BRAKE CONTROL SYSTEM FOR MOTORIST VEHICLE

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

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NOVEMBER, 2007

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Signature : ______________________________

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Date : 23 NOVEMBER 2007

To my beloved father and mother ....

who always give me a courage to finish this thesis.

Also, to those people who have guided and inspired me throughout my journey. Thank you for the supports and advices that have been given.

ACKNOWLEDGEMENT

This project would not have been possible without considerable guidance and support. So, I would like to acknowledge those who have enabled me to complete this project.

In particular, I wish to express my sincere appreciation to my main thesis supervisor, Encik Muhammad Sharfi Bin Najib, for encouragement, guidance, critics and friendship.

Secondly, I would also like to thank for all other University Malaysia Pahang staff members that I may have called upon for assistance since the genesis of this project. Their opinions and suggestions have helped me in realizing this project. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space.

Finally, I would like to thank to my family for their understanding, encouragement and support, towards the completion of my project.

ABSTRACT

Braking control system for motorist vehicle is a study and implements safety braking system into PLC (Omron) to control the speed of AC motor. The purpose of this project is to design and develop a brake control system using a Programmable Logic Control, (PLC) and implement it into brake control system nowadays. This brake system is using OMRON CQM1H programmable controllers as controller, MITSUBISHI FR-S 500 inverter as a converter to convert DC source from PLC to AC source for AC motor and DC voltage power supply as a sensor. This braking control system will detect any obstacle in front of the vehicle and reducing the AC motor rotation depends on the distance of the obstacle. This concept is almost similarly to nowadays braking control system, Adaptive Cruise Control (ACC). As a result, this brake control system is able to be controlled by varying the voltage regulated based on distance sensor specification.

ABSTRAK

Sistem kawalan henti kenderaan bermotor ini adalah satu kajian dan pengaplikasian sistem henti yang selamat dengan menggunakan kawalan PLC (Omron) untuk mengawal kelajuan motor AC. Tujuan projek ini adalah untuk mereka dan membangunkan sebuah sistem kawalan henti kenderaan bermotor menggunakan PLC dan mengaplikasikannya ke dalam kehidupan seharian. Sistem kawalan henti ini menggunakan OMRON CQM1H sebagai kawalan, MITSUBISHI FR-S 500 sebagai penukar iaitu menukarkan sumber arus terus daripada PLC kepada sumber arus ulang-alik untuk motor AC dan DC voltage supply sebagai sensor. Sistem kawalan henti ini akan mengesan sebarang halangan di hadapan kenderaan dan mengurangkan kelajuan putaran motor AC bergantung kepada jarak halangan dengan kenderaan. Konsep sistem kawalan henti ini menyerupai dengan teknologi sistem kawalan henti Adaptive Cruise Control (ACC). Kesimpulannya, sistem kawalan henti ini mampu dikawal dengan mengubah nilai voltan kawalan dan ia bergantung kepada spesifikasi sensor jarak.

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RH	-	Rotation High
RM	-	Rotation Medium
RL	-	Rotation Low
STF	-	Start Forward
STR	-	Start Reverse
COM	-	Common

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CHAPTER 1

INTRODUCTION

1.1 Background

The development of brake technologies start from self-adjusting brakes, disk brakes, tandem hydraulic systems, diagonally split hydraulic systems, vacuum operates booster, self-contained electrically power hydraulic booster, computer-control antilock braking systems and self adjusting parking brakes. Latest technology in braking control systems is called Adaptive Cruise Control (ACC).

This project is referring to the new technology braking control concept, Adaptive Cruise Control or ACC where all new vehicles soon will be fit with computer-controlled radar systems that will automatically apply the brakes when a potential hazard is sensed.

Adaptive cruise control is a braking control systems that can automatically adjust a car‘s speed to maintain a safe following distances in the same lane. If ahead vehicle is slowing down, or if any obstacle is detected, the system sends a signal to the engine or braking system to decelerate. Then, when the road is clear, the system will re-accelerate the vehicle back to the set speed. The forward-looking radar that used in this braking control system can sense up to 150 meter and place behind the grill of vehicle to detect the speed and distance of vehicle ahead of it.

TRW and Delphi Automotive Systems is a of international company that developing this braking control systems and get the positive feedback from car manufacturer such as Mercedes-Benz, BMW and Jaguar. TRW adaptive cruise control products called Auto-cruise was implement to European S-class Saloon for Mercedes-Benz. Then BMW followed the Mercedes-Benz step and installed this braking control system for its European models.

1.2 Objectives

1.2.1 The main objective of this project is to design and develop a brake-control system for motorist vehicle using PLC. Current brake control systems for motorist vehicles nowadays are manual that required driver to control the speed and the gap between the vehicles and the front car. 60% of front-end crashes would not occur if the driver could react a split second earlier.

1.2.2 The secondary objective of this project is to introduce and implement PLC in contemporary system nowadays. Normally controllers related to industry but this time we try to implemented the PLC controller in daily day for improving and better environments. Beside, this brake control system is added to aids driver comfort by reducing driving stress and fatigue, which allows better concentration when driving.

1.3 Project Goal

This brake control system is not fully controlled the vehicle brake. It still can be interrupt anytime by the driver in case for emergency. After a bit of research we determined it would be another solution for safety driving aid for driver.

- Reducing driving stress and fatigue which allows a better concentration when driving.
- Improved safety driving aid for driver which allows a safety driving and second back up driver.

1.4 Thesis Organization

This final thesis is a combination of 5 chapters that contain the introduction, literature review, methodologies review, result and discussion, conclusion and further development that can be applied in this project.

Chapter 1 is an introduction of the project. In this chapter, the main idea about the background and objectives of the project will be discussed. The overview of the entire project also will be discussed in this chapter to show proper development of the project.

Chapter 2 will be discussed about the literature review for the development of the Brake-Control System for Motorist Vehicle. This includes explanation about Adaptive Cruise Control (ACC) and Programmable Logic Control (PLC) in this project.

Chapter 3 will be discussed about the methodologies for the development of the Brake-Control System for Motorist Vehicle. This section will be focused on all the hardware such as controller of this system which Programmable Logic Control (PLC), MITSUBISHI FR-S 500 inverter, AC motor and DC voltage power supply as a sensor.

Chapter 4 will be discusses all the results obtained and the limitation of the project. All discussions are concentrating on the result and performance of the Brake-Control System for Motorist Vehicle.

Chapter 5 will be discussed about the conclusion and recommendation of the project. This chapter also discusses the problem and the recommendation for this project for further future project development in this field.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The European Commission wishes to cut 50% of vehicle accidents by 2010. In the meantime, studies made have revealed that 60% of front-end crashes would not occur if the driver could react a split second earlier. In order to alleviate to this reaction time, research has demonstrated that Adaptive Cruise Control or ACC significantly aids driver comfort by reducing driving stress and fatigue, which allows better concentration when driving. This includes definitely ACC systems in active safety. [6]

2.2 Adaptive Cruise Control

Adaptive Cruise Control or ACC is a system that regulates speed and maintains a gap between a vehicle and the vehicle or obstacles immediately ahead. [1] This system has implemented in latest brake control system nowadays in worldwide cars such as BMW, Mercedes Benz and Audi. It was developed by TRW and Delphi Automotive System. They are advanced the brake control system technology that can automatically adjust a car's speed to maintain a safe following distance. This new technology uses forward-looking radar, installed behind the grill of a vehicle, to detect the speed and distance of the vehicle ahead of it. [7]

Mercedes-Benz became the first car manufacturer to install TRW's adaptive cruise control, called Auto-cruise, adding the device to its European S-Class Saloons. BMW followed Mercedes-Benz later by adding the system to some of its European models. Delphi Automotive Systems has developed a similar adaptive cruise control system, already available on the 2000 Jaguar XKR in Europe. [7]

Adaptive cruise control is similar to conventional cruise control in that it maintains the vehicle's pre-set speed. However, unlike conventional cruise control, this new system can automatically adjust speed in order to maintain a proper distance between vehicles in the same lane. This is achieved through a radar headway sensor, digital signal processor and longitudinal controller. If the lead vehicle slows down, or if another object is detected, the system sends a signal to the engine or braking system to decelerate. Then, when the road is clear, the system will re-accelerate the vehicle back to the set speed. [7]

The Auto-cruise radar system has a forward-looking range of up to 500 feet, and operates at vehicle speeds ranging from 18.6 miles per hour to 111 mph. Delphi's system can also detect objects as far away as 500 feet, and operate at speeds as low as 20 mph. [7]

Adaptive cruise control is just a preview of the technology being developed by both companies. These systems will be enhanced to include collision-warning capabilities that will warn drivers through visual and/or audio signals that a collision is imminent, and that braking or evasive steering is needed. [7]

2.3 Programmable Logic Control (PLC)

Since 1970's, PLC system began being used in order to ease human activities. It is a control system that is applied to change the behavior of the system. When industrial revolution started, PLC has become common choice for manufacturing controls. In the past, humans are the main methods for controlling a system. Nowadays, PLCs have been gaining popularity in factories sectors because it is advantages: [8]

- Cost effective for controlling complex systems
- Flexible and can be reapplied to control other systems quickly and easily
- Computational abilities allow more sophisticated control
- Trouble shooting aids make programming easier and reduce downtime
- Reliable components make these likely to operate for years before failure.

In addition, PLC is a user friendly, microprocessor specialized computer that can be used to implements many types of complex control function in various types and levels. It is widely used in control process. [8]

The type of control problem often determines the type of control system that can be used. Each controller will be designed to meet a specific objective. The major types of control are continuous or discrete. The continuous control can be divided into two-types of control which are linear and non-linear. As for linear, PID is used while for the non-linear Fuzzy logic is the best method control system. The function of continuous controller is to control values to change smoothly. For the example is the speed of a car. [8]

There are many types of PLC being used in industries according to their needs such as OMRON, SIEMENS and FESTO. The main method of PLC is ladder diagram. In this project CX-Programmer is used as software to PLC run up. They can be programmed, controlled and operated by drawing the lines and devices of a ladder diagram with a keyboard onto a display screen. The drawing is converted into computer machines language and run as a user program. It is usually used for motor control or a process that involved relays (switch). This technique is based on relay logic wiring schematics. In the past, electrical control based on relay and nowadays it has been used for control whereby these relays allow power to be switched ON or OFF without a mechanical switch. The use of relays is the decision especially to make a simple logic control. It can operate any system with discrete or digital as well as analog output. [8]

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this brake control system, there are four methods that we used such as direct online, PLC connected to inverter for single speed, multi speed and multi speed with approaching to Fuzzy logic. These methods are used to check the hardware either properly functioning or not and fit with the task that it will conduct later. Besides this project have to start from below to upper simultaneously

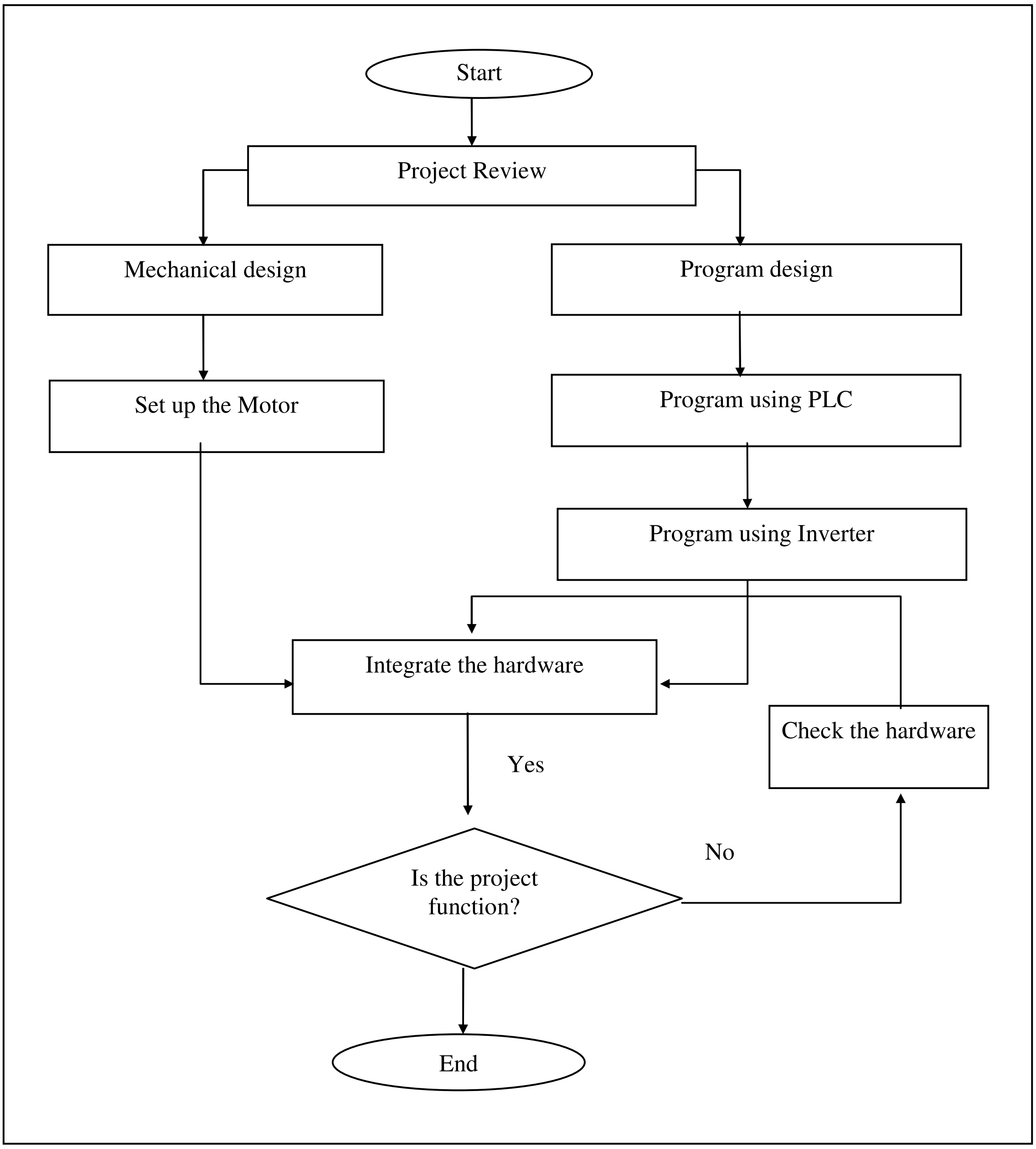

Figure 1: Project flow chart

3.2 Project Flow Chart

From the figure 1, this project started with project review then divided into two sections which mechanical design and program design. Project review is about searching for the data and information about this project. The data and information can be getting from books, magazines, journals, internet or personal person. Note that all these references are copyright to their owner. Hence we must state the references in each data, info or sentences in this project with respect to them.

In mechanical design the method that we used is direct online method where we tested and set up the AC motor for proper functioning. Direct online means we connected the AC motor to inverter directly without using any controller. This step is used to check the AC motor either can integrate with inverter or not. The result is yes where inverter can control the speed of AC motor rotations in 3 types of speeds. There are Rotation Low (RL), Rotation Medium (RM) and Rotation High (RH).

In program design we have the remaining methods such as PLC with inverter for single and multi speed. We have to wiring and program the PLC and inverter. The wiring and program both PLC and inverter will discuss later in project block diagram. Then the project is integrated between the hardware and program to test the system either functioning or not. It have to test until it completely success and properly running in safety mode.

3.3 Methods

There are 4 methods that used in this project:

- Direct on-line (D.O.L.)
- PLC with inverter (Single speed)
- PLC with inverter (Multi speed)
- PLC with inverter (Multi speed) with approaching to Fuzzy logic

3.4.1 Direct Online (D.O.L.)

In this method, we connected the AC motor to inverter directly to determine the differential of the speed. There are 3 ports can be directly connect between AC motor and inverter such as Rotation Low (RL) port connect to common port (SD), Rotation Medium (RM) port connected to common port (SD) and Rotation High (RH) port connected to common port (SD). These 3 basic types of speed are different values. By default the value of RL speed is 10Hz, RM is 30Hz and RH is 50Hz. Note that in this method, SD is common port. Next when we set for multi speed setting PC is common port. In this method multi speed can be made manually with combine the basic speed RL, RM or RH and connected to common port (SD) but the value is not stated.

3.4.2 PLC with inverter (Single speed)

When PLC is connected to inverter, there are 5 port connected between both of them. There are RL port, RM port, RH port, STF port and common port (PC). In this method only single speed is conducted. There is single speed for RL with common port (PC) with speed 10Hz, RM port with PC port with speed 30Hz and RH with PC port with speed 50Hz. Note that we have to change the common port from SD to PC when inverter is connected to PLC. It is default setting has to taken. The result in this method is same as DOL but this time we make it controlled by PLC as a controller. In DOL method we just manually did by switch with no controller. The reason in this method is to make sure that the inverter can operate with PLC. The program can be referring to figure 2 below at rung 4, 7 and 10.

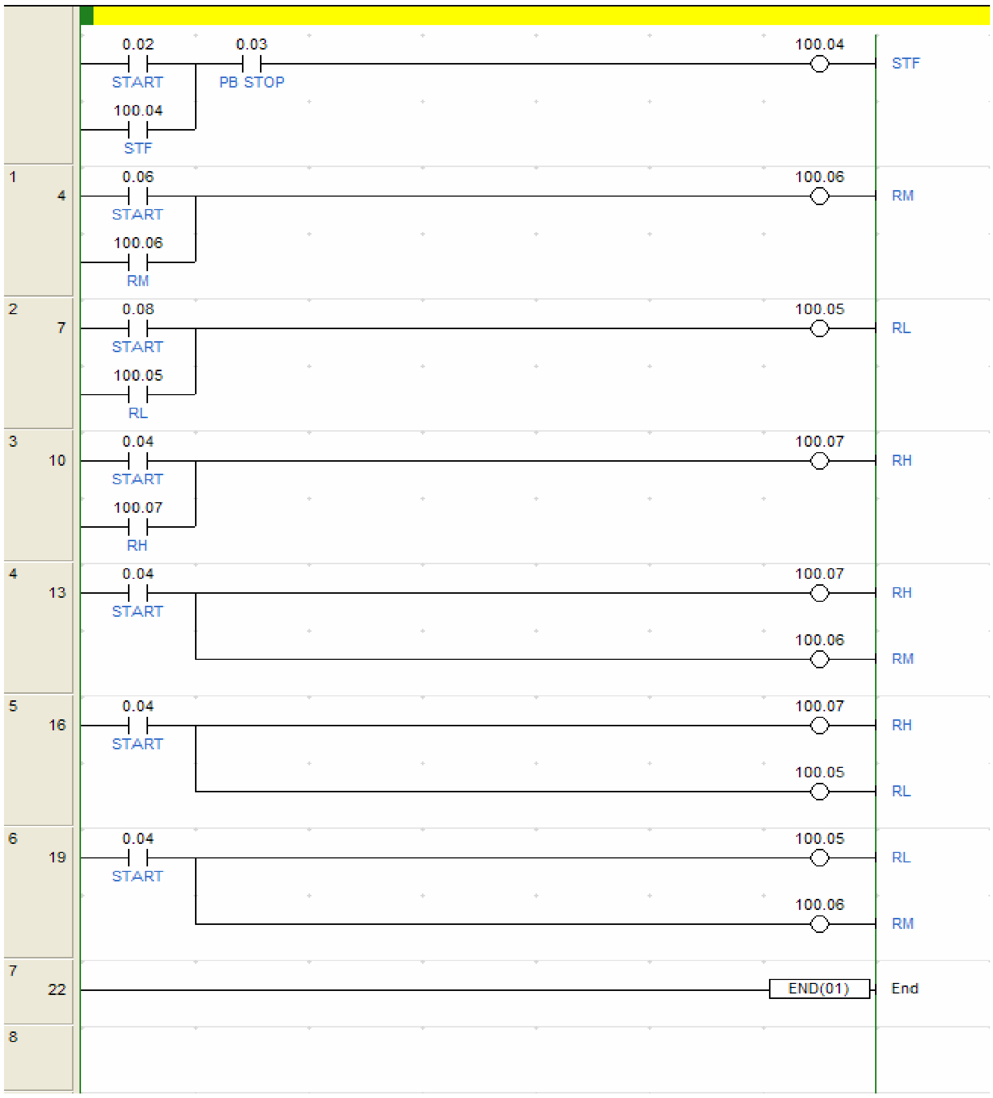

Figure 2: Program for PLC with inverter for single and multi speed method

3.4.3 PLC with inverter (Multi speed)

From figure 2, we can see that there are a few basic combinations to test up for multi speed condition such as between RH and RM for rung 13, RH with RL in rung 16 and RL with RM in rung 19. The result is excellent where these combinations produced other new types of speed. Hence it produced more speed and it is multi speed condition between PLC and inverter.

3.4.4 PLC with inverter (Multi speed) with approaching to Fuzzy logic.

This method gained from previously method where the variety combinations of RL, RM or RH produced multi speed for AC motor rotation. Hence it is multi speeds, we can make the control system approaching to fuzzy logic.

3.4 Project Block Diagram

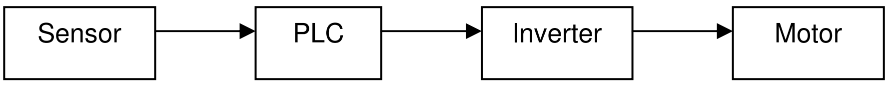

Figure 3: Block diagram of the project

- Sensor : DC Voltage Power Supply
- PLC : CQM1MH-CPU51 Omron
- Inverter : Mitsubishi FR-S 500

- Motor : AC motor

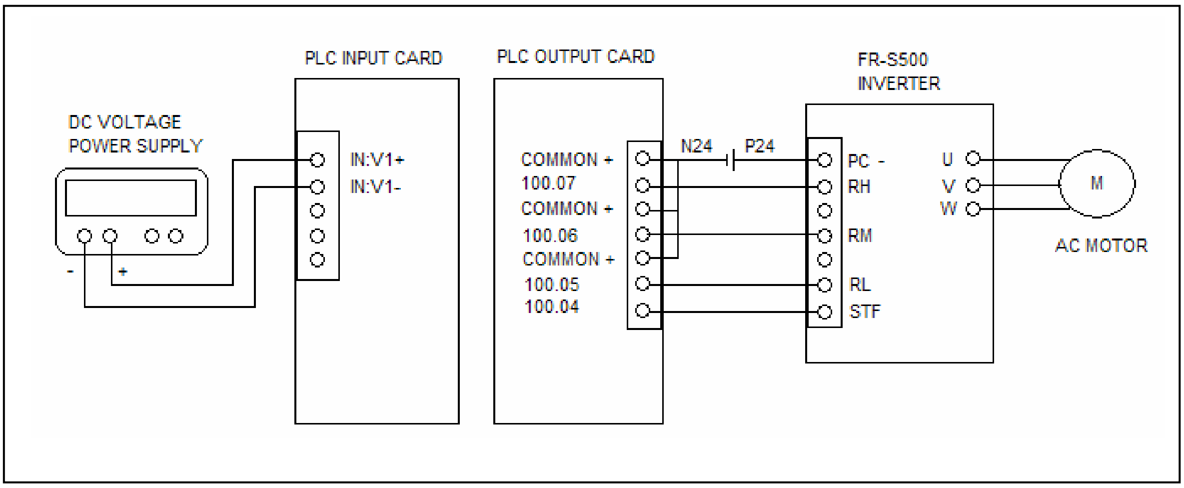

Figure 4: Project circuit

3.4.1 DC Voltage Power Supply

In ACC system, the sensor is located in front of the vehicle to detect any object or obstacles in certain distance. In this project, DC voltage power supply is used as a direct output sensor. It is because there is no suitable sensor that suited with this project. Noted that basic real sensor is the output from the sensor is in current or voltage signal. Hence DC voltage supply is used as a direct output voltage from sensor to PLC controller as a voltage input. This DC voltage supply can produce 0-10V and 0-20mA as an analog input for PLC controller. In this project we used 0-10V as analog input for PLC controller. The input signal is transferred to PLC via two cables from DC voltage power supply. There are positive RED cable connected to IN:V1+ port in PLC input card and negative BLACK cable connected to IN:V1- port in PLC input card . The highest voltage means the obstacles is far away from vehicle. Voltage is proportionally to distance of the object and proportionally to the speed of AC motor rotation. The voltage is divided to 7 parts for 7 inputs and 7 speeds.

3.4.2 CQM1MH-CPU51 Omron PLC Controller

Voltage inputs from DC voltage power supply will go to CQM1MH-CPU51 Omron PLC controller via analog input port. Positive RED cable from DC voltage supply will connect to IN:V1+ port and negative BLACK cable will connect to IN:V1- port. PLC will analysis the data and determines the speed of AC motor rotation using CX-Programmer. CX-Programmer is a 32-bits Windows programming support tool for Omron PLCs that used to program the system based on ladder diagram. Beside it is easy to create, monitor and online edit programs for Omron PLCs. Any changing input that received will change the speed of AC motor a rotation. The voltage is proportionally to speed of AC motor rotations. It means if the voltage increasing the speed of AC motor also increasing. There are 5 connections between PLC and inverter such as STF, PC, RH, RM and RL. STF, RH, RM and RL are connected to address port in output card PLC controller and PC is connected to COMMON port. Refer to figure 4

3.4.3 Mitsubishi FR-S 500 Frequency Inverter

The output signal from PLC is in DC signal. Hence, Mitsubishi FR-S 500 frequency inverter is used to convert DC signal from PLC to be AC signal to control the speed of AC motor rotation. This useful inverter can be manipulated into 15 types of frequencies. Only 7 types of speed are used in this project. Rotation Low (RL), Rotation Medium (RM) and Rotation High (RH) are the basic speed. The combination of these speed produced another types of speed and up to 7 speeds which are slow speed (speed 1), slow plus medium speed (speed 2), slow plus high speed (speed 3), medium speed (speed 4), medium plus high speed (speed 5), slow plus medium plus high speed (speed 6) and high speed (speed 7). Default setting had to change to make variety types of speeds based on the inverter frequency. The frequency is proportionally to the speed of AC motor rotation and input voltage from PLC. Means the higher voltage received by inverter the value of frequency changed to higher value. Hence the speed of AC motor rotation becomes increased. This Mitsubishi Electric product can operate with control method voltage/frequency control, modulation control: sinusoidal PWM, soft PWM, switching frequency: 0.7-14.5 kHz (user adjustable) and operating frequency: 0.5-120Hz. These inverters have 2 types which FR-S 520SE EC/ECR and FR-S 540SE EC/ECR. In this project, FR-S 520SE EC/ECR is used for input single-phase, 200-240V AC for power supply.

3.4.3.1 Wiring the inverter and PLC

The inverter has to wiring with PLC and reprograms to fit in this project. There are 5 connections between PLC and inverter such as STF, PC, RH, RM and RL. STF is connected to address port number 100.04, RH is connected to address port number 100.07, RM is connected to address port number 100.06, and RL is connected to address port number 100.05 in PLC output card. PC is connected to P24 and COMMON port is connected to N24. Refer to figure 4.

3.4.3.2 Setting the parameters

There are many parameters in this inverter have to reprogram to change the default value to be desired value. Example parameter 4 is a Rotation High (RH) parameter. It default value is 50Hz. In this project we need to change this default value to be 120Hz. This is an example the step to take to change the default of RH value to be 120Hz.

1. The RUN and operation mode indication is confirmed. Note that the inverter is stop and it is at PU operation mode.

2. MODE button is pressed to choose the parameter setting mode.
3. The ROTATE button is rotated until the RH parameter number is appeared. It is parameter number 4.
4. SET button is pressed to read the currently set value. It stated 50 means it is 50Hz.
5. The ROTATE button is rotated until 120. It means the new value of this RH parameter is 120Hz.
6. The SET button is pressed again to confirm the value. Watching the value is flicker. It means it done to set a new value of RH parameter is 120Hz.
7. After parameter setting is complete MODE button is pressed twice to return to the monitor display.

The other parameters such as Rotation Medium (RM) parameters and Rotation Low (RL) can be set with the same steps like above. The table of parameters is shown in below, table 1.

Table 1: Parameters table of inverter.

Speed	Terminal Input			Parameter	Frequency (Hz)
	RH-PC	RM-PC	RL-PC		
1	OFF	OFF	ON	4	20
2	OFF	ON	ON	24	35
3	ON	OFF	ON	25	50
4	OFF	ON	OFF	5	70
5	ON	ON	OFF	26	85
6	ON	ON	ON	27	100
7	ON	OFF	OFF	6	120

3.4.4 AC Motor

The speed of AC motor rotation changed depends on the value of the voltage signal received by PLC. The highest value of voltage signals received the highest speed of AC motor rotation become. PLC will exam the value of the voltage signal and determines the speeds. Then inverter will convert the signal become AC signal and AC motor rotated depends on the signal transmitted to it. Note that AC motor comprises both motor and generators and mostly used in industries. It is rugged, low maintenance, simple and low-price. AC motor runs at constant speed from zero to full-load even this motor is not easily adapted to speed control. It became mostly and widely used in industries to control the speed of commercial induction motor.

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

This chapter discusses all the results obtained and the limitation of the project. All discussions are concentrating on the result and performance of the Brake-Control System for Motorist Vehicle

4.2 Hardware Integrated

This is the result of the hardware integrated. There is integration between DC voltage power supply as a sensor, CQMIMH-CPU51 Omron PLC as a controller, Mitsubishi FR-S500 as an inverter and AC motor as a vehicle. Figure 5.1 shows the result of the Brake Control System for Motorist Vehicle after we had assembled.

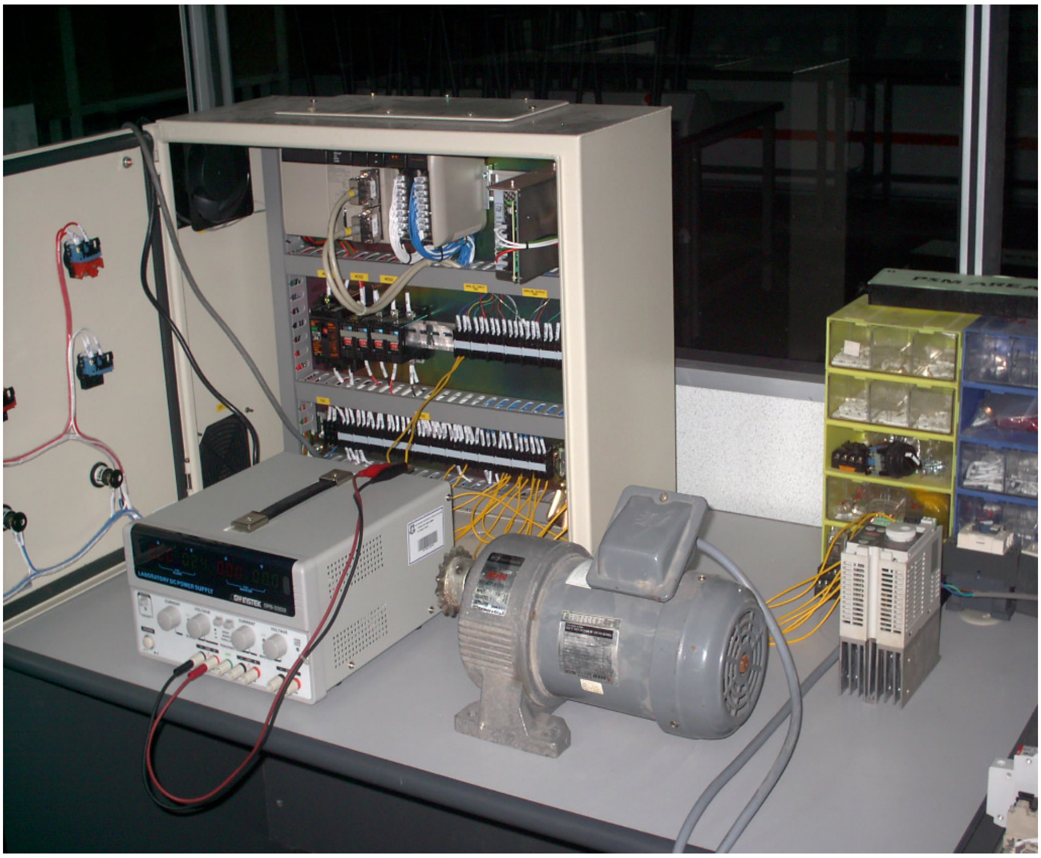

Figure 5: Complete Brake Control System for Motorist Vehicle

In this project there are seven conditions of speed need to be tested either from low to high or high to low speeds. It has to be checked to measure the efficiency of this project.

Note that the value in ladder diagram is in Hexadecimal units. Hence the input voltage needs to change to Hexadecimal. It can be done with adjust the voltage value at DC voltage power supply and measure the voltage value in Hexadecimal unit in CMP box instruction in comparison value 1. For example, if we set the voltage is 2.5V the Hexadecimal value is around #0208.

4.3 Multiple speeds of AC motor

This project has been design to control the speed of AC motor depends on the voltage that received from DC voltage power supply. All the voltage range has been tested to determine the speeds of AC motor. The voltage value is received and determined by the PLC. Then PLC will control the speed of AC motor depends on the value of voltage in it range. Below is the table showing the relationship between the values of voltage received from DC voltage power supply and AC motor speeds.

Table 2: Table of AC motor speeds and input voltage

Speed	Connection	Frequency (Hz)	Voltage (V)	Value (Hex)
1	RL	20	0<x<2.5	#0208
2	RL plus RM	35	2.5<x<3.5	#02D5
3	RL plus RH	50	3.5<x<4.5	#0395
4	RM	70	4.5<x<5.5	#0474
5	RM plus RH	85	5.5<x<6.5	#0541
6	RM plus RH plus RL	100	6.5<x<7.5	#0608
7	RH	120	7.5<x<10	#07FF

4.3.1 Speed 1

From the table 2, speed 1 can be made when terminal of Rotation Low (RL) is directly connected to common port (PC). This only can be happen if the input voltage from DC voltage power supply is in range 0V<x<2.5V received by the PLC. Note that x is voltage value. Speed 1 is the lowest speed and it is only 20Hz. Note that in ladder diagram the value is in Hexadecimal and it is #0208.

4.3.2 Speed 2

Speed 2 value is 35Hz from 20Hz plus 15Hz. It can be made when RL is combined with Rotation Medium (RM) to common port (PC). PLC will set this speed when it is detected the voltage value from DC voltage power supply is in 2.5V to 3.5V or $2.5V<x<3.5V$. We can see the speed of AC motor rotation is changed from slow speed to higher speed. It is approved by the value that shows in the inverter from 20Hz changed to 35Hz.

4.3.3 Speed 3

Speed 3 is 50Hz after 35Hz is plus to another 15Hz. Note that every gap range is plus 15Hz between speed 2 to speed 4.and speed 6 to speed 7. Speed 3 can be made with Rotation Low (RL) is combined with Rotation High (RH) and connected to common port (PC). It can be achieved when input voltage is in between 3.5V to 4.5V or $3.4V<x<4.5V$, speed 3 is set. The result can be seeing when the speed of AC motor rotation becomes increasingly.

4.3.4 Speed 4

Speed 4 value is 70Hz. This speed is achieved when input voltage value is in range $4.5V<x<5.5V$ and Rotation Medium (RM) is directly alone connected to common port (PC). Hence the speed of AC motor rotation becomes more faster.

4.3.5 Speed 5

Speed 5 value is 85Hz after plus 70Hz with another 15Hz. This speed can be made when PLC received the input voltage value between 5.5V to 6.5V or 5.5V<x<6.5V. This speed is extremely faster by looking the speed of AC motor rotation.

4.3.6 Speed 6

Speed 6 value is 100Hz and it is extremely high speed for AC motor rotation. This speed achieved when the input of voltage value is in range 6.5V to 7.5V or 6.5V<x<7.5V.

4.3.7 Speed 7

The higher speed is speed 7 where it is 120Hz, the maximum value of inverter frequency. This is mostly extremely speed for sure when the voltage value for input signal received by PLC is in 7.5V to 10.0V or 7.5V<x<10.0V.