Battery Monitoring System by Detecting Dead Battery Cells

Chanikarn Hommalai
Dept. of Electrical Engineering, Faculty of Engineering
King Mongkut's Institute of Technology Ladkrabang
Bangkok, Thailand, 10520
chanikarn5338@gmail.com

Surin Khomfoi
Dept. of Electrical Engineering, Faculty of Engineering
King Mongkut's Institute of Technology Ladkrabang
Bangkok, Thailand, 10520
kkhsurin@kmitl.ac.th

ABSTRACT--The development of battery monitoring system by detecting dead battery cell is proposed in this paper. The experiment of charging and discharging process is tested in different values of the current in order to compare the experimental parameter at different condition. During the process, the parameters of battery, which are current, voltage, and temperature are send to display on the computer and analyzed in order to detect the dead battery cell. The monitoring device also shows the parameter of battery during testing. CAN (Controlled Area Network Communication) is used to transfer all data between the microcontroller and the proposed PLC together with a computer. The outputs showing on the displaying screen are voltage per cell, current of charging or discharging, temperature within battery, power density, and also energy density. The dead battery cells and efficiency of battery can also be indicated by this monitor device.

Keywords-- Battery, Dead Cell Detection, Power density

I. INTRODUCTION

In recent years, the demand of electrical energy has been increasing. So the renewable energy system is developed as another choice to generate electrical energy. The renewable energy is not available for all time, for example, solar cell could produce power only when there is solar radiation and wind turbine generator could produce power only when there is an air flow. So batteries are widely used as energy storage in renewable energy system and also in industry. When the renewable energy system is not available, the battery is required in order to provide power supply to load. Moreover the advantage of battery are store net metered solar in battery to use at peak time, save money in peak energy costs and keep powered up during grid failed. The application of battery are from the small-sized portable devices to the large-sized equipment such as uninterruptible power supplies (UPS), which is used in energy storage system to provide emergency power to critical loads and improve power quality and reliability of power system.

Everyone wants to keep the battery as long as possible, but the battery must operate in environments that are conducive to optimal battery life. Furthermore, the life of a battery may be cut short by heavy use or unfavorable temperature condition. The capacity of battery would also drop when the number of cycle life is used. The battery may last shorter than what datasheet indicates. The deterioration of battery may not occur to all cells of battery, so the detection of dead battery cells could be a solution to tell the user that which battery cell is a problem. The detection of dead battery cells can be obtained by studying parameter characteristic of that battery.

Battery has its internal characteristic and circuit parameters are changed according to the lifetime and the operation temperature. Therefore the detection of dead battery cells by studying internal characteristic is proposed in this paper to indicate the deterioration of battery. In order to obtain the deterioration of battery, it is necessary to study its internal characteristic. An experiment is tested by constant current charging and discharging method. The experimental results are analyzed to find out the internal characteristic.

The development of battery monitoring system by detecting dead battery cells is proposed in this paper. The parameter of battery, which are voltage, voltage per cell, current, and temperature are shown. The monitoring device can also report the deterioration of battery to the user in order to avoid damage to the battery. Moreover it can reduce wasted battery to an environment.

This paper is organized as follow. Section II reviews the related theory. Section III introduces the monitoring circuit and explains each circuit in detail. Section IV describes a battery test and shows the experimental results. Finally, Section V concludes the paper.

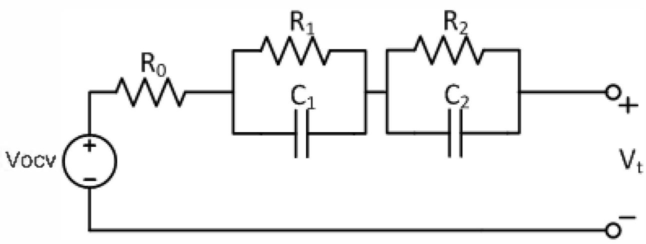

Fig. 1. Equivalent circuit of battery

II. RELATED THEORY

A. Analysis of equivalent circuit of battery

The equivalent circuit of battery is shown in Fig1 with a resistance R0, a resistance R1, a resistance R2, a capacitance C1 and a capacitance C2. In the experiment of battery testing, voltage, current, and temperature of battery are detected. The internal resistance varies directly to current and discharge time as shown in Fig2. Internal resistance of battery is the indicator of deterioration of battery. Resistance R0, which is considered

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as a cause of loss in battery, can be calculated by using constant current charging and discharging method. In the experiment, voltage varies immediately at the beginning of the discharging process. For this behavior, Ohm's law is used to calculate for the internal resistance as shown in Formula1.

$$R_0 = (V_1 - V_2) / I \qquad (1)$$

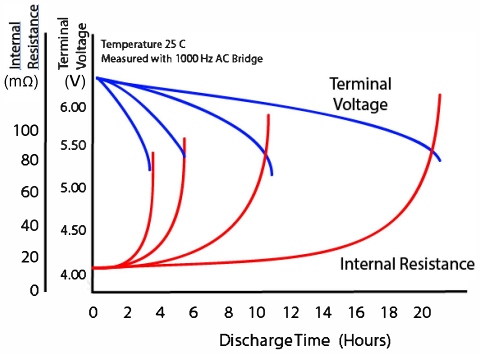

Fig. 2. Relationship between internal resistance and discharge time together with relationship between terminal voltage and discharge time

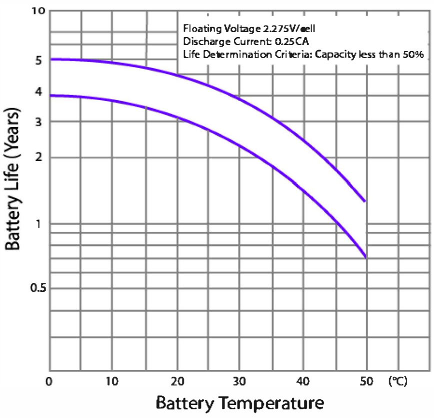

Fig. 3. Relationship between temperature and battery life

B. Temperature and lifetime of battery

Batteries function best at room temperature, and any deviation towards hot and cold changes the performance and longevity. Operating a battery at elevated temperatures momentarily improves performance by lowering the internal resistance and speeding up the chemical metabolism. Temperature, which is an important factor, affects chemical metabolism inside the battery. This temperature would also affect battery life. Fig.3 shows that battery life is reverse variation to battery temperature. If the battery is used in an unfavorable temperature condition, this would cause deterioration and shorten battery life. The battery may last shorter than what datasheet indicates. Main factor, which affects temperature inside battery, is internal resistance. If internal resistance is high, heat produced inside the battery during charging and discharging is high too.

III. MONITORING CIRCUIT

This part is discussed about monitoring circuit of battery, which is consisting of power circuit, control circuit, and communication circuit.

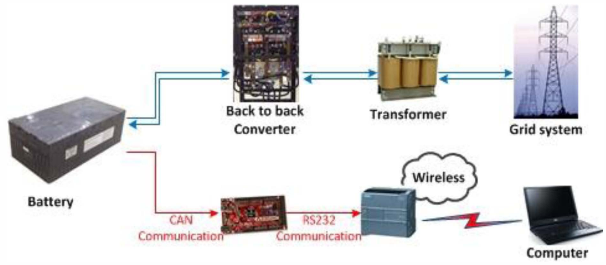

Fig. 4. The connection between testing device and battery

The connection between testing devices and battery is shown in Fig4. The grid system is connected to a transformer to transform voltage from grid system with 230V to 50V. After that this alternate current with 50V is fed to alternate side of a back to back converter. This back to back converter would convert alternate current to direct current. Another side of the back to back converter is connected to the battery. In the experiment, direct current can move forward from the back to back converter through the battery and also backward from the battery to the back to back converter. So the battery could be tested in both charging and discharging process.

Fig. 5. Battery testing in laboratory

During charging and discharging process, data consisting of current, voltage, voltage per cell, and temperature are send to CAN to TTL communication circuit in order to change a pattern of signal into TTL, which is supported by chipKIT Max32. After that this signal is processed by chipKIT Max32.

Then the data in TTL form are sent to TTL to RS232 communication circuit. This communication circuit chang pattern of the signal into RS232, which is supported by PLC. Finally, this data from PLC are sent through a computer for displaying the result, which are current, voltage, voltage per cell, and temperature.

A. Power circuit

In power circuit, a back to back converter is used to transfer power in both forward and backward. For the back to back converter, a triggering angle can be adjusted to vary the direct current in charging and discharging process. In the experiment, the charging and discharging current are 40A, 80A and 120A. From this function of back to back converter, the experiment can be tested in both charging and discharging. Fig6 shows equivalent circuit of back to back converter.

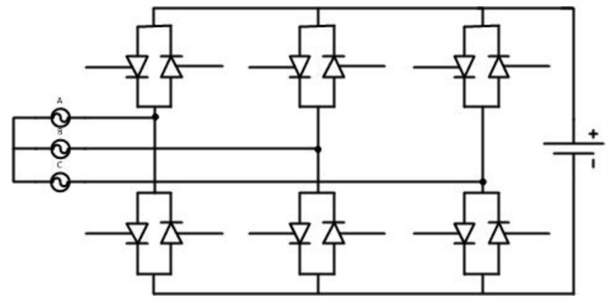

Fig. 6. equivalent circuit of back to back converter

B. Control circuit

Control circuit consisting of chipKIT Max 32, CAN to TTL communication circuit ,and TTL to RS232 communication circuit. In this control circuit, the chipKIT Max32, which is consisting of microcontroller PIC32MX795F512L is used to access data from battery. This microcontroller can manage data in a form of CAN communication. The CAN to TTL communication circuit is used to transform CAN from battery to TTL,which is used in microcontroller. Last, the TTL to RS232 communication transform TTL from microcontroller to RS232 before sending to PLC.

IV. EXPERIMENTAL RESULT

The experiment is constant current charging and discharging process in order to analyze varied voltage and calculate for internal resistance. The battery in the experiment is 40Ah Lithium ion battery with 27.6 volt. In the experiment, charging and discharging current are 40A (1C), 80A (2C), and 120A (3C). The discharging process with 40A (1C) is shown in Fig7. This takes around 60 minutes to finish the process. The discharging process with 80A (2C) is shown in Fig8. This takes around 30 minutes to finish the process. Last, the discharging process with 120A (3C) is shown in Fig9. This takes around 20 minutes to finish the process. During the discharging process at different discharging current, we could notice that voltage drop immediately at the beginning of the process, which is an effect of internal resistance. For this behavior, the internal resistance could be considered as an indicator of deterioration of battery. The discharging process is tested repeatedly with different value of current. Internal resistances at different value of current are shown in Table1. The internal resistance of battery is around 16 milliohm. The value of internal resistance is higher at higher charging and discharging current. In the constant current charging and discharging method, the relationship between temperature and time are considered. The temperature during discharging at 40A (1C) as shown in Fig.10 stay nearly constant, but the temperature during discharging at 80A (2C) and 160A (3C) increase continuously. Fig.11 shows discharging process at 120A (3C). The average voltage is 26.45V and average power is 2101Watt. Surrounding temperature during testing is 32ºC

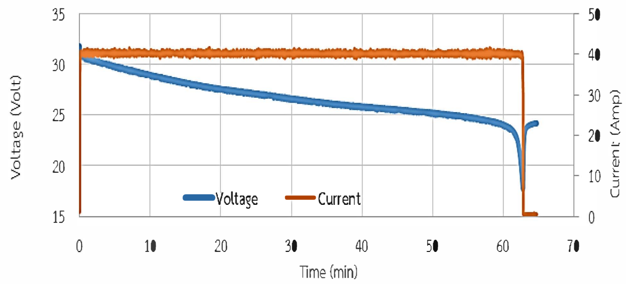

Fig. 7. Voltage and current during discharging at 40A(1C)

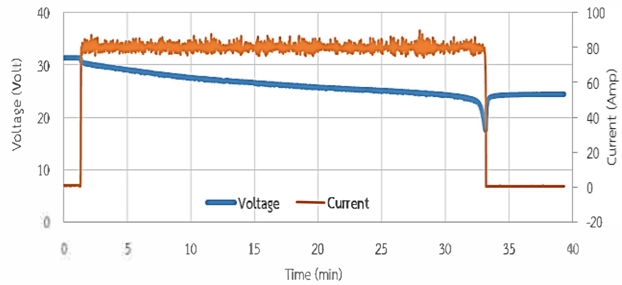

Fig. 8. Voltage and current during discharging at 80A(2C)

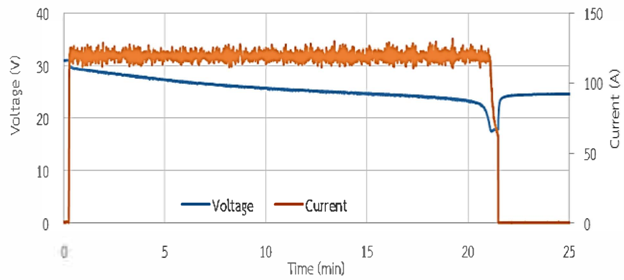

Fig. 9. Voltage and current during discharging at 120A(3C)

TABLEI. Internal resistance of battery at each value of current during charging and discharging process

Internal resistance of battery during discharging	
Current	Internal resistance (milliohm)
40A (1C)	16.0805
80A (2C)	16.3521
120A (3C)	16.5532
Internal resistance of battery during charging	
Current	Internal resistance (milliohm)
40A (1C)	16.0806
80A (2C)	16.4608
120A (3C)	16.7143

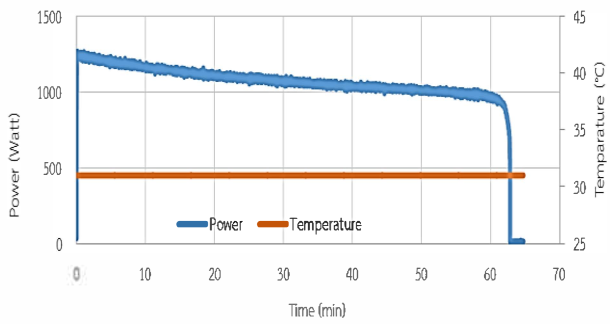

Fig. 10. Power and temperature during discharging at 40A(1C)

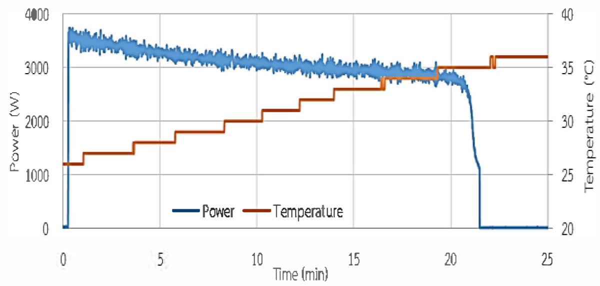

Fig. 11. Power and temperature during discharging at 120A(3C)

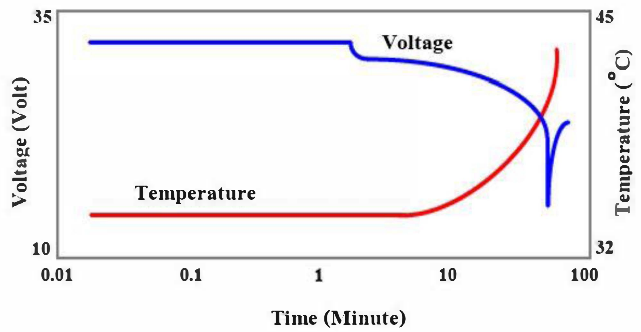

Fig. 12. Voltage and temperature during discharging at 80A(2C)

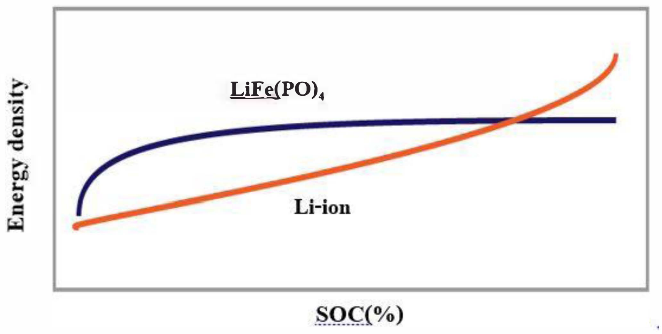

Fig. 13. Comparison of power density between LiFe(PO)$_4$ battery and Li-ion battery

Fig12 shows discharging process at 80A (2C). The graph shows voltage and temperature during discharging. In the discharging process, voltage (blue line) gradually decreases, while temperature (red line) increases.

Fig13 shows comparison of power density at each %SOC between 2 kinds of battery, which are LiFe(PO)$_4$ battery and Li-ion battery. It shows that Li-ion battery (orange line) has power density higher than LiFe(PO)$_4$ battery (blue line) at high %SOC. On the other hand, LiFe(PO)$_4$ battery has power density higher than Li-ion battery (orange line) at low %SOC. This behavior of battery would be advantageous for considering battery to different load characteristic. If an application could be used with low %SOC, LiFe(PO)$_4$ battery would be suited, because the capacity of LiFe(PO)$_4$ battery is higher with low %SOC and the net weight is lower. If some application must be used with high %SOC, Li-ion battery would be suited. Fig14 shows displaying screen of battery monitoring system.

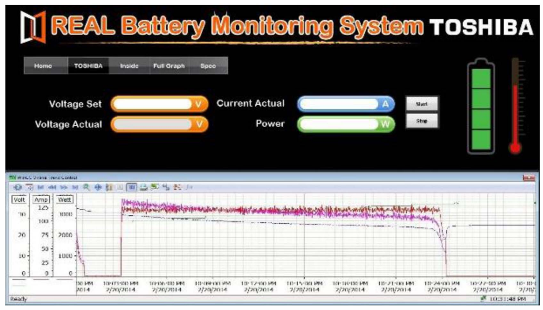

Fig. 14. Displaying screen of battery monitoring system

V. CONCLUSION

This paper proposed the development of battery monitoring system by detecting dead battery cells. Internal resistance is considered by constant current charging and discharging method. The internal resistance is increasing when charging and discharging with higher current. This internal resistance affect directly to temperature and voltage of battery. The higher value of internal resistance could indicate the deterioration of battery. Moreover, the used of battery with high internal resistance would cause loss in resistance. The temperature produced would exceed the range of identified datasheet. The temperature, which is a main factor, affect lifetime of battery and cause under voltage of battery in each cell. Voltage across internal resistance cause under voltage in each cell. So internal resistance is an indicator of deterioration. The experimental result also compare power density between LiFe(PO)$_4$ battery and Li-ion battery at each %SOC to find suitable battery for different application

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