MATLAB EXPO 2019

Developing Battery Management Systems using Simulink

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Application Engineering Group
Motivation

Collaboration

Short Iteration Cycles

High Integrity System
Components of the BMS

**Software**

- Supervisory tasks
- SOC estimation
- Contactor management
- Isolation monitoring
- Fault detection and recovery
- Thermal Management
- Current & Power Limits
- Charge specific behaviour

**Electronics**

- Block Voltage, Temperature Measurement
- Cell Diagnostic
- Cell Balancing

**Battery Pack**
Where do you start?
Name the Model!
Building Models in Simulink and Simscape

Block Count: 9

Block Count: 8
Start with Simulation

Cell Dynamics

Thermal Model

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Building and Fitting Equivalent Circuit Models

Current

discharge pulse

I₀

Open circuit potential

Voltage

V₀

Exponential relaxation

Instantaneous response

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Fitting Equivalent Circuit Models using Parameter Estimation
Develop your Algorithms
Building a BMS in Simulink and Stateflow
Run Closed-Loop Simulations of BMS and Plant model
Test and Verify Algorithms

Automated Testing

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Link Requirements to Implementation
Test and Verify against Requirements
Generate C/C++ Code From BMS Algorithm Models
Generate C/C++ Code From BMS Algorithm Models
Perform HIL Testing for BMS ECUs

Testing ECUs with Battery Cells
- Longer test cycles
- Difficult to reproduce results
- Limited test automation
- Difficult to test fault conditions
Perform HIL Testing for BMS ECUs

Automatic Code Generation

Wiring and Signal Conditioning
Workflow for BMS Development

**Desktop Simulation**
- Simulink Model
  - Algorithms for cell balancing, SOC, SOH
  - Environment, source, battery, circuit, load

**Real-Time Simulation**
- Rapid Prototyping
  - Algorithms running on a real-time computer
- Hardware-in-the-Loop Testing
  - Behavioral models running on a real-time computer

**Hardware Implementation**
- Hardware Prototyping
  - Battery packs, circuit, source, load
- Production Code
  - Algorithms running on an embedded microcontroller

Generate code from model

Real-time communication
Summary

Multi-Domain

Collaborate Across Domains

Long Iteration Cycles

Reduce Iteration Time

High Integrity System

Test and Verify Behaviour
Building Blocks for BMS Development

Physical Modelling

Parameter Estimation

Test Automation

Requirements Linking

Code Generation

Model Checks
Learn More about Battery Management System Design

Developing Battery Management Systems with Simulink and Model-Based Design

https://www.mathworks.com/discovery/battery-models.html

Battery Modeling

Model batteries when designing battery-powered systems

Technical Articles and Newsletters

Modeling and Simulating Battery Performance for Design Optimization

By Cecilia Wang, Romeo Power

Battery Modeling

Examples and How To
- Battery Management System Development in Simulink (7:17) - Video
- Lithium Battery Model with Thermal Effects for System-Level Analysis (24:55) - Video
- Automating Battery Model Parameter Estimation using Experimental Data (25:28) - Video
- Real-Time Simulation of Battery Packs Using Multicore Computers (22:57) - Video
- Battery Simulation and Controls - Consulting Services
- Sifting Through Multisource Data for Safer Battery Materials with Machine Learning - Article

Papers
- High Fidelity Electrical Model with Thermal Dependence for Characterization and Simulation of High Power Lithium Battery Cells - IEEE 2012
- Battery Model Parameter Estimation Using a Layered Technique - SAE 2013
- Simplified Extended Kalman Filter Observer for Battery SOC Estimation - SAE 2013
- Battery Pack Modeling, Simulation, and Deployment on a Multicore Real Time Target - SAE 2014
- Model-Based Parameter Identification of Healthy and Aged Li-ion Batteries for Electric Vehicle Applications - SAE 2015
Additional EXPO Talks

- Simplifying Requirements-Based Verification with Model-Based Design
  - Fraser Macmillen
  - 15:45 – 17:00, Master Classes

- Predictive Maintenance with MATLAB
  - Phil Rottier
  - 15:45 – 17:00, Innovation Auditorium

- Developing Fit-For-Purpose Simscape Models to Support System and Control Design
  - Rick Hyde
  - 16:15 – 17:00, Model-Based Design