March - April 2020
ISSN: 0193-4120 Page No. 4158 - 4163

A Study on the Correlation Analysis Between Battery Internal Resistance and Temperature

Hyun-Sung Lim[*1], Kil-Mok Shong[2], Gun-Ho Yi[3], Jae-Hyun Kim[4], Sung-Koo Cho[5], Pil-Sung Woo[6]

[*1,4,5,6]Senior Researcher, Department of ESS Research, Korea Electrical Safety Corporation, Wanju, Jeollabuk-do, Korea.
[2]Chief Researcher, Department of ESS Research, Korea Electrical Safety Corporation, Wanju, Jeollabuk-do, Korea.
[3]Head Researcher, Department of ESS Research, Korea Electrical Safety Corporation, Wanju, Jeollabuk-do, Korea.
hslim@kesco.or.kr[*1], natasder@kesco.or.kr[2], ghyi@kesco.or.kr[3], azalea@kesco.or.kr[4], chosk@kesco.or.kr[5], wps@kesco.or.kr[6]

Article Info
Volume 83
Page Number: 4158 - 4163
Publication Issue:
March - April 2020

Abstract
Energy Storage System is increasing to grid system and ESS accidents are also increased. So, it need to analyze safety standard in ESS system. To find safety element of ESS system, this paper analyze lithium-ion battery internal resistance. Experiments are studied from 18650 battery and pouch type battery internal resistance with correlation of temperature. The experiment result show that temperature is increased and internal resistance of battery is decreased both 18650 battery and pouch type battery. This means that temperature is great effect of internal resistance. This paper installed temperature sensor in operating ESS site and monitoring data for 20 days. Experiment result is showed that variation of temperature is large between top position and bottom position. So, It needs to control temperature in energy storage system and maintain stable environment. This paper analyze correlation between internal resistance and temperature and it is important to control stable temperature. Future studies will analyze various environment element which effect to internal resistance.

Article History
Article Received*: 24 July 2019*
Revised*: 12 September 2019*
Accepted*: 15 February 2020*
Publication*: 26 March 2020*

Keywords: *Internal Resistance, Energy Storage System, Temperature, Battery, Lithium-ion*

1. Introduction

The supply of Energy Storage Systems (ESS) is increasing in terms of stabilization and demand management of the power system[1]. Most of the storage systems in the ESS consist of lithium-ion batteries. Lithium-ion batteries can store large amounts of electric energy in small capacity[2], but there are difficult to digest in case of fire. Battery Management System (BMS) monitor battery statement like cell or rack voltage, temperature, and BMS provide battery information and provide reliable operation[3]. The condition of battery is provided by the BMS as State of Charge(SOC) and State of Health(SOH). But, this factors(SOC, SOH) are different from manufactures, it is difficult to define indicator of battery safety. Several methods proposed for estimating SOC and Coulomb counting method measure the current constantly and count the Coulomb charge/discharge in order to estimate SOC[4,5]. Some researches use the internal resistance R for the estimation for the SOH[6-8]. So, the internal resistance can evaluate lithium-ion battery's safety condition. Electrochemical impedance spectroscopy(EIS) can measure and calculate of internal resistance of batteries[9] which is difficult to estimate Energy Storage System because of high equipment cost. Other method for determining battery's internal resistance are DC internal resistance measurements. In this paper, we present internal resistance of lithium ion battery based on temperature. This work is useful for studying the Energy Storage System safety evaluation. Firstly, the internal resistance of 18650 batteries measure

with temperature. Then variation trends of the internal resistance of batteries with temperature changes were analyzed. Finally, the deviation of internal resistance between same batteries was measured and presented to calibrate internal resistance considering temperature.

2. Internal Resistance Measurement

Energy Storage System batteries are several different equivalent models because of the complexity of the internal battery resistance[10]. Equivalent circuit of battery is presented [Figure 1] and equation (1) ~ (3).

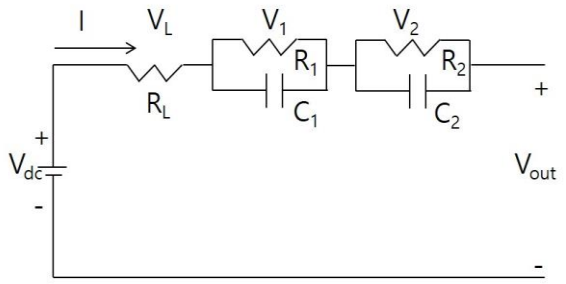


Figure 1. Equivalent circuit of battery

$$V_1 = -\frac{1}{R_1 C_1} V_1 + \frac{1}{C_1} \quad (1)$$

$$V_2 = -\frac{1}{R_2 C_2} V_2 + \frac{1}{C_2} \quad (2)$$

$$V_{out} = V_{dc} + R_L I + V_1 + V_2 + \cdots \quad (3)$$

The internal resistance of battery consist of ohmic resistance R_L and polarization resistance R_1, R_2, … .

DC method is measured to voltage drop through rapid load change. Because DC voltage and current have no frequency, capacity of internal battery C_1, C_2,... can't flow DC current and zero value. Therefore, the results of internal resistance of batteries are presented by equation (4)

$$R_{DC} = R_I + R_1 + R_2 + \cdots \quad (4)$$

AC method send specified amplitude and frequency signal to battery. Electrochemical Impedance Spectroscopy(EIS) is the method of measuring the internal resistance value to signals of various frequency. Thus basic test of AC method frequency is 1kHz. In case of capacity C1, C2, … is very low AC impedance values in 1kHz frequency. So, the internal resistance value will be closed to R_L in equation (5)

$$R_{AC-1kHz} = R_L \quad (5)$$

DC method provide valuable measurement for DC system such as high capacity facility (heating or light load), while AC method with 1kHz is more exactly measurement for digital load such as computer or mobile phone that rely on capacitive characteristics of a battery. So, this paper used AC method with 1kHz for measuring energy storage system internal resistance.

• 18650 Battery Type

This paper tested 18650 batteries internal resistance and temperature. The dimensions of batteries used in experiment are as follows Table 1.

Table 1. 18650 batteries used for the experimentation

Capacity (kWh)	125	System Voltage(V)	750
Num of Module	32	Num of Rack	4
SOC(%)	53	SOH(%)	100

18650 batteries are consisted in 4 Rack and each Rack has 8 modules. Battery Capacity is 125kWh

March - April 2020
ISSN: 0193-4120 Page No. 4158 - 4163

and System voltage is 750V. State of Charge is 53% and State of Health is 100%.

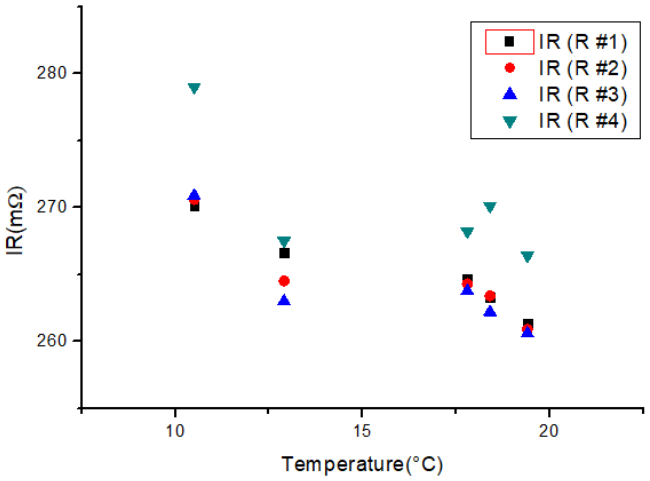


Figure 2. Variation of 18650 internal resistance according to temperature

Figure 2 shows the variations of relationship graph between 18650 internal resistance and temperature. There is Rack internal resistance that sum of each module. The temperature at the measurement site was 10℃ to 20℃. The values of internal resistance show decreased pattern between low temperature and high temperature. Therefore, variation of temperature effects to internal resistance of battery. Each rack internal resistance was different, and it means that the internal resistance of battery is not same for same product.

• Pouch Battery Type

This paper tested pouch type batteries internal resistance and temperature. The dimensions of batteries used in experiment are as follows Table 2.

Table 2. Pouch type batteries used for the experimentation

Capacity (kWh)	1000	System Voltage(V)	850
Num of Module	104	Num of Rack	13
SOC(%)	30	SOH(%)	98

Pouch type batteries are consisted in 13 Rack and each Rack has 8 modules. Battery Capacity is 1,000kWh and System voltage is 850V. State of Charge is 30% and State of Health is 98%.

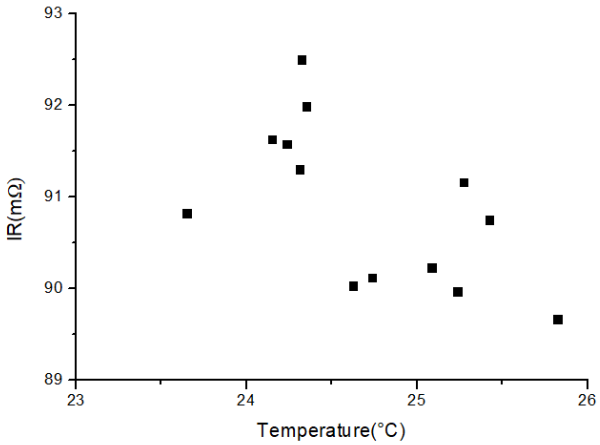


Figure 3. Variation of pouch type battery internal resistance according to temperature

Figure 3 shows the variations of relationship graph between pouch type battery internal resistance and temperature. The temperature at the measurement site was 23.6℃ to 25.8℃. The value of battery internal resistance is decreased between low temperature and high temperature. There shows same pattern of 18650 battery.

3. Result and Discussion

The internal resistance of the battery is closely related to temperature, according to the above experiment. In particular, lower temperature can affect battery capacity because of the internal resistance is increasing. The manufacturer recommend the temperature of battery room

March - April 2020
ISSN: 0193-4120 Page No. 4158 - 4163

which is between 18℃ to 28℃. This paper installed temperature sensor to monitoring battery room temperature in Energy Storage System connected photovoltaic system. The sensors of location are shown Figure 4.

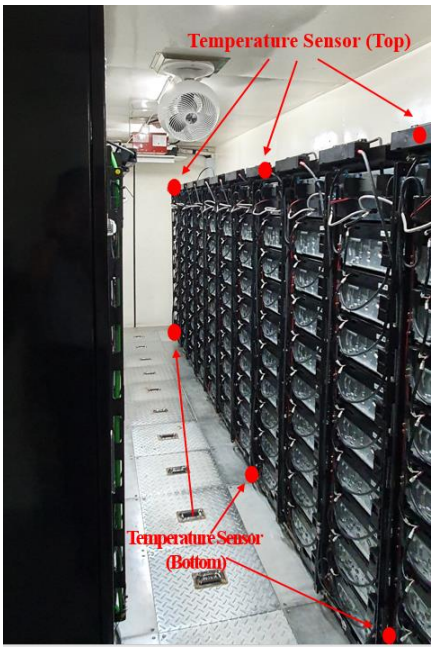
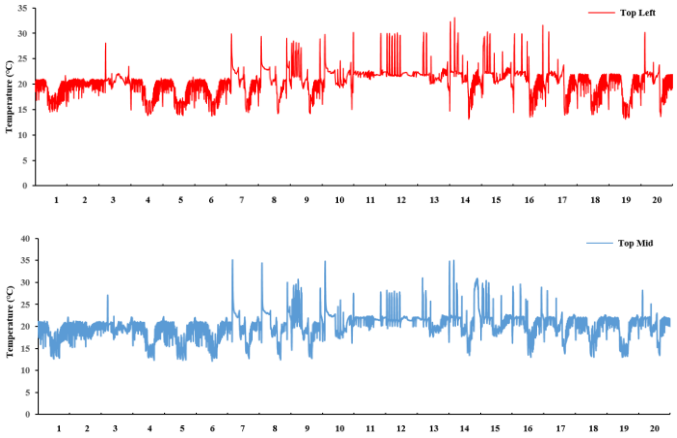


Figure 4. The Temperature sensors location

Temperature sensors installed at the top and bottom of batteries and measured for 20 days.



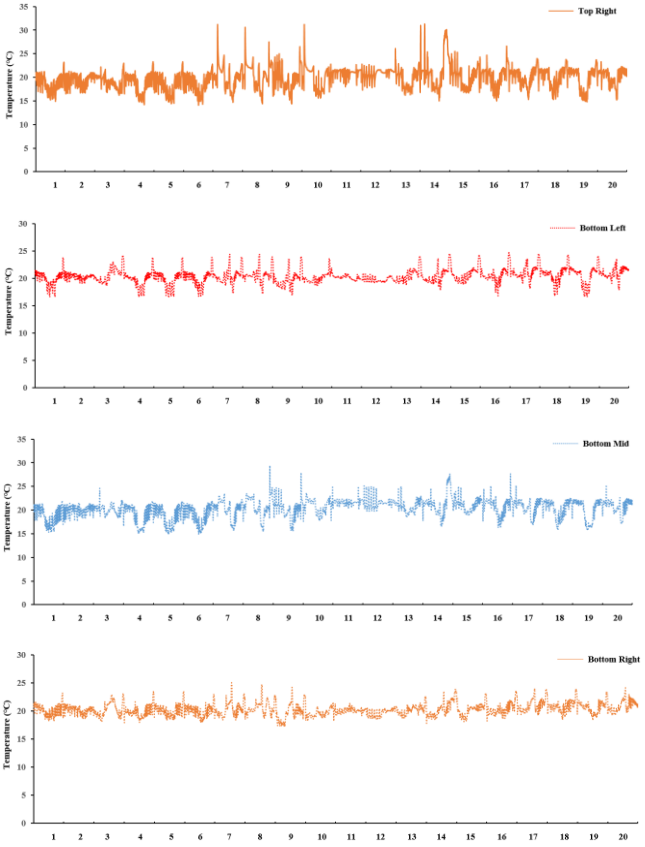


Figure 5. Result of Battery Room Temperature at the top and bottom

The experiment of battery room temperature shows a large deviation in temperature between top and bottom in Figure 5. In particularly, the temperature at the top was high and temperature at the bottom was low. The maximum and minimum temperatures for each position are shown in the following Table 3.

Table 3. Maximum and Minimum Temperature for each position

Position	Max Temp(℃)	Min Temp(℃)	Dev Temp(℃)
Top-Left	33.1	13.1	20
Top-Mid	35.1	12.1	23
Top-Right	31.3	14.1	17.2
Bottom-Left	24.7	16.6	8.1
Bottom-Mid	29.4	14.8	14.6
Bottom-Right	25	17.2	7.8

Each position of max temperature and min temperature has exceeded the manufacturer's recommended criteria. Maximum temperature position is Top-Mid and value is 35.1℃. Minimum temperature position is Top-Mid and value is 12.1℃. Max deviation temperature value is 23℃ and Min deviation temperature value is 7.8℃. The large temperature deviation has a great effect on the internal resistance of the battery and it can be occurred fire accident with battery deterioration. The experiment site is equipped with an air conditioner that can only be cooling. So, Cooling system can't control low temperature situation.

4. Conclusion

This paper analyzed correlation between lithium-ion battery internal resistance and temperature. The experiment result is show that temperature increased, the internal resistance decreased both 18650 battery and pouch type battery. So, This experiment result means that internal resistance is effected by temperature. It is important to maintain constant environment in battery room. The temperature of the battery room in ESS site currently in operation was not being controlled. The battery room temperature was controlled by air cooling conditioner. This system can control high temperature status, but can't control low temperature. Therefore, deviation of temperature occurred large and this is too hazard to batteries. So, To maintain stable batteries, It need to control system of environment in Energy Storage System. Experimental results will provide that improved decision of maintain ESS system and better prediction safety system on operators.

5. Acknowledgment

This work was supplied by the Korea Institute for Advancement of Technology and the Ministry of Trade Industry & Energy (MOTIE) of Republic of Korea (NO. 20191210301940)

References

[1] Farihan Mohamad, Jiashen The, Ching-Ming Lai, Liang-Rui Chen. Development of Energy Storage Systems for Power Network Reliablility : A Review. Energies. 2018 Aug;11(9):2278

[2] Holger C.Hesse, Michael Schimpe, Daniel Kucevic, Andreas Jossen. Lithium-Ion Battery Storage for the Gird – A review of stationary battery storage system design tailored for applications in modern power grids. Appl. Energies. 2017 Nov;10(12):2107

[3] Dian Wang, Yun Bao, Jianjun Shi. Online Lithium-Ion Battery Resistance Measurement Application in State-of-Charge Estimation Using the Extended Kalman Filter. Appl. Energies. 2017 Aug;10(9):1284Viceconti M, Hunter P, Hose R. Big data, big knowledge: big data for personalized healthcare. Journal of Biomedical and Health Informatics 2015;19(4):1209–15.

[4] Piller. S, Perrin M, Jossen A. Methods for state-of-charge determination and their applications. J.Power Sources. 2011;96:113-120

[5] Ng. K.S, Moo C.S, Chen Y.P, Hsieh. Y.C. Enhanced coulomb counting method for estimating state-of-charge and state-of-health of lithium-ion batteries. Appl. Energy. 2009;86:1506-1511

[6] Remminger. J, Buchholz. M. State-of-Health Monitoring of Lithium-Ion Batteries in Electric Vehicles by on-board Internal Resistance Esitmation. J.Power Sources. 2011;196:5357-5363

[7] Sepasi. S, Ghorbani. R, Liaw D, Chen Z. Remaining useful life prediction of lithium-ion battery based on discrete wavelet transform. Energy Procedia. 2017;105:2053-2058

[8] Dubarry. M, Svoboda. V, Hwu R, Yann Liaw B. Incremental Capacity Analysis and close to equilibrium OCV Measurements to Quantify Fade in Commercial Rechargeable Lithium Batteries. Electrochem Solid-State Lett. 2006;9:A454-457

March - April 2020
ISSN: 0193-4120 Page No. 4158 - 4163

[9] Xu. J, Mi. C. C, Cao. B, Cao. J. A. A new method to estimate the state of charge of lithium-ion batteries based on the battery impedance model. J. Power Sources. 2013;299:246-254

[10] Hongwen He, Rui Xiong, Jinxin Fan. Evaluation of Lithium-ion battery Equivalent Circuit Models for State of Charge Estimation by an Experimental Approach. Appl. Energies. 2011 Dec;4(4). DOI:10.3390