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Original Article

Resolving The Speed-Efficiency Trade-Off Through a Hybrid SOC Equalization Technique for EV Battery Management Systems

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Abstract - *The rise in popularity of electric vehicles has raised demand for lithium-ion battery systems that provide improved safety, efficiency, and battery life. One of the most crucial factors influencing a battery pack's performance is the state of charge imbalance among its cells. This causes cells to degrade more quickly, have less useful capacity, and be less efficient. Active and passive balancing are two ways of Cell balancing that are already available. Both approaches have their own advantages and disadvantages as well. The passive balancing approach is fast but results in significant energy loss, whereas the active balancing method is energy-efficient but operates at a slower speed. This trade-off is achieved through the proposal of a novel hybrid cell equalization approach that leverages the high energy efficiency of capacitive charge transfer while also ensuring fast convergence through resistive equalization. The approach combines capacitive charge transfer to diminish large state of charge variations at the beginning and resistive balancing during the final equalization phase for enhancing convergence speed. This hybridized operation enables competent redistribution of charge with a reduction in balancing time and energy loss. Simulation results confirm that the hybrid approach is more energy efficient and faster than both the current approaches. The results indicate that the proposed hybrid balancing approach has great potential in imminent battery management systems to increase the lifetime and reliability of electric vehicles.*

Keywords - *Electric Vehicles (EVs), Battery Management System (BMS), Cell Balancing Techniques, State of Charge (SOC).*

1. Introduction

The rising levels of pollution in the air due to the increasing use of public and private transportation make green energy solutions paramount all over the world. Electric vehicles are a promising alternative for eco-friendly transportation in this regard [1, 2]. Their efficiency and robustness, however, rest on the effective design and coordination of their elementary components. An EV may generally include major components such as an electric motor, an inverter controller, and a battery equipped with the BMS. Of these, the battery is a key and crucial ingredient in such systems. The three most common battery types used in EV applications to date are lithium-ion (Li-ion), nickel-metal hydride, and lead-acid [3]. Li-ion batteries are the most recommended and widely preferred for EVs on account of their multiple benefits. These advantages are reflected in high energy and power densities, low self-discharging, high working voltages, long life, almost no memory effect, and low maintenance [4-6]. Despite all Li-ion batteries' advantages, a key issue is that the battery's temperature, voltage , and current must always be maintained within a predetermined safe working range. To ensure this, a BMS acts as an important protective and control circuit [7]. As the "Brain" of a battery pack, the BMS keeps an eye on and controls vital factors for each individual Cell, including voltage, current, SOC, temperature, and State of Health (SOH) [8].

Preventing overcharge and overdischarge, as well as thermal problems, is critical for safe battery operation. This is particularly critical in EVs, where large battery packs contain hundreds or thousands of cells, making BMS a fundamental component for safe and optimal operation, and extended battery life [9, 10]. These cells connected in series result in a challenging issue called cell SOC imbalance. This imbalance may cause some cells to attain their highest state of charge or discharge more quickly than others, as shown in Figure 1. This can result in safety risks like overcharging or overdischarging, along with a reduced usable capacity and a shorter driving range. Furthermore, they can lead to early deterioration and eventually reduce the overall battery pack lifespan [11-14].

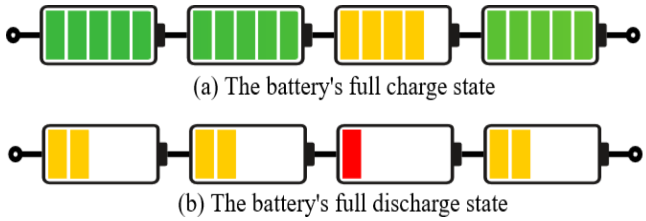

Fig. 1 A schematic arrangement of series-connected cells in different charge states

A number of Cell balancing techniques for Li-ion battery applications have been developed to accommodate this imbalance [15, 16]. These techniques can be mainly classified as active balancing and passive balancing [17]. Active balancing redistributes charges between cells, and passive balancing transforms the surplus energy of a cell with higher SOC into heat. Each of these balancing strategies has its perks and shortcomings [18, 19]. Current research predominantly treats active and passive balancing as mutually exclusive. Active balancing research focuses on maximizing energy retention but fails to overcome the inherent transfer latency caused by inductive or capacitive components.

Conversely, passive balancing research focuses on speed but accepts high dissipation loss as an unavoidable byproduct. Although both methods are well-established on their own, there is a significant lack of a cohesive architecture in current research. Previous research has not examined a coordinated control strategy that facilitates the synergistic operation of these two mechanisms. This study addresses the gap by moving away from the binary approach. A new hybrid balancing strategy combines the best parts of both methods, using the high efficiency of active balancing and the quick equalization abilities of passive balancing. The suggested hybrid strategy aims to yield better results than traditional individual strategies.

The subsequent sections of this work are structured as follows: Section II examines various cell-balancing techniques employed for Li-ion batteries. Section III introduces the proposed novel hybrid balancing technique along with simulation results and discussions. Finally, Section IV concludes the study.

2. Review of Cell Balancing Techniques

The two main categories of Cell balancing approaches are passive and active cell balancing techniques. Passive Cell balancing approaches equalize the SOCs of all cells to the lowest SOC cell by dissipating the surplus charge from higher SOC cells via a resistor component. Active cell balancing approaches extract charge from cells with greater SOC and redistribute it to cells with lower SOC [17]. In the following sections, both passive and active cell balancing techniques are explored.

2.1. Passive Cell Balancing Techniques

There are two main types of passive cell balancing methods: one involves fixed shunt resistors, and the other uses switched shunt resistors, as explained below.

2.1.1. Fixed Shunt Resistor

With the fixed shunt resistor balancing, as displayed in Figure 2, a constant current flows through the parallel-connected shunt resistor of each Cell. It is feasible to equilibrate the energy levels of the cells without controlling operations since the bypass current in this case is proportionate to the cell terminal voltages [20]. However, persistent dissipation results from bypass currents. The balancing speed of this method is also very low. Overcharging and over-discharging may occur, which is not permissible for lithium-ion batteries [21].

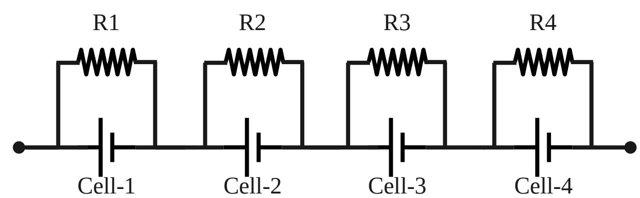

Fig. 2 Fixed resistor balancing

2.1.2. Switched Shunt Resistor

Switched resistor balancing, depicted in Figure 3, has an extra switch linked to each shunt resistor. Before starting the balancing process, it is required to know the SOC value for each Cell [12]. The balancing is achieved by connecting a resistor in parallel with the Cell having an SOC higher than the minimum SOC value. The resistors will remain connected until the Cell reaches its minimum SOC value. The balancing will be completed once all cells are discharged to this minimum SOC value [19].

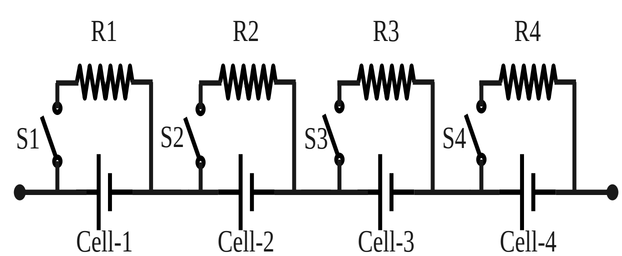

Fig. 3 Switched shunt resistor balancing

2.2. Active Cell Balancing Techniques

Active Cell balancing techniques use various circuit components like capacitors, inductors, transformers, and power electronic converters [22]. Among these, capacitor-based balancing methods have gained significant attention because of their structural simplicity, high reliability, and cost-effectiveness. Thus, active Cell balancing using capacitor-based methods and their working principles are the main concerns of this section.

2.2.1. Switched Capacitor

Switched capacitor balancing uses the same PWM signals for every balancing switch that runs at the same frequency, as seen in Figure 4. In order to regulate the transfer of charge, each switch periodically connects its corresponding Capacitor between the two neighboring cells. This design facilitates the flow of energy from cells with a higher SOC to those with a lower SOC. A bonus of this control method is that it does not require SOC measurements, thereby simplifying the control strategy and reducing sensor circuits.

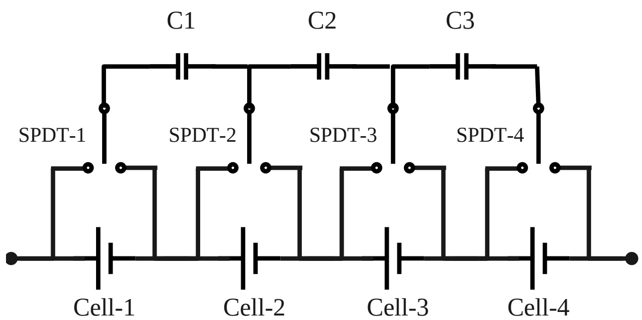

Fig. 4 Switched capacitor balancing

Despite its simplicity and robustness, the balancing process in this approach tends to be time-consuming due to its inherent limitations. Additionally, energy exchange can only happen between cells that are next to each other. This means that transferring charge between cells that are not directly next to each other takes multiple cycles. This method of indirect energy transfer increases the total time required to balance the entire battery pack. Because of this, switched capacitor balancing is an easy and sensor-free way to balance cells, but its operational delay needs to be taken into consideration when quick balancing is needed [23-25].

2.2.2. Double-Tiered Switched Capacitor

The double-tier switched capacitor balancing system makes SOC equalization faster and more efficient by using a hierarchical capacitor design, as shown in Figure 5. Capacitors C1, C2, and C3 make up the first level, which is in charge of the normal charge transfer between cells that are next to each other. The second level, which has capacitors C4 and C5, is used to move energy directly between cells that are not next to each other, such as cells 1 and 3. This direct routing function skips the first level's intermediary capacitors, which cuts down on the number of steps needed to transfer charge. This makes the balancing process fast and cuts down on the energy losses that come with having several switching cycles, which makes the whole system more efficient. However, this increased efficiency comes at a cost of increased hardware and more complicated circuits. Adding more capacitors and switches to the balancing circuit makes it bigger and more expensive. But a double-tiered design is a good choice for systems that want to quickly equalize SOC and increase energy efficiency [26-28].

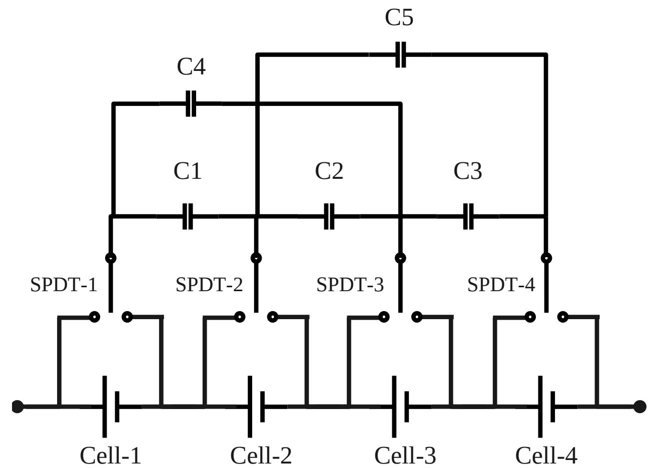

Fig. 5 Double-tiered switched capacitor balancing

2.2.3. Single Switched Capacitor

Figure 6 shows a technique of Capacitor balancing using a single switch that increases control algorithm flexibility. This method requires the calculation and monitoring of the SOC of each Cell. The system identifies the cells with the highest and lowest SOCs and turns on the switches that connect those cells to the Capacitor. After that, SPDT-1 and SPDT-2 switches switch back and forth at a set frequency, to transfer energy from the Cell with the highest SOC to the Cell with the lowest SOC [24]. The balancing process is completed when the SOC differences are less than the set threshold value. This method quickly balances when there is a large SOC difference between just two cells, no matter where they are located. It takes a longer time if all the cells have different SOC levels because only two cells can be balanced at a time [29].

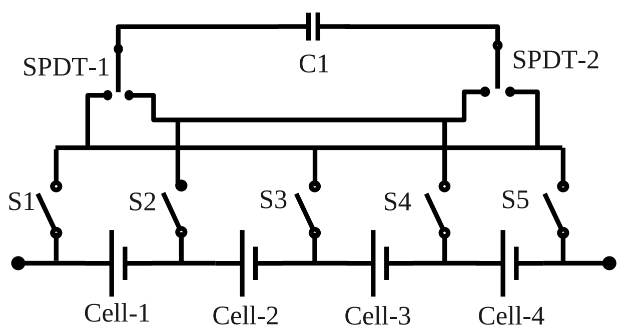

Fig. 6 Single switched capacitor balancing

2.3. Comparative Analysis between Passive and Active Cell Balancing

Passive cell balancing methods are simple and reliable techniques that equalize the SOC among all cells by discharging excess energy from cells with higher SOC through resistors. This approach is relatively swift because the excess energy is directly dissipated as heat without any energy transfer mechanisms. However, it is inherently inefficient because the discharged energy is wasted, reducing the overall system efficiency and potentially causing thermal stress due to heat generation. Passive balancing is often used in low-cost or small BMS where quick balancing and a simple circuit are more important than energy efficiency, since it is easy to use, cheap, and easy to set up.

The active cell balancing method, on the other hand, uses capacitors that are controlled by switches to move energy from cells with higher SOC to cells with lower SOC. This method improves battery performance and makes it more energy-efficient by moving charge between cells efficiently instead of dispersing it as heat. However, this process is slow because it takes a few switching cycles to move charges across capacitors and achieve equal SOC levels. The active balancing technique is more complicated than passive techniques and uses more parts. This is why it is often used in BMS, where long-term performance and energy efficiency are more important than speed.

In this context, passive balancing has the cells balance their charge by dumping excess charge as heat energy which is fast but not efficient, a process that is quick but not efficient. Active balancing methods, however, are both slow and effective, as they perform charge transfer across cells with capacitors while conserving energy. Therefore, there exists the possibility of combining the benefits of active and passive balancing.

3. Hybrid Cell Balancing Technique

3.1. Proposec Hybrid Cell Balancing Technique

This study proposes a novel hybrid balancing technique that combines the beneficial features of active and passive balancing. Specifically, it combines switched resistor balancing with switched capacitor balancing to accomplish better performance. When compared to independent switched resistor balancing, the suggested hybrid approach is more efficient, and when compared to independent switched capacitor balancing, it balances more quickly. The suggested hybridization of the imbalance control strategies produces an enhanced, more complete technique for Cell balancing in battery management systems by addressing the shortcomings of each applicable balancing methodology.

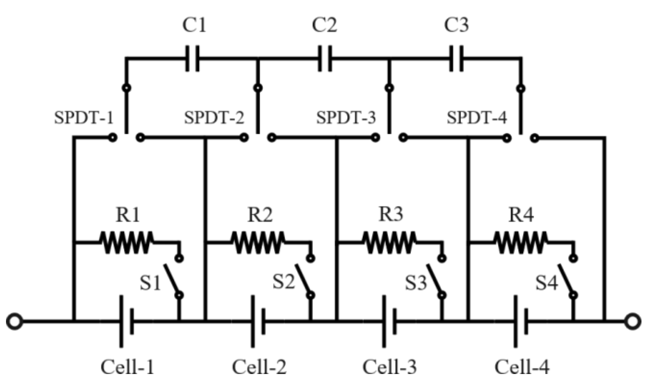

Fig. 7 Circuit diagram of the proposed hybrid cell balancing circuit

Figure 7 shows the circuit diagram of the proposed hybrid cell balancing technique. The hybrid technique uses a combination of resistive and capacitive cell balancing. Resistors were connected in parallel to each Cell using controlled switches. Capacitors were connected between the two cells using SPDT switches. When the SOC difference between cells is high, the system follows a capacitive cell balancing approach by alternatively connecting capacitors across adjacent cells to balance their SOC. With a significant difference in cell voltages, capacitive cell balancing operates more quickly and efficiently. When the difference between the SOC of the cells falls below a certain predefined threshold value, the circuit switches to resistive balancing and completes balancing.

Using this hybrid technique and the control algorithm shown in Figure 8, we achieved an output that was more efficient than resistive balancing alone, and the time required to complete the balance was less than that required for capacitive balancing alone, increasing both efficiency and speed.

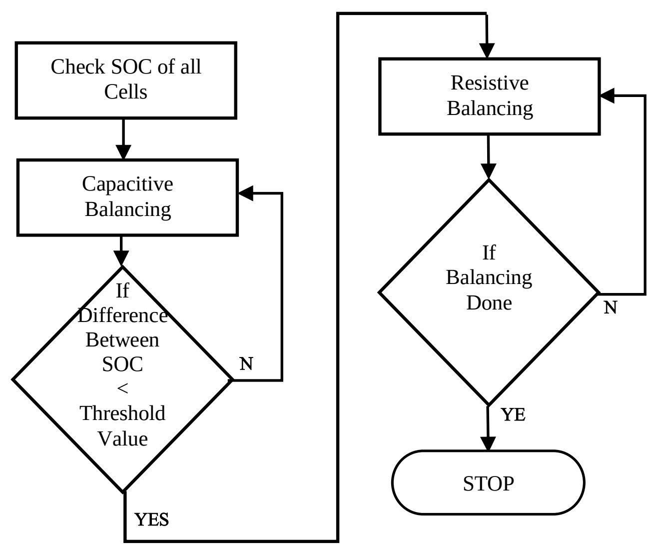

Fig. 8 Control algorithm for hybrid cell balancing

3.2. Simulation Model of Hybrid Cell Balancing Technique

The MATLAB modelling of resistive, capacitive, and hybrid Cell balancing strategies produced simulation results. To run the simulation, four cells with various SOCs were connected in series. The resistive balancing block provides switching signals when it detects the SOC of each Cell, allowing for resistive balancing, as shown in Figure 9. Resistors are connected in parallel to cells that have an SOC value higher than the minimum. When every Cell reaches a SOC equal to the minimal SOC value, balancing is stopped. The capacitors are first linked across a cell and then swapped to neighboring cells in the setting of capacitive balancing, as shown in Figure 10. By repeatedly executing this process, the charges are evenly distributed among all cells, balancing the SOCs of all cells.

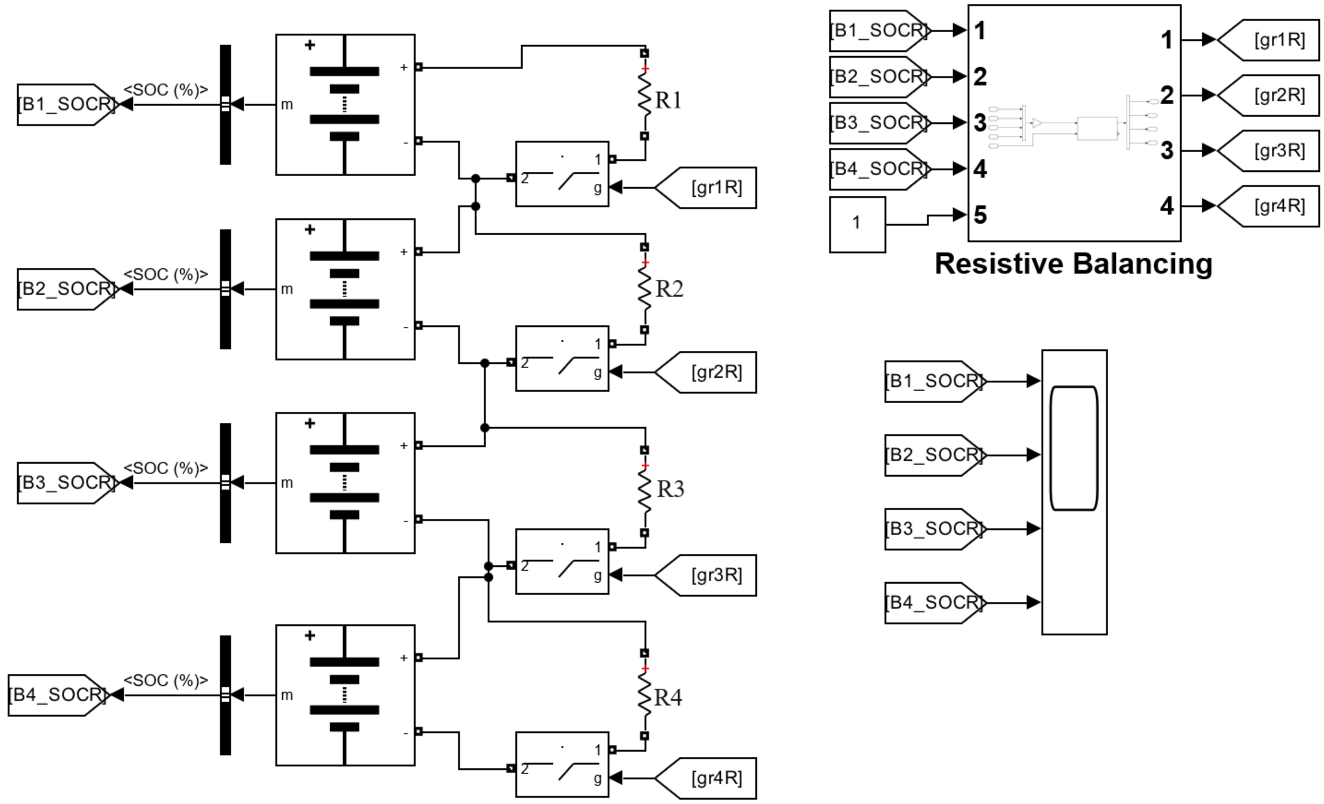

Fig. 9 Simulation circuit for resistive cell balancing

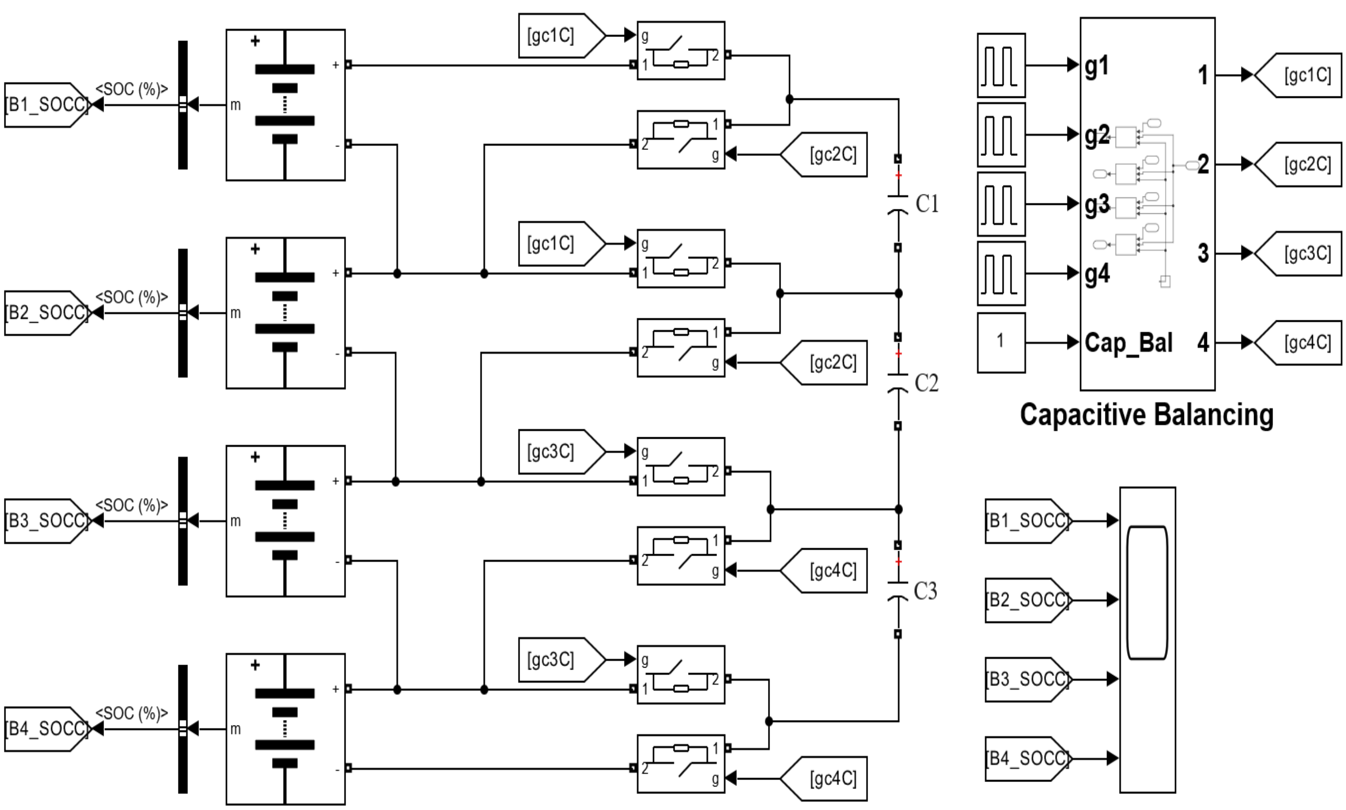

Fig. 10 Simulation circuit for capacitive cell balancing

Figure 11 shows the simulation model for hybrid cell balancing. The simulation employed capacitive cell balancing until the SOC difference between the cells exceeded a specified predefined threshold value. Once the SOC difference fell below this threshold, the simulation transitioned to resistive Cell balancing to complete the balancing process. A control mechanism was developed to facilitate the transition between capacitive and resistive balancing when the SOC difference decreased below a threshold value. Figure 12 illustrates the SOC waveforms of all four cells during resistive cell balancing, capacitive cell balancing, and the hybrid cell balancing process.

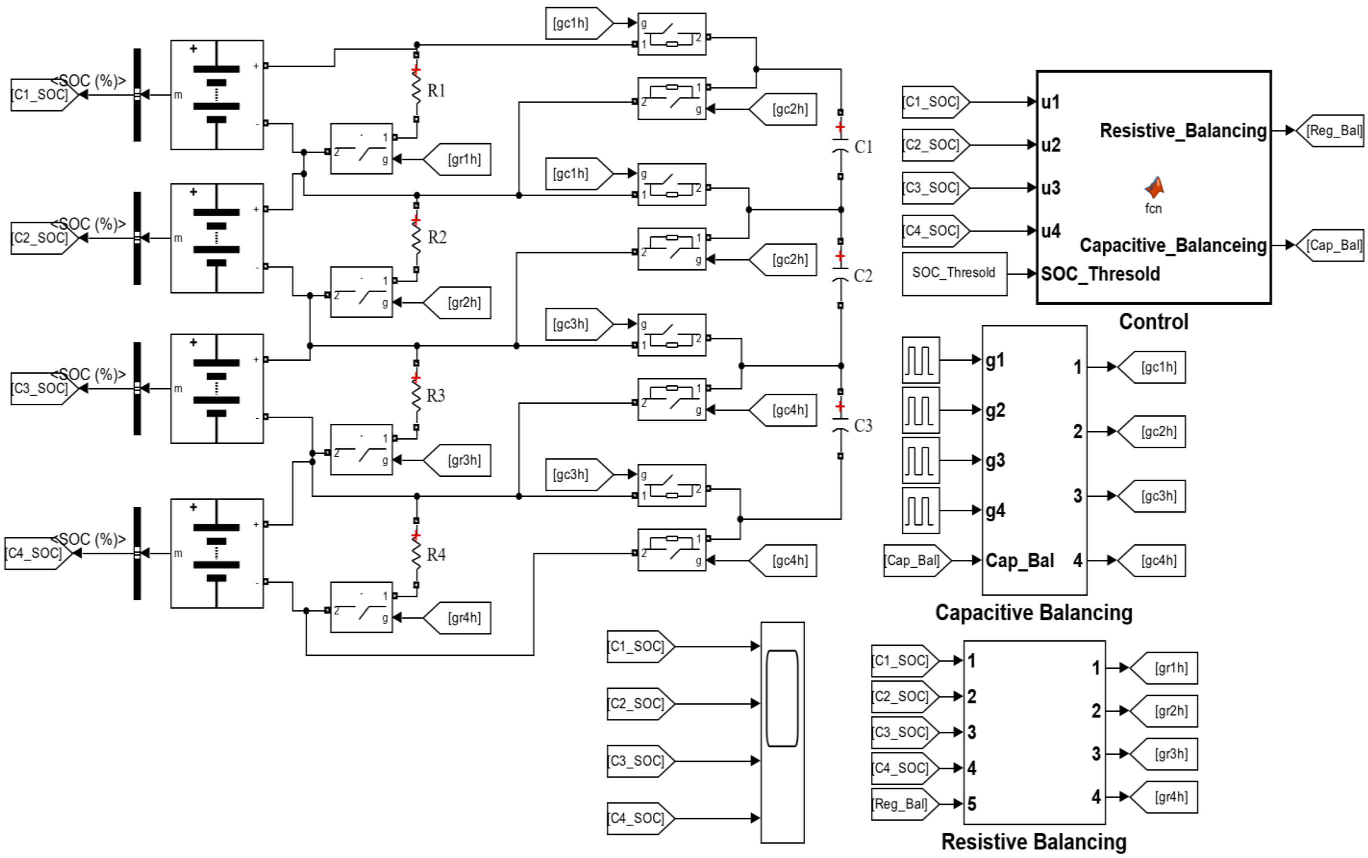

Fig. 11 Simulation circuit for hybrid cell balancing

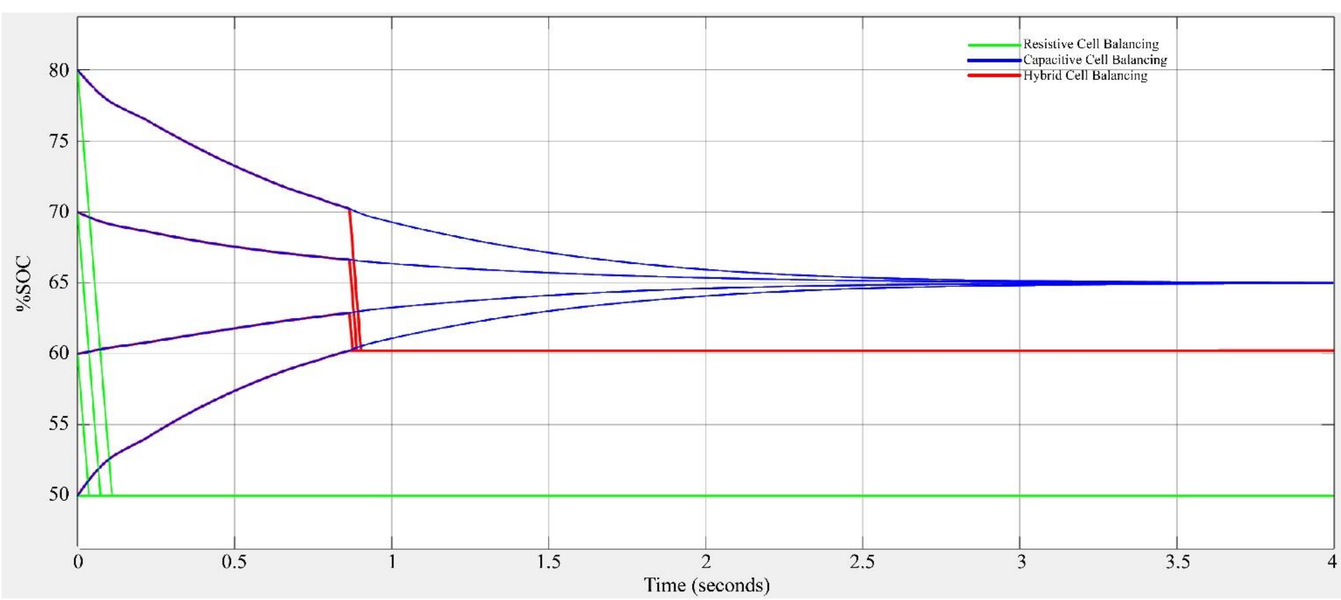

Fig. 12 Waveforms for different cell balancing techniques

3.3. Result Analysis and Discussion

Figure 12 illustrates the waveforms associated with various cell balancing techniques. For the simulation, we used the parameters specified in Table 1. Four cells were connected in series, with initial SOC values of 80%, 70%, 60%, and 50%. In the case of resistive cell balancing, the process concluded in 0.11×10^4 s. However, the SOC of all cells at the end of the balancing process was 50%. As depicted in the resistive Cell balancing waveforms in Figure 12, cells with an SOC exceeding 50% (the minimum SOC) were discharged through resistors connected in parallel until all cells achieved an equal SOC of 50%. Consequently, the energy stored in the other cells was dissipated as heat to achieve cell balance.

Conversely, through the implementation of capacitive cell balancing, the charge from a cell with a higher SOC is transferred to a cell with a lower SOC via a Capacitor by continuously switching capacitors between adjacent cells, thereby eliminating energy wastage. Upon completion of the balancing process, the SOC of all cells was around 65%, which was significantly higher than the 50% achieved through resistive balancing. However, the duration required to complete the balancing process was considerably long, amounting to $4 \times 10^4 s$.

Table 1. Simulation parameters

Parameter	Value
Battery Capacity	2600 mAh
Battery Type	Li-Ion
Nominal Voltage	3.6V
SOCs	Cell-1: 80% Cell-2: 70% Cell-3: 60% Cell-4: 50%
Switching Frequency	1 kHz
R1 R2 R3 R4	1.5 Ω
C1 C2 C3	$100e^{-3}$ F

During the initial phase of the hybrid balancing, the system works in a capacitive balancing mode. This is done by switching SPDT switches at a constant frequency, which connects capacitors to cells next to them and makes it easier for charge to move from cells with a higher SOC to cells with a lower SOC. When the SOC difference between the cells dropped below a threshold value of 10%, the circuit changed to resistive balancing. This step ends capacitive balancing and completes the balancing process by connecting resistors across cells with an SOC higher than the minimum SOC until all cells have the same SOC as the minimum SOC. When comparing hybrid Cell balancing with the two alternative techniques, it was observed that the state of charge at the end of the balancing process was 60.25%. Furthermore, the time required to complete the balancing is only $0.9 \times 10^4 s$, which brings about 68% more efficiency of SOC than solely resistive balancing and 79% faster than solely capacitive balancing.

4. Conclusion

This work focused on developing and validating an improved cell balancing approach to enhance the performance and longevity of Li-ion battery packs used in electric vehicles. The simulation outcomes conclusively demonstrate the superior performance of the proposed hybrid Cell balancing technique in achieving efficient charge equalization among series-connected Li-ion cells.

The research presented here uses a novel hybrid technique to set a new standard for Cell balancing performance. The proposed technique achieves a final SOC of 60.25%, which is significantly higher than the resistive balancing value; the entire charge process takes only $0.9\times 10^4 s$. As compared to resistive balancing, the hybrid technique results in 68% higher SOC utilization efficiency and is 79% faster than capacitive equalization. The deliberate use of the benefits of both resistive and capacitive methods in a composite structure presents a viable solution to overcome the traditional trade-off between speed and energy loss. With longer-lasting battery packs, faster vehicle readiness, and more energy efficiency, all essential for widespread EV adoption and lowering greenhouse gas emissions, this breakthrough marks a major advancement for sustainable battery management systems.

References

[1] Mehrdad Ehsani et al., "State of the Art and Trends in Electric and Hybrid Electric Vehicles," *Proceedings of the IEEE*, vol. 109, no. 6, pp. 967-984, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[2] Michele Garau, and Bendik Nybakk Torsæter, "A Methodology for Optimal Placement of Energy Hubs with Electric Vehicle Charging Stations and Renewable Generation," *Energy*, vol. 304, pp. 1-15, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[3] Dinesh Kumar, Rekha Sharma, and Sapna Nehra, *Advanced Materials for Batteries: Advantage, Disadvantage, and Future Applications*, 1st ed., CRC Press, Boca Raton, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[4] Mohammad Abul Kashem, Mohammad Shamsuddoha, Tasnuba Nasir, "Sustainable Transportation Solutions for Intelligent Mobility: A Focus on Renewable Energy and Technological Advancements for Electric Vehicles (EVs) and Flying Cars," *Future Transportation*, vol. 4, no. 3, pp. 874-890, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[5] Yuanli Ding et al., "Automotive Li-Ion Batteries: Current Status and Future Perspectives," *Electrochemical Energy Reviews*, vol. 2, no. 1, pp. 1-28, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[6] Zvonimir Šimić et al., "Battery Energy Storage Technologies Overview," *International Journal of Electrical and Computer Engineering Systems*, vol. 12, no. 1, pp. 53-65, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[7] K.W. See et al., "Critical Review and Functional Safety of a Battery Management System for Large-Scale Lithium-Ion Battery Pack Technologies," *International Journal of Coal Science and Technology*, vol. 9, no. 1, pp. 1-17, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[8] Qi Zhang et al., "A Concise Review of Power Batteries and Battery Management Systems for Electric and Hybrid Vehicles," *Energies*, vol. 18, no. 14, pp. 1-16, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[9] B. Devi, and V. Suresh Kumar, "Lithium-ion Battery Management System: A Review," *2022 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS)*, Chennai, India, pp. 1-6, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[10] Fangfang Zhu et al., "Battery Management System for Li-Ion Battery," *The Journal of Engineering*, vol. 2026, no. 1, pp. 1437-1440, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[11] Thealfaqar A. Abdul-jabbar et al., "Efficient Battery Cell Balancing Methods for Low-Voltage Applications: A Review," *2022 IEEE International Conference in Power Engineering Application (ICPEA)*, Shah Alam, Malaysia, pp. 1-7, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[12] Sonu Kumar et al., "Switched-Resistor Passive Balancing of Li-Ion Battery Pack and Estimation of Power Limits for Battery Management System," *International Journal of Energy Research*, vol. 2023, no. 1, pp. 1-21, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[13] Roberto Di Rienzo et al., "Passive Balancing Algorithm for Charge Equalization of Series Connected Battery Cells," *2020 2nd IEEE International Conference on Industrial Electronics for Sustainable Energy Systems (IESES)*, Cagliari, Italy, pp. 73-79, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[14] Chia Ai Ooi Shreasth et al., "A Novel Active Lithium-Ion Cell Balancing Method based on Charging and Discharging State of Power in Electric Vehicles," *Scientific Reports*, vol. 15, no. 1, pp. 1-25, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[15] Wai Chung Lee, David Drury, and Phil Mellor, "Comparison of Passive Cell Balancing and Active Cell Balancing for Automotive Batteries," *2011 IEEE Vehicle Power and Propulsion Conference*, Chicago, IL, USA, pp. 1-7, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[16] Thiruvonasundari Duraisamy, and Kaliyaperumal Deepa, "Evaluation and Comparative Study of Cell Balancing Methods for Lithium-Ion Batteries used in Electric Vehicles," *International Journal Renewable Energy Development*, vol. 10, no. 3, pp. 471-479, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[17] Shukla Karmakar, Aashish Kumar Bohre, and Tushar Kanti Bera, "Recent Advancements in Cell Balancing Techniques of BMS for EVs: A Critical Review," *IEEE Transactions on Industry Applications*, vol. 61, no. 2, pp. 3468-3484, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[18] Adnan Ashraf et al., "Review of Cell-Balancing Schemes for Electric Vehicle Battery Management Systems," *Energies*, vol. 17, no. 6, pp. 1-18, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[19] Amar Nath, and Bhooshan Rajpathak, "Analysis of Cell Balancing Techniques in BMS for Electric Vehicle," *2022 International Conference on Intelligent Controller and Computing for Smart Power (ICICCSP)*, Hyderabad, India, pp. 1-6, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[20] Jian Cao, Nigel Schofield, and Ali Emadi, "Battery Balancing Methods: A Comprehensive Review," *2008 IEEE Vehicle Power and Propulsion Conference*, Harbin, China, pp. 1-6, 2008. [CrossRef] [Google Scholar] [Publisher Link]

[21] Luo Wei et al., "Study on Passive Balancing Characteristics of Serially Connected Lithium-Ion Battery String," *2017 13th IEEE International Conference on Electronic Measurement and Instruments (ICEMI)*, Yangzhou, China, pp. 489-495, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[22] Adnan Ashraf et al., "A Comprehensive Review of the Art of Cell Balancing Techniques and Trade-Offs in Battery Management Systems," *Energies*, vol. 18, no. 13, pp. 1-19, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[23] C. Pascual, and Philip T. Krein, "Switched Capacitor System for Automatic Series Battery Equalization," *Proceedings of APEC 97 - Applied Power Electronics Conference*, Atlanta, GA, USA, pp. 848-854, 1997. [CrossRef] [Google Scholar] [Publisher Link]

[24] Daniel Marcin et al., "Capacitor-based Active Cell Balancing for Electric Vehicle Battery Systems: Insights from Simulations," *Power Electronics and Drives*, vol. 9, no. 1, pp. 317-330, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[25] Yunlong Shang et al., "A Switched-Coupling-Capacitor Equalizer for Series-Connected Battery Strings," *IEEE Transactions on Power Electronics*, vol. 32, no. 10, pp. 7694-7706, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[26] Yuma Takeda, and Hirotaka Koizumi, "Modularized Double-Tiered Switched Capacitor Voltage Equalizer," *IECON 2017 - 43rd Annual Conference of the IEEE Industrial Electronics Society*, Beijing, China, pp. 2782-2787, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[27] Yunlong Shang et al., "An Optimized Mesh-Structured Switched-Capacitor Equalizer for Lithium-Ion Battery Strings," *IEEE Transactions on Transportation Electrification*, vol. 5, no. 1, pp. 252-261, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[28] Yuanmao Ye et al., "Double-Tiered Cell Balancing System with Switched-Capacitor and Switched-Inductor," *IEEE Access*, vol. 7, pp. 183356-183364, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[29] Mohamed Daowd et al., "Single Switched Capacitor Battery Balancing System Enhancements," *Energies*, vol. 6, no. 4, pp. 2149-2179, 2013. [CrossRef] [Google Scholar] [Publisher Link]