Impacts of Module Configuration on Li-ion Battery Performance and Degradation

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Background

- Most battery cycling studies take place at the single cell level, but data needs to be collected across battery scales (including modules) to understand and close the systematic gap in performance between cells and systems
- Additionally, new power electronics topologies enable lower voltage battery systems and allow us to rethink optimal battery module configurations

Module Cycling Methodology

We explored all series and parallel combinations of an eight-cell module board. Well-matched cells were selected based on characterization of a lot of 400 3Ah 18650 NMC cells. Module boards had cell-level current (Hall effect sensors) and voltage monitoring. Cycling was done at 25 °C, with 0.5C charge and discharge, in a range of 2.5-4.1 V per cell, without balancing. The program moved on to the next step once any cell in the module reached the voltage limit.

Discharge Energy Fade

% discharge energy fade at 200 cycles ranges from 9.7% for 8P-1S config. to 14.2% for 8S-1P

Current Redistribution

Current redistribution for parallel cells can yield up to 1.7x the expected cell current

Voltage Divergence

After 200 cycles, mean cell voltage diverges by up to 0.1 V without balancing

Conclusions

- Generated broadest module cycling dataset in open literature
- Per cycle discharge energy fade can proceed at up to 40% higher rate in increasingly series configurations
- Current redistribution in parallel cells can lead to significantly higher individual cell currents than expected, which could cause operation outside of mfr. bounds at higher currents

Future Work

- Repeat original experiment with well-matched cells to confirm the consistency of the results
- Repeat original experiment with poorly-matched cells
- Repeat module experiments with current ripple

Motivating Questions

1. How do different module configurations impact battery performance and degradation?
2. How does aging of a cell in a given module configuration compare with aging results observed in single cell studies?
3. Given results to the questions above, how can we leverage new battery configurations or converter topologies to force cell performance closer to the ideal results indicated by cell-level studies?

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