PID IMPLEMENTATION OF UMP MINI AUTOMATION PLANT
PART 1 - HEATING TANK

LEE MING JIE

UNIVERSITY MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS♦

IMPLEMENTATION OF AC MOTOR CONTROL USING PID CONTROLLER IN PLC

SESI PENGAJIAN: **2010/2011**

Saya **LEE MING JIE (890206-14-5799)**
(HURUF BESAR)

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40150 SHAH ALAM,
SELANGOR

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Date : 29 NOVEMBER 2010

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LEE MING JIE

This thesis is submitted as partial fulfillment of the requirements for the award of the Bachelor of Electrical Engineering (Hons.) (Electronics)

Faculty of Electrical & Electronics Engineering
University Malaysia Pahang

NOVEMBER 2010

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To my beloved father and mother

ACKNOWLEDGEMENT

Foremost, I would like to express my sincere gratitude to my supervisor Mr. Reza Ezuan bin Samin for the continuous support, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my bachelor degree study.

Besides my supervisor, I would like to thank Mr. Helmie Razif Abdul Halim for giving me advise in software development and all UMP FKEE lab assistants for their encouragement, insightful comments, and willingness to help me in UMP mini plant troubleshooting.

I thank my partner Sufri for hardware troubleshooting and modification we done together, simulation discussions, for the sleepless night we were working together before deadlines. And for all the fun we had in the last three and a half years, I thank all my fellow friends and course mates.

Last but not least, I would like to thank my parents for giving birth to me at the first place and always supporting me from behind throughout my life

ABSTRACT

A temperature control unit is a special I/O units that receive inputs directly from thermocouple, perform PID control with 2 degree of freedom and output results through open collector outputs. Temperature control is very difficult to be implemented by using ordinary control techniques, hence the purpose of this research is to describe the implementation of PID controller design based on programmable logic controller (PLC) in order to control the time to heat up a particular solution to a desired temperature. The PLC OMRON CJIM-CPU12 and the temperature control unit CJ1W-TC001 is 2 vital parts in this research. UMP mini automation plant involved in this project is initially malfunction, so reverting it back to its original functional state is set to main priority and followed by detail PID analysis of heating tank (tank 2) of UMP mini automation plant.

ABSTRAK

Unit pengawal suhu ialah I/O unit khas yang menerima input secara langsung daripada thermocouple, melaksanakan PID *control* dengan *2 degree of freedom*, dan keputusan dihantar melalui *open collector outputs*. Pengawalan suhu adalah sangat susah untuk dilaksanakan dengan pengawalan biasa, tujuan penyelidikan ialah untuk menghuraikan implimentasi PID *controller* berdasarkan *programmable logic controller* (PLC) untuk mengawal masa yang diperlukan untuk memanaskan sesuatu larutan ke suhu yang dikehendaki. PLC OMRON CJIM-CPU12 dan Unit pengawal suhu CJ1W-TC001 ialah 2 bahagian yang paling penting dalam penyelidikan ini. Disebebkan *UMP mini automation plant* adalah dalam keadaan tidak berfungsi, tumpuan utama telah disetkan untuk membaiki mini plant dan seterusnya PID analisis dibuat terhadap *heating tank (tank 2) UMP mini automation plant.*

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LIST OF ABBREVIATIONS

PLC	Programmable Logic Controller
P	Proportional Controller
PI	Proportional-Integral Controller
PID	Proportional-Integral-Derivative Controller
SP	Set Point
MV	Manipulated Variable
PV	Process Variable
TCU	Temperature Control Unit
CPU	Central Processing Unit (Computer)

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

This chapter explains the overview of this project, giving readers a general idea of what this project concept are about. Chapter starts with explanation of PID concept, followed by component introduction where PID are implemented. Problem statement, objective and project scopes are clarified next, subsequently some examples are given as application of project.

1.1 Concept Background

The proportional-integral-derivative (PID) controllers are broadly used in many industrial control systems for several decades since Ziegler and Nichols proposed the first PID tuning method. This is because the PID controller structure is simple and its principle is easier to understand than most other advanced controllers [1].

On the other hand, the general performance of PID controller is satisfactory in many applications. For these reasons, the majority of the controllers used in industry are of PI/PID type. PID controllers are widely used for process control applications requiring very precise and accurate control. Unlike on/off controls, the smooth and steady state control is achievable using these controllers. Various models are available featuring single loop with universal input, two to eight loops with eight independent inputs and sixteen control outputs.

1.1.1 Project Introduction

The purpose of a temperature controller unit is to heat up a particular solution to a desire temperature with the minimum overshoot and quickest time constant, in other word the optimum result. Heater comes in a variety of size and power consumption, basically the higher the power consumption the faster the heating process will be. The system operates in a closed loop system to ensure the desired temperature will be obtained in fastest time and accurately.

PID Controller in this study requires the knowledge of tuning the constants to find the best value. The theory show that the control with Proportional-Integral-Derivative Controller (PID) can improve in terms of percentage overshoot and time constant.

This project development include implementing PID controller with Programmable Logic Controller (PLC) ladder diagram programming to control the heater. UMP mini automation plant involved in this project is initially malfunction, so reverting it back to its original functional state is set to main priority in this project and followed by detail PID analysis of heating tank (tank 2) of UMP mini automation plant.

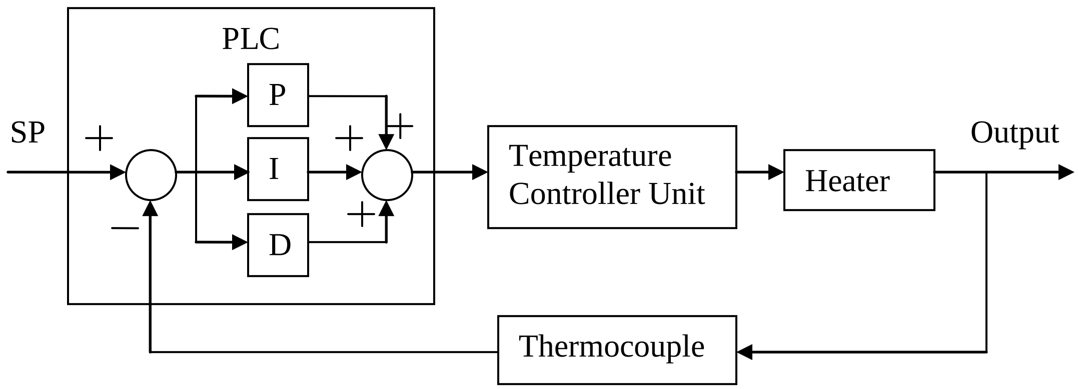

Figure 1.1: Project overview

Figure 1.1 is the block diagram of this project, showing how PLC, PID, TCU, heater and sensor are related to each other to form a closed loop system. Further explanation regarding PID controller and tuning is available in chapter 2 along with detail information about PLC and TCU used.

1.1.1 Problem Statements

Plant mechanism are easily damage without implementation of any controller methodology in the system so a closed loop system is used to overcome this. Besides, human supervisory is also ineffective to be applied in gigantic industries. Thus, control system is applied to the industries to replace the supervisory position's responsibility.

Furthermore a closed loop system able to predict and make correction to current process so that output will remain in a range and not differ too much. Comparing to manual operation or an open loop system, closed loop system is far more superior due to its ability to detect, predict and give feedback to the system when needed. Closed loop system able to improve few things that are always concerned in these kind of process time constant and overshoot for example.

In industries workers often need work under hazard condition, by implementing PLC this problem can be solved partially. Because not only it act as a monitor but a controller, as it able to connect to all kinds of hardware. Recent technology improved to a new level of wireless connection using Bluetooth device or wireless wavelength, enabling user to monitor and control PLC at PC distance away from PLC.

1.2 Objectives

The objectives of this project is to ensure the mini plant able to run again at the end of this project and to implement PID at the heating tank, analyze and obtain the best tuning constant to allow the mini plant work in the optimum condition. Finally to add few new features to existing PLC and touch screen program.

1.3 Project Scopes

This research is to implement PID controller in heating tank, ladder diagram will be modify to improve process and allow more option to make simulation easier. Simulation will be made by using different PID constant and the analysis will show the efficiency and performance of different tuning constant at system:-

i. Maintenance and repairing mini plant.
ii. Studies of Touch screen programming consist of Project Manager.
iii. Studies of PLC Programming consist of CX-Programmer (V 6.1)
iv. Design to improve PLC ladder diagram programming and PID Controller implementation at the heating tank.

1.4 Project Applications

UMP mini plant is designed based on automated drink manufacturing plant, the stations and components it installed with is almost identical with the actual ones from food processing industry starting from bottle supply station to rejecting station and packaging station.

As mentioned above, UMP mini plant is not only a dummy but actually a functional system, it is very suitable to act as teaching material and exclusively great introduction to student that lack of real life interaction with hardware, machinery and their applications.

1.5 Thesis Outline

Chapter 1 Introduction, put main concept and project overview into the picture. Followed by clarifying problem statement, objective and project scope to make sure works done are always right on track. Lastly, some project application that able to make use of this project was suggested.

Chapter 2 is about Literature Review, which it goes into detail on PLC, TCU, touch screen, PID controller and each of its component. Related books, journals and articles are used as references as guide to aid finishing this project.

Chapter 3 Methodology, describe the process to accomplish this project in flow chat and explanation are available for each phase, also related software used are introduced here generally on what it capable to do.

Chapter 4 is Result and Discussion, of which all work done are presented in words, tables, and graphs, finally best tuning constant are clarified and statement according to graph and discussion are made.. In addition, limitation to this project is stated here, this part is also important as a reminder and guide for future references.

Chapter 5 is Conclusion and Recommendation which conclude the development of project. Recommendation is included to encourage more improvement made to UMP mini plant.

CHAPTER 2

LITERATURE REVIEWS

This chapter is the summary of all related study material and components required in this research. All ideas and concepts yield are to be implemented on the research. This Chapter reviews PID controller, PLC, Temperature Control Unit and Touch Screen.

2.1 PID Controller

Conventional proportional-integral-derivative (PID) controller are widely used in industry process control ,due to its simplicity in structure and ease of implementation [1]. Although the control theory and method has got great progress, PID controllers are still common and well known.

Statistic of metallurgical industry, chemical industry and food industry etc. show that 97% of the controllers select PID structure [2]. An important objective of control system design is to minimize the effects of external disturbances. The problem if disturbance rejection arises in many industrial fields, such as motion-control, active noise control and vibration control [8].

Generally a PID controller is a control loop feedback mechanism widely used in industrial control system sector. In practice the dynamics of the rise and decay of the plant output parameter $Y_a(t)$ can be different. The plants with this feature are called Plants with the asymmetric dynamics [3] or asymmetrical processes [4,5]. Often they are found in water supply and heating control systems. The parameters of such a plant transfer function or even the transfer function itself changes when the sign of the Y(t) time derivative d Y(t)/dt changes. In fact such kinds of plants are plants with switched parameters do not allow us to achieve good behavior of the control systems [3].

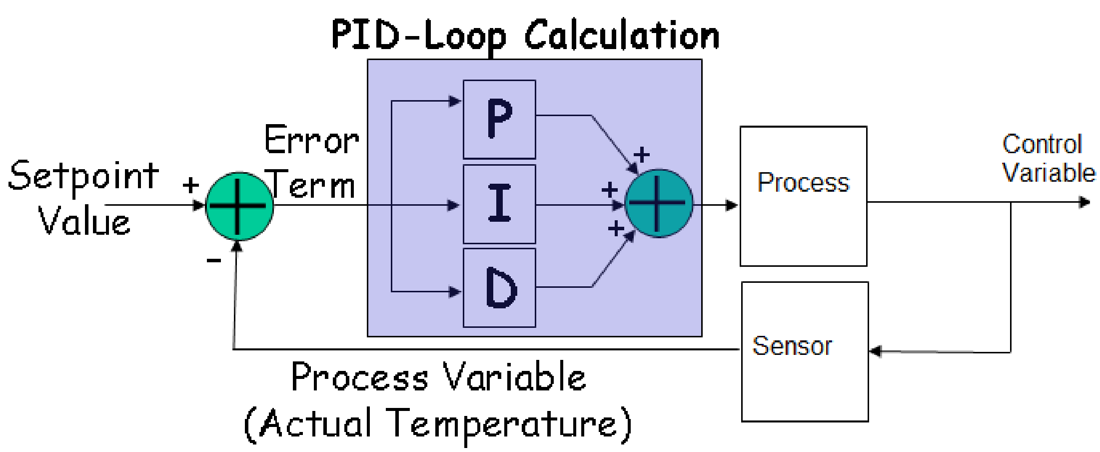

Figure 2.1: PID loop

PID measure the differences between the desire value and the actual value, by using the error calculated, it attempt to minimize it by adjusting the control input to obtain the desire output value. By tuning the 3 parameters in PID, the controller can provide specific control action designed for different requirements. In the field of metallurgy, chemistry, food industry and oil refining due to the time delay and process parameter uncertainty, the parameter of PID controller need automatic adjustment [6].

2.1.1 Proportional Control

The proportional value determines the reaction to the current error, the proportionality constant (KP) is known as the proportional gain of the controller. to get a higher performance output, the gain must be increase but it is well known that the controller with too large gain should be avoided because it will cause instability [7]; while a low proportional gain will result small output response and a less sensitive controller.

2.1.2 Integral Control

The integral value determines the reaction based on the sum of recent errors, by adding instantaneous error over time gives the accumulated offset that should have been corrected previously [8,9]. The integral gain eliminates the residual steady-state error that occurs with a proportional only controller, however it can cause the present value to overshoot the set point value, since the integral term is responding to accumulated errors from the past.

2.1.3 Derivative Control

The derivative value determines the reaction based on the rate at which the error has been changing. Adding a derivative term can improve the stability, reduce the overshoot that rises when proportional or high gain integral terms are used, and improve response speed by predicting changes in the error [10]. However, differentiation of a signal amplifies noise and thus this term in the controller is highly sensitive to noise in the error term.

3 most common used controller were the P controller, PI controller and PID controller. A P controller able to reduce the rise time, but never eliminate the steady state error. A PI controller will eliminate the steady state error, but it also may make the transient response worse. A PID controller will increase the system stability, reduce the overshoot, and improve the transient response.

2.2 Programmable Logic Controller (PLC)

2.2.1 Background

Before the introduction of PLC, there have been many sequence control device, including those using camshafts and drums, when electromagnetic appeared, relay control panel become the mainstay of sequence control. When transistor appeared, they were also applied in fields where electromagnetic relay are inadequate, such as high-speed control response. In modern manufacturing, the PLC is well adopted to a range of automation task [11], control field is expending to include the complete factory and total control system combined with feedback control , data processing and centralized monitoring systems.

A PLC is an Industrial Computers with specially designed architecture in both their central units (the PLC itself) and their interfacing circuitry to field devices (input / output connections to the real world). It's widely used in automation of industrial processes, such as control of machinery on plant.

Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, and it's immunity to hazard condition such as extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed or non-volatile memory. A PLC is a real time system since output results must be produced in response to input conditions within a bounded time, otherwise unintended operation will result.

2.2.2 CJ1M

The CJ1M is the extension of CJ1 Series to meet the reduced requirements of more compact machine designs: greater functionality, less memory and built-in I/O. The CJ1M provides a low-cost solution for applications with lower I/O counts and shorter programs compared to the more powerful CJ1G/H CPUs.

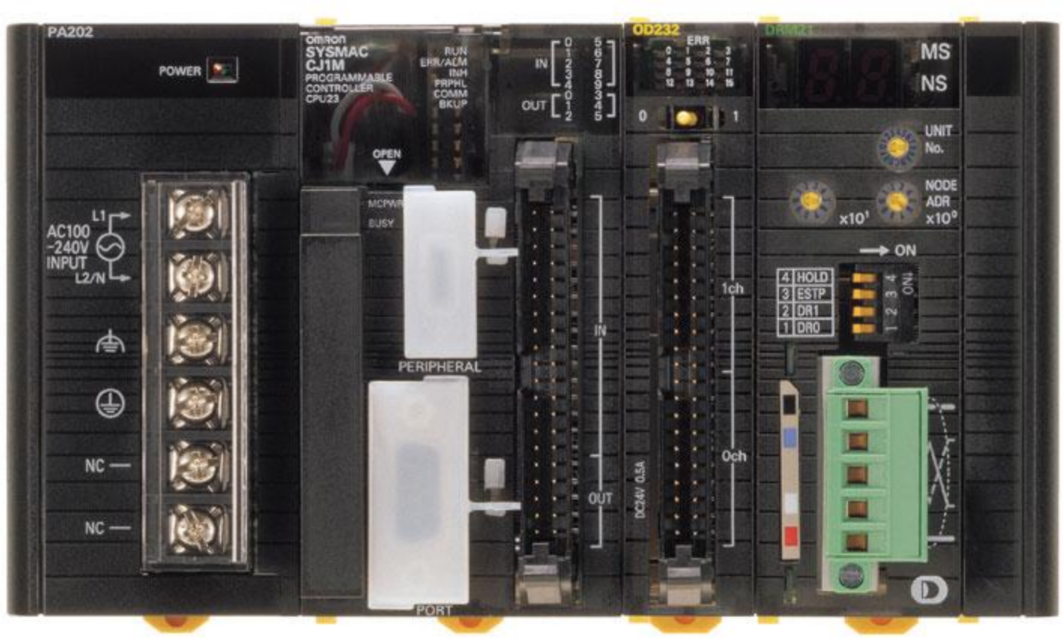

Figure 2.2: CJ1M-CPU12

All CJ1 Series use the same instruction set and I/O modules, so existing programs and equipment can be easily reused in small and large-scale installations. A common memory area and powerful serial link among nine CJ1M CPUs can help integrate processes or coordinate activities. Two of the four CJ1M CPUs offer integrated I/O with programmable functionality normally found in six separate I/O modules. In

CJ1M-CPU22/23 models, 10 inputs and 6 outputs are built in. They can operate as general-purpose DC I/O, 4 interrupt inputs, 4 pulse catch inputs, 2 high-speed counters, and pulse train outputs for 1 or 2-axis positioning.

2.3 Temperature Control Unit (TCU)

2.3.1 Background

A temperature controller unit can provides an effective method to monitor and maintain material temperature by heating or cooling during its operations. By virtue of their powerful computing engines these controllers feature high accuracy, programmability and adaptability. The temperature sensors used in these systems, however provide their outputs in current or voltage form. Therefore, a high precision analog-to-digital converter is required for interfacing the sensor with the central unit [12]. In addition some controllers required digital-to-analog converters to drive the heater according to the control algorithm.

2.3.2 CJ1W-TC001

The CJ1W-TC001 Temperature Control Unit is a Special I/O Units that receive inputs directly from thermocouple or platinum resistance thermometers, perform PID control with two degrees of freedom, and output results through open collector outputs.

Figure 2.3: CJ1W-TC001

There are two main types of Unit: One provides four control loops and the other provides two control loops with a heater burnout detection function. Each of these has one model that is compatible with thermocouples (R, S, K, J, T, B, or L) and another model that is compatible with platinum resistance thermometers (JPt100 or Pt100).

Both NPN outputs and PNP outputs are available. Auto tuning of the PID control is also possible. Detail of TCU used are as below:

i.	I/O type:		4 control loop thermocouple NPN
ii.	Operation when CPU is in program mode:		Continue
iii.	Temperature unit:		Celsius
iv.	Data Format:		16 bit binary
v.	Control operation loop 1 and 3:		Reverse heating
vi.	Control operation loop 2 and 4:		Heating
vii.	Control method:		PID control
viii.	Initialize setting in EEPROM:		Not initialize
ix.	Transfer setting in EEPROM:		Transfer
x.	Special I/O unit word allocated in:	CIO area:	CIO 2000 - CIO 2029
		DM area:	D20000 - D20199
xi.	Hardware setting:	$X10^1$:	0
		$X10^0$:	1
		Input type:	0
		Temperature setting:	Type K (-200 - 1300 Celsius)

2.4 Touch Screen

2.4.1 Background

A touch screen work based on tactile sensor application where it is a visual display screen of which it can detect the presence of a particular location being touch within the visual display area. The model of touch screen had been used is GP2500-SC41.

2.4.2 GP2500-SC41

The reason choosing this kind of model because it is provided with Compact Flash™ Port, Ethernet and dual serial ports for communications. Additional features include sound output for audio machine feedback, and larger memory (compared to GP2501S) for large or highly detailed HMI applications. Add-in powerful data collection software and web-enabled features, the GP2500S offers low cost color data collection and process monitoring HMI solution.

Figure 2.4: GP2500-SC41

Touch screen can be real-time acquisition and display the data of temperature, flow rate etc[13].In addition, design for warning purpose such as malfunction alarm, water pump, water level, bottle stuck warning etc. also displayed to ease the user from checking station by station if anything comes up.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes how this research has been done and the method used to achieve the research objectives and purpose. The overview of this researches shown here in methodology, one of the most important elements to be considered as it is the guideline to make sure that this research is right on track and on time.

3.2 Project Flowchart

There are two major parts that need to be complete at the end of the research which is the software development and real time simulation. Figure 3.1 showed the flow chart of this research and all phases involved are listed below:

Phase I : Project preview
Phase II : Troubleshooting and maintenance
Phase III : Touch screen development
Phase IV : PLC programming development
Phase V : PID simulation and auto mode test run
Phase VI : Result and analysis

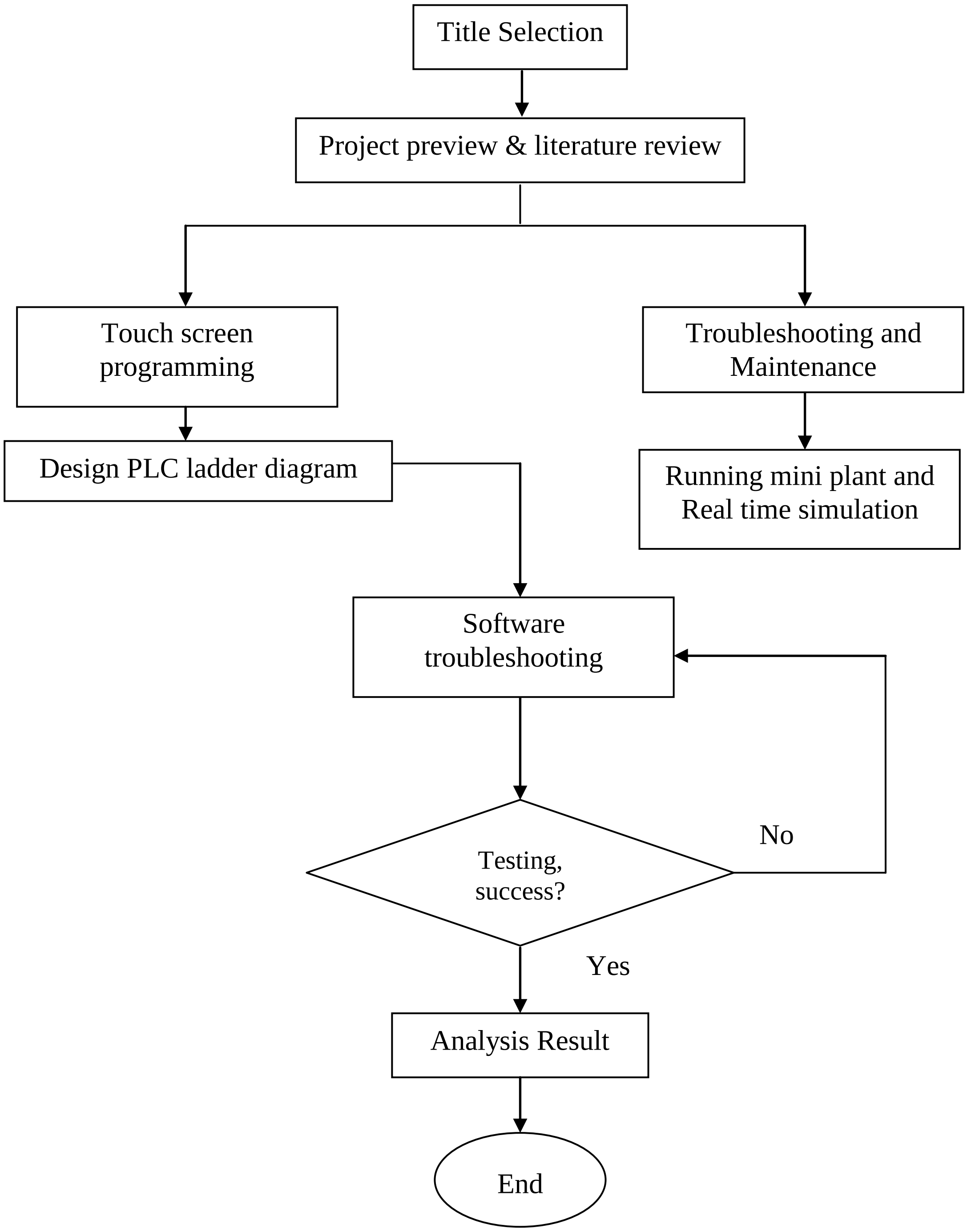

Figure 3.1: Project flow chart

3.2.1 Phase I: Project Preview

The research begins with the understanding of the title "PID implementation of UMP mini automation plant Part1 - heating tank". Based on the objectives, the purpose, problem statement and scope of project is identified. Knowledge about PID controller, Programmable Logic Control programming and touch screen programming is essential toward completion of this research. To find the right source of information in doing the literature review the following methods are used:

1. Internet surfing
2. Discussion with supervisor and lecturers
3. Related hardware Manuals

3.2.2 Phase II : Troubleshooting and Maintenance

UMP mini automation plant is deserted for years and it isn't working at all. Major troubleshooting had to be done so that the project could be continued, it is discovered later on that the host link port is damaged causing communication problem, the heater is not functioning and furthermore all 3 ultrasonic level sensor can't detect water level properly. Moreover few cables are not connected properly and 1 of them is not connected to supply as shown in Figure 3.2. Maintenance is done not long after that to replace the damaged part and make sure all other parts are functioning correctly.

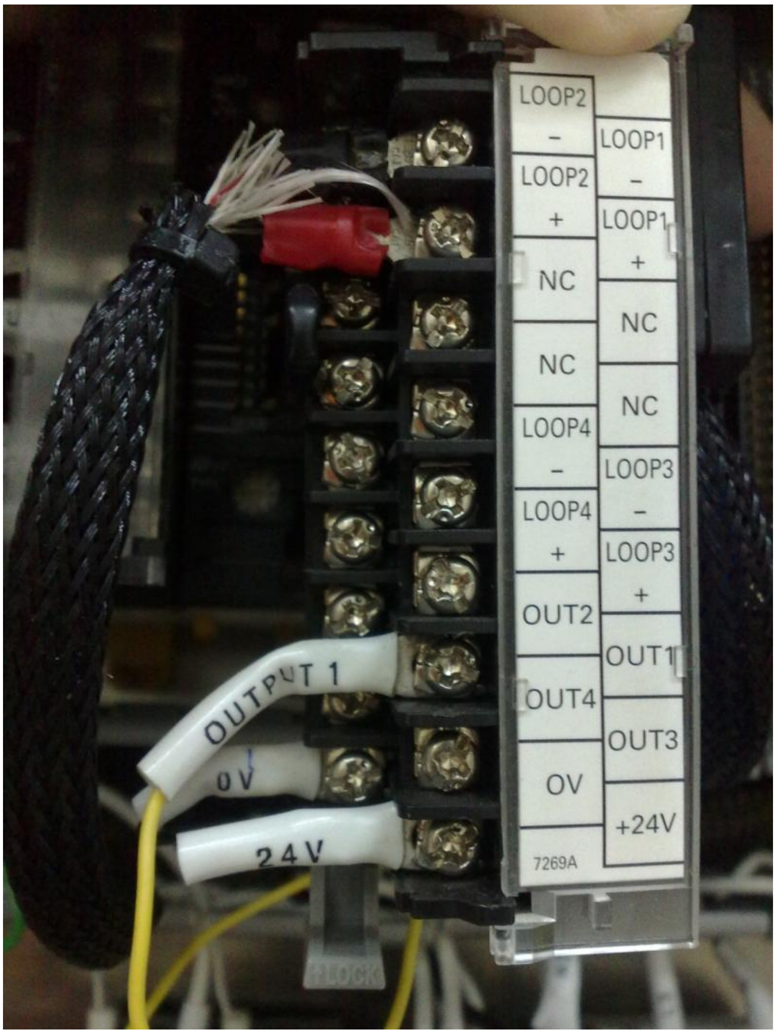

Figure 3.2: TC001 +24V not connected

At this phase due to overwhelming error at hardware and software interface. Scopes and objectives are revised, some minor part had been changed and repairing the malfunction mini plant has been considered in new scopes and objectives.

3.2.3 Phase III: Touch Screen Programming Development

Project Manager is a software to design GUI for PROFACE touch screen specifically. Above is an example of what Project manager capable of producing, text, shape, button, figure, waveform to name a few. A few minor adjustment is applied to the original program as improvement, after improvement, the file is can be download into touch screen to interface with PLC

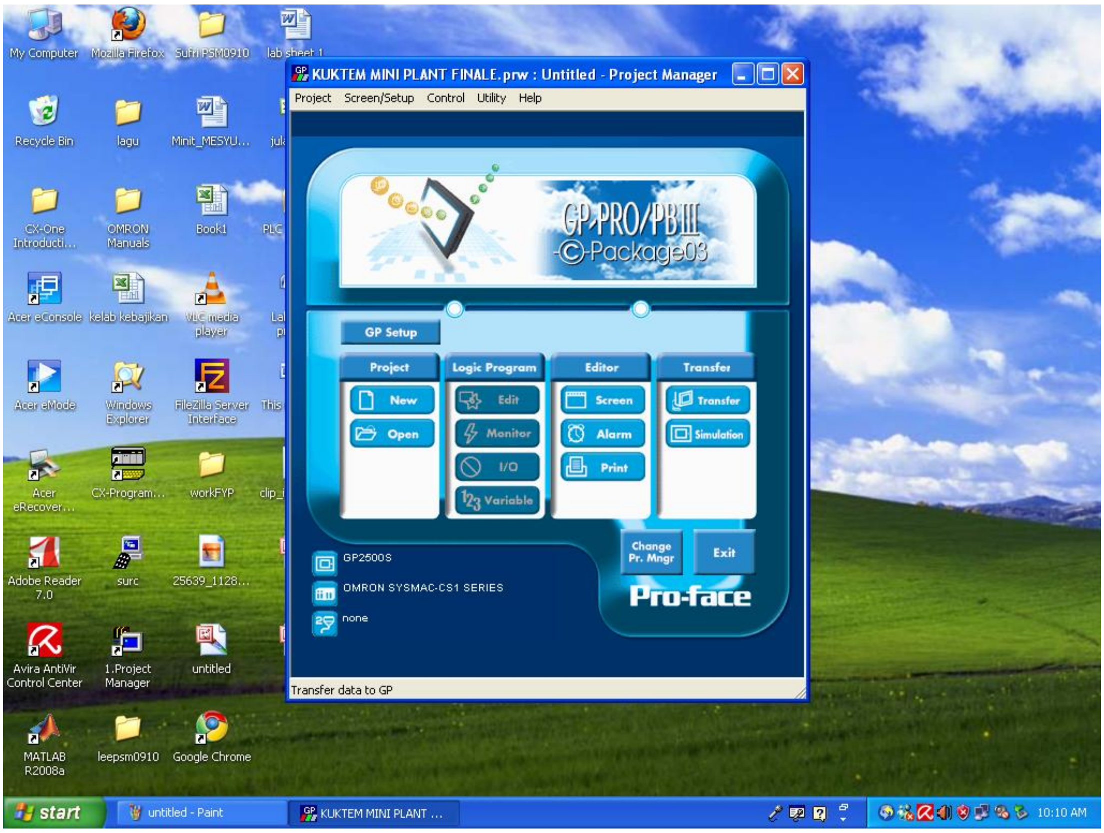

Figure 3.3: Project Manager

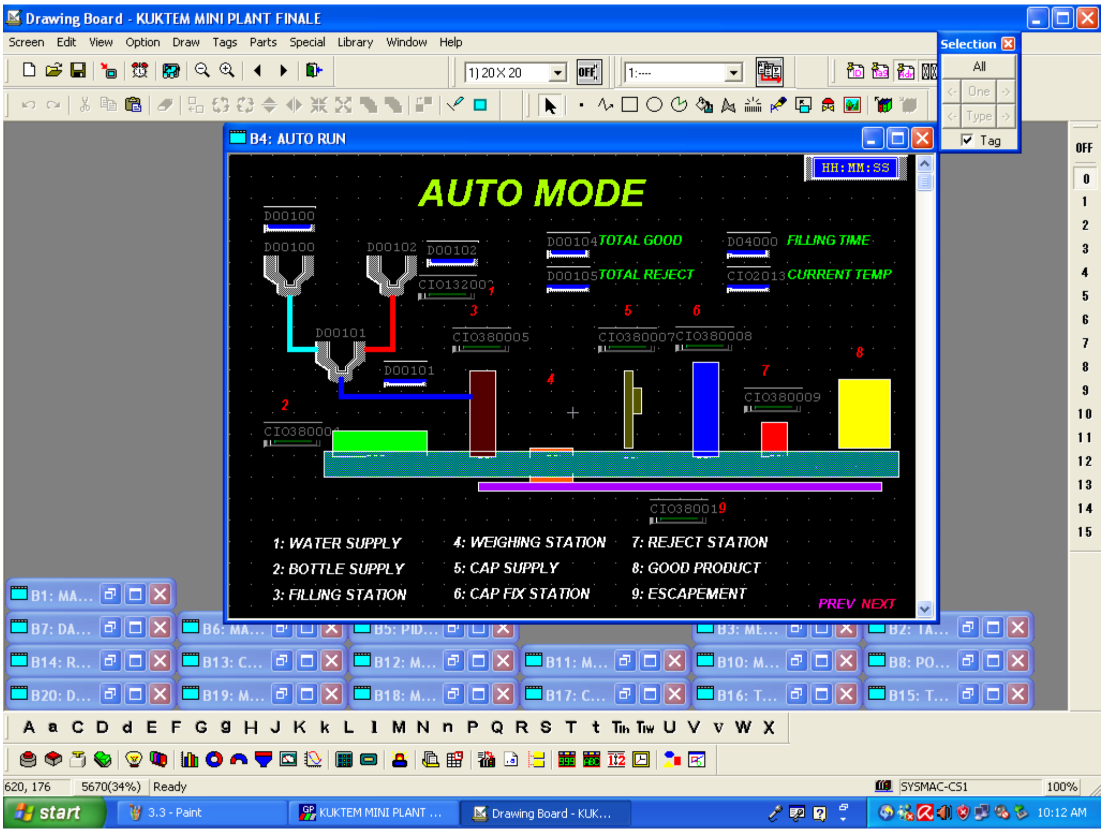

Figure 3.4: Project Manager Editor

GP Viewer on the other hand is a data collection software package that allows production site data to be collected and sent to information management PCs in real-time. It automatically records and accumulates production data, for immediate playback of either past or present line operating conditions allowing user to control touch screen at PC as if the user is touching the touch screen using mouse pointer clicks.

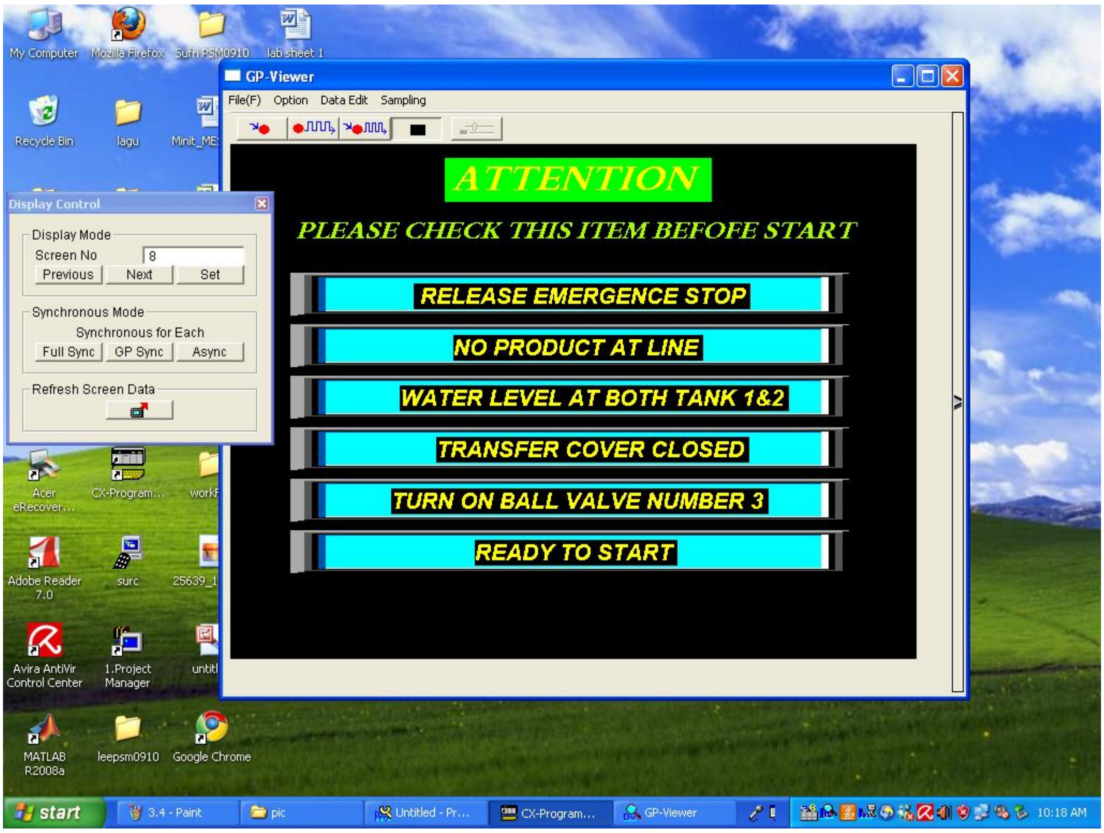

Figure 3.5: GP Viewer

Considering plant work area environment may be hazardous, not suitable for human to stay for too long, the reason for applying this software to the project is to allow user to control and monitor the plant form far. By connecting it to network, person in charge are able give input to touch screen as if the person are using the touch screen itself directly. In display control 3 mode can be selected:

i.	Full sync.	- affect both GP viewer and touch screen
ii.	GP sync.	- affect both and limited on 1 screen only
iii.	Asnc.	- affect GP viewer only

Figure 3.6: Touch Screen networking

Figure 3.6 Showed touch screen are connected to CPU through networking, touch screen is then set to a fixed IP so that CPU able to communicate with it using GP viewer and project manager.

3.2.4 Phase IV: PLC Programming Development

CX-Programmer is an application software to create and debug programs for SYSMAC CS/CJ/CP/NSJ-series, C-series, and CVM1/C-series CPU Units. It easily achieve position control with wading through user manuals. Also it has complete support for synchronous operation between units and therefore enable easier connection to PLCs. CX-Programmer can perform batch backup/restore with a computer. With its vast and comprehensive programming environment plus high program readability, is essential to make program smoothly without restriction. By using ladder diagram for CJ1W-TC001 as reference, a different ladder diagram is constructed to replace it using CX-programmer build in PID function block.

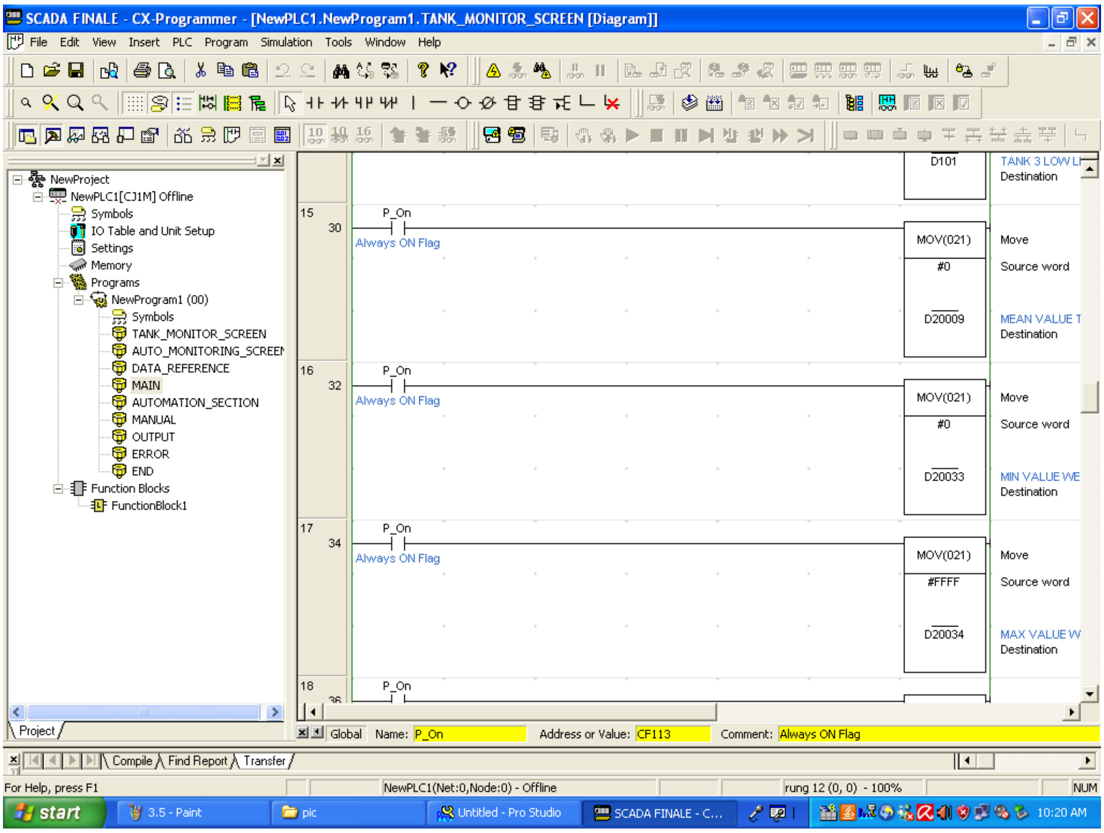

Figure 3.7: CX-Programmer

The ladder diagram available is functional, vital parts for PID implementation of heating tank are identified to be edited for simulation purpose. Information of ladder diagram programming addition and modification will be detailed in Chapter 4, Result and Discussions.

3.2.5 Phase V: PID Simulation and Auto Mode Test Run

The newly designed ladder diagram is now downloaded to PLC to be tested, and any after design minor problem is solved here before the simulation is carried out. Once again the details for water to heat up from 25℃ to 50℃ is recorded every minute for each set of PID constant tested. The optimum tuning constant and data set are highlighted for later on discussion.

As for auto mode test run, the plant still works the same way as it is, with new options to choose from auto mode screen at touch screen. This two part are repeated constantly each time a small part of modification or features are added to make sure the plant still functional and to make programming troubleshooting easier.

3.2.6 Phase VI: Result and analysis

Based on the PID results obtained from heating tank, graph are plotted and analyzed. Based on analysis values and graphs, detailed discussion are made. As for overall status, auto mode are able to run, with addition of new features and option to make the plant more flexible and future analysis more easier.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this chapter, all results obtained are shown. Details of result are presented in discussion, explanation and figure. There are 3 separate section in this chapter where 4.1 was about hardware repairing and 4.2 was about data of PID implementation on heating tank. As for 4.3, it is about new features that are added to PLC and touch screen programming to improve its interface and to more option.

4.2 UMP Mini Plant Maintenance and Repairing

UMP mini plant is deserted for past few years without proper maintenance or even regular test run, and a major relocation due to faculty relocation. This two reason had result quite a number of problem land upon UMP mini plant causing failure to run. Below are efforts given to troubleshoot and repair in order to allow mini plant to work once more again.

4.2.1 CJ1M Peripheral Port Failure - Replaced With New CJ1M

UMP mini automation plant is unable to operate all along because the peripheral port that allow communication between PLC and touch screen is unable to function properly.

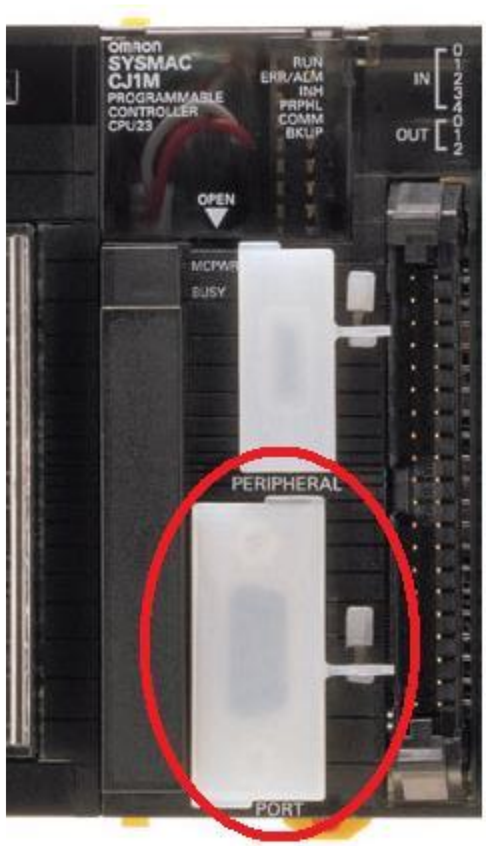

Figure 4.1: CJ1M peripheral port

Being unable to send or receive any data causing communication error at touch screen, this also explained why UMP mini plant at that point is unable to work at any part when given input from touch screen but is able to perform some output such as moving conveyer belt when it is ”force on" from CX-programmer where PLC connect to PC through host link port. The malfunction CJ1M is replaced with a new PLC of same model, slowly reverting every part of the plant back to its original state.

4.2.2 Ultrasonic Level Sensor Failure - Sent Back To Manufacture To Fix It

The ultrasonic level sensor, located above tank 1 and tank 2 is labeled failure when it send data for touch screen to display low water level at both tank whereby water are filled for both tank. A function able Ultrasonic level sensor is able to show blinking light at its indicator showing it was reading the water level at that time as shown in figure 4.2 where a failure sensor will not have the blinking light.

Figure 4.2: Ultrasonic level sensor

The failure Sensor are sent for repairing. It is fixed and sent back to UMP within 2 weeks later, it is then tested function able. Ultrasonic level sensor is very sensitive to atrocious condition such as an accidentally drop to floor may cause failure. Even after repairing at some state the sensor will still show incorrect reading, the best solution to this is to reset the whole system and empty that particular tank and refill the water.

Figure 4.3: Ultrasonic level sensor location

Figure 4.3 Showed the location of ultrasonic level sensor placed, above all 3 tanks, and the sensor will be able to read the distance of current water level to the top. Be sure that the water filled must not be too much, if water filled is higher level than a blue stripe patched at near top of the tank the sensor will result an error result.

4.2.3 Incorrect CJ1W-TC001 Wiring - Rewire Hardware

Heater is not functioning during auto mode, but when it is tested whereby pressing the PCB contactor, heater is able to function. Later on it is discovered that problem occur at CJ1W-TC001, reason for Incorrect Temperature Control Unit wiring is unknown, and it is causing heater unable to function when it is suppose to. By referring to relevant datasheet all incorrect ones are removed and wired to correct position, in addition the most fatal error occur here is no wiring done to +24V, meaning there's no power supply to this part of hardware. Figure 4.4 clearly showed there's no wiring to +24V originally.

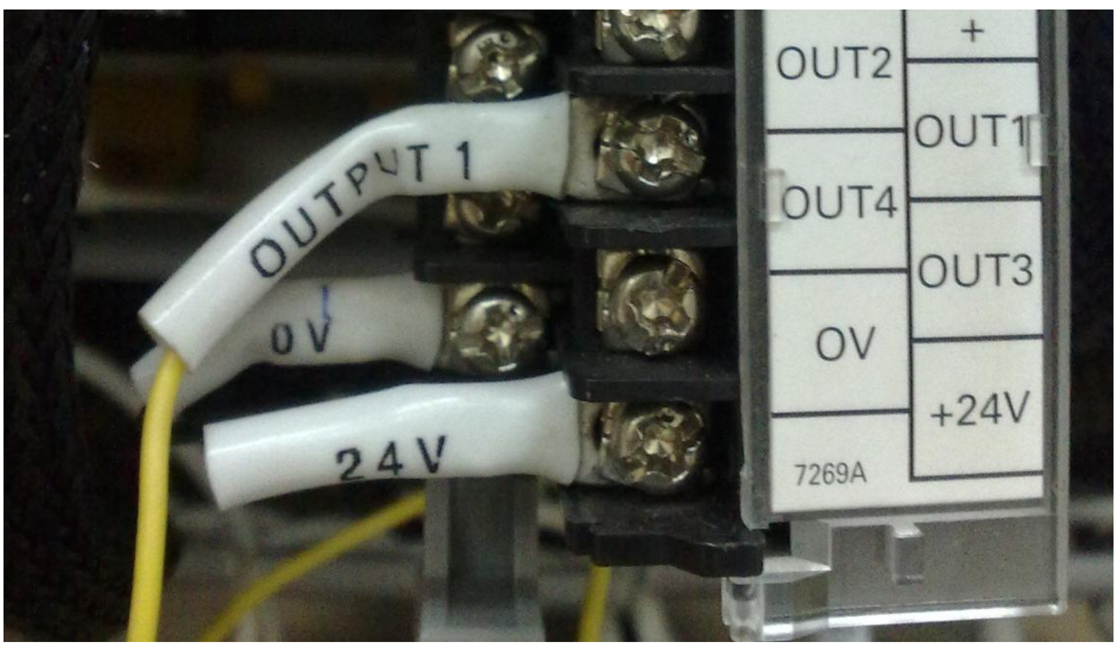

Figure 4.4: TCU TC001 wiring error

4.2.4 Slow Conveyer Belt Speed - Adjust Speed

When the Conveyer belt speed is too slow, bottle will stuck at the 1st stopper, the flow is disrupted and the "mover" will cause damage to them; when the conveyer belt speed is too fast the bottle will lose balance and fall when block by stopper and if proceed, it will be damaged by the "mover". Speed is carefully adjusted not too fast nor too slow to a suitable speed, whereby the controller located below the transfer cover panel.

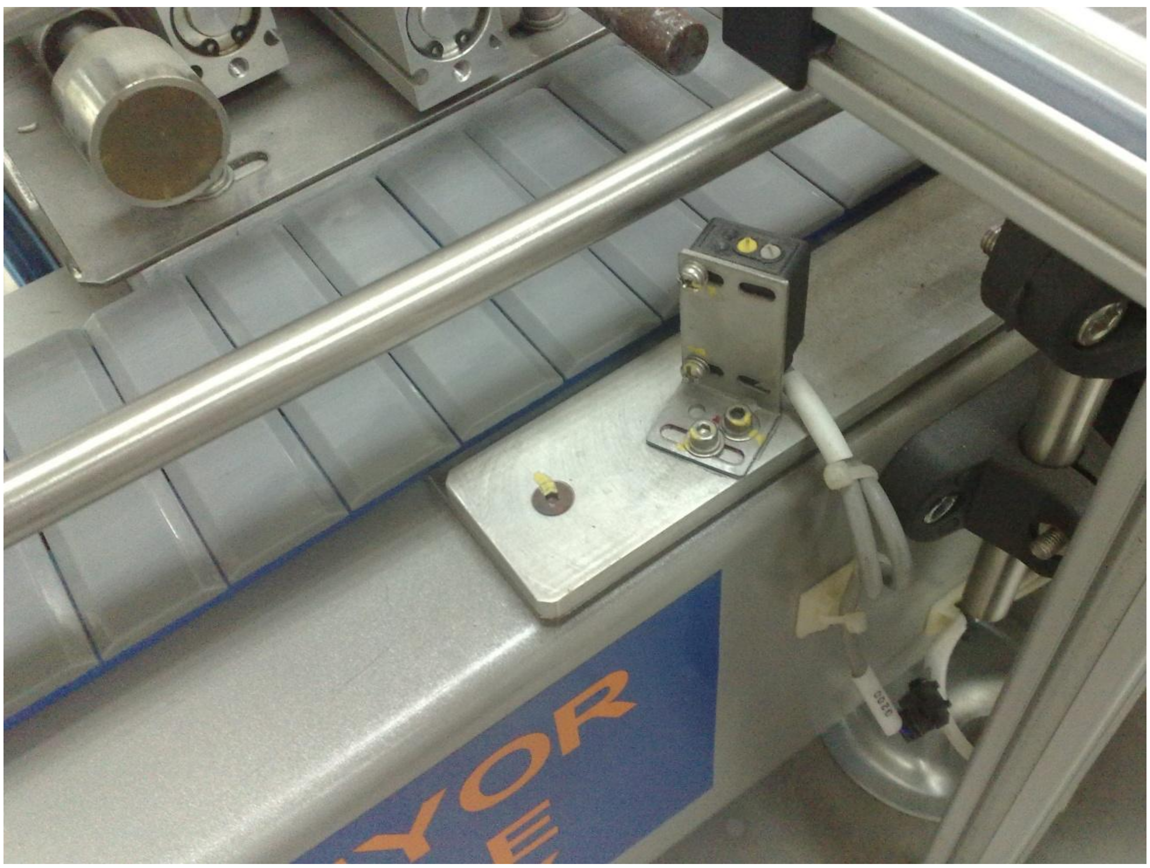

Figure 4.5: Conveyer belt

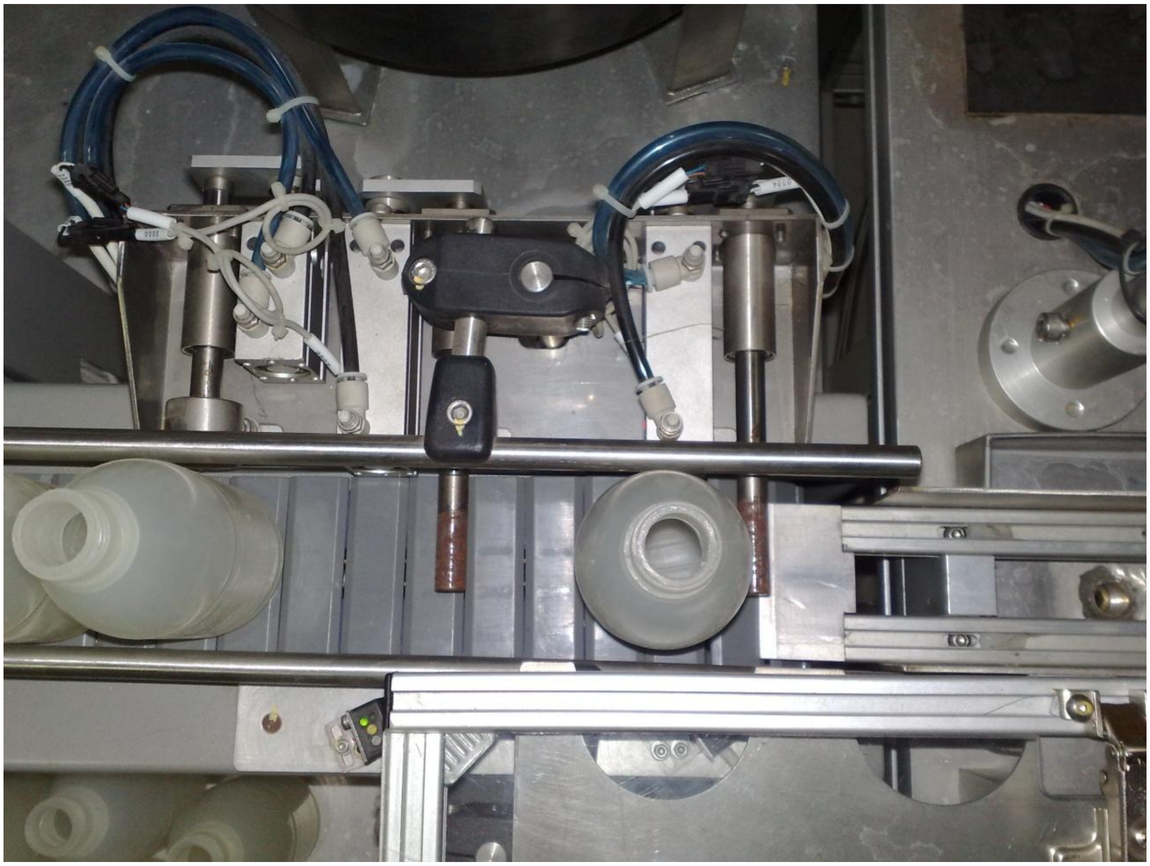

Figure 4.6: 2 Stopper at conveyer

Figure 4.6 showed a smooth system, if the conveyer is moving too slow, the bottle will still reach the space between those 2 stoppers, but occasionally it will get clamped by 1st stopper cause moving too slow.

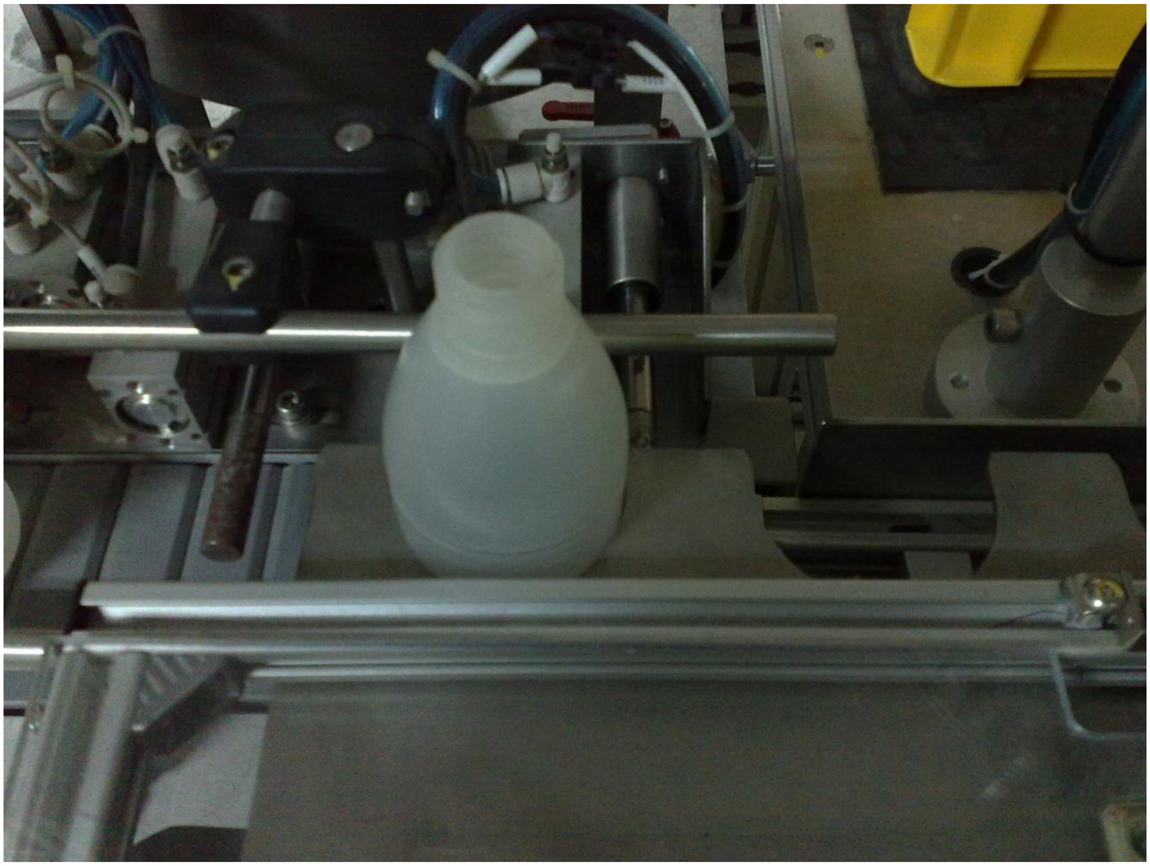

Figure 4.7: Transferring mechanism

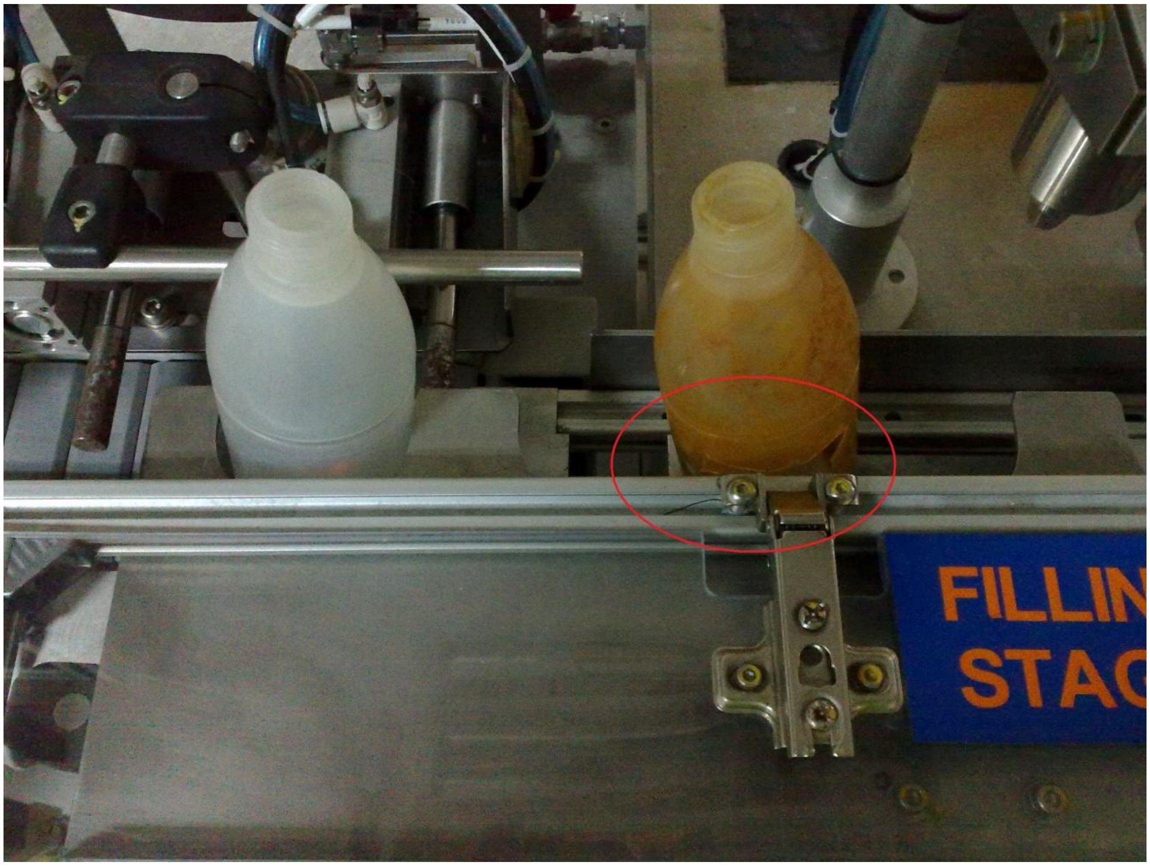

Figure 4.8: Transferring mechanism clamped into bottle

Figure 4.7 and 4.8 showed 2 allocation of bottles, the white bottle is fit nicely on the transferring mechanism in figure 4.7 while the yellow bottle on right hand side bottle of figure 4.8 is not, the transferring mechanism metal clamp into the bottle and damage it, figure 4.8 clearly showed what will happen if the conveyer is moving too slow.

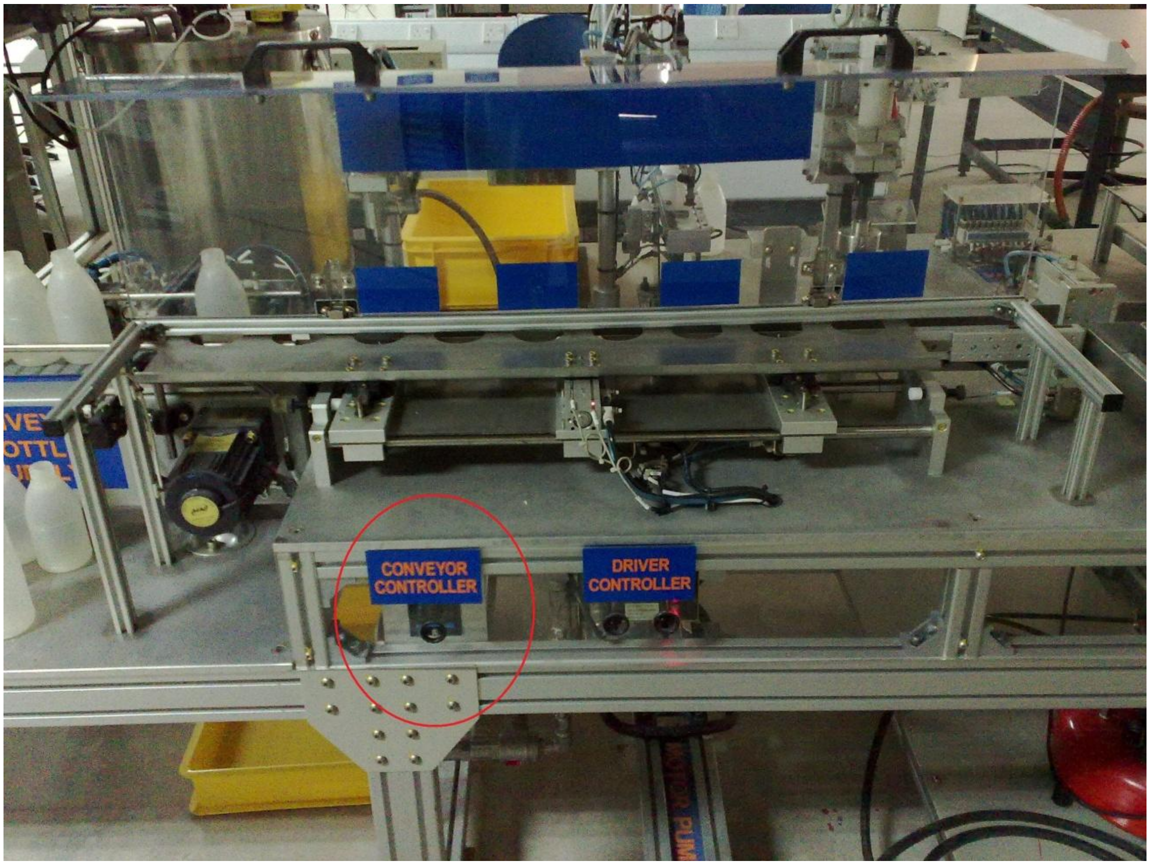

Figure 4.9: Lifted up transfer cover

Figure 4.10: Conveyer belt speed controller

Figure 4.9 is the transfer cover usually closed down as safety precaution, a limit switch will be 'close' when the transfer cover is closed down. When UMP mini plant is running and the transfer cover is lifted up, the limit switch will be 'open' and will trigger alarm as error. Also from figure 4.9 conveyer belt speed controller location can be seen clearly.

Figure 4.11: Damaged bottle

7 figures above showed where, how to control the conveyer speed and its importance to avoid any accident because any accident occur by this reason will not only cause severe damage to the bottle but blockage to the whole system at this stage. If this problem occur in an operating factory, it will cause that factory to sustain heavy loss due to mass damaged bottle, waste of material and no production loss. To avoid this kind of accident, regular maintenance is essential to make sure the plant is at its tip top shape.

4.2.5 Compressor Failure - Connect To A Further Compressor

Basically, when the compressor is at failure, the whole system can't execute "auto mode" due to ladder diagram programming. Many component of the system is running based on pneumatic system, cap supply station for example. A temporary compressor is installed to the system while looking for alternative ways.

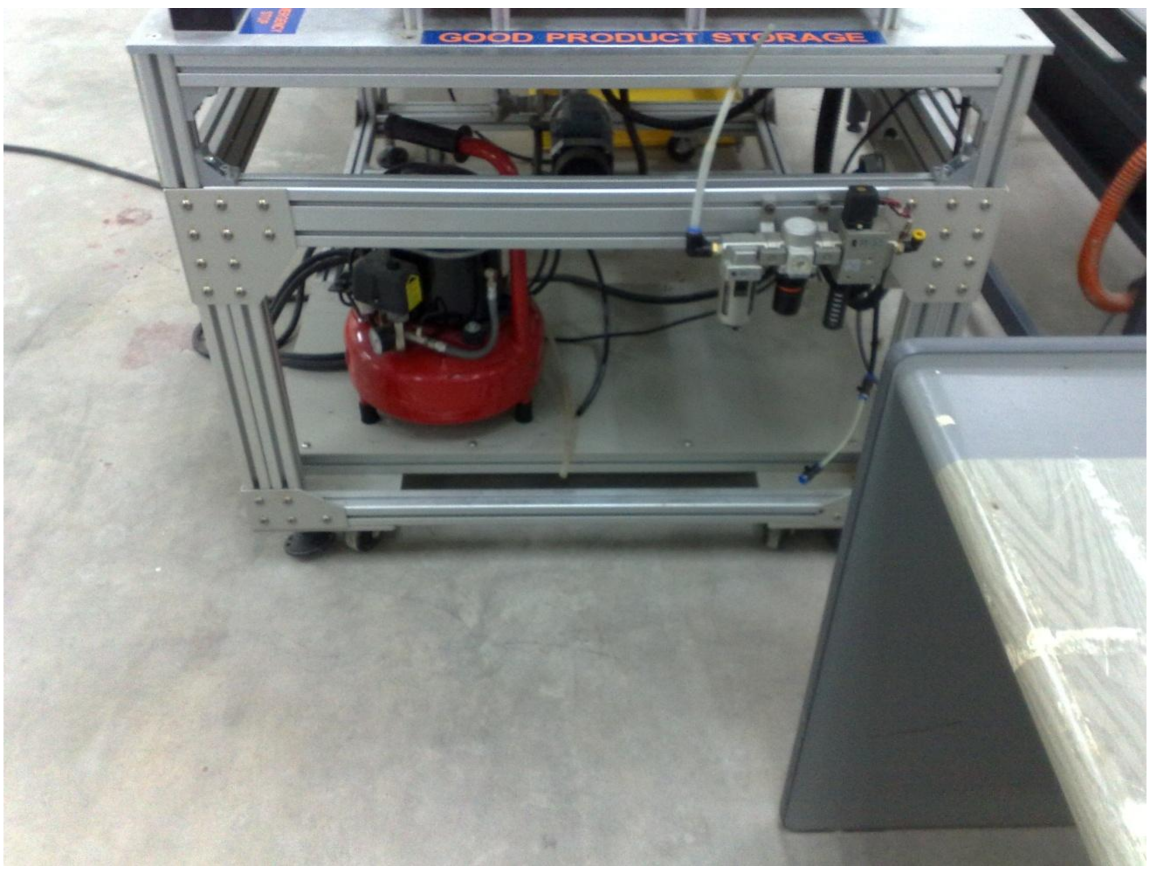

Figure 4.12: The malfunctioned red compressor is removed from system

Figure 4.13: Compressor connected from far

Later on, mini plant are connected to a compressor further away as a better solution and still looking for even better alternative ways. This part is very important as most of the output work based on pneumatic applications, if there's no pressure in compressor, only PID simulation are able to run through manual mode because auto mode not able to initialize due to some output not in initial condition when no air pressure is present.

4.3 PID Implementation Analysis

Experiment had been carried out by varying each of PID parameters, analysis upon tank 2 filled with water had been made into 3 section:

i. P mode
ii. PI mode
iii. PID mode

All set point (SP) in experiment are set to 50 and data for all experiment are taken for 40 minutes (data are recorded one a minute) only as all set of parameters will reach SP by that time and the rest of the graph can be predicted. If few set of analysis of each mode will be explained in detail below and because graph for parameter values in range of 100 showed almost no different, a big gap for different parameters are taken to made analysis.

Table 4.1: PID values for each mode

Controller Type	Proportional Band, PB	Integral Time, T1	Derivative Time, Td
P	*	∞	0
PI	*	*	0
PID	*	*	*

* represents different value for each analysis
∞ is represented by 999 in experiment

6 aspects below taken into analysis below is defined as:

i. Delay time, Td: The time required for the response to reach half the final value the very first time
ii. Rise time, Tr: The time required for the response to rise from 0.1(10%) of the final value to 0.9(90%) of the final value.
iii. Peak time, Tp : The peak time is the time required for the response to reach the first peak of the overshoot
iv. The settling time, Ts is the time required for the response curve to reach and stay within 2% of the steady-state value.
v. Percent overshoot, %OS : The percent overshoot is defined as the maximum peak value of the response curve measured from unity, which is expressed as a percentage of the steady-state value.

$$\%OS = \frac{C_{\max(T_p)} - C_{final(\infty)}}{C_{final(\infty)}} \times 100\% \tag{4.1}$$

vi. To calculate 2nd order equation

$$\%OS = \frac{C_{\max(T_p)} - C_{final(\infty)}}{C_{final(\infty)}} \times 100\% = e^{-\left(\zeta\pi / \sqrt{1-\zeta^2}\right)} \times 100\%$$

$$\zeta = \frac{-\ln(\%OS/100)}{\sqrt{\pi^2 + \ln^2(\%OS/100)}} \tag{4.2}$$

$$\omega_n = \frac{\pi}{T_p\sqrt{1-\zeta^2}} \tag{4.3}$$

$$C(s) = \frac{\omega_n^2}{s(s^2 + 2\zeta\omega_n s + \omega_n^2)} \tag{4.4}$$

4.3.1 P Mode Analysis

A high proportional gain (P) yield a large change in the output for any change in the error; in the system it affect how long the heater will heat, the higher P gain the longer heater will heat before it rest. In P mode, parameter I is set to ∞ which is represented by 999 in experiment and parameter D is set to 0. Three set of parameters are detailed here are as follow:

i. Data P.1 (P=500 I=999 D=0)
ii. Data P.2 (P=999 I=999 D=0)
iii. Data P.3 (P=30 I=999 D=0)

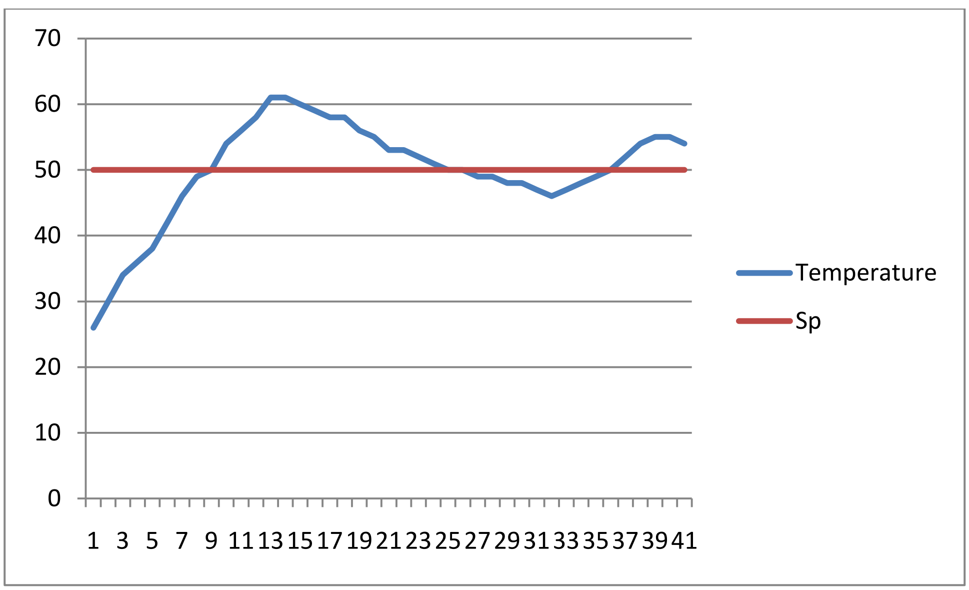

Figure 4.14: Graph of Data P.1 (P=500 I=999 D=0)

From graph

Td	=	5 min
Tr	=	8 min
Tp	=	13 min
Ts prediction	=	more than 1 hour

$$\%OS = \frac{61-50}{50} \times 100\% = 23\%$$

$$\zeta = \frac{-\ln(24/100)}{\sqrt{\pi^2 + \ln^2(24/100)}} = 0.4522$$

$$\omega_n = \frac{\pi}{13\sqrt{1-0.4522^2}} = 0.2709$$

$$C(s) = \frac{0.0734}{s(s^2 + 0.2450s + 0.0734)}$$

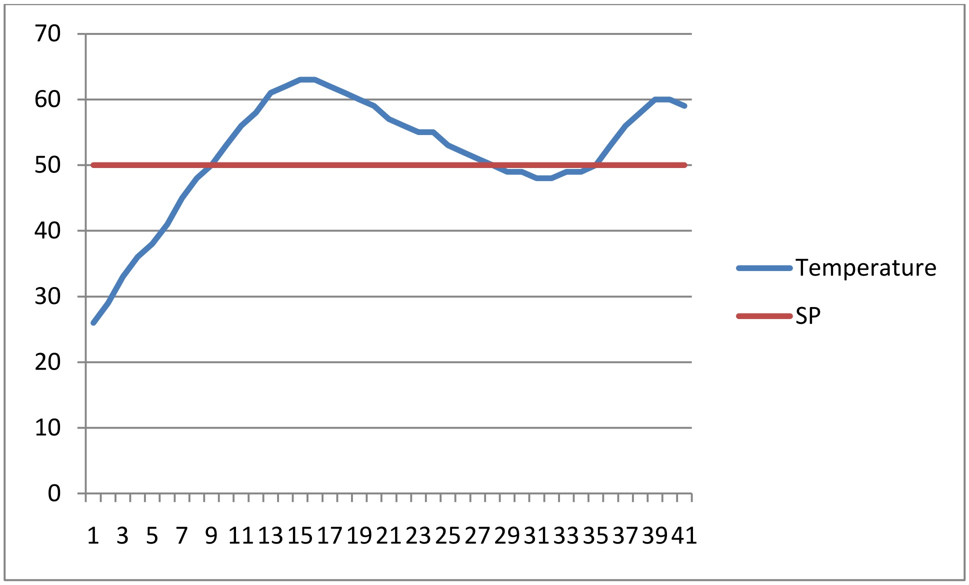

Figure 4.15: Graph of Data P.2 (P=999 I=999 D=0)

From graph

Td	=	4 min
Tr	=	7 min
Tp	=	12 min
Ts prediction	=	more than 1 hour

$\%OS$

$$= \frac{63-50}{50} \times 100\%$$

$$= 26\%$$

ζ

$$= \frac{-\ln(26/100)}{\sqrt{\pi^2 + \ln^2(26/100)}}$$

$$= 0.4102$$

$$\omega_n = \frac{\pi}{12\sqrt{1-0.4102^2}} = 0.2871$$

$$C(s) = \frac{0.0824}{s(s^2 + 0.0.2355s + 0.0824)}$$

If the P gain is too high, the system will become unstable; as shown in both figure 4.14 and 4.15 where both set of data even after temperature reach SP heater is still heating because high P gain results longer heating time before rest. The first overshoot stop at 60+ Celsius and when temperature drop below SP, heater will heat for quite long again because high P gain result large change for change in error, causing the system unstable and will take very long time to reach SP in stable state.

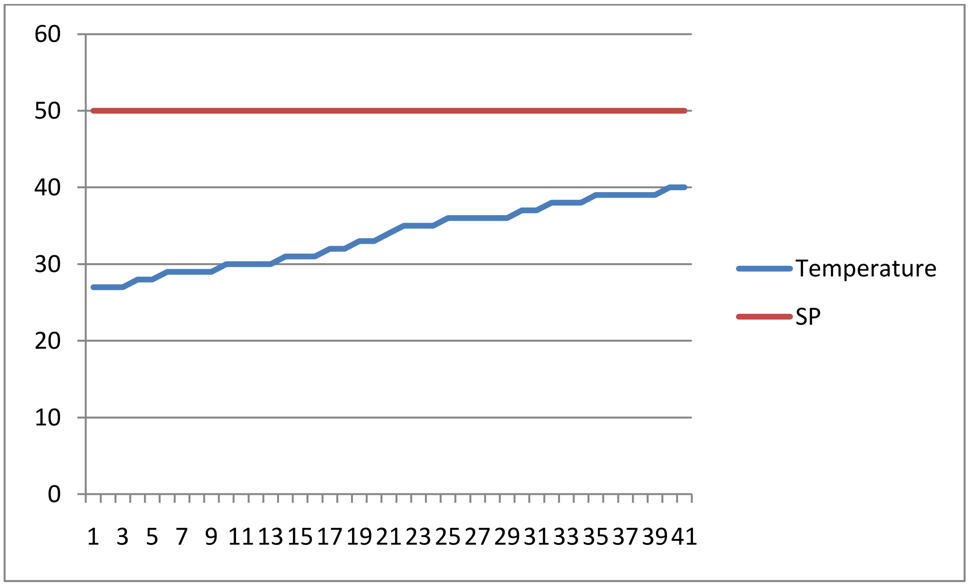

Figure 4.16: Graph of Data P.3 (P=30 I=999 D=0)

From graph

Td	=	39 min
Tr prediction	=	more than 1 hour
Tp prediction	=	more than 1 hour
Ts prediction	=	more than 1 hour

Percentage overshoot not able to calculate because too many unknown constant.

In the other hand, a small gain results in a small output response to a large input error resulting a less sensitive controller. With a small gain (lower than 50) heater will heat only a while before it rest, no overshoot will happen because the water will heat ridiculously slow. From figure 4.16 prediction can be made that the water will continue to heat even more slowly as the temperature raise closer SP.

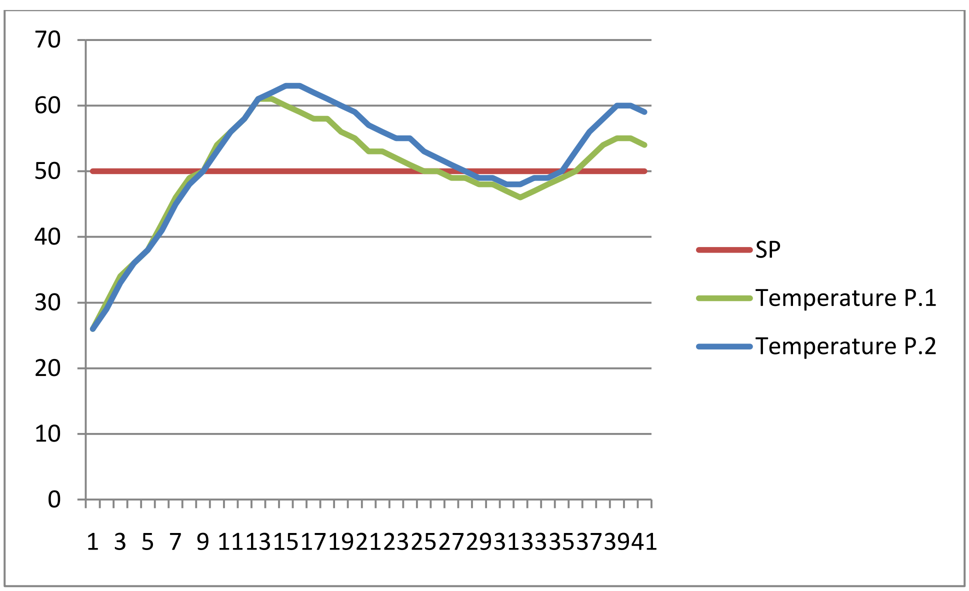

Figure 4.17: Comparison of Graph Of Data P.1 and P.2

Too high of P gain will yield an unstable system; too low of P gain will cause the system very long time to finish the process making it inefficient. It has been tested P gain should be around 50-100 where gain over 100 will have less and less difference in hasting system process but promotes a more unstable system. As shown in figure 4.17 difference in graph of data P.1 and P.2, the 1st peak is near identical indicates nearly same effect is hasting the process and 2nd peak indicate the unstable of system, a noticeable gap is viewed between temperature P.1 and P.2 here, indicating instability grows from P = 500 to P = 999.

4.3.2 PI mode analysis

In PI mode D gain is set to 0 and P is made constant to 500 to get shorter time constant and more clear view on the whole process. Three set of parameters are detailed here are as follow:

i. Data PI.1 (P=500 I=800 D=0)
ii. Data PI.2 (P=500 I=600 D=0)
iii. Data PI.3 (P=500 I=400 D=0)

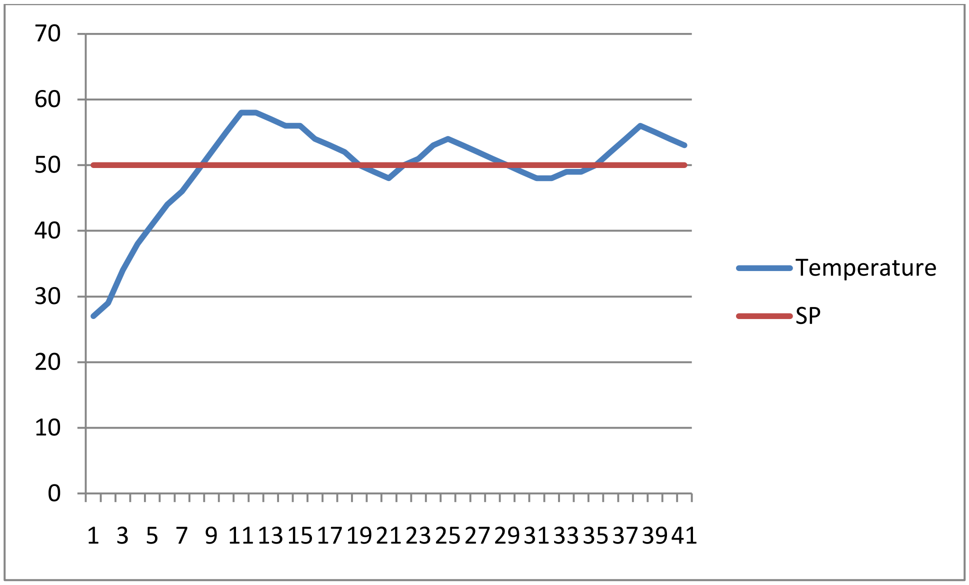

Figure 4.18: Graph of Data PI.1 (P=500 I=800 D=0)

From graph

Td	=	6 min
Tr	=	9 min
Tp	=	12 min
Ts prediction	=	more than 1 hour

Percent overshoot and second order equation not able to calculate because the graph is predicted to be oscillating for a long time.

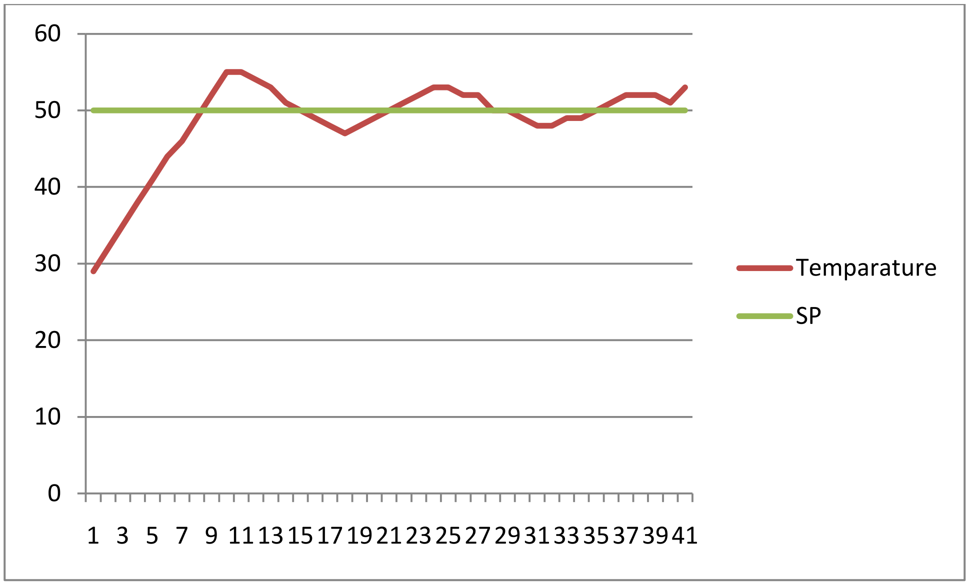

Figure 4.19: Graph of Data PI.2 (P=500 I=600 D=0)

From graph

Td	=	4 min
Tr	=	9 min
Tp	=	11 min
Ts prediction	=	more than 1 hour

Percent overshoot and second order equation not able to calculate because the graph is predicted to be oscillating for a long time.

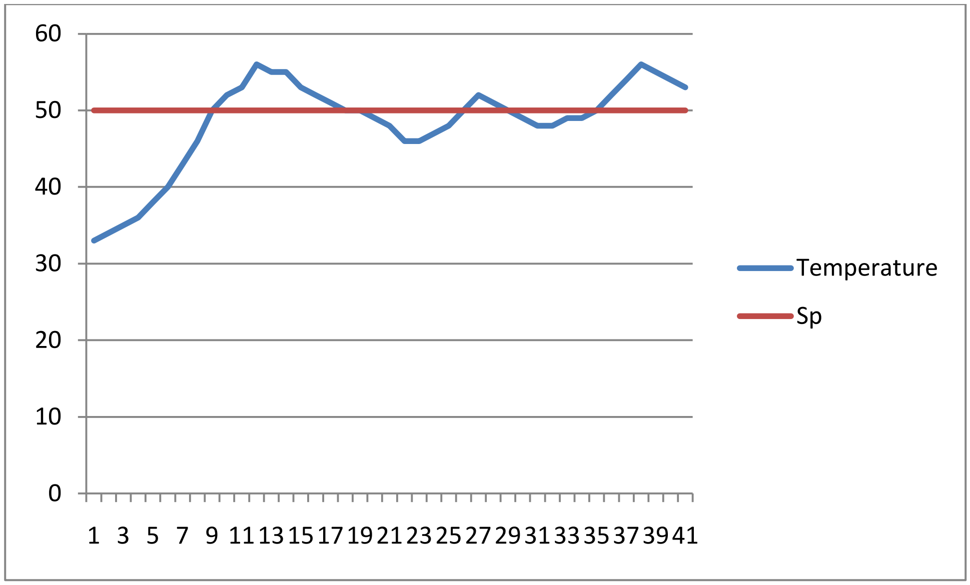

Figure 4.20: Graph of Data PI.3 (P=500 I=400 D=0)

From graph

Td	=	6 min
Tr	=	10 min
Tp	=	12 min
Ts prediction	=	more than 1 hour

Percent overshoot and second order equation not able to calculate because the graph is predicted to be oscillating for a long time.

I gain accumulate error from past to correct it on present and overshoot will occur because of this. A high I gain yield a faster output to encourage faster process toward SP and eliminate residual steady-state error that occurs with a P only controller. In the system it affect how long heater will rest before resume heating. From all 3 graph of data PI.1, PI.2and PI.3 can clearly seen the shape of starting to oscillate because P gain is set high.

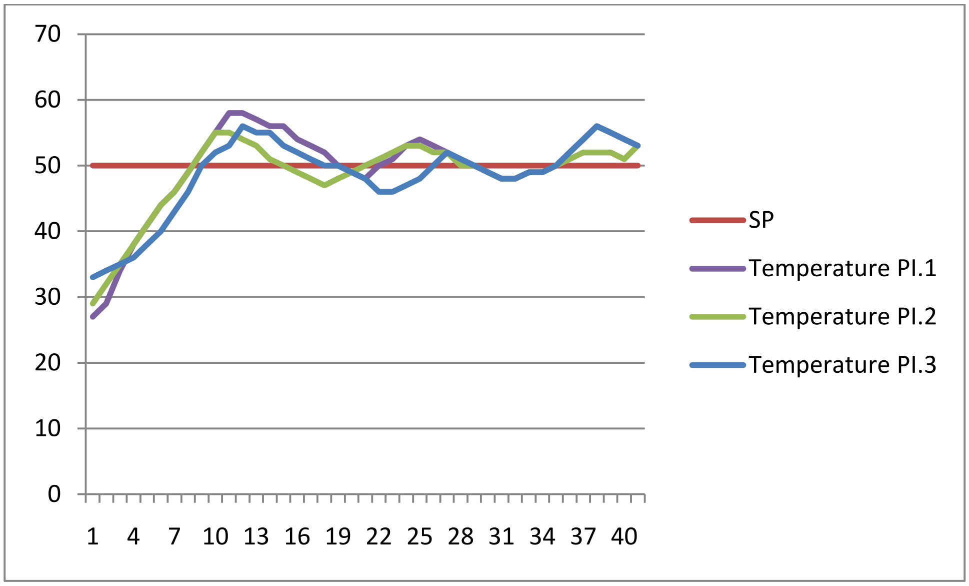

Figure 4.21: Comparison of Graph Of Data PI.1, PI.2 and PI.3

Figure 4.21 indicates a high I gain give faster rise time but higher overshoot and more encourage output to oscillate as well. Whereas a lower I gain have lower rise time, overshoot produced comparable to high I gain and promotes oscillating as well. So it is better to use a high I gain than a low one, but P gain should get more attention this way so that the output won't oscillate. I gain recommended is as high as above 800.

4.3.3 PID mode analysis

In PID mode D gain is made constant to 150 to get shorter time constant and other varies to get variation in result. Three set of parameters are detailed here are as follow:

i. Data PID.1 (P=53 I=871 D=150)
ii. Data PID.2 (P=500 I=800 D=150)
iii. Data PID.3 (P=999 I=600 D=150)

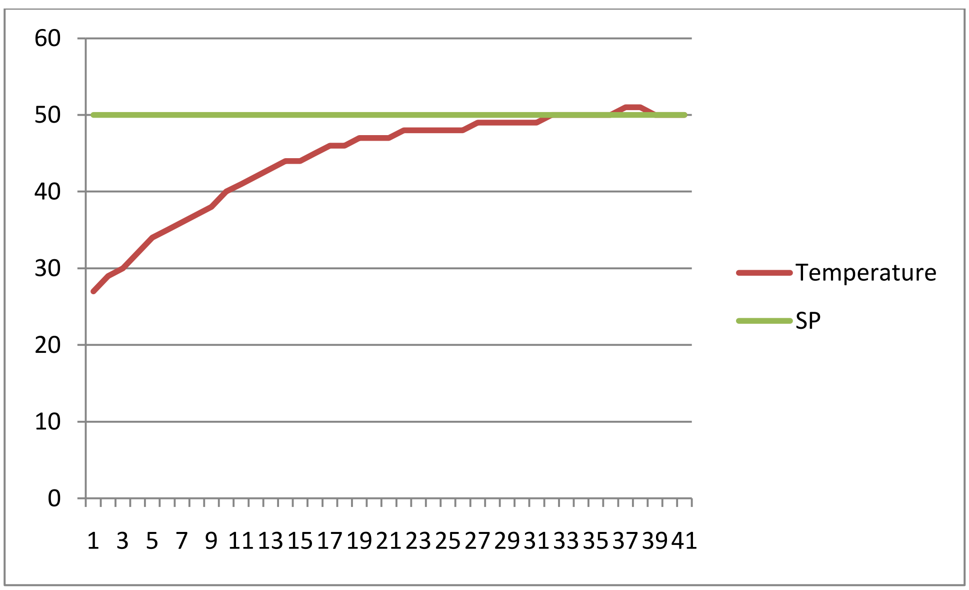

Figure 4.22: Graph of Data PID.1 (P=53 I=871 D=150)

From graph

Td = 10 min

Tr = 33 min

Tp = 37 min

Ts = 39 min

$\%OS$

$= \frac{51-50}{50} \times 100\%$

$= 2\%$

ζ

$= \frac{-\ln(2/100)}{\sqrt{\pi^2 + \ln^2(2/100)}}$

$= 0.7797$

ω_n

$= \frac{\pi}{37\sqrt{1-0.4102^2}}$

$= 0.1356$

$C(s)$

$= \frac{0.0184}{s(s^2 + 0.2115s + 0.0184)}$

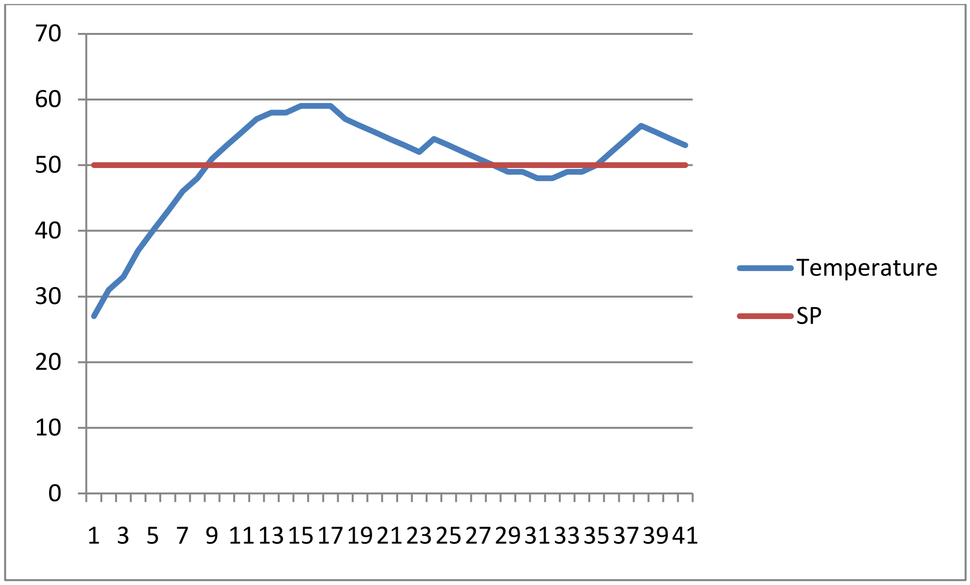

Figure 4.23: Graph of Data PID.2 (P=500 I=800 D=150)

From graph

Td	=	4 min
Tr	=	9.5 min
Tp	=	16 min
Ts prediction	=	more than 1 hour

$\%OS$

$$= \frac{59-50}{50} \times 100\%$$

$$= 18\%$$

ζ

$$= \frac{-\ln(2/100)}{\sqrt{\pi^2 + \ln^2(2/100)}}$$

$$= 0.4791$$

$$\omega_n = \frac{\pi}{16\sqrt{1-0.4791^2}} = 0.2237$$

$$C(s) = \frac{0.05}{s(s^2+0.2143s+0.05)}$$

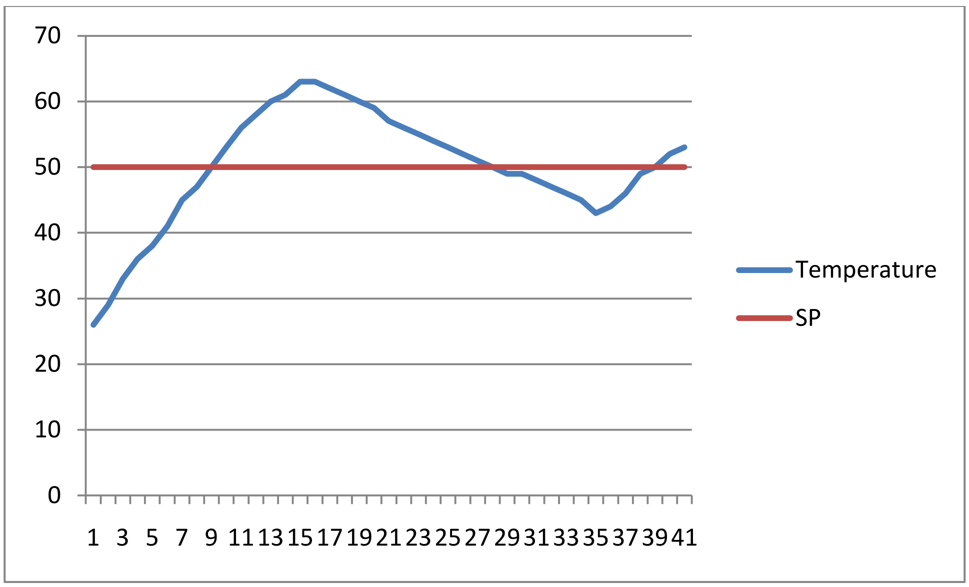

Figure 4.24: Graph of Data PID.3 (P=999 I=600 D=150)

From graph

Td	=	5 min
Tr	=	9 min
Tp	=	16.5 min
Ts prediction	=	more than 1 hour

$\%OS$

$= \dfrac{63-50}{50} \times 100\%$

$= 26\%$

ζ

$= \dfrac{-\ln(26/100)}{\sqrt{\pi^2 + \ln^2(26/100)}}$

$= 0.3941$

ω_n

$= \dfrac{\pi}{16.5\sqrt{1-0.3941^2}}$

$= 0.2072$

$C(s)$

$= \dfrac{0.0429}{s(s^2 + 0.1633s + 0.0429)}$

D gain tend to slow the rate of change of controller output but in UMP mini plant tank 2 there's only mechanism to heat up but no mechanism to cool down. D gain here plays more minor role than P and I gain. Data from figure 4.22 is obtained using original parameters of UMP mini plant tank 2 PID parameters. It showed a smooth rise time and small overshoot which is ideal for this process. Figure 4.23 showed a partially oscillating graph, to obtain a better result P gain should be lowered a lot and I gain may maintain or increase slightly. Figure 4.24 showed an oscillating graph because P gain is set to maximum and I gain are not enough.

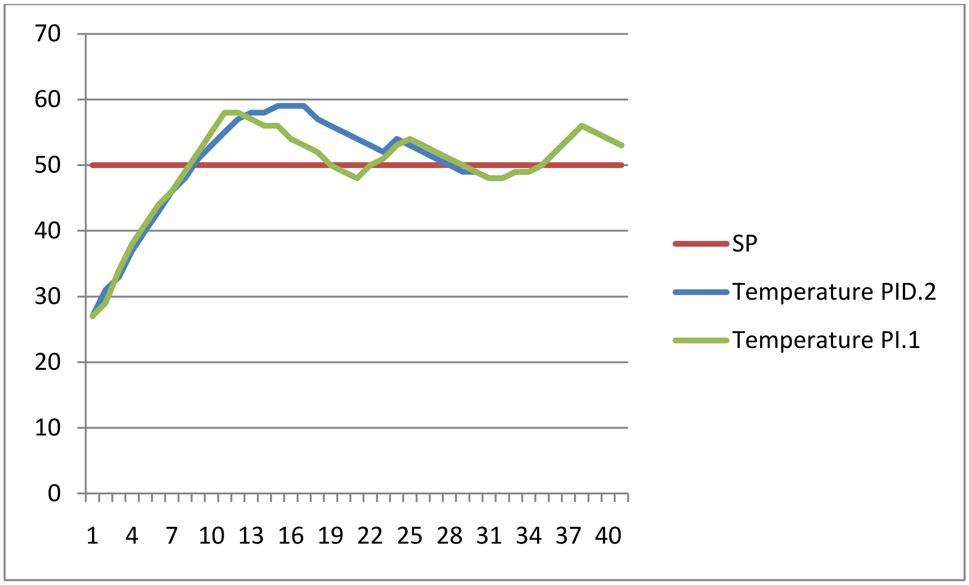

Figure 4.25: Comparison of Graph of Data PID.2 and PI.1

Figure 4.25 showed the role of D gain. D gain tend to slower the output so that it will become closer to SP. Because there's no mechanism to cool down tank 2, D gain works only when heater work, where it tend to let heater rest more often when temperature is near SP. In figure 4.25 temperature graph oscillate lesser and tend to heat fewer times when near SP, graph is almost identical because of P is set high, for lower P with same parameters PID graph will more noticeable to bent toward SP when it's near.

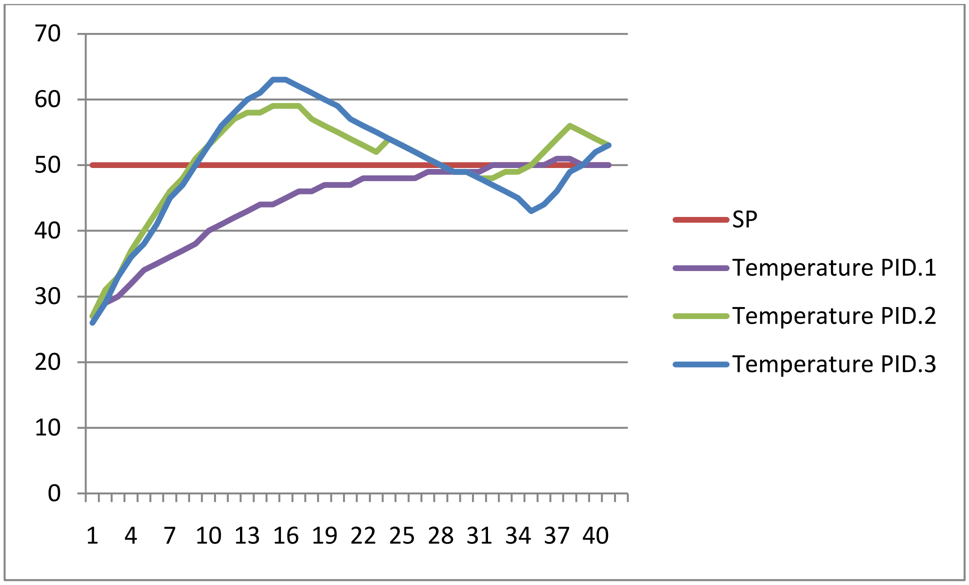

Figure 4.26: Comparison of Graph of Data PID.1, PID.2 and PID.3

Parameters of data PID.1, PID.2 and PID.3 is vary and from figure 4.26 it is cleared that high P gain promotes faster rise time but produce large overshoot that affect after the first peak; I gain should be as high as possible as it hasten the process; D gain plays a more minor role here but theoretically D gain act as counterpart to P and I gain to reduce overshoot and instability, D gain is usually 4 times or more lower than I gain.

4.3.4 Overall Analysis

Table 4.2: Overall performance comparison

Mode	P	I	D	Td (min)	Tr (min)	Tp (min)	Ts (min)	%OS (%)
P	30	999	0	5	8	13	>1 hour	23
	500	999	0	4	7	12	>1 hour	26
	999	999	0	39	>1 hour	>1 hour	>1 hour	N/A
PI	500	800	0	6	9	12	>1 hour	N/A
	500	600	0	4	9	11	>1 hour	N/A
	500	400	0	6	10	12	>1 hour	N/A
PID	53	871	150	10	33	37	39	2
	500	800	150	4	9.5	16	>1 hour	18
	999	600	150	5	9	16.5	>1 hour	28

Based on graphs and explanation above table 4.2 can be summarized and following statement can be made:

i. P gain: Excess gain cause unstable system, insufficient gain cost time. Recommended gain: 50 - 100
ii. I gain: Higher gain hasten process but cause overshoot and promotes oscillating; lower gain yield slower process and still cause overshoot and promotes oscillating comparable to higher gain. Recommended gain : 800 - 999
iii. D gain: Counterpart to P and I gain, usually 4 times or more smaller than I gain. Recommended gain: below 250
iv. Best PID parameters so far is P=53 I= 871 D=150

4.4 Programming Improvement

4.4.1 PLC

Two main component to be set at ladder diagram as default are the PID tuning constant and time gap to record temperature during PID simulation. PID tuning constant are set to 53, 871, 150 respectively as shown in result in previous section, a suitable tuning constant. As for time to record, it is set to 1 minute, record start from 0th minute, which is very suitable too as the temperature only rise about 23 Celsius in each simulation; 2 minute gap can be implemented as if simulation run to test time needed for temperature rise for 50 Celsius because too many similar data will be acquire if 1 minute gap is used.

4.4.2 Touch screen

First and foremost, a new main page is created stating title of this project and this page is set to 1st screen in touch screen setting so that whenever touch screen is reset, this page will showed up 1st. Next, a "return to manual mode menu" button is added in each of manual mode output screen. And lastly, "KUKTEM MINI AUTOMATION PLANT" title had been changed to "UMP MINI AUTO MATION PLANT". Because of the addition of all these, few modification had been done also to some screens related such as screen order and buttons.

In addition, networking application are used instead of connecting touch screen to CPU directly. Touch screen and CPU is connected to network and now connected to each other indirectly. By searching and selecting the correct IP of touch screen when using Project Manager editor or GP Viewer, it can be connected the same way both connected directly using LAN.

4.5 Project Limitation

The 1st limitation of this project is at PID application, tank 2 has heater which able to heat up the liquid but no mechanism to cool it down when liquid temperature is exceed SP and caused overshoot. The only way for it to achieve steady state after overshoot is for it to cool down naturally, which is slow. There will be a certain improvement in terms of performance if this matter is overcome.

2nd limitation will be after simulation where liquid are heated up to SP temperature. Following simulation will have to wait until the liquid totally cooled down to room temperature and the heater are as well. This cause multiple simulation time consuming. But in real life application in industry, this is not a problem as second batch of liquid will be heat up as well, so it doesn't matter the tank or the heater is still hot, in fact, it cost a little less time to heat up the liquid which is good as it improves initial temperature.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The progress of PID implementation of UMP Mini Automation Plant Part 1 - Heating Tank has been presented. This project was developed by fixing and revamping the mini plant, making analysis upon PID implementation on heating tank.

Theoretically, a system with PID controller can perform better than a system without it. By using the control scheme it is able to fabricate better result in terms of faster rise time, maximum percentage overshoot and avoiding the oscillation before reaching the steady state error.

In this research, PID implementation has been done through temperature unit controller, result has been achieve and presented as graph. From this research, various PID tuning constant has been tested, difference of each mode and effect of increasing and decreasing each component are explained. In short PID is important to improve heating tank performance and PID mode outperform P and PI mode, which is why chose to be implemented on heating tank over the other 2 mode.

Auto mode now able to run again with some new options to choose from touch screen. As for touch screen few new features are added too in line with PLC programming development. The hardware of all stations remain the same but some modification are made corresponding to another title implementing UMP mini automation plant: Improvement Efficiency Of UMP Mini Automation Plant Part 2 - In Terms Of Rejection Rate, modification made allow UMP mini plant to produce less rejected product. In short major repairing has been done to allow UMP mini plant revert back to its functional state but helps little upon hardware modification upon completing this project.

5.2 Recommendation And Further Improvements

Recommendations below may installed to this UMP mini plant to make it more user friendly and flexible. Based on this project, suggestion that able to improve the implementation of PID at tank 2 and overall mini plant performance is:

5.2.1 Automated Tank Filling and Water Recycle

Pipe are added to mini plant to implement automated water filling for tank 1 and material or solution filling for tank 2. As for recycling all 3 tank are slightly modified so that user can choose weather liquid are drained or recycle back to another tank or itself, this suggestion is not applicable in industrial plant but very helpful for UMP mini plant as its main usage is as study material where a lot simulation are need to be carry out.

5.2.2 Thermocouple Location

Thermocouple at tank 2 are installed at the middle of the tank instead of higher end to make sure temperature at any time is more accurate since the heater is located at the bottom of the tank. As we all know hotter water density are lower because water molecule collide more often making it locate further than those colder water density. What actually happen in tank 2 is hotter water are sensed where less hotter are at bottom because they are more dense, by locating thermocouple at middle of tank 2, result of temperature obtained will be more accurate.

Also it is made to be more flexible as it now able to faction even without filling the tank almost full; whereby what available now is water must filled to thermocouple level to allow the PID functional.

5.2.3 Cap Supply And Cap Fix Station Improvement

Cap fix station are modify so that it is more accurate when the fixer is descend on the bottle, it is not accurate due to small disturbance happen at route from cap supply station to cap fix station.

5.2.4 Water Resistance Counter Measure

UMP mini plant deals with wet material as liquid can done serious damage to electric and mechanical parts if counter measure not done properly. This idea act as an insurance as if accident happen, only product or material will sustain damage. In industry application, if the plant is damaged due to liquid leak from tank or filling station to vital parts, the factory will sustain further loss due to plant failure and no product loss.

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APPENDICES

APPENDIX A

PID Simulation Data Of Tank 2

PID mode	53 871 150	
Time (minutes)	Temperature	
0	27	50
1	29	50
2	30	50
3	32	50
4	34	50
5	35	50
6	36	50
7	37	50
8	38	50
9	40	50
10	41	50
11	42	50
12	43	50
13	44	50
14	44	50
15	45	50
16	46	50
17	46	50
18	47	50
19	47	50
20	47	50
21	48	50
22	48	50
23	48	50
24	48	50
25	48	50
26	49	50
27	49	50
28	49	50
29	49	50
30	49	50
31	50	50
32	50	50
33	50	50
34	50	50
35	50	50
36	51	50
37	51	50
38	50	50
39	50	50
40	50	50

PID mode	500 800 150	
Time (minutes)	Temperature	
0	27	50
1	31	50
2	33	50
3	37	50
4	40	50
5	43	50
6	46	50
7	48	50
8	51	50
9	53	50
10	55	50
11	57	50
12	58	50
13	58	50
14	59	50
15	59	50
16	59	50
17	57	50
18	56	50
19	55	50
20	54	50
21	53	50
22	52	50
23	54	50
24	53	50
25	52	50
26	51	50
27	50	50
28	49	50
29	49	50
30	48	50
31	48	50
32	49	50
33	49	50
34	50	50
35	52	50
36	54	50
37	56	50
38	55	50
39	54	50
40	53	50

PID mode	999 600 150	
Time (minutes)	Temperature	
0	26	50
1	29	50
2	33	50
3	36	50
4	38	50
5	41	50
6	45	50
7	47	50
8	50	50
9	53	50
10	56	50
11	58	50
12	60	50
13	61	50
14	63	50
15	63	50
16	62	50
17	61	50
18	60	50
19	59	50
20	57	50
21	56	50
22	55	50
23	54	50
24	53	50
25	52	50
26	51	50
27	50	50
28	49	50
29	49	50
30	48	50
31	47	50
32	46	50
33	45	50
34	43	50
35	44	50
36	46	50
37	49	50
38	50	50
39	52	50
40	53	50

Pmode	500 999 0	
Time (minutes)	Temperature	
0	26	50
1	30	50
2	34	50
3	36	50
4	38	50
5	42	50
6	46	50
7	49	50
8	50	50
9	54	50
10	56	50
11	58	50
12	61	50
13	61	50
14	60	50
15	59	50
16	58	50
17	58	50
18	56	50
19	55	50
20	53	50
21	53	50
22	52	50
23	51	50
24	50	50
25	50	50
26	49	50
27	49	50
28	48	50
29	48	50
30	47	50
31	46	50
32	47	50
33	48	50
34	49	50
35	50	50
36	52	50
37	54	50
38	55	50
39	55	50
40	54	50

Pmode Time (minutes)	999 999 0 Temperature	
0	26	50
1	29	50
2	33	50
3	36	50
4	38	50
5	41	50
6	45	50
7	48	50
8	50	50
9	53	50
10	56	50
11	58	50
12	61	50
13	62	50
14	63	50
15	63	50
16	62	50
17	61	50
18	60	50
19	59	50
20	57	50
21	56	50
22	55	50
23	55	50
24	53	50
25	52	50
26	51	50
27	50	50
28	49	50
29	49	50
30	48	50
31	48	50
32	49	50
33	49	50
34	50	50
35	53	50
36	56	50
37	58	50
38	60	50
39	60	50
40	59	50

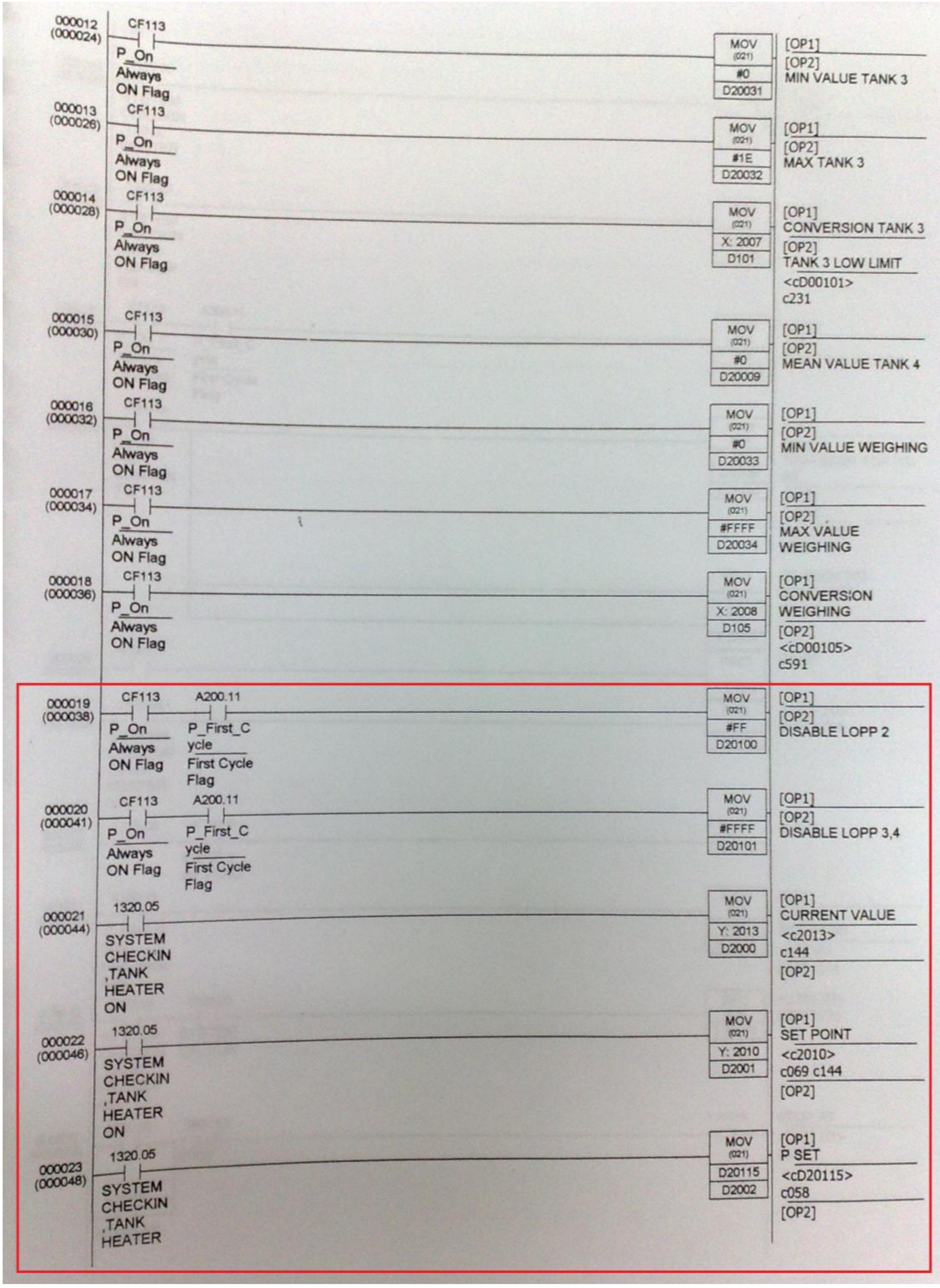
PI mode Time (minutes)	500 400 0 Temperature	
0	33	50
1	34	50
2	35	50
3	36	50
4	38	50
5	40	50
6	43	50
7	46	50
8	50	50
9	52	50
10	53	50
11	56	50
12	55	50
13	55	50
14	53	50
15	52	50
16	51	50
17	50	50
18	50	50
19	49	50
20	48	50
21	46	50
22	46	50
23	47	50
24	48	50
25	50	50
26	52	50
27	51	50
28	50	50
29	49	50
30	48	50
31	48	50
32	49	50
33	49	50
34	50	50
35	52	50
36	54	50
37	56	50
38	55	50
39	54	50
40	53	50

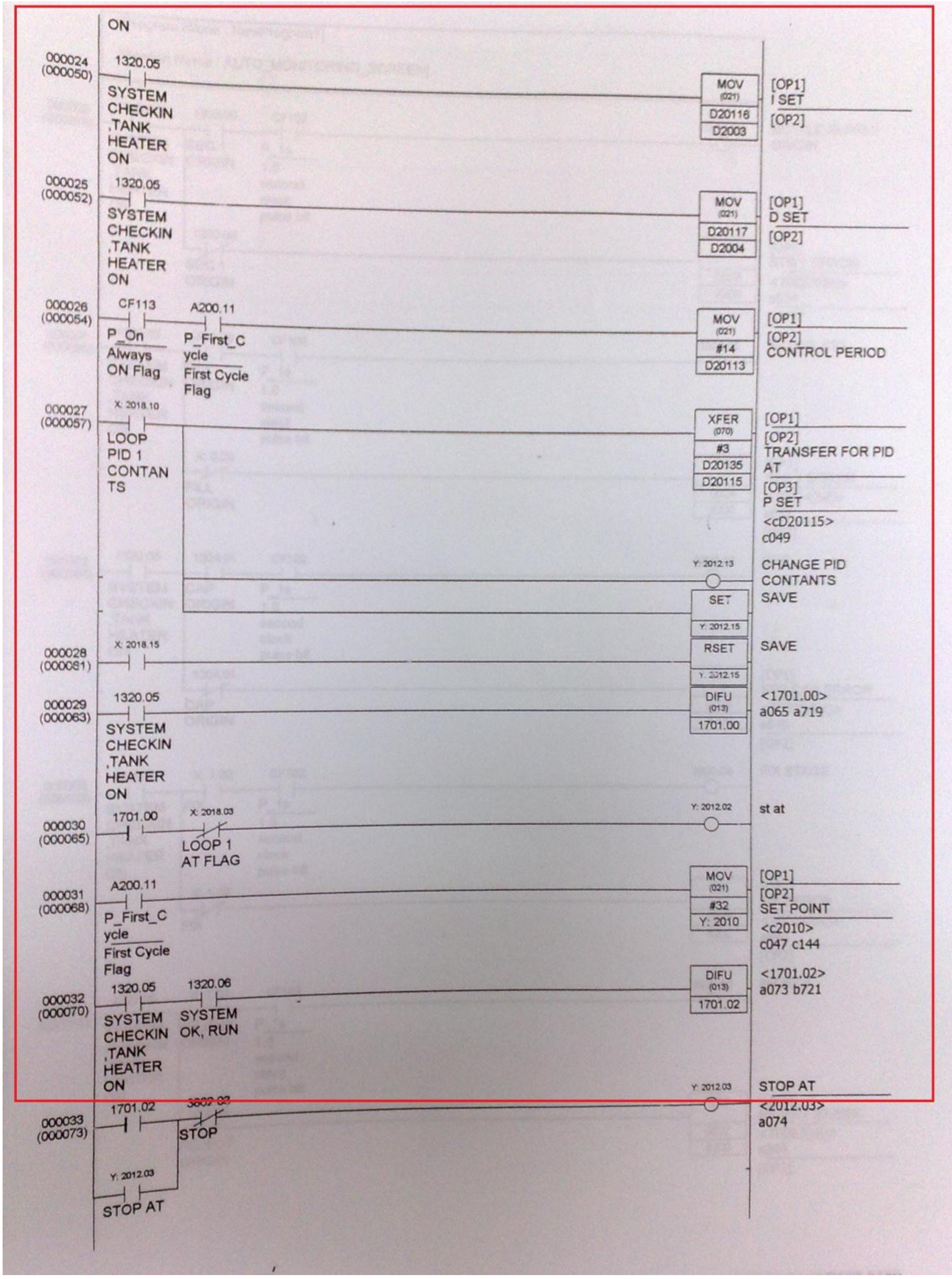
PI mode Time (minutes)	500 800 0 Temperature	
0	27	50
1	29	50
2	34	50
3	38	50
4	41	50
5	44	50
6	46	50
7	49	50
8	52	50
9	55	50
10	58	50
11	58	50
12	57	50
13	56	50
14	56	50
15	54	50
16	53	50
17	52	50
18	50	50
19	49	50
20	48	50
21	50	50
22	51	50
23	53	50
24	54	50
25	53	50
26	52	50
27	51	50
28	50	50
29	49	50
30	48	50
31	48	50
32	49	50
33	49	50
34	50	50
35	52	50
36	54	50
37	56	50
38	55	50
39	54	50
40	53	50

PI mode Time (minutes)	500 600 0 Temperature	
0	29	50
1	32	50
2	35	50
3	38	50
4	41	50
5	44	50
6	46	50
7	49	50
8	52	50
9	55	50
10	55	50
11	54	50
12	53	50
13	51	50
14	50	50
15	49	50
16	48	50
17	47	50
18	48	50
19	49	50
20	50	50
21	51	50
22	52	50
23	53	50
24	53	50
25	52	50
26	52	50
27	50	50
28	50	50
29	49	50
30	48	50
31	48	50
32	49	50
33	49	50
34	50	50
35	51	50
36	52	50
37	52	50
38	52	50
39	51	50
40	53	50

APPENDIX B

PID Implementation Related PLC Programming


000012
(000024)
CF113
P_On
Always
ON Flag
MOV
(021)
#0
D20031
[OP1]
[OP2]
MIN VALUE TANK 3
000013
(000026)
CF113
P_On
Always
ON Flag
MOV
(021)
#1E
D20032
[OP1]
[OP2]
MAX TANK 3
000014
(000028)
CF113
P_On
Always
ON Flag
MOV
(021)
X: 2007
D101
[OP1]
CONVERSION TANK 3
[OP2]
TANK 3 LOW LIMIT
<cD00101>
c231
000015
(000030)
CF113
P_On
Always
ON Flag
MOV
(021)
#0
D20009
[OP1]
[OP2]
MEAN VALUE TANK 4
000016
(000032)
CF113
P_On
Always
ON Flag
MOV
(021)
#0
D20033
[OP1]
[OP2]
MIN VALUE WEIGHING
000017
(000034)
CF113
P_On
Always
ON Flag
MOV
(021)
#FFFF
D20034
[OP1]
[OP2]
MAX VALUE
WEIGHING
000018
(000036)
CF113
P_On
Always
ON Flag
MOV
(021)
X: 2008
D105
[OP1]
CONVERSION
WEIGHING
[OP2]
<cD00105>
c591
000019
(000038)
CF113
A200.11
P_On
Always
ON Flag
P_First_C
ycle
First Cycle
Flag
MOV
(021)
#FF
D20100
[OP1]
[OP2]
DISABLE LOPP 2
000020
(000041)
CF113
A200.11
P_On
Always
ON Flag
P_First_C
ycle
First Cycle
Flag
MOV
(021)
#FFFF
D20101
[OP1]
[OP2]
DISABLE LOPP 3,4
000021
(000044)
1320.05
SYSTEM
CHECKIN
,TANK
HEATER
ON
MOV
(021)
Y: 2013
D2000
[OP1]
CURRENT VALUE
<c2013>
c144
[OP2]
000022
(000046)
1320.05
SYSTEM
CHECKIN
,TANK
HEATER
ON
MOV
(021)
Y: 2010
D2001
[OP1]
SET POINT
<c2010>
c069 c144
[OP2]
000023
(000048)
1320.05
SYSTEM
CHECKIN
,TANK
HEATER
MOV
(021)
D20115
D2002
[OP1]
P SET
<cD20115>
c058
[OP2]


ON
000024 (000050)
1320.05
SYSTEM CHECKIN ,TANK HEATER ON
MOV (021)
D20116
D2003
[OP1] I SET
[OP2]
000025 (000052)
1320.05
SYSTEM CHECKIN ,TANK HEATER ON
MOV (021)
D20117
D2004
[OP1] D SET
[OP2]
000026 (000054)
CF113
P_On Always ON Flag
A200.11
P_First_C ycle First Cycle Flag
MOV (021)
#14
D20113
[OP1]
[OP2] CONTROL PERIOD
000027 (000057)
X: 2018.10
LOOP PID 1 CONTAN TS
XFER (070)
#3
D20135
D20115
[OP1]
[OP2] TRANSFER FOR PID AT
[OP3] P SET
<cD20115> c049
Y: 2012.13
CHANGE PID CONTANTS SAVE
SET
Y: 2012.15
000028 (000061)
X: 2018.15
RSET
Y: 2012.15
SAVE
000029 (000063)
1320.05
SYSTEM CHECKIN ,TANK HEATER ON
DIFU (013)
1701.00
<1701.00> a065 a719
000030 (000065)
1701.00
X: 2018.03
LOOP 1 AT FLAG
Y: 2012.02
st at
000031 (000068)
A200.11
P_First_C ycle First Cycle Flag
MOV (021)
#32
Y: 2010
[OP1]
[OP2] SET POINT
<c2010> c047 c144
000032 (000070)
1320.05
SYSTEM CHECKIN ,TANK HEATER ON
1320.06
SYSTEM OK, RUN
DIFU (013)
1701.02
<1701.02> a073 b721
000033 (000073)
1701.02
STOP
Y: 2012.03
STOP AT
<2012.03> a074
Y: 2012.03
STOP AT

APPENDIX C

CJ1W-TC Series Operation Manual Sample Programs

Appendix B
Sample Programs

Reading the Process Value

Summary

This program reads each loop's process value (PV) data and stores the data in a DM Area word (D00100 to D00103 for loops 1 to 4). Each loop's input value is read by the MOV Instruction when the loop's Sensor Error Flag is OFF.

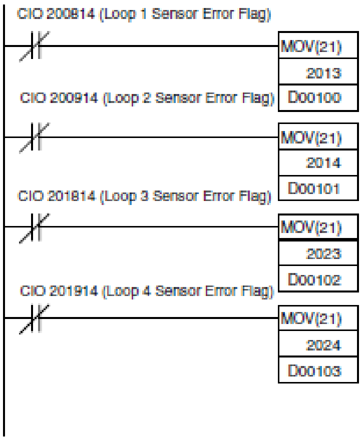
Example Unit Settings

- Unit: CJ1W-TC001 Temperature Control Unit
- Unit number: 00

Note The unit number switches are on the front of the Unit. Refer to *2-3-3 Unit Number Switches* for details.

Example Program

The Sensor Error Flags are in bit 14 of CIO (n+8), CIO (n+9), CIO (n+18), and CIO (n+19).



Writing the Set Point

Summary

This program writes the set point (SP) for loop 1.

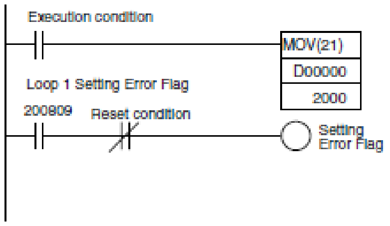
Example Unit Settings

- Unit: CJ1W-TC001 Temperature Control Unit
- Unit number: 00

Note The unit number switches are on the front of the Unit. Refer to *2-3-3 Unit Number Switches* for details.

Example Program

The Setting Error Flag for loop 1 is bit 09 of CIO (n+8).



Performing Autotuning and Refreshing the PID Constants

Summary

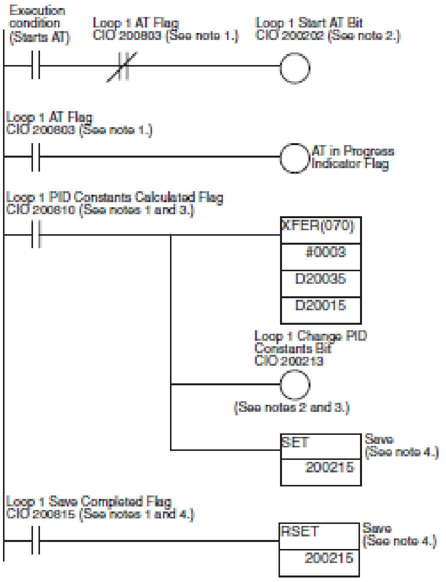
This program performs autotuning for loop 1 and refreshes the Temperature Control Unit's PID constants with the calculated PID constants.

Example Unit Settings

- Unit: CJ1W-TC001 Temperature Control Unit
- Unit number: 00

Note The unit number switches are on the front of the Unit. Refer to *2-3-3 Unit Number Switches* for details.

Example Program



Note 1. The Loop 1 AT Flag is bit 03 of CIO (n+8), the Loop 1 PID Constants Calculated Flag is bit 10 of CIO (n+8), and the Loop 1 Save Completed Flag is bit 15 or CIO (n+8).

2. The Loop 1 Start AT Bit is bit 02 of CIO (n+2) and the Loop 1 Change PID Constants Bit is bit 13 of CIO (n+2).

3. The PID Constants Calculated Flag will go OFF when the Change PID Constants Bit is turned ON.

4. If pin 8 of the DIP Switch is set to ON so that the settings in the Unit's EEPROM are transferred to the CPU Unit during initialization, always turn ON the loop's Save Bit to save the new settings to Temperature Control Unit's EEPROM.

Converting Data from Signed Binary to Signed BCD

Summary

This program converts binary setting/monitor values from signed binary (4 digits) to signed BCD (8 digits).

- When the most significant bit (leftmost bit) in a word is 1, that word is treated as 2's complement binary data.
- With signed BCD, the leftmost digit indicates the sign (0 for +, F for -) and the remaining 7 digits contain the BCD value.

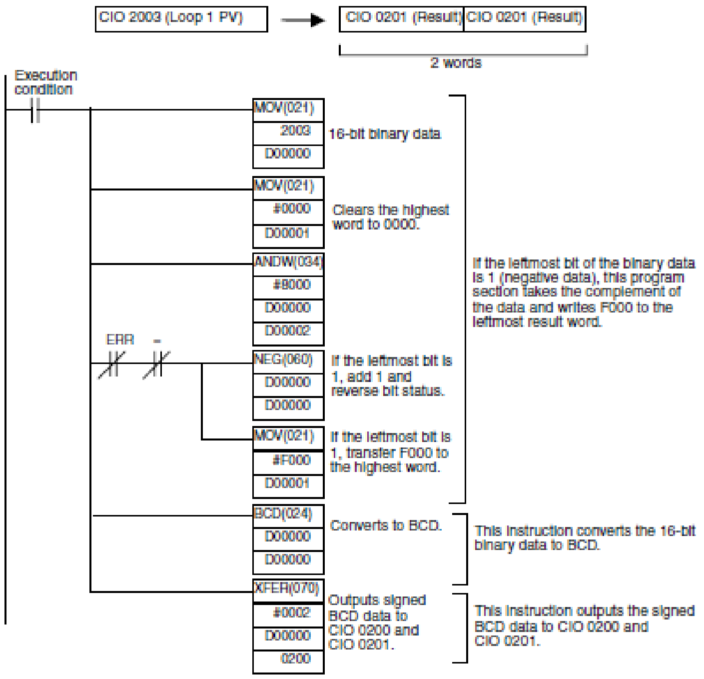
Example Unit Settings

- Unit: CJ1W-TC001 Temperature Control Unit
- Unit number: 00 (See note 1.)
- Data format: 16-bit binary (See note 2.)

Note 1. The unit number switches are on the front of the Unit. Refer to *2-3-3 Unit Number Switches* for details.

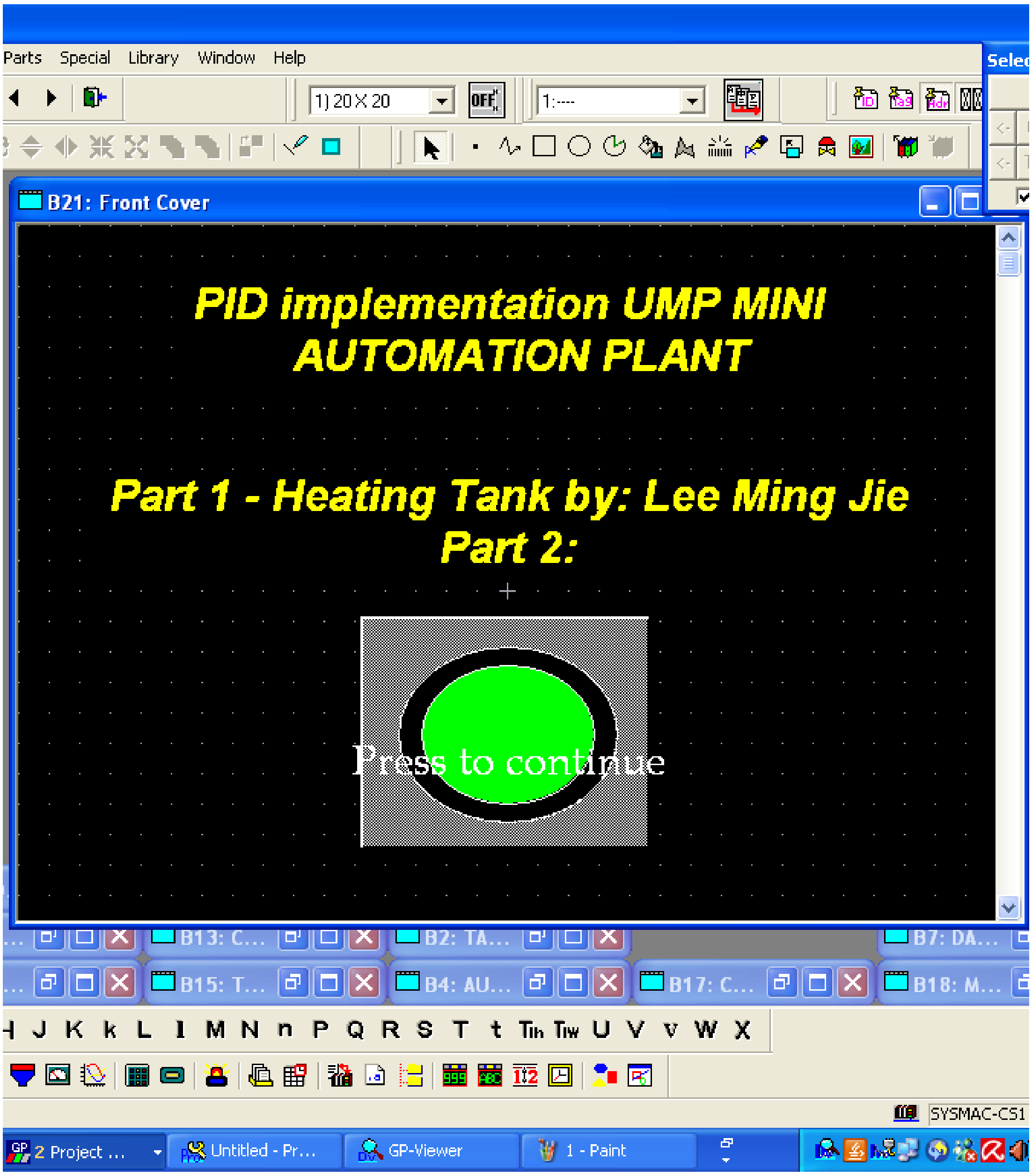
2. Turn ON pin 3 of the DIP switch to select the binary data format.

Example Program



APPENDIX D

Created And Edited Touch Screen's Screen Programming

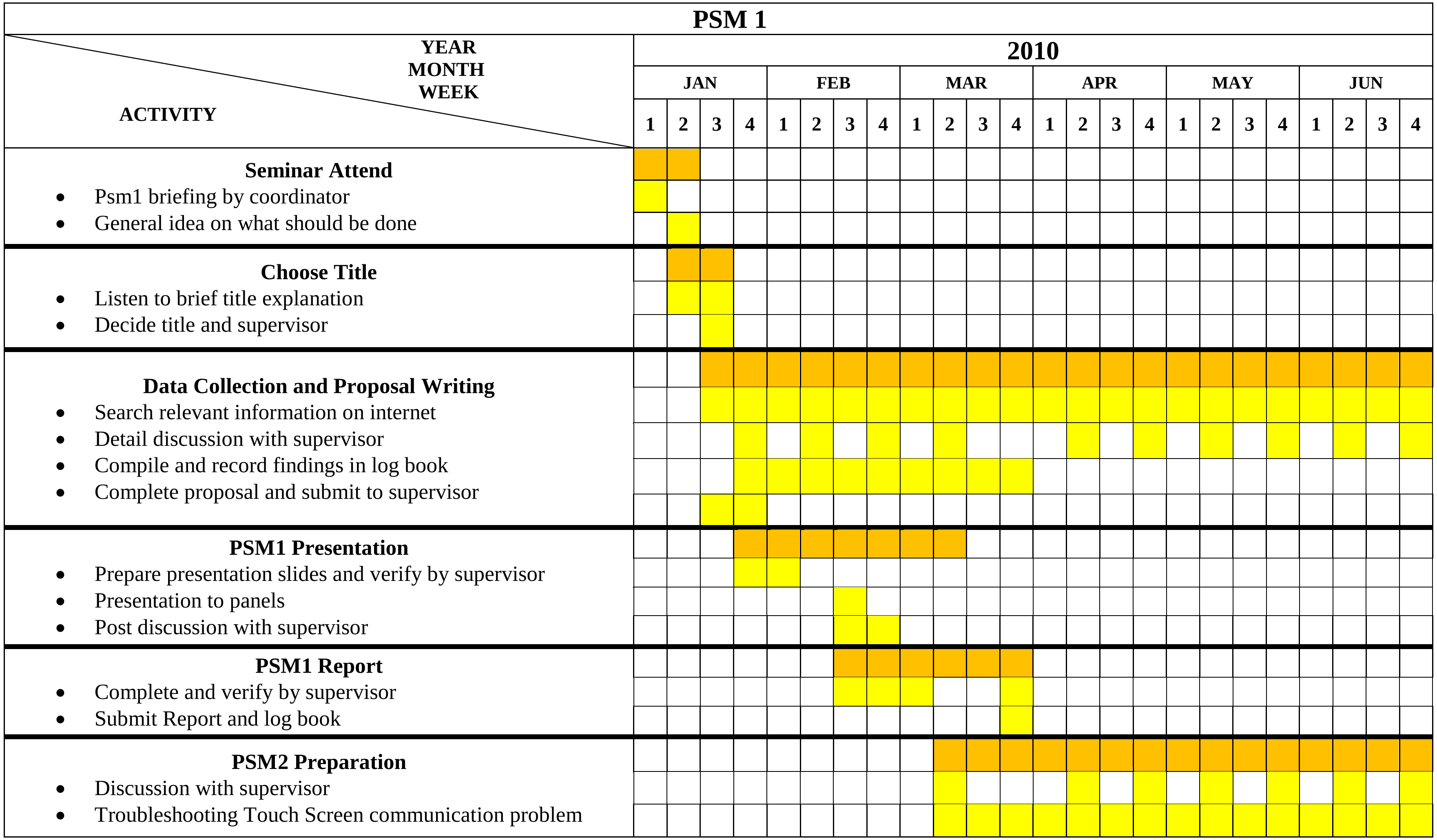

Parts Special Library Window Help
B21: Front Cover
PID implementation UMP MINI AUTOMATION PLANT
Part 1 - Heating Tank by: Lee Ming Jie
Part 2:
Press to continue
SYSMAC-CS1
GP-Viewer
1 - Paint


Board - MJL de S
View Option Draw Tags Parts Special Library Window Help
B1: MAIN LAYER
UMP MINI AUTOMATION PLANT
CIO380400
MENU
CIO380400
AUTO START
DESIGN BY EASY TECHNOLOGY SDN BHD
EDITED BY LEE MING JIE
562(3%) Ready

APPENDIX E

PSM 1 and PSM 2 Gantt Chart

Gantt chart PSM 1



Gantt chart PSM 2

PSM 2																								
YEAR	2010																							
MONTH	JULY				AUG				SEPT				OCT				NOV				DEC			
ACTIVITY / WEEK	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Seminar Attend																								
• PSM 2 Briefing and talk on how to write thesis																								
• Review of PSM 1 and correction on all mistakes																								
Literature Review																								
• Review: Temperature Control Unit, PID and PLC																								
• Studies of PLC and tough screen programming																								
Preparation & Submission of Thesis Drafts																								
• Prepare and Submit Draft 1 to Supervisor																								
• Prepare and Submit Draft 2 to Supervisor																								
• Submit Final Draft, Log Book and Evaluation Form to Supervisor																								
• Submit abstract, Final Draft and Evaluation Form to 2nd Evaluator																								
Hardware Development																								
• Constant maintenance and repairing																								
• Attempt to run auto mode																								
• PID simulation on tank 2																								
Software Development																								
• Study the PID ladder and screen																								
• Add new features to existing programming																								
PSM2 Seminar																								
• Abstract, Presentation Slide and Evaluation Form submission to Panels																								
• Attending PSM 2 Seminar and Demo Session																								
Compilation and Submission of Thesis																								
• Printing and Submit Thesis for Hard Binding																								