Battery Durability and Reliability under Electric Utility Grid Operations

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Objective/Significance
Evaluate degradation & lifetime of BESS in support of grid scale deployment
Improve economic understanding of future commercial & base deployments

Approach
Assess battery performance in BESS and under controlled conditions
Analyze degradation using non-destructive methods
Link controlled and deployed degradation to forecast remaining useful life

Integrate **field data** with **lab testing** to predict lifetime BESS
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Usage analysis

In three years:
In use 90% of the time
Stored 1.5 GWh of energy
>5000 battery cycles

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Usage of the cells can be described by 5 parameters:
9 second pulses, C/2 current, 5% SOC swings, 0.75% SOC/min ramp rate, and 35°C

Big Island, HI (grid: 190MW)
Altairnano GEN1 50Ah cells,
1MW/250kWh, 384(7P)S1P
Commissioned in December 2012
Frequency regulation, Wind Smoothing
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Laboratory testing – Cycle aging

After 880 full SOC swings / 4000 cycles, the cells lost up to 7% of their capacity. Impact of T, C and ΔSOC

3 C rates, 3 temperatures, 3 SOC swings, 1 pulse duration, 1 SOC ramp rate
Temperature increase responsible for most degradation, followed by current increase and SOC swing decrease.
~ 1% loss after 16 months for $T \leq RT$
Above RT, lower SOCs becomes aggravating factor
>10% loss at HT and LSoC replicated.
Composite PE: LCO+NCA
No access to individual components
Fit with reference materials

Emulation of degradation modes on voltage:
- Loss of lithium inventory (LLI),
- Loss of active material (LAM) on positive and negative electrodes (PE & NE).

M. Dubarry et al. Journal of Power Sources 219 (2012) 204-216
M. Dubarry et al. / Journal of the Electrochemical Society, in preparation
Mechanistic modeling: Use fit to predict voltage response under different degradations

Assessed the impact of each active component of the cell
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Incremental capacity analysis – Cycle aging

Degradation is much more important than that shown by capacity loss

Use mechanistic understanding to predict capacity fade

Use IC curves to quantify $LAM_{NE}$, $LAM_{PEs}$ and LLI

End of testing

BESS after 3 years
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Incremental capacity analysis – Calendar aging

Use IC curves to quantify $LAM_{NE}$, $LAM_{PEs}$ and LLI

Degradation is much more important than that shown by capacity loss

Use mechanistic understanding to predict capacity fade
Conclusions

Found major impact for temperature, and SOC swing

Explain spread observed in the field?

Big degradation despite small capacity losses

Significant LAM_{PE} (both components) and LLI. Not yet associated with capacity loss

Path dependent degradation: different signature cycle / calendar and T / SOC.

Perspective

Model performance based on laboratory testing

Compare lifetime performance model to field data to determine BESS SOH

Optimize BESS control strategies to limit degradation
Acknowledgments

This work was supported by the Office of Naval Research (ONR) Asia Pacific Research Initiative for Sustainable Energy Systems (APRISES), award # N00014-13-1-0463 and N00014-16-1-2116.

The authors are grateful to the Hawaiian Electric Company for their ongoing support to the operations of the Hawaii Sustainable Energy Research Facility.

Thank you for your attention! Questions?

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Aging path dependence

Calendar aging induces different degradations
Significant degradation despite small capacity loss

Different that cycle aging degradation
Highlight importance to test a particular battery for a given application
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Field data

O‘ahu, HI (grid: 1.1TW)
1MW/250kWh, Commissioned in February 2016
Altairnano GEN2 60Ah cells, 384(7P)S1P
Volt-VAR, Power quality

Big Island, HI (grid: 190MW)
1MW/250kWh, Commissioned in December 2012
Altairnano GEN1 50Ah cells, 384(7P)S1P
Frequency regulation, Wind Smoothing

Moloka‘i, HI (grid: 5.5MW)
2MW/330kWh, Commissioned in February 2016
Altairnano GEN2 60Ah cells, 416(7P)S1P
Reserve, Fault response

Demonstrated over 8000 full cycles equivalent operation