CHARGING AND DISCHARGING METHODS OF LEAD ACID BATTERY

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"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Power Systems)"

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I declare that this thesis entitled *"Charging and Discharging Methods of Lead Acid Battery"* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ______________________________

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Date : 21 JUNE 2012

Specially dedicated to my beloved mother and father, my brothers,
my beloved friends, for their encouragement and support.

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Firstly, I like to say Alhamdulillah and thank Allah for His Rahmah, mercy and guidance in my life. With His blessing I could finish my final year project on time.

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ABSTRACT

Battery has played a major in many applications such as electric vehicle and uninterruptable power supply (UPS). Battery becomes a must choice because it can provide immediate power when needed. Among the battery family, lead-acid battery become a popular choice because it came in variety of output voltage and can be recharge. Although the lead-acid can be recharge, problems still occur when recharging the battery. The battery tend to undergo overcharge if the is no control mechanism to stop the charging. This paper represents a method of charging and discharging the battery by using electronic control circuit based on the minimum and maximum voltage battery level. A NI-DAQ 6212 was introduced and configures to connect the electronic control circuit to the personal computer for display and data storage using LabVIEW. A charge and discharge program was developed to use for charging and discharging purpose. The output of this project would be displaying the voltage-time graph as well as the charging and discharging state of the lead-acid battery.

ABSTRAK

Bateri telah memainkan utama dalam banyak aplikasi seperti kenderaan elektrik dan bekalan kuasa uninterruptable (UPS). Bateri menjadi pilihan mesti kerana ia boleh memberikan kuasa serta-merta apabila diperlukan. Antara keluarga bateri, bateri asid-plumbum menjadi pilihan popular kerana ia datang dalam pelbagai voltan keluaran dan boleh caj semula. Walaupun asid plumbum boleh caj semula, masalah masih berlaku apabila mengecas semula bateri. Bateri cenderung untuk menjalani harga yg terlalu mahal jika ada mekanisme kawalan untuk menghentikan pengecasan. Kertas kerja ini merupakan satu kaedah mengecas dan menyahcas bateri dengan menggunakan litar kawalan elektronik yang berdasarkan tahap voltan bateri minimum dan maksimum. A 6212 NI-DAQ telah diperkenalkan dan mengkonfigurasi untuk menyambung litar kawalan electronic untuk komputer peribadi untuk paparan dan penyimpanan data menggunakan LabVIEW. Satu program caj dan pelepasan telah dibangunkan untuk digunakan untuk mengecas dan melaksanakan tujuan. Keluaran projek ini akan memaparkan graf voltan-masa serta keadaan mengecas dan menyahcas bateri asid plumbum.

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LIST OF ABBREVIATIONS

AGM	-	Absorbed Glass Mat
GUI	-	Graphical User Interface
DAQ	-	Data Acquisition
DC	-	Direct Current
USB	-	Universal Serial Bus
NI	-	National Instrument
PC	-	Personal Computer
VRLA	-	Valve Regulated Lead Acid

CHAPTER 1

INTRODUCTION

1.1 Background of Project

Charging and discharging lead-acid battery is an important element to make sure that the battery can still provide power when needed. Charging is process where the energy is being flow into the cell or rechargeable battery by forcing an electrical current through it. Charging a lead acid battery typically have two tasks to accomplish which are to restore the capacity as quickly as possible and to maintain the capacity compensating or self discharge. When a typical lead-acid cell is charged, lead sulphate is converted to lead on the battery’s negative plate and lead dioxide on the positive plate. Over-charge reactions begin when the majority of lead sulphate has been converted, typically resulting in the generation of hydrogen and oxygen gas. At moderate charge rates, most of the hydrogen and oxygen will recombine in sealed batteries. In unsealed batteries however, dehydration will occur.

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To maintain capacity on a fully charged battery, a constant voltage is applied. The voltage must be high enough to compensate for self discharge, but not to high as it will cause excessive over-charging. The software that will be use in this project is LabVIEW. The purpose of this software is to monitor and control the voltage so that the control circuit can be switch between charge and discharge mode.

1.2 Problem Statement

There are some problems occur while charging and discharging a battery. The problem is the charging process tends to undergo overcharging because typical lead acid battery does not give signal when it fully charged. To encounter this problem, a new method of charging and discharging technique is used. This method use a software that will cut-off the battery charging and discharging process when the maximum and minimum voltage parameter has been set. There are many types of charging and discharging method use nowadays, each one of them has its own advantages and disadvantages. In this project, the method use is based on the voltage of the lead-acid battery.

1.3 Objectives

The objectives of this project are:

a) To create the charging and discharging program of lead acid battery.

b) To develop an electronic control circuits to control the charge-discharge process.

c) To develop GUI using LabVIEW software, to record, save and monitor the voltage level and charge-discharge state.

d) To experiment the characterization of lead acid battery

1.4 Scope of Project

In this project, a charge-discharge cycle will be created for monitor the lead acid battery voltage level. The electronic control circuit will be developed to control the charge-discharge process. The output from the battery will interface by using DAQ card and monitor from the PC. The output then will be presented in voltage-time graph and charge-discharge state by using the GUI software.

1.5 Chapter Outline

This thesis consists of five chapters including this chapter. The content of each chapter can be outlined as follows:

Chapter 2 provides a literature review, background, previous research done by others researchers in the same area and relevant issues related to the charging and discharging of lead acid battery. This include on overview of battery types use into scope of study. The different types of charging methods are presented to justify the best method that use in the project. Chapter conclusion justifies the need of research on charging and discharging method of lead acid battery.

Chapter 3 describes a broad description of the research methodology in this project. This chapter begins with description of flow chart of the project. The first part of this chapter describes the hardware development. The electric schematic diagram of charge discharge mode with complete relays connection is developed as part of the project. The second part of this chapter describes the programming development that use to control the charge discharge process of lead acid battery. The last part of this chapter is experimental and characterization of lead acid battery. Chapter conclusion summarized the methodology in this study.

Chapter 4 described the result for experimental and characterization of lead acid battery. Result and discussion of the project is presented.

Chapter 5 provides general conclusion based on the project. The limitation of the project is stated and future works for improving the project is highlighted.

CHAPTER 2

LITERATURE REVIEW

2.1 Battery

Battery is a device containing an electric cell or a series of electric cells storing energy that can be converted into electrical power. Battery produces electricity from a chemical reaction [1]. Generally, battery consists of two or more cells connected in series or parallel. A cell consists of a negative electrode; an electrolyte, which conducts ions; a separator, also an ion conductor; and a positive electrode. The electrolyte may be aqueous (composed of water) or non-aqueous (not composed of water), in liquid, paste, or solid form. When the cell is connected to an external load, or device to be powered, the negative electrode supplies a current of electrons that flow through the load and are accepted by the positive electrode. There are two types of battery that commonly use which are primary batteries (disposable battery) and secondary batteries (rechargeable battery).

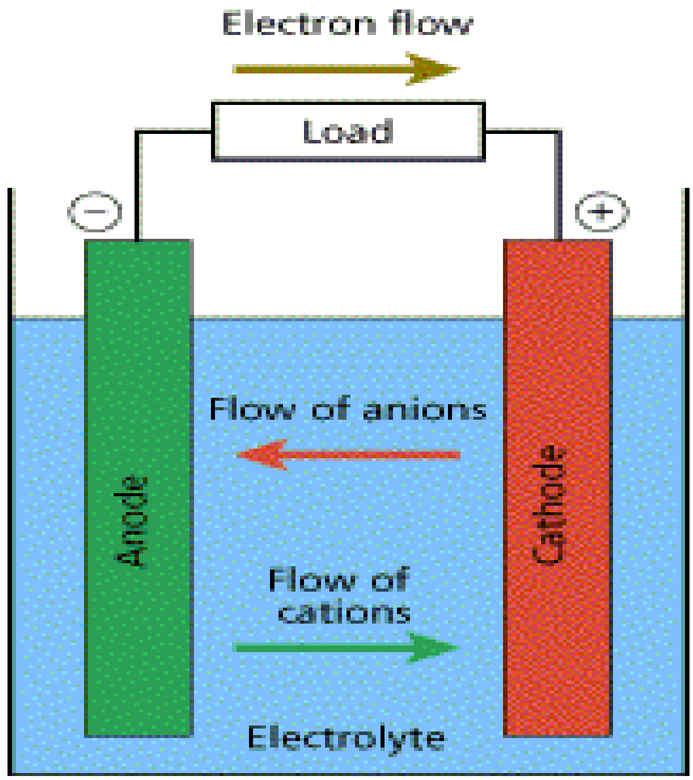

Figure 2.1 Battery operation

2.1.1 Lead Acid Battery

Lead acid battery is the oldest type of rechargeable battery. It is an electrical storage device that uses a reversible chemical reaction to store energy. It uses a combination of lead plates or grids and an electrolyte consisting of a diluted sulphuric acid to convert electrical energy into potential chemical energy and back again. Despite having a very low energy-to-weight ratio and a low energy-to-volume ratio, their ability to supply high surge currents means that the cells maintain a relatively large power-to-weight ratio [2]. In a lead acid cell the active materials are lead dioxide (PbO_2) in the positive plate, sponge lead (Pb) in the negative plate, and a solution of sulfuric acid (H2SO4) in water as the electrolyte [4]. The chemical reaction during discharge and recharge is normally written:

$$PbO_2 + Pb + 2H_2SO_4 \xrightarrow[\text{Charge}]{\text{Discharge}} 2PbSO_4 + 2H_20 \qquad \textbf{(2.1)}$$

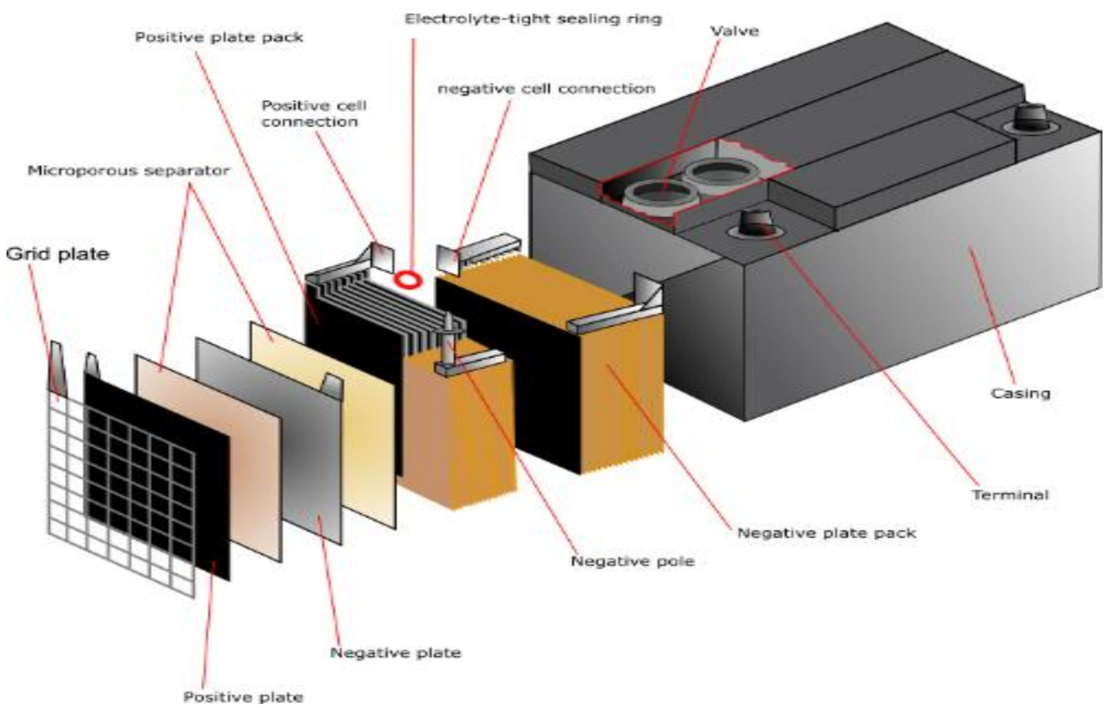

Figure 2.2 Lead acid battery constructions [3]

A lead acid battery is composed of a series of plates immerse in a solution of sulfuric acid. Each plate consists of a grid upon which is attached the active material (lead dioxide on the negative plates, pure lead on the positive plates.) All of the negative plates are connected together, as are all of the positive plates. When the battery is discharged (when it is subjected to an electrical load), acid from the elecrolyte combines with the active plate material. This releases energy and converts the plate material to lead sulfate. The electrolyte become less acidic in the process, and the specific gravity of the solution drops. When a battery is recharged, the opposite occurs: the lead sulfate reverts back to active material, and the electrolyte becomes more acidic with a higher specific gravity. During discharge, the lead dioxide (positive plate) and lead (negative plate) react with the electrolyte of sulfuric acid to create lead sulfate, water and energy. During charging, the cycle is reversed: the lead sulfate and water are electro-chemically converted to lead, lead oxide and sulfuric acid by an external electrical charging source [5].

2.1.2 Valve-Regulated Lead Acid (VRLA) Battery

VRLA battery is a type of lead acid rechargeable battery that commonly known as sealed battery. VRLA battery construction does not require regular addition of water to cells and it vents less gas than flooded lead acid battery. VRLA battery can be used in confine space or poor ventilated spaces because of the venting advantage that result in less gas produce [6]. VRLA batteries are commonly classified as Absorbed Glass Mat (AGM) battery and gel battery (gel cell).

The construction of VRLA is different than flooded lead-acid battery. When the battery is recharged at high voltage, typically greater than 2.30 volts per cell, it will active the pressure relief valve. By releasing the some gas on the battery, it decreased the overall capacity of the battery. The cell covers typically have gas diffusers built into them that allow safe dispersal of any excess hydrogen that may be formed during overcharge. They are not permanently sealed, but are maintenance free. They can be oriented in any manner, unlike normal lead acid batteries, which must be kept upright to avoid acid spills and to keep the plates' orientation vertical. At high overcharge currents, electrolysis of water occurs, expelling hydrogen and oxygen gas through the battery's valves. Constant-voltage charging is the usual, most efficient and fastest charging method for VRLA batteries, although other methods can be used.[7] VRLA batteries may be continually "float" charged at around 2.35 volts per cell at 25 °C.

2.2 Charging Methods

Charging is a process of supplying direct current to the battery so as to convert it back into chemical state at high energy level, capable of delivering electric power. Charging voltages have a significant effect on battery longevity. Some cells may deteriorate faster than others during operations. Deteriorated cells reduce the output voltage of the battery, and affect the usability and reliability of the circuit [13]. There are varieties of charging methods which can be used to charge sealed lead acid battery. By controlling the charging process, these methods can be classified into some basic categories which are constant-voltage, constant-current, tapered-current and combination charge systems. There are also new methods of charging lead acid battery that use internal voltage control [8] and current pulse or ‘pulse charging’ [9] which will be discussed later.

2.2.1 Constant Current Charging

Constant current charging is a method that is commonly uses for charging lead acid battery. The advantage of using this method is it easy to determine the amount of capacity (amp hrs) supplied during charging process [14]. Besides that, there is no need for temperature compensation which is required in constant voltage systems. Usually, at high-rate of charging, the battery voltage rises excessively and the water decomposes, causing heat generation at the final stage of the charge, thus, damaging the battery. However, the constant current method relatively kept a low rate of charging process and charging time is not critical. The constant current methods may be used as refreshing charge when many batteries is being charge at one time, as this method easily determine the amount of charge returned to the battery. It is not recommended to use constant current charging as refreshing the battery because it will shorten the battery life.

2.2.2 Constant Voltage Charging

Constant voltage charging is a methods use to restore the battery to a fully charge condition in short period of time. This type of charging must has a very stable output voltage and high current capacity, as extremely large currents are allowed to flow in the initial stage of charge, where the battery voltage is low. However, this type of charging method is not practical because the requirement of a high current capacity, results in high cost. The heat generation in the battery is also high because of the high current flow in the battery causing the battery life to be short. Generally, constant voltage charger has a device to limit initial current. This can be accomplished by a constant current regulator, or by designing the overall impedance of the circuit. Constant voltage charger is effectively to charge the battery at short period of time, as during the final stage of charge, the current automatically decreases and the water decomposition will be minimized.

2.2.3 Tapered Current Charging

Tapered current charging is simple and relatively inexpensive method. This charging method requires circuit with power transformer, rectifiers and a suitable resistance for limiting current. In this method, the charging current drops gradually as the charging proceeds. If the impedance of the circuit is low, a step current slope can be obtained. This type for charge is generally considered to be unsuitable for charging sealed lead acid batteries because the charging current will vary with fluctuation of line voltage as well as changes in battery voltage [10]. These effects, however, can be minimized by using a power transformer with a secondary voltage which is considerably higher than the battery voltage and a suitably high resistance in the circuit for current limiting. This type of charger will perform similar to a constant current charger, and can be utilized instead of a constant current charger for industrial uses; not only for recharging many batteries at one time, but also as a trickle charging system.

2.2.4 Combination Charging (Two-Step)

A combination charging uses two types of charging. It's called a "Two-rate" or "Two-step" charging. A variety of couples can be made, such as constant – current/constant current, constant-voltage/constant-current and so on [10]. In general the first step uses a quick or fast charge mode, and the second uses a low charge current. The switching from the first step to the second can be carried out by many different methods such as battery voltage sensing, a time control, charge current sensing and many more.

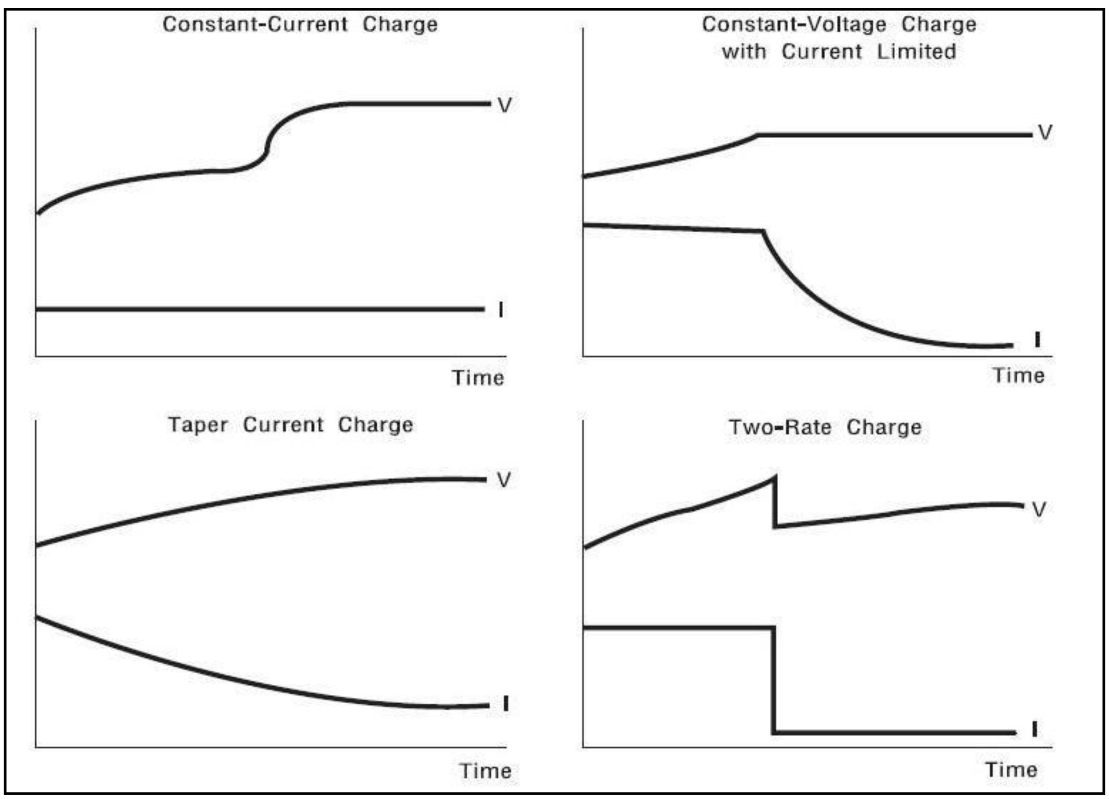

Figure 2.3 Different Types of Charging Methods [10]

2.2.5 Internal Voltage Control Charging

Internal voltage control charging methods is employs by controlling charging and discharging of the internal voltage of the battery instead of terminal voltage. The new methods has been discovered because the capacity of the battery is estimated by the potential differences between two electrodes of the battery, named external voltage and the battery has internal resistance that makes it difficult to control the charging and discharging process. Usually, when battery is being charge, the voltage increased and as it discharging, the voltage decrease. As the number of charging cycle increase, the discharge time of the battery becomes shorter [8]. This is caused by the increasing in internal resistance as the battery deteriorates causing the voltage of battery rapidly depletes to 10.5 V.

The objective of the internal voltage charging is to fully charge a battery by flowing sufficient current to it. It uses meter relays to control the charging and discharging process. The meter relay is connected to the battery and has been set to start charging when the battery voltage is 10.5 V and discharging when the voltage is 14.5 V [8]. This methods has been proved to prolong the battery life because as the battery is fully charge, no excess current can flow into the battery as the relays has switch to discharging state. The capacity of the battery can sufficiently utilized when the methods is used. Furthermore, this method proved to increase the effectiveness of the battery because the upper limit of charging batteries increases.

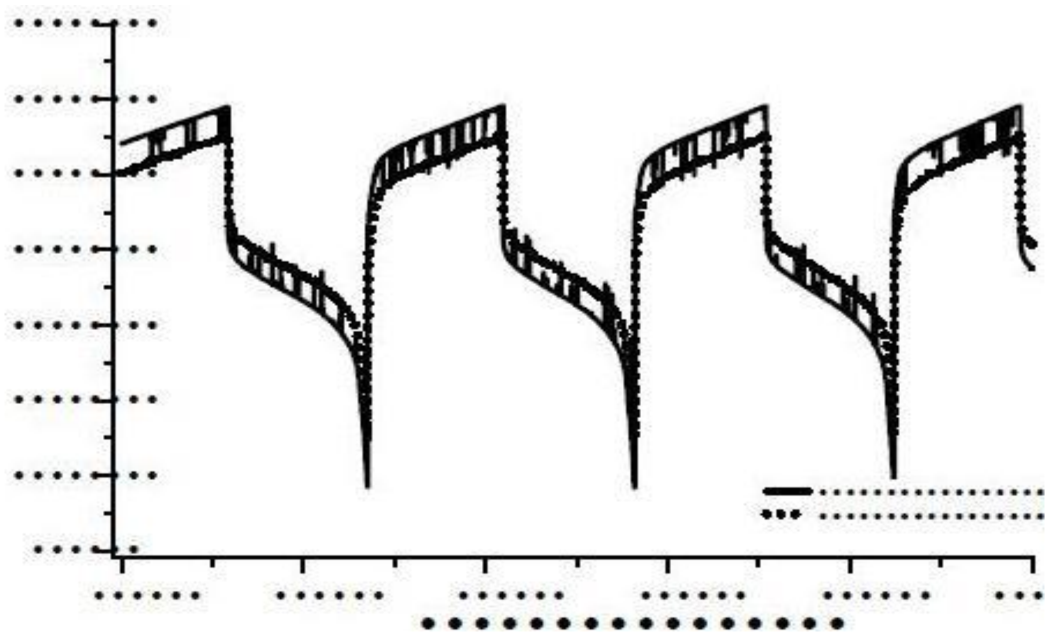

Figure 2.4 Time variation of the internal and external voltage of test battery [8]

2.2.6 High Current Pulse Charging

The principles of current pulse charging is by applying large currents into the battery at periodic intervals with a defined pulse width to reduce or avoid gassing and thus increase charge acceptance and efficiency. Research show that pulse charging method produce significant reductions in charging time and increase the battery cycle life [11]. Experimenting test show that when applied to specific battery and compared it to other conventional charging methods, it show improvements in charging time of an order magnitude and improvements in battery life by three to four times [9]. Current pulse charging uses a circuit that consists of mirco-controlled current source, synchronous rectifier, supervisory microprocessor and personal computer for interfacing. The designed circuit supply up to 100amp current pulses for charging or discharging of lead acid battery. It also provide constant charge and discharge currents but with much lesser value due to heating of semiconductors. The result show dramatically improves of charge rate with a constant current. Besides, it appear to eliminate gassing at the high state of charge. The inclusion of a small discharge pulse gives a slight improvement in charging efficiency without reducing charging time, despite the initial lower average current [9].

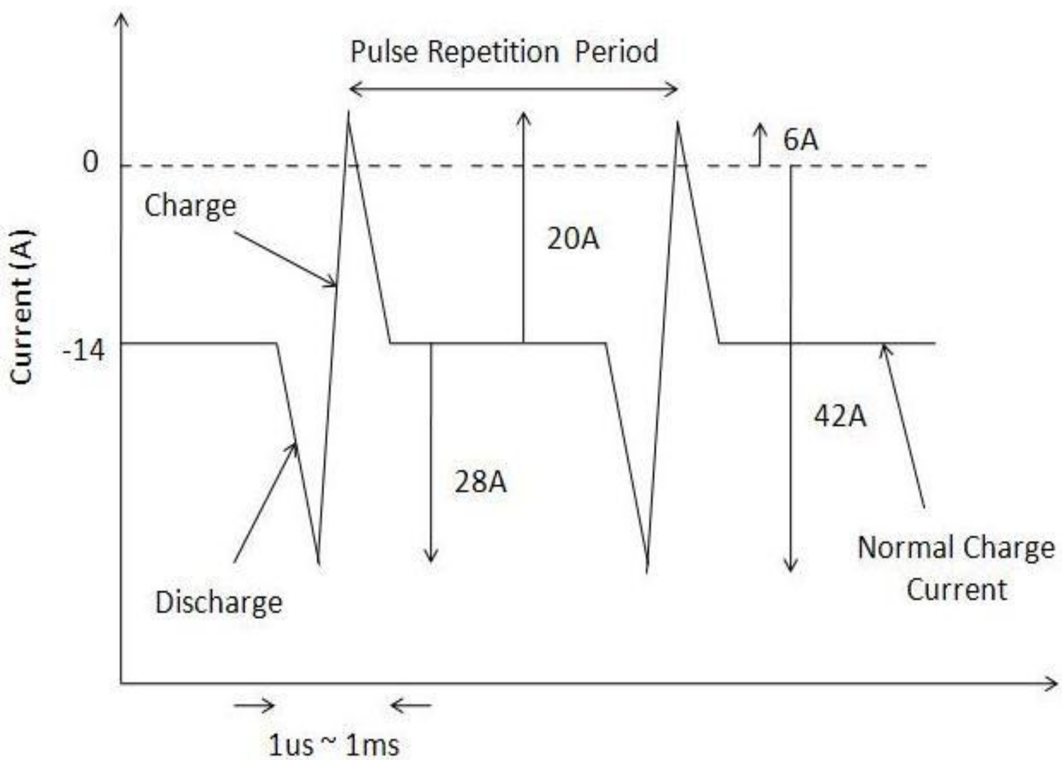

Figure 2.5 Pulse current and charge current in discharging and charging [9]

2.3 Chapter Conclusion

Two types of lead acid battery has been review in this chapter. By comparison, VRLA battery gives better advantages than normal lead acid battery. VRLA battery construction does not require regular addition of water to cells and it vents less gas than flooded lead acid battery. VRLA battery can be used in confine space or poor ventilated spaces because of the venting advantage that result in less gas produce. VRLA battery also is a sealed type battery. Sealed types battery is better than normal lead acid battery because the probability for battery water to leak can be avoided. Thus, VRLA battery is a better choice to use than normal lead acid battery.

There are six charging methods has been reviewed in this chapter. Each of the methods uses different operation but still maintain it main objectives of charging the battery. Constant current charging is better choice for this project because easy to determine the amount of capacity (amp hrs) supplied during charging process. By comparison, constant current method is cheapest to operate because it does not require specific circuit such as constant voltage and tapered current charging. Besides that, constant current charging do not require a special requirements that need to be fulfill to charge the battery such as internal voltage control and high current pulse charging.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will explain about the methods that will be done to complete the project. It will include the information about methods involved, tools and equipments used as well as the procedures and processes involved in the hardware and software development and implementation of the project.

3.2 Project Preview

Phase 1 is basically about introduction or project preview that will be done in this project. For this project, a charge-discharge cycle of a lead battery must be develops based on the project scope. Based on the project, a research about the related project has been conducted. Every related article or journal has been through to find the best methods that will be use in this project. The methods use for this project will be following the flow chart below.

Figure 3.1 Flow chart of the project

3.3 Hardware Development

The first step of the hardware development is to develop a electronic control circuit. The purpose of the circuit is to control the relays so that it will operate based on the charge-discharge mode. The control circuit is connected with two relays, where one relays will operate on charge mode and the other one on discharge mode. The electronic control circuit with relays is develops by referring to Figure 3.1.

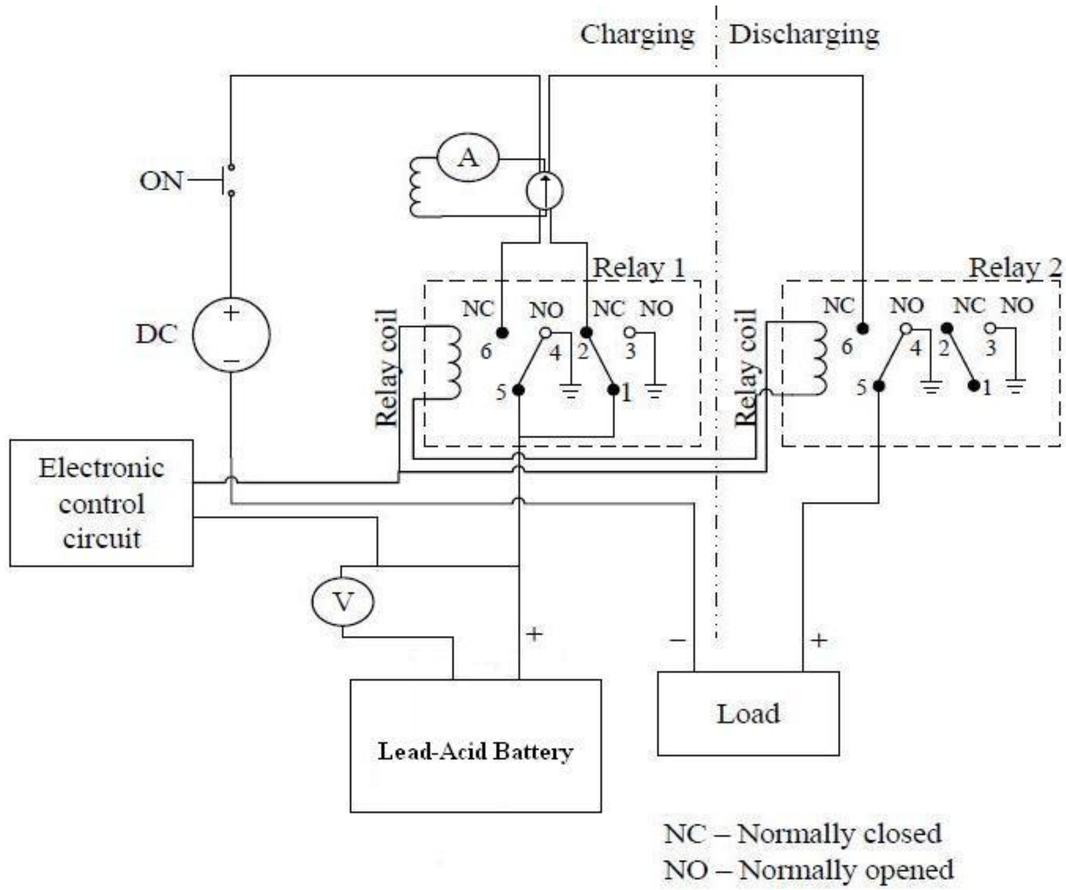

Figure 3.2 Electrical schematic for charge-discharge mode of lead acid battery system with details connection of relay control circuit (Adapted and Modified from [12])

The circuit is divided into two parts, charging and discharging. The circuit uses two relays that will alternate during charging process or discharging process. The relay coil gets it power from electronic control circuit. There are two electronic circuits that is developed for charging and discharging purpose. The electronic control circuit gets it signal from NI-DAQ card to trigger the charging or discharging relay based on the state of the lead acid battery. For this project, 6V lead acid rechargeable battery is used as part of the project.

3.3.1 Relay

Relays are remote control electrical switches that are controlled by another switch, such as a horn switch or a computer as in a power train control module. Relays allow a small current flow circuit to control a higher current circuit. In this project, relays are use to switch between the charging and discharging operation. The switching relays get it input from the electronic control circuit. The relays pins are connected based on the Figure 3.2. Signal from the electronic control circuit will make the relays to alternate between each other where one relay provides a charging path while the other one provide the discharging path.

Figure 3.3 HJQ-18F-12D (8pin) relay

Table 3.1 Relays specification

	Description
Relay Model	HJQ-18F-12D (8pin)
Coil	12Vdc
Maximum DC voltage	28Vdc 5A
Maximum AC voltage	280Vac 5A

3.3.2 Lead Acid Battery

Lead-acid battery is important element of the project. The battery use in this project is VRLA type battery. It is a sealed lead battery and compare to normal lead-acid battery, it does not require additional water to cell and vent less gas. Compare to traditional lead-acid battery, VRLA battery performance in better and improved by recent research [15].VRLA battery voltage for this experiment is 6V and contains 3 cells per unit. In this project, the battery is connected as shown in Figure 3.2. The battery will be charge or discharge based on its terminal voltage.

Figure 3.4 GPP645 Rechargeable Sealed Lead Acid Battery

3.3.3 Electronic Control Circuit

Electronic control circuit purpose is to control the switching between the charging and discharging process. The electronic control circuit consists of two NPN transistors. Transistors amplify current and can be used as a switch. The transistor has three leads labelled as base (B), collector (C) and emitter (E). In this project, the base of transistor is connected to the DAQ output. Each of transistors base is connected to different port of DAQ card. The relays are connected to the collector lead while emitter lead is connected to the ground.

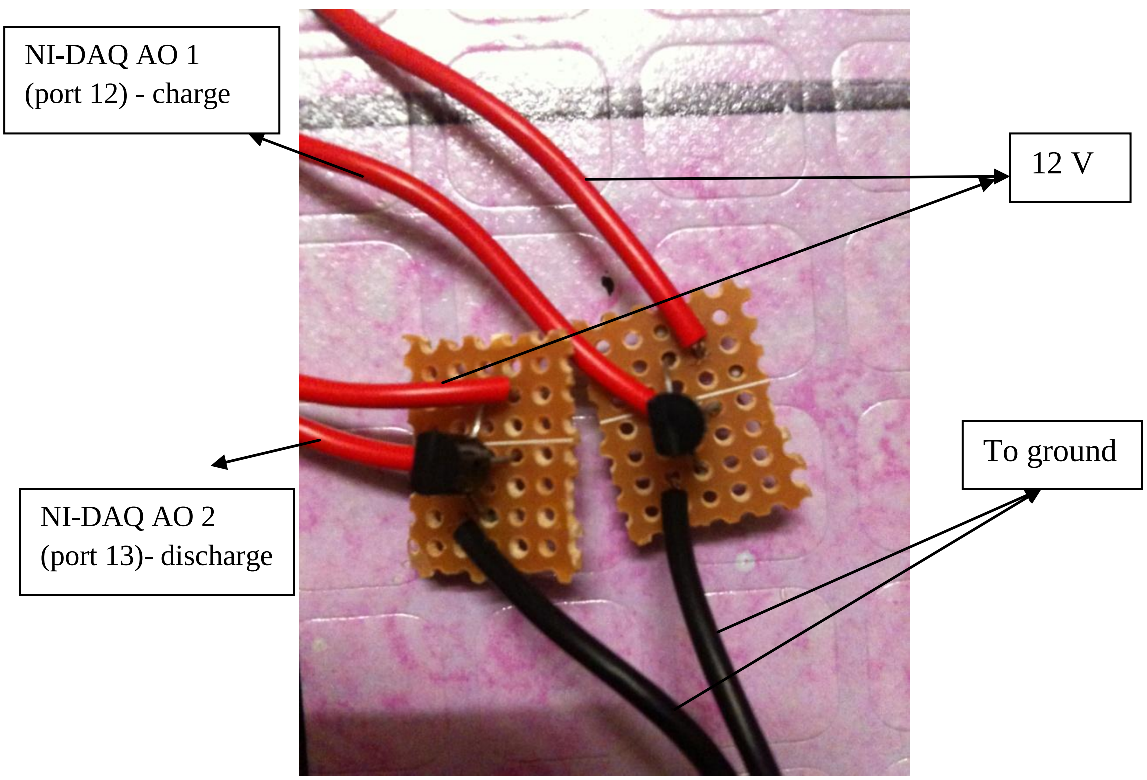

Figure 3.5 Electronic control circuit connections

3.3.4 DAQ Card

Data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition systems (abbreviated with the acronym DAS or DAQ) typically convert analog waveforms into digital values for processing [16]. The components of data acquisition systems include:

DAQ hardware usually interfaces between the signal and a PC. It could be in the form of modules that can be connected to the computer's ports (parallel, serial, USB, etc.) or cards connected to slots. DAQ cards often contain multiple components (multiplexer, ADC, DAC, TTL-IO, high speed timers, RAM). These are accessible via a bus by a microcontroller, which can run small programs. In this project, DAQ card is necessary because it will be interface between the battery and electronic control circuit.

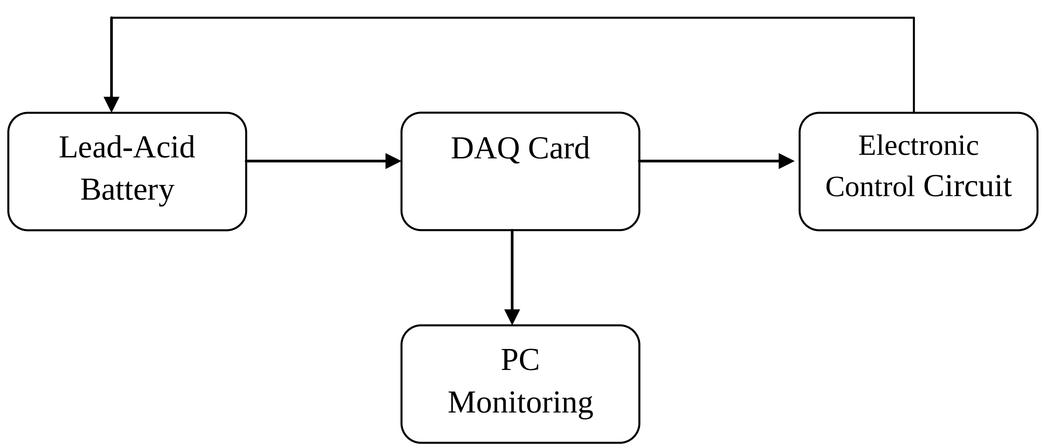

Figure 3.6 Flow chart of interfacing DAQ card between lead acid battery and electronic control circuit

3.3.4.1 ADVANTECH USB-4716

ADVANTECH USB-4716 is a 16-bit multifunction module with 200kS/s maximum sampling rate. It provides 16 single-ended/8 differential AI channels along with 2 AO channels. It also offers 8TTL DI/O channels for on-off control applications. Besides, one 16-bit counter channel is available onboard. USB-4716 has maximum input protection of 30V and maximum input impedance of 1GW.

Figure 3.7 ADVANTECH USB-4716

3.3.4.2 NI-USB 6212

Figure 3.9 shows that the NI-USB 6212 DAQ card. This DAQ have 16 analog inputs with a 16-bit with 400 kS/s for sampling data and powered by USB for high mobility. It has two analog outputs with two 32-bit counters. NI signal streaming for sustained high-speed data streams over USB. It is compatible with LabVIEW, ANSI C/C++, C#, Visual Basic .NET, and Visual Basic 6.0

Figure 3.8 NI-USB 6212

ADVANTECH USB-4716 is use in the early stage of the project. It is use to interface between the battery and the electronic control circuit. Problems occur when the USB-4716 DAQ card is not compatible with the software use which is LabVIEW 2011. The ADVANTECH USB-4617 has its own function that is different from NI LabVIEW function. Whenever NI function is use and interface with the USB-4716, the LabVIEW software can't detect the device thus makes the program can't operate

The problem has been overcome by the use of NI-USB 6212 DAQ card. NI-USB 6212 is compatible with LabVIEW software. The software also easy to detect the NI-USB 6212 every time the device is plug-in to PC. Thus, during the project is conducted, NI-USB 6212 is use because of it reliability and easy to use.

3.4 Programming Development

This phase of the project will be focusing on programming development. The program that will be develops is a charge-discharge mode for relays. The control and supervision system is used as key part of controlling, measuring and management will be develops by using LabVIEW 2011 software. LabVIEW is a platform and development environment for a visual programming language. LabVIEW is commonly used for data acquisition, instrument control, and industrial automation. For this project, the programming develop will be use to control the switching of the relays either in charge or discharge mode. From the control circuit, the data is sent LabVIEW programming by NI-DAQ 6212 USB that is connected to personal computer and hardware. The program includes the cut-off limit for the relays to start switching based on the terminal voltage of the battery. Figure 3.10 shows the Graphical User Interface (GUI) programming that has been develop to capture and record the data. Figure 3.11 shows the block diagram of the project by using LabVIEW 2011 software.

3.4.1 Front Panel

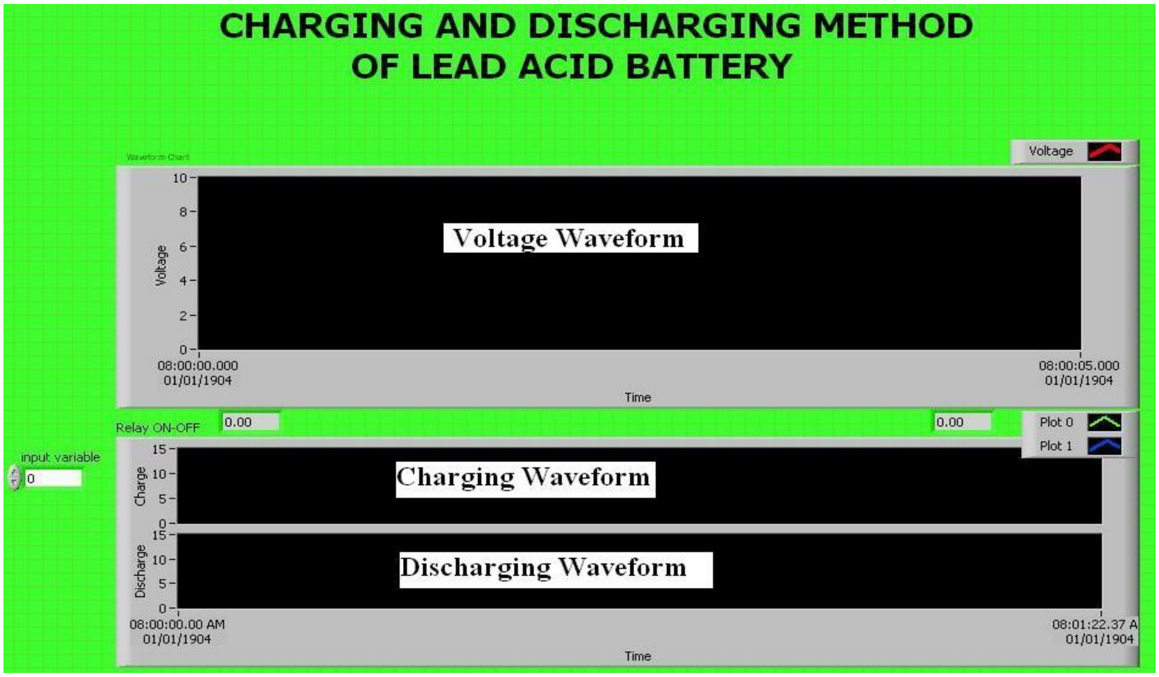

Figure 3.9 Front panel for charging and discharging display.

The front panel of the program consists of two major graphs which are for voltage waveform and the other one is for charging/discharging waveform. The voltage waveform read the actual battery voltage. The graph for voltage waveform is representing in voltage-time graph. The voltage parameter has been set to 0-10V. During the experiment is conducted, time taken for every experiment is vary depending on the experiment conducted. The charging/discharging waveform shows a value according to the current operation. During charging process, the charging graph shows a value that indicates the battery in the charging process and same things happen during the discharging process. The data taken during the experiment can be save to Microsoft Excel by simply export the data from voltage waveform to excel.

3.4.2 Block Diagram

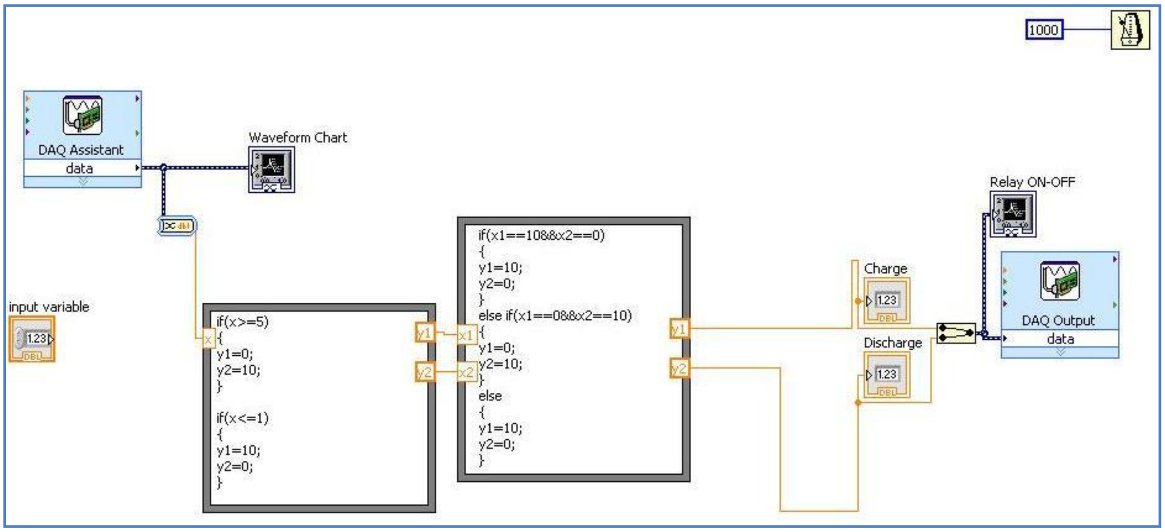

Figure 3.10 Block diagram for charging and discharging program.

Figure 3.11 shows the operation of the charging and discharging program.' DAQ Assistant' reads the input from the battery. On the DAQ card, the port use for input is port 15 for positive channel and port 28 for negative channel. The input is connected to the waveform chart to shows the actual battery voltage and connected to the formula node that responsible for the battery to be in charging or discharging state. The first formula node get input from the DAQ Assistant and read the input. The program then determine whether the battery in charging or discharging process. The second formula node is connected to the DAQ Output. The second formula node responsible to shows the charging or discharging waveform. The DAQ output use two different port which gives output to the electronic control circuit. Charging process use port 12 and discharging process use port 13 on the DAQ card. The program can be operated in Automatic or Manual mode. In Automatic mode, the program is following Figure 3.11 and it continued to operating until the stop button has been pushed. In Manual mode, the connection between the DAQ Assistant and formula node is cut and input variable is connected to the formula node. Manual mode enables the user to test-run the program without having to get the input from the battery.

3.4.2.1 Wait Function

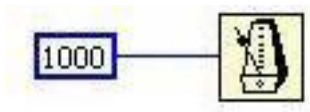

Figure 3.11 Wait Until Next ms Multiple function

In the block diagram, *'Wait Until Next ms Multiple'* function has been use. The *Wait Until Next ms Multiple* function watches the millisecond counter and waits for it to reach a multiple of the user-specified time, in milliseconds, which in this case is 1000, before running the next iteration of the loop. The function allows the processor time to complete other tasks such as updating and responding to the user interface.

3.4.2.2 Terminal Configuration

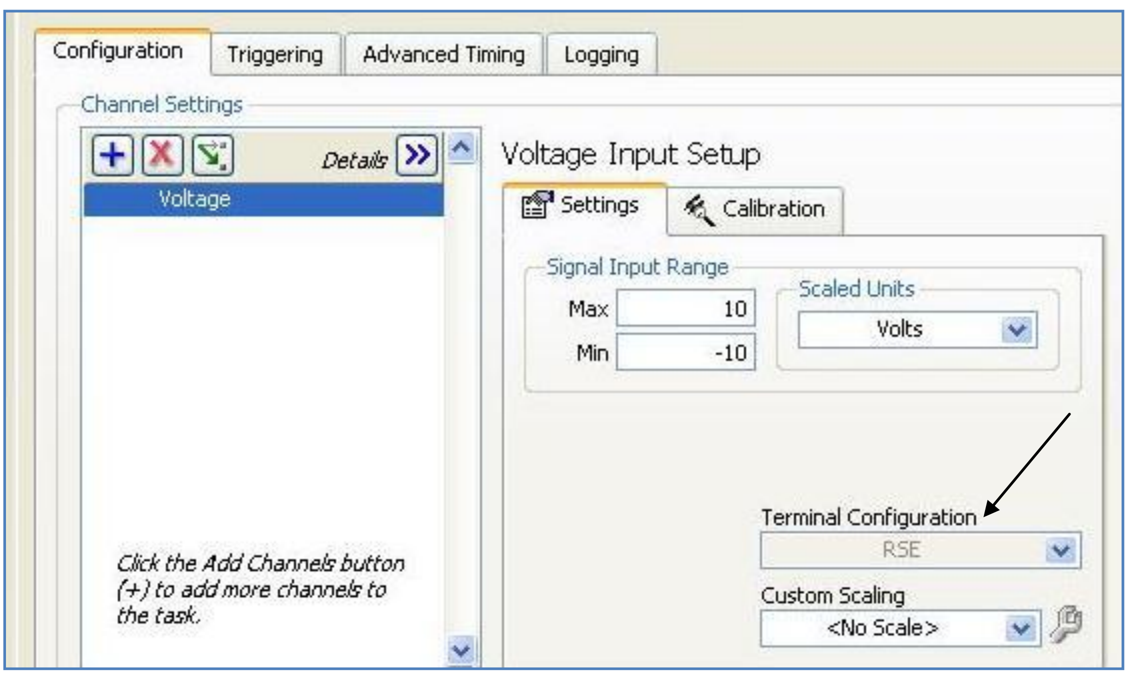

Figure 3.12 Terminal Configurations for DAQ Card.

There are two normally use terminal configuration for the DAQ card. There are *Differential* and *Referenced Single-Ended (RSE).*

Differential typically used to measure small voltage differences between two input voltages, especially if there is a possibility of a large common mode voltage. Three connections are needed: a high side, a low side and a path to ground. The path to ground is important; if the inputs are purely floating, the voltages may drift outside the valid voltage range, a problem that is solved by connecting one of the input voltages to ground using a resistor (usually valued around 10 kΩ). A typical application of this configuration is for a thermocouple.

RSE configuration is used when all measurements are referenced to a common ground, usually the ground pin on the DAQ. Two connections are needed, the input signal and a path to ground. The most common application of RSE is for a power supply, oscilloscope, battery or waveform generator.

This project use RSE terminal configuration because it is very suitable for battery application. *RSE* and *Differential* use different port on the DAQ Card. For this project, the RSE terminal configuration use port 15 for positive channel and port 28 for negative channel.

3.4.2.3 Cut-off Limit Program

The limit program is an important element in this project. This program was developed so that the DAQ card can give signal to electronic control circuit for charging or discharging process. Figure 3.13 shows the limit program that is use in this project.

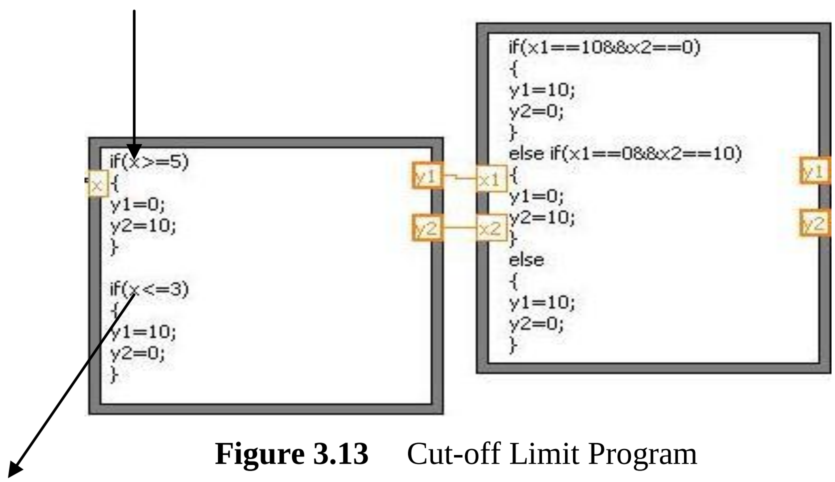

Figure 3.13 Cut-off Limit Program

The program uses simple command to determine the charging or discharging state. The 'x' refers to the actual battery voltage that is sent by DAQ card. In this program, there are two 'x' used which are for maximum limit and the minimum limit. The maximum limit means the highest voltage that set while minimum limit means the lowest voltage set. The program reads the input from DAQ card and sent the reading to the second formula node. The second formula node responsible for the program to displayed the charge or discharge state of the battery. The program can be set by setting the new value of 'x' desired. The output from the second formula node is channel through the DAQ card output. The output gives the signal to the electronic control circuit and switching the charge or discharge operation based on the input get from the DAQ card.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter describes the experimental results of charging and discharging method of lead-acid battery. It includes results analysis and output captured by the GUI LabVIEW simulation. In this project, four sets of experiment have been conducted to get series of data.

4.2 Maximum Limit = 5 and Minimum Limit=3

The first experiment was conducted to see the charging and discharging state of the battery based on the maximum limit =5 and minimum limit =3.

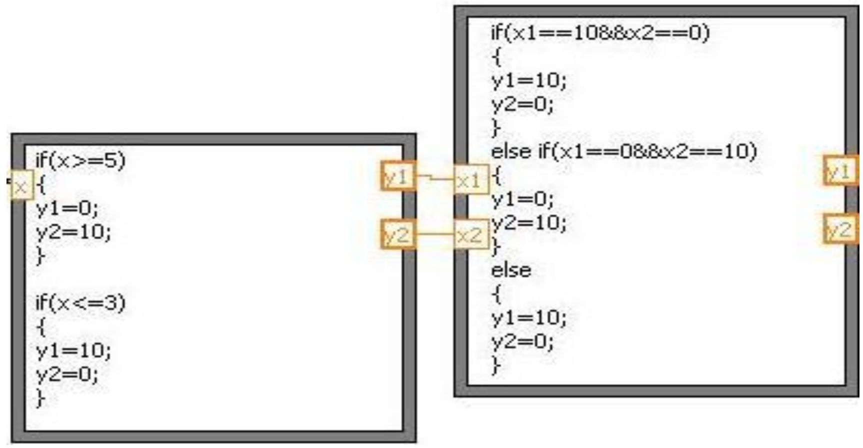

Figure 4.1 Maximum limit =5 and minimum limit =3

The first loop of the program is for voltage input. The maximum limit has been set to 5V and the minimum limit has been set to 3V. 'y1' and 'y2' refer to charging and discharging state of the battery. If input is bigger or equal to 5, the battery undergoes discharging state. The 'y1' and 'y2' parameter will be shown in graph to display whether it is in charging or discharging state.

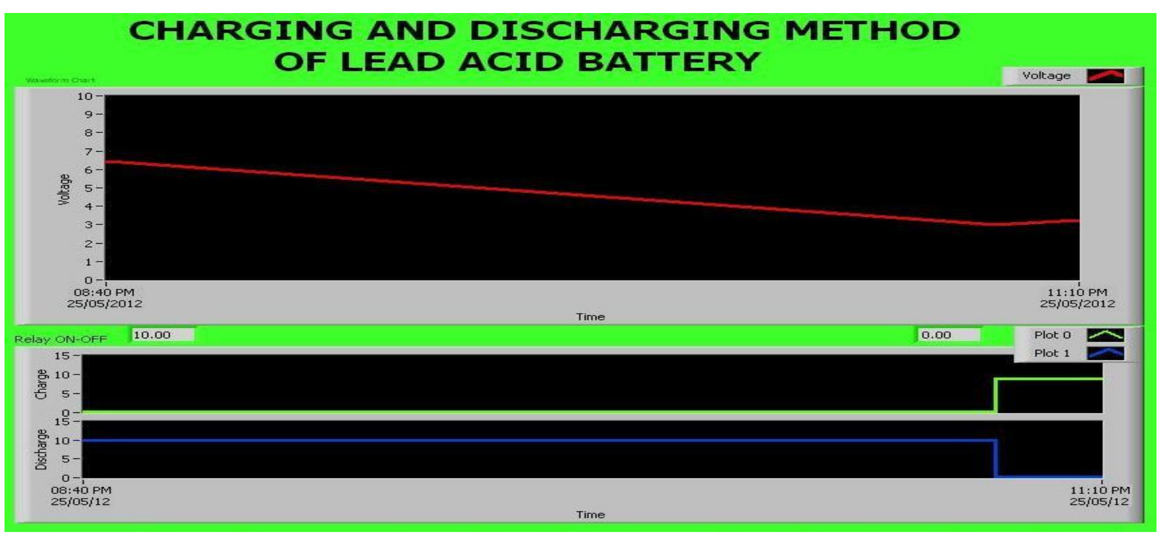

Figure 4.2 Discharging graph for maximum limit =5 and minimum limit =3

Figure 4.2 show the discharging state of the lead-acid battery. The time for this graph has been set to 2 hours and 30 minutes. The initial voltage of the battery is 6.34V. After connected to the load, the voltage started to decrease. The green line shows the charging state of the battery while blue line shows discharging state of the battery. Based on the figure, the blue line constantly gives a positive value until the voltage limit reach it minimum value. At this point, the voltage has enter the minimum value with is 3V. The DAQ get it signal and sent it to the electronic control circuit so that the charging process can operate. The battery voltage slowly started to charge and there is a change in the charging state waveform. The green line start to give a positive value that it indicates the battery is in the charging state while the discharging waveform gives a zero value.

Table 4.1 Discharging Voltage-time

Date	Time	Voltage (V)
25.5.2012	8.40 PM	6.340
	8.45 PM	6.214
	8.50 PM	6.092
	8.55 PM	5.972
	9.00 PM	5.851
	9.05 PM	5.723
	9.10 PM	5.598
	9.15 PM	5.477
	9.20 PM	5.351
	9.25 PM	5.229
	9.30 PM	5.114
	9.35 PM	4.976
	9.40 PM	4.859
	9.45 PM	4.728
	9.50 PM	4.607

	9.55 PM	4.481
	10.00 PM	4.356
	10.05 PM	4.233
	10.10 PM	4.109
	10.15 PM	3.980
	10.20 PM	3.863
	10.25 PM	3.729
	10.30 PM	3.612
	10.35 PM	3.483
	10.40 PM	3.257
	10.45 PM	3.117
	10.50 PM	3.001

Table 4.1 shows the data of the battery voltage and time for discharging process. The total duration for the process to complete from initial voltage 6.340V to minimum set voltage 3V is 2 hours and 10 minutes. The data are recorded by using 5 minutes time interval. From the table, it is clearly shows that the battery constantly discharging as the voltage reading is decreasing. The voltage decreased almost as the constant value from one interval time to one another. The battery continued to discharge until it reached 3V. At this point, the battery is still can provide power to the load, but because the program has been set to minimum voltage 3V, the battery undergoes charging process. From the table, the last value recorded from battery voltage before it change to charging process is 3.001V.

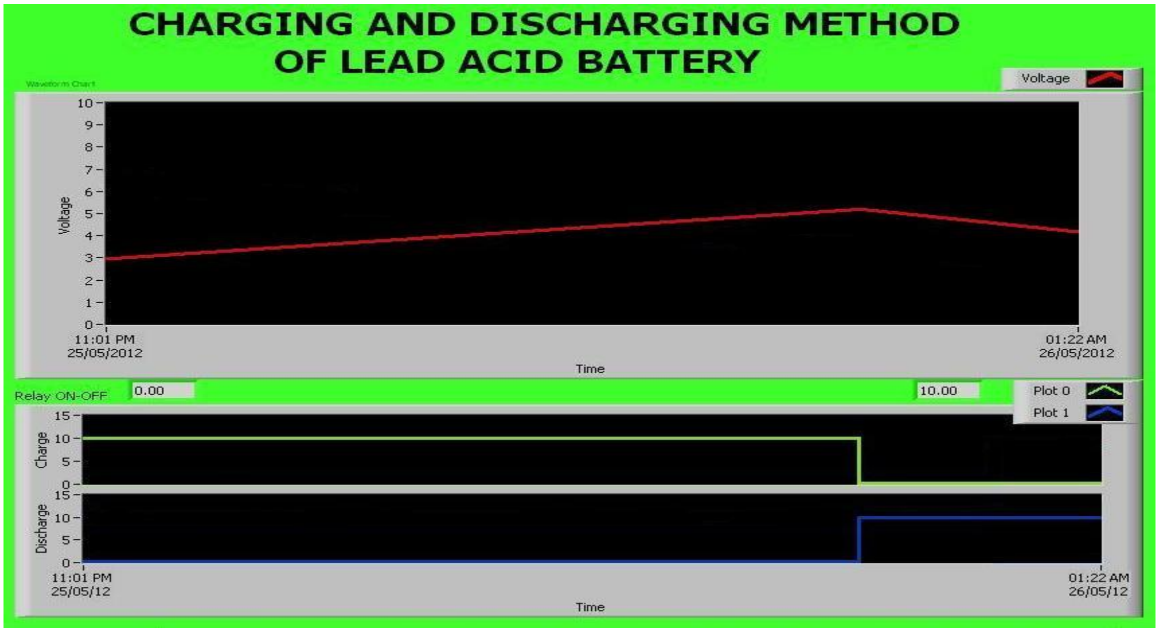

Figure 4.3 Charging graph for maximum limit =5 and minimum limit =3

The figure above shows the charging graph of the lead-acid battery. The battery starts to charge if the voltage is equal to 3V. The charging state shows a positive value. The voltage slowly starts to increase until it reaches the maximum value of 5V. At this point, the battery enters the discharging state. The battery voltage start to decrease as the discharging waveform shows a positive value. The cycle of the battery will be continued until the power supply for circuit is disconnected. By using DC supply, the charging voltage use is 8V 2A. The data of the charging and discharging data is get and put in the table.

Table 4.2 Charging Voltage-time

Date	Date	Voltage (V)
25.5 2012	10.50 PM	3.001
	10.55 PM	3.079
	11.00 PM	3.166
	11.05 PM	3.245
	11.10 PM	3.328
	11.15 PM	3.403
	11.20 PM	3.492
	11.25 PM	3.577
	11.30 PM	3.659
	11.35 PM	3.743
	11.40 PM	3.823
	11.45 PM	3.914
	11.50 PM	3.995
	11.55 PM	4.075
26.5.2012	12.00 AM	4.158
	12.05 AM	4.243
	12.10 AM	4.325
	12.15 AM	4.409
	12.20 AM	4.491
	12.25 AM	4.573
	12.30 AM	4.675
	12.35 AM	4.737
	12.40 AM	4.827
	12.45 AM	4.996

Table 4.2 shows the data for battery voltage during charging process. The total duration taken to complete the charging process within the program is 1 hours and 55 minutes. The data are recorded with 5 minutes of time interval. The initial battery voltage when it started to charge is 3.001V. During charging, a constant current has been applied to the battery. From the table, it is clearly shows that the battery voltage started to increase at the constant rate between the time intervals. The battery continued to charge until it reached the maximum limit set which is 5V. At that time, the battery start to undergoes the discharging process and circuit has been disconnected.

4.3 Maximum Limit = 6 and Minimum Limit=3

The experiment is continues with maximum voltage limit equal to 6V and minimum limit is 3V. The reason minimum limit is set to 3V is because to avoid the battery from over-discharging and thus damaging the battery. The program written for this experiment can be refers to Figure 4.4.

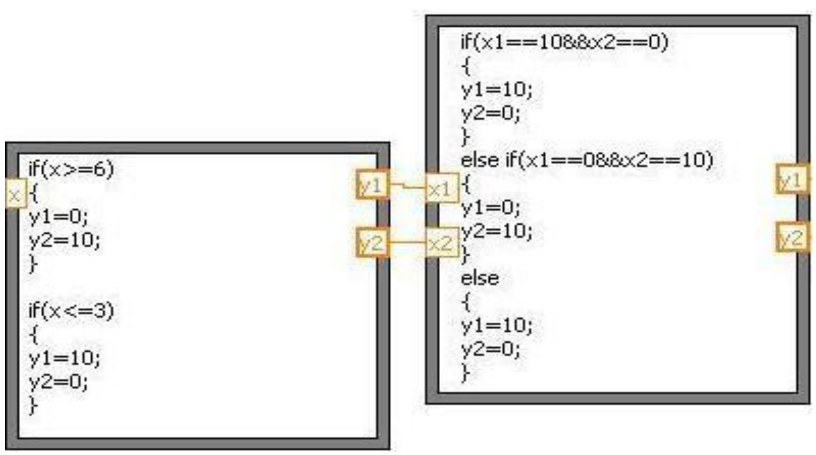

Figure 4.4 Maximum Limit = 6 and Minimum Limit=3

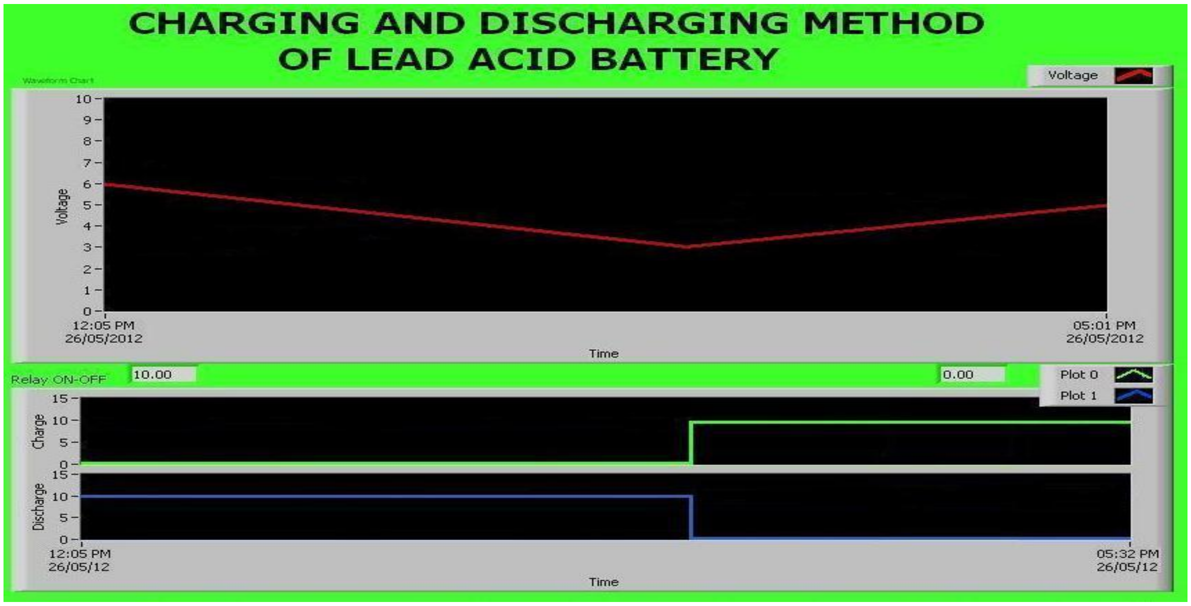

Figure 4.5 Charging and discharging graph for maximum Limit = 6 and Minimum limit=3

Figure 4.5 shows the charge and discharge graph of the lead-acid battery. For this experiment, the time of the graph has been set to 5 hours. The initial voltage of lead-acid battery is 6V. As the voltage decrease, the decreasing graph shows a positive value while the charging graph shows zero value. The time taken for battery to reach minimum limit is about 2 hours and 45 minutes. After the battery reach 3V, DAQ sent a signal to electronic control circuit, and the battery start to charging.

Table 4.3 Discharging Voltage-time

Date	Time	Voltage (V)
26.5.2012	12.05 PM	6.002
	12.10 PM	5.908
	12.15 PM	5.812
	12.20 PM	5.721
	12.25 PM	5.623
	12.30 PM	5.533
	12.35 PM	5.437
	12.40 PM	5.345
	12.45 PM	5.254
	12.50 PM	5.158
	12.55 PM	5.066
	1.00 PM	4.970
	1.05 PM	4.877
	1.10 PM	4.781
	1.15 PM	4.687
	1.20 PM	4.595
	1.25 PM	4.502
	1.30 PM	4.408
	1.35 PM	4.324
	1.40 PM	4.231
	1.45 PM	4.125
	1.50 PM	4.033
	1.55 PM	3.936
	2.00 PM	3.845
	2.05 PM	3.752
	2.10 PM	3.658
	2.15 PM	3.564
	2.20 PM	3.471

26.5.2012	2.25 PM	3.377
	2.30 PM	3.283
	2.35 PM	3.189
	2.40 PM	3.097
	2.45 PM	3.002

Table 4.3 shows the data for battery voltage during discharging process for different set of experiment. For this experiment, the maximum limit has been set to 6V while the minimum limit is 3V. The total duration taken to complete the discharging process within the program is 2 hours and 40 minutes. The data are recorded with 5 minutes of time interval. The initial battery voltage when it started to discharge is 6.002V. During discharging, the battery is connected to the load. From the table, it is clearly shows that the battery voltage started to decrease at the constant rate between the time intervals. The battery continued to discharge until it reached the minimum limit set which is 3V. The last recorded data for battery voltage before it starts to charge is 3.002V.

Table 4.4 Charging Voltage-time

Date	Time	Voltage (V)
	2.45 PM	3.002
	2.50 PM	3.097
	2.55 PM	3.193
	3.00 PM	3.288
	3.05 PM	3.379
	3.10 PM	3.475
	3.15 PM	3.463
	3.20 PM	3.661

26.5.2012	3.25 PM	3.764
	3.30 PM	3.859
	3.35 PM	3.955
	3.40 PM	4.051
	3.45 PM	4.142
	3.50 PM	4.241
	3.55 PM	4.336
	4.00 PM	4.438
	4.05 PM	4.527
	4.10 PM	4.622
	4.15 PM	4.717
	4.20 PM	4.813
	4.25 PM	4.911
	4.30 PM	5.003
	4.35 PM	5.098
	4.40 PM	5.194
	4.45 PM	5.289
	4.50 PM	5.385
	4.55 PM	5.479
	5.00 PM	5.575

Table 4.4 shows the data for battery voltage during charging process for different set of experiment. For this experiment, the maximum limit has been set to 6V while the minimum limit is 3V. The total duration taken to complete the discharging process within the program is 2 hours and 15 minutes. The data are recorded with 5 minutes of time interval. The initial battery voltage when it started to charge is 3.002V. During charging, a constant current has been applied to the battery. Charging process was continued until clock reach 5.00PM. At this time, the process has to be stop because the load experienced overheating and to avoid the DAQ card from damaging. The voltage recorded at that time is below 6V and it not reaches the maximum voltage limit.

4.4 Experimental Characterization of Lead Acid Battery

The program has been set to have maximum limit=10 and minimum limit=1. The purpose of this experiment is to analyze the maximum and minimum voltage the battery can stored until constant voltage has been reach.

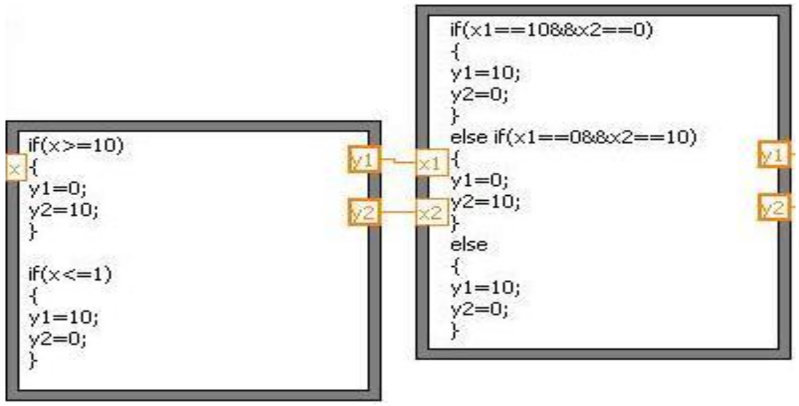

Figure 4.6 Maximum limit=10 and minimum limit =1

4.4.1 Overcharging

Figure 4.7 Overcharging waveform

Figure 4.7 shows the overcharging characteristic of lead-acid battery. The 6V battery has been charged with constant current for 2 hours. The initial battery voltage is 6V and as the battery starts charged, the battery voltage is gradually increased. The battery continued to charge until it reached a maximum constant value which is 8.08V. The circuit is then disconnected and the battery voltage slowly starts to decreased until it reached a nominal voltage value which is 6.64V.

Table 4.5 Overcharging

Date	Time	Voltage (V)
13.6.2012	9.07AM	6.00
	9.12 AM	6.06
	9.17 AM	6.13
	9.22 AM	6.24
	9.27 AM	6.32
	9.32 AM	6.47
	9.37 AM	6.60
	9.42 AM	6.68
	9.47 AM	6.73
	9.52 AM	6.81
	9.57 AM	6.90
	10.02 AM	7.01
	10.07 AM	7.15
	10.12 AM	7.28
	10.17 AM	7.36
	10.22 AM	7.51
	10.27 AM	7.67
	10.32 AM	7.83
	10.37 AM	7.97

	10.42 AM	8.01
	10.47 AM	8.03
	10.52 AM	8.04
	10.57AM	8.05
	11.02 AM	8.06
	11.07 AM	8.08

4.4.2 Fully-discharge

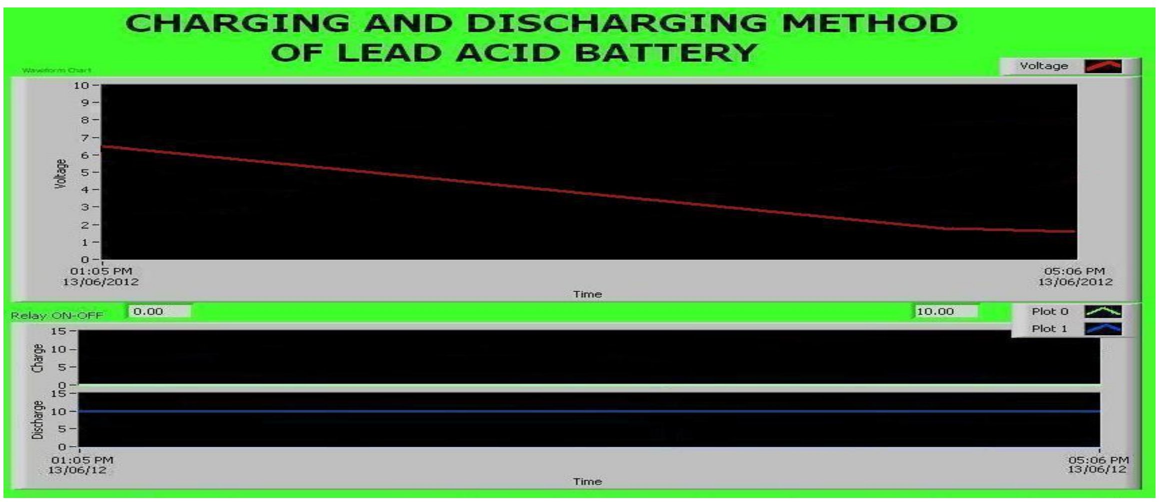

Figure 4.8 Fully-discharge waveform

The figure above shows the fully-discharge characteristic of 6V lead-acid battery. The initial voltage of the battery is 6.64V. The battery start discharged until it reached minimum voltage value which is 1.64V. At this time, the load use, which is DC motor, was no longer operates. The time taken for the battery to fully-discharged is about 5 hours.

Table 4.6 Fully-discharge

Date	Time	Voltage (V)
13.6.2012	1.05PM	6.64
	1.15PM	6.41
	1.25PM	6.20
	1.35PM	5.97
	1.45PM	5.74
	1.55PM	5.49
	2.05PM	5.29
	2.15PM	5.07
	2.25PM	4.83
	2.35PM	4.57
	2.45PM	4.36
	2.55PM	4.11
	3.05PM	3.92
	3.15PM	3.64
	3.25PM	3.42
	3.35PM	3.20
	3.45PM	2.95
	3.55PM	2.73
	4.05PM	2.58
	4.15PM	2.21
	4.25PM	1.98
	4.35PM	1.91
	4.45PM	1.84
	4.55PM	1.73
	5.05PM	1.64

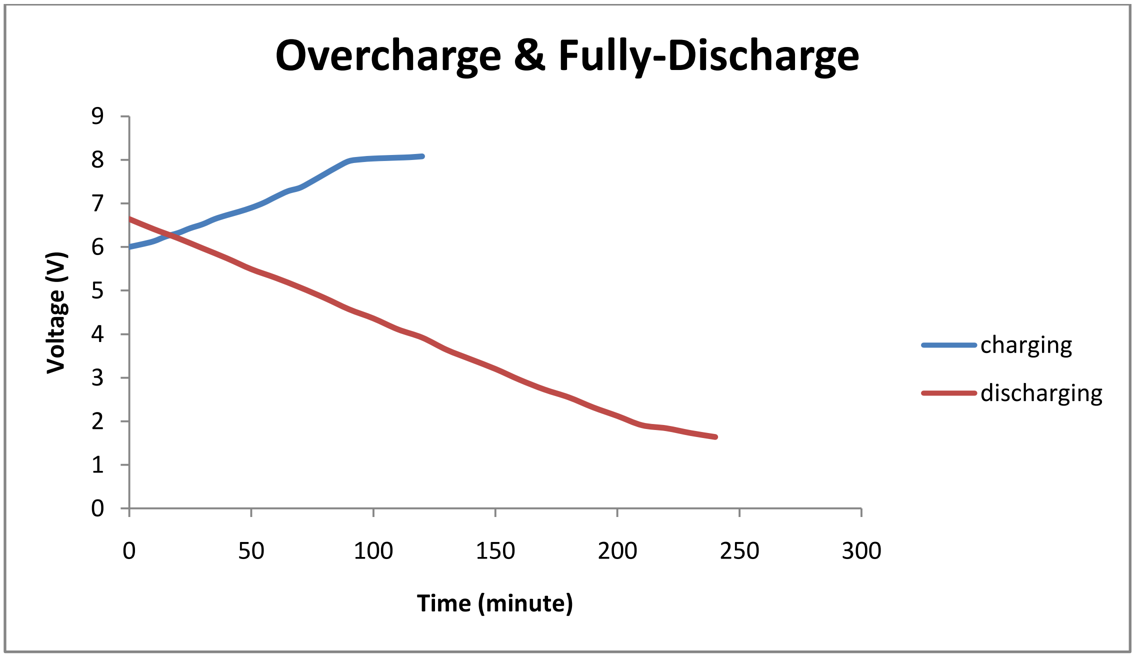

Figure 4.9 Overcharge and fully-discharge graph

Figure 4.9 shows the graph for overcharge and fully-discharge for lead acid battery. The data are taken from Table 4.6 and Table 4.6. From the figure, it is clearly shows that the graph is similar to the waveform shown LabVIEW software. For overcharge graph, the initial voltage is 6.00V. A constant current has been applied to the battery during charging process. The graph shows that the graph is gradually increase by time. At one point, the graph almost reached the maximum constant value. The final value of battery voltage during overcharge recorded is 8.08V and the time taken is about 2 hours. The battery then disconnected and slowly decreased to its nominal value 6.64V.

Discharging time duration is long compare to the overcharge. It takes about 4 hours to completely discharge the battery. From the graph, it is clearly shows that the voltage is decrease at a constant rate until reach the minimum voltage value. At this time, the load use is no longer functional and the last recorded battery voltage is 1.64. By comparing to the constant-current charging graph [10], the shape of the charge graph is almost similar to theory. Thus, it is proven that the experiment achieved it objectives as stated in the introduction chapter.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This project aims to develop a charging and discharging method of lead-acid battery. The method use is by interface the battery with LabVIEW software. The project has achieved it objectives as the battery can be charges and discharge based on the program that has been develop.

The project advantages is allowing the user to set its own charging and discharging maximum and minimum voltage. The battery can be preserved from the overcharging and fully discharged that can cause the life cycle of the battery to be reduce. The control circuit has played it function well to change the charge discharge state without affecting the process operation. The overall project has achieved it targets and method of charging and discharging of lead-acid battery has been develop.

5.2 Limitation of the Project

In this project, several problems occur while conducting the project. First, is NI-DAQ. NI-DAQ maximum rating voltage is 10V. So, the whole project has been limited to using the 6V lead-acid battery. Using higher rating battery might cause damage to the DAQ thus affecting the project.

5.3 Recommendations

There are still a lot of research effort can be done. For future recommendations, The suggestions and recommendation of future extension research are:

a) Install a buzzer or alarm to indicate battery charging or discharging state.
b) Use high voltage DAQ.
c) Experiment under variety of cases such as temperature, variable charge voltage and current.

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APPENDIX A

NI-DAQ 6212 TERMINAL PORT