IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 1, December 2024

Comparative Analysis of Active and Passive Cell Balancing Strategies in Battery Management Systems

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Abstract: *Battery management systems (BMS) play a crucial role in ensuring the performance, reliability, and longevity of modern battery systems by employing cell balancing techniques. This paper presents a comparative study of active and passive cell balancing strategies, focusing on balancing speed, energy dissipation, thermal effects, and State of Health (SoH). Passive balancing methods, utilizing resistive dissipation, are simple and cost-effective but suffer from low efficiency and significant energy loss as heat. Active balancing, on the other hand, redistributes energy between cells using converters, offering superior performance and energy efficiency but at a higher cost and complexity.*

Simulation models were developed in MATLAB/Simulink to evaluate both strategies under various conditions. For passive balancing, resistances of 1 Ω, 0.5 Ω, and 0.1 Ω were used, while active balancing employed a buck-boost converter with MOSFETs. The results demonstrated that active balancing achieved faster SOC (State of Charge) equilibrium with minimal energy dissipation. However, low-resistance passive balancing (e.g., 0.1 Ω) offered comparable balancing speed at the expense of increased thermal impact. A thermal analysis was conducted to evaluate dynamic temperature changes during operation, incorporating aging and environmental factors, which revealed their significant influence on battery performance and SoH degradation.

Additionally, a mathematical scaling approach was applied to extrapolate the findings from a two-cell model to larger systems, providing insights into the scalability of both techniques. The study concluded that active balancing is ideal for high-performance applications requiring efficiency and speed, while passive balancing remains viable for cost-sensitive systems with lower performance requirements. This research highlights the trade-offs between energy efficiency, thermal stability, and complexity in cell balancing, offering valuable guidance for the design and optimization of BMS across various applications..

Keywords: Cell Balancing Techniques, Active vs. Passive Balancing, Battery Management Systems (BMS),Energy Dissipation and Thermal Effects