DETECTION OF ELECTRICAL ABUSE IN EV LIB CELLS

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Abstract

Accelerated state of health (SOH) estimation, specifically remaining capacity assessment, is critical for successfully repurposing electric vehicle (EV) lithium-ion battery (LIB) modules at end of life (EOL) to secondary, less demanding applications. Additionally, successful repurposing requires the detection of prior abuse that could lead to catastrophic thermal runaway events. Moreover, detecting abuse history is more critical than estimating capacity fade alone, as standard testing procedures may inadvertently trigger thermal runaway in previously abused modules during routine capacity evaluation. Among the three primary thermal runaway mechanisms (thermal, mechanical, and electrical), electrical abuse presents the greatest challenge for retrospective detection due to the absence of visible physical markers. This manuscript comprehensively reviews the current state of the art in detecting thermal runaway potential and empirically testing for abuse indicators and presents an original empirical study investigating novel electrical testing methodologies for identifying prior electrical abuse. Experiments were conducted exclusively at the cell level to minimize energy release risk during potential thermal runaway events, as the test protocols were intentionally designed to push cells to the edge of failure thresholds. Cells extracted from the same module were divided into two experimental groups: one subjected to controlled overcharge abuse and the other to overdischarge abuse conditions. Both groups were subsequently evaluated within normal operating voltage ranges to assess detectable signatures of prior abuse. The primary diagnostic approach analyzed transient voltage response characteristics during rest periods following pulsed charging cycles. This methodology was selected because rest periods allow cells to electrochemically stabilize, thereby revealing subtle changes in internal resistance and electrochemical behavior indicative of prior abuse. Multiple rest periods at different states of charge (SOC) were intentionally incorporated, recognizing that used module, particularly those with abuse histories, arrive with varying SOC levels. Each rest period corresponded to a distinct SOC level, enabling anomaly detection across a broader operating range and increasing the likelihood of identifying abuse-related electrochemical signatures that may manifest only under specific SOC conditions.

Keywords: EV, LIB repurpose, timed-domain, transient response, SOH estimation, capacity fade, unknown SOC