"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)

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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.

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بسم الله الرحمن الرحيم

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

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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.

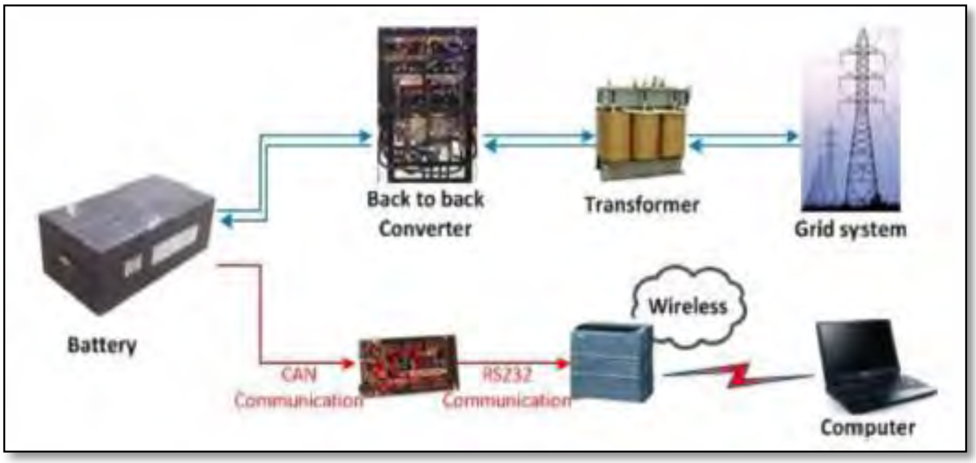

Figure 2.1: The connection between testing device and battery courtesy of [4]

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].

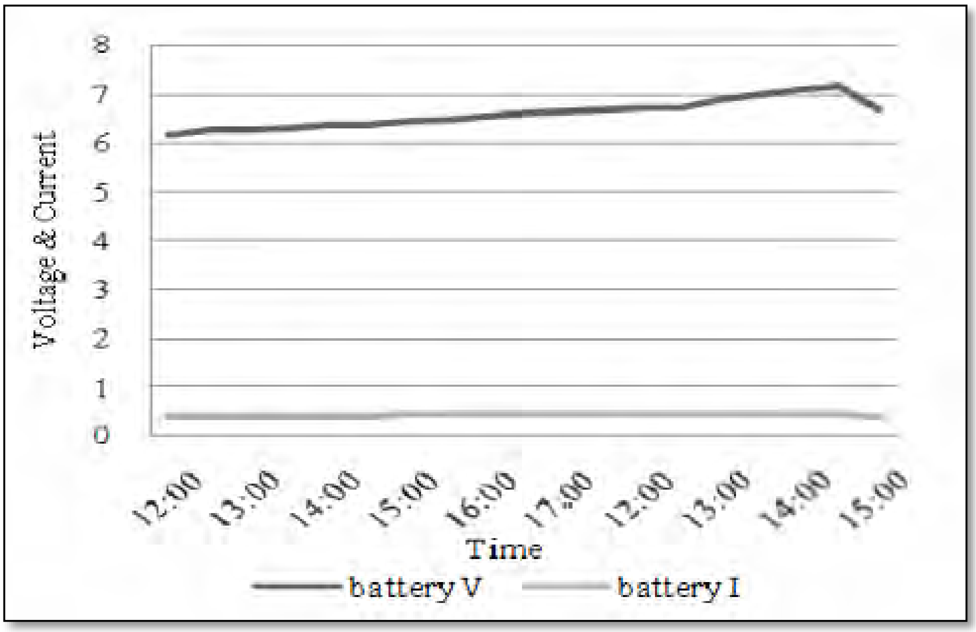

Figure 2.2: Charging characteristics of Lead Acid Battery courtesy of [14]

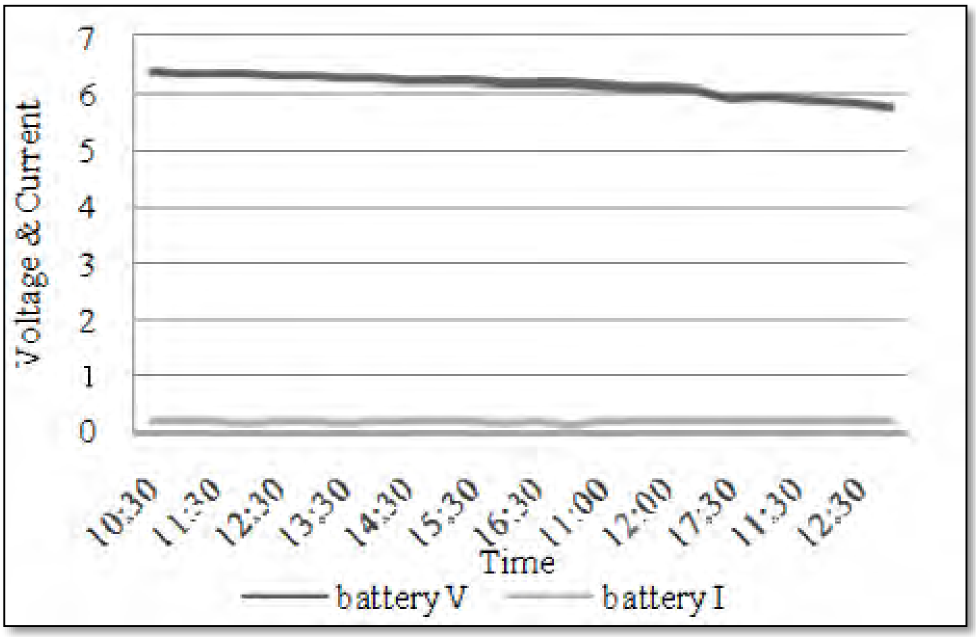

Figure 2.3: Discharging characteristics of Lead Acid Battery courtesy of [14]

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].