MATLAB EXPO 2019

Simulink를 이용한 배터리 관리 시스템(Battery Management System) 개발

강효석
Motivation

Collaboration
Multi-Domain
Physical Modeling

Short Iteration Cycles
Virtual Prototyping

Safety Critical System
HIL Testing

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What is BMS?

**Software**

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

**Electronics**

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

**Battery Pack**

- Monitoring
- Current & Voltage
- System Protection

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Agenda

- Battery Modeling
  - Equivalent Circuit Model
  - Expansion of Physical Model

- Algorithm Development
  - Algorithm Modeling
  - Code Generation

- Hardware-In-the-Loop Test
Battery Modeling
Battery Modeling

- Equivalent Circuit
- Parameter Estimation
Cell Modeling Using 1RC circuit
Cell Modeling Using 3RC circuit
Battery Cell ↔ Large Battery Pack

Cell Dynamics

Thermal Model
Battery Pack Modeling with Thermal Dynamics
Large Battery Pack Modeling
Battery Cell ↔ Large Battery Pack

Cell Dynamics

Thermal Model
System Level Simulation - Collaboration

Battery  
Converter  
Inverter  
Motor  
Vehicle
## Simulation Level

<table>
<thead>
<tr>
<th></th>
<th>Cell Level</th>
<th>Pack Level</th>
<th>System Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current</strong></td>
<td><img src="image1" alt="Current" /></td>
<td><img src="image2" alt="Current" /></td>
<td><img src="image3" alt="Current" /></td>
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<tr>
<td><strong>Voltage</strong></td>
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<td><img src="image5" alt="Voltage" /></td>
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<tr>
<td><strong>SOC</strong></td>
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<td><img src="image8" alt="SOC" /></td>
<td><img src="image9" alt="SOC" /></td>
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<tr>
<td><strong>Temperature</strong></td>
<td><img src="image10" alt="Temperature" /></td>
<td><img src="image11" alt="Temperature" /></td>
<td><img src="image12" alt="Temperature" /></td>
</tr>
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Develop & Test Algorithms in Simulink
BMS Algorithm

- Supervisory control
- Fault detection and recovery
- Contactor management
- Current & Power Limits
- Cell Balancing
- SOC estimation
Make it easy to design algorithms

Stateflow

Simulink
Passive Cell balancing
Test with Algorithms
Test with Algorithms using Simulink Test
Generate C/C++ Code From BMS Algorithm Models

Find out more:
간편해진 C/C++코드 생성 설정 방법 소개

Tech Talk Special 트랙 유재흥
Agenda

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Perform HIL Testing for BMS ECUs (1/2)

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 (2/2)
What is Simulink Real-Time?
From Desktop Simulation to Real-Time Execution

1. Code Generation
2. Compile and Link
3. Download and Ready to Run
What is Simulink Real-Time?
Connect to Your Physical System

- Support for a broad range of I/O types and communication protocols
- Easy drag and drop and configuration within a Simulink model

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Fast-Track from Desktop to Real-Time Simulation and Testing
Add HMI and scope blocks to Simulink for real-time tuning, monitoring, and data logging
**Speedgoat Machine**

- Real-time target machines for office, lab, and field use
- 200+ commercial off-the-shelf I/O modules
- Each target machine is configured to meet your I/O, environmental, and sample rate requirements
- Simulink Real-Time is expressly and exclusively designed to work together with Speedgoat hardware
- Most current MATLAB release always supported
IO991: Battery Emulation I/O Module

- **Key Features:**
  - 6 independent isolated channels
  - Architecture allows series & parallel combinations
  - Independent power and sense lines
  - Voltage range of 0-7 V with 14-bit resolution
  - 300 mA source to load
  - 100 mA sink adjustable in 16 steps

- **Enables:**
  - Test automation and repeatable testing
  - Fault testing safely
  - Reuse testcases from earlier desktop testing
Automated Testing with Simulink Test
Real-Time Test Automation, Ideal for Hardware-in-the-Loop

Download real-time application
Collect verification data

Target Computer  I/O  Physical System
LG Chem Develops AUTOSAR - and ISO 26262 - Compliant Software for a Hybrid Vehicle Battery Management System

Challenge
Design and implement production battery management system (BMS) software for the Volvo XC90 plug-in hybrid

Solution
Use Model-Based Design with MATLAB and Simulink to model, simulate, verify, and generate production code for AUTOSAR application layer software components

Results
- Existing library of core components reused
- Software issues reduced by more than 50%
- ISO 26262 ASIL C certification achieved

“Model-Based Design with MATLAB and Simulink] enables us to increase component reuse, reduce manual coding, improve communication with our customers, and ultimately deliver higher-quality BMS in less time.”
- Won Tae Joe, LG Chem

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Summary

Collaboration
Physical Modeling

Short Iteration Cycles
Virtual Prototyping

Safety Critical System
HIL Testing

Collaborate Across Domains
Reduce Iteration Time
Functional Safety Certification

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데모 부스와 상담부스로 질문 하시기 바랍니다.

감사합니다
Taking It Further

Parameter Estimation

Model Checks

Test Automation

Design Error Detection

HDL Code Generation

Model Coverage
Learn More about Battery Management System

WHITE PAPER

Developing Battery Management Systems with Simulink and Model-Based Design

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

MathWorks®

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 (24:05) - 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