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A Review on Enabling Waste and Carbon Reduction with Battery Management Systems for Second-Life Batteries

Abstract

The rapid rise of electric vehicles has sparked a parallel challenge: the sustainable management of end-oflife lithium-ion batteries. While no longer suitable for automotive applications, these batteries often retain a considerable amount of usable capacity, making them strong candidates for second-life deployment in stationary energy storage systems. As the world advances toward circular economy models and low-carbon energy systems, repurposing electric vehicle batteries offers a strategic solution to reduce both electronic waste and lifecycle greenhouse gas emissions. However, second-life batteries face inherent challenges chiefly aging, uneven degradation, and variable state-of-health that threaten their safety, performance, and reliability. In this context, battery management systems emerge as critical enablers for successful second life batteries integration. Intelligent battery management system technologies can continuously monitor battery health, detect faults, optimize energy throughput, and adapt system control to extend battery lifespan and improve performance.

This review presents a comprehensive examination of recent advancements in battery management system technologies specifically designed for second-life battery applications. Key areas include state of health estimation, fault diagnostics, adaptive control algorithms, and battery management system integration with renewable energy sources. The paper analyzes the impact of battery management system on system-level metrics such as reliability, degradation rate, and environmental performance, with studies indicating notable gains in battery longevity and emission reductions. Future research directions are identified in artificial intelligence based health prediction, modular battery management system architectures, and real-time diagnostics. Overall, this review underscores the essential role of battery management system in enabling scalable, efficient, and sustainable second-life battery systems. By addressing technical barriers and improving lifecycle management, battery management system technologies unlock the full environmental and economic potential of second life battery in modern energy infrastructures.

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