Continuous Battery Monitoring System (CBMS) for Battery Application

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Abstract: This paper proposes Continuous Battery Monitoring System to identify the battery health and condition. The Continuous Battery Monitoring System is able to detect the battery failure during the early stage of the event. The Continuous Battery Monitoring System will monitor the battery's voltage and current continuously. Measuring the voltage and current of the battery is the specialty of the proposed Continuous Battery Monitoring System for early battery failure detection. With that, the system will be able to measure the battery's capacity and will be able to measure the left over capacity. Addition to that, a real time clock function is also integrated into the Continuous Battery Monitoring System to allow the system to operate at real time basis and as well as monitor the battery's voltage and current continuously.

Keywords: Battery Failure, Continuous System, Monitoring System, Early Detection.

I. INTRODUCTION

Battery is known for its capacity to store electrical energy in the form of usable energy which energy can be used when it is required. With that, battery is an essential device to store the energy for devices ranging from small electronics to large system such as renewable energy systems. Small electronic devices such as video/audio players, medical equipment, power tools, meters and data loggers, and remote sensors are installed with batteries. Installed batteries in these devices freed the users from the power cord connection and allow the users to portable application. Periodically the stored energy in the batteries installed in this application will reduce and these batteries require a charging process to restore the capacity. Hence, this has seen that batteries are getting more intention and is being research for further improvement. Apparently, batteries are not only used in small electronic devices but today batteries are widely used as power backup device and is trusted as most reliable power supply when there are any power destructions. Application such as transportation and renewable energy systems are seen as one of the growing application. With increasing price electricity and depletion of fossil fuel sources, battery energy storage system technology is introduced into the transportation and renewable energy systems. In the mid-19th century first battery installed electric vehicle (EV) was introduced [1]. Since then EV has gained increasing popularity for its capability to reduce the gasoline consumption up to 75% [1]. Due to the remarkable achievement in battery improvement has provide a reliability towards the development of EV and Hybrid Electric Vehicle (HEV) [2]. Additional to that, renewable energy system is another application that uses battery to store energy. With the increase of awareness of renewable energy resources usage, energy storing is very essential. Hence, battery is an important device since it is an important device to store energy. Addition to that, the stored energy which is known also as electric energy can be used to strengthen the power distribution network [3]. At present, batteries are mostly used as centralized electric energy storage and as energy distributer to all the connected facilities. The growth of battery usage in all the applications and to complement the battery importance battery management system (BMS) and smart battery system (SBS) is introduced. Both the BMS and SBS are developed to protect the battery from operating outside the safe area. Research such as in [4], [5], [6], [7], [8] are all about managing the battery with optimum performances, provide high reliability, effectively control the charging-discharging with maximization of the availability capacity. Over the years the BMS and SBS significantly become important because the needs to balance between the production and consumption [9]. Thus to continuously provide a reliable service it is important to have a battery maintenance check regularly.

With that, this paper presents a new research about continuous battery monitoring system for early battery failure detection. Since battery is an important source in most electronic and electrical based application, early battery failure detection could potentially reduce the battery failure and assist the maintenance team with all the real-time necessary information from the proposed system. The proposed continuous battery monitoring system will focus to perform test on the battery parameters to determine the battery condition and will send a report to the management team to ease their task. The research scope is divided into two components, hardware and software. The paper will be organized is follows: Section II will discuss about the hardware design, development and operational, Section III will discuss about the software design and development, Section IV will discuss about the hardware and software integration, Section V will discuss about the results and discussion and finally in Section VI conclusion.

II. Hardware Design and Development

The Continuous Battery Monitoring System (CBMS) is proposed for early battery fault detection and whilst is capable to ensure the battery health status. This is important to ensure the battery is always available when it is required. Figure 1 shows the design concept of the continuous battery monitoring system. The system concept is using two microcontrollers which microcontroller A is for battery parameters testing and microcontroller B is integrated as a communicator between microcontroller A and the Global System Mobile Communication (GSMC). The GSMC communication is to allow the CBMS to inform the maintenance team about real-time battery condition.

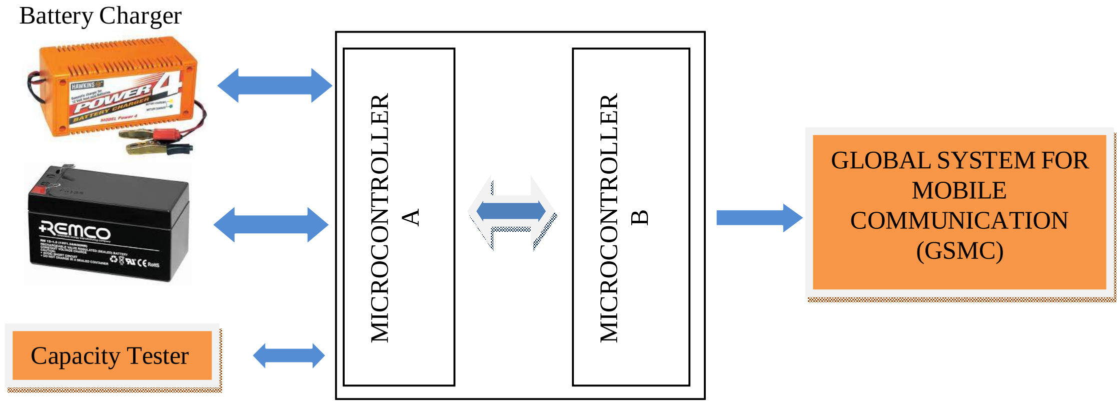


Figure 1: Concept of Continuous Battery Monitoring System (CBMS) for Early Battery Failure Detection.

The overall CBMS architecture at components level design is presented in Figure 2. The CBMS design architecture consists of two microcontroller, voltmeter, ammeter, lead acid battery, load tester, battery charger, real time clock and global system mobile communication. Two relays are integrated to microcontroller A to create the testing communication between the microcontrollers and lead acid battery.

In the following the system integration and explanation is discussed. The microcontroller A is integrated with the voltmeter and ammeter. Therefore, the output of the lead acid battery is connected to the voltmeter and ammeter. The readings from the voltmeter and ammeter are sent into the microcontroller A via the analog to digital channels (ADCs). The voltage divider concept is applied to continuously measure voltage and current. The real time voltage and current reading will be displayed onto the liquid crystal display (LCD). The voltage and current reading is necessary to allow the microcontroller A to make battery's condition decision. If microcontroller A detects a faulty condition when the battery test is being conduct, then, this information is will be sent to the maintenance team through the GSMC. The real time clock (RTC) is used to retrieve information exactly at the moment when a fault is detected.

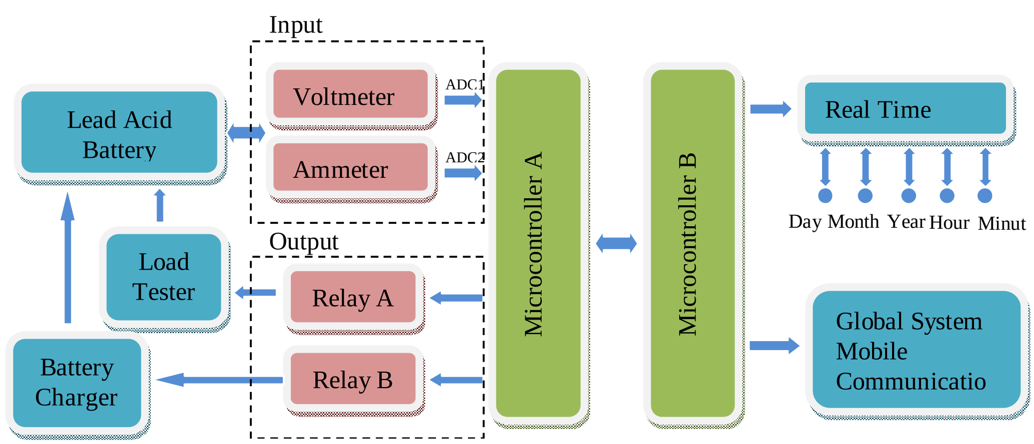


Figure 2: Architecture Overview of CBMS for Early Battery Failure Detection.

Two relays are used as switches and are controlled as output by the microcontroller A, one is connected to the load tester and another one is connected to the battery charger. Relay A acts as a switch to turn on the load tester to test the battery capacity. During this process, the load tester constantly consumes 2 Ampere current from the battery. This process is necessary to obtain information about the battery capacity holding characteristics, if the battery is unable to hold capacity then it probably is damaged. Relay B acts as a switch to turn on the battery charger to constantly give a 13.6 volt voltage output. When the measures battery voltage is below 13.6 volt, the microcontroller A will send a signal to turn on the battery charger to charge the battery to 13.6 volt. After the battery is fully charged at 13.6 volt, microcontroller A will send a signal to relay B to turn off the relay B.

The GSMC is a communicating device that used to send message to inform about the battery status or condition. The CBMS usually send out four messages, one when the battery's capacity is left at least at 10%. Second message is send out when the battery's capacity is less than 10%, this usually occurs if the battery test result shows failure. Third message is about to inform about the system connection either about battery or the overall system. Finally the last message is send if only the battery is dead or damage, whilst require a battery change.

Real time clock (RTC) is integrated to make sure the system is able to provide accurate system timing during its operational or failure. The RTC design is shown in Figure 3, six push buttons are integrated to adjust the time parameters. Also, the RTC operates based on the built-in power which continuously supply the power source at all time and especially when power failure occurs.

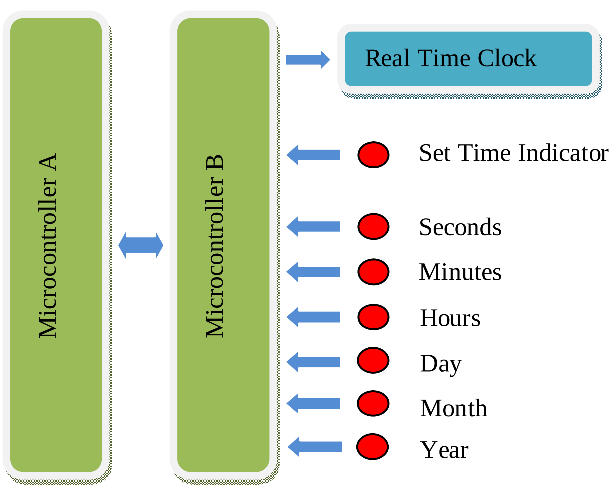


Figure 3: Real Time Clock Architecture Design.

III. SYSTEM OPERATIONAL

In this section the overall CBMS functionality and operation will be explained. Firstly, CBMS will perform check on the battery to determine whether it is connected or disconnected to the system. If the battery is disconnected, the CBMS will detect no battery connected and will continue to perform this test to check the battery health condition. Therefore, if the battery is connected, CBMS will indicate the battery present. Next, the battery voltage will be measured continuously using the ADC channel on the microcontroller. During the battery health measurement, if the battery voltage is measured more than 12 volt, that indicates the battery is in good condition. While, if the battery's measured voltage is less than 12 volt and more or equal to 2 volt, the battery is required a charging. If the battery's voltage is below 2 volt, CBMS will indicate battery is disconnected or loss connection. Then, CBMS will send message via the GSMC to inform about the current status of the battery.

Next, while the battery is charging, CBMS will continue to measure the battery's voltage. If the battery's voltage is at 13.4 volt, Relay B will be deactivated thus disconnecting the connection between the battery charger and the battery. After the Relay B is deactivated, CBMS will continue to perform the battery check. This process is necessary to perform the battery capacity test. The battery capacity is also necessary to verify whether the battery is able to hold more than 10 percent of the capacity hence will not undermine the CBMS functionality.

The function to measure the battery's capacity is one of the specialties of the proposed CBMS. Another special function of the CBMS is integration of the RTC for the battery capacity test. The RTC is used to preset time to perform the battery capacity test, when the RTC time is same as the preset time for battery capacity testing, then the capacity tester will perform the battery capacity test. Relay A will be triggered and will connect the battery with the capacity tester. The capacity tester will perform a minimum 10 percent of battery capacity test. If the battery does not have sufficient capacity, then CBMS will send a message to inform the battery's capacity is insufficient or battery is damage. If the minimum capacity level is measured, then the Relay A is disconnects the capacity tester and battery. Then, CBMS will continuously measure the battery's voltage.

For an example, 12 volt battery with capacity of 3.2 Ampere/Hour is used in the CMBS. Hence, 10 percent of the battery capacity is 0.32 Ampere/Hour. CBMS will take 576 seconds or 9.6 minutes to verify whether the battery hold a minimum of 10 percent of capacity or other way around. Next is shown the calculation to measure the battery's capacity.

Battery Capacity = 3.2 Ampere/Hour

Capacity Tester = 2 Ampere (Constant)

Minimum Capacity (10 percent)

$$= \frac{10}{100} \times 3.2\,Ampere/Hour$$

= 0.32 Ampere/Hour

Time to perform Capacity Test

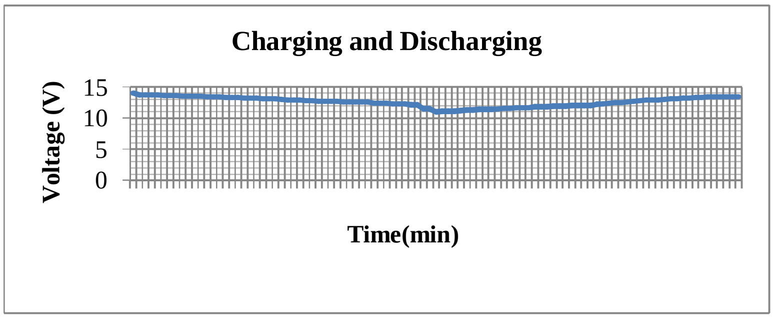
$$= \frac{0.32\,Ampere/Hour}{2\,Ampere} \times 3600\,seconds$$

= 576 seconds or 9.6 minutes

IV. Results and Discussion

A. Charging and Discharging

Figure 4 (a) shows the battery charging and discharging graph. As it is shown in Figure 4 (b) the voltage drops to 11.91 volt on the CBMS. As mentioned in the section III, if the battery voltage is less than 12 volt, Relay B will be switched on to connect the battery charger to charge the battery. CBMS will automatically start charging the battery on CBMS detects the voltage drops. The battery will be charged up to 13.4 volt, and then the battery will be disconnected from the charger.



(a)

(b)

Figure 4: Battery Charging and Discharging

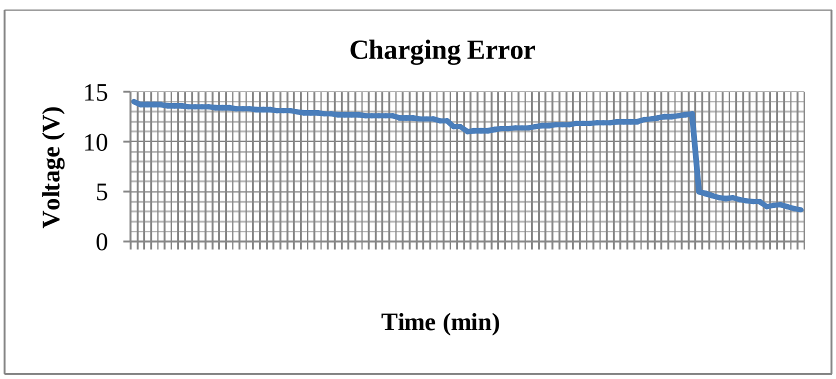
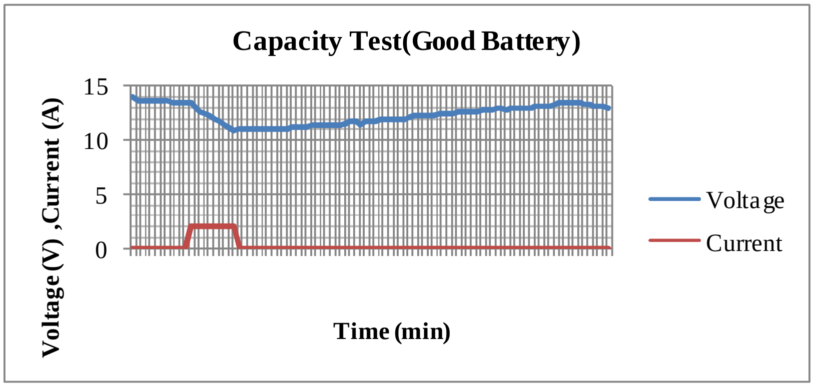


Figure 5: Battery Charging Error

Figure 5 shows the battery charging error during the battery charging process. While the charging process is performing and the battery voltage decrease to less than 5 volt, the CBMS will indicate there is a problem to the battery or the system. Hence, immediately the CBMS will send a message to the maintenance team via the GSMC to inform the status.

B. Capacity Test

Figure 6 show the result of capacity test for a healthy battery condition. Figure 6 (a) indicates the voltage and current measurement during the battery capacity test. The battery will perform a capacity test only when the battery's voltage reaches at optimum voltage more than 12 volt. When the test is being performed the green LED indicator as shown in Figure 6(b) on the CBMS will turn on to indicate the capacity test is being performed. At the same time, the date and time also is displayed on the screen as to indicate it is a real time process. Figure 6 (c) shows the result after the capacity test is completed. Therefore at this particular period the battery voltage is below 12 volt, hence the battery charger will be turned on immediately to charge the battery. At the same time a message as shown in Figure 6 (d) will be sent to the maintenance team to inform about the battery health condition.



(a)

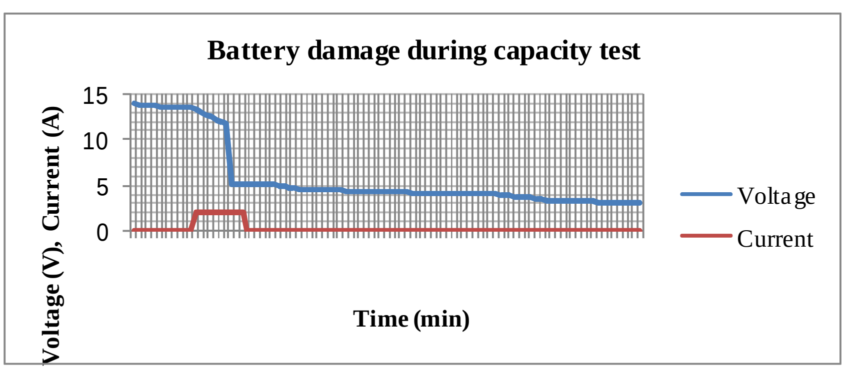
(b) (c)

(d)

Figure 6: CBMS Capacity Test – Good Battery

C. Battery Damage

Figure 7 shows the result of failed battery during the capacity test. Figure 7 (a) shows the battery voltage decreased to 5 volt significantly during the capacity test and gradually reduce to less than 5 volt. Figure 7 (b) shows the message when the battery failed the capacity test. Hence, a message will be sent to the maintenance team to inform the battery status and the maintenance team will replace the damage battery. Figure 7 (c) is an additional feature in the CBMS when the battery has loss the circuitry connection. This situation might occur due to the short circuit incident. If the loss connection is detected, then CBMS will send a message to the maintenance team to inform about the system downfall.



(a)

(b) (c)

Figure 7: Battery Failure during Capacity Test

V. CONCLUSION

This study aims to design and develop a CBMS for battery application. The CBMS is able to check the battery health and condition in real time mode. The CBMS has the ability to update the maintenance team with the exact date and time if the battery is detected fail. Therefore, this paper put forward the CBMS test results in the section IV which significantly proof the system is able to perform the battery check in real time mode.

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