International Journal of Internet, Broadcasting and Communication Vol.14 No.2 129-135 (2022)
http://dx.doi.org/10.7236/IJIBC.2022.14.2.129

IJASC 22-2-17

Development of Aging Diagnosis Device Through Real-time Battery Internal Resistance Measurement

Sang-Bum Kim[1], Sang-Hyun Lee[2]

[1]*Assistant Professor, Department of Electronic Engineering, Honam University, Korea*
[2]*Associate Professor, Department of Computer Engineering, Honam University, Korea*
{2021115, leesang64}@honam.ac.kr

Abstract

Currently, the rapid growth of electric vehicles and the collection and disposal of waste batteries are becoming a social problem. The purpose of this paper is to propose a fast and efficient battery screening method through a safe inspection and storage method according to the collection and storage of waste batteries of electric vehicles. In addition, as the resistance inside the waste battery increases, an instantaneous voltage drop occurs, and there is a risk of overcharging and overdischarging compared to the initial state of the battery. Accordingly, there are great difficulties in operation, so the final goal of this study is to develop a device for diagnosing aging through real-time battery internal resistance measurement. Final result As a result of simulation of the internal resistance measurement test circuit through external impedance (AC), the actual simulation value was 0.05Ω, RS = Vrms / Irms => Vrms = 8.0036mV, Irms = 162.83Ma. Substitute the suggested method. The result was calculated as Rs = 0.0495Ω. It is possible to measure up to 64 impedances inside the aging diagnostic equipment that enables real-time monitoring of the developed battery cells, and the range can be changed according to the application method.

Keywords: *Waste battery, Overcharging, Over discharge, Impedance, Aging diagnosis device, Battery internal resistance.*

1. Introduction

The government has recently announced support policies to increase electric vehicle consumption in accordance with environmental regulations, etc., and demand is also increasing as the market grows rapidly.

With the rapid growth of electric vehicles, the problem of recycling waste batteries is emerging as a social problem, and it is a field that is receiving great attention at home and abroad [1].

Since these waste batteries are a major cause of high cost and environmental pollution to chemically treat, recently global automakers are conducting research to recycle the waste batteries recovered from electric vehicles. In particular, it is possible to save a lot of money by recombining waste batteries to build an energy storage system and reuse it [2].

In general, a waste battery is defined as a waste battery from the point in time when it reaches 80% of the initial battery capacity, and there is a great difficulty in estimating the state because the internal resistance increases and the characteristics are more non-linear. This is how it looks compared to a battery in the normal

Manuscript Received: March. 23, 2022 / Revised: March. 25, 2022 / Accepted: April. 2, 2022
Corresponding Author: leesang64@honam.ac.kr
Tel:+82-62-940-5285, Fax: +82-62-940-5285
Associate Professor, Department of Computer Engineering, Honam University, Korea

use area [3]. Therefore, in the case of using a waste battery, as internal resistance increases significantly compared to the initial state of the battery, internal heat generation increases, so more attention is required for stability.

In addition, as the resistance inside the waste battery increases, an instantaneous voltage drop occurs, and there is a risk of overcharging and overdischarging compared to the initial battery. According to these characteristics of lithium-ion batteries, the biggest issue in the waste battery recycling market is research to identify safety issues in advance by monitoring information on internal batteries in real time [4-5].

As the importance of collection and storage of such waste batteries for electric vehicles increases, it is necessary to classify batteries through safe inspection and storage methods.

Therefore, in this paper, we intend to develop a device capable of diagnosing aging by measuring the internal resistance of waste batteries in real time. Battery performance diagnosis can secure safety and reliability by identifying and resolving problems that occur during operation of various battery facilities such as spare power, Uninterruptible power supply (UPS), and rectifier in advance, and identifies and predicts the most appropriate battery replacement time It can reduce the cost of replacing.

2. Measurement of Charge/Discharge Resistance Inside a Battery Cell

2.1 Measurement of battery cell internal charging resistance

The battery internal resistance measurement method is a method of calculating the internal resistance using the value of the voltage change and the current flowing through the test circuit by connecting a separate test circuit consisting of a switch and a resistor to the Energy Storage System (ESS) battery cell in parallel [6]. The configuration of the charging test circuit is shown in Figure 1, and it consists of a test resistor, a switch unit and a current sensor connected in series with the test resistor, and a voltage sensor configured in parallel.

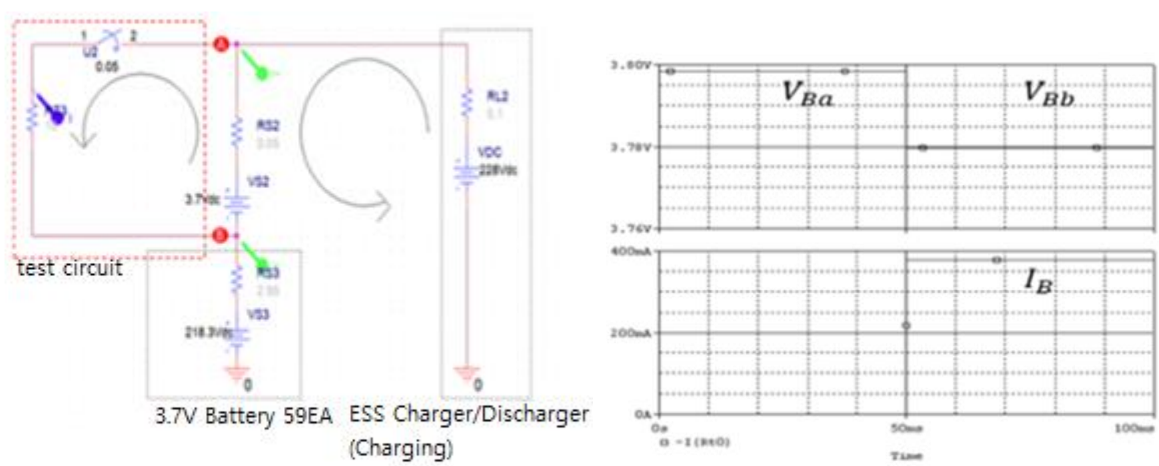

Figure 1. State of charge internal resistance measurement test circuit

When the switch is in Off state, Voltage of terminals (A, B) is marked as V_{Ba}, and in case of On state, V_{Bb} is marked. In addition, when the switch is off, the size of the charging current is expressed as I_A state, when the switch is turned on, the current flowing through the resistor is indicated as I_B, and R_s measurement is the change and test of the terminal voltage in the On/Off state and it is induced by the relational expression of the current fluctuation.

$$(\textit{Loop A: } R_t\textit{, before connection}) \quad V_S + R_S I_A + R_{INV} I_A = V_{INV},\ V_{Ba} = R_S I_A + V_S \tag{1}$$

Equation (1) represents Loop A: *Rt*, before connection, Equation

$$(After\ 0.05\ second\ R_t,\ connection)\quad IB = \frac{VBa}{\frac{RS\times RINV}{RS+RINV}+Rt},\ VBa = \frac{RS\times RINV}{RS+RINV}I_B + R_tI_B,\ V_{Bb} = R_tI_B \qquad (2)$$

Equation (2) represents after 0.05 second *Rt*, connection, and Equation

$$\frac{RS\times RINV}{RS+RINV} = \frac{VBa - VBb}{IB},\ if\ R_{INV} >> R_t, R_S = \frac{VBa-VBb}{IB} \qquad \frac{\text{voltage fluctuations}}{\text{fluctuations in current}} \qquad (3)$$

Equation (3) represents voltage and current fluctuations. V_{Ba} means the battery cell voltage before the test circuit, that is, *Rt* is connected, and V_{Bb} means the battery cell voltage after connection.

When calculated by substituting 59 3.7V batteries as the actual simulated value: 0.05Ω, *VBa* = 3.7984V, V_{Bb} = 3.7752V, I_B = 0.4713A, and *Rs* = 0.0492Ω, as the result of the formula.

2.2 Measuring the Internal Discharge Resistance of a Battery cell

The configuration of the discharge test circuit is shown in Figure 2, and the configuration is the same as the charging resistance measurement. The discharge test circuit consists of a test resistor, a switch unit and a current sensor connected in series with the test resistor, and a voltage sensor configured in parallel.

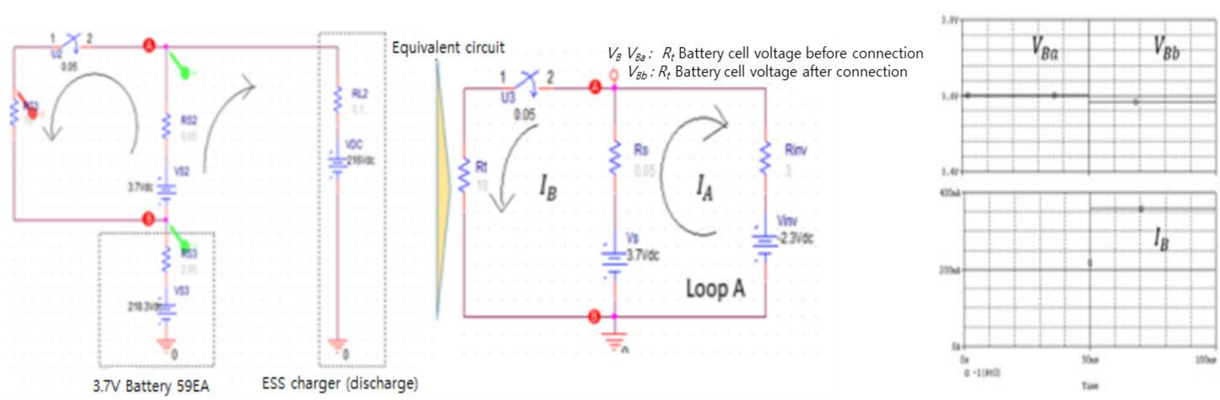

Figure 2. Discharge state internal resistance measurement test circuit

When the switch is in Off state, Voltage of terminals (A, B) is marked as V_{Ba}, and in case of On state, V_{Bb} is marked. In addition, when the switch is off, the size of the charging current is expressed as I_A state, when the switch is turned on, the current flowing through the resistor is indicated as I_B, and R_s measurement is the change and test of the terminal voltage in the On/Off state and it is induced by the relational expression of the current fluctuation.

$$(Loop\ A:\ R_t,\ before\ connection)\quad V_S + R_SI_A + R_{INV}I_A = V_{INV},\ V_{Ba} = R_SI_A + V_S \qquad (4)$$

Equation (4) represents Loop A: *Rt*, before connection

$$(\text{After 0.05 second } R_t\text{, connection})\quad IB = \frac{VBa}{\frac{RS\times RINV}{RS+RINV}+Rt},\ VBa = \frac{RS\times RINV}{RS+RINV}I_B + R_tI_B,\ V_{Bb} = R_tI_B \qquad (5)$$

Equation (5) represents after 0.05 second *Rt*, connection

$$\frac{RS\times RINV}{RS+RINV} = \frac{VBa - VBb}{IB},\ if\ R_{INV} >> R_t,\ R_S = \frac{VBa-VBb}{IB} \quad \frac{\text{voltage fluctuations}}{\text{fluctuations in current}} \tag{6}$$

Equation (6) represents voltage and current fluctuations. V_{Ba} means the battery cell voltage before the test circuit, that is, Rt is connected, and V_{Bb} means the battery cell voltage after connection.

If 59 3.7V batteries are calculated as the actual simulated value: 0.05Ω, V_{Ba} = 3.6032V, V_{Bb} = 3.5856V, I_B = 0.3582A and the result of the equation is Rs = 0.0491Ω.

3. Development of a Model to Improve Battery Internal Resistance Precision

As a method for improving the accuracy of the internal resistance of a battery proposed in this paper, signal change is periodically generated Alternating Current (AC signal) through continuous switching operation and Root Mean Square (RMS) value and test for change value of cell voltage (AC signal) in contrast to measurement in a linear way by averaging the rms value for the change in current, precise calculation of internal resistance is possible. It is possible to precisely calculate the internal resistance with the average voltage change value and the test current change value and it is possible to measure the terminal voltage and test current of a circuit that turns on/off the test resistance of a battery cell at 500Hz per second. Figure 3 shows the test circuit for measuring internal resistance through external impedance (AC).

voltage fluctuations: $V_{ac}(t) \rightarrow V_{rms\ (1\ sec\ average)}$, current fluctuation: $I_{ac}(t) \rightarrow I_{rms}$, $R_s = \frac{V_{rms}}{I_{rms}}$ (7)

Here, Equation (7) used to measure the occurrence of continuous fluctuations using the On/Off switch shows voltage fluctuations and current fluctuations.

In Figure 3, for the simulation of the internal resistance measurement test circuit through external impedance (AC), the actual simulated value: 0.05Ω, $R_S = Vrms / Irms$ => $Vrms = 8.0036mV$, $Irms = 162.83Ma$ is substituted into Equation (7). The result was calculated as Rs = 0.0495Ω.

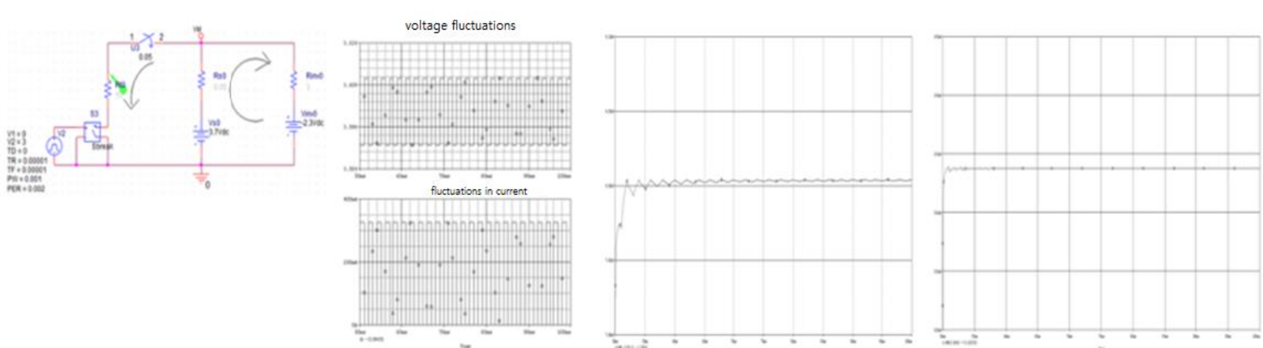

Figure 3. Internal resistance measurement test circuit through external impedance (AC)

According to the results of this study, when the internal impedance is measured in a linear form, the error range can be expanded, and in the case of a battery operated in an actual field, the error range increases with high C-rate through high resistance, and many variables occur due to non-linearity. This results in low accuracy.

Therefore, in this paper, data accuracy is visualized by measuring the internal resistance by converting the external impedance into alternating current, and the internal resistance of the battery cell can be monitored in real time regardless of the charging/discharging situation. When detected, it is possible to provide information that can prevent the battery from causing a fire by leaving the battery unattended.

3.1 Circuit Design

In this paper, we design an external impedance switching stage for AC, not a linear method, and design a DC/AC that can measure voltage and current continuously as shown in Figure 4.

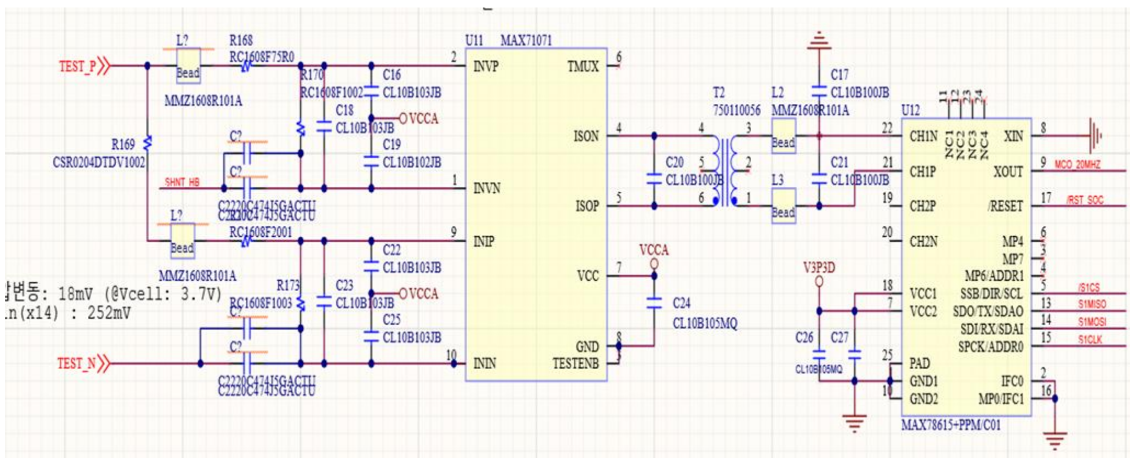

Figure 4. DC/AC design for continuous measurement of voltage and current fluctuations

Figure 5 is the overall blueprint of the aging diagnostic device capable of real-time monitoring of battery cells.

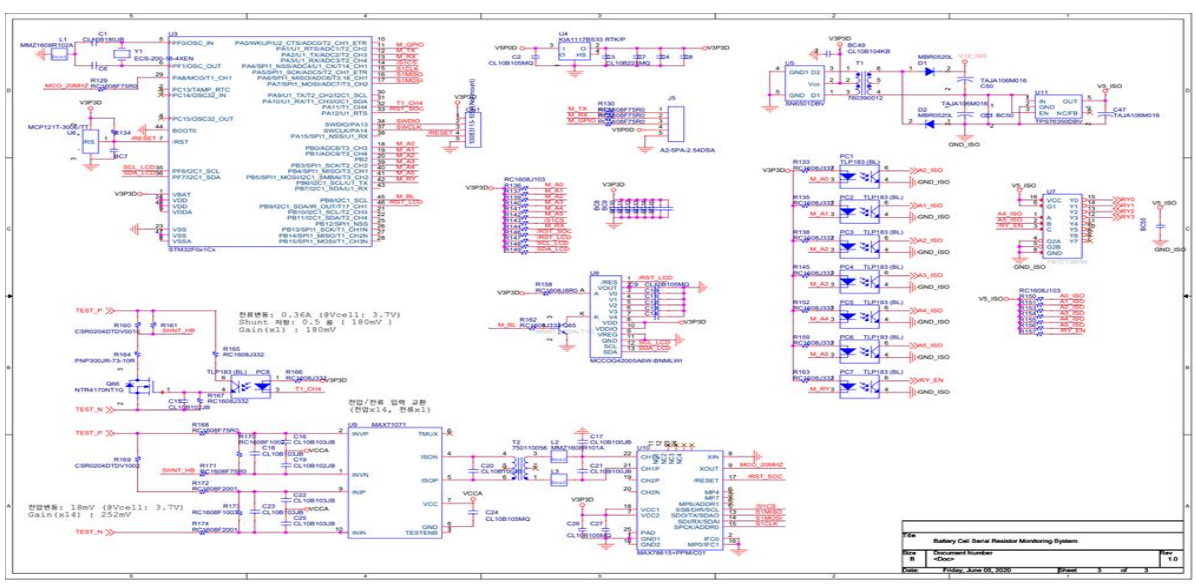

Figure 5. The overall blueprint of the aging diagnostic device capable of real-time monitoring of battery cells

3.2 Result of battery aging diagnosis device development

As shown in Figure 6, a battery aging diagnostic device that enables real-time monitoring of battery cells was manufactured. The completeness of the product was improved through design and mechanism design, and during the test, 2, 4, and 8 cell connectors could be connected so that it could be operated depending on the battery platform. It was made so that the measured values of each star could be checked on the Liquid Crystal Display (LCD) screen.

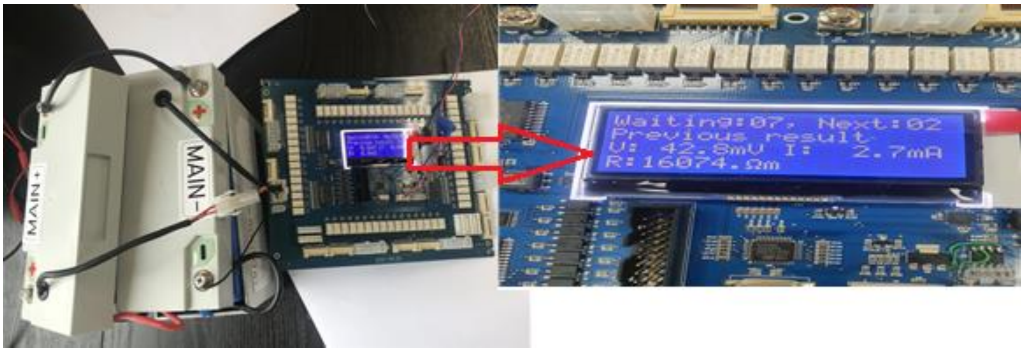

Figure 6. Development of aging diagnostic equipment capable of real-time monitoring of battery cells

Aging diagnosis equipment capable of real-time monitoring of the developed battery cells can measure up to 64 internal impedance measurements per unit cell, and the range can be changed according to the application method.

As a method to improve the accuracy of the internal resistance of a battery proposed in this paper, the internal resistance can be accurately calculated differently from the conventional method by accurately calculating the internal resistance using the average voltage change value and the test current change value.

In addition, the terminal voltage and test current of circuits and cells can be measured by turning the test resistor on/off. As a result of simulation of the test circuit for measuring internal resistance through external impedance (AC), the *actual simulated value: 0.05Ω, RS= Vrms / Irms => Vrms= 8.0036mV, Irms= 162.83Ma Calculated as Rs = 0.0495Ω.*

4. Conclusion

This study has become a topic of great interest both at home and abroad as the problem of disposal of waste batteries, which occurs in line with the rapid growth of electric vehicles, is becoming a social problem. In general, a waste battery is defined as a waste battery from the point where it becomes 80% of the initial battery capacity, and there is a great difficulty in estimating the state because the internal resistance increases and the characteristics show a more non-linear shape compared to the battery in the general use area.

Therefore, when a waste battery is used, as the internal resistance increases significantly compared to the initial state of the battery, internal heat is increased, so more attention to stability is required.

In this paper, the internal resistance can be precisely calculated using the average voltage change value and the test current change value to accurately calculate the internal resistance unlike the conventional method. Terminal voltage and test current can be measured.

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