AUTOMATIC FOOD PROCESSING SYSTEM USING WATER HYDRAULIC TECHNOLOGY

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I hereby declare that i have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Hons)

Signature : ....

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A thesis submitted in fulfilment of the requirements for Bachelor of Mechanical Engineering (Hons)

Faculty of Mechanical Engineering

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2018

DECLARATION

I declare that this project report entitled "Automatic Food Processing System Using Water Hydraulic Technology" is the result of my own work except as cited in the references

Signature : ....

Name : ....

Date : ....

DEDICATION

Special dedication to my beloved Abah and Umi,

Without them I am nothing.

ABSTRACT

This project main objective is basically to improve the food processing that uses water as the power transmission medium. Cleanliness is one of the focus of this project which water as the working fluid plays major role in this. Studies, journals and data from past researchers were used as reference to determine the methods used in this project. The methods that has been used in this project refer to the reconstruction of automation controller and testing the working fluid to ensure the food processing unit is fit to operate in a hygienical environments. PLC has been used as a controller for the system and two programs or diagrams has been design for the automation of the system. The used of PLC is much more reliable in terms of cost and troubleshooting. The results showed that the water pH is still within the limits but increasing on average 1.14% per week over time. Next the TDS readings of ppm shows scale formation inside the system. The experiments are also focused monitoring the working to determine the presence of impurities such as rust and scale. The expectation for this project is that the presence of scale and rust will be inside of the system and some equipment will be affected.

ABSTRAK

Objektif utama projek ini adalah untuk menambah baik mesin pemprosesan kuih semprit yang menggunakan air sebagai medium penghantaran kuasa. Kebersihan juga salah satu factor utama dimana air sebagai bendalir yang digunakan memainkan peranan penting untuk kebersihan. Kajian, jurnal dan juga data daripada penyelidik sebelum ini digunakan bagi menentukan kaedah yang digunakan oleh projek ini. Kaedah yang digunakan oleh projek ini adalah pembikinan semula pengawal automatik dan menguji air yang digunakan bagi memastikan sama ada mesin pemprosesan kuih semprit ini boleh digunakan ditempat yang mementikan kebersihan. PLC juga digunakan sebagai pengawal sistem ini dan dua program PLC sudah dicipta untuk mengautomasikan sistem ini. Penggunaan PLC memudahkan kerja penyelesaian masalah bagi pemasangan fizikal. Hasil kajian mendapati bahawa tahap pH air semakin lama semakin meningkat sebanyak 1.14% setiap minggu. Bacaan TDS juga menunjukan peningkatan nilai ppm dan juga karang. Experimen ini juga fokus kepada pengawasan air untuk menyiasat kehadiran benda asing di dalam sistem ini. Harapan projek ini adalah penemuan karat dan hasil mineral di dalam sistem ini dan beberapa peralatan akan mengalami masalah daripada ini.

ACKNOWLEDGEMENTS

In the name of Allah S.W.T, the most gracious and merciful, praise to Allah the lord of the universe and may blessing and peace of Allah be upon his messenger Muhammad S.A.W. First and foremost, I would like to thank to Allah the Almighty for giving me opportunity, wellness and ideas to complete this project report. Without any of those, I surely not able to complete this project within the time gave.

I would like to express my biggest gratitude to my supervisor, Dr. Ahmad Anas bin Yusof for guidance and giving brilliant advices to me as well as provision of the valuable time management. Not to forget his encouragement and patience on guiding me during the time of completing this project. I also would like to thank engineer assistant, En. Ikhmal for helping me in the lab and give ideas to conduct my project.

Last but not least, to my entire family and friends, I would like to express my greatest appreciation and thankful for the moral and financial support. Without all of you, I won't be able to be where I am right now.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATION

PLC	Programmable Logic Controller
pH	Power of Hydrogen
I/O	Input / Output
LED	Light Emitted Display
TDS	Total Dissolved Solid
(NO)	Normally Open
(NC)	Normally Closed
ppm	Parts per million
lpm	liter per minute
DCV	Directional control valve

CHAPTER 1

INTRODUCTION

1.1 Background of study

This project is basically a combination and continuation research from past researchers named Muhammad Syafiq (2013), Mohamad Haikal and Hafizi (2014), and Muhammad Zulfaqqar (2017). Previously, Hafizi had completed his research which related with the generation of water-based power unit while Muhammad Syafiq research was related to the design and manufacturing process for the food processing unit. Afterward, Mohamad Haikal proceeded it by improvising the machine component and installing programmable logic controller (PLC) into the system. Some way or another, Syafiq and Haikal just figured out how to conduct the food processing unit research by utilizing oil as a medium for the hydraulic system. However, Zulfaqqar did manage to utilize water as the working fluid for this food processing unit. This project is focused on the cleanliness of the system continuing Zulfaqqar research, repairing the electrohydrolic or timer-relay circuit that has been designed by Zulfaqqar and applying the said circuit to PLC for complete automation that previously Mohamad Haikal only manage to design the PLC for manually operated system.

Normally in food processing industries, they valued the cleanliness in their surroundings. In this manner, significant amount of the industries utilizing pneumatic system since it has a higher hygienic value in contrast with oil based hydraulic system. Despite the fact that water-based hydraulic system more prominent than of the pneumatic system, they would incline toward pneumatic system because of the technological limitation of that time. Since limitation happened in the past easily overcome these days, water-based hydraulic system should re-develop again in this industry. Utilizing pneumatic system has low efficiency because the system requires a compressor. The function of compressor is compress the air and store it in a container for later use. However, it is impossible to accomplish uniform and constant piston speeds with compressed air.

Water based hydraulic system is already famous and being active back on 1980 in the western nation after it's declined in the early 1906 (Krutz and Chua, 2004). The development of water hydraulic can be visualized as a time graph shown in Figure 1. The deterioration and re-emergence of water hydraulic system was caused by several factors. First due to the limitation of water such as corrosion, freezing, low viscosity, higher bulk modulus, cavitation, formation of scale, and poor lubrication. Water hydraulic then reemerge back to society as increased of safety awareness, new environmental policy, health and safety of product consumers, long-term manufacturing cost, technological advancement, and advantages of water hydraulics against oil as working fluid.

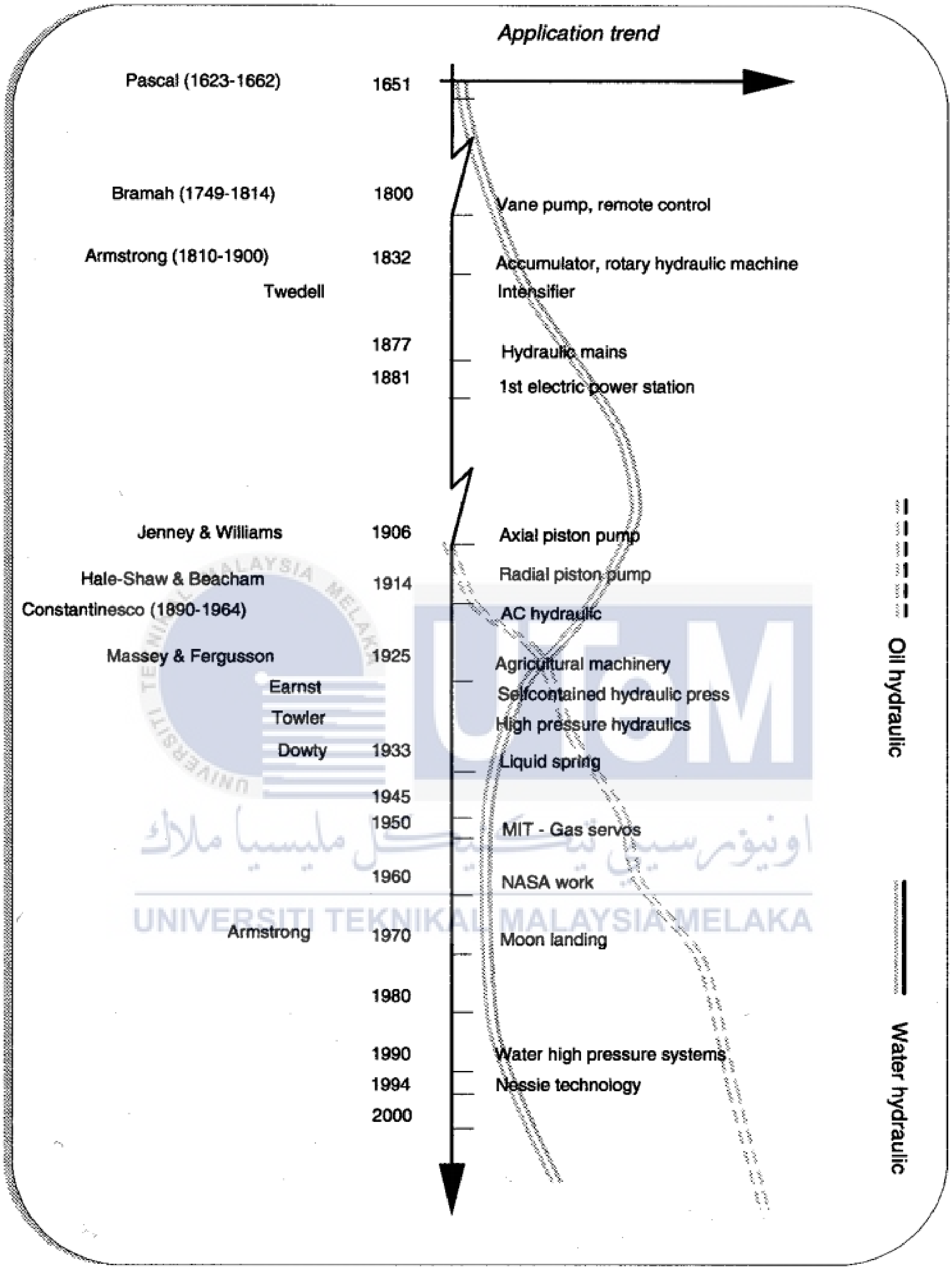


Figure 1.1: The Historical Development of Oil and Water Hydraulics

(Krutz & Chua, 2004)

1.2 Problem statement

Cleanliness and hygiene is the most imperative thing in the food industries. On modern day food industries use pneumatic system as it main system replacing older working fluid such as oil but with air the system engages many problems not only hygienically speaking but in terms of efficiency as well. Water hydraulic system however, fit all the criteria that pneumatic system also has and even several advantages against pneumatic system. Leakage problem for example, water hydraulic system will not harm its users because there is no dangerous gases or oil that will leaks out but only water. It also easier to detect where the leak is in the system. Water pose bigger threat than mineral oil which is rust, this will effect the overall performance and lifespan of the system. Besides that, safety is also the main reason to replace the system. Other than that, for processing unit that requires automation, installing a controller that met the safety requirement, easy to use, inexpensive and easy to maintain is a must.

1.3 Objectives

The objectives of this project are as follow:

1. To upgrade the system's controller and making it fully automated.

2. To investigate the working fluid's (water) pH and TDS level.

3. To investigate the effect of rust on the food processing unit parts by using visual inspection

1.4 Scope

The scope of this project are:

1. Upgrading the controller system from using a set of mechanical relays to the use of PLC with two sets of programs.

2. Monitoring the working fluids (water) by recording the pH and TDS readings every week for 12 weeks.

3. Installing conveyor belt to the system to move the product from the machine to another station

4. Checking and maintaining the DCV for rust and erosion damage by dissembling the parts from the system.

CHAPTER 2

LITERATURE REVIEW

2.1 History

Water hydraulics is not something new in the advancement of innovation. The world's first researcher, in The Greek Thales inspired further research on water when he announced water is a substance and not a blessing from the gods. After that Aristotle pronounced water a continuum which all of hydraulics depends on the law, what occurs at point A is transmitted to point B. After that, numerous gadgets in light of handy articulations of the water driven standards had been made by Ktesibios which originates from Alexandria and he is not from Greek province (Koskinen, 2011).

Around of the time, Archimedes was the primary individual to express that the presence of a pressure gradient was fundamental to flow. Archimedes additionally confirms that the impact of a disturbance in a closed framework at point A will be seen at point B. Another astonishing individual that takes out mathematical equation is Da Vinci. His equation is to compute volume flow and he is the first individual managing the stream of water past a mill wheel by applying closed-loop control. The first individual to make a difference between ideal and viscose fluids is Simon Stevin. He also said the result of head and area as pressure independent with body of vessel (Koskinen, 2011).

Between the year of 1608 and 1647, Evangelista Torricelli runs barometric test and the relationship between outflow and head. Blaise Pascal is accountable for the affirmation that in a static fluid the pressure is the same anywhere and it is known as Pascal's Law until today. Blaise Pascal additionally inveterate relationship between the force area and the pressure. After that Robert Boyle set up the connection between volume, pressure and temperature known as Boyle's Law (Koskinen, 2011).

Additional contemplate is made and Sir Isaac Newton made his Second Law which permits calculating pressure required in a mass-based system and Daniel Bernouilli inveterate the relationship between flow velocity and local pressure. On 1703 until 1783, Leonhard Euler built a arrangement of mathematic in light of particles as opposed to points which had a colossal effect to those researching the specific nature of fluids (Koskinen, 2011).

Joseph Bramah an English inventor, has invented a hydraulic press that used water as its hydraulic fluid in 1976. This press also goes by the name of Bramah press. Bramah's press encapsulated the rule originally settled by Pascal in 1647, where by applying a force to a small area plunger in a closed cylinder can be utilized to act upon a bigger area plunger to deliver a correspondingly bigger force if the fluid spaces in the two plunger or piston cylinder is connected to each other (Gibson, 2009).

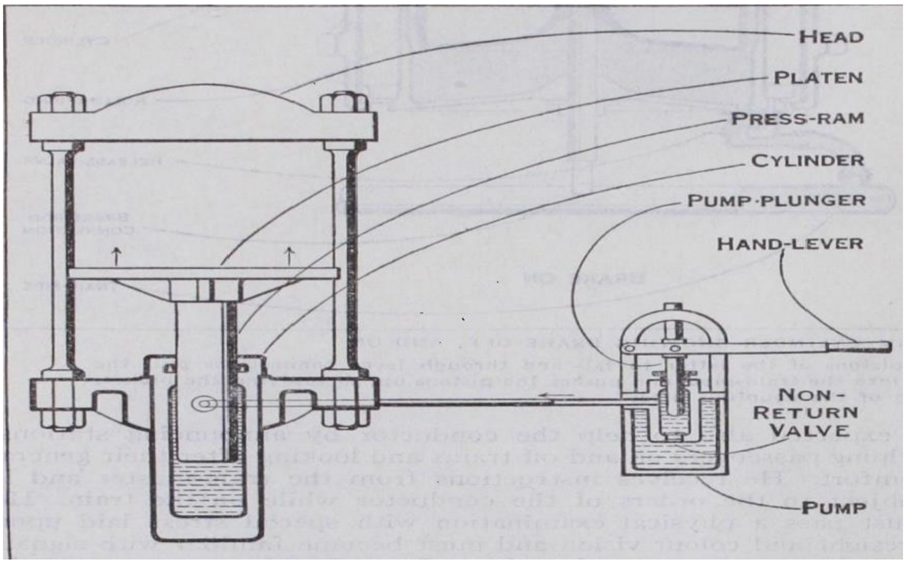


Figure 2.1: Bramah Press

This significantly improves hydraulics related invention as water produce no hazardous waste and much cheaper than oil. This became one of the greatest invention that's environmental friendly. After his creation, water was utilized as power transmitter in the fluid power system. After some time in 1900's, electrical innovation has associated with the fluid power system and water turns into the greatest restriction since water will go act as a conductor and possess a major health risk (Park, 2009).

2.2 Water

Essentially, water is a compound which mixture of one oxygen atom and two hydrogen atoms, bonded together by shared electrons. It is known as V-shaped polar molecule, which implies that the hydrogen atom is positive charged and pulls in to the negative charged oxygen atom. As a result of the polarity, water molecules are normally pulled in and adhere to each other, forming hydrogen bond. This hydrogen bond is the reason water have numerous unique properties, for example, the way that water is significantly denser in its fluid state contrast with its solid state.

Water is the only compound that exists naturally as solid (ice), its most common form liquid, and gas (vapour). Around 70 percent of the surfaces of the Earth are wrapped by water which gives a number roughly 1,386 million cubic kilometres. Only 3 percent of it is freshwater and 77 percent of freshwater exist as ice while the other 23 percent only half of it consumable and able to sustain living organisms on earth.

2.3 Water-based hydraulic system

Generally, water-based hydraulic system has been utilized years back in long-wall mining applications and in hot-metal regions of steel factories. The fundamental motivation behind why water is broadly utilized as the fluid power system in these industries is their undeniable advantage of resistance to fire (Alan Hitchcox, 2012). Water hydraulic systems likewise is said to have less overall cost over oil based fluid. The innovations of water hydraulics have quickly advanced to wind up noticeably practical and appealing solutions for many fluid power applications. Here are some of the benefits of a water-based hydraulic system:

2.3.1 Waste-less Substance

Water is a natural form of fluid and can be obtain all over the place. The water-based hydraulic systems can operational even with different type of water, for example, tap water, salt water, and different other low viscous mediums which make it the perfect solution for some applications where oil contamination is the main risk factor to the earth. Water also produce zero waste from itself unless debris from the container or pipe which can be filtered out.

2.3.2 Low Overall Costs

Other than the basic saved cost when utilizing water, transfer costs are one of the upsides of utilizing water hydraulics systems. Water is considerably simpler to dispose rather than mineral oil which require appropriate treatment.

2.3.3 Non-flammable

Mineral oils are combustible because of its temperament. Thus, such working systems which have high fire hazard frequently require costly specialized fluids to counter. Utilizing water as a medium eradicates the hazard and offering a significantly less expensive and achievable solutions.

2.3.4 Efficiency

The main characteristic of water which contributes most to efficiency is the nearly incompressible nature of it resulting higher energy transmission throughout entire system. Increasing in energy transmission leads to smaller components for the system. Water also much more hygienic than mineral oil which reducing the amount of maintenance required further increasing the efficiency in terms of the amount of hour the system can operates.

2.4 Properties of water

2.4.1 Density

The density, ρ which is mass, M, per unit volume, V of a substances is described as:

$$\rho = \frac{M}{V} \tag{1}$$

Hydraulic energy losses in the system are influenced by the density of the hydraulic fluid. The change in the temperature and pressure in the hydraulic system will influence the density of a hydraulic fluid. It is imperative to keep the density of the hydraulic fluid as low as conceivable with a specific goal to limit pressure losses and to diminish dynamic effects on the control valves. Figure 2.3 and 2.4 beneath demonstrates how the mass density of water is influenced by the temperature and pressure and the variation of the relative mass density of water with that of mineral oil for a given temperature as pressure fluctuates. The mass density of water is around 10% higher than that of mineral oil (Krutz and Chua, 2004).

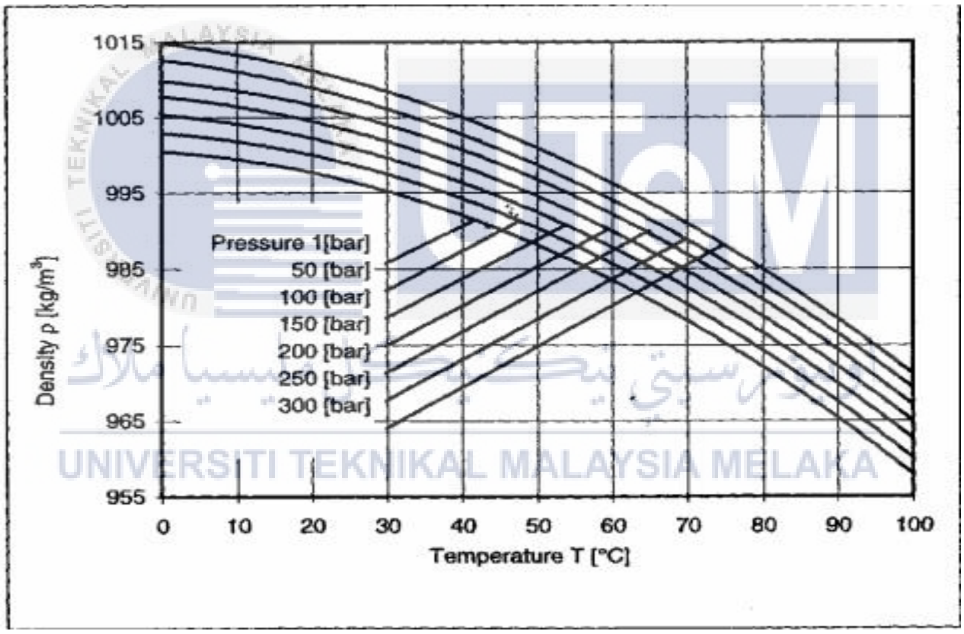


Figure 2.2: Density of water against temperature and pressure (Krutz and Chua, 2004).

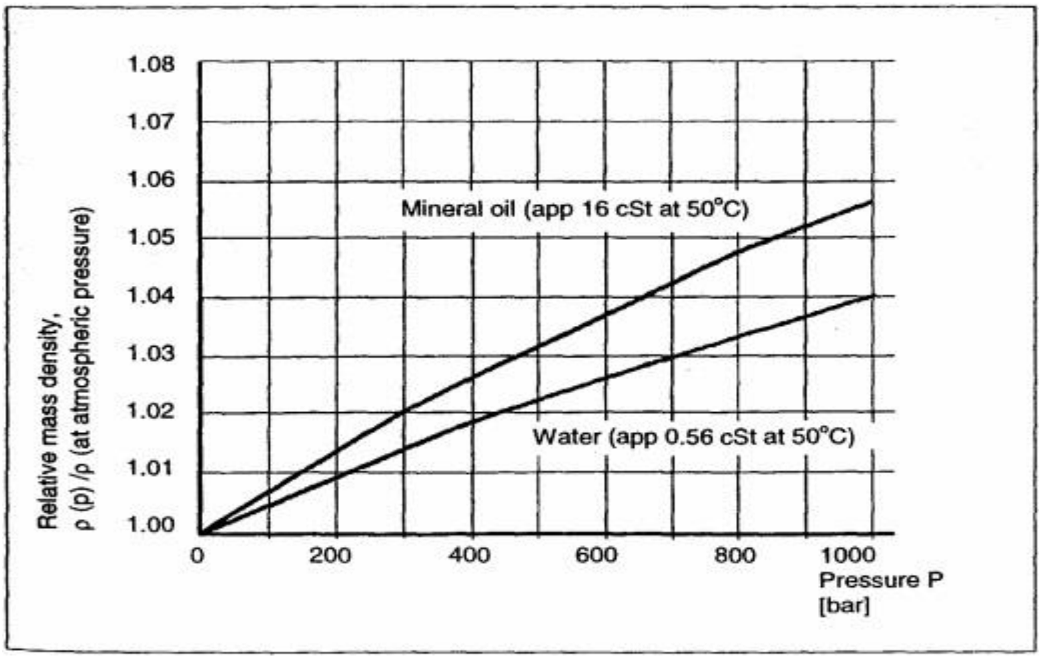


Figure 2.3: Relative mass density against pressure for mineral oil and water (Krutz and Chua, 2004).

2.4.2 Specific Heat

The specific heat capacity at steady pressure is characterized as the amount of energy expected to change the temperature of one kg of a substance by 1℃ and it does not fluctuate much with temperature and pressure as appeared in Figure 2.5. It is high for water in contrast with most substances and it is twice that of the mineral oil. For water, the common average values at steady pressure and temperature 40℃ are 4.180 kJ/kg ℃ while for mineral is1.90 kJ/kg ℃. This implies water has a more capacity (2.2 times) to absorb the heat correlate with mineral oil and along these lines, it would consume more time to be heated up compared with an equal amount of mineral oil for the same capacity.

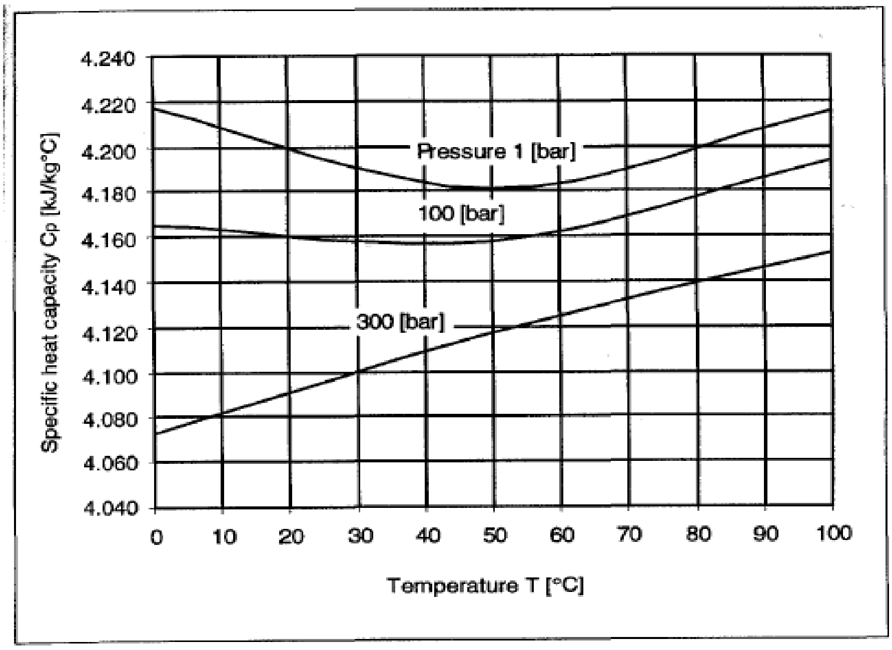


Figure 2.4: Specific heat capacity against temperature and pressure (Krutz and Chua, 2004).

2.4.3 Viscosity

The most noticeable difference between water and oil is the viscosity of the two fluids. The measurement of the internal friction in a fluid when one layer moves in connection to another layer is call viscosity and it also express as a fluid's resistance to flow. Water at atmospheric pressure and 20°C, has a viscosity of 1cSt. The viscosity of water is commonly under $1/30^{th}$ of that mineral oil at 50°C. A steady low viscosity of water shows advantages which resulting in low line losses. These low pressure drops result in hydraulic systems to be more efficient and requires less power to operates, which implies smaller pumps and motor can be utilized. Oil systems needs to be fully tested first as oil's viscosity changes with temperature. adding Glycol substances to water may just change viscosity between 3 to 5 cSt.

Water's viscosity characteristics mostly have to do with the viscosity relationship to temperature. The viscosity of water in relation with temperature changes is much weaker than that of oil. At a pressure scope of 1-1000 bar and a temperature range of 3°C - 50°C, the viscosity of water differs by a factor around 3 while in equal pressure range but that of oil varies by a factor around 10 in the temperature range of 20°C - 70°C. This gives another great asset to water hydraulic system in that it is steadier, as far as flow velocity and efficiency, over an extensive range of working temperatures than a system utilizing oil. However, the disadvantages of having a low viscosity is that there is increase in risk of having internal leakage in water hydraulic system, requiring hydraulic parts to be built with considerably tighter tolerances.

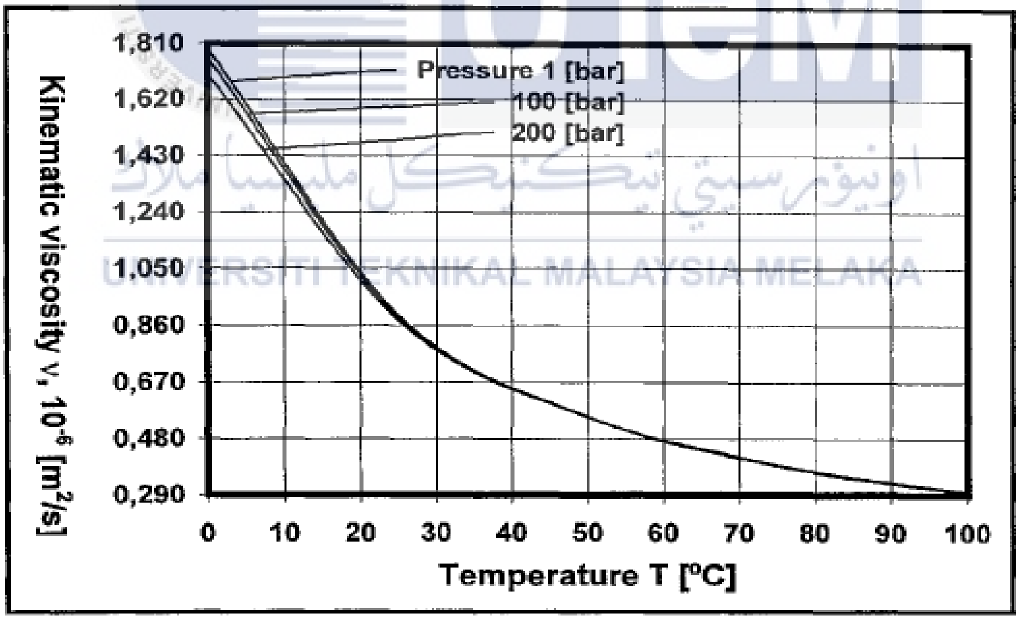


Figure 2.5: The Kinematic Viscosity of water against Temperature and Pressure (Krutz and Chua, 2004).

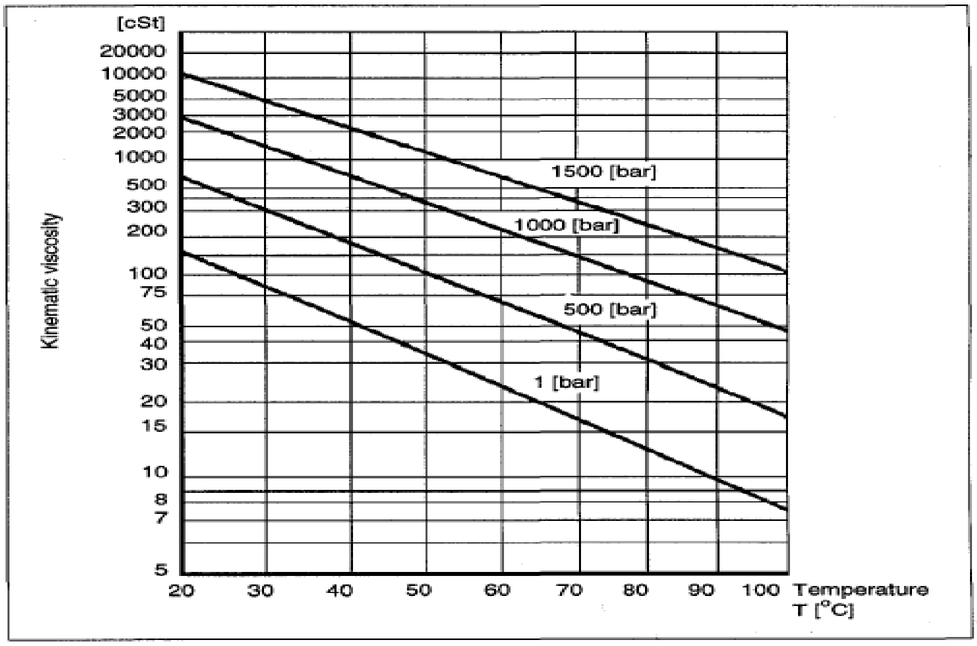


Figure 2.6: Kinematic Viscosity for mineral oil against temperature and pressure (Krutz and Chua, 2004).

2.5 Advantages of water hydraulic system

The main advantage on using water hydraulic system is that water is hygienic. Considering the surrounding area, its cleanliness is the main reason water hydraulic system is important. Water as hydraulic fluids is easy to dispose and does not pose any environmental threat in case of pipe leakage. Other than that, the overall low cost for setting up this system is also one of the advantages because of their relatively easy to obtain substances and does not required specific storage design automatically makes it environmental friendly (Koskinen et al., 2008).

The fact that water is the most abundant substances make it the most reliable substances to use. In fact, 70 percent of the earth covered by water (Perlman, 2013). Water by its nature is incombustible compared to oil, making water hydraulic system fire resistant (Koskinen et al, 2008).

2.6 Disadvantages of water hydraulic system

In the early days for modern era, water is becoming unreliable for working fluids because of several flaws. For instance, dissolved gases such as oxygen can cause corrosion on metal. Most of the material used in previous days are metal-based for example piping system. Micro-organisms in water can also motivate the corrosion. Because of this regular maintenance on chemical treatment needs to be done. Micro-organisms can also cause bad odour, reduce in capacities and reduce in efficiency (Krutz & Chua, 2004).

The next disadvantages is freezing factor. Water have lower freezing point at 0℃ than other fluids which can cause it to freeze up and jams the system faster. This can also cause equipment failure as water expands up till 9 percent from its initial volume when it is in solid state. This is the biggest limitation for four seasoned countries that needs to operate in temperature below 0℃. They need to installed antifreeze system when using water as working fluids (Krutz & Chua, 2004).

After that water also has lower viscosity which means that decreasing in friction while causing more leakage and erosion inside the system. More leakage mean more power losses and less efficient. They have to adjust the clearance and tolerance on their equipment. Today oil hydraulics still monopolize in its use for working fluids except in condition which are environmental sensitive (Krutz & Chua, 2004).

2.7 The effect continuous usage of control valve for water hydraulics

Most of the DCV available in the market is for mineral oil, thus the material is likely wear faster with the usage of water. Rust will be main factor for a valve to jammed. Using water with a common control valve will also increase the pressure surge effect by 12% (Franc Majdičet al,. 2011).

However it is still applicable to use water with common directional control valve. A good filtering system before entering the valve is crucial for maintaining the wear for the sliding spool. A simple way to increase the life of the DCV is by substituting the sliding spool with the one made from stainless steel (Franc Majdič et al,. 2011).

2.8 Application of water hydraulic system in food processing

The common type of system that been used in the food processing are pneumatic and electric with low power output. Water hydraulic will replace both system in the near future as water hydraulic system becomes more evolves. Even though pneumatic system are both light and compact, it also comes with lower efficiency, produce pollution from oil mist and noise from air and moving components. Electric motor needs to be covered and water proof which will increase the overall size, weight, and making the ventilation for the motor poor. Using electric motors comes with a high risk of getting electrocuted. Water hydraulic system shows no potential for contamination for food processing as long as the system is well-maintained. The equipment can be regularly washed to decrease the risk of contamination. Ultra-low pressure water hydraulic system is the most applicable in food industry (Krutz and Chua, 2004).

2.9 Programmable Logic Controller

Automation and industries relates to each other strongly, as time moves forward both of them evolves as well. Automation system and processes is just an act of controlling the "on/off" for both input/output signal. For modern industries such control systems are built as digital computers which is programmed to act like a electromechanical relays or discrete logic gates (Avvaru Kiran et al., 2013)

The main purpose of PLCs was to replace the physical relays into a stored program that able to communicate between many relays, timers, counters and others to perform specific logical tasks. In simpler terms, PLCs converts analog input to digital input then after computing it converts it back to analog output and send it to said output channel. The PLC is designed for multiple inputs and output arrangements, increased temperature range, immune to electrical noise, and resistant to vibration and impact. The difference between PLC and normal computer is that PLC is much more durable and able to be placed in condition where a normal computer would not survive (Avvaru Kiran et al., 2013).

One of the advantages of PLC rather than electronic controller is that PLC is programmable through specific software (different maker means different softwared) for example an Omron PLC use a program called ‘CX ONE’ which can only be use by Omron’s PLC. Other than that, a PLC performs a repetitive cycle of operation which makes it suitable in making controller for processor unit as it uses the same cycle of tasks. Engineers also can now have numerical control over automated devices which leads to a rapid expansion in range of usage and human activities (Avvaru Kiran et al., 2013).

Figure 2.7 PLC Board

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the methodology used in this project to make it fully/semi-fully automatic. The scope of this project has been made as a flowchart to ease the workflow as shown below and weekly planning has been shown through a Gantt chart on the appendices. This project starts by reviewing some literature studies to understand the scope of the project. After that repairing the electric controller made by previous student to check the integrity of the system. Next designing a new electrical schematic diagram for PLC which said PLC is then replaced with the electronic controller.

The working fluid in this case is water which is known to cause corrosion. Hence the water is then sampled after every usage of the food processor (when testing) to measure the amount of rust contained in the water.

Literature view:

a) Generate project's flow: Problem statement, Objective and Scope.

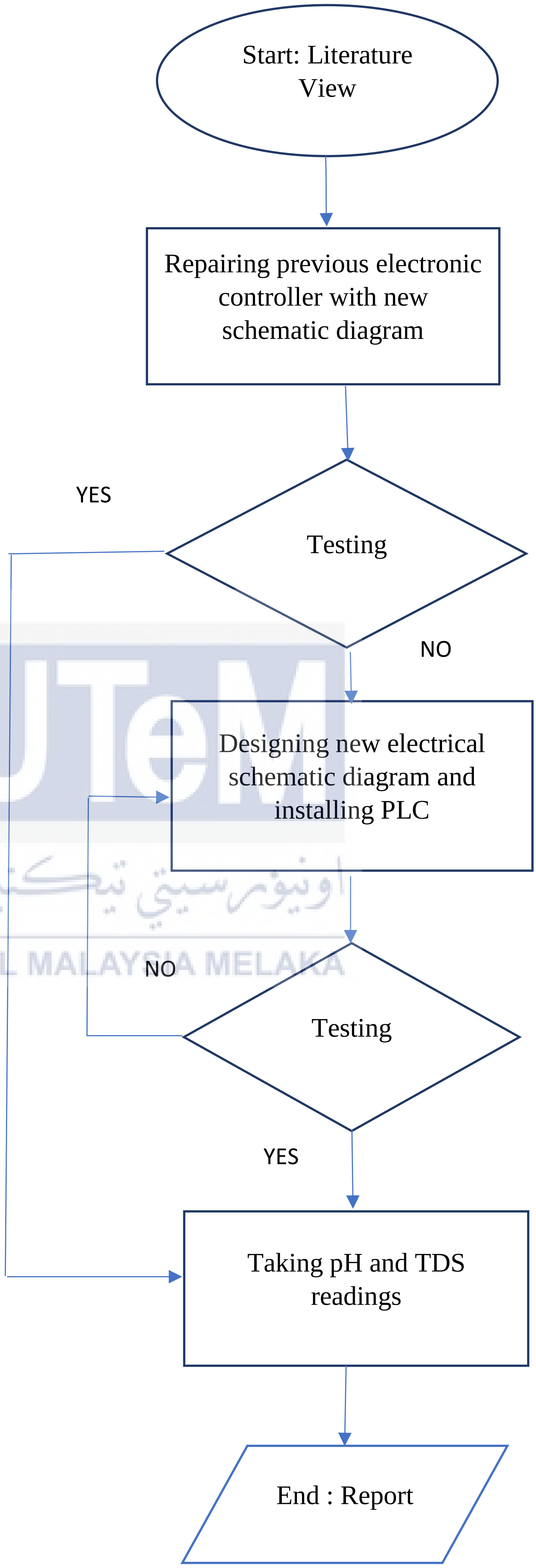
b) Generate project by Flow chart and Gantt chart based on scope.

c) Machine mechanism study and water hydraulic system study.

Objective 1: To monitor the working fluid's (water) pH level, and parts per million level.

Objective 2: To upgrade the previous timer-relay circuit to a PLC with a new circuit system.

Objective 3: To investigate the area which has been damaged by corrosion and erosion.



3.2 Literature view

Literature review is a procedure to assemble all information in regard to the task. There are past study, research and further development that was finished by another researcher. All of sort of information which are books, journal, technical papers, designs, website, indexes, articles and other unregistered resources has been utilized for this project in order to attain the objective and better understanding. Hypothesis, application and problem for this project were discovered in this procedure. Majority of the knowledge and data accumulated is adding to the accomplishment of this project.

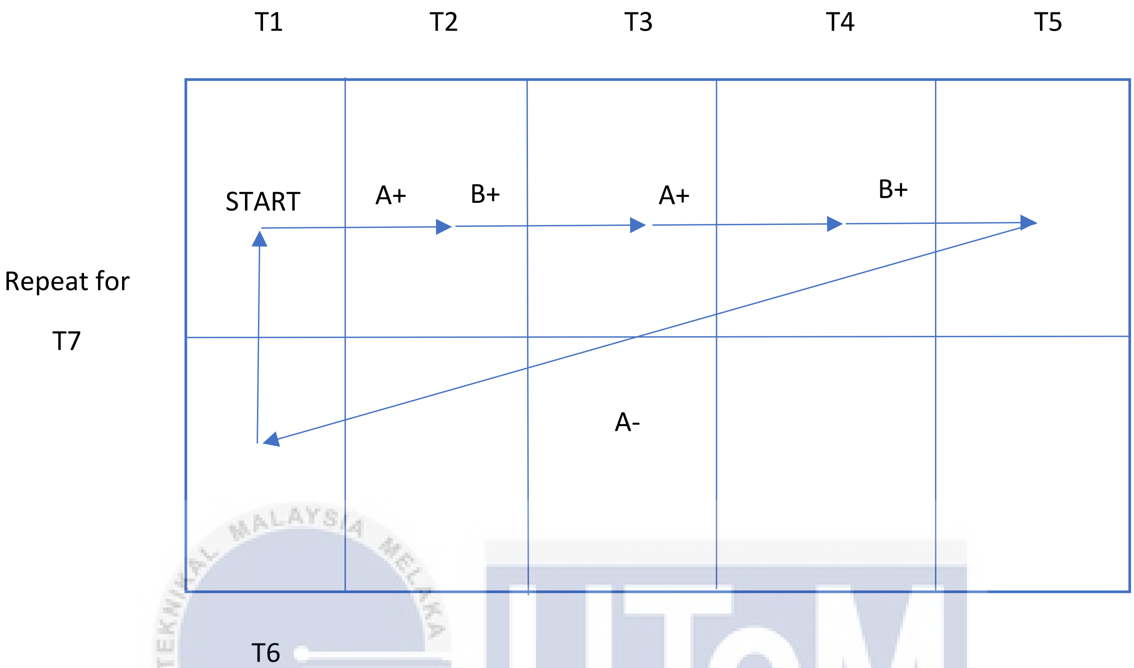
3.3 Repairing the old electronic controller

The previous student, Muhammad Zulfaqqar bin Zolkiphli has already made one of the electro water hydraulics system controller but the controller only able to operate the machine manually as the automation process did not work properly. At the start of this project, to understand more about the flow of the automation process, designing new electrical schematic diagram based on the previous design to repair it.

Karnaugh map is a useful method of showing the sequence of a circuit. The sequence is then controlled by a control panel which is divided into three controller circuit and that is main circuit, automatic/semi-automatic circuit and timer circuit. The sequence that has been used is referring to the solenoid pole of the actuator and that will be:

A+ , B+ , A+ , B+ , A- , repeat

Where A is the batch cylinder and B is the extrusion cylinder. The batch cylinder will extend first for 1 second and later followed by the extension of extrusion cylinder. After the first cycle stops the sequence continues with the batch cylinder retracting and returning to its original position for the next batch of cookies.



T1 = Timer Coil 1

T2 = Timer Coil 2

T3 = Timer Coil 3

T4 = Timer Coil 4

T5 = Timer Coil 5

T6 = Timer Coil 6

T7 = Timer Coil **7**

A+ = Batch cylinder extends

A- = Batch cylinder retracts

B+ = Extrusion cylinder extends

B- = Extrusion cylinder retracts

Figure 3.1 Karnaugh Map Sequence of A+ B+ A+ B+ A- repeat with

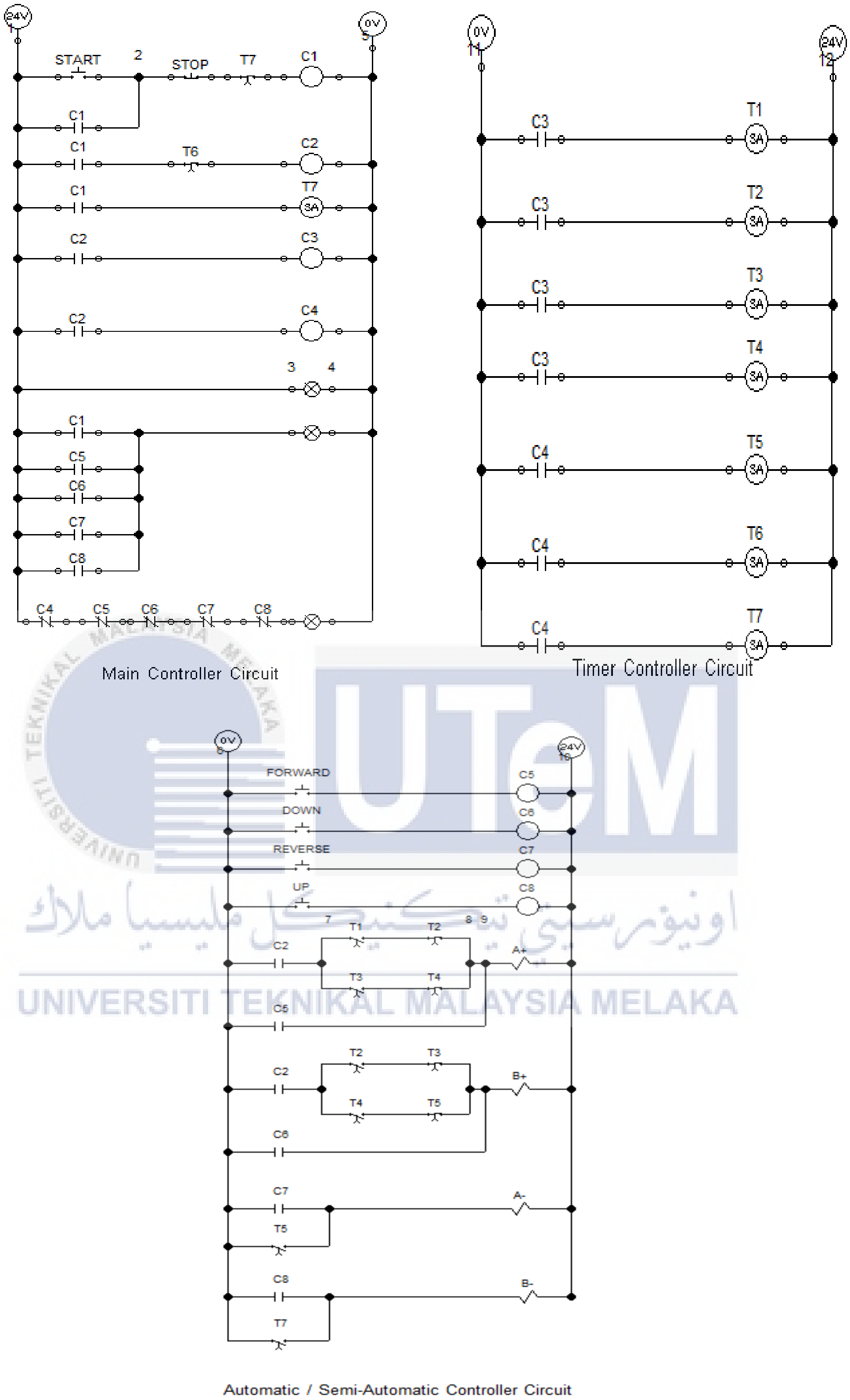


Figure 3.2: Electrical schematic diagram for food processor

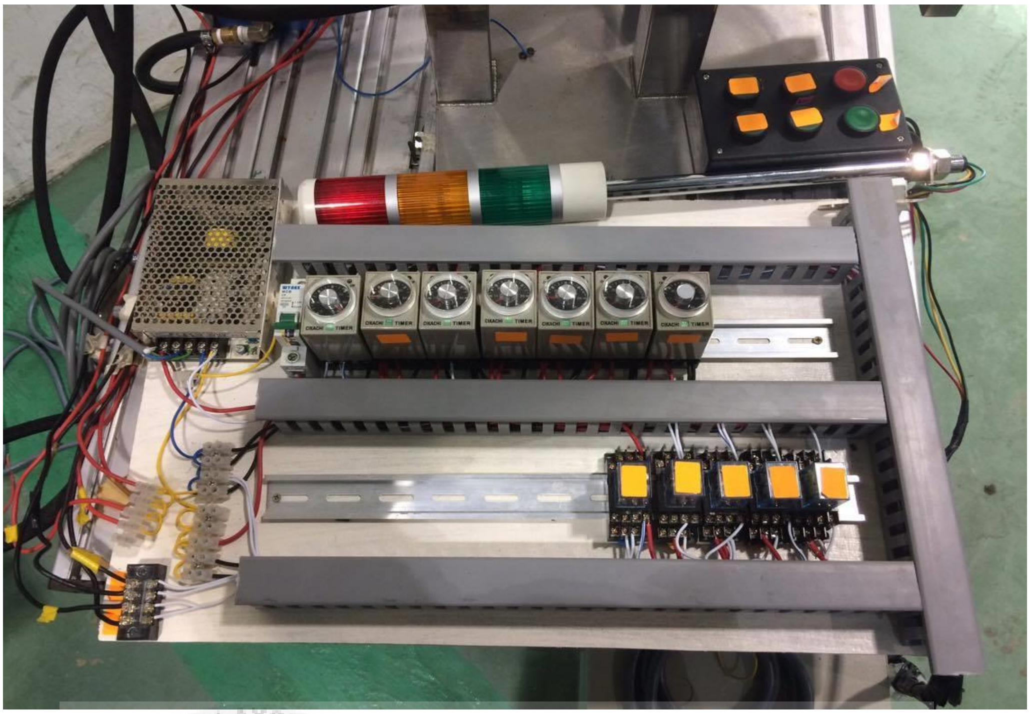


Figure 3.3: Previous design of timer relay circuits

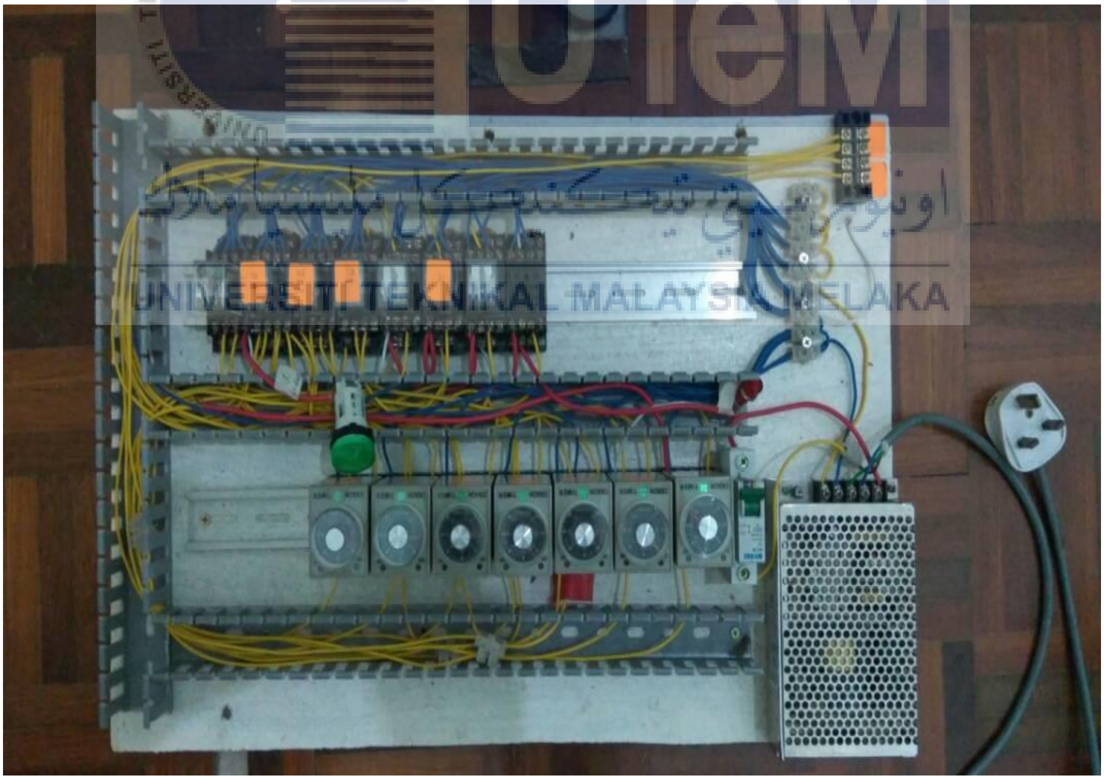


Figure 3.4: Newest design of timer relay circuits

3.4 Programmable Logic Controller

One of the scope mention for this project is the use of PLC as controller replacing electrohydraulic controller. PLC is basically a small computer to compute the program to a physical task. In terms of practicality, PLC is more reliable than using timer and relays because timer and relays in plc exist virtually it is easier to adjust the number of timer and relay used whereas physical relays need to be hardwired to a board causing longer installation process.

3.4.1 Designing/ coding for PLC

In order to operate a PLC we need to design a series of code in a software. Typically, we need to understand the code language but in this case it is easier because the code for PLC can also be write as a ladder diagram. Ladder diagram is another translation of electro circuit. Because of this designing the code is just translating the previous electrical schematic diagram into a ladder diagram. The PLC that we use is CPM2A from Omron and the software for it is CX ONE

Figure 3.5: CPM2A PLC from Omron

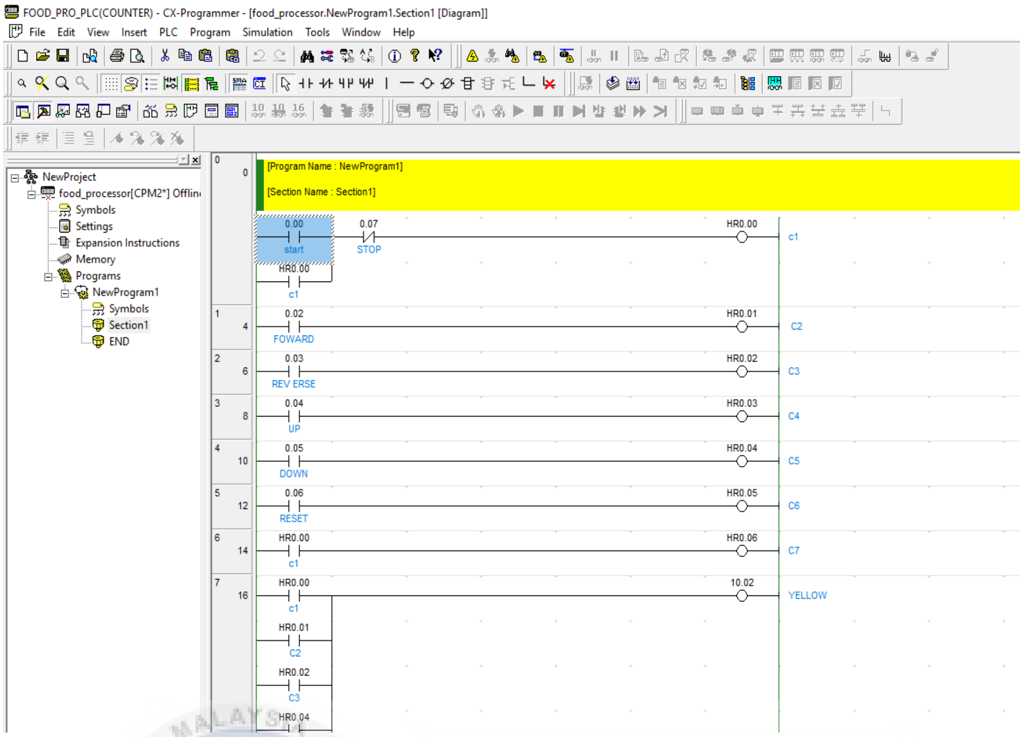


Figure 3.6: Switches, relays, timers, and counters represented as ladder diagram in CX ONE

3.4.2 Installation of PLC board

PLC needs to be connected physically through a 24 – 240 V connections or also known as I/O ports. The PLC is placed on a board similar to timer relay circuit board. The bracket for previous board has already been installed but the size of the hole is different so new hole is drilled on the PLC circuit board

Figure 3.7: PLC circuit board

3.5 Installing conveyor belt to the system

Part of the automation process is sending the extracted cookies to the next station which is baking. The conveyor belt will be transporting the cookies through the oven and lastly to the packaging station. The design of the conveyor belt system is as follows; The belt is driven by 240volt AC motor with a speed converter to manipulate the speed. As for this machine are for experimentation purposes only, the belt is made with low temperature rubber.

For automation part a coil relay is used to control the timing for conveyor belt figure 3.8 shows the configuration for using relay to control the timing. The live wire (red) is connected to any normally-open contact (9 and 5) and the plc is connected to the coil contact (13 and 14) of the relay to power up a relay. The plc sends a signal to energise the coil relay the normally-open contact will closed allowing the AC motor to power up turning the conveyor belt.

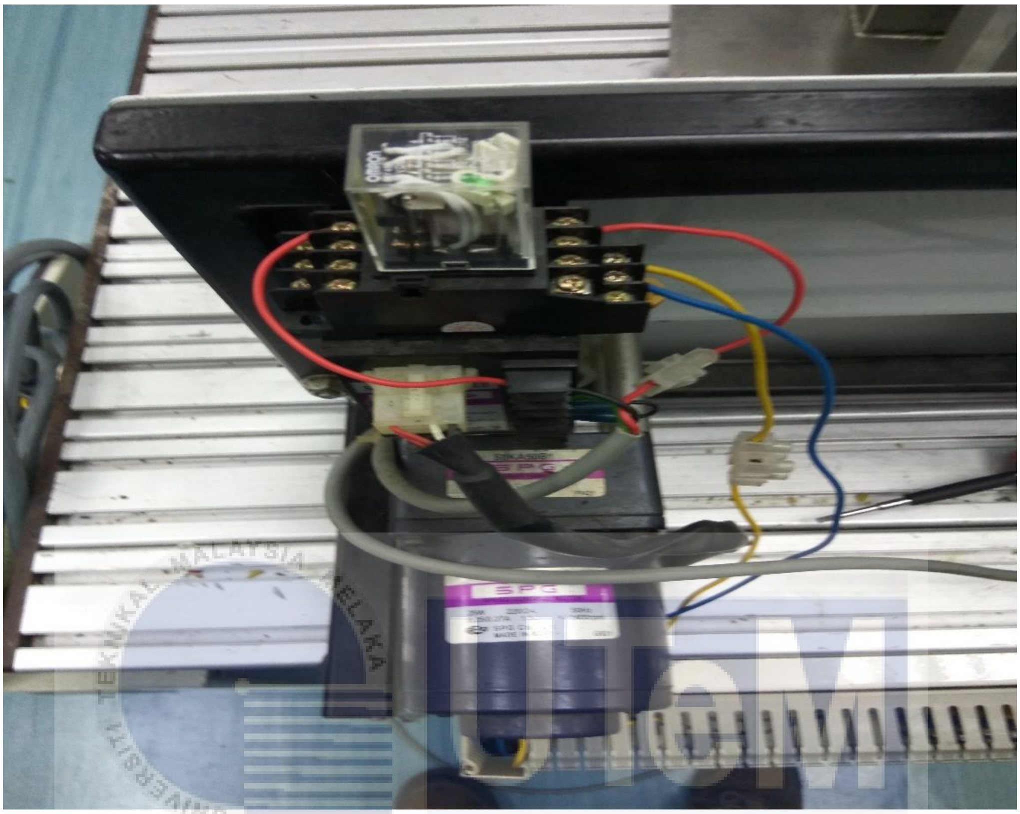


Figure 3.8: Conveyor to PLC connection

3.6 Testing and Simulation

As mention before in the previous sub chapter, previous project used electro water hydraulics system controller. The method to test this controller reliability is through simulation and trial and error testing. These are the methods that has been used to test this controller:

3.6.1 FluidSIM

FluidSIM is a software for the creation, simulation, instruction and study of electropneumatic, electrohydraulic, digital and electronic circuits. It can be used as a creation tool for designing a circuit and as a simulator for testing electrical circuit. In addition, the software has all the equipment of pneumatics and hydraulics delivered by different symbols depending on the type of equipment. The parameters for the actuator in FluidSIM can be set up according to our original actuator. Figure 3.9 showed the circuit for our electro water hydraulics system that has been designed in the software. FluidSIM is designed to make creating and simulating electrohydraulic easier, because of the compressive design of FluidSIM we can design and test the circuit at the same time and the circuit is designed right next to the model system of actual product as shown in Figure 3.9a.

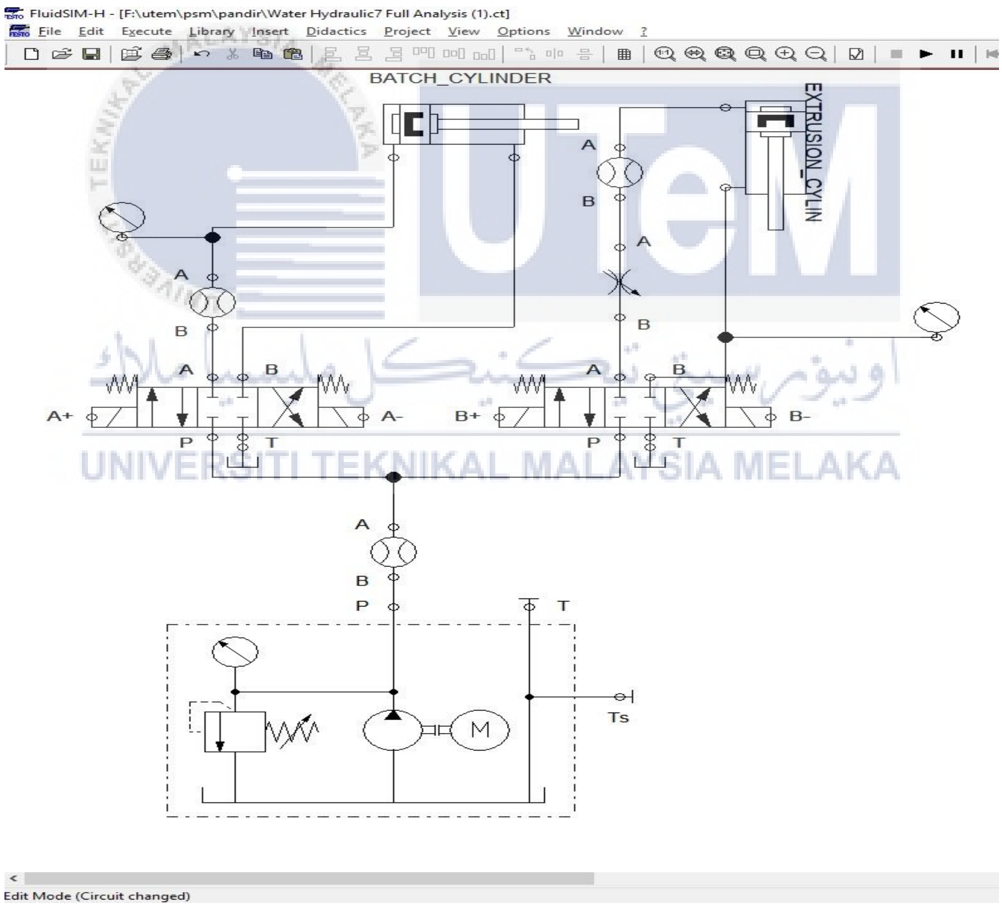


Figure 3.9a: FluidSIM hydraulic circuit design

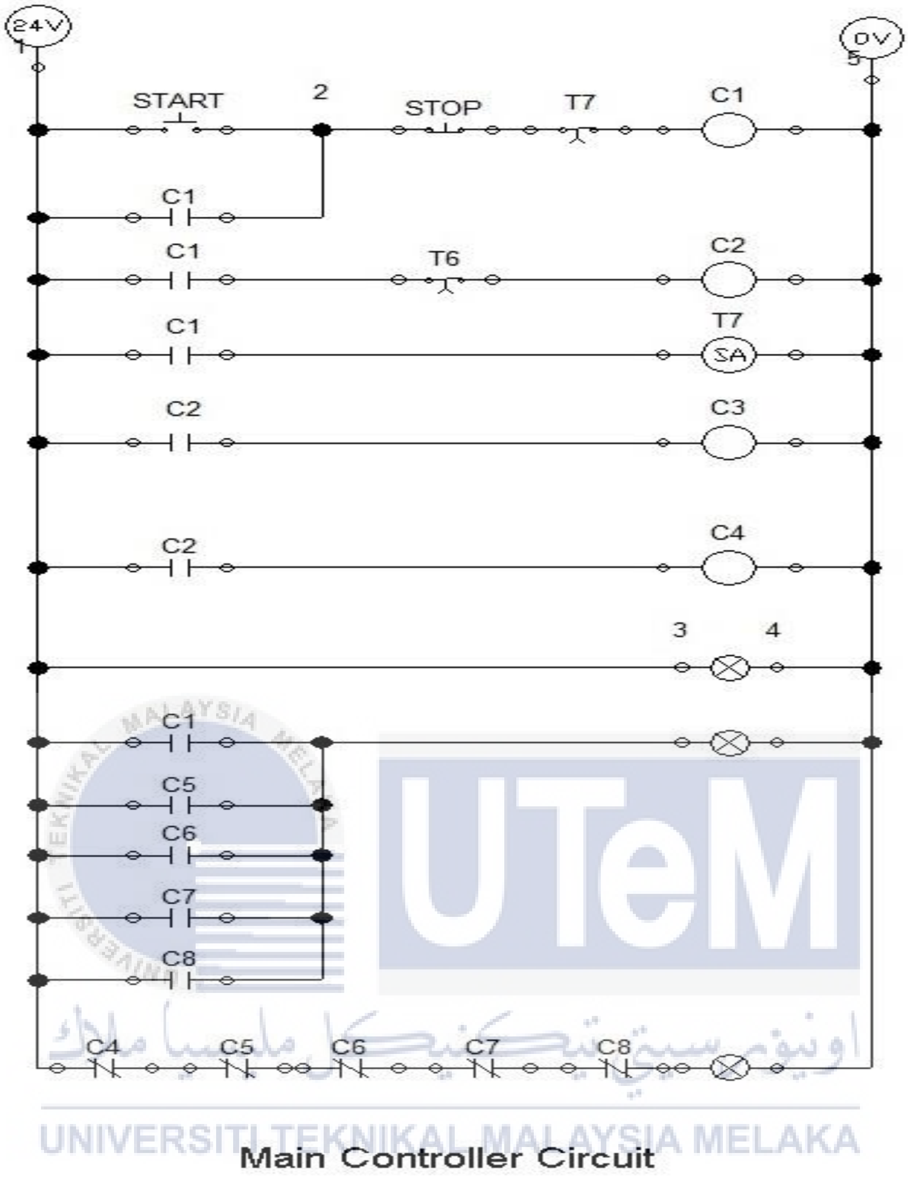


Figure 3.9b: FluidSIM main controller circuit

Figure 3.9b shows the main controller which uses indirect approach to the system. All the inputs must go through relays to activate the solenoids. The automation of the system is controlled with a series of timer and counter which then activates the solenoid for the following sequence A+, B+, A+, B+ then ends at B-. Figures 3.9c shows the placements of the solenoids and timer which controls the automation.

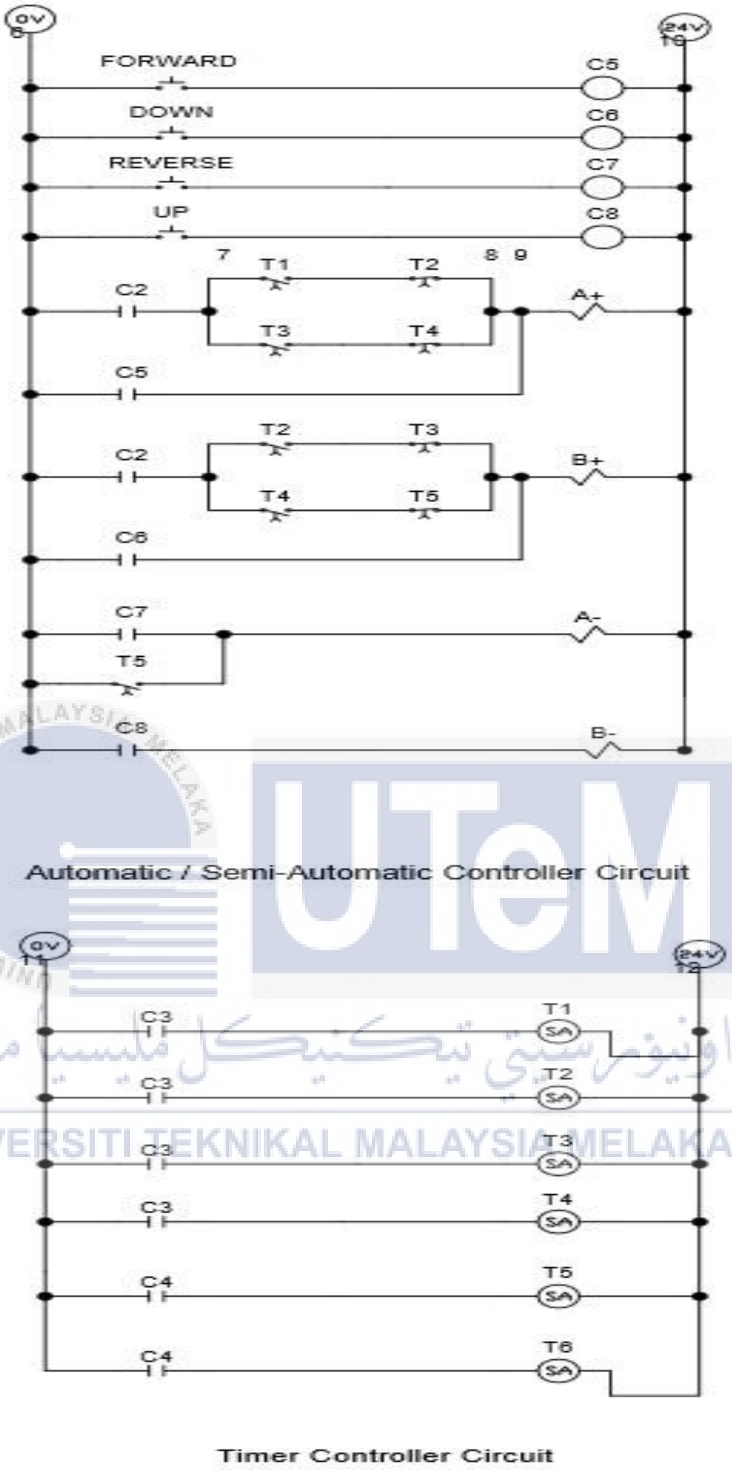


Figure 3.9c: FluidSIM auto and timer circuit

For running simulation, we need to press to ‘play’ symbol on FluidSIM and we can observe that some of the circuit line has been highlighted by red colour as shown in Figure 3.10a and 3.10b. After that the switch in this circuit can be pressed to connect the power source to positive or negative pole of the solenoid and changing the position of the FCV to move the batch cylinder forward as shown in Figure 3.10a. Next for the simulation of the extrusion cylinder we can refer that to Figure 3.10b.

Through this we can check either the circuit will function or not. This way we can save time for the trial and error part of testing by ensuring our circuit reliability.

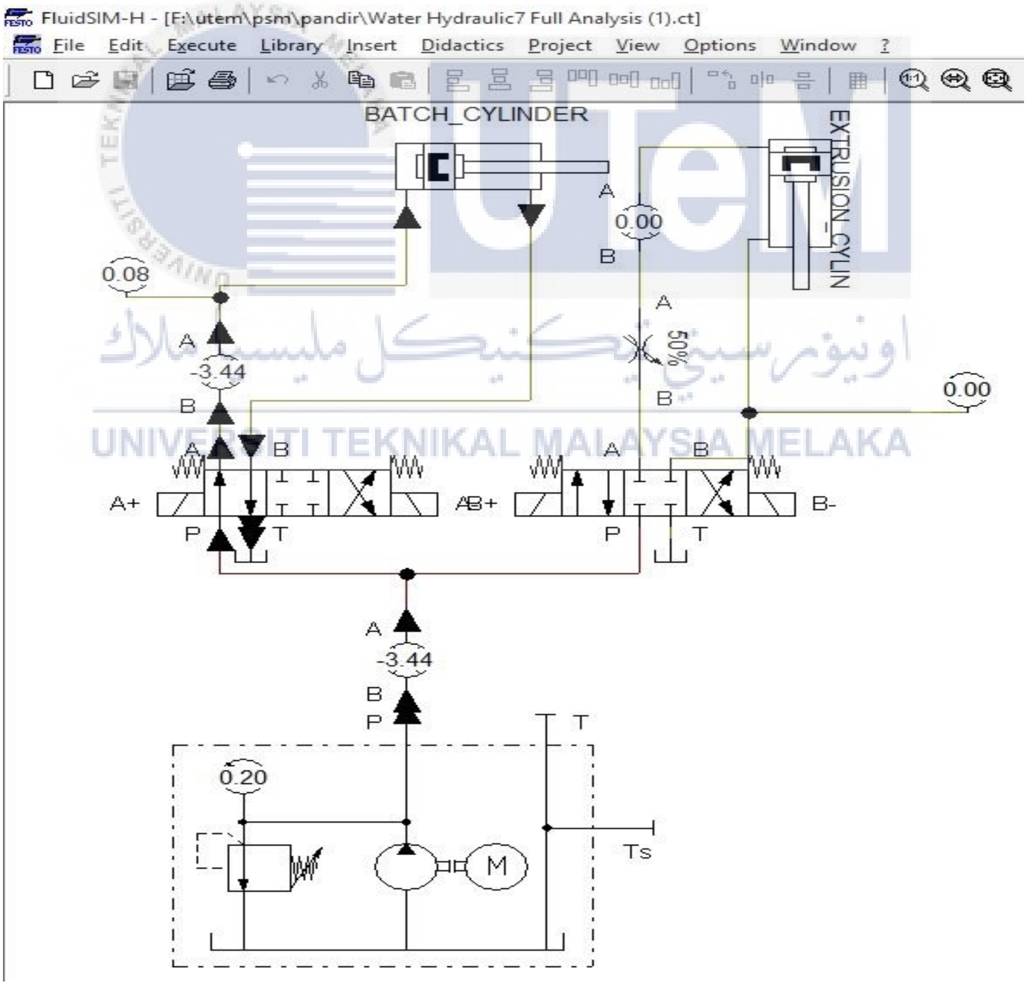


Figure 3.10a: FluidSIM simulation for hydraulic circuit for batch cylinder

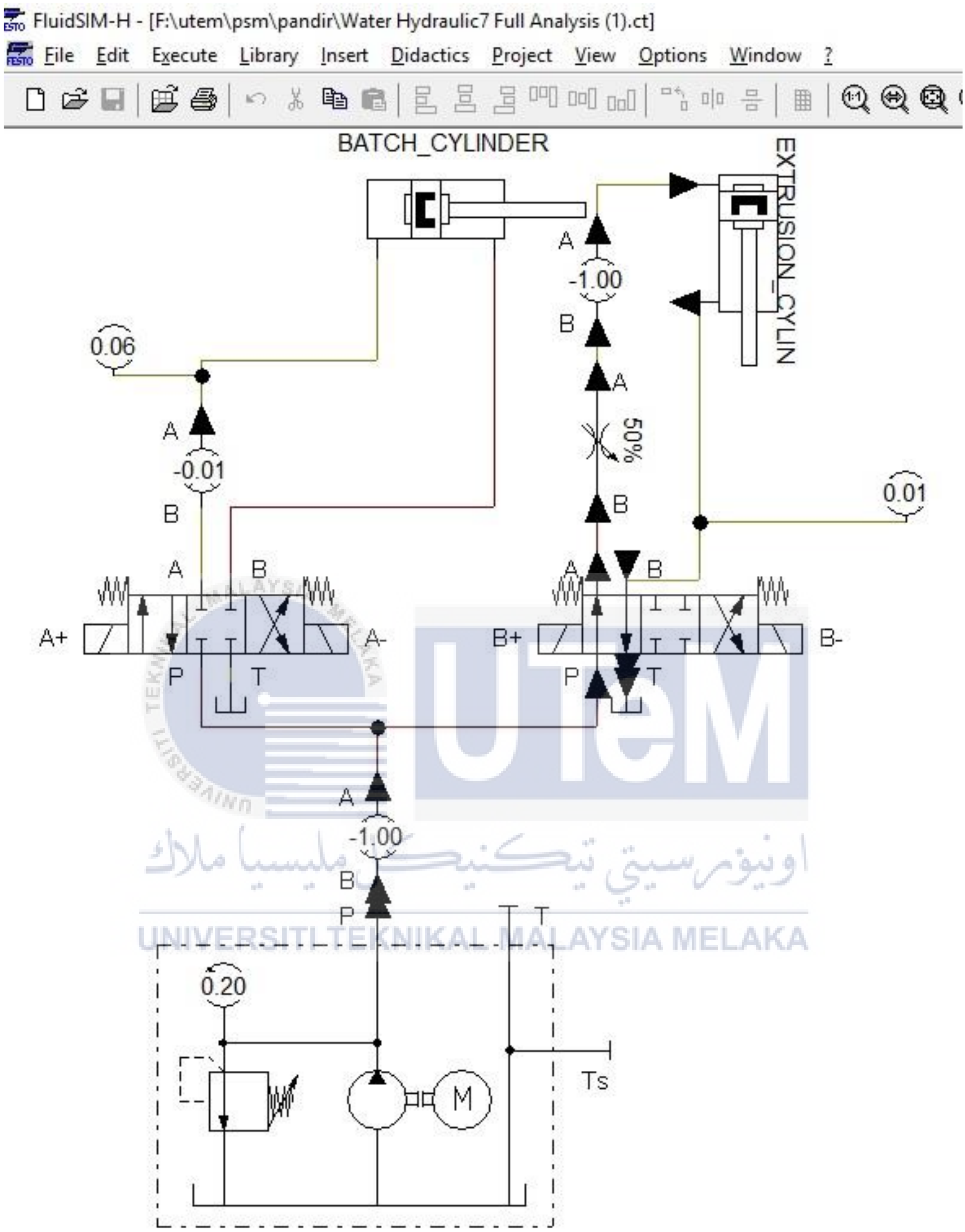


Figure 3.10b: FluidSIM simulation for hydraulic circuit for extrusion cylinder

3.6.2 CX ONE simulation

For CX ONE simulation we need to set the computer for the PLC from CPM2A to CJ1M only then the CX ONE software can run the simulation. This is because CPM2A is an older model and does not have any simulation option. The simulation in CX ONE is quite similar to FluidSIM with only difference of no actuator and solenoid in CX ONE. Simulation in CX ONE is used to ensure the ladder diagram design can circulate the current before the actual or physical test. In this simulation we can check the connectivity, set the counter and timer, and closing or opening switches. The line that been highlighted green in Figure 3.11 shows that there is current passing through the line.

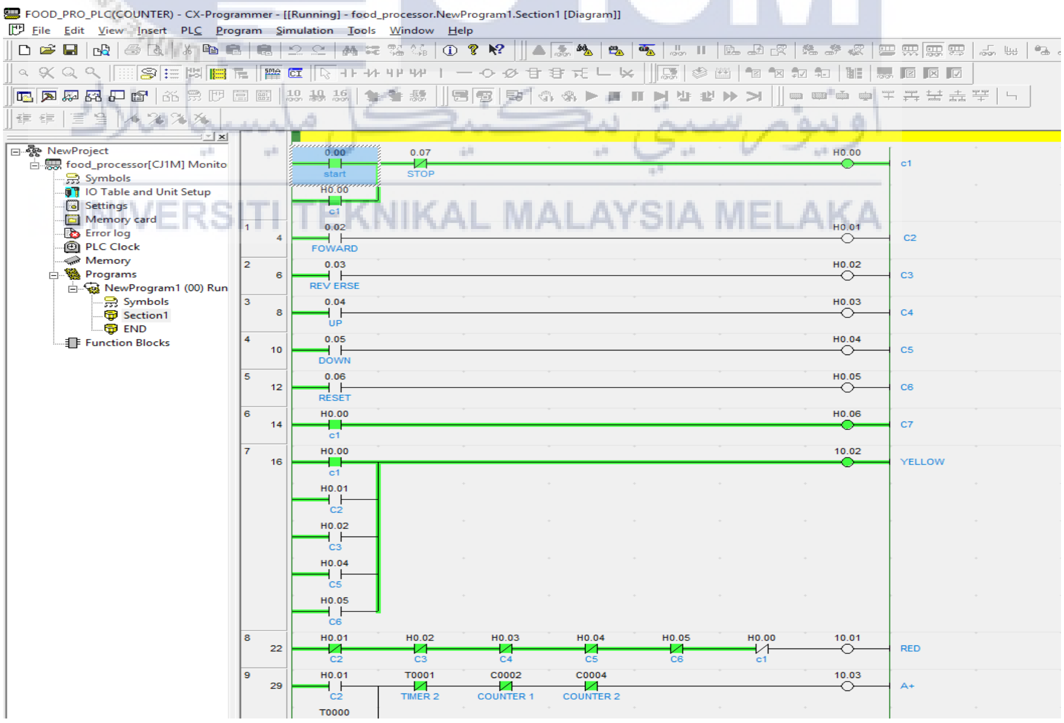


Figure 3.11: CX ONE simulation

3.6.3 Trial and error testing

Trial and error test or physical test is done to ensure the functionality of a product. Test such as this put the product to a real-world scenario and problems can be detect almost immediately. Using this test can save up time and cost in order to find or solve problems regarding the product. For this project physical test is used to test the automation of the food processor. First, we test the timer relay circuit by installing LED with different colours to represent different polarity of the solenoid as shown in Figure 3.12. If the LED is light up it means that current has passed through it. With this we can test the automation without connecting it to the food processor itself and detecting problems within the timer and relays. Same method is used for PLC, the PLC is first connected to a number of LED to represent the different polarity of solenoid as shown in Figure 3.12. However, in PLC we use this to check if the ports is still usable or not.

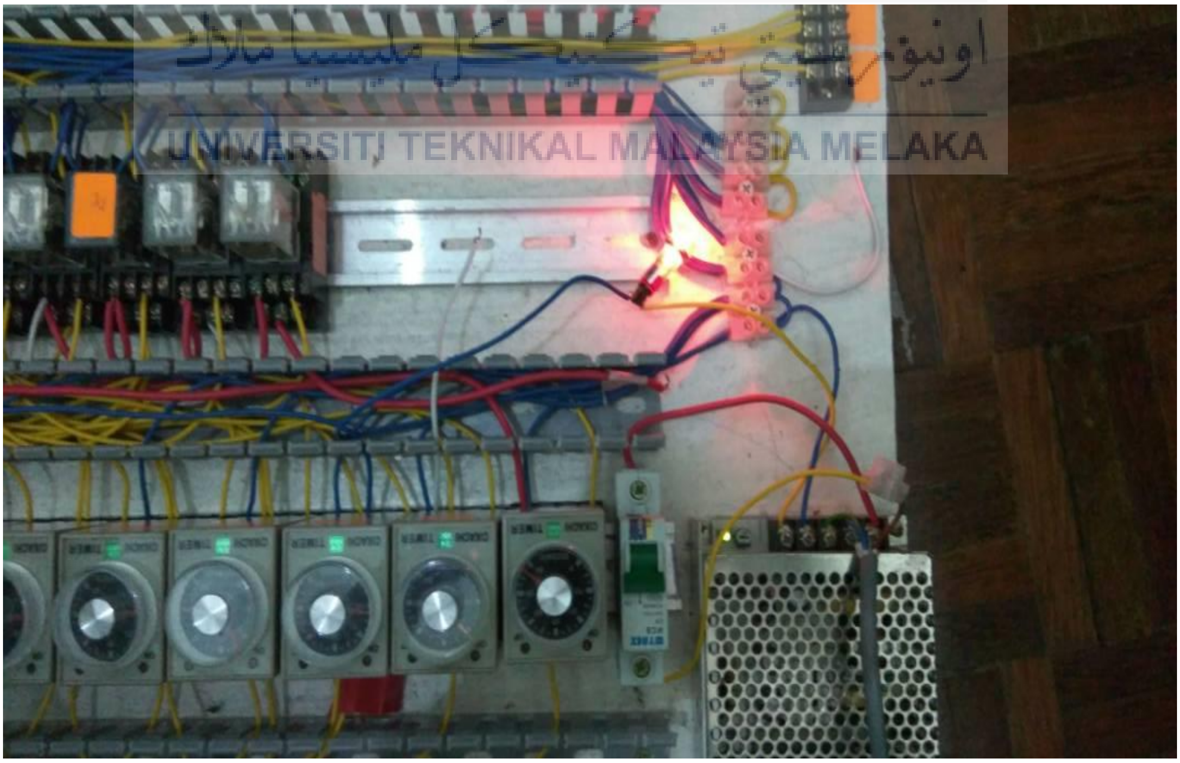


Figure 3.12: Timer relay circuit physical test

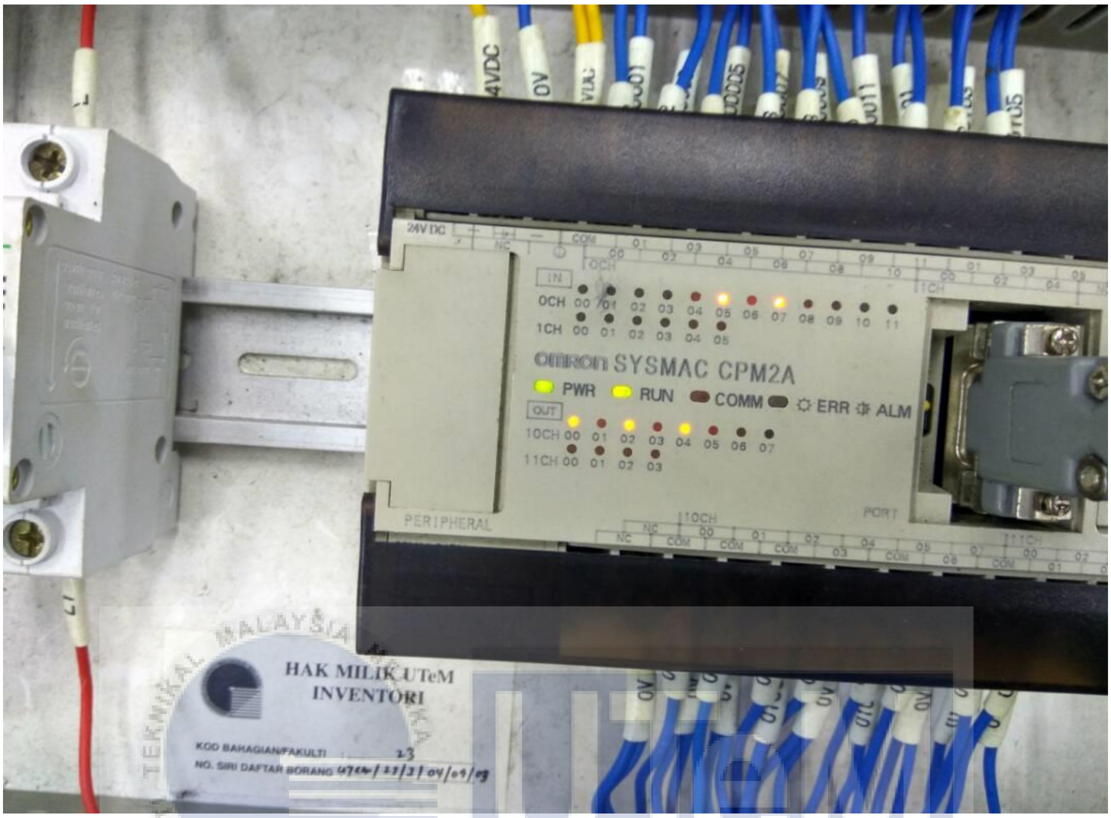


Figure 3.13: PLC physical test

3.7 Water sampling and monitoring

This project focus on the cleanliness of water hydraulic system. The cleanliness of water hydraulics is obtained through testing the working fluid or water. Couple of water sample is taken for each usage of the food processor. The water is then must go through pH measurement and rust check.

3.7.1 Water pH measurement

The pH of water plays huge effect on the material corrosion. The pH is a measure of how acidic or fundamental water is and additionally, it can determine the solubility of water. Fundamentally, the range for pH measurement is from 0 – 14 where 7 is neutral, under 7 indicate acidity and more than 7 indicates a base. On this test, the instrument that used to measure the pH of water is pen type pH meter. This meter needs to drench the electrode in pH 6.8 at 25 Celsius before taking the estimation for water tested. Hence, the neutral pH is 6.8 for this type of the measurement. PH-009(I) is the type of the pen type pH meter as shown at Figure 3.14.

Figure 3.14: Pen Type PH-009(I) pH meter

3.7.2 Parts per million measurement

To measure the amount of rust in the system that caused by water, we can do it by measuring TDS in water. TDS or total dissolved solids refer to the total amount of inorganic salts such as calcium, magnesium, ptoassium, sodium, bicarbonates, chlorides, sulfates, and some small amounts of organic matter that are dissovled in water. To measure the TDS we need to use TDS tester or meter. TDS tester gives a reading in parts per million (ppm) of all dissolved solids, good or bad. To test the amount of solid dissolved in water for this project, the water used in the system in tested using TDS tester before the water runs throughout the system. Next, the water is then sampled and tested each time after every usage of the food processor. The result is then compared to the initial result of the tester to dertemine the amount of solid from the system that has been dissolved in water. TDS tester gives reading in ppm, for example the initial reading of the TDS tester at the start of this project is 250ppm, that means the total content of the minerals dissolved in the water make up 250 parts per million of the total volum of water used. This test is taken as often as possible to gain the most accurate result.

Figure 3.15: Handheld type COM-80 EC /TDS Hydro Tester

3.7.3 Measuring water level inside reservoir.

The reservoir that has been installed is an open reservoir which mean evaporation process will occur. Water level is important in order to avoid cavitation inside the hydraulic system. Figure 3.16 shows how the water level is measured visually by using a measuring ruler to calculate the height of the water. The data is then recorded. The readings are taken over the span of 1 week to determine how often the water needs to be refilled.

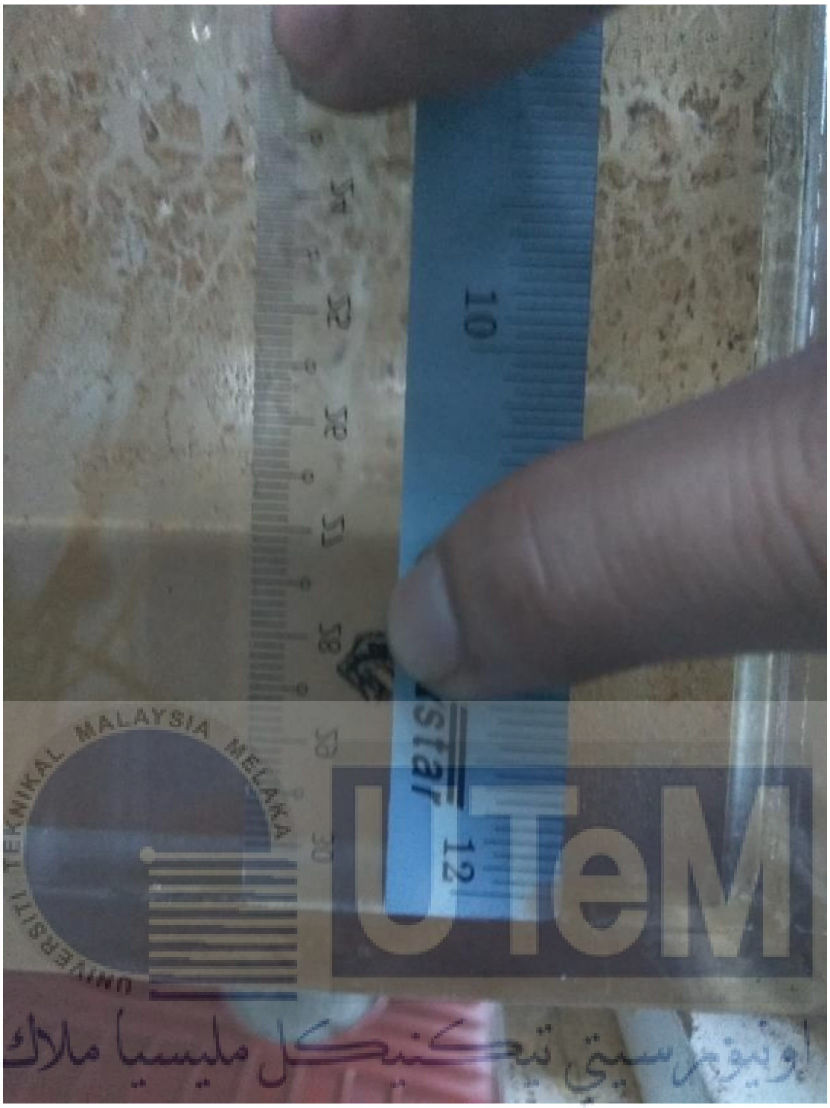


Figure 3.16: Metered ruler is used to measure the water level

3.8 DCV maintenance process

All hydraulic equipments have their lifespan, however by changing the material of the working fluid the lifespan of the equipment will differ. The difference will be significant for equipment which have moving parts such as DCV. This system is using a DCV with a sliding spool system. There is a spool which slides to change channels for the valve. The spool is controlled by 2 solenoids. If there is impurities in the working fluid such as dirt and rust the sliding spool will jammed and the valve will stop operating. Thus DCV is the most affected equipment if rust and erosion occurs inside the system.

Maintaining the valve requiring the water to be filtered before entering the valve and the sliding spool also need to be cleaned. To clean the sliding spool, both solenoid needs to disconnect with the DCV and figure 3.17 shows the solenoid is being removed with a wrench. After removing both solenoids, the sliding spool is then can be retrieved by pushing the sliding spool with a hammer and a centre punch. The sliding pool is then cleaned with oil and rinsed with water. After drying the sliding spool with a soft microfibre cotton to dry it. The channels are also cleaned by using compressed air to blow away the impurities.

Figure 3.17: Disconnecting the solenoid from the valve

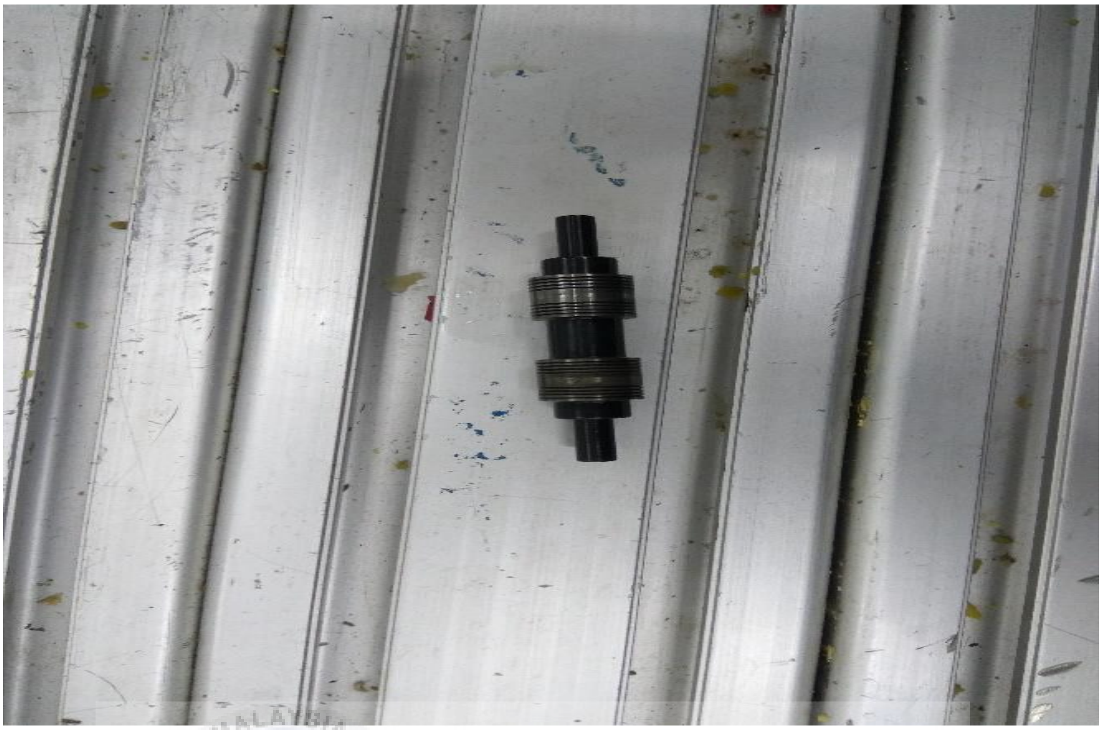


Figure 3.18: Sliding spool after being cleaned.

CHAPTER 4

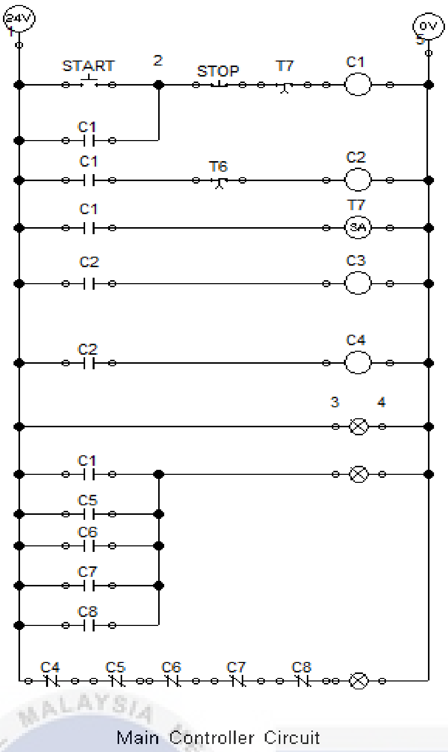
DATA AND RESULT

4.1 Introduction

On this chapter, it will be focussing on the result of the experiment that had been done in methodology.

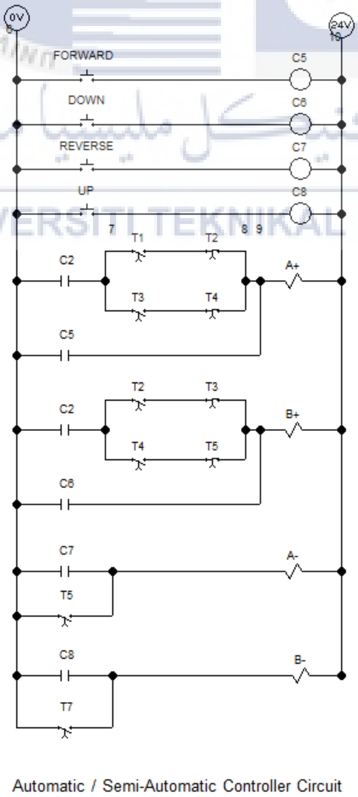
4.2 Control circuit design for timer-relay circuit

In the automatic/semi-automatic controller circuit in Figure 4.5, relay coil C5 is utilized to control the expansion cycle of batch and extrusion cylinder. At the point when relay coil C2 in the primary controller circuit is energized, the activated relay contact C2-1 will energize relay coil C5. This will bring about the activation of relay contact C5-1 that will energize relay coil C3. Relay coil C3 is utilized to control the timer controller circuit, which control the automatic cycle of the chambers. Once the relay coil C3 is energized, it will activate relay contact C3-1 and C3-2. Relay contact C3-1 will energize timer T1 and T2, while relay contact C3-2 will energize timer T3 and T4 situated in timer controller circuit, as appeared in Figure 4.1.



C1	Make switch (Ladder)
C1	Make switch (Ladder)
C1	Make switch (Ladder)
C1	Make switch (Ladder)
C1	Relay (Ladder)
C2	Make switch (Ladder)
C2	Make switch (Ladder)
C2	Make switch (Ladder)
C2	Make switch (Ladder)
C2	Relay (Ladder)
C3	Make switch (Ladder)
C3	Make switch (Ladder)
C3	Make switch (Ladder)
C3	Make switch (Ladder)
C3	Relay (Ladder)
C4	Brake switch (Ladder)
C4	Make switch (Ladder)
C4	Make switch (Ladder)
C4	Relay (Ladder)
C5	Brake switch (Ladder)
C5	Make switch (Ladder)
C5	Make switch (Ladder)
C5	Relay (Ladder)
C6	Brake switch (Ladder)
C6	Make switch (Ladder)
C6	Make switch (Ladder)
C6	Relay (Ladder)
C7	Brake switch (Ladder)
C7	Make switch (Ladder)
C7	Make switch (Ladder)
C7	Relay (Ladder)
C8	Brake switch (Ladder)
C8	Make switch (Ladder)
C8	Make switch (Ladder)
C8	Relay (Ladder)

Figure 4.1: Main controller circuit with description.

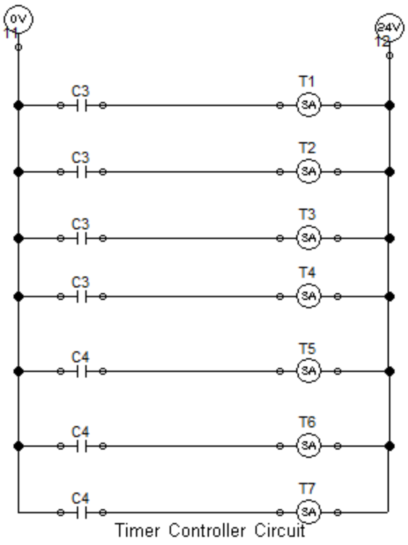


A+	Valve solenoid
A-	Valve solenoid
B+	Valve solenoid
B-	Valve solenoid
DOWN	Pushbutton (make, Ladder)
Extrusion Cylin	Cylinder B
FORWARD	Pushbutton (make, Ladder)
REVERSE	Pushbutton (make, Ladder)
START	Pushbutton (make, Ladder)
STOP	Pushbutton (break, Ladder)
T1	Make switch (Ladder)
T1	Relay with switch-on delay (Ladder)
T2	Brake switch (Ladder)
T2	Make switch (Ladder)
T2	Relay with switch-on delay (Ladder)
T3	Brake switch (Ladder)
T3	Make switch (Ladder)
T3	Relay with switch-on delay (Ladder)
T4	Brake switch (Ladder)
T4	Make switch (Ladder)
T4	Relay with switch-on delay (Ladder)
T5	Brake switch (Ladder)
T5	Make switch (Ladder)
T5	Relay with switch-on delay (Ladder)
T6	Brake switch (Ladder)
T6	Relay with switch-on delay (Ladder)
T7	Brake switch (Ladder)
T7	Relay with switch-on delay (Ladder)
UP	Pushbutton (make, Ladder)

Figure 4.2: Automatic/Semi-automatic controller circuit with description

In the timer controller circuit, timer T1, T2, T3, T4 and T5 fundamentally control the extension and retraction of batch chamber and extrusion barrel. All timers are utilizing delay-on mode, with T1 is set with 1 s time delay, T2 with 2 s time delay, T3 = 3 s time delay, T4 = 4 s and T5 = 5 s of time delay. Once the push button is pushed, it takes around 1 second for the timer coil T1 to activated. From that point, the make switch/normally open (NO) timer contact T1-1 will be activated, simultaneously with already activated make switch/normally open (NO) relay contact C5-2. This will energize solenoid A+, which will switch the position of 4/3 way directional control valve DCV1 controlling the batch chamber. The batch cylinder will stretch out for 1 second, before timer coil T2 is energized. Once energized, it will activate both brake switch/normally close (NC) timer contact T2-1 and make switch/normally open (NO) timer contact T2-2.

The action will de-energized solenoid A+ and in this way permitting the return spring in the 4/3 way directional control valve DCV1 to move the spool into an neutral position. This will stop the movement of the batch cylinder, in the wake of being dislodge for 66.62 mm. Simultaneously, the activation of make switch/normally open (NO) timer contact T2-2 will energized solenoid B+, hence exchanging the position of 4/3 way directional control valve DCV2 which controls the extension of the extrusion cylinder. The extrusion piston will push the dough into the nozzle mold for 1 second. At this time, the time has accumulated for an aggregate of 3 seconds. At t = 3 s, timer coil T3 is energized. This will activate both make switch/normally open (NO) timer contact T3-1 will again energize solenoid A+, and in the meantime de-energized solenoid B+ in the automatic/semi-automatic controller circuit.



T1	Make switch (Ladder)
T1	Relay with switch-on delay (Ladder)
T2	Brake switch (Ladder)
T2	Make switch (Ladder)
T2	Relay with switch-on delay (Ladder)
T3	Brake switch (Ladder)
T3	Make switch (Ladder)
T3	Relay with switch-on delay (Ladder)
T4	Brake switch (Ladder)
T4	Make switch (Ladder)
T4	Relay with switch-on delay (Ladder)
T5	Brake switch (Ladder)
T5	Make switch (Ladder)
T5	Relay with switch-on delay (Ladder)
T6	Brake switch (Ladder)
T6	Relay with switch-on delay (Ladder)
T7	Brake switch (Ladder)
T7	Relay with switch-on delay (Ladder)

Figure 4.3: Timer Controller circuit with description.

This will end the extension of the extrusion cylinder, leaving a 21.25 mm displacement. At the same time, batch cylinder starts to stretch out from the previous position. The batch cylinder will again extend for 1 seconds, before timer coil T4 is energized at t=4 s. Once energized, it will activate both brake switch/normally close (NC) timer contact T4-1 and make switch/normally open (NO) timer contact T4-2. The action will again de-energize solenoid A+, and in this way permitting the return spring in the 4/3-way directional control valve DCV1 to move the spool into a neutral position. This will again stop the movement of the batch cylinder, in the wake of being displaced for 55.36 mm. The entire batch cylinder extension gives a displacement of 121.98 mm. Simultaneously, the activation of make switch/normally open (NO) timer contact T4-2 will energize solenoid B+, hence changing the position of 4/3 way directional control valve DCV2 which controls the extension of the extrusion cylinder. The extension will push the batter into the nozzle for an additional 1 second. In this time, the time that has gathered for an aggregate of 5 seconds. For t = 5 s, timer coil T5 will energize. This will activate both brake switch/normally close (NC) timer contact T5-1 and make switch/normally open (NO) timer contact T5-2. The activation of brake switch/normally close (NC) timer contact T5-1 will de-energize solenoid

B+ for the second time. The extension of the extrusion cylinder will stop, leaving a 20.95 mm displacement, after extending to a distance of 42.20 mm. Simultaneously, the activation of make switch/normally open (NO) timer contact T5-2 will energize relay coil C6. Relay contact C6-1 will be activated and will energize solenoid A-. This will result in the retraction of batch cylinder. During the retraction, the time should accumulate up to t = 6s, whereby timer coil T6 will be energized. At this moment, two cookies have been extruded. This will activate both brake switch/normally open (NO) timer contact T6-1 and make switch/normally close (NC) timer contact T6-2. When this happens, the green indicator will go off, and the red indicator will light. This basically shows that the batch cylinder is returning to the full retraction condition, before moving into the next cycle. Now, two cookies have been extruded. At this moment, the time should be accumulating to t = 7s. Thus, timer coil T7 will briefly energize and activate a brake switch/normally close (NC) timer contact T7-1. This will reset the whole automatic/semi-automatic controller circuit and the timer controller circuit. After that, the cycle repeat itself until the accumulated time reaches 22 seconds, where it will stop

Table 4.1: Simulated result using electro circuit

Parameter	Case 1			Case 2		
Pressure	5 bar	5 bar	5 bar	5 bar	7.5 bar	10 bar
Flow Rate	5 lpm	7.5 lpm	10 lpm	5 lpm	5 lpm	5 lpm
Possible Cycles	6 cycles	6 cycles	6 cycles	6 cycles	5.5 cycles	4 cycles
Possible Cookies	12 cookies	12 cookies	12 cookies	12 cookies	10 cookies	8 cookies
Extrusion Cylinder	11.04 mm	11.04 mm	11.04 mm	11.04 mm	13.43 mm	15.5 mm
Batch Cylinder 1st Displacement	66.66 mm	73.28 mm	73.29 mm	66.66 mm	66.73 mm	66.81 mm
Batch Cylinder 2nd Displacement	122 mm	125 mm	125 mm	122 mm	124.86 mm	125 mm

The result of the simulated process is shown in **Table 4.1**. In the simulated cases, the system is set at 5 bar, 7.5 bar and 10 bar of pressure. The flow is set at 5, 7.5 and 10 liters per minute, which goes into the batch cylinder. About a quarter of the flow goes into the extrusion cylinder, since the opening of the flow control valve is set at 25% opening. The maximum stroke of the cylinder is 125 mm, while the diameter of the piston is set at 40 mm. The increment of 1 second is introduced to all timers, from timer coil T1 until T5. T6 is set for 8 s, while T7 is set for 50s. In Case 1, the result shows that a constant of 12 cookies can be produced, even if the flow rate is increased. However, an increasing displacement of batch cylinder is noticeable, with the increase of flow rate. It is noted that the space between two cookies per cycle will be reduced, during the extrusion. The result also shows that, in Case 2, the increase in pressure reduces the cycles of the batch cylinder. Thus, the amount of the produce cookies is also reduced, but with an increase in thickness. This is due to the increase of extrusion cylinder displacements.

Table 4.2: Time set for the timer in FluidSIM simulation

TIMER	TIME (s)
T1	1.0
T2	2.0
T3	3.0
T4	4.0
T5	5.0
T6	6.0
T7	7.0

4.3 PLC circuit

The PLC circuit shown in Figure 4.5 is the circuit built using the CX ONE programming software which uses as a tool of arrangement and simulation. Circuit constructed in FluidSIM is not in the correct format for CX ONE to read it. Thus we need to rebuild and tweak the circuit a little bit in order to apply it to PLC. The PLC computing unit that has been used in this project is CPM2A that reads the ladder diagram one by one from start till the end. Two types of PLC program has been made, one for a process which involves two (2) rows and the other one only involves one (1) row

4.3.1 PLC program for two-rows

When the START button is pushed, it will switch its (NO) contact to (NC) and current will passed through it and stop button because it is originally (NC) and charge coil relay C1. After being charged it will change the (NO) contact for C1 on rung 0 to (NC) allowing electrical current to pass through TIMER 0. On the same time, C1 (NO) contact on rung 12 will change to (NC) which allow current to flow through and energize solenoid B- making the extrusion cylinder move downwards. When t = 0.5 s, TIMER 0 will be charged and activates the timer switch at rung 12 switching it from (NC) to (NO) which prevent current from charging solenoid B- stopping the extrusion cylinder. The (NO) contact for TIMER 0 on rung 15 will also change to (NC) allowing current to pass through TIMER 4. TIMER 4 is a delay timer used to delay the time for the cookies to extracted from the extrusion cylinder and separate it from the cylinder. When t= 1s, TIMER 4 (NO) contact on rung 9 will change to (NC) and energizing solenoid A making the batch cylinder extends foward. Simultaneously, on rung 16 the limit switch for solenoid A+ (NO) contact will transformed to (NC) allowing current to pass through TIMER 1. When t = 2s, (NC) contact for TIMER 1 on rung 9 will change from (NC) to (NO) discharging solenoid A+ which will stop the batch cylinder. On the other hand, on rung 17 the (NO) limit switch contact for solenoid A+ will also change to (NC) which acts as an input for COUNTER 1. After 2 counts all contacts for COUNTER 1 will change activating solenoid A- on rung 10 and TIMER 3 on rung 18 making the batch cylinder retracts for 1s and simultaneously moving the conveyor belt. The conveyor belt moving time will be determined by TIMER 5 which is activated 0.8s after COUNTER 2 (NO) contact on rung 21 changes to (NC). Because of each rung has a reset contact the operation above will repeat itself until either COUNTER 1 is activated or STOP button is pushed. Example of reset contact is (NC) contact of TIMER 1 on rung 14 for resetting TIMER 0, the contact will change to (NO) and resets TIMER 0 by disconnecting electrical current from supply. When solenoid A- is activated, its (NO) contact on rung 19 will change to (NC) which then acts as an input for COUNTER 2. COUNTER 2 has been set to activates after 4 counts which will change all contact for COUNTER 2, in this case it needs 4 input of solenoid A-. After contact for COUNTER 2 has changed, rung 10 and 11 will activated. This will reset all of the cylinder position and simultaneously moves the conveyor belt as well. After TIMER 3 has been charged for 3.5s the (NC) contact for TIMER 3 on rung 11 will become open (NO) stopping the movement of batch cylinder. COUNTER 2 also activates TIMER 3 and conveyor belt which will activates it for 1s. The first cycle is then done and the cycles continue until the STOP button is pushed. Total accumulated time is 15.5 seconds.

Table 4.3: Contact and addresses for PLC.

No.	Contact	Address
1.	Start button (START)	0.00
2.	Stop button (STOP)	0.07
3.	Limit switch 1 (FORWARD)	0.02
4.	Limit switch 2 (REVERSE)	0.03
5.	Limit switch 3 (UP)	0.04
6.	Limit switch 4 (DOWN)	0.05
7.	Limit switch 5 (RESET)	0.06
8.	Limit switch 6 (conveyor)	0.08
9.	Relay 1 (C1)	HR0.00
10.	Relay 2 (C2)	HR0.01
11.	Relay 3 (C3)	HR0.02
12.	Relay 4 (C4)	HR0.03
13.	Relay 5 (C5)	HR0.04
14.	Relay 6 (C6)	HR0.05
15.	Relay 7 (C7)	HR0.06
16.	Timer 0	TIM000
17.	Timer 1	TIM001
18.	Timer 2	TIM003
19.	Timer 3	TIM005
20.	Timer 4	TIM007
21.	Counter 1	CNT002
22.	Counter 2	CNT004
23.	Green LED (GREEN)	10.02
24.	RED LED (RED)	10.01
25.	Solenoid A+	10.03
26.	Solenoid A-	10.05
27.	Solenoid B+	10.06
28.	Solenoid B-	10.04

Figure 4.4: Installed PLC circuit board with switch button.

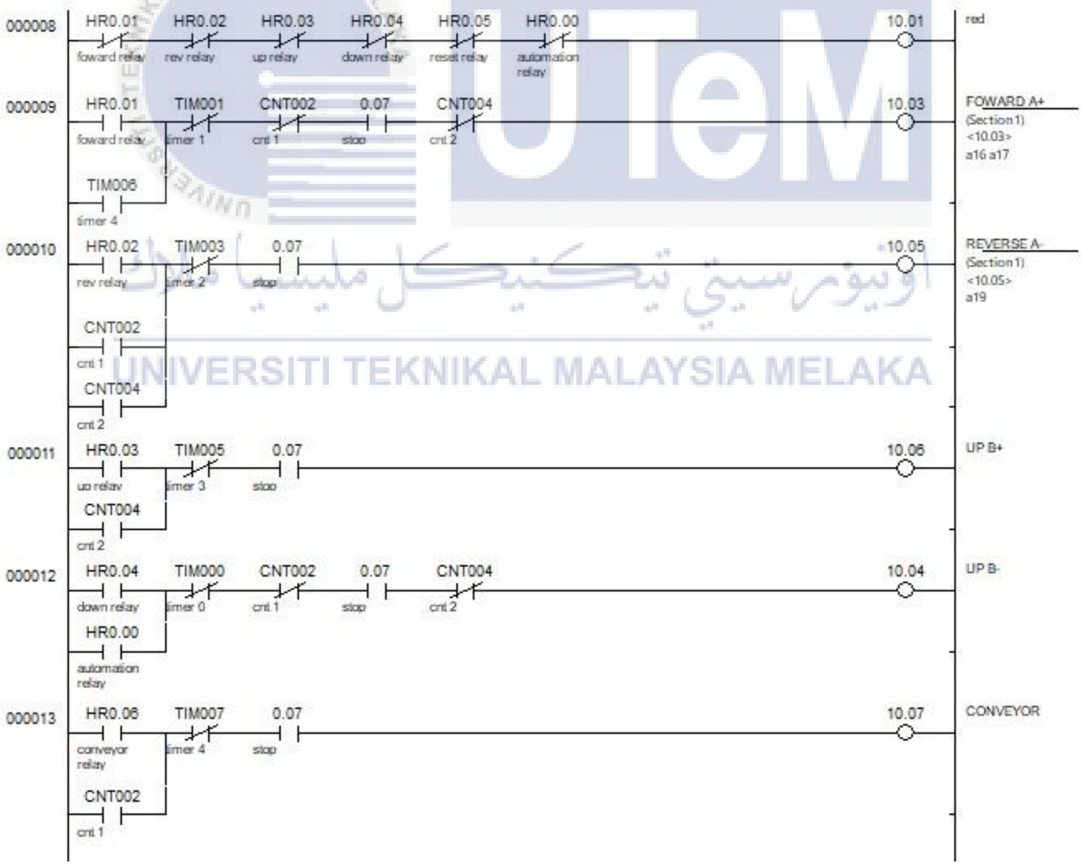


Figure 4.5: PLC main controller unit

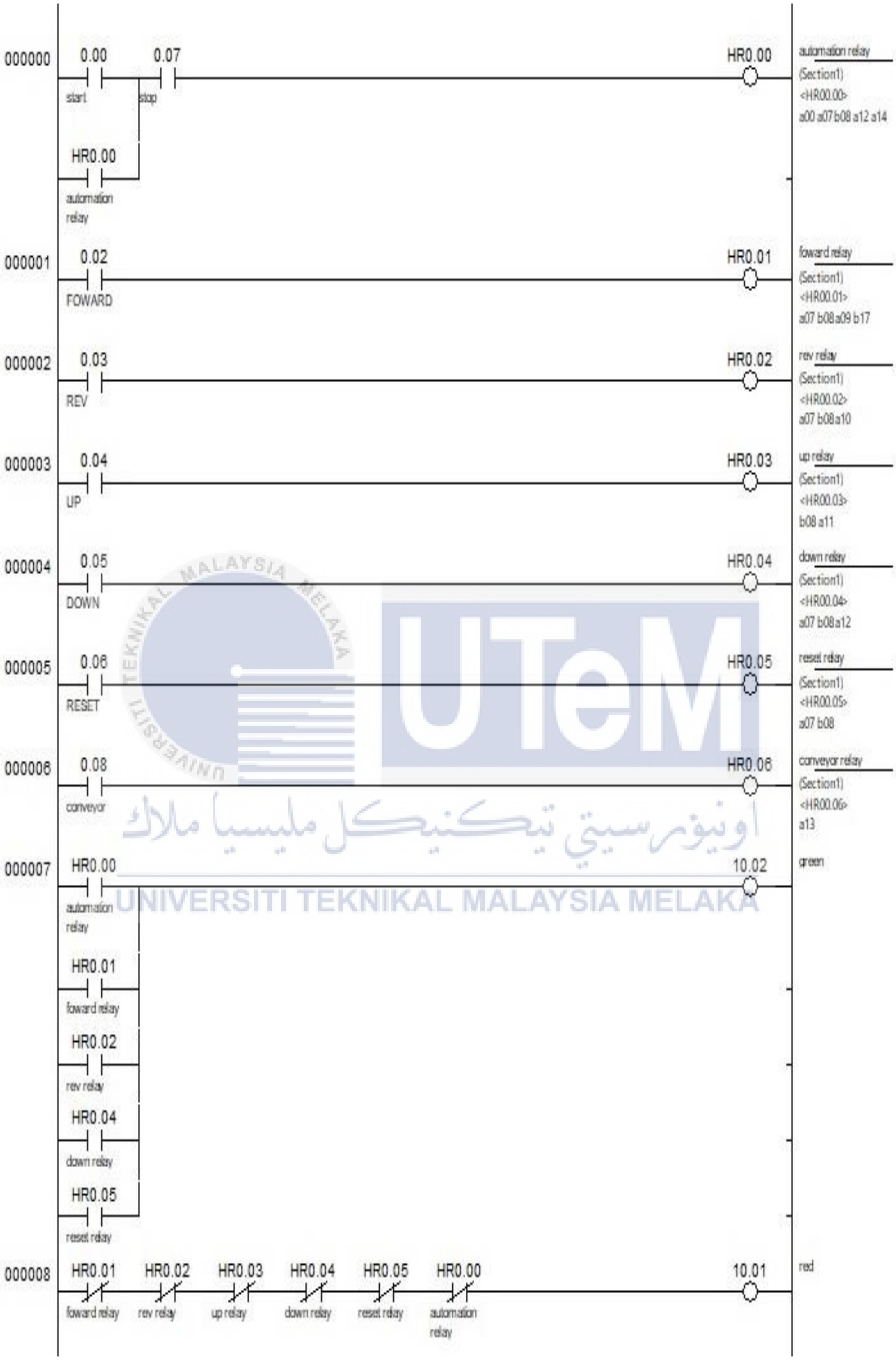


Figure 4.6: PLC main input unit

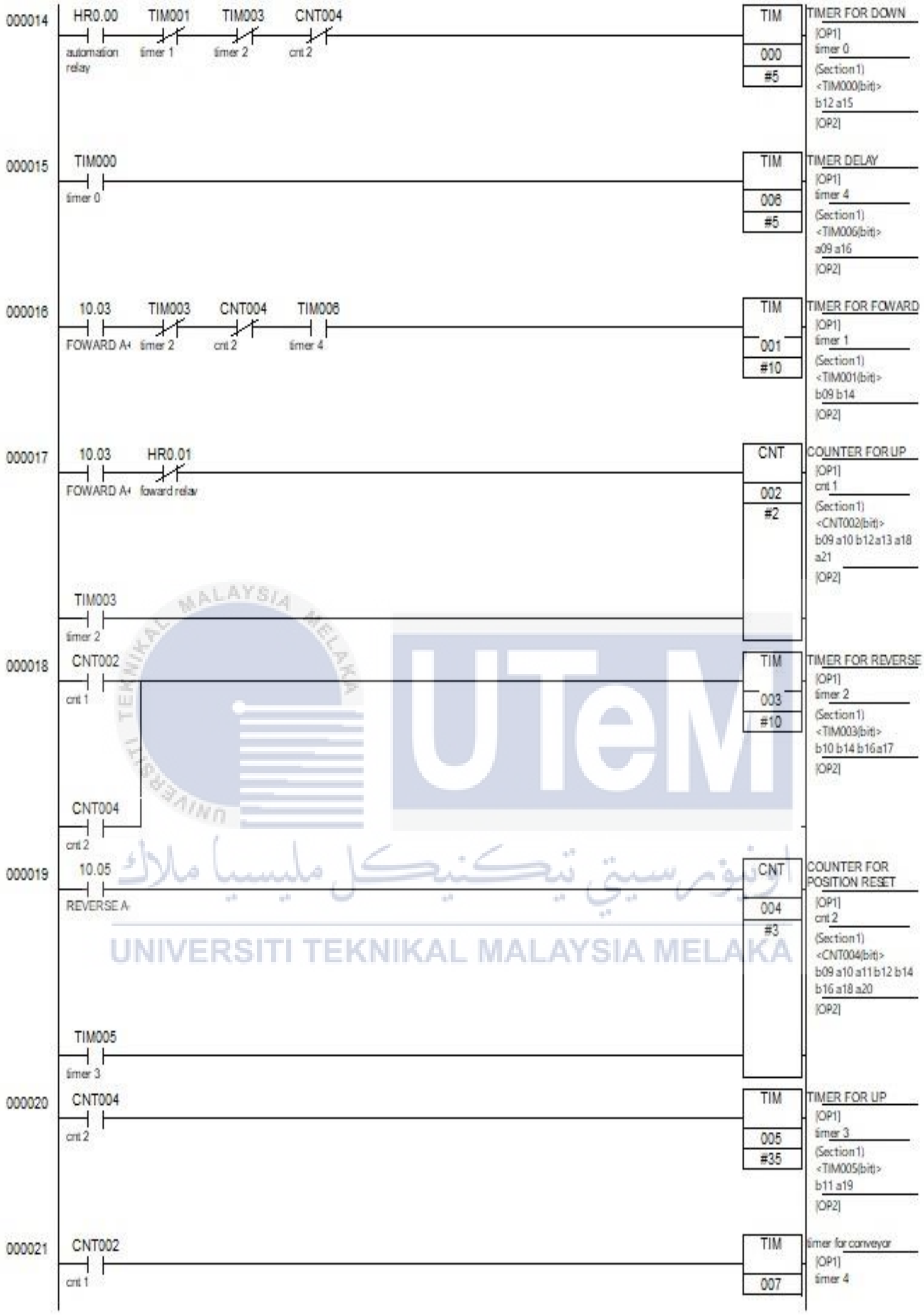


Figure 4.7: PLC timer and counter unit

4.3.2 PLC program for one-row

The operation for one row is similar with two rows as well, the only difference is that the batch cylinder operation is unneeded. When the START button is pushed, it will switch its (NO) contact to (NC) and current will passed through it and stop button because it is originally (NC) and charge coil relay C1. After being charged it will change the (NO) contact for C1 on rung 0 to (NC) allowing electrical current to pass through TIMER 0. On the same time, C1 (NO) contact on rung 12 will change to (NC) which allow current to flow through and energize solenoid B- making the extrusion cylinder move downwards. When t = 0.4 s, TIMER 0 will be charged and activates the timer switch at rung 12 switching it from (NC) to (NO) which prevent current from charging solenoid B- stopping the extrusion cylinder. The (NO) contact for TIMER 0 on rung 15 will also change to (NC) allowing current to pass through TIMER 1. TIMER 1 is a delay timer used to delay the time for the cookies to be extracted and separated from the extrusion cylinder. After 1.5s, TIMER 1 (NO) contact on rung 13 and 16 will change to (NC) allowing current to pass through and the conveyor belt will start moving. After 1s, TIMER 3 will be activated changing the (NC) contact on rung 13 and 14 to (NO) stopping the conveyor belt and resetting the time for TIMER 1. Solenoid B- is set to be input for COUNTER 1, each time solenoid B- is activated the count for COUNTER 1 will be decrease by one. The counter is set to have 6 counts. After solenoid B- is activated for 6 times, all contact for COUNTER 1 will change which activates conveyor belt on rung 13 and solenoid B+ on rung 11. The (NO) contact on rung 17 will also change to (NC) which activates TIMER 2. After 3.5s all contact for TIMER 2 will change and on rung 11 the (NC) TIMER 2 contact will change to (NO). Hence after 6 pieces of cookies is extracted the system will be reset and the extrusion cylinder will return to its original position.

The first cycle is then done, and the cycles continue to rotate until the STOP button is pressed. Total accumulated time is 19 seconds.

Table 4.4: Contact and addresses for PLC

No.	Contact	Address
1.	Start button (START)	0.00
2.	Stop button (STOP)	0.07
3.	Limit switch 1 (FORWARD)	0.02
4.	Limit switch 2 (REVERSE)	0.03
5.	Limit switch 3 (UP)	0.04
6.	Limit switch 4 (DOWN)	0.05
7.	Limit switch 5 (RESET)	0.06
8.	Limit switch 6 (conveyor)	0.08
9.	Relay 1 (C1)	HR0.00
10.	Relay 2 (C2)	HR0.01
11.	Relay 3 (C3)	HR0.02
12.	Relay 4 (C4)	HR0.03
13.	Relay 5 (C5)	HR0.04
14.	Relay 6 (C6)	HR0.05
15.	Relay 7 (C7)	HR0.06
16.	Timer 0	TIM000
17.	Timer 1	TIM001
18.	Timer 2	TIM003
19.	Timer 3	TIM005
21.	Counter 1	CNT002
23.	Green LED (GREEN)	10.02
24.	RED LED (RED)	10.01
25.	Solenoid A+	10.03
26.	Solenoid A-	10.05
27.	Solenoid B+	10.06
28.	Solenoid B-	10.04

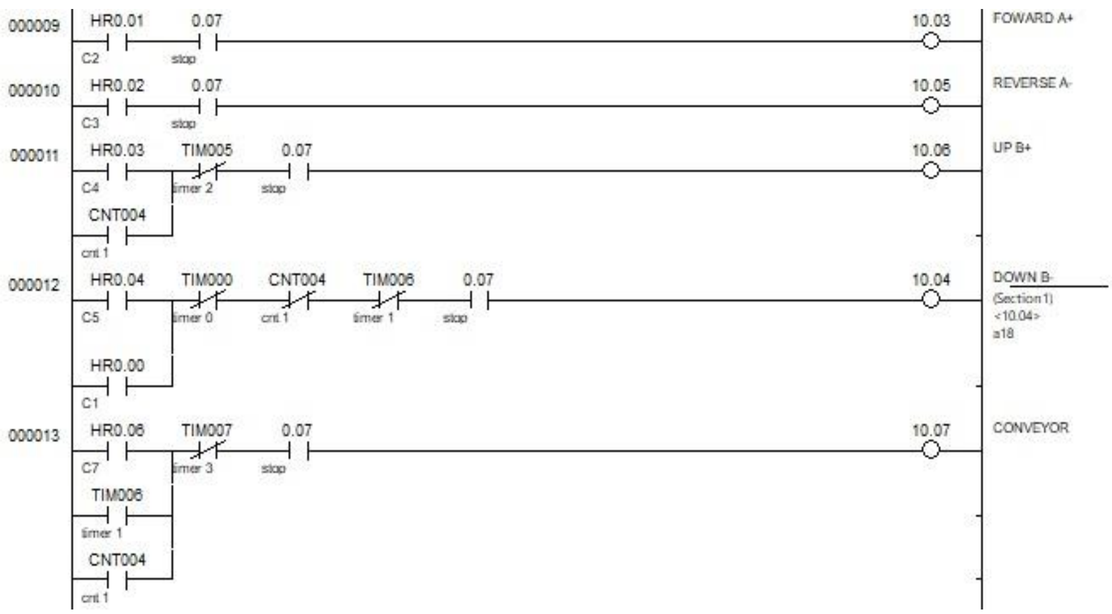


Figure 4.8: PLC main controller unit

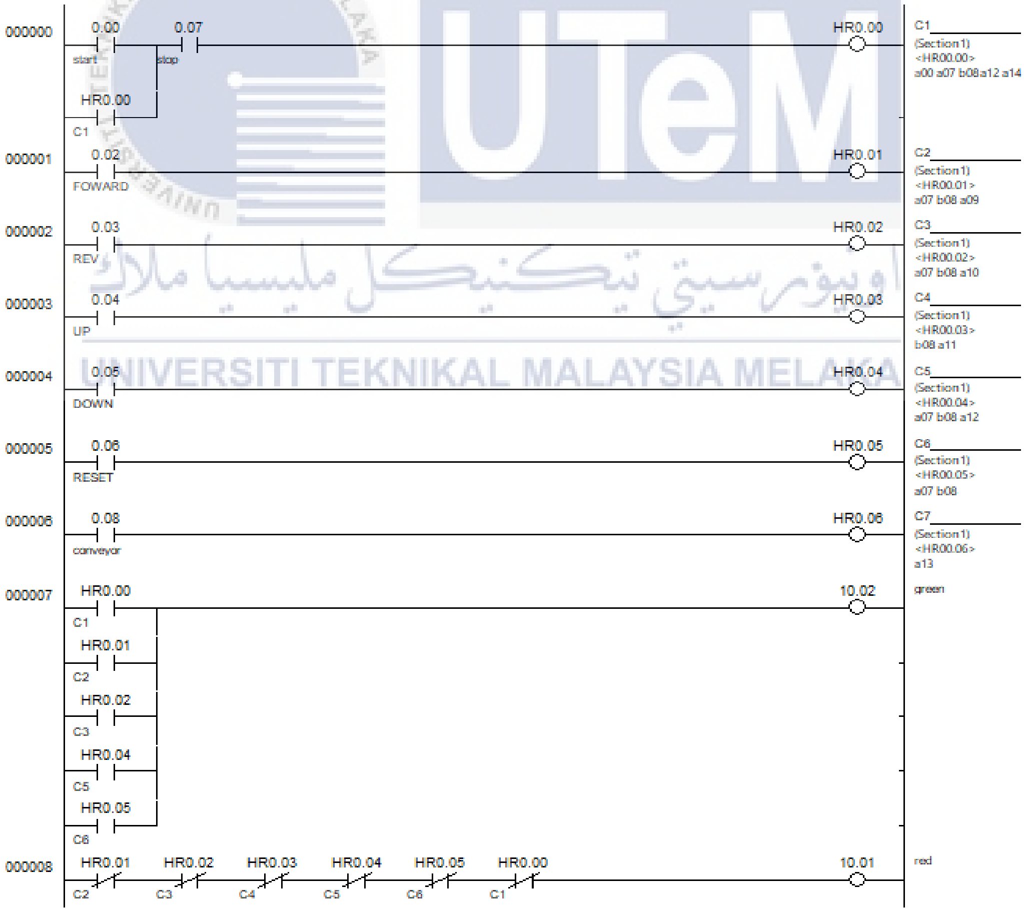


Figure 4.9: PLC main inputs unit

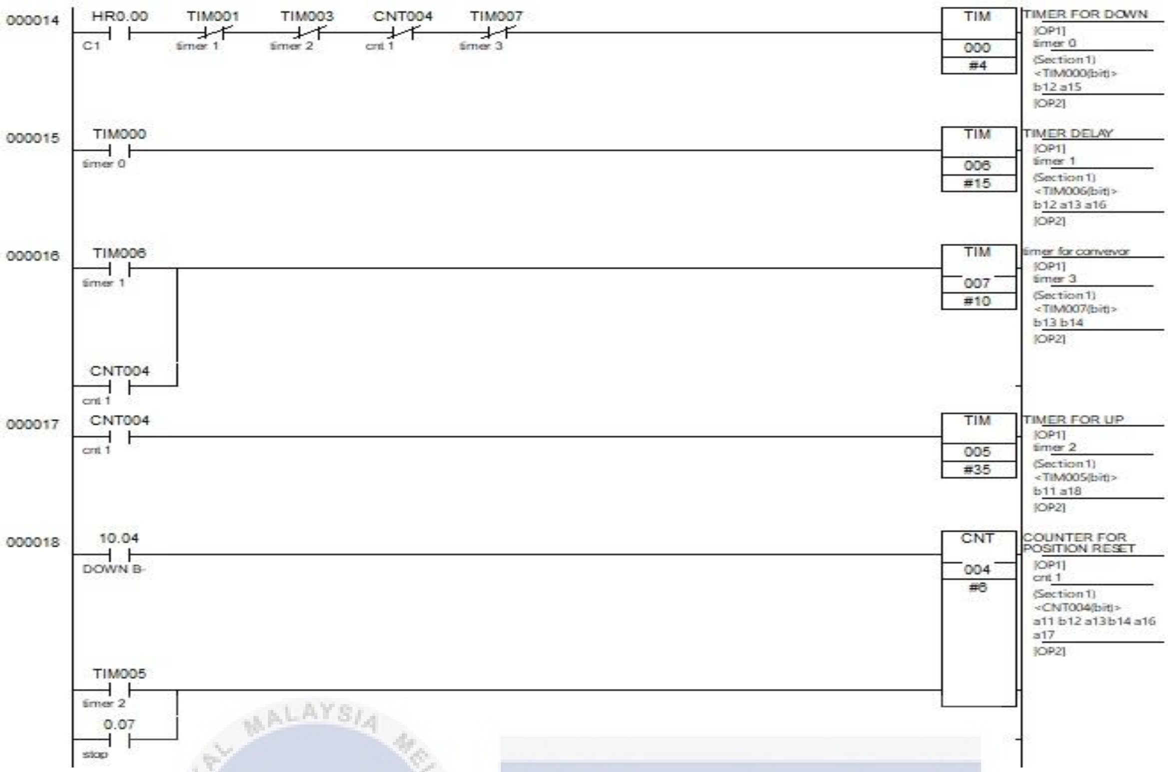


Figure 4.10: Timers and counter unit

Table 4.5: Simulated Result using PLC for 1 and 2 rows

Parameter	**1 row**			**2 rows**		
Pressure	2bar	2 bar	2 bar	2 bar	2 bar	2 bar
Flow	9 lpm	12.5 lpm	15 lpm	9 lpm	12.5 lpm	15 lpm
Possible Cycles per	5 cycles	5 cycles	5 cycles	7 cycles	7 cycles	7 cycles
Total cookies	41	40	40	4233	42	42
Extrusion Cylinder Displacements	11.04mm	11.04mm	11.04 mm	11.04 mm	11.04 mm	11.04 mm
Batch Cylinder 1st Displacement	65mm	65mm	65 mm	65mm	65mm	65mm
Batch Cylinder 2nd Displacement	125mm	125mm	125 mm	65mm	65mm	65mm
Time to complete 1 cycle	15.5 s	14.7 s	13.0 s	19.0 s	18.5 s	17.3 s
Cookies produce per second (cookies/second)	0.5	0.6	0.8	0.3	0.4	0.6

The result of this experimentation is shown in Table 4.5. In this case there is only one case which the pressure is set to a constant 5 bar. With the absence of flow gauge, we need to determine the flow by converting the frequency of the motor to flow by using flow to frequency ratio. The pump flow for 50hz is 60 lpm, thus for frequency value of 7.5hz, 10.5hz, and 12.5hz the flow rate of the pump is 9 lpm, 12.5 lpm, and 15 lpm respectively. The machine is equipped with frequency inverter which controls the motor speed by adjusting the electrical frequency. The maximum stroke of the cylinder is 125 mm, while the diameter of the piston is set at 40 mm. The increment of 1 second is set to all timers inside the PLC. The result shows that 41 cookies can be produced if the frequency is set to 9 lpm, while for 12.5 lpm and 15 lpm can only produce total of 40 cookies. However, the cookies made by higher frequency is much more attractive. In terms of the cookies mass and size, the one produced by higher frequency is much more acceptable. The time required for the one-row to complete one cycle is higher compared to the two-rows program.

4.4 pH level measurement

The situations are by measuring the water in tank after every usage. Measurement for water in tank that applied filter on the machine need to be conducted for long period of time. The data obtain are on weekly period from 29th of January until 27th of April for a total of 12 weeks. The water is tested three 3 times per week and taken before and after machine usage. Table 4.6 and Figure 4.11 shows the result obtained for pH measurement and graph for pH against time respectively. As a reference pure untreated water has a pH reading of 7.66.

Referring to the Figure 4.11, we can observe that at the start of the experiment the pH measurement is high, this is due to the build-up of calcium carbonate or scale deficit inside the system. Calcium carbonate ($CaCO_3$) pH level is 9.91 which increase the pH of the water. For the difference on before and after operating the machine, water temperature could also affect the pH level, the lower the temperature the higher the pH. After operating the machine, friction and heat are supplied to the water through increase on pressure which also increase the temperature. Higher temperature means that decrease for the pH level. The food processor has been unused for about 3 weeks before this experiment. Because of the food processor having an exposed reservoir. This can also be seen even if the food processor is left for 2 days. Next is that the pH reading after the experiment is lower than before, this is due to the present of a filter. this indicates that the filter is working perfectly

The graph from Figure 4.11 shows that from week 2 until week 5 the pH readings stabilize within 7.8 before operation and 7.82 for after operation. Next the pH readings for both before and after operation fluttered from week 6 until week 10 ranging from 7.83 and 7.82 to 7.86 and 7.85 respectively. After that the readings increased steadily until week 12 for after operation from 7.85 to 7.9. For before operation, the pH readings increase slightly until week 12 from 7.86 to 7.89. Lastly, we can see that the readings after operation exceeds before, this indicates scale deficit inside the system especially the filter which contributed to the increase in pH. This also has been proven by the decreasing in difference between before and after operations pH readings.

From this we can observed that the pH readings are becoming higher thus making the water more alkali. The formation of scale can be observed on Figure 4.12. However, we have also observed that rust did not affect the pH reading.

Table 4.6: pH readings for 12 weeks

Week	Date	Reading before (pH)	Reading after (pH)
1	29/01/2018	7.93	7.82
	31/01/2018	7.83	7.80
	02/01/2018	7.82	7.81
2	06/02/2018	7.81	7.80
	07/02/2018	7.81	7.80
	09/02/2018	7.83	7.81
3	12/02/2018	7.84	7.80
	13/02/2018	7.80	7.80
	16/02/2018	7.83	7.81
4	20/02/2018	7.85	7.80
	21/02/2018	7.80	7.80
	23/02/2018	7.81	7.80
5	26/02/2018	7.82	7.80
	28/02/2018	7.81	7.81
	03/03/2018	7.83	7.80
6	13/03/2018	7.81	7.80
	15/03/2018	7.79	7.80
	16/03/2018	7.84	7.81
7	19/03/2018	7.84	7.82
	21/03/2018	7.85	7.82
	23/03/2018	7.84	7.81
8	26/03/2018	7.83	7.82
	28/03/2018	7.83	7.82
	29/03/2018	7.84	7.82
9	04/04/2018	7.87	7.85
	05/04/2018	7.85	7.85
	06/04/2018	7.86	7.85
10	09/04/2018	7.86	7.85
	11/04/2018	7.85	7.85
	13/04/2018	7.86	7.86
11	17/04/2018	7.87	7.86
	18/04/2018	7.87	7.86
	20/04/2018	7.86	7.89
12	23/04/2018	7.89	7.90
	25/04/2018	7.89	7.90
	27/04/2018	7.90	7.90

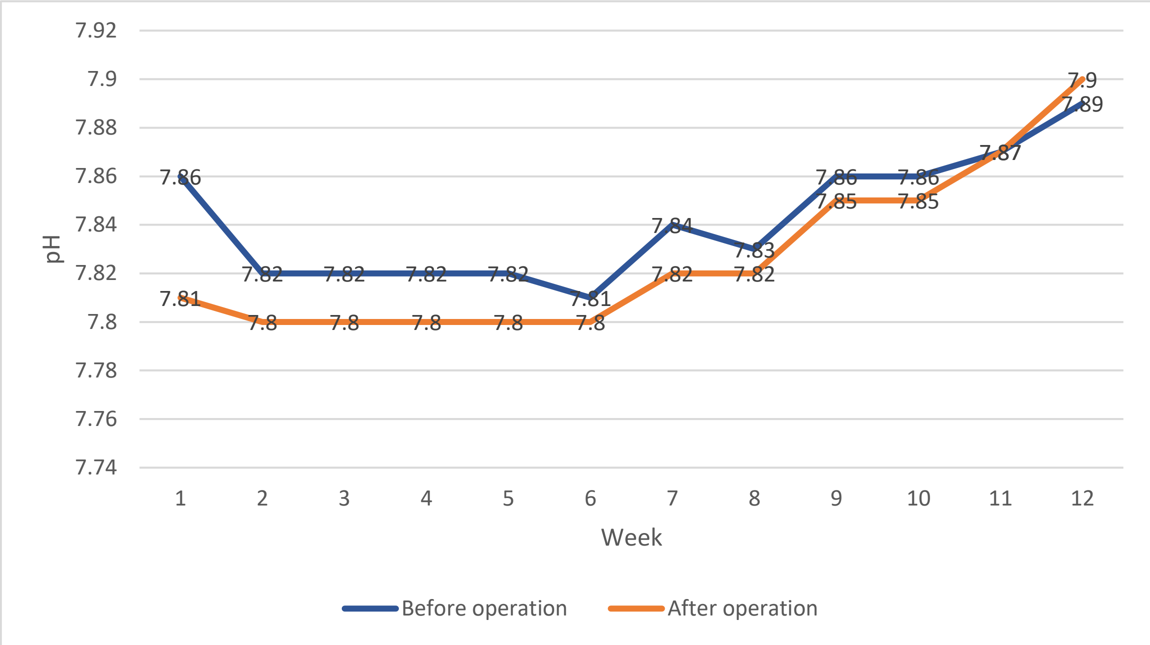


Figure 4.11: Graph for pH readings of water against time (weeks)

Figure 4.12: Scale formation inside the tank

4.5 TDS sampling and testing for rust

This is one of the method to measure the amount of rust or iron dissolved in water. By knowing the specific content of iron in water we can analyse the corrosion level in the system. In this project, rust is a major factor in causing the food processing unit to breakdown and is also one of major hygiene factor. In order to test it, sample of water for each time we used the food processor is taken and each water sample is then tested with a TDS tester or meter. We then compared the result with pure water result from that we can determine the iron level. The method used to monitor parts per million level is similar to pH readings method, that is within the span of 12 weeks the water is sampled three days per week. Table 4.6 shows the result for TDS readings. For reference purposes pure water has a ppm reading of 66ppm.

Based on Table 4.6 and Figure 4.13, we can witness that the overall trend for the TDS reading is slightly increasing. There is also difference in before and after operation readings however the difference is lessening after week 6. Regarding to that, we have observed that the TDS readings before always leads the readings for after operation. First, for before operation readings we can witness that from week 2 until week 5 the value for ppm is increase significantly from 119.3ppm to 161ppm. Next the value for ppm increase moderately from week 6 until week 12 from 162ppm to 191.7ppm.

For after operation readings the ppm value starts lower than before operation at 118ppm. Next the value increased slightly to 119.3ppm on week 2. After that, the ppm value increase greatly from week 3 until week 5 increasing from 125.3ppm to 154.3ppm. Next the ppm value increase slowly from 160.3ppm to 191.7ppm in the span of 7 weeks from week 6 until week 12.

We can also observe that the difference between before and after is decreasing after week 5. From the average of 5.27ppm to almost zero difference, from this we can conclude that the filter is unable to filters any minerals or solid contents inside the system

Table 4.7: TDS reading for 5 weeks

Week	Day	Reading before (ppm)	Reading after
1	29/01/2018	121	118
	31/01/2018	118	118
	02/01/2018	120	118
2	06/02/2018	119	119
	07/02/2018	119	119
	09/02/2018	121	120
3	12/02/2018	129	124
	13/02/2018	130	124
	16/02/2018	136	128
4	20/02/2018	146	141
	21/02/2018	146	146
	23/02/2018	150	147
5	26/02/2018	156	150
	28/02/2018	159	154
	03/03/2018	168	159
6	13/03/2018	160	160
	15/03/2018	165	161
	16/03/2018	161	160
7	19/03/2018	166	165
	21/03/2018	167	166
	23/03/2018	167	167
8	26/03/2018	170	169
	28/03/2018	171	170
	29/03/2018	172	171
9	04/04/2018	173	171
	05/04/2018	173	172
	06/04/2018	175	174
10	09/04/2018	179	178
	11/04/2018	180	179
	13/04/2018	183	181
11	17/04/2018	187	185
	18/04/2018	188	187
	20/04/2018	190	187
12	23/04/2018	191	191
	25/04/2018	193	192
	27/04/2018	194	192

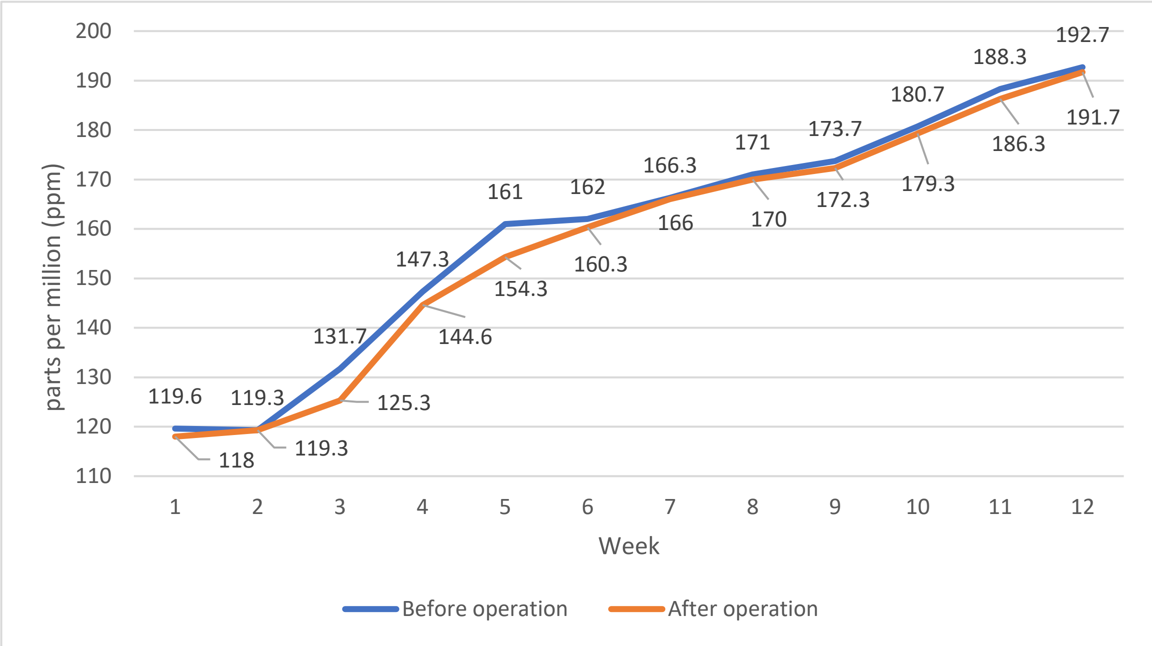


Figure 4.13: Graph of parts per million readings (ppm) against time (week)

4.6 Problem occurs

It is obvious that some problem will occurs and most of it is caused by rust and scale formation. The problems that we have observed are; The directional control valve (DCV) have been compromised, leakage from pump, corrosion on the 90° elbow joint used for water outlet from system to reservoir.

4.6.1 Compromised DCV

The DCV that we have been used is OMAX 4/3 ways solenoid operated DCV. This valve used ‘wet solenoid’ which means that the solenoid is part of the channel and working fluid is contacting the solenoid. From Figure 4.14a and Figure 4.14b we can observe that the magnet which pushes the activating rod for the sliding spool have several scale and oxidation marks. The rod itself need to be cleaned. Next the sliding spool also has been contaminated with rust and scale. The sliding spool movement has been compromised and in need of maintenance. This happened for both DCV.

Figure 4.14a: Magnet contact for wet solenoid and the sliding spool rod (top view)

Figure 4.14b: Magnet contact for wet solenoid and the sliding spool rod (top view)

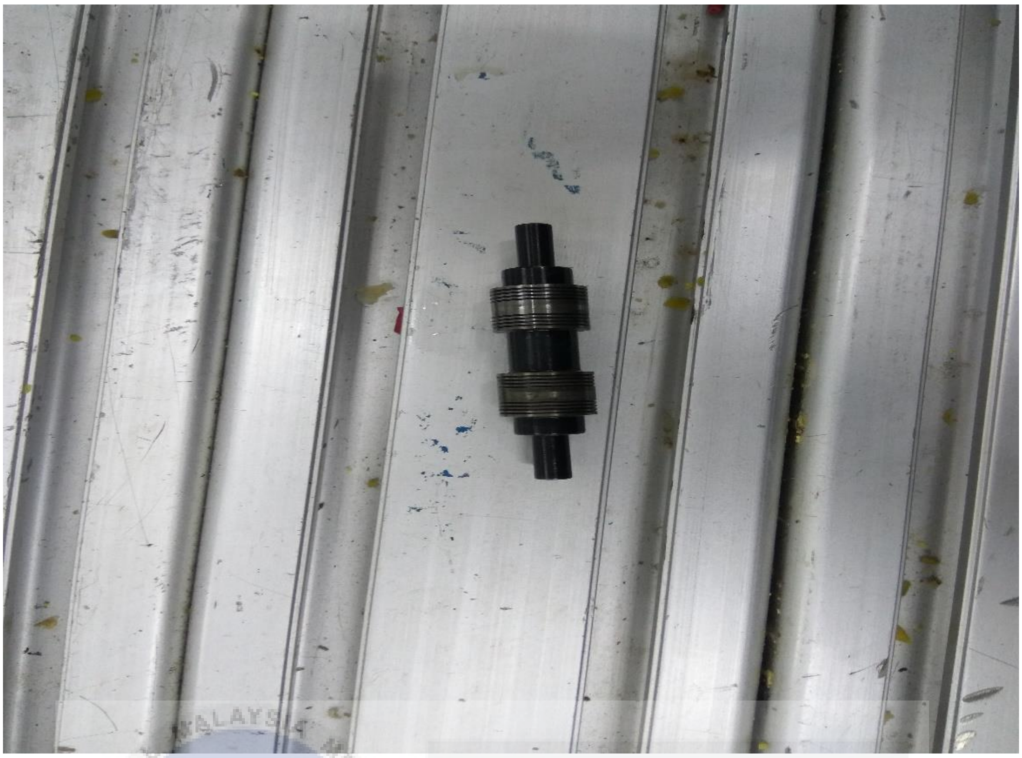


Figure 4.15: Sliding spool for the FCV

4.6.2 Pump leakage

On the end of week 11, some leakage problem has appeared on the piston pump. The operating pressure for the machine is 2bar but when the pressure exceeds 3bar the one of the three piston chamber for the pump have water leaking from it. Because of time and knowledge constraint we are unable to further investigate the matter. Furthermore, the system performance is acceptable with the pressure limit set to 3bar only.

Figure 4.15 and 4.16 shows the leakage and the operating pressure when the leakage is happening respectively.

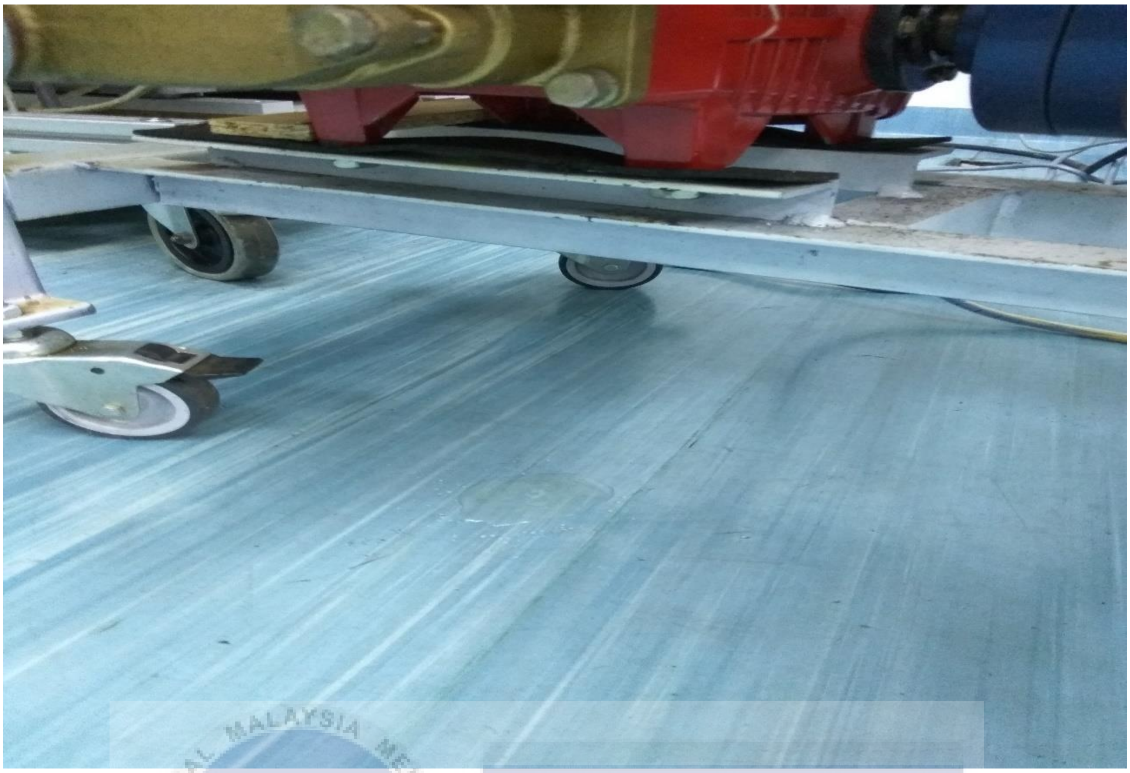


Figure 4.16: Puddle formed from the leakage

Figure 4.17: Pressure gauge showing 5bar operating pressure

4.6.3 Corrosion on 90° elbow joint used for water outlet from system to reservoir

Because of the exposed container and exposed outlet for the elbow joint, the elbow joint is where rust will likely occur. The elbow joint act as a return pipe from the system to the reservoir which is placed at the top of the reservoir. From Figure 4.17, rust is observed on both ends of the elbow joint.

Figure 4.18: The inside of the elbow joint

Table 4.8: Summary for problems detected

Parts	Problem detected	Cause
1. Batch cylinder	-	-
2. Extrusion cylinder	-	-
3. Flow Control Valve	Jammed (Figure 4.14a, 4.14b, and 4.15)	Solid and scale built up detected inside the valve channel thus blocking the movement of the sliding spool
4. 90° elbow join	Rust and scale detected which contaminates the water and blocks the flow to the reservoir (figure 4.18)	i. Inside of the join is exposed to air which leads to rust ii. Scale deficit caused by the hardness of water
5. Reservoir	Scale, dirt and debris detected (Figure 4.12)	i. The open and exposed nature of the reservoir ii. Filter is no longer usable
6. Filters	Increase in TDS level and the condition of reservoir (dirty)	i. Not enough filter ii. Filter requires proper maintenance
7. Pump	Leaking in one of the piston chamber	The seal for the pump has been degrade due to age.

4.7 Results for cookies production

For the visual test, we have 2 results and that is; for one row operation and two row operations. We need to check if the cookies have acceptable size and shape based of the Malaysian traditional cookies that is 'Kuih Semperit Dahlia'. Furthermore, for two-row operation the available conveyor belt could not support it thus it is arranged manually on the tray. Figure 4.19 shows the visual result using two row operations.

Next, for the one-row operation the available conveyor belt is able to support it. With the use of the conveyor belt the system is then fully automated. The shape and size of the cookies is about the same because same operating flow and pressure but the one-row operation produce much more consistent shape. Figure 4.19 shows the cookies shape and sizes using one-row operation.

Figure 4.19: Picture of a sample 'Kuih Semperit Dahlia' made by the water hydraulic food processor (two-row operation)

Figure 4.20: Picture of a sample 'Kuih Semperit Dahlia' made by the water hydraulic food processor (one-row operation)

The obvious difference between using the PLC and electrohydraulic circuit (hardwire) is the difficulty level of problem troubleshooting. With electrohydraulic circuit board, it takes considerable time to retrace the wire connection. Furthermore, the only way to detects it is by testing the relays, timers, and counters individually. With PLC, all of the relays, timers, and counters exist inside the PLC and there is indicator for each part. This reduce time to troubleshoots significantly. Next, PLC is also known for robust build which can last longer than electro circuit board. Using PLC requires high initial cost but reduce the maintenance and variable costs which in return gives higher return of investment than electrohydraulic circuit board. But using PLC requires practical skills such as coding and wiring.

CHAPTER 5

DISCUSSION AND ANALYSIS

5.1 PH and TDS level

One of this project's objective is to monitor the pH and ppm level. Using these two parameters, we can obtain the performance and the cleanliness of the water. First the value for pH and ppm are taken before and after the operation to determine if the filter is working properly or not. The filter is installed to ensure the water stays clean and within the optimum range of pH and ppm levels. However, in this experiment we can conclude that the filter has been compromised or the lifespan is over. This is because throughout the 12 weeks, the pH and ppm measurement should be decreasing after the machine is in operation, but we discover that after 5 weeks the filter is deteriorating and the difference between the readings before and after decrease.

For pH, external factor such as temperature affected the difference between before and after operation readings. While for TDS readings the decreasing in difference between before and after operation is because of the decrease in filter performance. Due to scale formation occurs inside the system tank, the scale and impurities would be able to enters the system which would hinder the mechanical movement inside the system such as DCV.

5.2 Controller performance

On this experiment, we have established two sets of PLC program; one-row operation and two-row operation. We have also added a conveyor belt to fully automated the system. We have also observed that there is difference in both quantity and time to complete all the cycles for both system.

For the one-row operation, it will produce less total number of cookies but requires less time to complete all the cycles compared to two-row operation. For 15 lpm, the machine able to produce 0.8 cookies per second. For the two-row operation, for the same flow it will produce 0.6 cookies per second. From this we can see the general difference between the two systems.

5.3 Parts compromised by corrosion and scale

With the presence of rust and scale inside the water, some of the parts is compromised and thus reducing the system performance. One of the parts that has been compromised is the DCV which controls the movement of the hydraulic cylinder. The moving parts of the DCV that is the sliding pool has been contaminated by scale and fragments or debris. The dimension of the sliding pool is matched with the dimension or size of the valve channels. Even tiny bits of debris and scale would cause the valve to break down. The valve is operational again after maintenance work.

Next, the part which also been affected by rust is the 90° elbow joint. The inside of the joint is filled with rust and scale formation. The major cause of this is that the joint is exposed to surrounding air. Because the joint act as a return pipe from the system to the pump, the rust from the joint also contaminated the tank forming a rust debris. This reduce the system performance and lifespan.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Introduction

On this Chapter 6, it will explain thorough about this study. It is also will conclude all the result obtained from the approach used to meet the objective.

6.2 Conclusion

From this project, it can be concluded that the system performance has been improved by using one-row PLC program compared to two-row PLC program. The pH and ppm measurement indicate that the system needs total flushing and cleaning because rust has affected the system. The system also requires routine maintenance to prolong its lifespan. The system is still fully operational after the DCV have been maintained.

6.3 Future recommendation

According to the issues that occur during the development process, there are several recommendations to improve for a better trainer on future as listed:

6.3.1 Using treated water

The water that has been used in this experiment is untreated tap water which contains minerals. To avoid scale formation treated pure water which contains zero minerals should be use.

6.3.2 Flushing the system with chemicals

To eliminate rust and scale formation inside the system. Cleaning the system before changing the working fluid is important so that the new working fluid is not contaminated.

6.3.3 Filter

The filter that this experiment use has been used for the past three years without changing and maintenance. Hence proper cleaning of the filter is needed. The filter that this machine use also needs to be revise again to ensure the filtering performance met.

6.3.4 Adding new base for conveyor

The existing base for the cookies production machine is to small and low for the conveyor belt. The base needs to be redesign with the conveyor belt in mind.

6.3.5 Changing the reservoir to a closed reservoir

The existing reservoir is an open reservoir which can easily be contaminated with dust and debris. Not only that, exposed reservoir would increase the evaporation rate of water and thus requires refilling water to the reservoir.

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APPENDIX A (STANDARD OPERATION PROCEDURE FOR PLC)

1. Start New Project

1. Open CLICK Programming Software
    - Start → All Programs → Local →AutomationDirect →Click_Programming_Software
2. Select "Start a new project"

2. Write to PLC

1. Write Project

- PLC → Write Project into PLC
- Click "OK" to begin read/write program
    - If PLC is in RUN Mode, click "YES" to change to STOP Mode
- Click "OK" to acknowledge transfer complete
- Click "OK" to set PLC mode to RUN

2. Connect to PLC (Only if Write Project fails)

    - PLC → Connect
    - Verify settings
        - PC COM Port No.: COM6
        - Baud Rate: 38400
        - Address: 1
        - Parity Bit: Odd
        - Stop Bit: 1
    - Click "OK" to connect to PLC

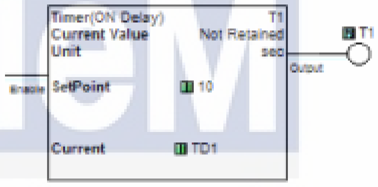
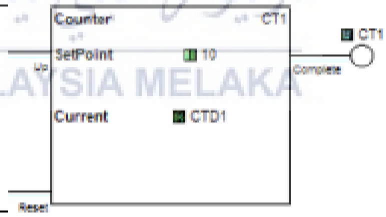
3. Address Naming Convention

Each element has an independent name. The following address naming convention is used by the CLICK Software.

- X001-X008: Input
- Y001-Y006: Output
- C1-C2000: Coil
- T1-T500: Timer
- CT1-CT250: Counter

4. Ladder Logic Elements

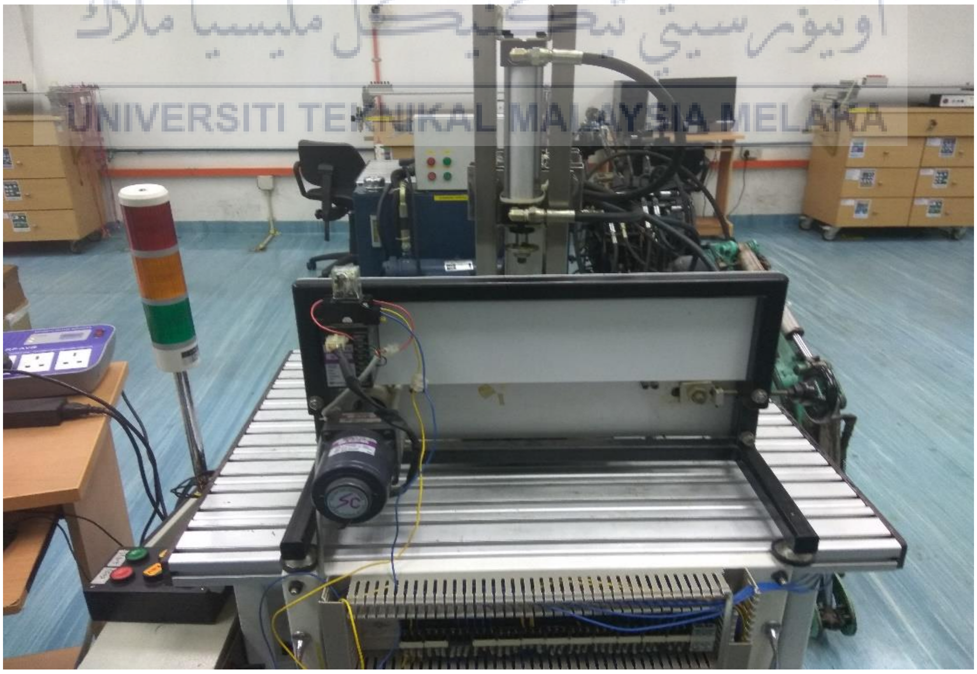
The following standard ladder logic elements are available in the CLICK Software.

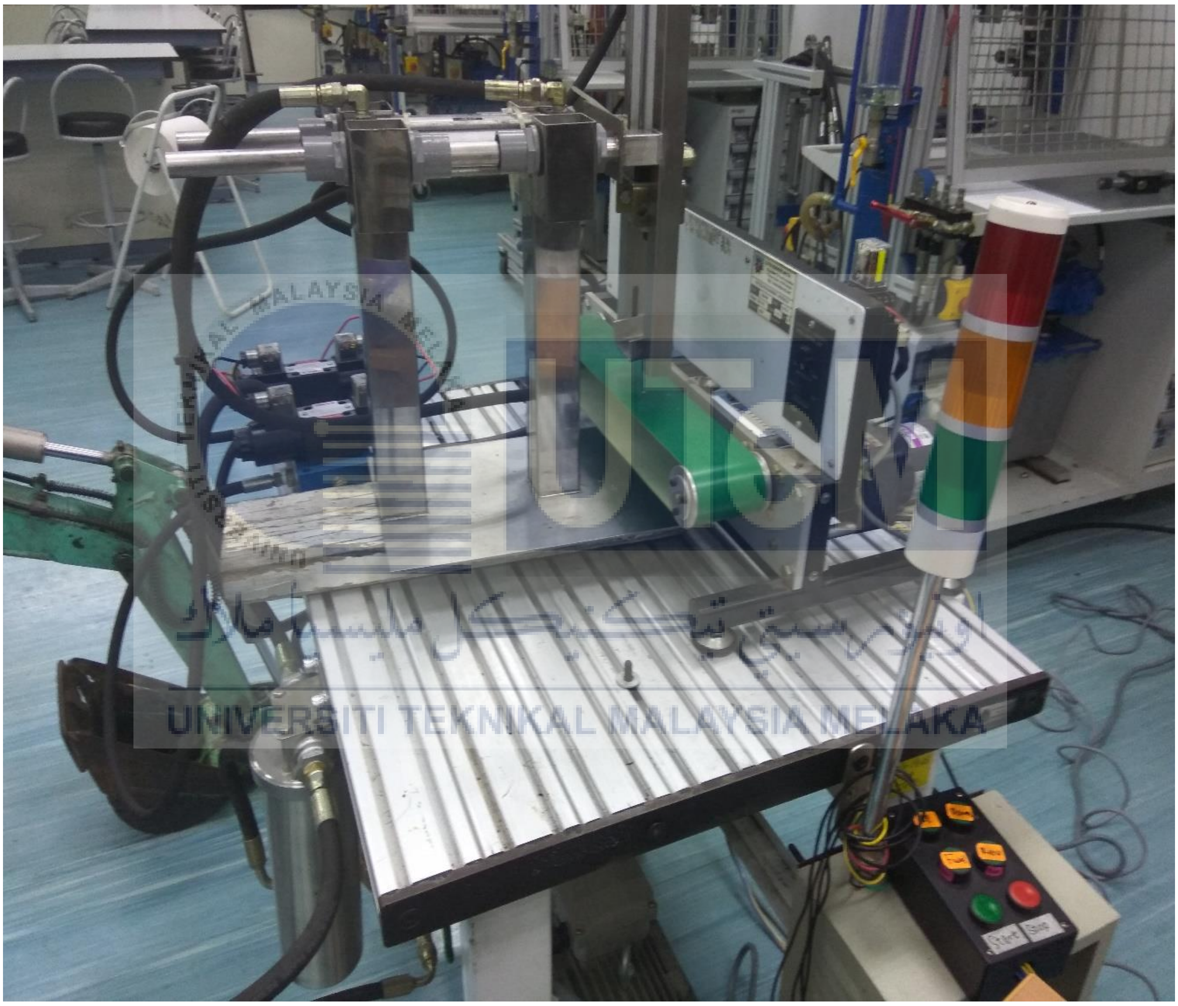
Element	*Description*	*Ladder Logic Representation*
Normally Open Contact Contact (NO)	*Is ON when the defined address (eg. X001, Y001, C1, or T1) is ON*	
Normally Closed Contact Contact (NC)	*Is ON when the defined address (eg. X001, Y001, C1, or T1) is OFF*	
Out Coil Out	*Turns ON/OFF a given address (eg. Y001 or C1) when the rung is true/false.*	
Timer Timer	*When enabled, measures the elapsed time. Turns on output address once it reaches the set point.*	
Counter Counter	*When enabled, counts up or down until it reaches the set point*	
End Instruction End	*Marks the termination point of a program*	

APPENDIX B (MACHINE SETUP)

1. Food processing machine with PLC installed.

2. Food processing machine with PLC and Conveyor Belt installed.





APPENDIX C (Kuih Semperit Dahlia recipe)

1. 250g of buttermilk at room temperature
2. 250g of fine granulated sugar
3. 2 pieces of egg yolk
4. 500g corn flour
5. 200g custard flour
6. 1 teaspoon of vanilla essence
7. Thinly sliced cherry for topping