Sandia National Laboratories

CIRCUIT-AGNOSTIC LIFETIME PREDICTIONS FOR SUSTAINED BATTERY OPERATION

VIA DUAL ACTIVE BRIDGE RELIABILITY MODELING

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PROJECT PROFILE
Topic: Power Electronics | Vertical: Safety & Reliability
Strategic Pathway: Stabilize (Addressing urgent conditions to ensure safety, reliability, and system security)
Project start and finish: FY26-FY27

PROBLEM

Grid storage relies on power electronic converters (e.g., Dual Active Bridge or DAB) to interface batteries with the grid.

- Predicting battery lifecycles and stability is made difficult by stresses imposed via auxiliary power electronic systems.
- Power system failure rates are specific to circuit topology and operating conditions

Objective

Develop a dynamic reliability model framework that treats batteries and auxiliary wide-bandgap power converters as integrated systems rather than isolated components.

APPROACH

LTspice → Kinetic Degradation Feedback Loop

1. *LTspice model of DAB topology provides steady-state operating conditions of 3.3kV SiC MOSFET*
2. *Extracted MOSFET performance is evaluated using empirical kinetic models to calculate parameter degradation.*
3. *Calculated MOSFET parameters are fed back into DAB model, creating a non-linear iterative loop.*
4. *DAB performance is projected over operational lifespan via finite difference methods.*

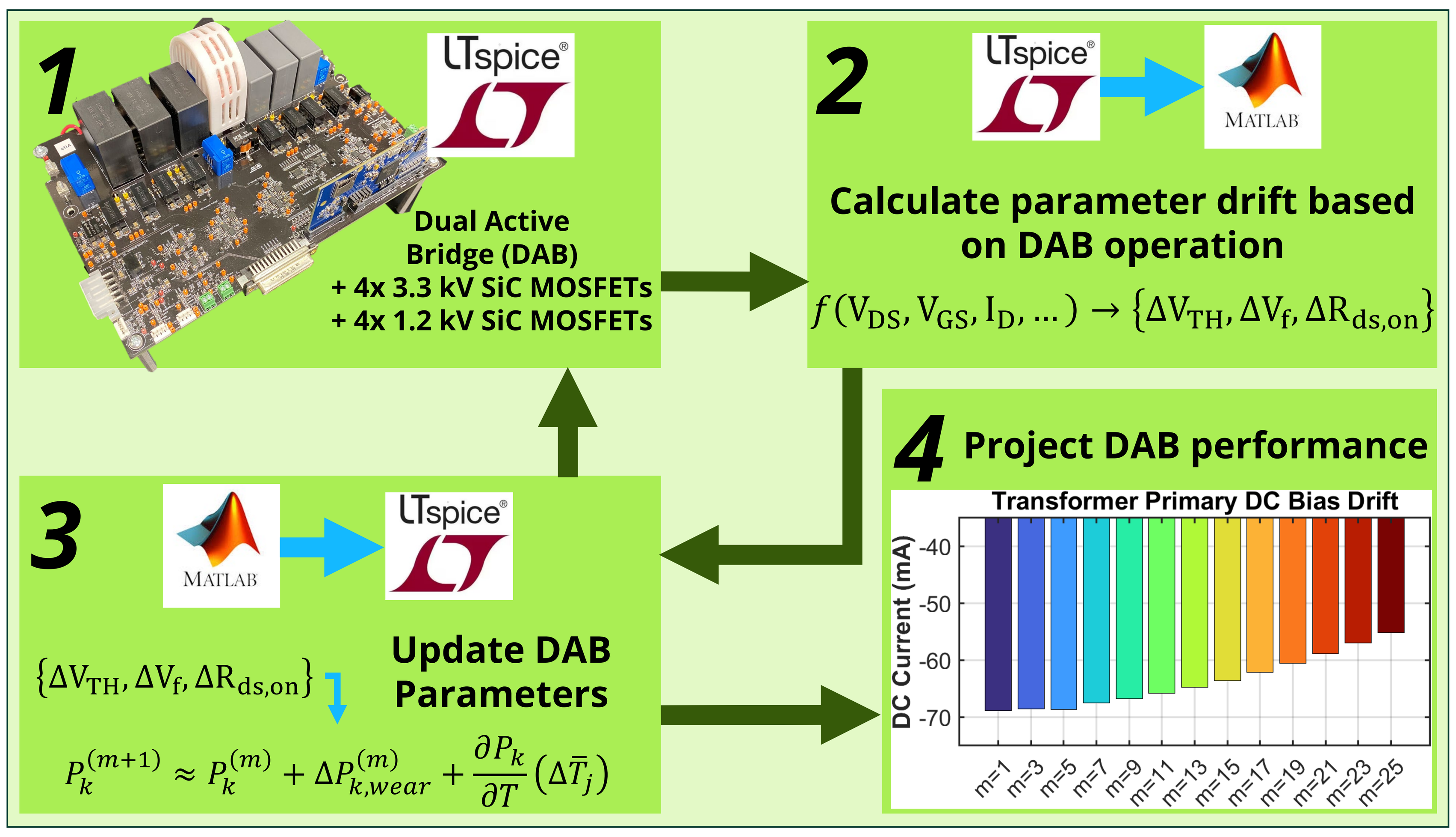


Fig. 1: *An iterative electro-thermal feedback loop dynamically calculates transistor degradation based on the operating conditions of the DAB.*

RESULTS

Fig. 2: *Fundamental transistor wear can be predicted <u>only if</u> the kinetic degradation models properly consider real aging phenomena.*

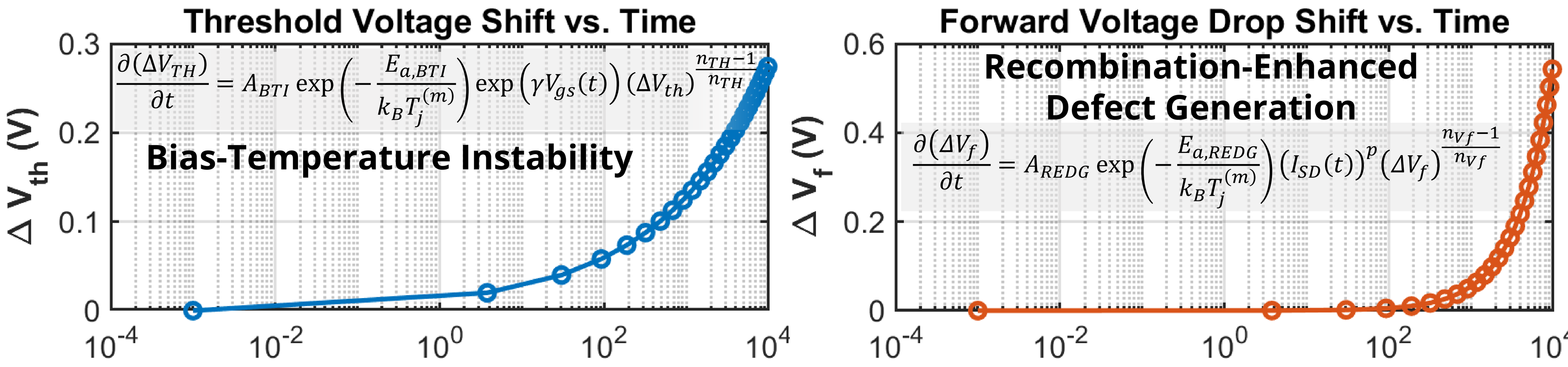
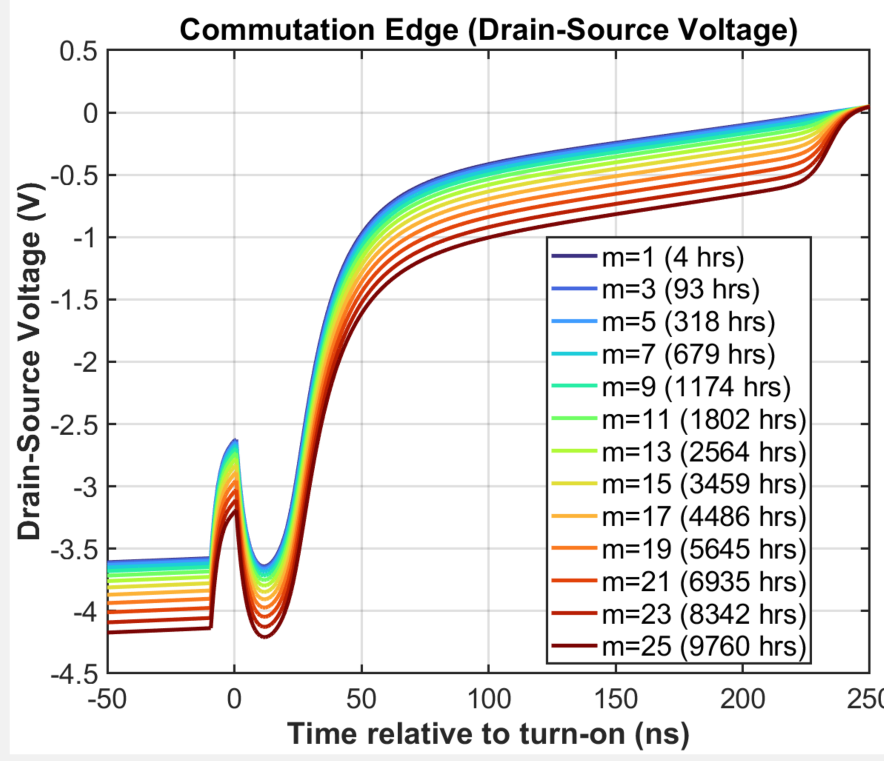


Fig 3 (Left): *Soft-switching window collapse reduces power transfer efficiency, subjecting battery system to unintended electrical stress.*



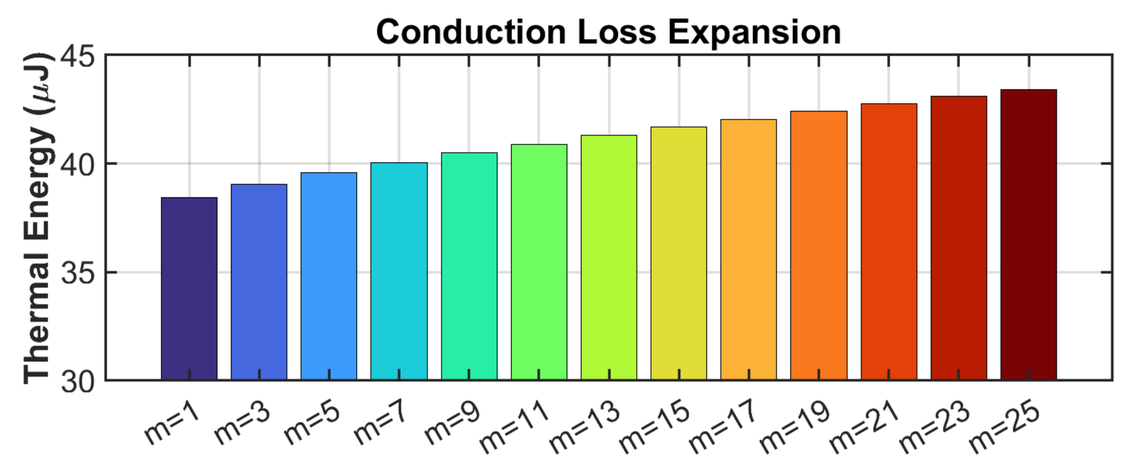


Fig 4 (Above): *20% increase in thermal dissipation in the DAB discharges batteries faster, directly accelerating electromechanical aging of the battery.*

CONCLUSIONS & IMPACT

Key Takeaway

Battery lifespan predictions are fundamentally incomplete without accounting for the degradation of the power electronics interface.

Implications

By predicting converter degradation before hard failure, operators can intercept damage to expensive battery assets caused by semiconductor device failures.

Impacts

This project's success will allow for highly optimized, preemptive maintenance to prevent unexpected grid-storage downtime and improve the overall safety and reliability of MV infrastructure.

FUTURE DIRECTIONS

- Translate dynamic model from LTspice/MATLAB to PySpice.
- Experimentally calibrate the kinetic degradation rates of wide-bandgap power device parameters in DAB system.
- Extend the boundary of the reliability model to couple degraded converter profiles with simulated battery circuits.

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