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Engineering Suitability Analysis of Sodium-Ion Batteries for Medium-Power Energy Storage Applications

With the large-scale integration of renewable energy sources, modern power systems increasingly demand medium-power energy storage solutions to provide peak shaving, renewable energy smoothing, and frequency regulation services. Sodium-ion batteries (SIBs) have emerged as a promising storage technology due to their abundant raw materials, low cost, and favorable cycle life. Compared to conventional lithium-ion batteries, SIBs offer slightly lower energy density but demonstrate potential advantages in safety, environmental adaptability, and economic feasibility, making them suitable candidates for medium-power energy storage applications.

Medium-power energy storage systems typically require rapid response capabilities, reliable charge-discharge cycling, and stable operational efficiency. The performance of sodium-ion batteries in these applications depends on material selection, electrode design, electrolyte formulation, and thermal management strategies. Key factors influencing engineering suitability include rate capability, cycling stability, and temperature sensitivity, which directly affect power delivery, operational reliability, and lifetime performance. Additionally, energy conversion efficiency, capacity degradation patterns, and maintenance costs are critical considerations for evaluating the economic viability and practical deployment of SIB-based systems.

To comprehensively assess the engineering suitability of sodium-ion batteries for medium-power energy storage, this study develops an integrated evaluation framework encompassing electrochemical performance, thermal behavior, and system integration characteristics. Through simulation and experimental data analysis, key metrics such as charge-discharge efficiency, temperature rise, capacity fade, and power response are investigated under varying operating conditions. Furthermore, system-level considerations, including scalability and interaction with grid regulation requirements, are evaluated to determine the contribution of SIBs to energy efficiency improvement and renewable energy integration.

The findings of this study provide engineering insights into the practical deployment of sodium-ion batteries in medium-power energy storage scenarios. They support informed decision-making in system design, technology selection, and operational strategy, facilitating the effective integration of SIBs in distributed storage systems, renewable energy smoothing, and grid regulation. This research contributes to advancing the engineering adoption of sodium-ion batteries as a cost-effective and technically viable storage solution in modern power systems.