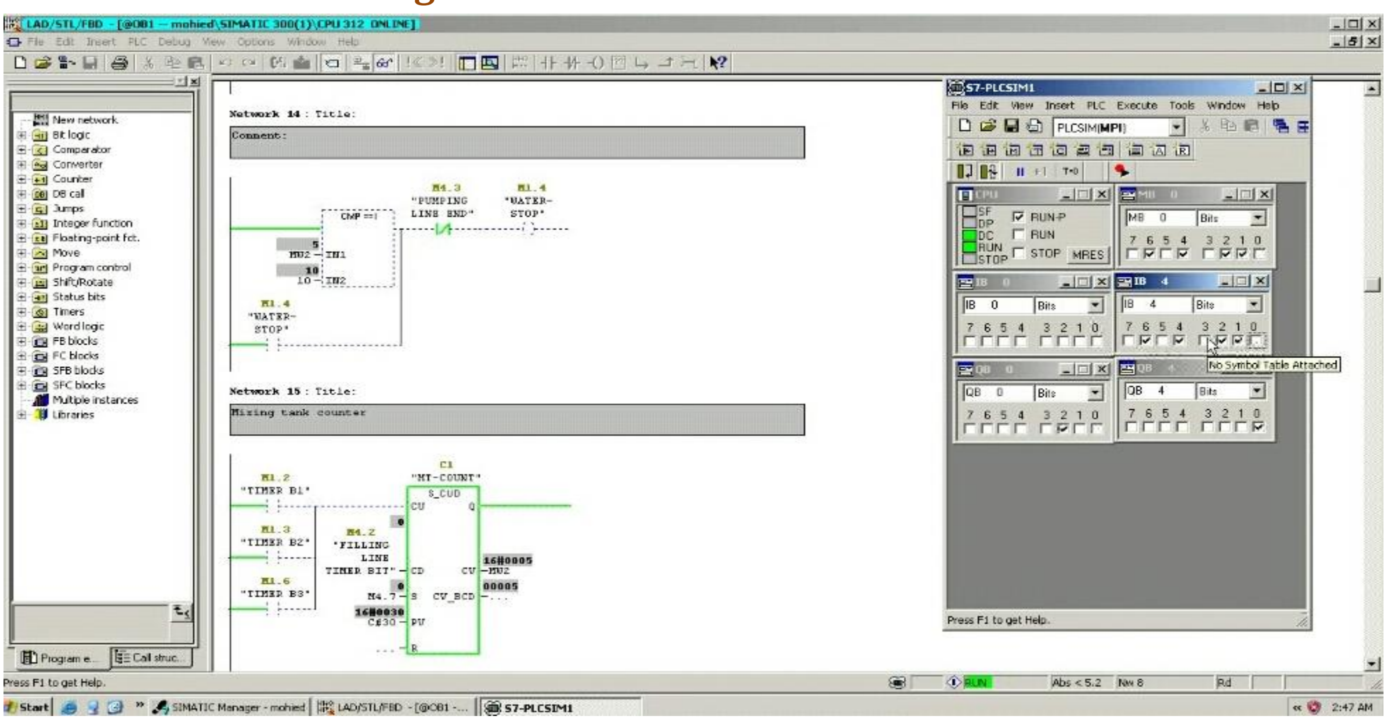


Figure 5.12: shows the adding water process

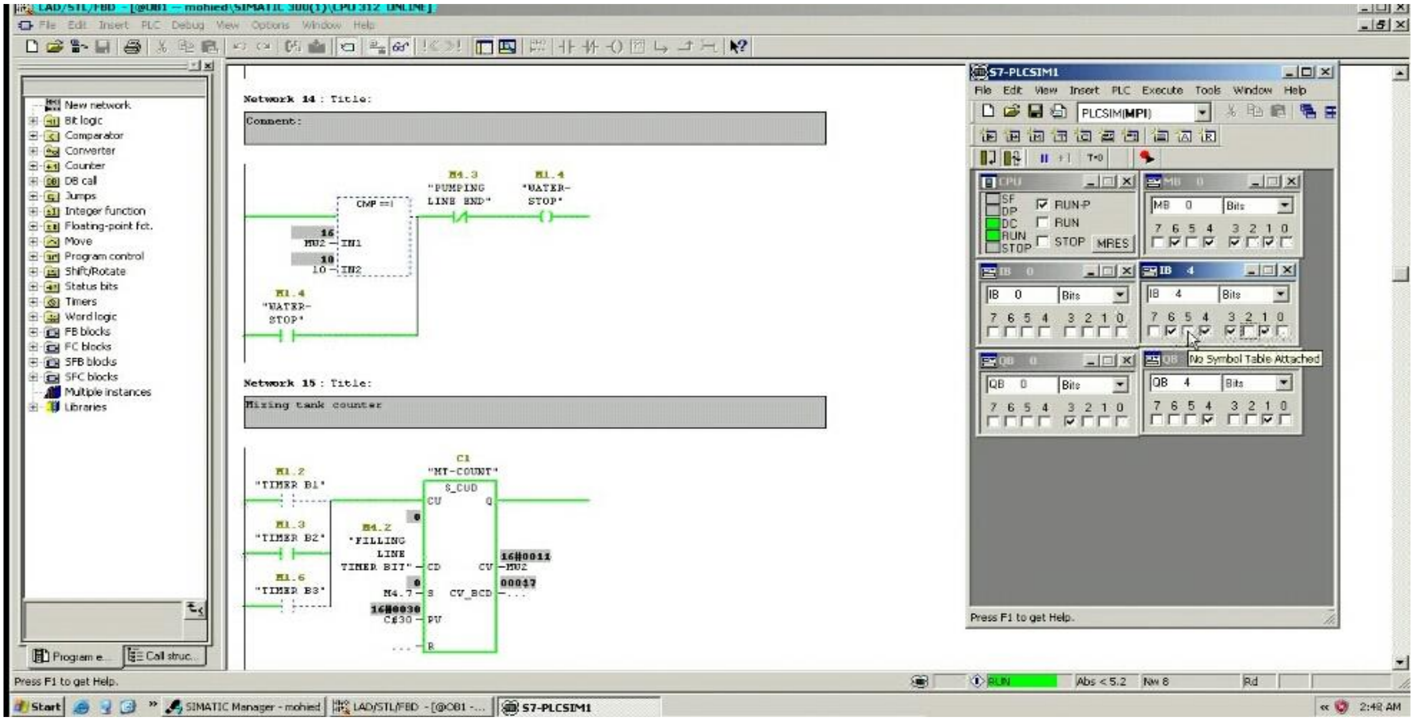


Figure 5.13: shows the adding QR process

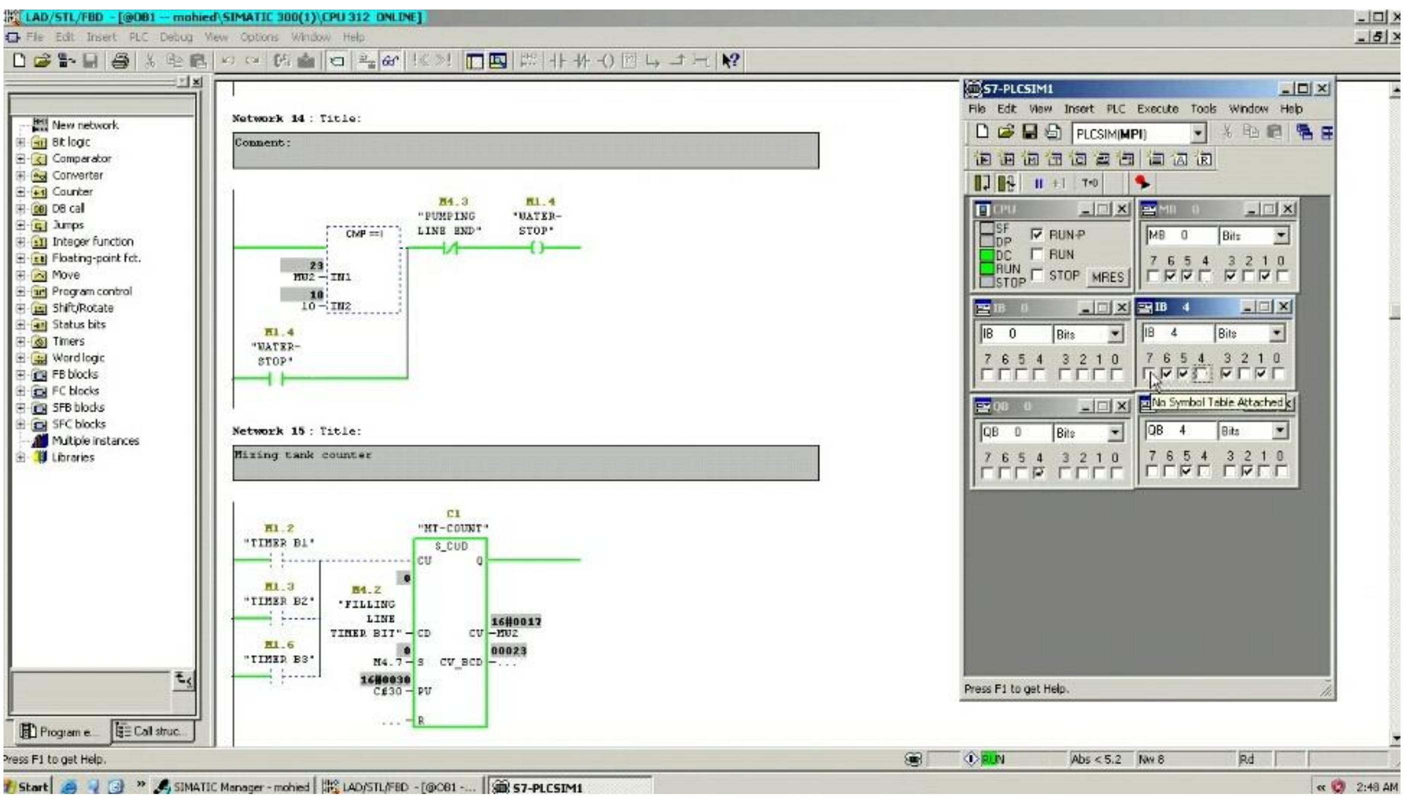


Figure 5.14: shows the adding KM process

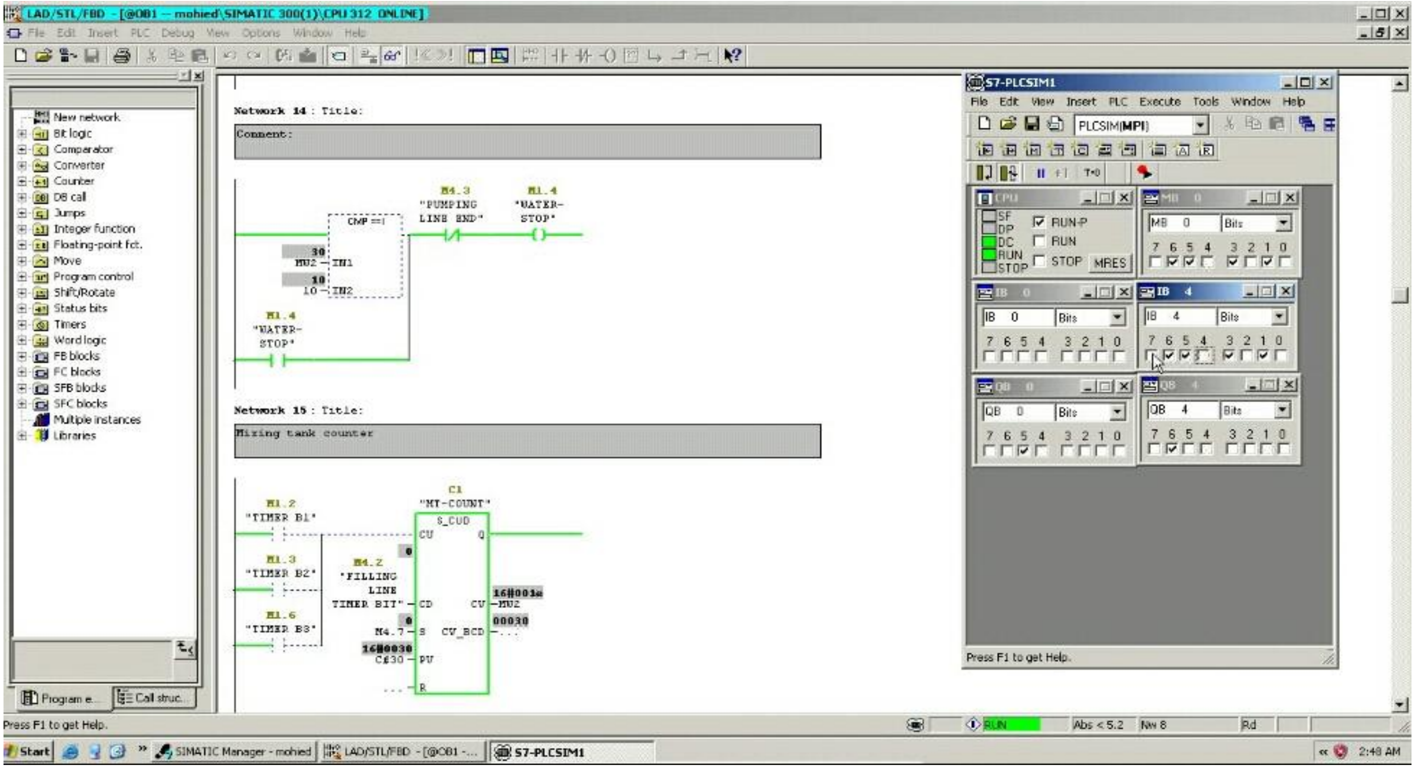


Figure 5.15: shows blending process

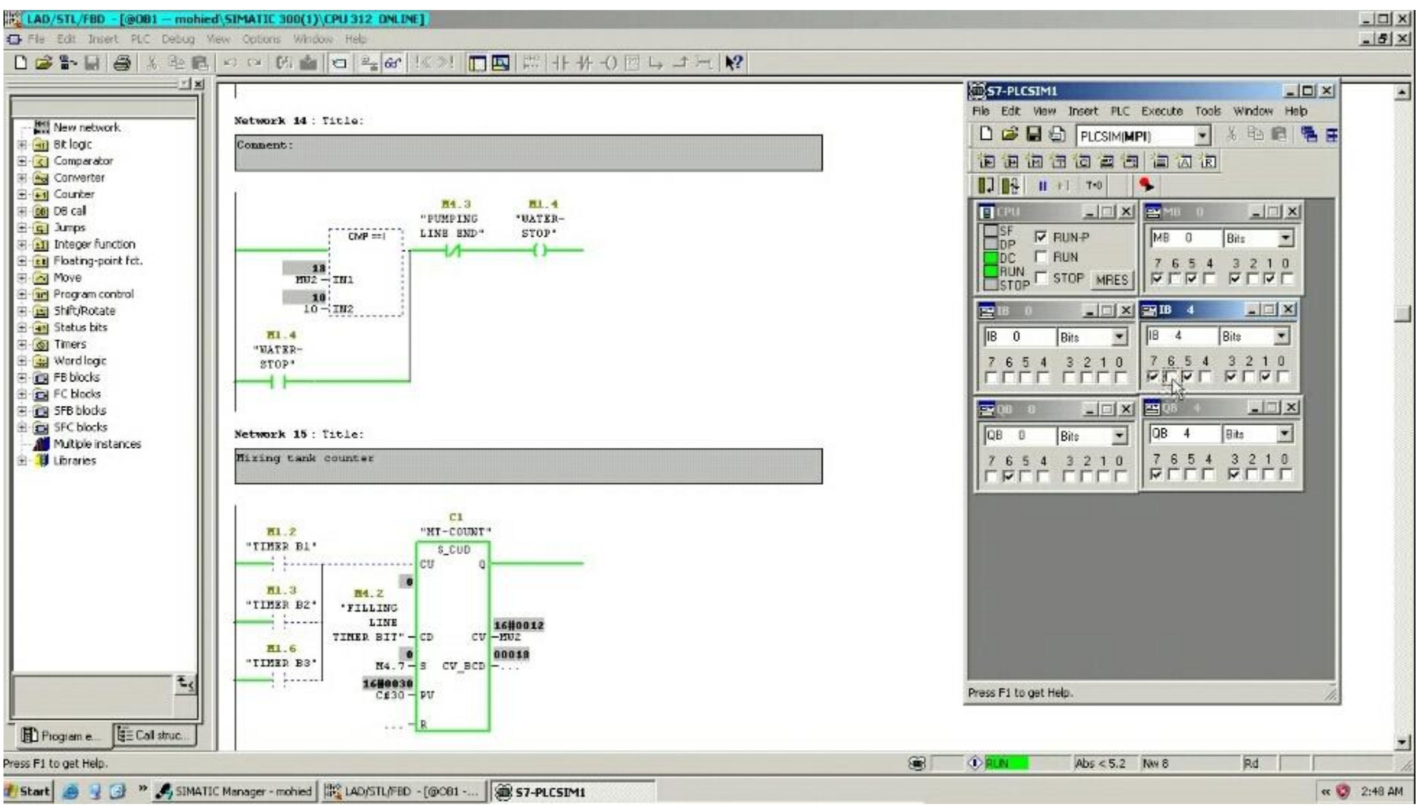


Figure 5.16: shows the pumping to the lines process

5.5.3 Fault system:

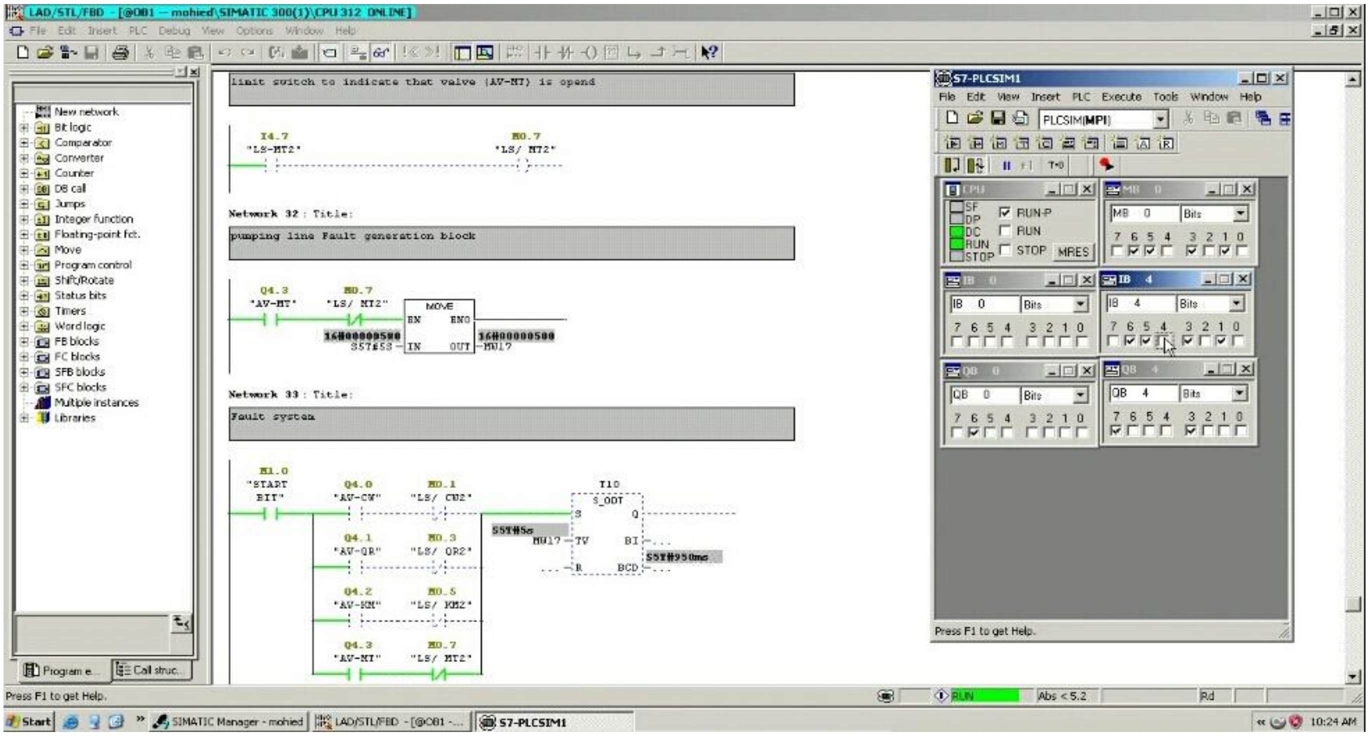


Figure 5.17: shows fault system

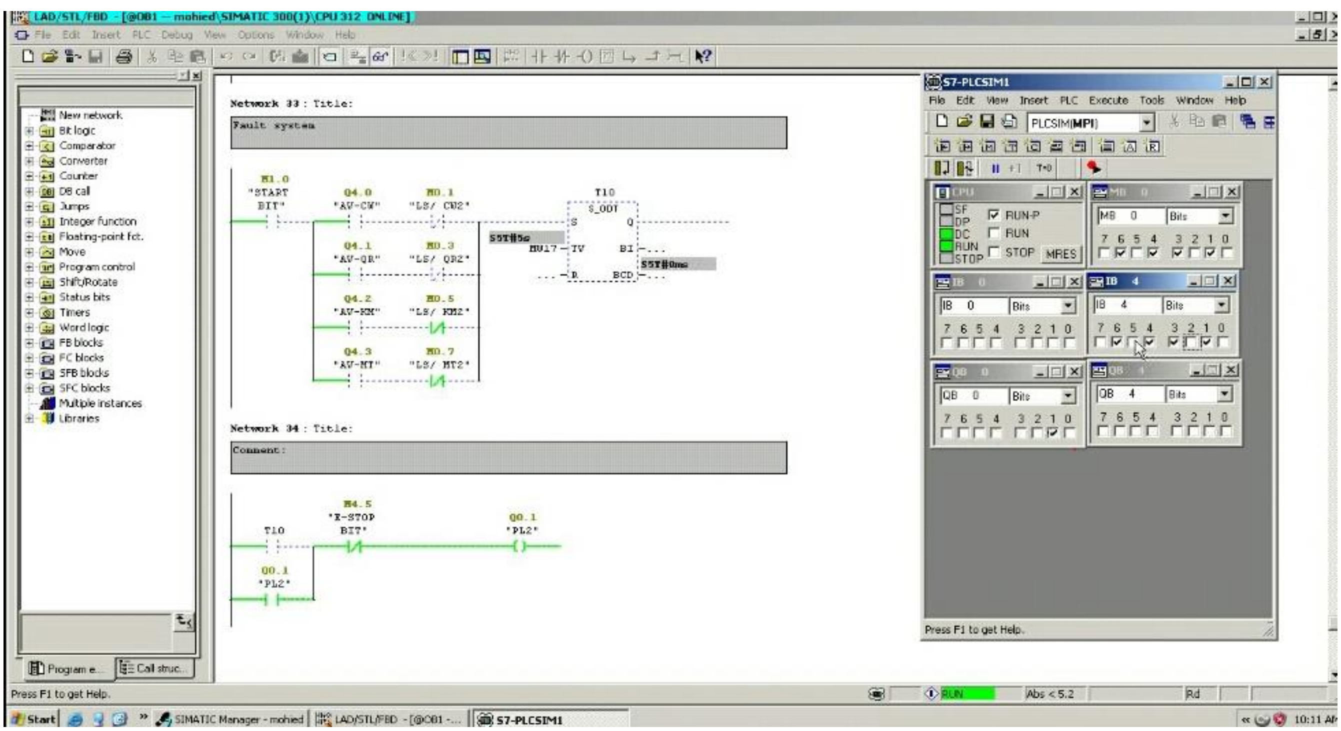


Figure 5.18: shows fault system

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

CONCLUSION AND RECOMMENDATION

An Automatic BatchingSystem using Programmable Logic Controller has been successfully designed and simulated by applying all the concept of control system at this project. Thesystem that is produced can be modified to be better if some of the electricaldevices and system are upgraded and improved.

6.1 Conclusion

The theory and concept of the automatic batching system is based on the control system. In electrical design, the features and functions of the electrical components are required to determine the system requirement. Furthermore, the theoretical of the wiring system is required for connecting the inputs and outputs devices to PLC. In programming design, understandings of the desired control system and how to use the Ladder Diagram to translate the machine sequence of operation are the most important parts, because it have direct effect on the system performance. The main aim in this process is to apply PLC to design automatic batching system and all objectives in this project were successfully done as planned. Finally, the basis control system and logic design apply in this project can be used as a references to design other applications of automation system, and also can be used as a teaching material for the Industrial Control subject.

6.2 RECOMMENDATION

Although the designed automatic control system (PLC) base works satisfactorily,but still this project needs much more developing to gain further accuracy, instead of filling the ingredient tanks by using complex logic of many timers and counters it’s much easier and reliable to use level sensors at the top and bottom of the tanks and using a real hardware (plc) instead of the simulator which we could not afford it along with its associated devices.

6.3 References

1. By: Hugh Jack, Automation manufacturing systems with PLC,Version 5.0, may 4, 2007
2. By: (Gary A.Davis,Phillip dickey, Dana Duxbury, Barbara Griffith Brian Oakley & Katherine Cornell).
   Household Cleaners Environmental Evaluation and Proposed Standards for General Purpose Household Cleaners, University of Tennessee center for clean products and clean technologies
   prepared for green seal, Inc. July 1992.
3. By: M.daas, Introduction to Fundamentals of Programmable Logic Controller, Compiled by IIATCA, Kolkata, India
4. By: Siemens SIMATIC S7 manuals and guides
5. By: LEV NELIK, Centrifugal and Rotary Pumps fundamentals with applications,by CRC press L.L.C. Boca Raton London New York Washington, D.C 1991
6. By: MukeshSahdev, Centrifugal pumps: Basics Concepts of Operation, Maintenance and Troubleshooting, Part 1, Associate Content Writer, presented at the chemical engineer's resource page, 2007.
7. By: Srinivas Medida, pocket guide on Automation for engineering and technicians, REV1.04.
8. By: Headquarters, Department of the Army, Field Manual, No.5-499, Washington, D C, Hydraulics
9. By: Austin Hughes, Electric Motors and Drives fundamentals, types and applications, school of electronic and electrical engineering university of Leeds, third edition. First edition 1990, second edition 1993, third edition 2006.
10. www.gemotors.com , AC Motor Selection and Application, 7.3.2005
11. By: Siemens SIMATIC S7, PROGRAMMING WITH STEP7. This manual is part of the documentation package with the order number: 6ES7810-4CA08-8BW0 edition 03/2006.

APPENDIEXES

Appendix A

SIEMENS

Product data sheet **6ES7312-1AE14-0AB0**

SIMATIC S7-300,
CPU 312 CPU WITH MPI INTERFACE,
INTEGRATED 24 V DC POWER SUPPLY 32 KBYTE
WORKING MEMORY,
CARD NECESSARY

-

General information	
Hardware product version	01
Firmware version	V3.3
Engineering with	
Programming package	STEP 7 V5.5 + SP1 or higher or STEP7 V5.2 + SP1 or higher with HSP 218
Supply voltage	
24 V DC	Yes
permissible range, lower limit (DC)	19.2 V
permissible range, upper limit (DC)	28.8 V
External protection for supply cables (recommendation)	2 A min.
Mains buffering	
Mains/voltage failure stored energy time	5 ms
Repeat rate, min.	1 s
Input current	
Current consumption (rated value)	650 mA
Current consumption (in no-load operation), typ.	140 mA
Inrush current, typ.	3.5 A
I^2t	1 $A^2 \cdot s$

Power losses	
Power loss, typ.	4 W
Memory	
Work memory	
integrated	32 kbyte
expandable	No
Size of retentive memory for retentive data blocks	32 kbyte
Load memory	
pluggable (MMC)	Yes
pluggable (MMC), max.	8 Mbyte
Data management on MMC (after last programming), min.	10 a
Backup	
present	Yes ; Guaranteed by MMC (maintenance-free)
without battery	Yes ; Program and data
CPU processing times	
for bit operations, typ.	0.1 µs
for word operations, typ.	0.24 µs
for fixed point arithmetic, typ.	0.32 µs
for floating point arithmetic, typ.	1.1 µs
CPU-blocks	
Number of blocks (total)	1024 ; (DBs, FCs, FBs); the maximum number of loadable blocks can be reduced by the MMC used.
DB	
Number, max.	1024 ; Number range: 1 to 16000
Size, max.	32 kbyte
FB	
Number, max.	1024 ; Number range: 0 to 7999
Size, max.	32 kbyte
FC	
Number, max.	1024 ; Number range: 0 to 7999
Size, max.	32 kbyte
OB	
Description	see instruction list
Size, max.	32 kbyte
Number of free cycle OBs	1 ; OB 1
Number of time alarm OBs	1 ; OB 10
Number of delay alarm OBs	2 ; OB 20, 21
Number of time interrupt OBs	4 ; OB 32, 33, 34, 35
Number of process alarm OBs	1 ; OB 40

Number of startup OBs	1 ; OB 100
Number of asynchronous error OBs	4 ; OB 80, 82, 85, 87
Number of synchronous error OBs	2 ; OB 121, 122
Nesting depth	
per priority class	16
additional within an error OB	4
Counters, timers and their retentivity	
S7 counter	
Number	256
Retentivity	
adjustable	Yes
lower limit	0
upper limit	255
preset	Z 0 to Z 7
Counting range	
lower limit	0
upper limit	999
IEC counter	
present	Yes
Type	SFB
Number	Unlimited (limited only by RAM capacity)
S7 times	
Number	256
Retentivity	
adjustable	Yes
lower limit	0
upper limit	255
preset	No retentivity
Time range	
lower limit	10 ms
upper limit	9990 s
IEC timer	
present	Yes
Type	SFB
Number	Unlimited (limited only by RAM capacity)
Data areas and their retentivity	
retentive data area, total	All (incl. memory bits, times, counters)
Flag	

Number, max.	256 byte
Retentivity available	Yes ; MB 0 to MB 255
Retentivity preset	MB 0 to MB 15
Number of clock memories	8 ; 1 memory byte
Data blocks	
Number, max.	1024 ; Number range: 1 to 16000
Size, max.	32 kbyte
Retentivity adjustable	Yes ; via non-retain property on DB
Retentivity preset	Yes
Local data	
per priority class, max.	32 kbyte ; Max. 2 KB per block
Address area	
I/O address area	
Inputs	1024 byte
Outputs	1024 byte
Process image	
Inputs	1024 byte
Outputs	1024 byte
Inputs, adjustable	1024 byte
Outputs, adjustable	1024 byte
Inputs, default	128 byte
Outputs, default	128 byte
Digital channels	
Inputs	256
Outputs	256
Inputs, of which central	256
Outputs, of which central	256
Analog channels	
Inputs	64
Outputs	64
Inputs, of which central	64
Outputs, of which central	64
Hardware configuration	
Racks, max.	1
Modules per rack, max.	8
Expansion devices, max.	0
Number of DP masters	
integrated	0

via CP	4
Number of operable FMs and CPs (recommended)	
FM	8
CP, point-to-point	8
CP, LAN	4
Time of day	
Clock	
Software clock	Yes
battery-backed and synchronizable	No ; Buffered No Can be synchronized Yes
Deviation per day, max.	10 s ; Typ.: 2 s
Behavior of the clock following POWER-ON	The clock continues at the time of day it had when power was switched off
Operating hours counter	
Number	1
Number/Number range	0
Range of values	0 to 2^31 hours (when using SFC 101)
Granularity	1 hour
retentive	Yes ; Must be restarted at each restart
Clock synchronization	
supported	Yes
to MPI, master	Yes
to MPI, slave	Yes
in AS, master	Yes
in AS, slave	No
Interfaces	
Number of USB interfaces	0
Number of parallel interfaces	0
Number of 20 mA interfaces (TTY)	0
Number of RS 232 interfaces	0
Number of RS 422 interfaces	0
Number of other interfaces	0
1st interface	
Type of interface	Integrated RS 485 interface
Physics	RS 485
Isolated	No
Power supply to interface (15 to 30 V DC), max.	200 mA
Functionality	
MPI	Yes
DP master	No

DP slave	No
Point-to-point connection	No
MPI	
Transmission rate, max.	187.5 kbit/s
Services	
PG/OP communication	Yes
Routing	No
Global data communication	Yes
S7 basic communication	Yes
S7 communication	Yes ; Only server, configured on one side
S7 communication, as client	No
S7 communication, as server	Yes
Communication functions	
PG/OP communication	Yes
Data record routing	No
Global data communication	
supported	Yes
Number of GD loops, max.	8
Number of GD packets, max.	8
Number of GD packets, transmitter, max.	8
Number of GD packets, receiver, max.	8
Size of GD packets, max.	22 byte
Size of GD packet (of which consistent), max.	22 byte
S7 basic communication	
supported	Yes
User data per job, max.	76 byte
User data per job (of which consistent), max.	76 byte ; 76 bytes (with X_SEND or X_RCV); 64 bytes (with X_P or X_GET as server)
S7 communication	
supported	Yes
as server	Yes
as client	Yes ; Via CP and loadable FB
User data per job, max.	180 byte ; With PUT/GET
User data per job (of which consistent), max.	240 byte ; as server
S5-compatible communication	
supported	Yes ; via CP and loadable FC
Number of connections	
overall	6
usable for PG communication	5

reserved for PG communication	1
Adjustable for PG communication, min.	1
Adjustable for PG communication, max.	5
usable for OP communication	5
reserved for OP communication	1
adjustable for OP communication, min.	1
adjustable for OP communication, max.	5
usable for S7 basic communication	2
Reserved for S7 basic communication	0
adjustable for S7 basic communication, min.	0
adjustable for S7 basic communication, max.	2
S7 message functions	
Number of login stations for message functions, max.	6 ; Depending on the configured connections for PG/OP and S7 basic communication
Process diagnostic messages	Yes
simultaneously active Alarm-S blocks, max.	300
Test commissioning functions	
Status block	Yes ; Up to 2 simultaneously
Single step	Yes
Number of breakpoints	4
Status/control	
Status/control variable	Yes
Variables	Inputs, outputs, memory bits, DB, times, counters
Number of variables, max.	30
of which status variables, max.	30
of which control variables, max.	14
Forcing	
Forcing	Yes
Force, variables	Inputs, outputs
Number of variables, max.	10
Diagnostic buffer	
present	Yes
Number of entries, max.	500
adjustable	No
Of which powerfail-proof	100 ; Only the last 100 entries are retained
Number of entries readable in RUN, max.	499
adjustable	Yes ; From 10 to 499
preset	10

Can be read out	Yes
Ambient conditions	
Operating temperature	
Min.	0 °C
max.	60 °C
Configuration	
Configuration software	
STEP 7	Yes ; V5.2 SP1 or higher with HW update
programming	
Command set	see instruction list
Nesting levels	8
Programming language	
LAD	Yes
FBD	Yes
STL	Yes
SCL	Yes
GRAPH	Yes
HiGraph®	Yes
Software libraries	
System functions (SFC)	see instruction list
System function blocks (SFB)	see instruction list
Know-how protection	
User program protection/password protection	Yes
Block encryption	Yes ; With S7 block Privacy
Dimensions	
Width	40 mm
Height	125 mm
Depth	130 mm
Weight	
Weight, approx.	270 g

Appendix B

SIEMENS

Product data sheet	6ES7323-1BH01-0AA0

SIMATIC S7-300, DIGITAL MODULE SM 323, OPTICALLY ISOLATED, 8 DI AND 8 DO, 24V DC, 0.5A AGGREGATE CURRENT 2A, 1X20 PIN

Supply voltage	
Load voltage L+	
Rated value (DC)	24 V
permissible range, lower limit (DC)	20.4 V
permissible range, upper limit (DC)	28.8 V
Input current	
from load voltage L+ (without load), max.	40 mA
from backplane bus 5 V DC, max.	40 mA
Power losses	
Power loss, typ.	3.5 W
Digital inputs	
Number/binary inputs	8
Input characteristic curve acc. to IEC 1131, Type 1	Yes
Number of simultaneously controllable inputs	
all mounting positions	

up to 40 °C, max.	8
up to 60 °C, max.	8
Input voltage	
Type of input voltage	DC
Rated value, DC	24 V
for signal "0"	-30 to +5 V
for signal "1"	13 to 30 V
Input current	
for signal "1", typ.	7 mA
Input delay (for rated value of input voltage)	
for standard inputs	
at "0" to "1", min.	1.2 ms
at "0" to "1", max.	4.8 ms
at "1" to "0", min.	1.2 ms
at "1" to "0", max.	4.8 ms
Cable length	
Cable length, shielded, max.	1000 m
Cable length unshielded, max.	600 m
Digital outputs	
Number/binary outputs	8
Functionality/short-circuit strength	Yes ; Electronic
Response threshold, typ.	1 A
Limitation of inductive shutdown voltage to	L+ (-53 V)
Lamp load, max.	5 W
Controlling a digital input	Yes
Load resistance range	
lower limit	48 Ω
upper limit	4 kΩ
Output voltage	
for signal "1", min.	L+ (-0.8 V)
Output current	
for signal "1" rated value	0.5 A
for signal "1" minimum load current	5 mA

for signal "0" residual current, max.	0.5 mA
Output delay with resistive load	
0 to "1", max.	100 µs
1 to "0", max.	500 µs
Parallel switching of 2 outputs	
for increased power	No
for redundant control of a load	Yes ; only outputs of the same group
Switching frequency	
with resistive load, max.	100 Hz
with inductive load, max.	0.5 Hz
on lamp load, max.	10 Hz
Aggregate current of outputs (per group)	
horizontal installation	
up to 60 °C, max.	4 A
Cable length	
Cable length, shielded, max.	1000 m
Cable length unshielded, max.	600 m
Encoder	
Connectable encoders	
2-wire BEROS	Yes
permissible quiescent current (2-wire BEROS), max.	2 mA
Isochronous mode	
Isochronous mode	No
Interrupts/diagnostics/status information	
Alarms	
Alarms	No
Diagnoses	
Diagnostic functions	No
Diagnostics indication LED	
Status indicator digital output (green)	Yes
Status indicator digital input (green)	Yes
Galvanic isolation	
Galvanic isolation digital inputs	

between the channels	Yes
between the channels, in groups of	8
between the channels and the backplane bus	Yes ; Optocoupler
Galvanic isolation digital outputs	
between the channels	Yes
between the channels, in groups of	8
between the channels and the backplane bus	Yes ; Optocoupler
Permissible potential difference	
between different circuits	75 VDC / 60 VAC
Isolation	
Isolation checked with	500 V DC
Connection method	
required front connector	20-pin
Dimensions	
Width	40 mm
Height	125 mm
Depth	120 mm
Weight	
Weight, approx.	220 g