Enable Model-Based Diagnostics and Prognostics for Lithium-Ion Batteries

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Objective: To improve computation speed of state-of-the-art nonlinear multiscale battery model while maintaining solution accuracy

Enhanced Computational Efficiency

- GH-MSMD:** Quasi-explicit, modular and extendable, tightly coupled nonlinear multiscale multiphysics battery model framework
- Electrode-domain model Benchmark:** Comparison of electrical/thermal response of battery for mid-size plug-in hybrid electric vehicle (PHEV10) from GH-MSMD and original MSMD. 100~1,000-fold speed increase while maintaining solution accuracy
- CAE Tool:** Implemented in a commercial software - ANSYS Fluent

Pack Management and Control

- Fluent ↔ MATLAB interactive modeling:** Enable battery control, safety device analysis; Improve numerical stability; Accurately capture multi-physics at pack-level
- Generalized circuit solver:** Essential to life and safety simulation at pack-level; Captures the effects of battery topology, cell variability and abnormal cells

Integrated Safety Modeling

- Understanding safety aspects of large-size cells is challenging because of the interplay of multiple physical phenomena and the limitations in experimental capabilities
- An integrated model has been established that resolves complex interplays among chemical, thermal, electrical characteristics, operational and environmental conditions, and type and nature of faults
- The model explained cascading thermal failure and the mechanism of a passive heat sink on the mitigation of thermal runaway in a battery module

Predictive Lifetime Modeling

- Semi-empirical models for physical mechanisms
- Regressed to cell aging test data and validated with cell and pack application data
- Integrated in control algorithms and battery systems analysis tools
- Case study:** Life prediction of large LIB Packs with active and passive balancing
- The life model prediction errors stay within +/-3% on capacity fade and +/-5% on resistance growth
- Life balancing resulted in 25-30% life extension benefit