



Battery energy storage system modeling: A combined comprehensive approach

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Objectives & Motivations



Predict battery life accurately based on usage, assembly, and chemistry



- Battery degradation is path dependent
- ESS performance depends on usage, environment, single cells and controls



Objectives & Motivations



Predict battery life accurately based on usage, assembly, and chemistry





BESS modeling

Comprehensive approach with material insights



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Degradation modes emulation



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Full cell emulation is based on half cell data for each electrode (or each component of a blend) at different rates.

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It only requires few parameters:

- The Loading ratio (LR)
- The offset (OFS

Simulation

4.2

4.2

- The Rate for each electrode (or component of the blend),

- The Resistance for each electrode (or component of the blend).

> https://www.soest.hawaii.edu/HNEI/alawa/ Dubarry M. et al. Journal of Power Sources 219 (2012) 204-216

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Degradation modes emulation

Licensing available

>170 registered users from >90 organizations worldwide



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Cell-to-cell variations



Cells in a batch do not all have the same characteristics

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- Δ Maximum capacity
- Δ Rate capability
- Δ Resistance
- Δ State of health

In packs need to account for additional variations

Δ State of charge

Significant impact on performance especially in series.

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Imbalance



As a result of cell-to-cell variations and environmental conditions (e.g. temperature gradients...) cells might all be utilized the same way

- Impact pack voltage response
- Impact pack OCV
- Impact available capacity
- Impact SOC/SOH tracking

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Imbalance



Understanding and accounting for proper degradation allows to test different balancing solutions in order to find the more adapted one.

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BMS model

Prepare for the unexpected



- Simulate any possible degradation
 <u>= Infinite training data</u>
- Millions of V vs. Q curves published.

Dubarry M. et al., *Energies*, 2021, 14(9), 2371 Dubarry M. et al., Journal of Power Sources 479 (2020) 228806 Dubarry, M., et al. (2017). Journal of Power Sources **360**: 59-69.

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BMS model





Use training data to develop data-driven diagnosis methods.

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|Diagnosis error| < 1% @ 4 cycles and for >
125,000 duty cycles

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BMS model

Prepare for the unexpected - Prognosis



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Questions?

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