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Analysis of Run Time of Li-polymer Secondary Cell with or without Flyback Converter Active Balancing BMS

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Abstract

In this paper, the run time of Li-polymer secondary cell with and without the active balancing BMS is analyzed. The Active balancing System using a flyback converter with two-way power control facility is designed to obtain the optimal characteristics of balancing. Li-polymer secondary cell run-time is drastically increased employing the flyback converter active balancing BMS. The run-time performance of Li-polymer secondary cell is analyzed during discharging and charging experiment with or without flyback converter Active balancing BMS

Keywords: Battery Management System (BMS), Active Balancing, Flyback converter, Li-Polymer, Secondary Cell

INTRODUCTION

The effective maintenance issue of renewable energy sources has been emerging due to the stability of nuclear power generation, depletion of fossil fuels, and the government's policy to develop new energy sources. To solve this problem the several techniques using secondary batteries have been proposed [1,2,3]. The BMS (Battery Management System), which is one of the proposed technologies, manages the battery cells in consideration of the voltage, temperature, and humidity of the secondary battery. In addition, it functions such as overvoltage and overcurrent protection, and safely manages the cell voltage deviation when a voltage deviation occurs between each cell [4,5,6].

Generally, a secondary battery pack and modules employs the several battery cells connected in series and in parallel to obtain a high-voltage output. As the charge / discharge cycle progresses, the charge / discharge rate of the battery pack is different due to the aging degree between the cells. The difference in charging and discharging rates causes voltage imbalance between battery cells. The voltage imbalance between cells causes a problem of overcharging and over discharging of a specific cell due to a difference in charging / discharging voltage between cells. In particular, the lithium polymer batteries have these factors that must be solved because of the risk of explosion [7,8,9]. In addition, the voltage unbalance between the secondary battery cells may cause a problem of shortening the cycle life of the secondary battery pack as a whole. Thus, although much research has been conducted on the secondary battery management system, the research on the secondary battery utilization time is limited.

In this paper, we design an active balancing BMS using flyback converter among BMS technologies to mitigate voltage imbalance between battery cells of lithium polymer rechargeable battery packs. The run-time was analyzed based on the designed active balancing BMS for lithium polymer rechargeable battery pack. As a result of employing the flyback converter active balancing BMS as described above, it was confirmed that the voltage unbalance between the battery cells of the battery pack was alleviated. For this reason, the run-time of the lithium polymer secondary battery has been increased.

DESIGN OF LITHIUM POLYMER RECHARGEABLE BATTERY PACK

Li-polymer secondary battery cell specification

Table 1 shows the 'TB077170226mFF1' specification of 'B Company' as a lithium polymer rechargeable battery cell applied to this paper. The nominal capacity shown in Table 1 means the amount of electricity obtained by discharging to the discharge end voltage with the current specified in the battery cell. These nominal capacitances vary in capacitance due to different polarizations or voltage drops depending on the type of battery, and differ depending on the discharge end voltage and discharge rate. The discharge voltage means a voltage capable of discharging the battery cell to the maximum. If the voltage drops below the discharge voltage, the rechargeable battery will over-discharge and seriously shorten the battery life. Therefore, in this paper, discharge is terminated when the battery cell voltage reaches 2.5V considering the life of the secondary battery.

Table 1. Specification of Li-polymer secondary cell from company B

nominal capacity	20,000mAh
nominal voltage	3.2V
Operation voltage	2.0 ~ 3.6V
Charging voltage	3.6V
Cutout voltage	2.75V
Discharging voltage	2.0V

Lithium Polymer Battery Discharge Characteristics:

The discharge characteristics of lithium polymer secondary batteries vary greatly with time, and also affect the number of charge and discharge cycles. Discharging current during battery discharge also affects secondary battery life. Generally, the discharge curve slope of a secondary battery shows a rapid falling slope in a short period of time in the early stage and a gentle slope in the middle stage in a long period of time. When the discharge is close to the end, there is a sudden gradient change.

Figure 1 shows the discharge characteristic curves of 'B' company 'TB077170226mFF1' rechargeable battery applied to this paper experiment

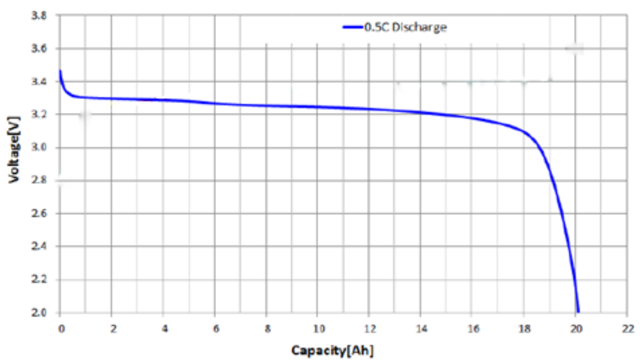

Figure 1. Battery discharge curve of secondary cell from company B

Lithium polymer secondary battery pack configuration:

As shown in Fig. 2, the battery pack of the lithium polymer rechargeable battery pack applied to this paper is composed of 12S (Series) 2P (Parallel).

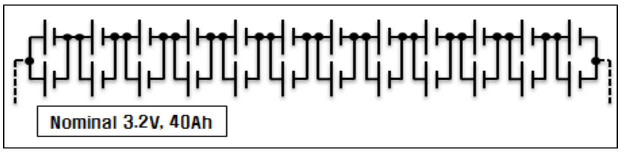

Figure 2. Composition of battery pack of 12S 2P Li-polymer secondary cell

Table 2 shows the specifications of a lithium polymer secondary battery pack composed of 12S 2P. Since 12 battery cells are connected in series, all of the items corresponding to the voltage portion increase by 12 times.

Table 2. Specification of battery pack of 12S 2P Li-polymer secondary cell

nominal capacity	40,000mAh
nominal voltage	38.4V
Operation voltage	24.0V ~ 43.2V
Charging voltage	41.4V
Cutout voltage	33.0V
Discharging voltage	24.0V

CONFIGURATION OF ACTIVE BALANCING BMS

Active balancing Circuit Using Flyback converter:

Figure 3 shows the active balancing BMS using the flyback converter employed in this paper. It is easy to control power in bi-direction and has a suitable characteristic for balancing. so it has structure suitable for the active balancing BMS.

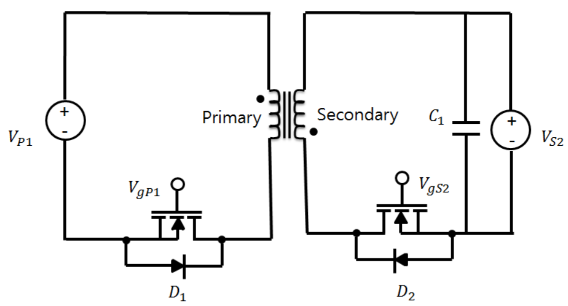

Figure 3. Active balancing BMS using Flyback converter

The balancing control was implemented by applying the LTC3300-1 chip of L Company to the circuit. The voltage was measured using the LTC6804-2 chip from L.

Figure 4 is a circuit diagram of 12 cells of lithium polymer rechargeable battery using flyback converter.

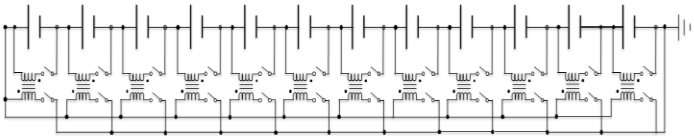

Figure 4. Linear Current-Voltage Equation for Resistance 1000 Ω

Active balancing using flyback converter for charging and discharging circuit :

An active balancing using flyback converter is employed to charge and discharge for the each cell through N-channel MOSFET. Figure 5 shows the active balancing heavy-duty circuit. The N-channel MOSFET gate signal of the battery pack inputs and the turn-on signal before the N-channel MOSFET gate signal of the battery cell to store the magnetic flux in the parasitic inductance of the transformer connected to the battery cell. If the gate signal of G1c is changed from turn-on to turn-off and the turn-on signal is applied to the G1p gate of the battery pack when the voltage of the G1c reaches a maximum value for a predetermined time or the charging charge flows to the battery pack side to charge the battery pack. As mentioned above, the charge signal is caused to flow to the battery pack side without switching the gate signal of G1c on the battery cell side from turn-on to turn-off and inputting the turn-on gate signal of G1p. However, since the charged charge flows to the battery pack side through the diode, a voltage drop occurs largely. The gate signal of G1p is also turned on to lower the voltage drop.

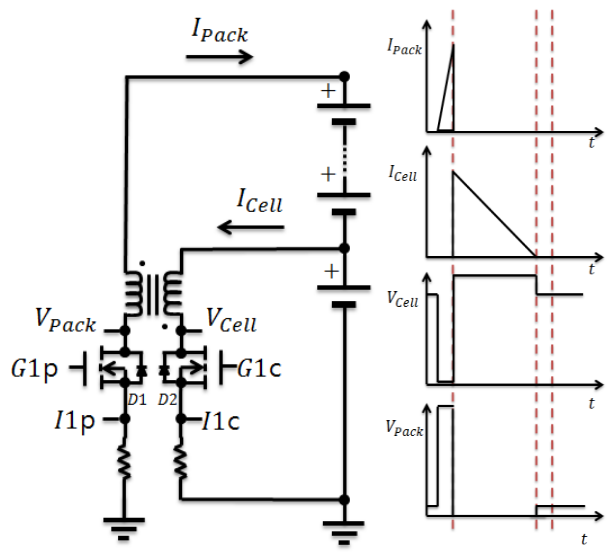

Figure 5. Active balancing BMS charging circuit

Figure 6 shows the active balancing discharge circuit. The operation principle is similar to the active balancing charging circuit using the flyback converter mentioned above. In the charging circuit of the active balancing flyback converter, the gate signal of the N-channel MOSFET on the battery pack is turned on before the battery cell. However, the active balancing discharge circuit first puts the turn-on signal into the gate signal of the N-channel MOSFET G1c on the battery cell side to store the magnetic flux in the parasitic inductance of the transformer connected to the battery cell. If the gate signal of G1c is changed from turn-on to turn-off and the turn-on signal is applied to the G1p gate of the battery pack when the voltage of the G1c reaches a maximum value for a predetermined time or voltage, charging charge flows to the battery pack side to charge the battery pack. As mentioned above, the charge signal is caused to flow to the battery pack side without switching the gate signal of G1c on the battery cell side from turn-on to turn-off and inputting the turn-on gate signal of G1p. However, since the charged charge flows to the battery pack side through the diode, a voltage drop occurs largely. The gate signal of G1p is also turned on to lower the voltage drop.

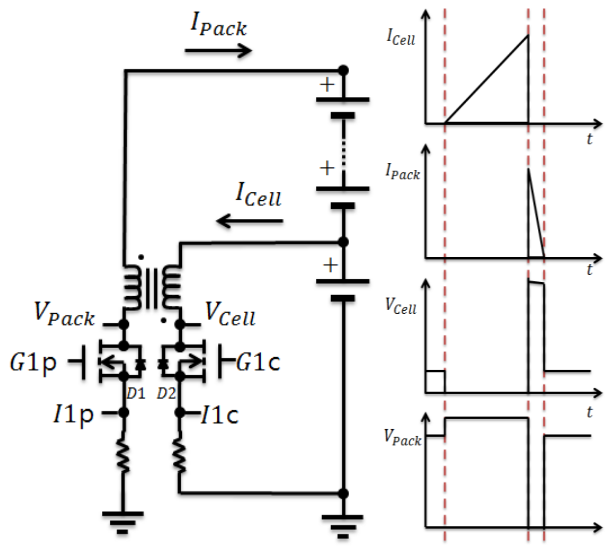

Figure 6. Active balancing BMS discharge circuit

EXPERIMENT

Li-polymer secondary battery discharge experiment configuration :

Figure 7 shows the device configuration for the life analysis of the lithium polymer secondary battery according to the application of the active balancing BMS. An electronic load ('W' company 'M9711') is connected to the battery pack to proceed with discharging the battery pack. In order to analyze the condition of the whole battery pack, a data logger ('G' company 'GL900') was connected to the battery pack. In order to, check the state of each cell voltage of the battery.

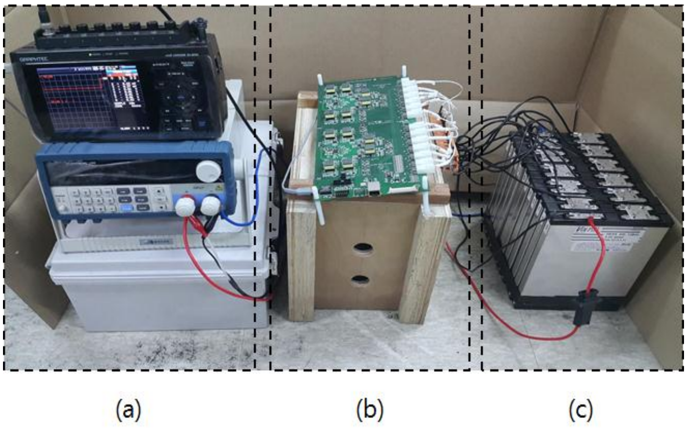

Figure 7. Active balancing BMS experimental setup (a) Electronic load & Data Logger, (b) Flyback Active balancing BMS, (c) Battery Pack Active balancing BMS experimental setup

Active balancing BMS Discharge Experiment :

Figure 8 shows the voltage of each battery cell before battery discharge experiment. The battery pack voltage is 39.38V. The battery cell voltage is 3.2828V on average. The deviation of the battery cell maximum voltage value from the minimum voltage value is 0.0199V. As a result, the battery pack is in an even voltage state.

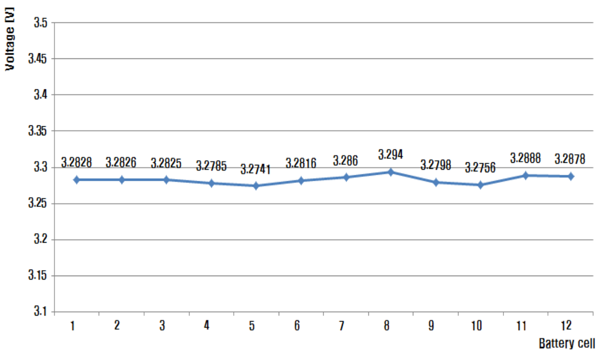

Figure 8. Voltage of each cell in battery before discharge experiment

At the end of the discharge, when there is a battery cell falling below 2.5 V among the 12 battery cells in the battery pack, the discharge is finished.

Figure 9 shows the voltage of each cell of the battery after battery discharge experiment. When the voltage of the battery cell No. 5 becomes 2.4983 V which is less than 2.5 V, the voltage of the battery cell No. 8 is 2.9998 V and the maximum voltage was confirmed. The deviation of the two battery cells was 0.5015V.

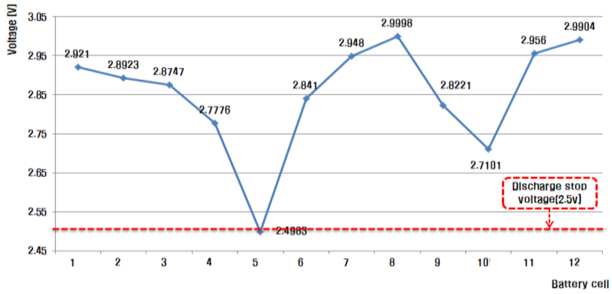

Figure 9. Voltage of each cell in battery after discharge experiment

Figure 10 shows the discharge curve of a lithium polymer battery pack through a data logger. Charging battery pack voltage is 39.38V.While battery cell 5 voltage is below 2.5V, the battery pack discharge and voltage is 34.2297V. The difference between charge and discharge battery pack voltage is 5.1503V. This discharging process takes 3 hours 53 minutes.

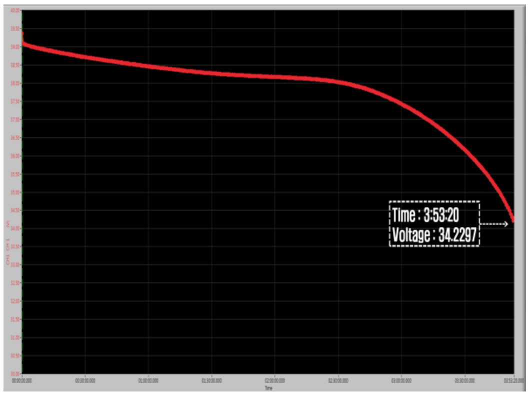

Figure 10. Discharge curve of Li-polymer battery pack

Discharge experiment using Active balancing BMS :

Figure 11 shows the voltage of each battery cell before battery discharge experiment. The battery pack and cell voltage are 39.32V and 3.2772V. The deviation between the maximum voltage and the minimum voltage value of the battery cell is 0.0061V and that is similar to the initial state of the active balancing BMS discharge test can do.

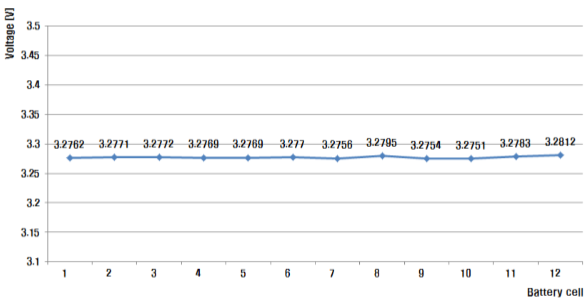

Figure 11. Voltage of each cell in battery with Active balancing BMS before discharge experiment

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Figure 12 shows the voltage of each cell of the battery after battery discharge experiment. When the battery cell voltage of 10 was 2.4994V which is 2.5V or less, the battery cell of 3 was able to confirm the maximum voltage at 2.5711V. The deviation of the two battery cells was 0.0717V.

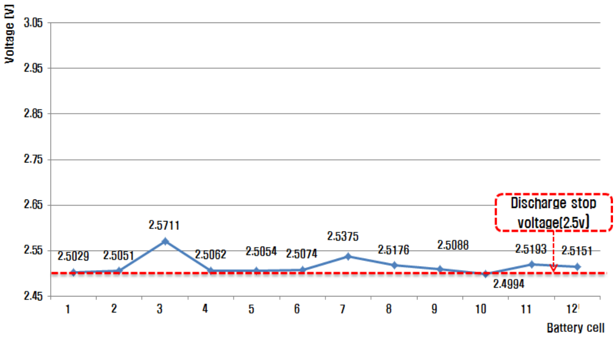

Figure 12. Voltage of each cell in battery with Active balancing BMS after discharge experiment

Figure 13 shows the discharge curve of a lithium polymer battery pack through a data logger. The voltage at the point when the battery cell No. 10 drops below 2.5V is 30.1958V, which is 9.1242V less than the discharge time point of 39.32V, and the discharge time is 4 hours and 38 minutes.

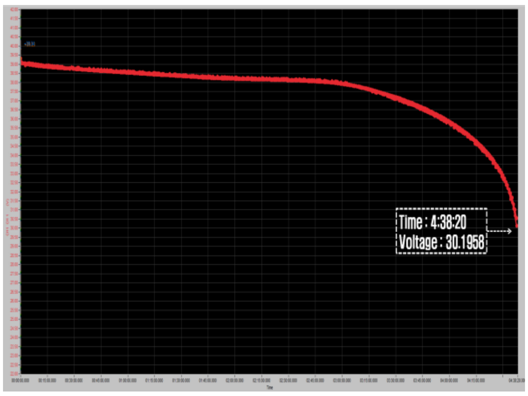

Figure 13. Discharge curve of Li-polymer battery pack with Active balancing BMS

Discharge Experiment Analysis

Figure 14 shows the voltage status of each cell according to the end of discharge criterion according to Active balancing BMS application. Discharge end criterion When the Active balancing BMS is not applied. The difference between the battery cell of the lowest and maximum voltage is about 0.5V. On the other hand, when the Active balancing BMS is applied, the deviation between the lowest and maximum voltage of the battery cell is about 0.07 V, which is about 84% lower when the active balancing BMS is not applied.

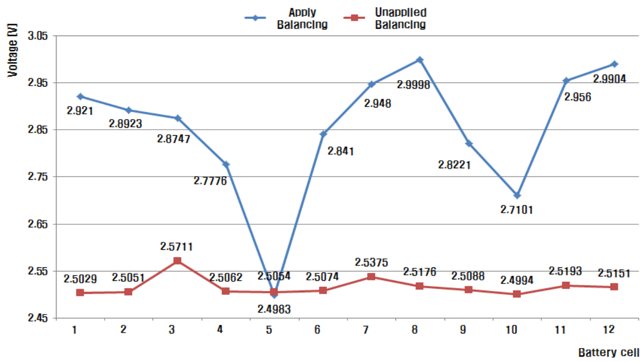

Figure 14. Voltage of each cell in battery with or without Active balancing BMS at the end of discharge experiment

Figure 15 shows the voltage deviation of the battery cell with the discharge end reference battery cell voltage of 2.5V or less with other battery cells. Active balancing if the BMS is not applied, the overall area is large and 0.3863V is obtained when the deviation is averaged. When the Active balancing BMS is applied, the deviation area is relatively small compared to the case where the Active balancing BMS is not applied. The average value of the deviation is 0.0184 V, which is about 4.76% when 0.3863 V is 100%. Therefore, it can be confirmed that the average deviation of 95.24% compared to the case where Active balancing BMS is not applied is lowered.

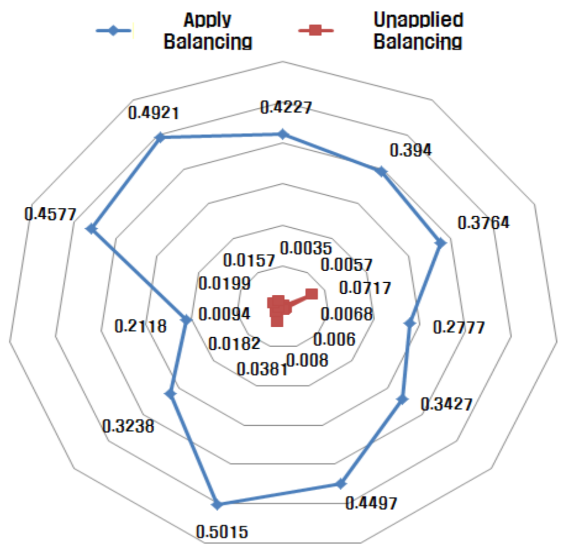

Figure 15. Voltage deviation of each cell in battery with or without Active balancing BMS

Figure 16 compares the discharge graph of the battery pack. When the Active balancing BMS is applied, it is proved that the discharge time, that is, the battery runtime, is extended by about 19.6% as compared with the case where the active balancing BMS is not applied

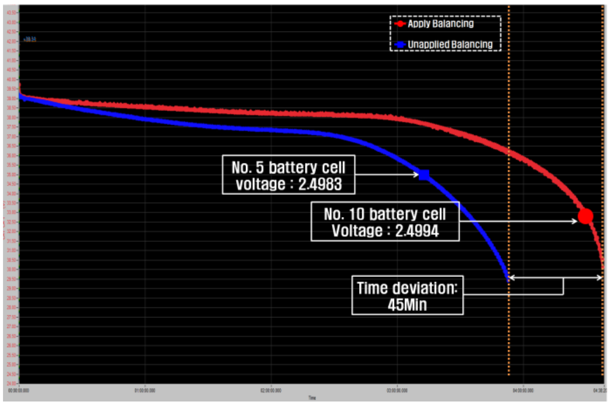

Figure 16. Discharge graph of battery pack with or without Active balancing BMS

CONCLUSION

In this paper, we analyzed the battery life of lithium polymer rechargeable battery according to active balancing BMS application of lithium polymer rechargeable battery. As a result, it was confirmed that the deviation of the maximum and minimum voltage of the lithium polymer battery cell was about 84% lower than without active balancing BMS after applied the active balancing BMS)

Furthermore, when the voltage average deviation of the discharged Li-polymer battery cell is compared with other cells based on the cell voltage of 2.5V or less, the average deviation of 95.24% is decreased compared with the case where the active balancing BMS is not applied

It was confirmed that the operating time of the lithium polymer secondary battery was extended by about 19.6%.

The extension of the battery discharge time of the lithium polymer secondary battery is predicted that the unbalance between the battery cells occurring at the time of discharging is alleviated by the active balancing BMS.

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