Design and analysis of heat pump control system by using Programmable Logic Controller

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“ I hereby declare that I have read through this report entitle “Design and analysis of heat pump control system by using PLC” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Mechatronic)”

Signature : ....

Supervisor"s Name : ....

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“I declare that this report entitle “Design and analysis of heat pump control system by using PLC” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Name : ....

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ABSTRACT

This paper presents a control system for heat pumps. As we know buildings like hotel requires a large amount of heat pumps to generate enough hot water to all the rooms. To assist the workers in monitoring the operation and performance of heat pump, a control system is proposed. The objectives of this project are to design a controller that can control different types of heat pumps and also to monitor the performance and operation of heat pump. Another objective of this project is to analyze time needed for the heat pump to increase the water temperature to a set point temperature using the controller developed and analyze the high and low pressure of the system during operation for safety and performance purpose. The scope of project is to design ladder diagram using Programmable Logic Controller (PLC) that can run the operation of heat pumps and indicate errors of heat pumps. Besides that hardware will be presented to demonstrate the operation. Programmable Logic Controller (PLC) software named as WindLDR, software that is made by IDEC will be used to design the program that operates the flow of heat pumps and errors indication. PLC hardware, IDEC's FC5A series Micro Programmable Logic Controller will be connected to a LCD display, HG3G series LCD display to monitor the operation and LED lamp to indicate the devices of heat pump that is operating and errors that occur in the system. The experiment is to analyze the discharge pressure, suction pressure of the compressor and also the water tank temperature. With these data recorded through the controller, the performance of the heat pump can be determine. Limits have been set for the pressure and temperature so that the heat pump operation will be terminate when the readings exceed the limit set. To conclude, the controller is able to monitor can control the operation of heat pump.

ABSTRAK

Kertas kerja ini membentangkan satu sistem kawalan untuk pam haba. Seperti yang kita tahu bangunan seperti hotel memerlukan sejumlah besar pam haba untuk menghasilkan air panas yang cukup untuk semua bilik. Untuk membantu pekerja dalam memantau operasi dan prestasi pam haba, sistem kawalan dicadangkan . Objektif projek ini adalah untuk membentuk pengawal yang boleh mengawal pelbagai jenis pam haba dan juga untuk memantau prestasi dan operasi pam haba. Satu lagi objektif projek ini adalah untuk menganalisis masa yang diperlukan untuk pam haba untuk meningkatkan suhu air pada suhu titik set menggunakan pengawal maju dan menganalisis tekanan tinggi dan rendah sistem semasa operasi untuk tujuan keselamatan dan prestasi. Skop projek ini adalah membentuk gambar rajah tangga dengan Programmable Logic Controller (PLC) yang boleh menjalankan operasi pam haba dan menunjukkan kesilapan pam haba. Selain perkakasan yang akan dibentangkan untuk menunjukkan operasi. Programmable Logic Controller perisian (PLC) yang dinamakan WindLDR, perisian yang dibuat oleh IDEC akan digunakan untuk membentuk program yang mengendalikan aliran pam haba dan kesilapan petunjuk. Perkakasan PLC, siri FC5A IDEC Micro Programmable Logic Controller akan dihubungkan dengan paparan LCD, HG3G paparan siri LCD memantau operasi dan lampu LED untuk menunjukkan peranti pam haba yang beroperasi dan kesilapan yang berlaku dalam sistem. Eksperimen ini adalah untuk menganalisis tekanan pelepasan, tekanan sedutan pemampat dan juga suhu tangki air. Dengan data ini direkodkan melalui pengawal, prestasi pam haba boleh menentukan. Had telah ditetapkan untuk tekanan dan suhu supaya operasi pam haba akan tamat apabila bacaan melebihi set had. Kesimpulannya, pengawal dapat mengawal operasi pam haba.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Conventional heat pump control system is very complicated. It requires many devices to control different parts of the system. To monitor the pressure compressor, it requires pressure transducer, pressure gauge, pressure switches. Besides that, many relays, contactors, timers are needed to be installed to control the heat pump. This require a large place to install all these components and it is costly. To simplify all these problems, a heat pump control system built using a PLC with a touchscreen interface. It can be connect with multiple sensors and transducer and also record the data which the conventional control system lack of. The PLC itself have numbers of internal relays, timers and counters that can replace all the relays that require place to install. This not only save space but also making the system easier to be control and monitor.

1.2 Problem Statement

The designs for controller today are getting more and more complicated. Designer tends to add more features into the controller which make customers require more time and knowledge to understand and learn the proper functions of the controller. To overcome this problem, the design of the controller of this project will be made simple and more users friendly so that even normal household owner will be able to control their heat pump themselves. The focus of this project is to develop a controller by implementing programmable logic controller with a touchscreen LCD display which able to control and monitor the operation of heat pump. Besides that, an analysis will be done using the controller to observe the water temperature changes through the controller and also the pressure changes within the system as the water is being heat. Input and output temperature data will be recorded for efficiency analysis.

1.3 Objectives

- To develop a controller using programmable logic controller that able to control different types of heat pumps and monitor its operation.
- To analyse the safety and performance of the heat pump by monitoring the suction pressure and discharge pressure at the compressor.
- To analyse time needed for the heat pump to increase the water temperature into a particular temperature using the controller developed.

1.4 Scope

The scope of this project is to design a multi-heat pump controller. The controller software will be programmed using WindLDR software. This is IDEC brand Programmable Logic Controller (PLC) ladder diagram software. A Programmable Logic Controller (PLC) will be used as the hardware of the controller where it will be connected to a LCD display to monitor the operation of the heat pump system and also analyzing the performance, water temperature and high low pressure of the compressor in the heat pump system. A temperature sensor is used to measure the temperatures whereas a pressure transducer will be used to measure the pressures of the compressor. The hardware used are IDEC's FC5A series Micro Programmable Logic Controller and HG3G series touch screen LCD display. Shinko's Temperature controller serve as the temperature sensor while Carel's Pressure Transducer is the chosen pressure transducer for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Review and comparison of journals

In the first journal [1], ST89C51 microcomputer is used as the core of the controller to execute the fuzzy logic algorithm to control the drying temperature of heat pump. The control system includes high power op-amp, analogue to digital and digital to analogue converter, input photoelectric isolation, drive circuit, a keyboard and a display circuit. Thermocouple is used to detect temperature in the system and send output voltage signal to the control system. As its signal value is small, hence an amplifier is needed to amplify the signal before converting into digital signal through the converter. After this, the digital signal will be sent to the microcomputer to compare the value before sending signal back to the heat pump. By using thermocouple as the sensor to gain feedback from the system, the algorithm will calculate the error and reduce the pure time delay, decrease the overshoot and increase stability into the system. The algorithm used is to vary the best possible power output to increase efficiency of the system and its rate of temperature rises.

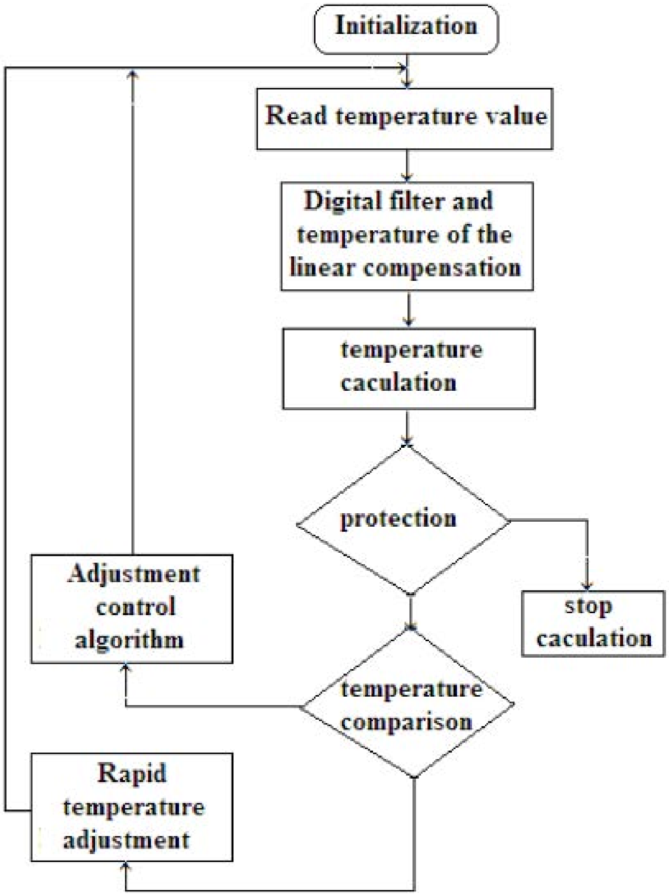

Figure 2.1.1: Flow chart of the system in journal 1.

In the second journal [2], the controller that is chosen is Omron CJM-CPU12 programmable logic controller. It is connected to a temperature control unit where it is used to determine the water temperature and send feedback into the system. A computer is used as display to record data and observe the changes in system using multiple software such as GP viewer and PROFACE project manager. The program that is used for operating the programmable logic controller is Omron's CX programmer. This controller is built to analyze the heating rate of the heating tank using different ways to controller. Three control methods that are used during the experiment are the proportional method (P), proportional integral method (PI) and proportional integral derivate method (PID). Among these three methods, PID controller have the best performance based on few criterias which are rise time, settling time, peak time, delay time and also the percent overshoot.

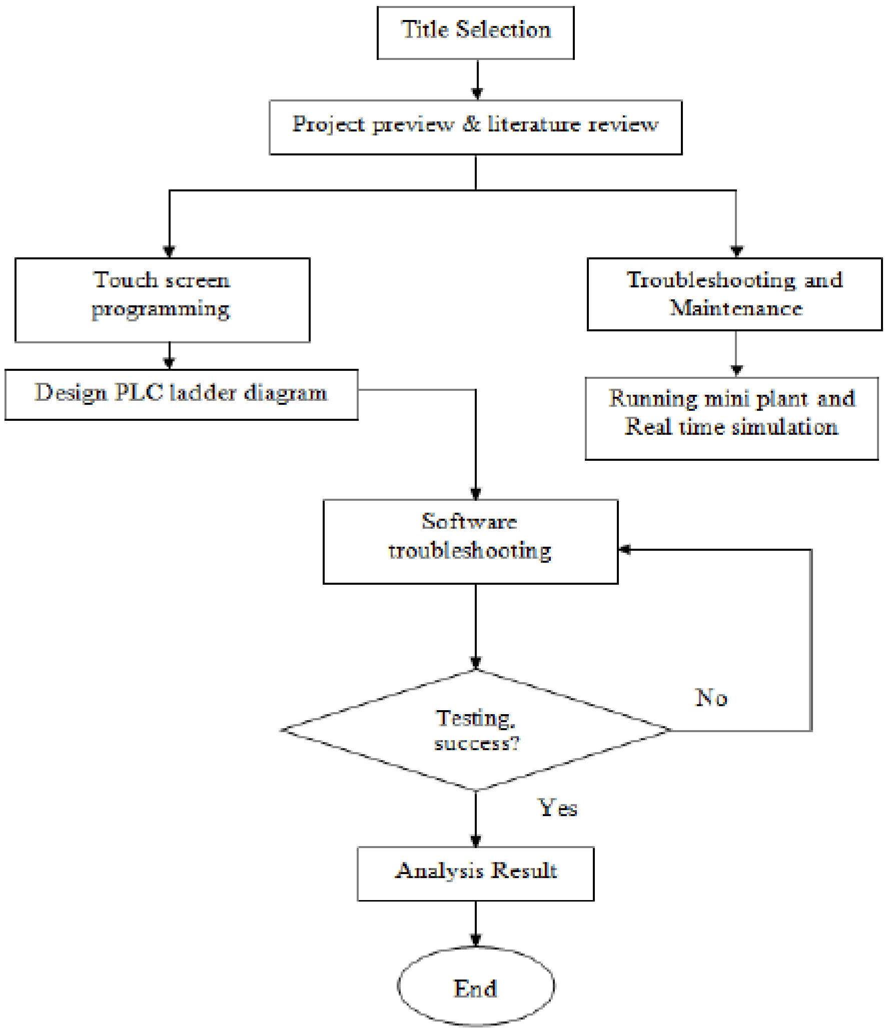

Figure 2.1.2: System flow chart for journal 2.

In Yan Yang and Haiyun Bian's paper [3], fuzzy self-tuning PID control method is implemented using programmable logic controller. A DVP-28SV Delta PLC is used and a DTC1000 temperature controller is utilized as a temperature sensor where thermocouple is connected as input. Thermocouple will detect the water temperature in the water tank and send feedback signal back to the programmable logic controller. PID controller will calculate using its algorithm to control the power output of the heater. The analysis is done using MATLAB Simulink simulation. There are two controllers used for comparison. One is the fuzzy auto-tuning PID controller whereas the other one is conventional PID controller. Based on the results got from the simulation, fuzzy auto-tuning PID controller has better performance compared to the other controller as it has smaller percent overshoot, adjustment time and dynamic response.

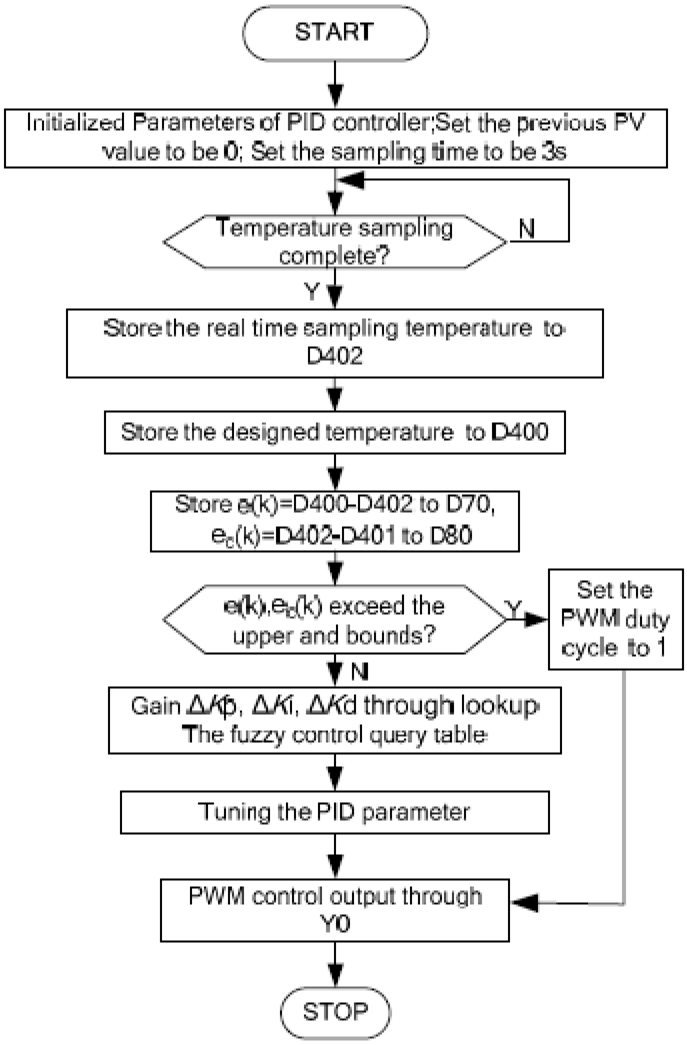

Figure 2.1.3: System flow chart for journal 3.

Based on Lv Shu-dong's experiment [4], it uses Mitsubishi FX2N series programmable logic controller to control the drying rate of refrigerant in the evaporator. The drying rate will be change by control the refrigerant mass flow rate entering the evaporator and compressor and vary rotational speed of compressor. A Siemens Simatic TP170B LCD touch screen display is connected to the programmable logic controller to monitor the status of the heat pump. This is to make sure the heat pump is functioning well and users can be notified if there is any fault or error occur in the system through the display.

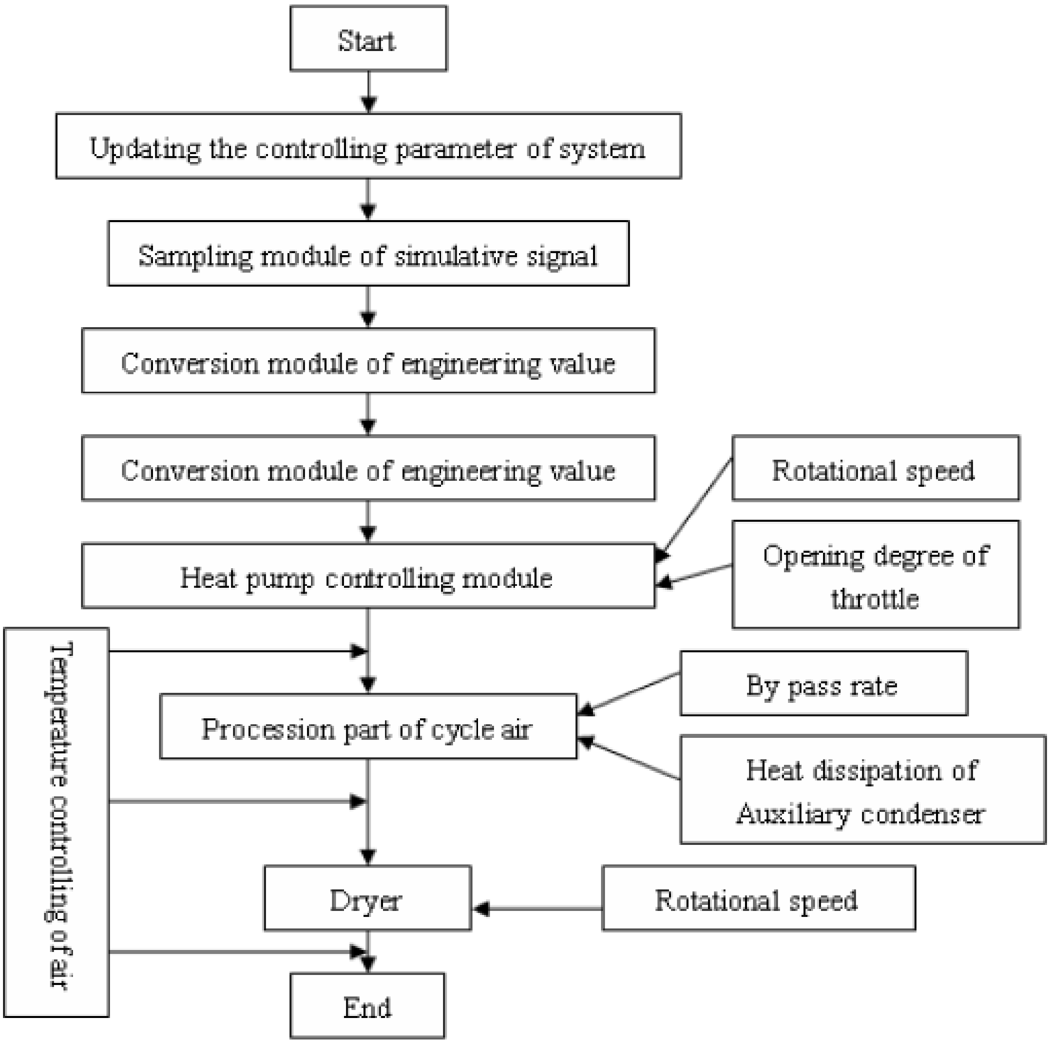

Figure 2.1.4: System procedure flow for journal 4.

According to the journal written by D.V. Pushpa Latha, K.R. Sudha and Devabhaktuni Swati [5], a millennium 3 programmable logic controller is used to control temperature by using LM35 as temperature sensor. The experiment in undergone by detecting temperature in the surrounding and compare to the temperature set point set in programmable logic controller. If the surrounding temperature is higher than the set point temperature the fan will turn on. On the other hand, heater will turn on if the surrounding temperature is lower than the set point temperature. Different types of control is tested to compare its performance. The methods are on/off control, proportional control, PID control and PLC control. The results shows that PLC is the most effective controller.

Table 2.1.1: Summary of comparison in between journals.

No.	Title	Control Method	Control unit	Advantages and disadvantages
1	Thermoelectric Heat Pump Drying Temperature Control System on the Basis of 89C51 (2012) [5]	Control the drying temperature of heat pump using fuzzy logic through a Single Chip Microcomputer (SMC). Performance such as rise time, settling time, peak time and percent overshoot is recorded for analysis.	**Single Chip Microcomputer ST89C51 (microcontroller)** o On-chip FLASH Program Memory o Speed up to 33 MHz o RAM expandable externally to 64 k bytes o 4 level priority interrupt o 6 interrupt sources o Four 8-bit I/O ports o Programmable clock out o Second DPTR register o 3 16-bit timers **Thermocouple (Temperature Sensor)**	<u>Advantages</u> o Thermocouple is inexpensive, high precision, wide measuring range and quick response. o Low cost. Cost only around RM15 per chip. <u>Disadvantages</u> o System has high overshoot due to unstable control system and algorithm.
2	PID Implementation of Heating Tank in Mini Automation Plant Using Programmable Logic Controller (PLC) (2011) [6]]	Control the time to heat up a particular solution in heating tank using the Programmable Logic Controller implementing Proportional Integral derivative (PID) control. Different kinds of PID parameter such as Proportional (P),	**PLC OMRON CJ1M-CPU12 (Programmable Logic Controller)** o Power: 5VDC (580mA) o Number of I/O points : 320 o Maximum number of modules : 10	<u>Advantages</u> o Able to monitor the condition of the system from far side. o Can control the heating time efficiently if using PID control.

		Proportional Integral (PI) and Proportional Integral derivative (PID) Is used to collect and compare the performance based on the settling time, rise time, peak time, delay time and percent overshoot.	o Program capacity: 10Ksteps o Data memory capacity: 32Kwords o Ladder diagram processing speed: 100ns **Omron Temperature control unit CJ1W-TC001 (connect with thermocouple to use as temperature sensor)** o No. of loops: 4 o Temperature sensor inputs: Thermocouple o Control outputs: Open collector PNP outputs o No. of unit numbers allocated: 2 o Current Consumption: 5V (0.25A) **CX programmer(PLC software)** o For ladder diagram design **PROFACE Project Manager (Display software)** o To monitor the system through computer or a LCD display **GP Viewer (Software)**	<u>Disadvantages</u> o High cost as the programmable Logic Controller cost at least RM2000 and the temperature control unit cost around RM1000 o PID parameters are fixed hence it cannot change its precision.

			Collect data from system and send to computer or LCD display	
3	Design and Realization of Fuzzy Self-tuning PID Water Temperature Controller Based on PLC (2012) [7]	Control the time needed to heat up the water in water tank using fuzzy-PID controller. The results are collected by comparing data from a PID controller and fuzzy-PID controller. Data such as peak time, rise time, settling time and percent overshoot is collected for comparison.	**Delta PLC (DVP-28SV) (Programmable Logic Controller)** - Power: 20.4 to 28.8 VDC - Digital Inputs: 8 (24VDC sink/source) - Digital Outputs: 12 NPN open collector - Output rating: 0.3A - Program capacity: 16Ksteps - Execution speed: 0.24µs per instruction - I/O points: Up to 512 points - High Speed counters:4 counters, 200KHz **DTC 1000 temperature controller (Connect with thermocouple to use as temperature sensor)** - Power: 24VDC - Input: Thermocouple, voltage and current - Output: Relay (240VAC, 3A), Voltage pulse (12VDC, 40mA)	<u>Advantages</u> - Control system have High accuracy - Small percent overshoot - strong anti-interference performance and good robustness <u>Disadvantages</u> - Expensive, PLC cost around RM1500 per unit.

			SIMATIC WinCC (Software) ○ Used to insert control parameter and collect data from the system. **Matlab (Simulink)** ○ Used for simulation.	
4	Study on Controlling Simulation of Heat Pump Drying System Based on PLC (2012) [8]	Control the drying rate of refrigerant in the evaporator by using programmable logic controller. The drying rate will be change by control the refrigerant mass flow rate entering the evaporator and compressor and vary rotational speed of compressor. The running status of the drying system can be monitor through a human machine interaction (HMI) LCD display. Fault alarm status, control parameter, electric power status and records of fault status can be monitor and control through the LCD touch screen display.	**Mitsubishi FX2N series (programmable logic controller)** ○ Power: 100 to 240VAC ○ Number of Input points: 64 ○ Input type: 24VDC sink/source ○ Number of Output: 64 ○ Output type: Relay MR-ES/UL, Transistor MT-ESS/UL **Siemens Simatic TP170B** ○ Display size: 5.7” (320*240) ○ Control: Touch screen ○ Power: 24VDC (0.25A) ○ Configuration Software: WinCC flexible compact 2004	<u>Advantages</u> ○ Able to monitor the status of the system through a display ○ Parameter can be control through display ○ Errors can be found through display <u>Disadvantages</u> ○ Lack of data in the results that didn’t show the performance in the control section. ○ Touch screen display is expensive as it cost $1790 which is around RM5000 per unit.

5	Millenium3 PLC Based Temperature Control Using LM 35 (2013) [9]	Control the temperature of a place using a temperature sensor called LM35 and control using Millenium 3 Programmable Logic Controller (PLC). Based on the temperature detected through the sensor, the PLC will turn on the fan or heater to maintain the temperature of the place. It has 3 types of control, on/off control, proportional control and PID control. Different types of control can obtain different results.	**Millenium 3 PLC (Programmable Logic Controller)** o Power: 24VDC o No. of Inputs: 12 (8 digital and 4 analogue) o No. of outputs: 4 (Relay type) o Output current:8A **LM35DZ temperature sensor** o Power: 4 to 30VDC o Output voltage:-1 to 1.5VDC (10mA) o Temperature range: -55 to 150^{o}C o Scale factor: 10mV/ ^{o}C	<u>Advantages</u> o Simple setup. o Small size PLC o Cheap temperature sensor. o Low price for PLC a it cost around RM500. <u>Disadvantages</u> o Lack of data

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