SOH Evolution and Differentiated Degradation Mechanisms of Energy Storage Batteries under Fault Conditions in Grid-Forming Microgrid

Electrochemical energy storage plays a pivotal role in supporting grid-forming microgrids. However, battery degradation mechanisms under typical fault conditions remain insufficiently understood, posing challenges for system security and lifetime prediction. However, most existing studies focus on normal operating states, while differentiated degradation characteristics triggered by short-circuit (SC) and open-circuit (OC) faults remain insufficiently understood. This study employs a simulation–experiment co-analysis framework, integrating a Simulink-based grid-forming microgrid model with accelerated aging experiments. The grid-forming microgrid model is developed to quantify the DC terminal responses of batteries under fault conditions, and accelerated aging experiments are conducted to investigate capacity, internal resistance, and material structural evolution. Results indicate that SC faults induce the most severe degradation, with the state of health (SOH) dropping to 77.05% after 500 cycles and the capacity fade rate 87% higher than steady-state operation. In contrast, OC conditions, due to charge–discharge switching segments, exhibit a degradation-mitigation effect, maintaining an SOH of 91.96% after 500 cycles and resulting in a 35% reduction in the fade rate compared with the steady-state operation. The findings highlight SC faults as a critical risk factor for battery lifetime prediction and health management in grid-forming energy storage systems. The identified differentiated degradation mechanisms provide theoretical support for developing battery health diagnosis and management strategies.

Keywords: Battery energy storage system, State of health (SOH), Degradation mechanism

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