

Life-Extension Control of Second-Life EV Battery Systems

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This study proposes a power allocation control strategy to maximize the service life of stationary energy storage systems composed of second-life lithium-ion batteries retired from electric vehicles. As the deployment of renewable energy sources continues to expand, stationary energy storage systems are becoming increasingly important for maintaining grid stability and energy flexibility. However, heterogeneity in the degradation states of second-life batteries remains a critical challenge, since the most degraded battery can dictate the service life of the entire system. As a result, the entire system may become unavailable even though the remaining battery modules still retain sufficient State of Health (SOH) and useful life.

To address this issue, a hierarchical control framework based on Model Predictive Control (MPC) is proposed. The upper layer utilizes battery degradation models to predict aging progression and determine power allocation policies that balance degradation among battery modules. The lower layer employs battery charge/discharge and thermal models to calculate current inputs while satisfying the constraints imposed by the upper layer. Through optimization, the proposed method allocates the required power among battery modules, thereby reducing the load on highly degraded batteries while shifting it to healthier ones.

In the power allocation simulation, multiple battery modules with different degradation characteristics were evaluated. The results showed that, during the initial 5,000 steps after the start of control, the current amplitude of Battery 3 was suppressed, whereas larger currents were distributed to Batteries 1 and 2 (Fig. 1). Furthermore, the battery lifetime simulation showed that, with the conventional equal power-sharing method, the SOH of Batteries 2 and 3 reached zero at approximately 41,500 steps (Fig. 2). In contrast, the proposed method equalized the SOH values of all batteries by approximately 6,000 steps, and all batteries reached an SOH of zero at approximately 46,300 steps (Fig. 3).

These results demonstrate that the proposed method effectively balances battery degradation and prolongs the lifetime of the overall system. Future research will focus on improving the accuracy of the degradation models and conducting experimental validation of the proposed approach.

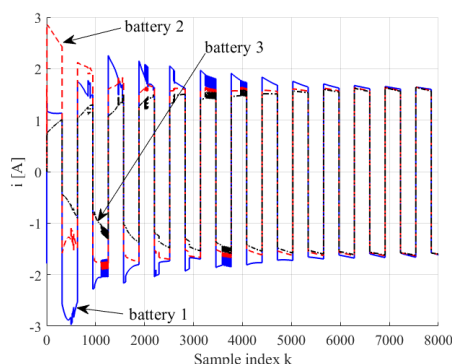


Fig.1 Current responses using the proposed method

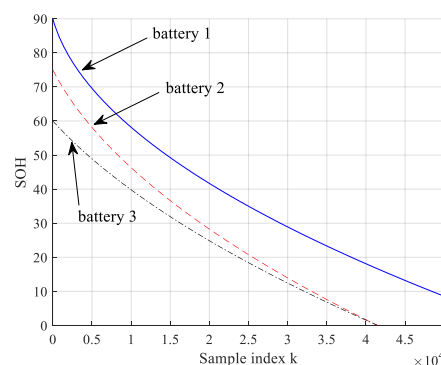


Fig.2 SOH without considering battery degradation

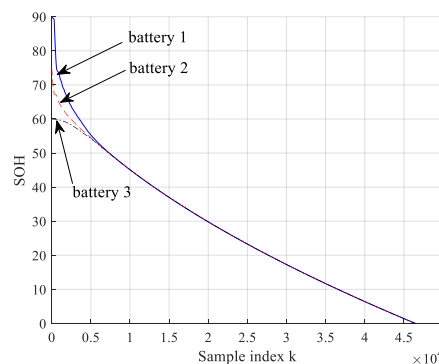


Fig.3 SOH using the proposed method