"I hereby declare that I have read through this report entitle " Smart Battery Monitoring System using Arduino UNO (SBMS)" and found that it has been comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power).

Signature : …………………………………………

Supervisor's Name : MOHD KHAIRI BIN MOHD ZAMBRI

Date : 17.06.2016

SMART BATTERY MONITORING SYSTEM USING ARDUINO UNO (SBMS)

AZROL ASHRAF BIN MOHAMAD ROBA'IE

A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

I declare that this report entitle "Smart Battery Monitoring System using Arduino UNO (SBMS)" 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.

Signature : ……………………………………………………….

Name : AZROL ASHRAF BIN MOHAMAD ROBA'IE

Date : 17.06.2016

To my beloved mother, father and family. Also, to my respected lecturers in UTeM.

ACKNOWLEDGEMENT

بسم الله الرحمن الرحيم

In the name of Allah, the Most Beneficent and the Most Merciful.

It is a deepest sense of gratitude to the Almighty that give me strength and ability to complete this Final Year Project (FYP) report.

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ABSTRACT

Electrical energy consumption increase rapidly every year. The continuous energy supply must be secure due to high electrical energy demand. Battery bank is required to store the energy. Limitation of method for continuous monitoring the battery bank performances caused the process of maintaining the battery bank to be challenging. In order to continuously monitor the battery bank, this report presents a model of Smart Battery Monitoring System (SBMS). The SBMS is capable of continuous monitoring the battery bank at a distance and store the data periodically for further analysis. The SBMS works by measure the parameters of the battery which are voltage (V), current (A), ampere hours (Ah), power (W), watt hours (Wh) and State of Charge (SoC). The system consists of hardware (a microcontroller, sensors, a Bluetooth module, a SD card module, a memory card, a LCD display) and software development. The microcontroller board used is an Arduino UNO board (ATmega328P). Voltage is measured by voltage sensor module based on voltage divider concepts while current is measured by current sensor (ACS712-20A) and the readings transferred using Bluetooth communication system to display on a smartphone. The data also will be displayed on LCD. All the data will be stored in memory card for further analysis. The analysis shows that only 1% to 15% error between the Fluke meter and SBMS due to charging and discharging process of the battery. Based on the results, the voltage is inversely proportional to the current. The value of current increases with the drop of voltage value. SBMS provides a real time data of voltage, current, ampere hours, power, watt hours and State of Charge (SoC), then display data on the LCD and smartphone simultaneously.

ABSTRAK

Penggunaan tenaga elektrik meningkat dengan mendadak setiap tahun. Bekalan tenaga berterusan mestilah selamat berikutan penggunaan tenaga elektrik yang tinggi. Bank bateri diperlukan untuk menyimpan tenaga elektrik. Had kaedah untuk memantau persembahan bank bateri secara berterusan menyebabkan proses penyelenggaraan mencabar. Dalam usaha untuk memantau secara berterusan bank bateri, laporan ini memperkenalkan model Sistem Pemantauan Bateri Pintar (SBMS). SBMS mampu untuk berterusan memantau bank bateri pada jarak tertentu dan menyimpan data secara berkala untuk analisis selanjutnya. SBMS berfungsi dengan mengukur parameter bateri iaitu voltan (V), arus (A), "ampere hours" (Ah) dan "State of Charge" (SoC). Sistem ini terdiri daripada perkakasan (pengawalmikro, sensor, modul Bluetooth, modul kad SD, kad memori, paparan LCD) dan perisian. Papan pengawalmikro yang digunakan adalah papan Arduino UNO (Atmega328P). Voltan diukur menggunakan modul sensor voltan yang berkonsepkan pembahagi voltan manakala arus diukur menggunakan sensor arus (ACS712-20A) dan dipindahkan menggunakan system komunikasi bluetooth untuk dipaparkan pada telefon pintar. Data itu juga akan dipaparkan pada LCD. Semua data akan disimpan dalam kad memori untuk analisis lanjut. Analisis menunjukkan bahawa hanya 1% hingga 15% ralat antara meter Fluke dan SBMS bagi proses pengecasan dan menyahcas bateri. Berdasarkan keputusan, voltan berkeadaan songsang dengan arus. Nilai arus meningkat berikutan penurunan nilai voltan. SBMS menyediakan dan memaparkan data voltan, arus, "ampere hours", kuasa, "watt hours" and "SoC" pada LCD dan telefon pintar secara serentak mengikut masa yang sebenar.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Electricity consumption or demand experienced a dramatically increase over the years. Electrical energy is vital to the modern sector like industry, transport, agriculture, household uses and etc. The continuous and robust energy supply must be secure and regulated due to high electrical energy demand. To ensure the continuous electrical energy supply, battery bank is required to store energy and thus could provide the power supply in case the generator does not function. Battery is an electrochemical cell (or enclosed and protected material) that can be charged electrically to provide a static potential for power or released electrical charge when needed [1]. Generally, battery can be used in a limited time only. Furthermore, the battery needs to be maintained, checked and monitored periodically. Therefore, a device should be invented to overcome the drawbacks of the battery.

Development of Smart Battery Monitoring System (SBMS) is a solution to overcome the problem. Smart Battery Monitoring System or SBMS is a device that capability to monitor lifespan and performance of the battery. SBMS able to measure and display the parameters of the battery. The parameters include voltage (V), current (A), power (W), ampere hours (Ah), watt hours (Wh) and State of Charge (SoC). SBMS also capable of storing all the parameters in memory card periodically for in-depth analysis of the battery characteristics and monitor at a distance by using smartphone. SBMS can be installed on UPS, DC plant, generator and switchgear battery systems. The SBMS could provide permanent and continuous monitoring of standby battery in order to prevent unplanned outages on the power supply system. In addition, SBMS can prolong battery life thus can save operating cost.

1.2 Problem Statement

The multimeter is commonly used to monitor characteristics of battery bank by measuring the battery voltage. This method is actually inefficient due to lack of human power Human power is very limited to monitor the battery from time to time by measuring the voltage for the each battery used. In industrial and DC power plant, a lot battery bank was used as a backup supply in case of power failure. In fact, most of the multimeter does not have a system that could save and monitor the data at a distance. To develop the SBMS, the suitable coding must be used in order to run the system. The coding for voltage and current sensor for this system is not easy to code due to the unstable of analog values. Therefore, some calculation and calibration need to be done to obtain the exact reading of the voltage and current as well as multimeter.

1.3 Objective

The objective of this project is:

i. To build a SBMS using Arduino UNO circuit.
ii. To analyse the performance of the battery at a distance using Bluetooth communication system.
iii. To save and collect the reading of the SBMS using Micro SD card.

1.4 Scope

This project is an emphasis on the new technology, which is Arduino. ATMega328 is used as a main controller that found on the Arduino UNO Board. The 12V Sealed Lead Acid battery is used as research materials because it is usually used as backup emergency power sources. The reading taken are voltage and current of the battery in different time. The analysis is based on DC load. The simulation used ISIS Proteus Professional 8 software. While, the coding for this system is created using Arduino Integrated Development Environment (IDE) software. All the reading of the battery that obtain using SBMS will be compared by the Fluke meter. The readings are construct in table and graph for further discussion.

1.5 Expected Project Outcomes

At the end of this project, a SBMS can be developed. The suitable electronic components and coding for Arduino are used in this project. Hence, the user will be able to monitor the performance of the battery using SBMS. The parameter which can be monitored are voltage, current, power, watt hours, ampere hours and State of Charge (SoC) of the battery. The system allows the user to monitor all the parameter same as multimeter. The system also allows the user to monitor the battery performance in a range of 10m using smartphone. In order to study the battery performance, all the data are saved in memory card. This SBMS is a compatible device for UPS, DC power plant, generator and switchgear battery systems.

1.6 Report Outline

This report contains five (5) main chapters consists of an introduction, literature review, methodology, result and discussion and lastly conclusion. The first chapter is introduction, it was explained in detail about the project background, problem statement, objective, scope and expected project outcome. The second chapter is the literature review. The literature review is overview of related past research included theory and methodology used, result and discussion. The third chapter is methodology, it completely explains how to build the prototype of the SBMS from the beginning until the end. The fourth chapter is result and discussion. This chapter shows the related result of the experiment and the discussion of the result. Lastly, the fifth chapter is conclusion.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A battery is a medium of energy storage for renewable energy system and also in industry. The using of the battery becomes more significant nowadays due to the development of renewable energy and industrial sector. Battery Monitoring System (BMS) is a solution to monitor the performance of the battery in order to prevent unplanned outages on the critical power backup system. This chapter will study about the recent development on BMS and the characteristic of the battery.

2.2 Reviews of the previous works

This part is about the previous works on BMS. Several articles related to the BMS were chosen to study about the recent development on BMS and the characteristic of battery. At the end of this chapter, a comparison between the articles was done to pick the suitable hardware, software and software to develop the SBMS.

2.2.1 A Smart Wireless Battery Monitoring System (WBMS) for Electric Vehicles (EVs)

The article is stated to calculate the consumer cost, the EVs should be monitoring and utilizing the energy from the battery without affect lifespan of the battery [3]. BMS detect the every cell voltage and temperature and study for fault conditions [2]. Continuous observing the battery life will reduce user's anticipation of the battery life when EVs is used. WBMS is the development of hardware and software elements. The hardware consists of

Base Transmit Module (BSTM). BSTM have a cell and interface unit, processing unit, cell balancing unit and communication unit. BSTM also monitor battery voltage, current and temperature. While the software elements are used to configure the hardware peripherals, observe and control the battery performances. WBMS is tested on 48V Li-ion battery pack. Wireless system uses less wire, thus improved reliability. The drive cycled test was run for 142 seconds. From the test, voltage is dropped when the vehicle is accelerating. The voltage of the battery is calculated and cell balancing algorithm is executed if needed.

2.2.2 Battery Monitoring System by Detecting Dead Battery Cells

This paper stated the application of a battery is widely used from smaller size to the larger size battery, which is used as a medium of storage system to provide emergency power to loads, improve quality of power and reliability of power system when needed [4]. The battery must be long lasting in order to operate in optimal battery life. The detection of dead battery can be obtained by observing and study the performance of the battery in term of voltage, voltage per cell, current, and temperature. The monitoring circuit consists of the power circuit, control circuit and communication circuit. The parameters of battery are sent to CAN and TTL communication circuit to change the signal to TTL, which processed by chipKIT Max32. The TTL data change to RS232 signal, which supported by PLC. Lastly, the data processed by using PLC and send the result to computer for displaying the result during charging and discharging process. Internal resistance contributes to temperature and voltage of battery as a result.

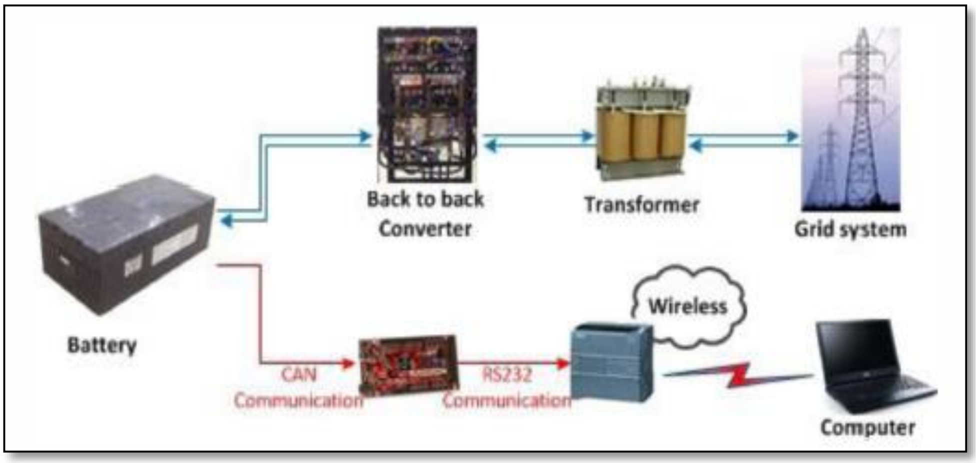

Figure 2.1: The connection between testing device and battery courtesy of [4]

2.2.3 Battery Monitoring System using Microcontroller

The article claims increasing in demand for clean fuel and energy has enhanced awareness to use electric vehicles (EVs) and hybrid electrical vehicles (HEVs) due to concerns of global warming issue [5]. The battery is a main part in EVs. BMS is used to monitor performance of battery in term of current, voltage and temperature. Depth of discharge (DOD), temperature and charging algorithm if affected the battery performance. This paper is to provide a measurement of electrolyte temperature, electrolyte level and how many hours of lead-acid batteries could withstand. BMS consists of two units which are slave unit and master unit. Slave unit is attached to 12V battery to measure temperature, voltage and water level of battery. The data are sent to the master unit. Meanwhile, master unit is major part which used to collect data from the slave unit via RS232 cable and record data in real time using RTC. Then, transfer the data to a LCD and PC. The current is measure using Hall Effect IC. Microcontroller functions as a programmer. The microcontroller was simulated by using M-IDE software. MIIDE-51 is an open source Integrated Development Environment (IDE) and comes with assembler, C compiler and simulator. The implementation of BMS gives the results of electrolyte temperature, electrolyte level and number of backup hours given of the battery in EVs and HEVs. This project helps to ascertain the performance of the battery.

2.2.4 Design Real Time Battery Monitoring System Using LabVIEW Interface for Arduino (LIFA)

This paper stated battery is vital part of electronic devices and the system and used as source energy [9]. The rechargeable is extensively used, so it is needed to monitor the battery performance. BMS is applied to observe battery voltage, current and temperature during charging or discharging condition [6]. This paper represents Real Time Battery Monitoring System Using LabVIEW Interface for Arduino (LIFA) and consist of hardware and software part which are sensor, microcontroller Arduino UNO and LabVIEW as the main display for collecting data. The sensor used are voltage sensor and the current sensor. The voltage sensor module is based on resistor divider principle to detect the apply voltage. Meanwhile, the current sensor used is ACS712-05B. This sensor is used the Hall-Effect principle. Microcontroller Arduino UNO is used as a microcontroller based on ATmega328.

For data acquisition, LabVIEW and LIFA are used in this system. LabVIEW as integrating platform for obtaining, processing and transfer data to develop modern measurement and experiment control system using impulsive graphical icons and wires that look like a flowchart [7]. Meantime, LIFA is software to allow a LabVIEW developer to simply take data to and from Arduino microcontroller. The software design is a combination of library LabVIEW on Arduino microcontroller with the Arduino Integrated Development Environment (IDE) for collecting data [8]. As a result, this system can be monitored battery voltage and current during charging and discharging condition.

2.2.5 Battery Health Monitoring System (BHMS)

This paper claim BHMS gives online and offline monitoring of batteries which avoid the battery from unusable [10]. The main objective is to let the user know the lifespan of the battery in order to take any action if any damage happen. BHMS logs the collected data give a report like charging AH and net AH discharged during power failure. The collected data is uploaded to PC to give a graphical presentation of each battery. It is to study the performance of the battery during charging and discharging process and also give warning based on the minimum and maximum value that can be set by the user. This device also capable to observe load currents, AC mains voltage and frequency, battery temperature and ambient temperature. By BHMS, user gets the analysis of present, past and future in order to identify failure of the battery. In conclusion, weak battery can be traced before a failure incident through net change and some calculation.

2.2.6 Real Time Automotive Battery Monitoring System

The article claim BMS is developed to prevent people from being aground and a car could be start due to a dead battery [11]. The main objective to avoid discharge of a car battery during restarting the car. Also, dead battery will reduce the battery lifespan. The system used to monitor a battery car and disconnect the battery from the car before discharge state. BMS consists of LM385 voltage regulator diode, LM324 low power quad operational amplifier, potentiometer, 1/8W resistors, SPDT relay, LEDs, LM741 operational amplifier and SPST sliding switch. Voltage divider concepts are used to monitor voltage across the battery. Furthermore, SPDT relay, LM324 and LM385, LM 741 operational amplifier used as comparator which used to turn on and off the output when reach maximum capacity. SPST is the part that used to disconnect the battery from the car when discharge state happen. As a conclusion, BMS give pleasant to use when draining of the battery car happen.

2.3 Sealed Lead-Acid Battery

Sealed Lead-Acid Battery was designed as a replacement of sealed nickel-cadmium batteries in the consumer application and could be used without leaking electrolyte. This battery does not require water addition as the batteries were sealed and ideally used in places that hardly to access for maintenance. Sealed Lead-Acid Battery also greatly reduced maintenance costs and economically due to long life and high capacity. The Equation (2.1) – (2.3) below apply to sealed recombination batteries, as well as to conventional flooded batteries. Equation (2.1) is referring to the positive electrode, Equation (2.2) is referring to negative electrode and Equation 2.3 is referred to net cell reaction.

$$PbO_2 + SO_4^- + 4H^+ + 2e^- = PbSO_4 + 2H_20 \quad (2.1)$$

$$PbO_2 + 2S0_4^- + 4H^+ + Pb = 2PbSO_4 + 2H_20 \quad (2.2)$$

$$Pb + SO_4 = PbSO_4 + 2e^- \quad (2.3)$$

The internal design of the battery is based on active material density to suit the application. A lower density material will produce less capacity but require for some application that often discharge. There must be enough negative active material to assure that recombination again. The positive grid of all lead-acid batteries is based on oxidation corrosion [12]. Highest occupied states of the registrant must have lower energy than its lowest unoccupied state. Another condition is the lowest unoccupied state of the oxidant must have higher energy than its highest occupied state. If one of these two conditions is disturbed, electrons can be substituted to or from the electrolyte to decrease it. Thus, the condition for thermodynamic stability of the electrolyte limits thermodynamic window of the electrolyte must be higher than the battery voltage [13].

2.4 Charging and Discharging Process

The lead acid battery is economical and easy to build. Compared to other batteries, this battery is lower self-discharged and 98% of lead acid batteries are recycled with low maintenance requirements. The main disadvantages are low energy density, short life, cannot be stored in a discharged condition and environmental unfriendly because of toxic that contain in the lead. The effect of the overcharging will cause battery temperature increase, corrosion of the positive plate and reduction of the chemical properties will reduce the battery life. Over discharging will lead to losses of battery capacity and lower the life cycle of the battery.

For the battery capacity of 6V and 4.5Ah lead acid battery, the full charge depends on the battery voltage when it has reached 7.2V. Voltage from 6.1V is starts increase until reach maximum voltage of 7.1V. The voltage value constant at this point, this called topping charge. Then, the voltage will reduce to 6.6V when disconnected from supply to compensate for self-discharge and called as float charging. Current during this charging process should be constant when voltage is increased and must be reduced in tops charge and zero in float charge period. The battery will be discharged when connected to the load such as LED. The voltage will be discharged from the maximum to the 5.2V. The LED will cut off at a voltage of 5.7V due to the protection circuit in the battery [14].

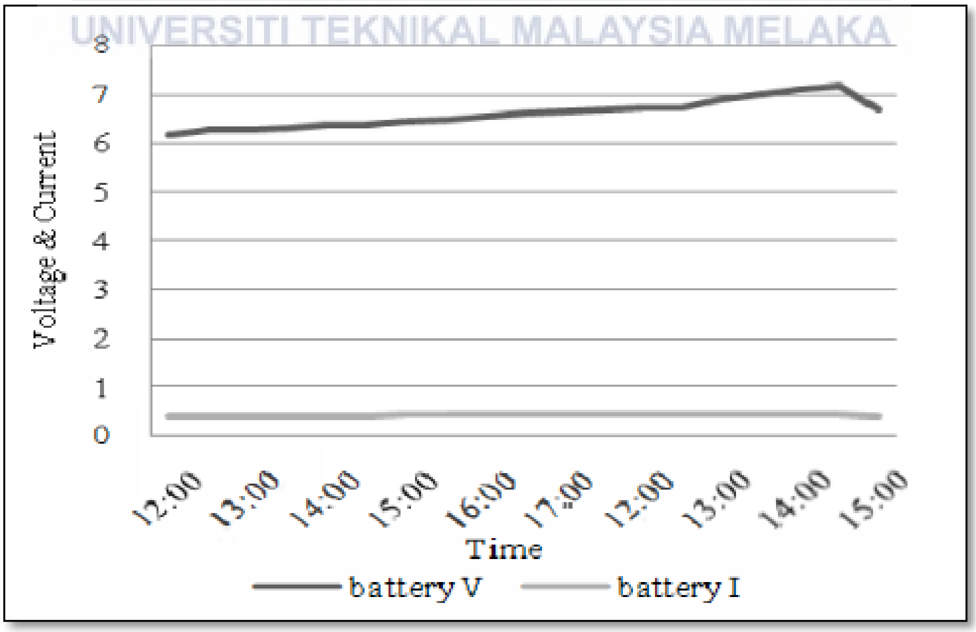

Figure 2.2: Charging characteristics of Lead Acid Battery courtesy of [14]

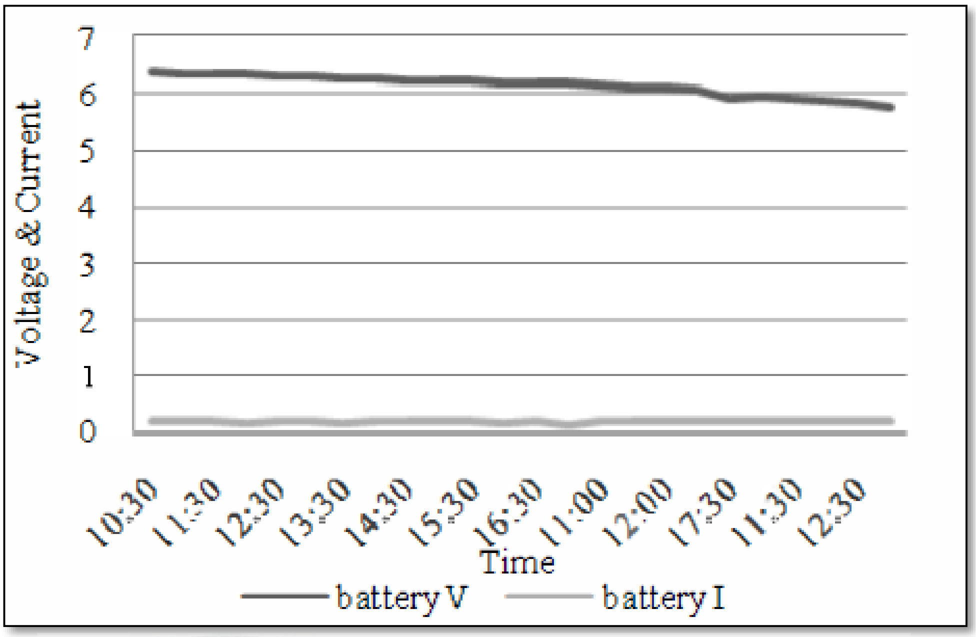

Figure 2.3: Discharging characteristics of Lead Acid Battery courtesy of [14]

2.5 State of Charge (SoC)

State of Charge (SoC) represents the total of charge expressed as the percentage of rated energy. The change in battery voltage from starting to charge until the discharging process state is very small. So, the state of charge of battery can be presented as available capacious (AHr) and expressed as the percentage of rated capacity (AHr) as stated in Equation (2.4) [15].

$$SOC = \frac{Available\ capacity\ (AHr)}{Rated\ Capacity\ (AHr)} \times 100\% \tag{2.4}$$

Measurement of the SOC of voltage is simplest methodology, but usually incorrect. Cell varieties have dissimilar chemical compositions that deliver varied voltage profiles. The higher the temperature will raise the open-circuit voltage. This development applies to any or all chemistries in varied degrees [16].

2.6 Charge Rate

The battery charge rate present as C and shows a charge and discharge process of rate is equivalent to the capacity of a battery divide by 60 minutes or 1 hour. For, 1200 mAh rated battery, it would be 1200 mA. 2C is twice this rate and 1/2C is half the rate [17]. The charging time of the battery is calculated as in Equation (2.5).

$$T = \frac{Ah}{A} \tag{2.5}$$

Charging current should be 10% of the Ah rating of the battery. Therefore, the equation of charging current is stated as in Equation 2.6.

$$I_{charging} = Ah \times \left(\frac{10}{100}\right) \tag{2.6}$$

Even though the charging current is useful for lifespan and performance of the battery on unvarying occurrences, but once battery has reach to fill capacity, it is very important not to continue in order to avoid harm to the battery [18].

2.7 Comparison of Previous Battery Monitoring System Researches

Table 2.1: Comparison of previous BMS

Previous Project	**A Smart Wireless Battery Monitoring System for Electric Vehicles**	**Battery Monitoring System Using Microcontroller**	**Real Time Battery Monitoring System using LIFA**
Type of Sensor	Voltage and current Interface circuit, thermistor	Hall Effect sensor (CS3500), Slave unit (voltage and temperature)	Current sensor (ACS712-05B) and voltage divider sensor module (DFR0051)
Type of controller	16 bit low power microcontroller (MCU)	MCS-51 microcontroller	Arduino UNO microcontroller
Effectiveness	Only use a PC to get data	Only use a PC to get data	Only use a PC to get data
User convenience	User monitor using PC through UART	User monitor using PC	User monitor using PC by BMS interphase

The previous researches can be used as a guideline to develop a SBMS. From Table 2.1, the suitable sensors that will be used are ACS712-05B current sensor and DIY voltage sensor based on voltage divider concepts. The Arduino UNO microcontroller is convenient because of it has open source software and quick prototyping tool for engineering projects. Most of the previous researches only use a PC as a medium to display performance of the battery. For this Battery Monitoring System, smartphone will be used to display data through the Bluetooth communication system. A storage medium, SD card is used to save all data for studying the characteristics of the battery.

2.8 Summary

The previous works give ideas and inspirations to develop SBMS. Comparison of previous BMS used as a guideline to develop SBMS in terms of hardware, software and method used. The characteristic of battery also were studied in order to do the experimental test on SBMS.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

In this chapter, a brief explanation of designing process and experimental test of SBMS. Designing process includes of hardware design and software design. Meanwhile, experimental test is conducted to ensure the SBMS is functional or not. The experimental test also to get the data of the battery and will be compared with the Fluke meter.

3.2 Flow of the project

The flow of this project is shown in Figure 3.1 below. Firstly, finding title for this final year project which is Smart Battery Monitoring System Using Arduino (SBMS). Then, define the objective and scope for this project. The problem statement of this project also has been identified before the further research. Next, a research on this project is carried out to give more understanding and the literature review of the previous project also done. After complete the research about this project, designing process of the hardware and software is executed to make the prototype. An experiment will be conducted to make sure whether the prototype works or not. The data of the voltage and current of the battery during nominal, discharging and charging process is monitored and collected. All the data are recorded. Analysis and discussion of the results are made. Lastly, the overall conclusion is made for this project and the objective is verify whether achievable or not.

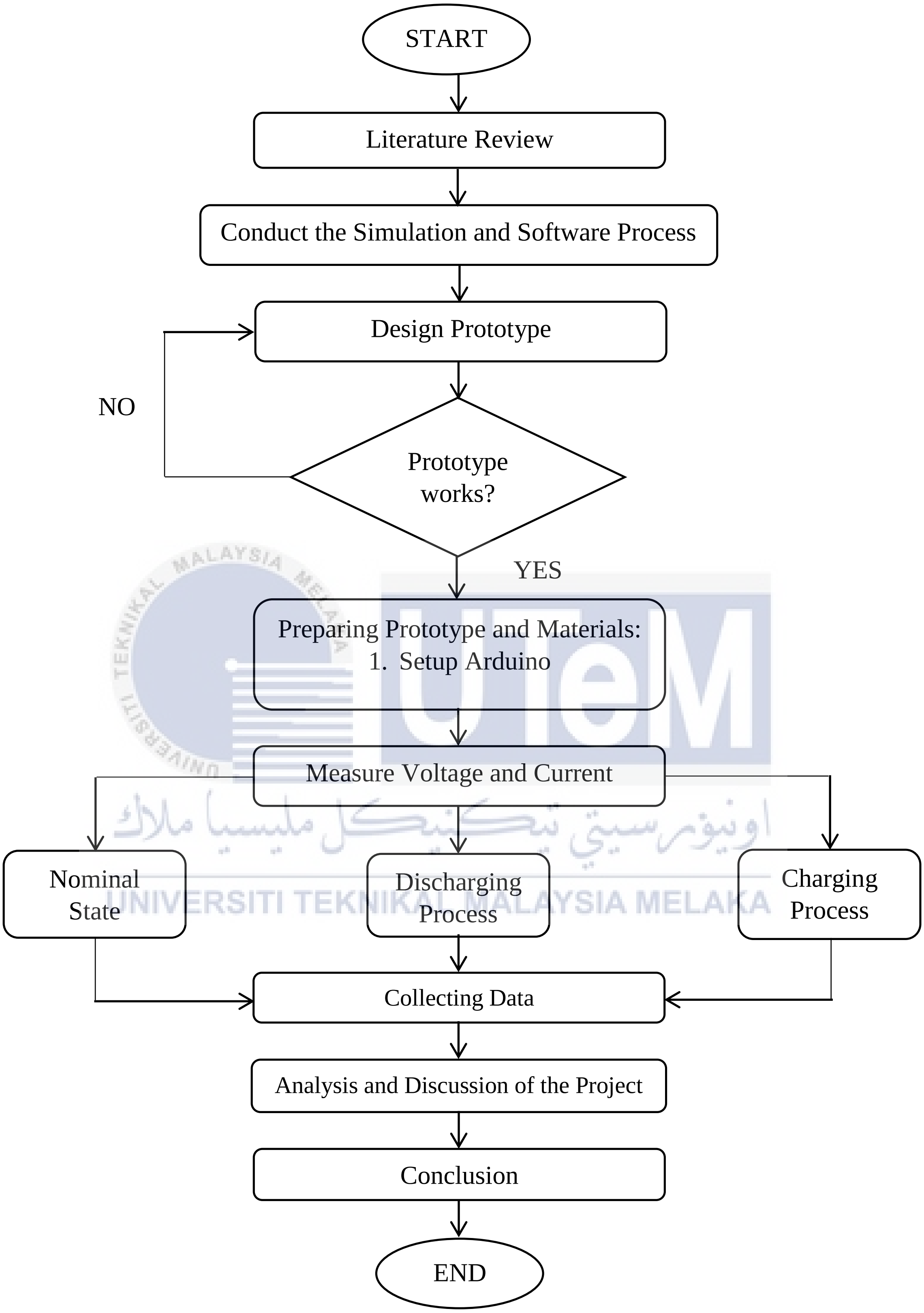

Figure 3.1: Flow chart of project methodology

3.3 Methodology

3.3.1 Hardware Design

The SBMS consists of several components that combined together. The SBMS combination of voltage sensor, ACS712-20A, Arduino UNO, SD card module, memory card, Liquid Crystal Display and bluetooth module.

3.3.1.1 Arduino UNO

The microcontroller used is Arduino UNO board since the best and simplest microcontroller compared to the other microcontrollers. The board based on the ATmega328P microcontroller. The board has 14 digital input/output pins which 6 of the pins can be used as PWM outputs, 6 analog input pins, a 16MHz quartz crystal, a USB connection, power supply jack, an ICSP header and a button for reset system. The board simply connects to a computer using USB cable or power supply given by AC-to-DC adapter or battery to get started. A software called Arduino Integrated Development (IDE) software used as compile and uploading program to ensure that the system works [19].

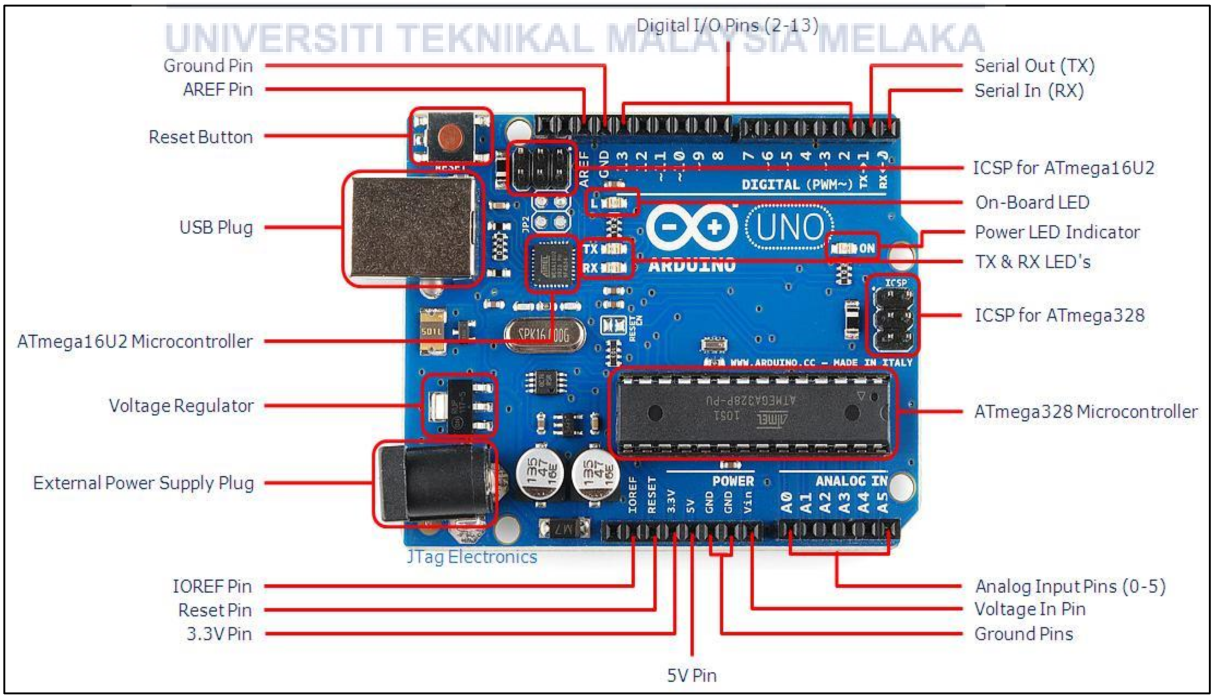

Figure 3.2: Arduino UNO board schematic diagram

3.3.1.2 Voltage Sensor

Measurement of voltage is used voltage divider concept. The voltage divider is a simple electrical circuit which has a high resistance across a voltage supply. The variable voltage output across the resistance is acquired by the varying position of sliding contact on the resistance. The output voltage is a fraction of voltage supply [20]. The equation for voltage divider is stated as Equation (3.1).

$$V_{supply} = \frac{R_2}{(R_1+R_2)} \times V_{out} \quad (3.1)$$

Therefore, the Equation (3.2) below shows the equation to calculate the value of R_2. Whereas V_{supply} is a reference voltage, V_{out} is the voltage of the battery and R_1 is a fixed value of the resistor.

$$R_2 = \frac{1}{(V_{supply} \div V_{Vout}) - 1} \times R_1 \quad (3.2)$$

3.3.1.3 Current Sensor

Meanwhile, the current sensor used is ACS712-20A and it is used to detect the current measurement for AC and DC signal. The sensor measures up to 20A of DC or AC current. In this case, the SBMS detect the current measurement for DC supply which is 12V of Lead-Acid Battery. The ACS712-20A current sensor also has an opamp gain stage for more sensitive current measurements [21]. The sensor has sensitivity of 100mV/A as stated in the datasheet. Thus, a calculation need to be done in order to get the actual reading of the current as stated in Equation 3.3.

$$I_{actual} = \frac{(49\text{mV} \times AnalogRead) - 10}{Sensitivity} \quad (3.3)$$

From the Equation 3.3, 49mV is the increment for each 1A. The AnalogRead is the value of the current sensor comes from the serial monitor of the Arduino software. The sensor can measure positive and negative currents (*range* -10A to +10A), and power supply is 5V for the sensor, and the middle sensing voltage is 10V when no current. ACS712-20A has sensitivity of 100mV/A as stated in the datasheet. So, the sensitivity need to be considered in this calculation [22]. The datasheet of ACS712-20A can refer in Appendix A.

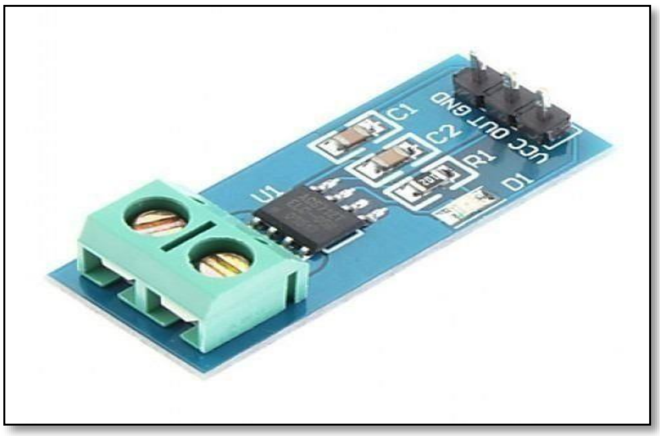

Figure 3.3: ACS712-20A current sensor

3.3.1.4 Liquid Crystal Display (LCD)

LCD is a flat panel display, electronic visual display, or display that uses the light modulating properties of liquid crystals and does not release light directly. In this system, LCD 20 × 4 (20 columns and 4 rows) character is used to display parameters of the battery. LCD needs 11 general input/output pins to interface to this LCD screen including LED backlight. The pins and its symbol show in Figure 3.4.

LCD Pin	Symbol	Function	Arduino Pin
1	Vss	ground (0 V)	ground (0 V)
2	Vdd	power (4.5 – 5.5 V)	+5V
3	Vo	contrast adjustment	9
4	RS	H/L register select signal	12
5	R/W	H/L read/write signal	ground (0 V)
6	E	H/L enable signal	11
11	DB4	H/L data bus for 4-bit mode	5
12	DB5	H/L data bus for 4--bit mode	4
13	DB6	H/L data bus for 4-bit mode	3
14	DB7	H/L data bus for 4-bit mode	2

Figure 3.4: LCD pin, symbol and function

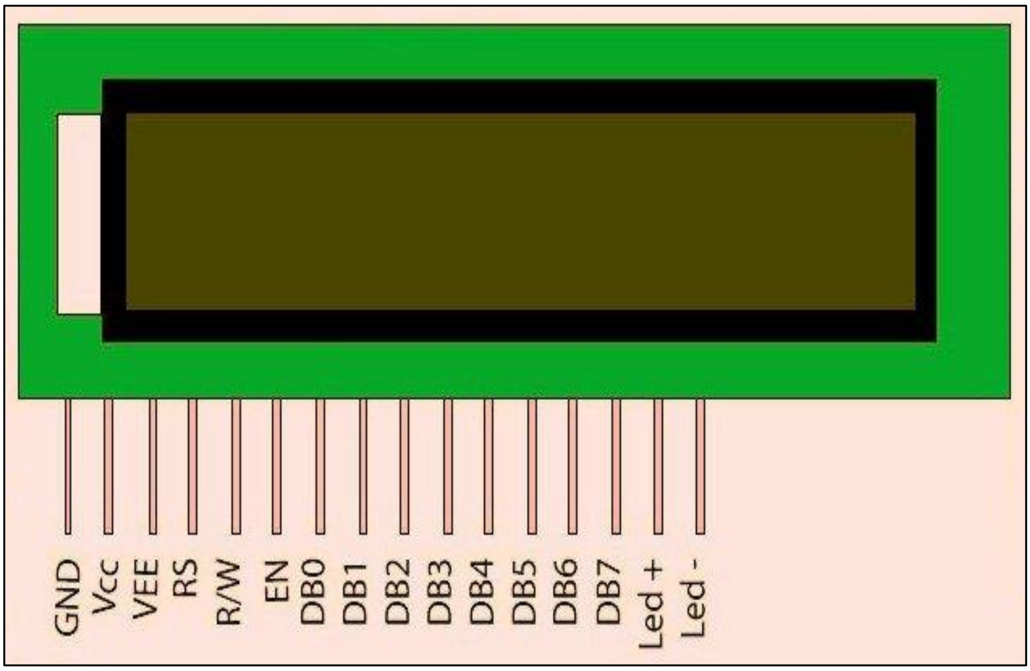

Figure 3.5: LCD characters

3.3.1.5 SD Card Module and Memory Card

A memory card is an electronic flash memory data storage device used in SBMS for storing digital information of battery parameters. The memory card is slotted into the socket of SD card module. The memory card works at 3.3V. It only works with SdFAT library and the memory card is in FAT32 and SD/HC format. The module has 4 pins which are SS (Slave Master), MOSI (Master Out Slave In), MISO (Master In Slave Out) and SCK (System Clock). The pins of this module connect to the Arduino UNO board [23].

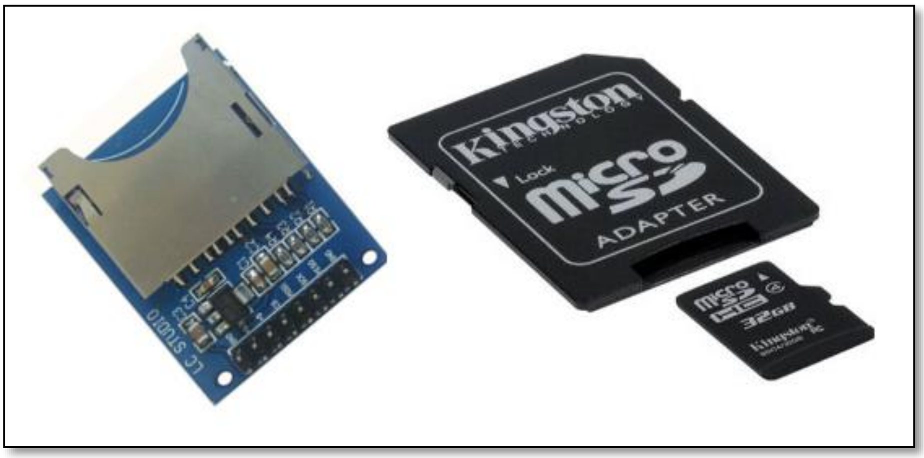

Figure 3.6: SD card module and Memory card

3.3.1.6 Bluetooth System Communication

The SBMS also uses bluetooth system communication as a medium to monitor battery performance at a certain distance. The bluetooth module used is HC-06. The range covered in this module is around 10 metres and its supply voltage needs about 3.6V to 6V. TXD is used to send data from the module to the serial receive pin (RX) of the Arduino. While RXD is used to receive data from the serial transmit pin (TX) Arduino.

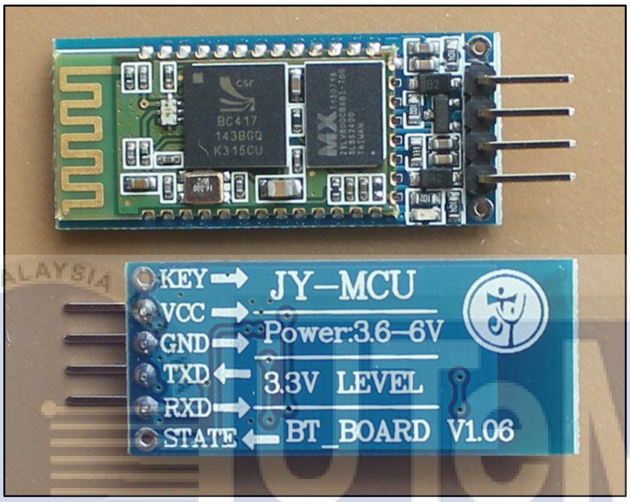

Figure 3.7: Bluetooth module

3.3.2 Software Design

The software that used in this project are ISIS Proteus Professional 8, Arduino Integrated Development Environment (IDE) and Blueterm application. Those software are important in order to facilitate and complete the project.

3.3.2.1 ISIS Proteus Professional 8

The simulation of the circuit design takes place in ISIS Proteus Professional 8. It gives basic simulator to give a full range and better understanding of the operation of the circuit. The simulation gives the analysis of the performances of the battery during charging and discharging state. The simulation also helps in future to make improvement of the design circuit. The circuit design in Figure 3.8 only shows the circuit for measuring voltage and detect the current of the battery. The Arduino UNO board is used as a microcontroller which connect to all the components. The microcontroller as a medium to receive the signal from both sensors in analog form and execute them in digital form. Then, both data will transmit for data presentation.

According to the simulation, dry cell is indicated as the Lead-Acid battery in real experiment. The measured voltage of the battery is using the voltage divider concept while detection of current is used ACS712-20A. Voltage of battery is taken across the resistance with a specified resistance value. The current sensor is series with load and battery in order to get the measurement of current. The reading of the voltage and current of the battery on LCD. The brightness of the LCD is controlled by the potentiometer. The red LED is used as an indicator to give warning when the voltage is 40% left. In order to remotely monitor the reading, Blueterm application is used together with a HC-06 bluetooth module in the range of 10m. For observing and analysis the battery performance, the reading will be saved by using a memory card that slot in SD card module in text format (.txt). The data from the memory card is transferred into Microsoft Excel to study the battery performance.

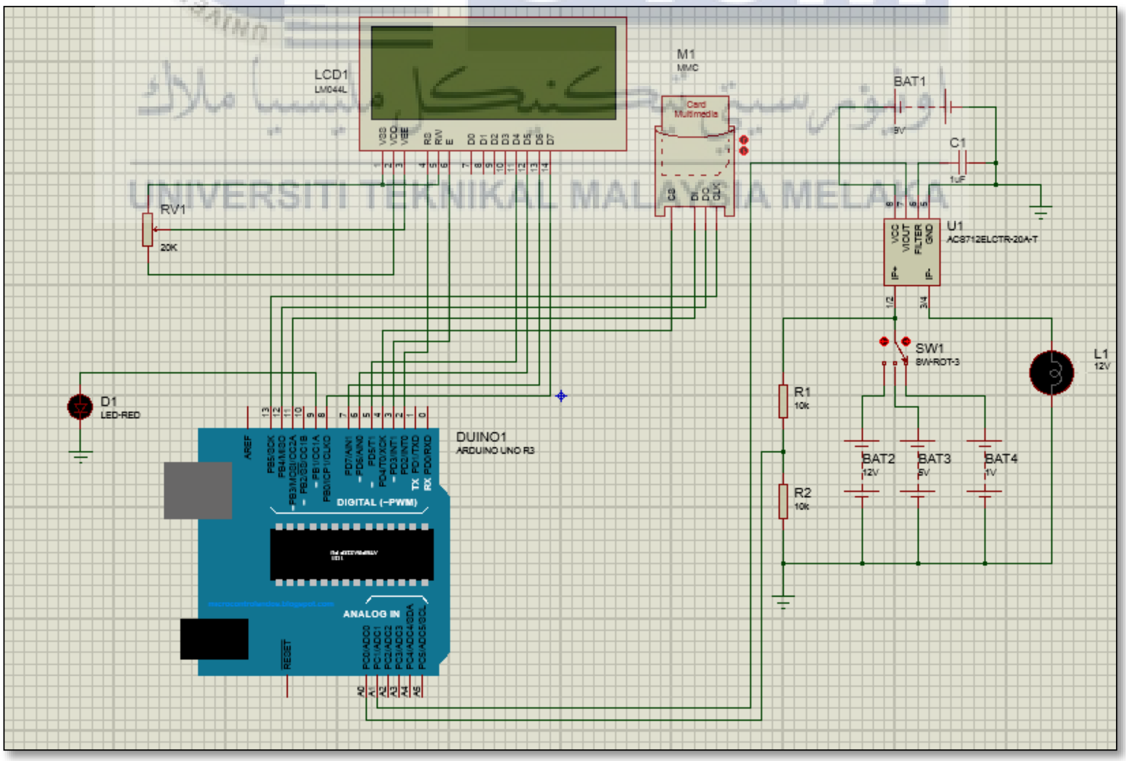

Figure 3.8: Circuit design by using the ISIS Proteus 8 Professional

3.3.2.2 Arduino Integrated Development Environment (IDE)

The ATmega328 on the Arduino UNO board comes programmed with a bootloader that used to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference C header files). The coding or program is uploaded by using Arduino IDE software. The program needs to be verified before uploading to Arduino UNO board. Appendix B shows the coding for the SBMS to function.

3.3.2.3 Blueterm Application

Blueterm App is terminal emulator for communicating with any serial device using a bluetooth serial adapter which is HC-06 bluetooth module. It provides many of the basic features that have come to expertise from a standard Serial Terminal on a PC. This application also does not emulate web terminal, SSH or other options that might find on the drop menu in TeraTerm or Hyperterminal. The application need to be installed just simply click the options device (HC-06) and enter the pairing code (1234, default code) and done the pairing process.

3.4 Operation of SBMS

The operation of SBMS is presented in Figure 3.9 and Figure 3.10 below. This SBMS system was designed for both charging and discharging processes. Both flowchart indicates the operation of SBMS. The Figure 3.8 shows the operation of the Arduino Integrated Development of Environment (IDE). For the Figure 3.9 shows the operation display of SBMS using Bluetooth.

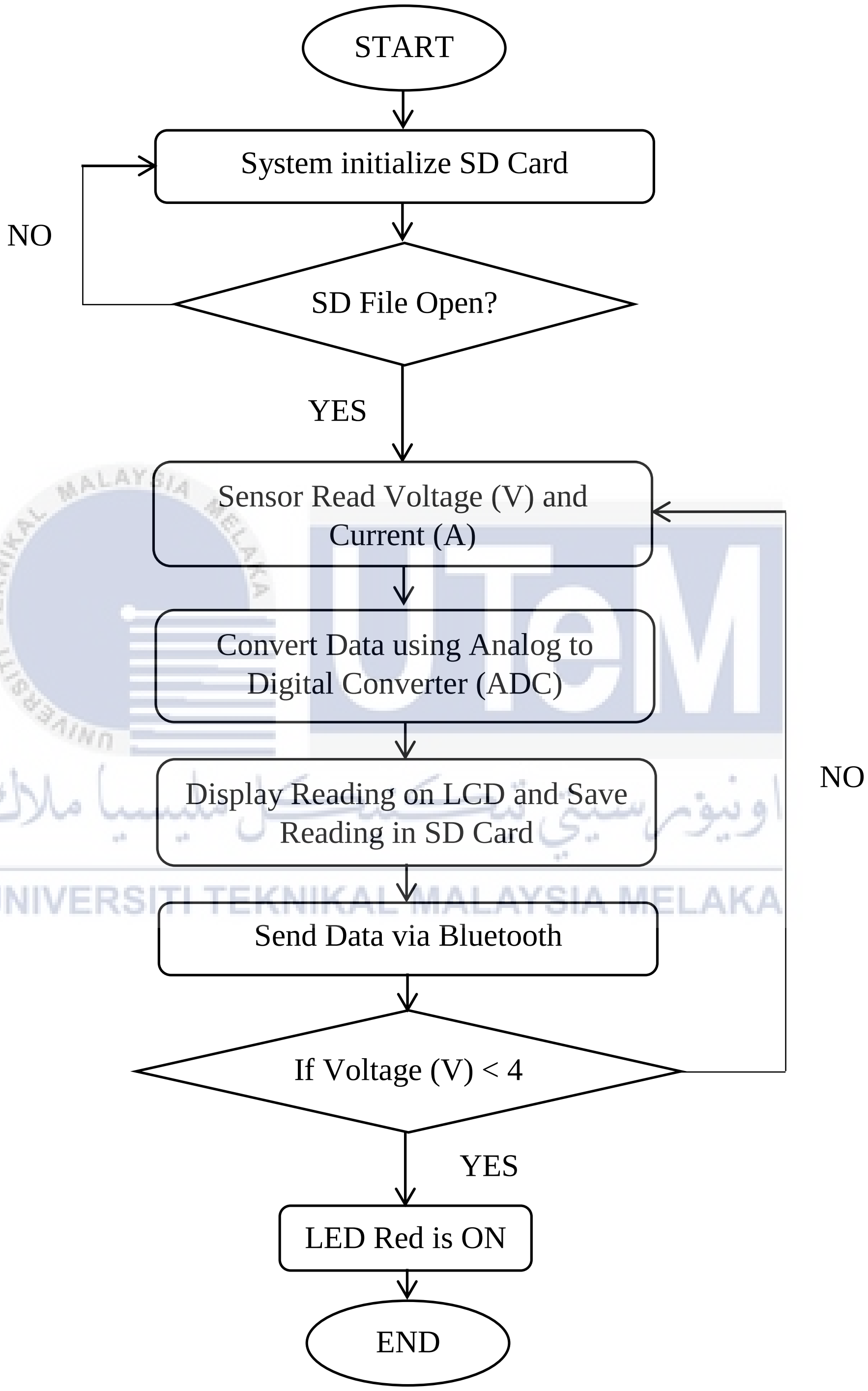

Figure 3.9: Flow chart of Arduino IDE

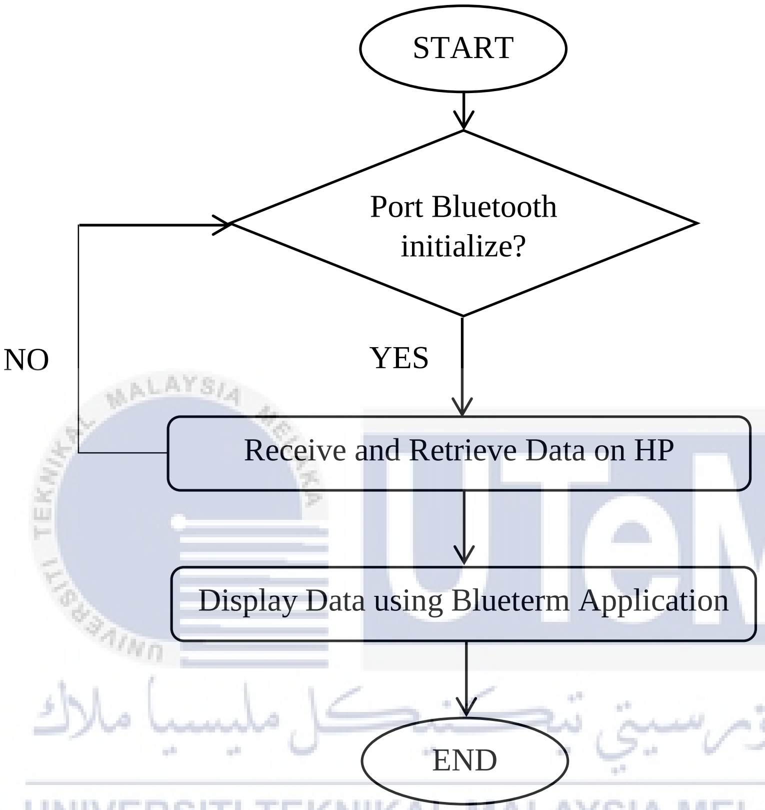

Figure 3.10: Flow chart of operation display of SBMS using Bluetooth

The main process of the whole SBMS system can be summarized as follows:

i. The Arduino will initialize SD Card until SD File is open

ii. If SD File is open, both sensors will operate to take the readings of voltage and current.

iii. Both readings will be appear on the LCD and also display on the smartphone using Android Bluetooth application.

iv. The reading will be stored in a .txt format in SD Card

v. If battery voltage is less than 4V, Arduino sends signal to apply voltage to LED

3.5 Block functional diagram of Smart Battery Monitoring System (SBMS)

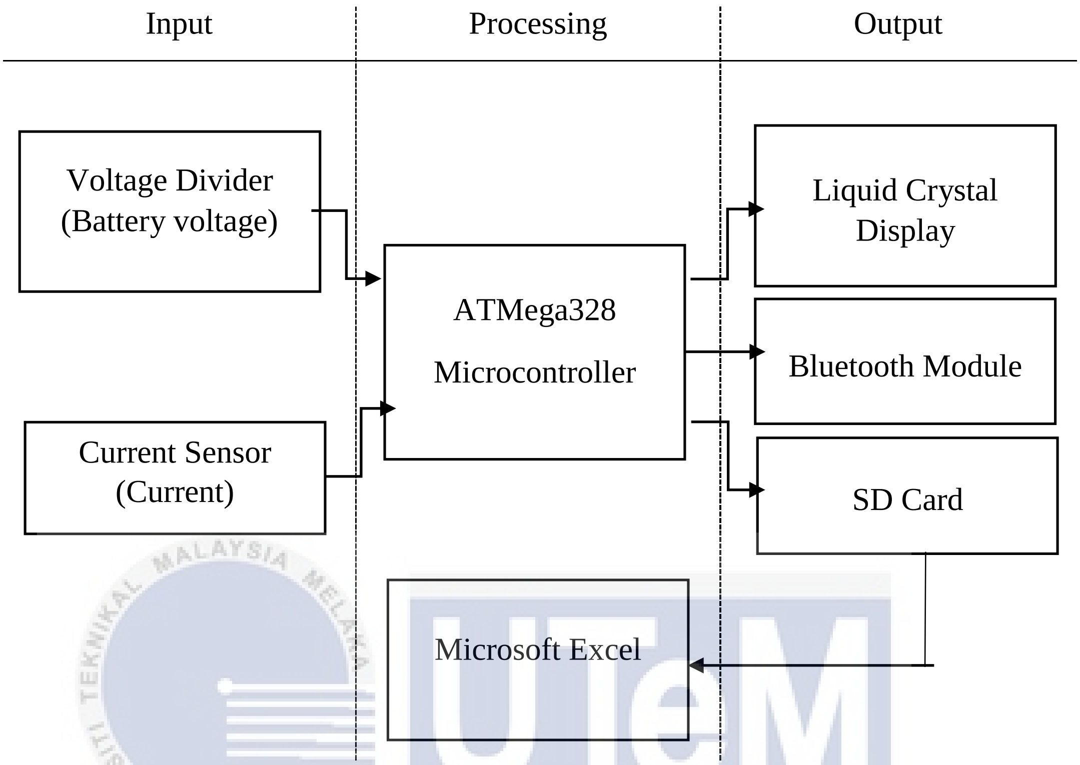

Figure 3.11: Block functional diagram of Smart Battery Monitoring System

Operation of the SBMS system when start up the program are referred as follows:

1. The battery will undergo a charging and discharging process.
2. Voltage divider will measure the battery voltage.
3. Current sensor, ACS712 will measure current of the battery through the load.
4. Arduino processing data by converting the analog value to digital value using analog to digital converter (ADC).
5. Reading will be appeared on the LCD.
6. Reading also will be appeared on smartphone via Bluetooth.
7. Load data to SD Card.
8. User may load data from the SD Card to running Microsoft Excel
9. The user can observe the performance of the battery

3.6 Experimental Test

The experiment is conducted for obtaining voltage and current during nominal, discharging and charging state of the battery. The battery used is 12V Sealed Lead-Acid battery. The nominal state refers to the voltage reference of the battery, also called as normal voltage the battery. The test for nominal state is conducted only for determining the battery voltage before discharging and charging process. A load is required to obtain current measurement which is a resistive and inductive load. The test of discharging and charging process is set up to obtain both parameters, voltage and current. All the data from SBMS is imported from the SD card and transferred to Microsoft Excel for obtaining graphical presentation. Meanwhile, all the data from the Fluke meter is transferred to the FlukeView for obtaining graphical data presentation. The data from SBMS and Fluke meter are compared whether identical or not. Further analysis will be discussed in discussion part.

3.6.1 Charging Process of the battery

The battery is charged by using battery charger and this is indicated as charging process. Teletron type of battery charger is used for the charging process. SBMS and Fluke meter are attached to the battery for obtaining the data. The battery is left until it reaches full capacity or Full Charge indicator turn ON. All the data are recorded.

3.6.2 Discharging Process of Resistive Load

A 12V light bulb is used as a resistive load during the discharging process. The experiment is set up by connecting the battery to the load. SBMS and Fluke meter is attached to circuit for obtaining the data. The test is carried out for 10 hours. All the data are recorded.

3.6.3 Discharging Process of Inductive Load

A 12V motor is used as an inductive load during the discharging process. The experiment is set up by connecting the battery to the load. SBMS and Fluke meter is attached to circuit for obtaining the data. The test is carried out for 6 hours. All the data are recorded.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

An experiment was carried out to test the effectiveness and functionality of SBMS. The SBMS was test on 12V Sealed Lead Acid battery to obtain the relevant results. The results obtained are current (A) and voltage (V). Two types of test was carried out to analyse state of the battery which are charging and discharging process of the battery. The discussion part is an explanation of the results obtained during charging and discharging process of the battery and. The Fluke Meter also use in the experiment in order to give comparison between SBMS reading and Fluke Meter reading.

4.2 Results and Discussions

4.2.1 Comparison between ISIS Proteus 8 and SBMS

Table 4.1: Current reading for ISIS Proteus 8 and SBMS

Proteus 8		**SBMS**	
Voltage (V)	**Current (A)**	**Voltage (V)**	**Current (A)**
11.95	0.54	11.91	0.49
5	1	5.03	1.09
1	5	1.05	4.65

Table 2.1 shows the reading of current using ISIS Proteus 8 and SBMS during charging process. The value of voltage was fixed in order to get the reading of current. This comparison is used to compare the functionality of SBMS with the simulation using ISIS Proteus 8. The voltage is set to 11.9V, 5V and 1V for both ISIS Proteus 8 and SBMS. The first reading of current for ISIS Proteus 8 is 0.54A while SBMS is 0.49A. There are 0.05A difference for both reading. While, the second reading shows 1A for ISIS Proteus 8 and 1.09A for SBMS. The difference of the reading only 0.09A. Lastly, the reading of current for ISIS Proteus 8 is 5A while SBMS is 4.65A. The difference shows only 0.35A. It can be conclude that there only 10% of error for the SBMS.

4.2.2 Charging State of the Battery

The experiment was carried out by charging the battery and was set up as shown in Appendix E1. The battery was charge using Teletron Battery Charger with 2A (Max) charging current used for Sealed Lead Acid battery only.

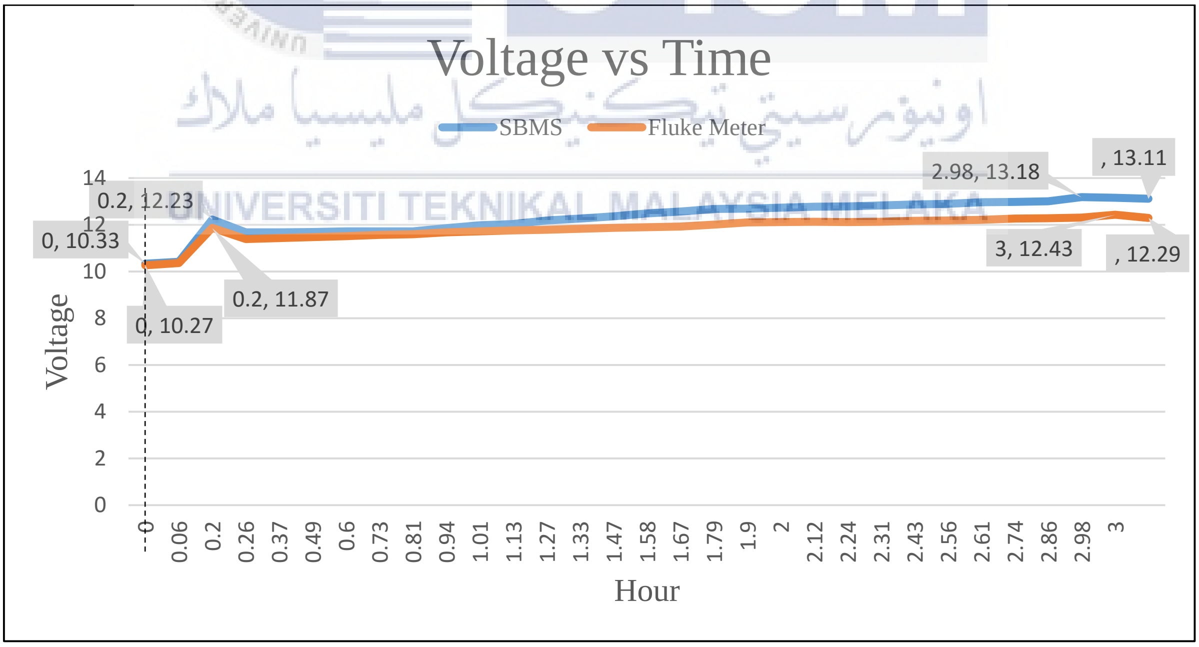

Figure 4.1: Voltage vs Time graph of charging process from Fluke meter and SBMS

Figure 4.1 shows the voltage reading waveform from Fluke meter and SBMS during charging process. The brown line is represent the Fluke meter reading. The battery charger is switch ON and the battery is left for charging process until the battery is full. The time taken for the battery to be fully charged is about 3 hours and 30 minutes. At the beginning time, the recorded voltage is 10.27V. The voltage value is called nominal voltage. Nominal voltage is a state where the voltage is measured at that time. At a moment after the battery charger is switch ON, the voltage is rising up to 11.87V. This condition is happened because of the high starting current and it is usually happen after an electrical equipment is switch ON. After a few minute, the voltage drop slightly before the voltage become stable. The voltage is recorded stable but shows only rising slight until the end of the charging process or the indicator of Full charge is turn ON. While, the blue line is represent the SBMS reading. The nominal voltage recorded is 10.33V. Just after the charger is switch ON, the voltage is rising to 12.23V. The voltage is drop slightly to 11.39V before rising again at 1.53H. Then, the voltage start to be stable around 13V until end of the charging process.

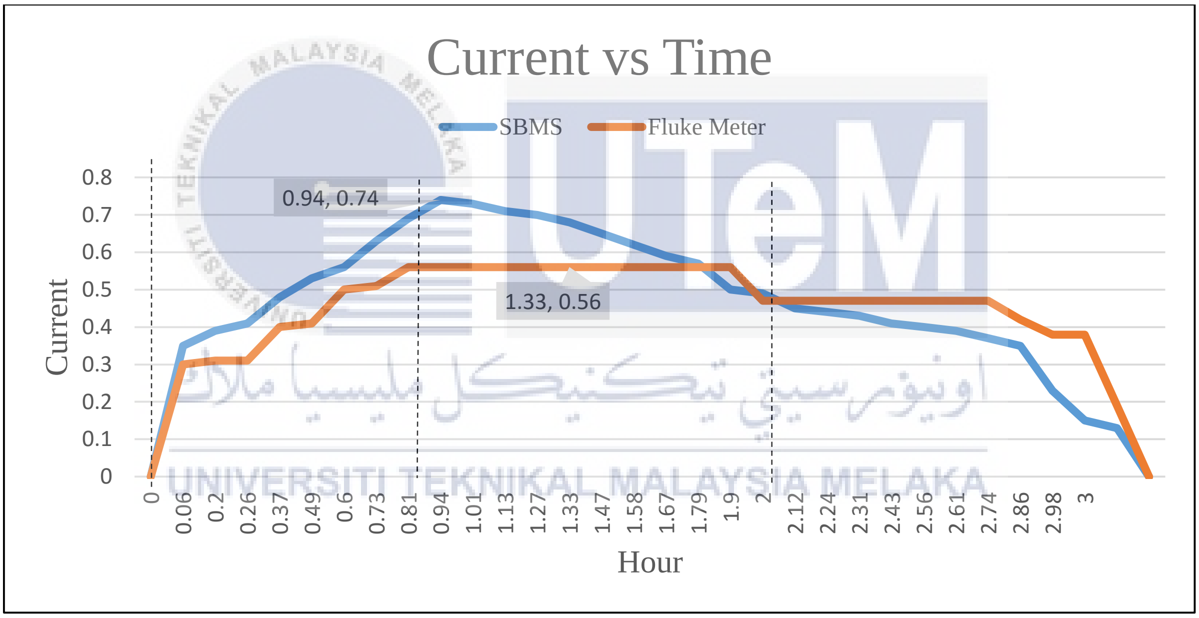

Figure 4.2: Current vs Time graph of charging process from Fluke meter and SBMS

Figure 4.2 shows the current reading waveform from Fluke meter and SBMS during charging process. The brown line is represent the Fluke meter reading. The initial current before the charger is switch ON is 0A. After the charger is switch ON, the current start to increase due to charge cycle called bulk charge current. Bulk charge level is a first stage of the process current is sent from the battery charger to the battery at the maximum safe rate it will accept until voltage is brought up to nearly 70% to 90% of full charge level. At this stage, the current rising from 0A to 0.56A at 0H to 0.83H. Second stage is absorption level where chargers will maintain a steady voltage, while the current decline once the battery has reached 80% State of Charge. Then, the current start maintained at 0.56A from 0.83H to 1.88H. Then, the current start to drop slightly from 0.56A to 0.47A. The third stage is float charge where the voltage will tapper down and retain at 13.2V to 13.4V, which is the maximum voltage a 12V battery can hold. While, the current decrease to a point where it is considered a trickle. This stage happen when the current starting to decrease from 0.47A to 0A starting from 2.74H to 3H. Before that, the current remain stable at 0.47A from 2.1H to 2.74H. While, the blue line is represent the SBMS reading. The maximum current draws at 0.94H which is 0.74A. The current starting decrease slowly after 0.74H until the battery is fully charged.

The values of voltage and current from both Fluke meter and SBMS show almost similar pattern of the graph. The voltage reading from SBMS almost same as the Fluke meter but not for current reading. The nominal voltage of SBMS is 0.6% higher, starting voltage is 3.03% higher and full charge voltage is 6.18% higher than Fluke meter reading. After isolate from the charger, battery voltage equal to 12.29V which indicates almost 75% State of Charge.   The current reading shows slightly different for both SBMS and Fluke meter. This is happen due to instrument error which is current sensor. The current sensor reading always fluctuated due to sensitivity of current sensor. The sample reading set in the coding was 1000 samples and based on the result, the sample was inadequate. Hence, the overall charging process undergo three different stages which bulk charge, absorption charge and lastly float charge.

4.2.3 Discharging State of Battery for an Resistive Load

The experiment was carried out by discharging the battery during connecting to the resistive load and was set up as shown in Appendix E2. The load used is 12V DC bulb and power rating is 5W hence the discharge rate will be in small value.

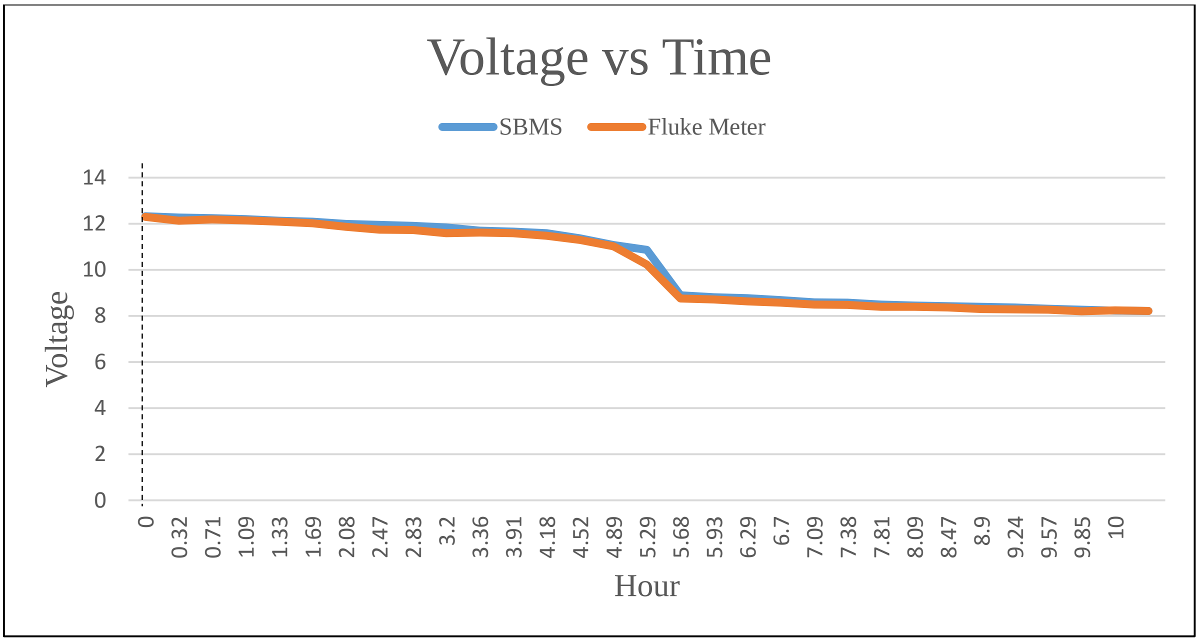

Figure 4.3: Voltage vs Time graph of discharging process from Fluke meter and SBMS

Figure 4.3 shows the voltage reading waveform from Fluke meter and SBMS during discharging process when connecting to a resistive load. The brown line is represent the Fluke meter reading and the blue line as SBMS reading. The test was left for 10 hours in order to get the graph pattern of voltage waveform. The initial voltage for both Fluke meter and SBMS shows almost the same reading about 12.29V. The voltage starts to slightly decrease and slowly until 5H. At beginning 5H, the voltage drop from 11.01V to 8.76V. While, the SBMS reading shows only slightly different for the voltage to drop from 10.86V to 8.81V at 5H. After the load was disconnected at 10H, the voltage reading from SBMS is 8.22V and from the Fluke meter is 8.18V.

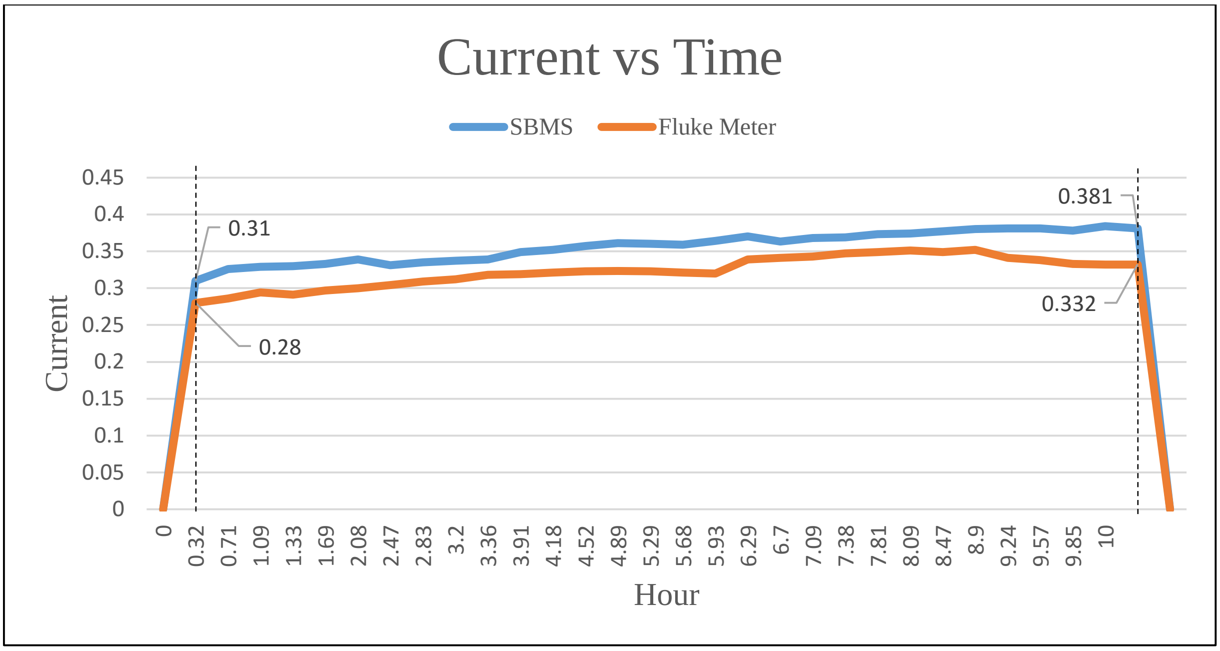

Figure 4.4: Current vs Time graph of discharging process from Fluke meter and SBMS

Figure 4.4 shows the current reading waveform from Fluke meter and SBMS during discharging process when connecting to a resistive load. The brown line is represent the Fluke meter reading and the blue line as SBMS reading. The reading for both show the same pattern of graph. From 0H to 0.32H the current increasing drastically to 0.28A and for SBMS, the current draws 0.31A. The current continually increase from 0.71H to 10H for both Fluke meter and SBMS reading because of voltage decreasing. After the load was disconnected, the current recorded for Fluke meter is 0.332A while the SBMS reading is 0.381A.

The pattern for the graph for both Fluke meter and SBMS almost same. Since the load consume less power, the voltage also draws a slightly decreased. Therefore, the current recorded only shows a slightly increased with 10% error at the beginning of time and 15% error at the end of the time. As a battery discharges, the lead plates become more chemically alike, the acid becomes weaker, and the voltage drops. Eventually the battery is so discharged that it can no longer deliver electricity at a useful voltage.

4.2.4 Discharging State of Battery for an Inductive Load

The experiment was carried out by discharging the battery during connecting to the inductive load and was set up. The load used is 12V DC motor.

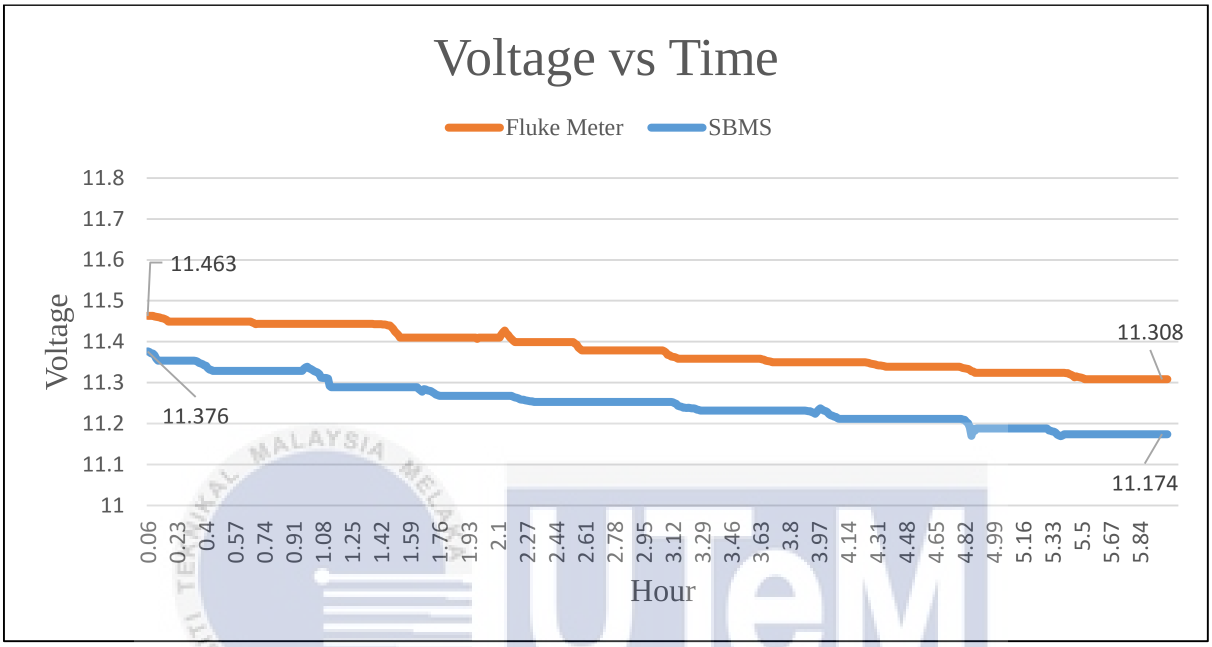

Figure 4.5: Voltage vs Time graph of discharging process from Fluke meter and SBMS

Figure 4.5 shows the voltage reading waveform from Fluke meter and SBMS during discharging process when connecting to an inductive load. The brown line is represent the Fluke meter reading and the blue line as SBMS reading. The reading for both show the same pattern of graph but with the slightly different of reading. The nominal voltage for Fluke meter shows 11.46V while 11.3V for SBMS. The both reading shows the drop of voltage because voltage was applied to the load. At the end of time, Fluke meter shows 11.3V while 11.17V for SBMS.

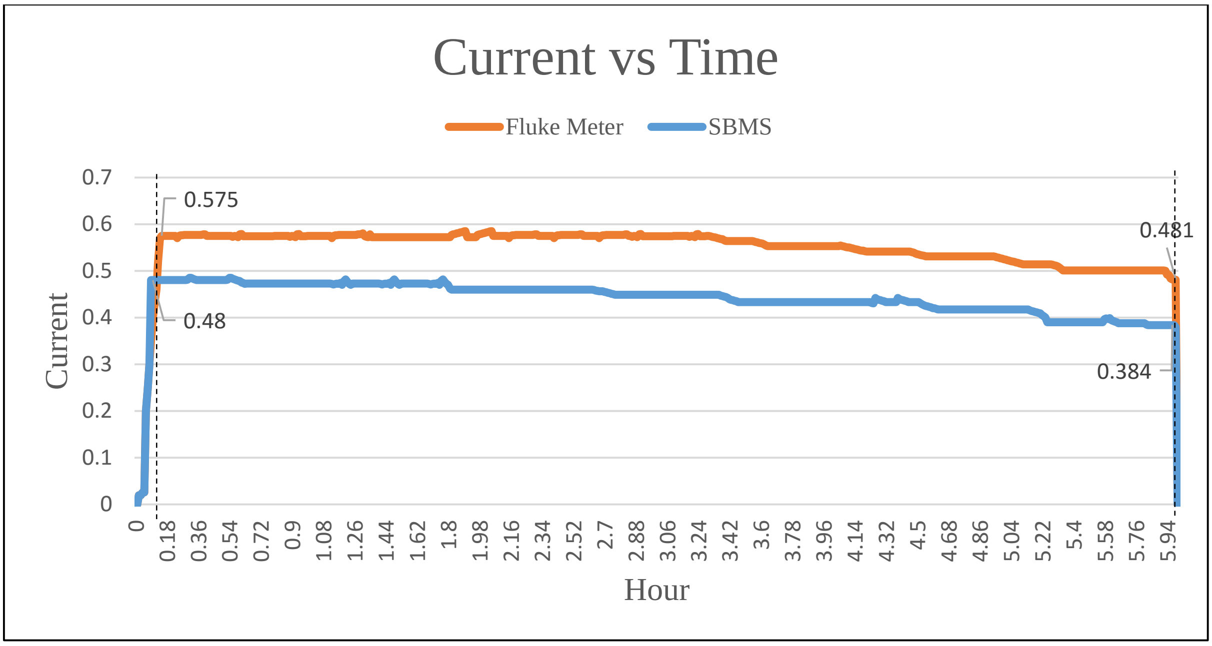

Figure 4.6: Current vs Time graph of discharging process from Fluke meter and SBMS

Figure 4.6 shows the current reading waveform from Fluke meter and SBMS during discharging process when connecting to an inductive load. The brown line is represent the Fluke meter reading and the blue line as SBMS reading. The reading for both show the same pattern of graph but with the slightly different of reading. The starting current for both reading was 0A before sharply increased at 0.18H. The current value from Fluke meter is 0.58A and 0.48A from SBMS. At the end of time, Fluke meter shows 0.48A while 0.38A for SBMS, then the value of current from both reading drop to 0A due to disconnected of the load.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.0 Conclusion

Battery was important and widely used as a medium storage of energy due to increasing in electrical energy demand. The battery should be monitored constantly in order to determine its performance. Hence, Smart Battery Monitoring System (SBMS) is a solution and very suitable for monitoring battery performance. SBMS was developed in order to monitor and study the battery performance in term of voltage (V), current (A), amperehour (Ah), power (W), watthour (Wh) and State of Charge (SoC) during charging and discharging process in real time. These parameters will be recorded and display on LCD as well as on smartphone with respect to time. The readings are remotely monitoring for observing, study and analyse the performance of the battery. By using SBMS, weak or failed battery in a bank can be identified in the analysis of the battery performance in order to take the required action. Through the analysis of battery performance, life of the battery can be extended by charging the battery. Through the analysis, it showed that the reading for both voltage and current from SBMS can be regarded almost similar with just 1% to 15% error only. The error occur due to systematic error regarding the value of resistor in voltage divider that act as voltage sensor. Meanwhile, the current reading always fluctuated due to sensitivity of current sensor. Even the current and voltage reading does not identical but the SBMS can be applied for the same function as multimeter.

5.1 Future Recommendation

The SBMS should be streamlined in order to match the reading with the Fluke meter. Therefore, the Arduino code must be edited or used the suitable coding. Besides, the SBMS could be monitored different types of battery just by editing the existing coding to in order to cope with the specific of the battery. The SBMS could be add up by led or buzzer as overcharge indicator. Lastly, GSM can be add up to the SBMS in order to give convenience to user who want to monitor the battery without limitation distances.

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APPENDICES

Appendix A1

Gantt Chart

Time / Project Activity	SEMESTER 1																	SEM BREAK				SEMESTER 2																
	SEPT			OCT				NOV				DEC				JAN				FEB				MAR				APR				MAY				JUNE		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	1	2	3	4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Supervisor meeting																																						
Project title selection and registration																																						
Develop and submit proposal																																						
Literature review																																						
Project methodology																																						
FYP Seminar 1																																						
Hardware and software development																																						
Experimental test and collecting data																																						
Develop discussion and conclusion																																						
Update final report																																						
FYP Seminar 2																																						
Final report submission																																						

Appendix A2

Key Milestone of the Project

Project Movement	Period
Project title selection and registration	7th-18th September 2015
Develop and submit proposal	7th-18th September 2015
Literature review	18th September 2015 – 2nd April 2016
Submit PSM I Report	4th December 2015
FYP 1 Seminar	14th – 15th November 2015
Hardware and Software development	1st November 2015 – 17th April 2016
Experimental test and collecting data	14th March – 30th April 2016
Develop discussion and conclusion	11th April – 31st May 2016
Submit PSM 2 Report	June 2016
FYP 2 Seminar	June 2016

Appendix B1

Datasheet for current sensor (ACS712-20A)

x20A PERFORMANCE CHARACTERISTICS T_A = –40°C to 85°C[1], C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–20	–	20	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	96	100	104	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 100 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	11	–	mV
Zero Current Output Slope	$\Delta I_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.34	–	mV/°C
		T_A = 25°C to 150°C	–	–0.07	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.017	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.004	–	mV/A/°C
Total Output Error[2]	E_{TOT}	I_P =±20 A, T_A = 25°C	–	±1.5	–	%

[1]Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.
[2]Percentage of I_P, with I_P = 20 A. Output filtered.

Appendix B2

Datasheet for bluetooth module (HC-06)

PIN Name	PIN #	Pad type	Description	Note
GND	13 21 22	VSS	Ground pot	
1V8	14	VDD	Integrated 1.8V (+) supply with On-chip linear regulator output within 1.7-1.9V	
VCC	12	3.3V		
AIO0	9	Bi-Directional	Programmable input/output line	
AIO1	10	Bi-Directional	Programmable input/output line	

Appendix B3

Datasheet for SD card module

Pin#	SD Mode			SPI Mode		
	Name	Type[1]	Description	Name	Type	Description
1	DAT2	I/O/PP	Data Line [Bit 2]	RSV		Reserved
2	CD/DAT3[2]	I/O/PP[3]	Card Detect / Data Line [Bit 3]	CS	I[3]	Chip Select (neg true)
3	CMD	PP	Command/Response	DI	I	Data In
4	V_{DD}	S	Supply voltage	V_{DD}	S	Supply voltage
5	CLK	I	Clock	SCLK	I	Clock
6	V_{SS}	S	Supply voltage ground	V_{SS}	S	Supply voltage ground
7	DAT0	I/O/PP	Data Line [Bit 0]	DO	O/PP	Data Out
8	DAT1	I/O/PP	Data Line [Bit 1]	RSV		Reserved

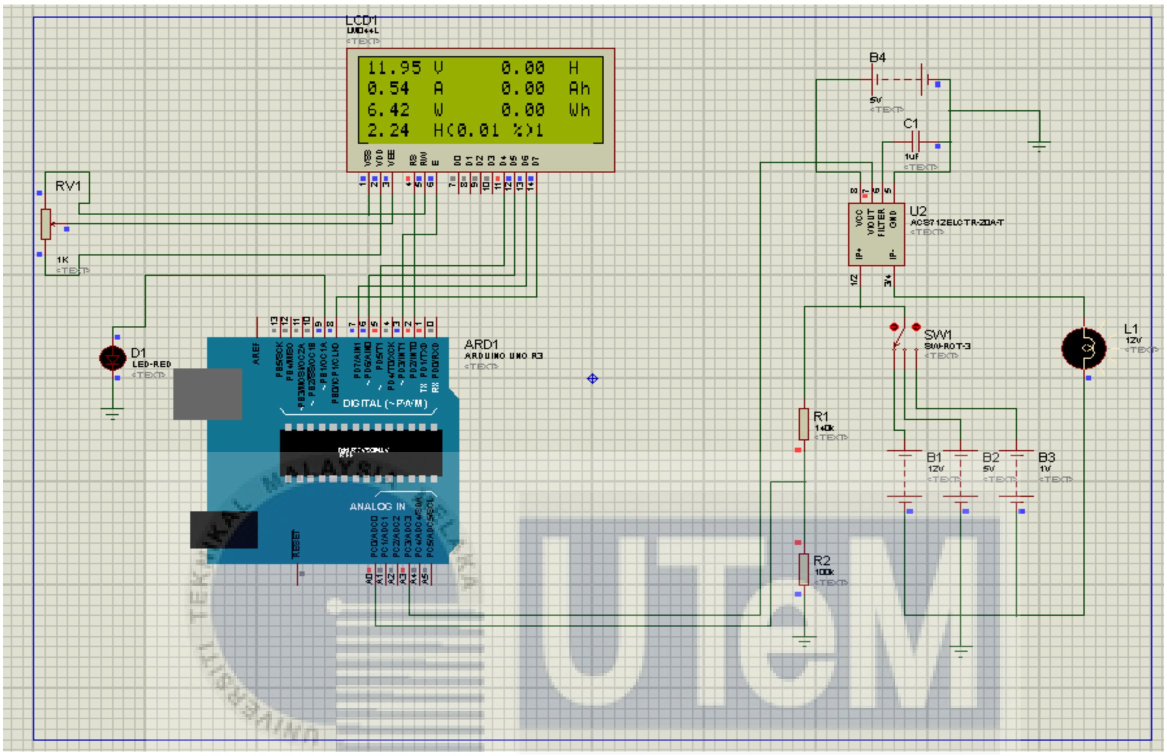
Appendix B4

Datasheet for LCD 20X4

Pin No.	Pin Name	Descriptions
1	VSS	Ground
2	VDD	Supply voltage for logic
3	V0	Input voltage for LCD
4	RS	H : Data signal, L Instruction signal
5	R/W	H : Read mode, L : Write mode
6	E	Chip enable signal
7	DB0	Data bit 0
8	DB1	Data bit 1
9	DB2	Data bit 2
10	DB3	Data bit 3
11	DB4	Data bit 4
12	DB5	Data bit 5
13	DB6	Data bit 6
14	DB7	Data bit 7
15	LED_A	Backlight Anode
16	LED_K	Backlight Cathode

Appendix C

ISIS Proteus Simulation



Appendix D

Arduino coding for operation of SBMS

```
//Declaration of SD Card===================================================

#include<SPI.h>

#include<SD.h>

const int chipSelect = 4;

File dataFile;


//Declaration of Bluetooth=================================================

#include <SoftwareSerial.h>

SoftwareSerial bluetooth (0, 1);


//Declaration of LCD=======================================================

#include <LiquidCrystal.h>

LiquidCrystal lcd (2, 3, 5, 6, 7, 8);


//Declaration of LED=======================================================

int LED = 10;


//Declaration of Time======================================================

unsigned long msec = 0;

float time1 = 0.0;

float time = 0.0;
```

```
//Arduino Setup=====================================================
void setup()
{
 Serial.begin (9600);
 bluetooth.begin (9600);

 Serial.println ("Press 'D' for Data of Battery");
 lcd.begin (20, 4);
 pinMode (LED, OUTPUT);
 pinMode (10, OUTPUT);
 SD.begin (chipSelect);
}

//Arduino Program===================================================
void loop()
{
 //Voltage
 float Voltage = 0.0;
 int sensorValue1 = analogRead (A0);

 Voltage = (sensorValue1 / 218) * 2.4;
```

```
if (Voltage < 0)
{
 Voltage = 0;
}
if (sensorValue1 < 150)
{
 Voltage = 0;
}

 //Current
 float Current = 0.0;
 float C = 0.0;
 int sensorValue2 = analogRead (A2);

 C = (((sensorValue2 /80) - 0.1) / 0.1) + C;
 Current = C /1000;

 if (Current < 0)
 {
  Current = 0;
 }
```

```
if (sensorValue2 < 350)

{

 Current = 0;

}


delay (1000);


//Time

msec = millis();

time1 = (float)msec / 1000;

time = (float)time1 / 3600;


//Power and WattHours

float Power = Voltage * Current;

float WattHours = (Power *time) + WattHours;


//AmpHours

float AmpHours = (Current * time) +AmpHours;


//Percentage

float Life = 0.0;

Life = (Voltage/12) * 100;
```

```
//Time Remaining
float timeremain = 0;
timeremain = 7 / Current;

if (Current == 0)
{
 timeremain = 0;
}

//LED
if (Voltage < 4)
{
 digitalWrite (LED, HIGH);
}

else
{
 digitalWrite (LED, LOW);
}
```

```
//LCD
lcd.setCursor(0, 0);
lcd.print(Voltage, 2);
lcd.setCursor(6, 0);
lcd.print("V");

lcd.setCursor(12, 0);
lcd.print(time);
lcd.setCursor(18, 0);
lcd.print("H");

lcd.setCursor(0,1);
lcd.print(Current, 2);
lcd.setCursor(6, 1);
lcd.print("A");
lcd.setCursor(12, 1);
lcd.print(AmpHours);
lcd.setCursor(18, 1);
lcd.print("Ah");

lcd.setCursor(0, 2);
lcd.print(Power);
lcd.setCursor(6, 2);
```

```
lcd.print("W");
lcd.setCursor(12, 2);
lcd.print(WattHours);
lcd.setCursor(18, 2);
lcd.print("Wh");

lcd.setCursor(0, 3);
lcd.print(timeremain);
lcd.setCursor(6, 3);
lcd.print("H");

lcd.setCursor(12, 3);
lcd.print("L=");
lcd.setCursor(14, 3);
lcd.print(Life);
lcd.setCursor(19, 3);
lcd.print("%");

//Bluetooth Program
if (bluetooth.available())
{
 char d = bluetooth.read();
```

```
if (d == 'D')
{
 Serial.println("Time = " + String(time) + "H");
 Serial.println("Voltage = " + String(Voltage) + "V");
 Serial.println("Current = " + String(Current) + "A");
 Serial.println("AmpereHours = " + String(AmpHours) + "Ah");
 Serial.println("Power = " + String(Power) + "W");
 Serial.println("WattHours = " + String(WattHours) + "Wh");
 Serial.println("Time Remaining = " + String(timeremain) + "H");
 Serial.println("Percentage Battery = " + String(Life) + "%");
 Serial.println();
}

//SD Card Program
File dataFile = SD.open ("Data.txt", FILE_WRITE);

if (dataFile)
{
 dataFile.print (Voltage);
 dataFile.print (",");
 dataFile.print (Current);
 dataFile.print (",");
 dataFile.print (time);
```

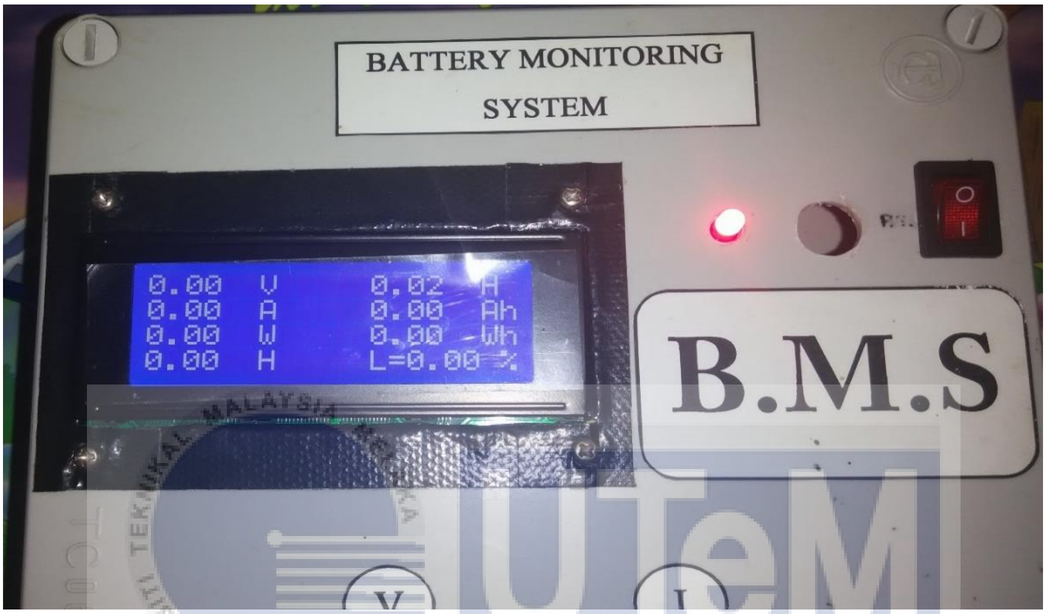
```
 dataFile.close();
}

else
{
 Serial.print("Error in opening Data.txt");
}

delay (1000)
}
}
```

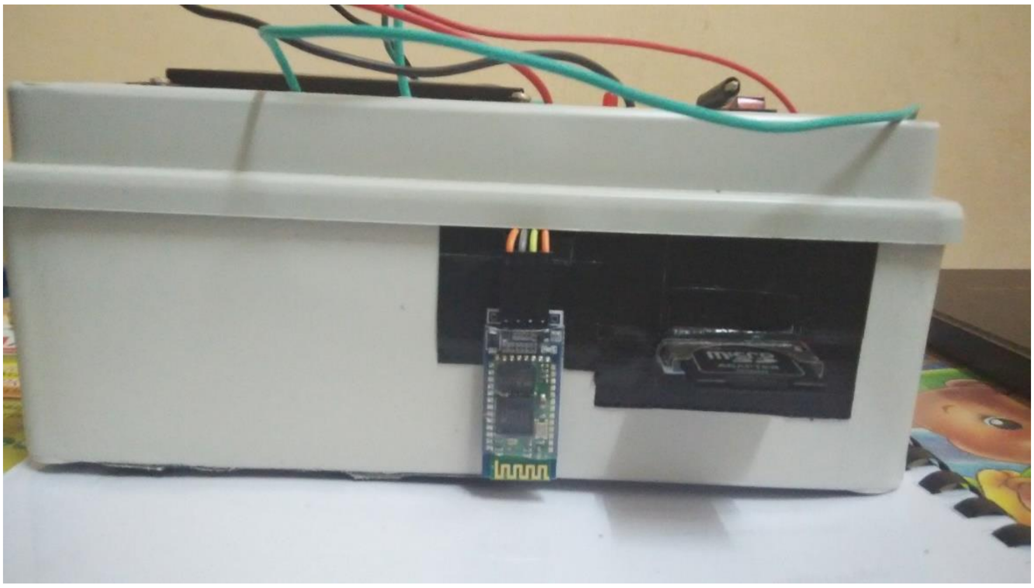
Appendix E1

SBMS prototype (Upper angle)



Appendix E2

SBMS prototype (bluetooth module, SD card slot)

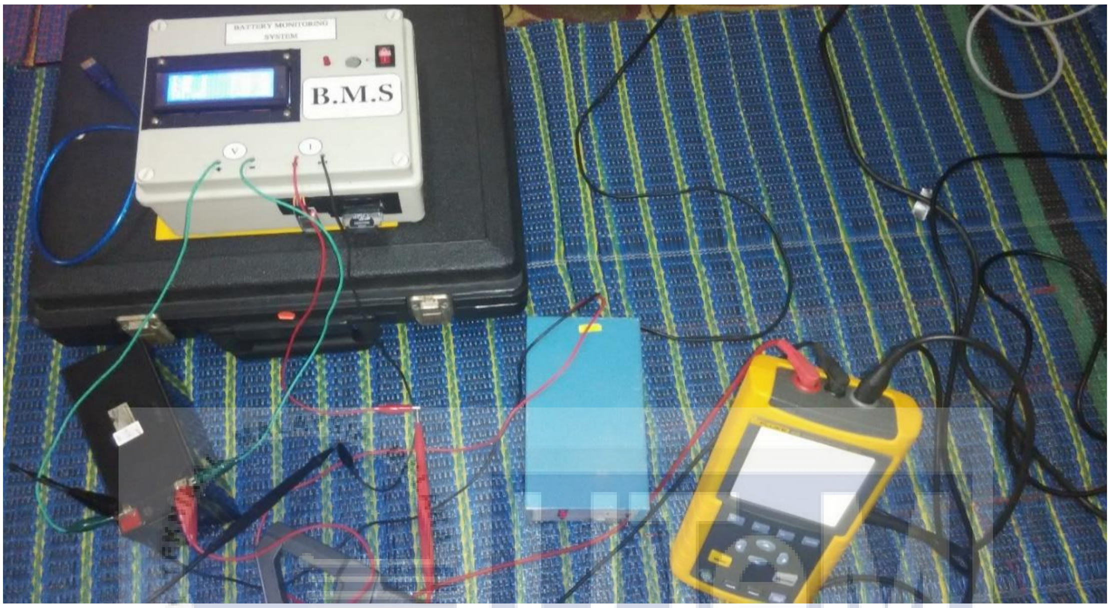


Appendix E3

SBMS prototype (Rear angle)

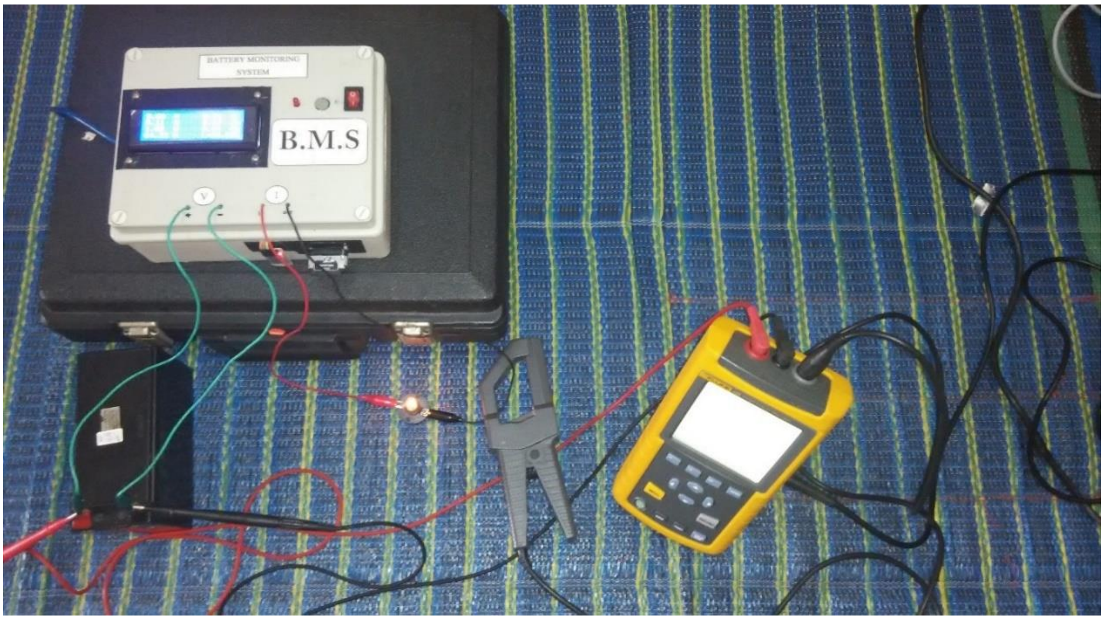
Appendix F1

Connection of charging process



Appendix F2

Connection of discharging process



Appendix G

Blueterm software interphase