IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 10, May 2025
Impact Factor: 7.67

Advanced Numerical Simulation of Lithium-Ion Battery Systems: Evaluating the Influence of Cell Form Factor at Cell, Module, and Pack Levels

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Abstract: *Lithium-ion batteries are integral to modern energy storage systems, particularly in applications such as electric vehicles, grid storage, and consumer electronics. The performance of these batteries is significantly influenced by their form factor, which impacts key parameters such as energy density, thermal behavior, cycle life, and safety. This paper presents an advanced numerical simulation study aimed at evaluating the influence of cell form factors (cylindrical, prismatic, and pouch) on the performance of lithium-ion battery systems at the cell, module, and pack levels. Using state-of-the-art modeling techniques, including finite element analysis (FEA), computational fluid dynamics (CFD), and electrochemical simulations, the study investigates the thermal, mechanical, and electrochemical performance across different hierarchical levels of the battery system. The research provides a comparative analysis of how the arrangement of cells within modules and packs affects overall system performance, with particular emphasis on thermal management, power density, and scalability. The findings highlight the importance of optimizing cell form factors for improving battery efficiency, safety, and lifecycle performance. This work contributes valuable insights for the design of advanced lithium-ion battery systems, offering a pathway toward more efficient and reliable energy storage solutions across a range of applications.*

Keywords: lithium-ion battery, electric vehicles, grid storage, and consumer electronics, energy density, thermal behavior, cycle life, safety, finite element analysis (FEA), computational fluid dynamics (CFD), and electrochemical simulations.