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An Efficient Passive Cell Balancing Approach for Lithium-Ion Batteries

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Abstract: Lithium-ion batteries find wide applications in electric vehicles, energy storage systems, and portable electronic devices due to their high energy density and long cycle life. In a series-connected battery pack, divergence in individual cell characteristics can lead to SOC imbalance, which severely degrades performance, safety, and cycle life. Thus, cell balancing emerges as one of the essential tasks of the BMS. This paper deals with the modeling and simulation of an efficient passive cell balancing method using MATLAB Simulink. The proposed scheme is applied on a ten-cell series-connected lithium-ion battery pack, and balancing is triggered by a threshold-based switching action. The simulation results show that the proposed method causes significant reduction in SOC imbalance and attains equilibration within some finite balancing time. Because of the simplicity and low cost of the method, it is suitable for low-to-medium-power applications in batteries..

Keywords: Lithium-ion Battery, Passive Balancing, Battery Management System, MATLAB Simulink, Cell Equalization, State of Charge (SoC)

I. INTRODUCTION

Li-ion batteries have evolved to be the energy storage of choice for modern applications such as EVs, HEVs, renewable energy storage, and consumer electronics. Some of the advantages of this technology include high energy density, low

self-discharge rate, and long service life. In order to achieve higher voltages and increased capacities, a number of cells are assembled into a series and parallel configuration known as a battery pack.

Even with identical design specifications, individual cells in any battery exhibit parameter variations in internal resistance, capacity, and aging characteristics. These variations result in unequal charging and discharging behavior, leading to SOC imbalance within the pack. Such imbalances can eventually result in decreased usable capacity, increased thermal stress, and safety risks like overcharging or deep discharging of particular cells.

The BMS must monitor the voltage, current, temperature, and SOC of every cell. Of its many important functions, the most critical involves equalizing different cells to make their SOC equal. In general, the techniques for balancing the cells can be divided into active and passive approaches. While passive balancing wastes excess energy through resistors, active balancing performs energy transfer between cells by using either capacitors or inductors.

II. LITERATURE REVIEW

The literature highlights practical applications of passive cell balancing in lithium-ion battery systems, especially in electric vehicles and energy storage systems. These case studies help evaluate how different balancing approaches perform under real-world operating conditions, highlighting recent improvements, limitations, and future opportunities.

Zhang et al. [1] presented the design of a passive balancing circuit based on a resistor for a series-connected lithium-ion battery pack used in electric vehicle applications. The system makes use of MOSFET-controlled resistors together with a dynamic threshold mechanism and manages to reduce cell voltage deviation from over 120 mV to below 20 mV within one charge cycle.

Kumar et al. [2] presented a passive balancing method using the switched-resistor approach, with which higher balancing speed was achieved with low energy losses and low hardware complexity. According to their results, the balancing time has been reduced by 25% and efficiency enhanced by 15%.

Ramachandran et al. [3] performed a comparison of passive and active techniques for balancing; they found that though active methods provide faster equalization, passive balancing techniques are generally more stable, simpler, and inexpensive.

Lee et al. [4] proposed an adaptive threshold-based passive balancing algorithm to further improve the voltage equalization accuracy for different lithium-ion cell types.

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Chavan and Kanawade [5] proved the practical feasibility of resistor-based passive balancing in a multi-cell lithium-ion module under different operating conditions.

III. PROBLEM STATEMENT

In series-connected lithium-ion battery packs, unequal cell characteristics cause state-of-charge imbalance during charge and discharge cycles. This state of charge imbalance limits the overall performance of the battery pack because the capacity utilization is controlled by the weakest cell. Without proper balancing, deteriorating efficiency and increased safety risks can be expected. Therefore, what is urgently needed is a robust and low-cost solution to mitigate SOC inconsistencies and enhance reliability in the battery pack.

IV. OBJECTIVES

Objectives that this project will address are as follows:
1. Investigate causes and consequences of the state-of-charge imbalance in lithium-ion battery packs
2.Develop the mathematical and behavioral models for lithium-ion battery cells using MATLAB/Simulink
3.Design passive cell balancing scheme using resistive elements
4. Implement switching logic to achieve SOC equalization.
5. Analyze the effectiveness of passive balancing via results from simulations

V. PROPOSED METHODOLOGY

A. SYSTEM OVERVIEW

The proposed system consists of a series-connected lithium-ion battery pack modeled in MATLAB Simulink. Each cell has been provided with a passive balancing network that includes a resistor and an ideal switch. Control logic continuously monitors state-of-charge values and turns on the balancing path for cells showing higher SOC.

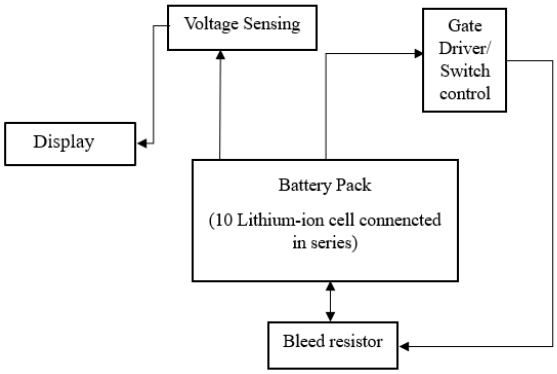

Fig.1:Block Diagram of cell balancing

The block diagram shows a passive cell balancing scheme for a lithium-ion battery pack comprising ten series-connected cells. The voltage-sensing block continuously senses the individual cell voltages within the pack and forwards this information to the control section. The sensed voltage data are also supplied to the display unit to provide real-time visual indication of cell status. By comparing the voltages, the gate-driver or switch-control unit identifies whether any cell voltage is higher than the maximum permissible limit. Upon detection of an imbalance, the gate driver turns on the corresponding switch, and current flows through the bleed resistor connected across the battery pack. The bleed resistor resists the excess energy drawn from the high-voltage cell in the form of heat, hence maintaining balance in the voltage and thereby equalizing the voltages among cells. This close-loop process ensures the safe and reliable balancing of Li-ion cells through a simple, inexpensive passive balancing method.

B. SOFTWARE COMPONENTS

The proposed passive cell-balancing system was developed and evaluated by means of a software-based simulation and hardware implementation. The modeling of the lithium-ion battery pack, along with the balancing logic, was done using MATLAB R2020, along with the Simulink and Simscape Electrical toolboxes. Three rechargeable battery cells were modeled using a Battery block whose parameters include nominal voltage, rated capacity, initial state of charge, and battery response time. The passive balancing strategy was then implemented using ideal switches that were controlled by a MATLAB Function block, which continuously evaluates the state of charge of each cell and turns on

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the respective balancing path if an imbalance is detected. Powergui, Gain, Mux, Scope, Display, and Goto/From blocks were used to configure the system and route the signals to monitor in real time the voltage and SOC variations during the simulation.

VI. RESULT AND DISCUSSION

A passive cell-balancing model has been simulated in the case of a multi-cell lithium-ion battery pack in MATLAB Simulink. An imbalance has been created by reducing the SoC of one cell. The simulation results showed that small SoC differences did not trigger the balancing circuitry, while cells with higher SoC retained their charge.

Cell No.	Initial SOC (%)	Final SOC (%)
Cell 1	100	93.26
Cell 2	99	92.32
Cell 3	98	91.35
Cell 4	97	90.37
Cell 5	96	89.57
Cell 6	95	89.57
Cell 7	94	89.57
Cell 8	93	89.57
Cell 9	92	89.57
Cell 10	95	89.57

Table I: SOC Difference Before and After Balancing (Simulation)

These results also show that the passive balancing system only actuates when the voltage or SoC difference exceeds a certain threshold. The strategy reduces significant imbalances without excessive energy dissipation. Finally, simulation verifies that passive cell balancing is indeed a simple, reliable, and low-cost technology in order to keep all battery cells at the same state of charge.

VII. CONCLUSION

This paper describes the design and simulation of a passive cell-balancing scheme for a multi-cell lithium-ion battery pack. Individual cell voltages are continuously monitored by the system, which activates resistive discharge paths for cells at a higher state of charge to facilitate uniformity in the State of Charge (SoC) within the pack. Simulation results show that the strategy proposed here effectively reduces large-scale imbalances without wasting much energy when voltage discrepancies are small. The simplicity, reliability, and low cost of passive balancing make it practical for embedding in a basic BMS for safe operation and prolonging the life cycle of lithium-ion batteries in electric vehicles, energy storage systems, and portable electronic devices.

VIII. FUTURE SCOPE

The passive cell balancing architecture discussed here can easily be scaled up to big lithium-ion battery pack configurations for different electric vehicle and stationary energy storage applications. Future research should consider integrating hybrid or active balancing methodologies to enhance overall efficiency and minimize energy dissipation. Further, embedding the balancing model within a comprehensive BMS providing for real-time monitoring, protective functionality, and hardware validation will enhance system reliability, scalability, and practical applicability.

REFERENCES

[1] Y. Zhang, X. Li, and H. Wang, "Design and implementation of a resistor-based passive cell balancing circuit with real-time voltage monitoring for lithium-ion battery packs," IEEE Transactions on Power Electronics, vol. 34, no. 5, pp. 4123–4132, 2019.

[2] R. Kumar, S. Patel and A. Verma, "Switched-resistor based passive balancing technique for lithium-ion batteries," International Journal of Electrical Power & Energy Systems, vol. 117, pp. 105–112, 2020.

[3] R. Ramachandran, P. Krishnan and M. Suresh, “Comparative analysis of passive and active cell balancing techniques for lithium-ion battery management systems,” Journal of Energy Storage, vol. 28, pp. 101 – 109, 2020.

DOI: 10.17148/IJIREEICE.2026.14101

[4] J. Lee, K. Park and S. Kim, "Adaptive threshold-based passive cell balancing algorithm for lithium-ion battery packs," IEEE Access, vol. 8, pp. 134567–134575, 2020.

[5] S. Chavan and R. Kanawade, "Implementation and analysis of resistor-based passive balancing for multi-cell lithium-ion battery modules," International Journal of Engineering Research & Technology (IJERT), vol. 9, no. 6, pp. 245–250, 2020.

