Statistical Modelling of Degradation for Battery Applications

Degree programme: BSc in Electrical Engineering and Information Technology
Specialisation: Automation, Control and Robotics
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This thesis develops a statistical visualization tool to compare battery degradation and performance using the Open-Sesame simulation software. By integrating a statistical data frame methodology, the project enhances the clarity and accessibility of degradation data, facilitating more effective analysis and informed decision-making in energy and battery management.

Objective

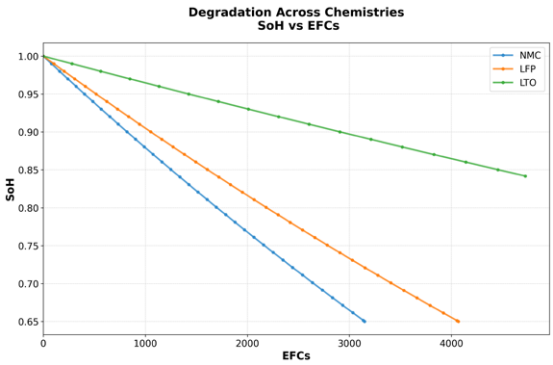
This thesis introduces a statistical visualization framework for analyzing battery degradation over time using simulation data. The core innovation is in the Statistical DataFrame (SDF), which integrates time-, cycle- and iteration-level inputs, to provide a multi-dimensional view on battery aging.Unlike traditional methods that track a single State of Health (SoH) metric, this framework analyzes six key stress factors and visualizes their distribution. The visualizations enable intuitive comparison across chemistries and usage scenarios, while also opening the way to trend recognition for machine learning.

Methodology and Implementation

Using the Open-Sesame semi-empirical simulation tool, which estimates SoH, a time-series degradation data is generated. The SDF organizes this data from across three sources:

— profile dataframe: forecast over time
— cyclic dataframe: performance over cycles
— iteration dataframe: per-iteration SoH forecast during the whole simulation

For each simulated battery, three visualizations, one at Beginning of Life (BoL) middle, and other at the End of Life (EoL), visualize these factors to reveal degradation patterns. The framework enables SoH comparison across chemistries under the same usage profile, using raw inputs with minimal preprocessing.



Comparison of State of Health (SoH) degradation across NMC, LFP, and LTO chemistries for the same power profile

It analyzes six stress factors affecting SoR and SoH:

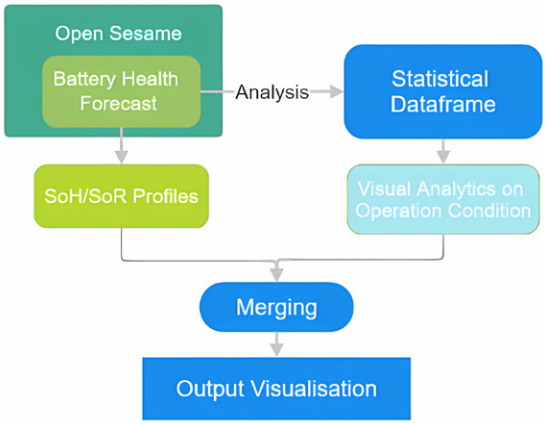
— time-based: state of charge (SoC), depth of discharge (DoD)
— cycle-based: DoD, average C-rate, average SoC, average temperature

Result

Comparing NMC under two profiles - one with fluctuating SoC and deep cycles, and another maintaining a stable ~50% SoC - showed slower degradation in the latter, confirming that NMC is highly sensitive to high SoC and temperature. In contrast, LTO remains largely unaffected by high C-rates and SoC conditions, These differences are easily visualized through the framework, enabling rapid comparative analysis, with minimal manual input. It captures changes in key degradation stress factors and allows SoH comparisons across chemistries and use cases.

Conclusion

This thesis presents a structured, visual method for analyzing battery degradation using Open-Sesame data. Integrating a Open-Sesame with the SDF allows lifecycle comparison with minimal preprocessing, delivering deeper insight and improved battery system decisions.



Schematic overview of the statistical visualization framework

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