MATLAB EXPO 2019

Simulink를 이용한 배터리 관리 시스템(Battery Management System)개발

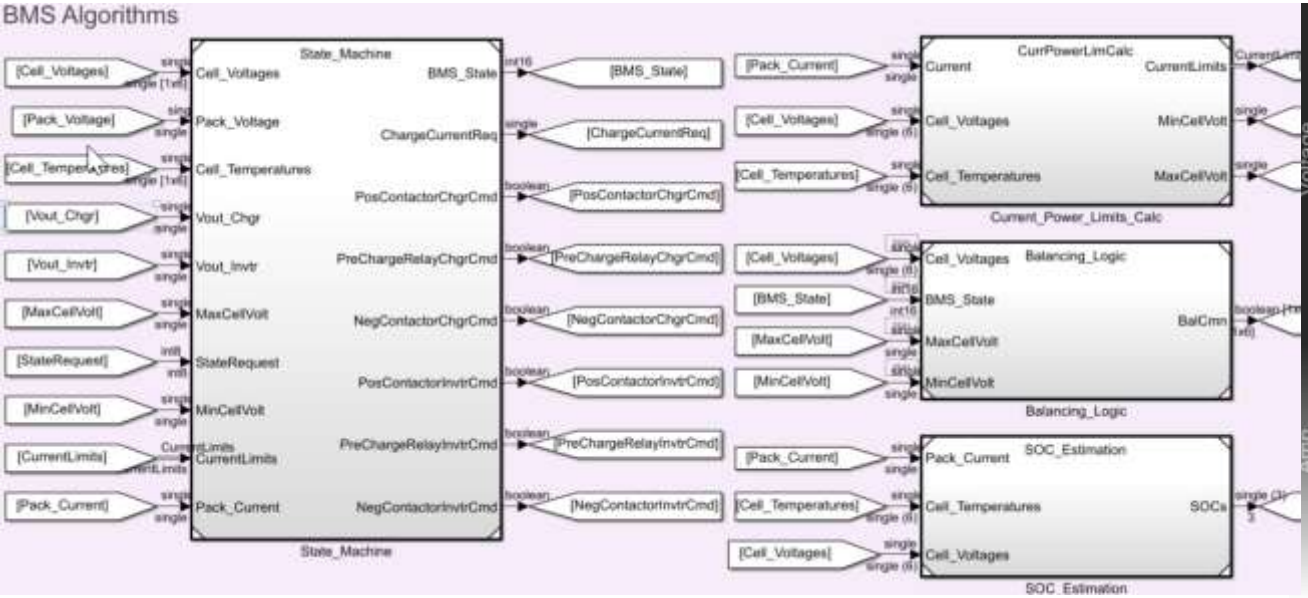
강효석

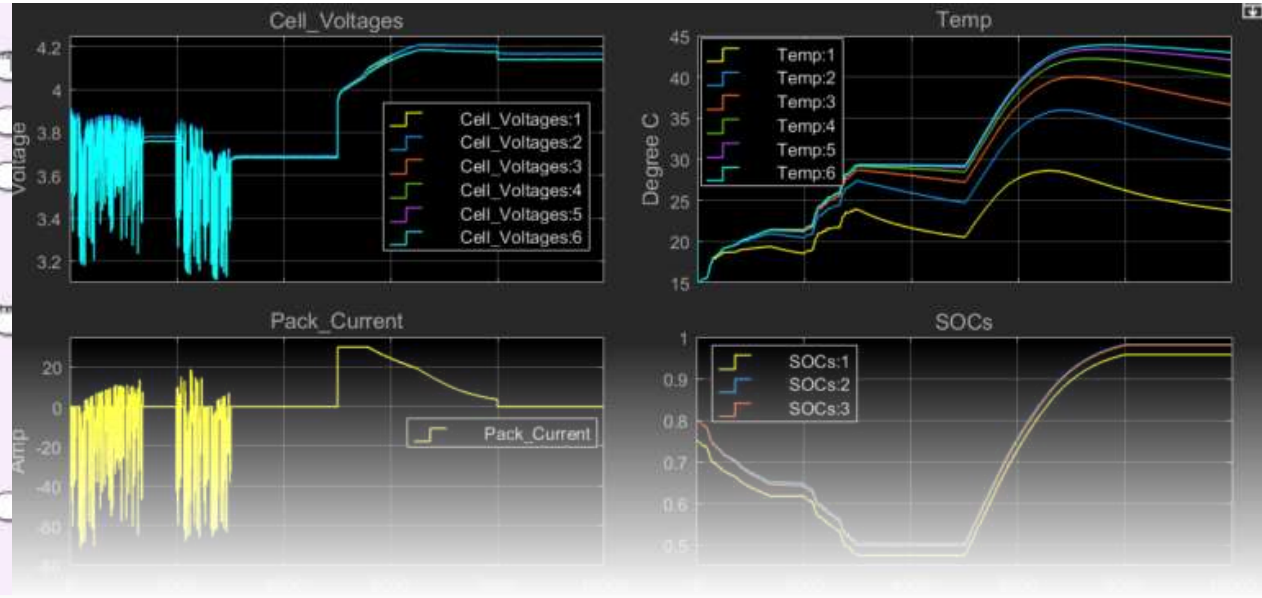
Motivation

Collaboration
Multi-Domain
Physical Modeling

Short Iteration Cycles
Virtual Prototyping

Safety Critical System
HIL Testing





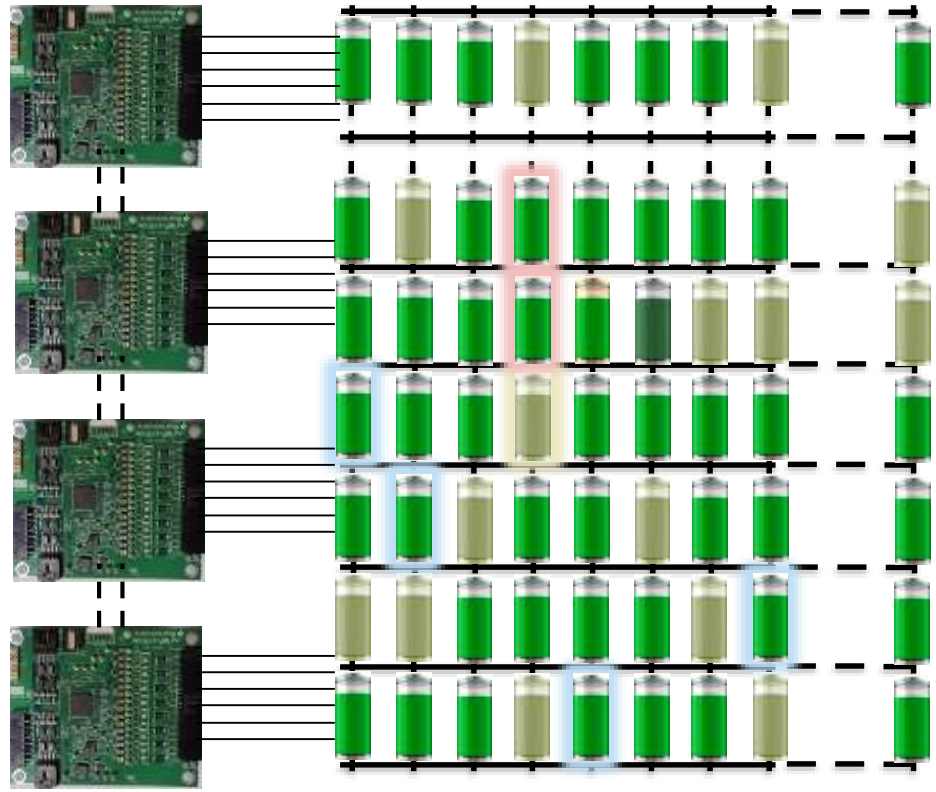
What is BMS?

Software | **Electronics** | **Battery Pack**

```
if (((uint32_T)State_Machine_DW.temporalCounter_i3) < 15U) {
  State_Machine_DW.temporalCounter_i3 = (uint8_T)((int32_T)(((int32_T)
    State_Machine_DW.temporalCounter_i3) + 1));
}

if (((uint32_T)State_Machine_DW.is_active_c2_State_Machine) == 0U) {
  State_Machine_DW.is_active_c2_State_Machine = 1U;
  State_Machine_DW.is_MainStateMachine = State_Machine_IN_Standby;
  *rty_BMS_State = 0;
  State_Machine_DW.MonitorCurrLimMode = MonitorCurrLimModeType_NoCurrLimFaul
  State_Machine_DW.MonitorCellVoltageMode =
    MonitorCellVoltageModeType_NoCellVoltFault;
  State_Machine_DW.Delta = (real32_T)fabs((real_T)((real32_T)
    ((*rtu_Pack_Voltage) - sum_gyOCKAG3(rtu_Cell_Voltages))));
  State_Machine_DW.FaultPresent = false;
```

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

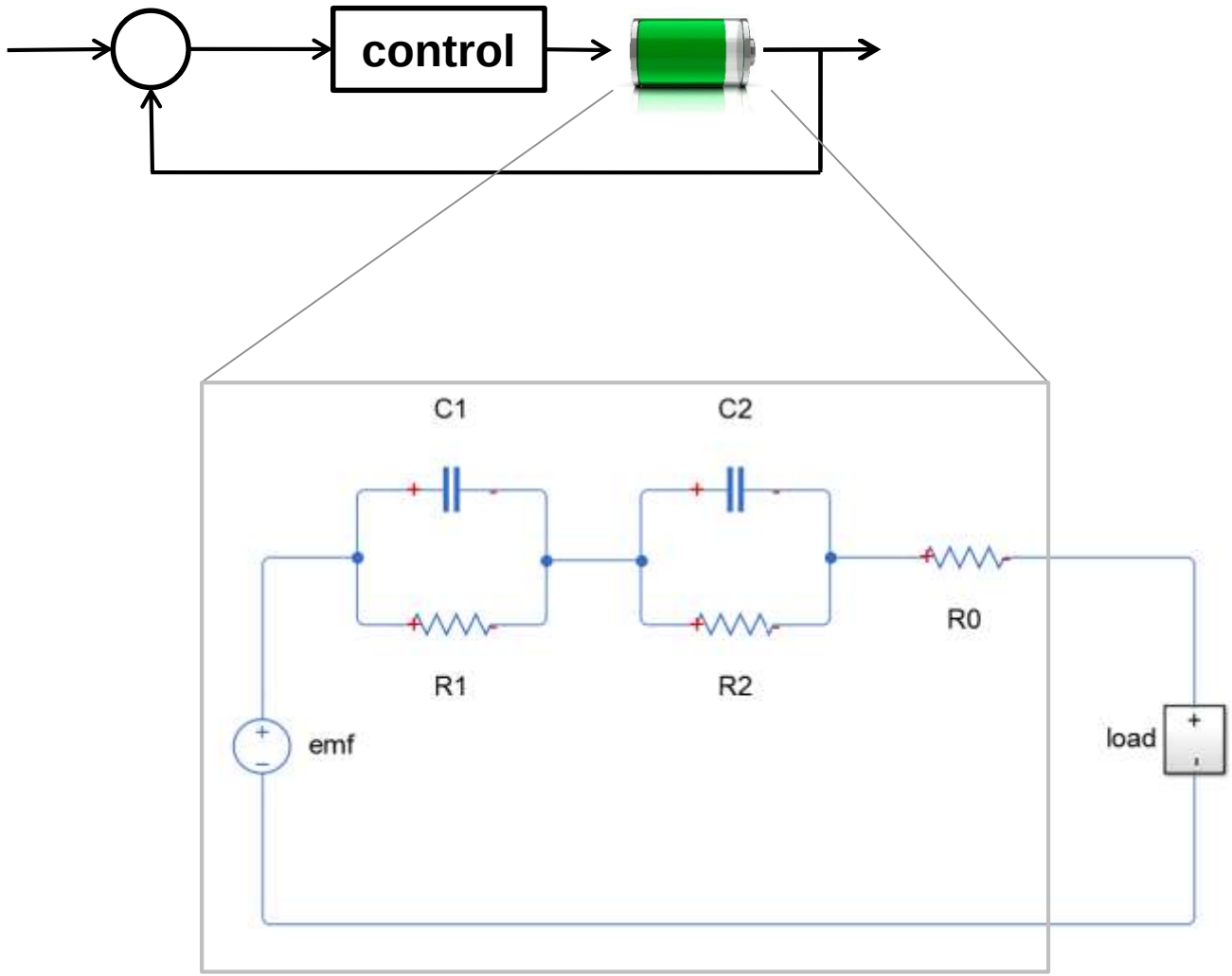


Block Voltage,
Temperature Measurement
Cell Diagnostic
Cell Balancing

Agenda

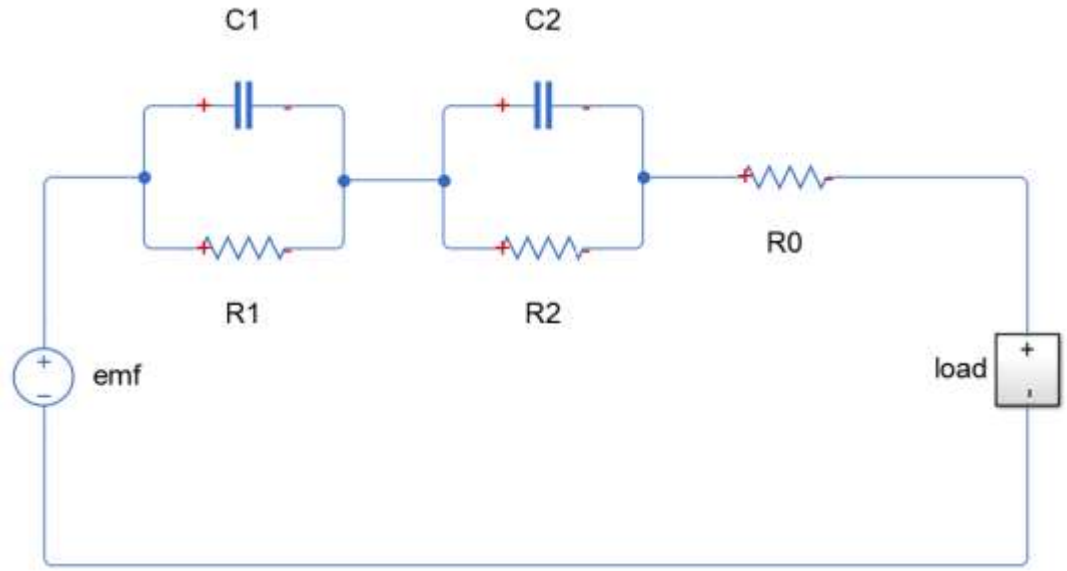
- Battery Modeling
  - Equivalent Circuit Model
  - Expansion of Physical Model
- Algorithm Development
  - Algorithm Modeling
  - Code Generation
- Hardware-In-the-Loop Test

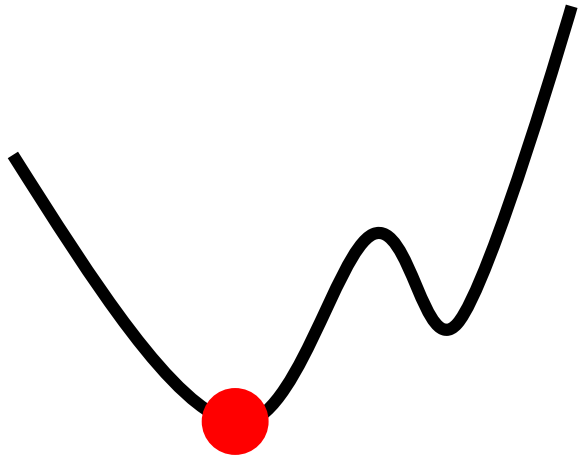
Battery Modeling



Battery Modeling

- Equivalent Circuit
- Parameter Estimation





High Fidelity Electrical Model with Thermal Dependence for Characterization and Simulation of High Power Lithium Battery Cells

Tarun Huria, Massimo Ceraolo
Department of Energy and Systems Engineering
University of Pisa
Largo Lazzarino, Pisa 56122 Italy
m.ceraolo@ing.unipi.it

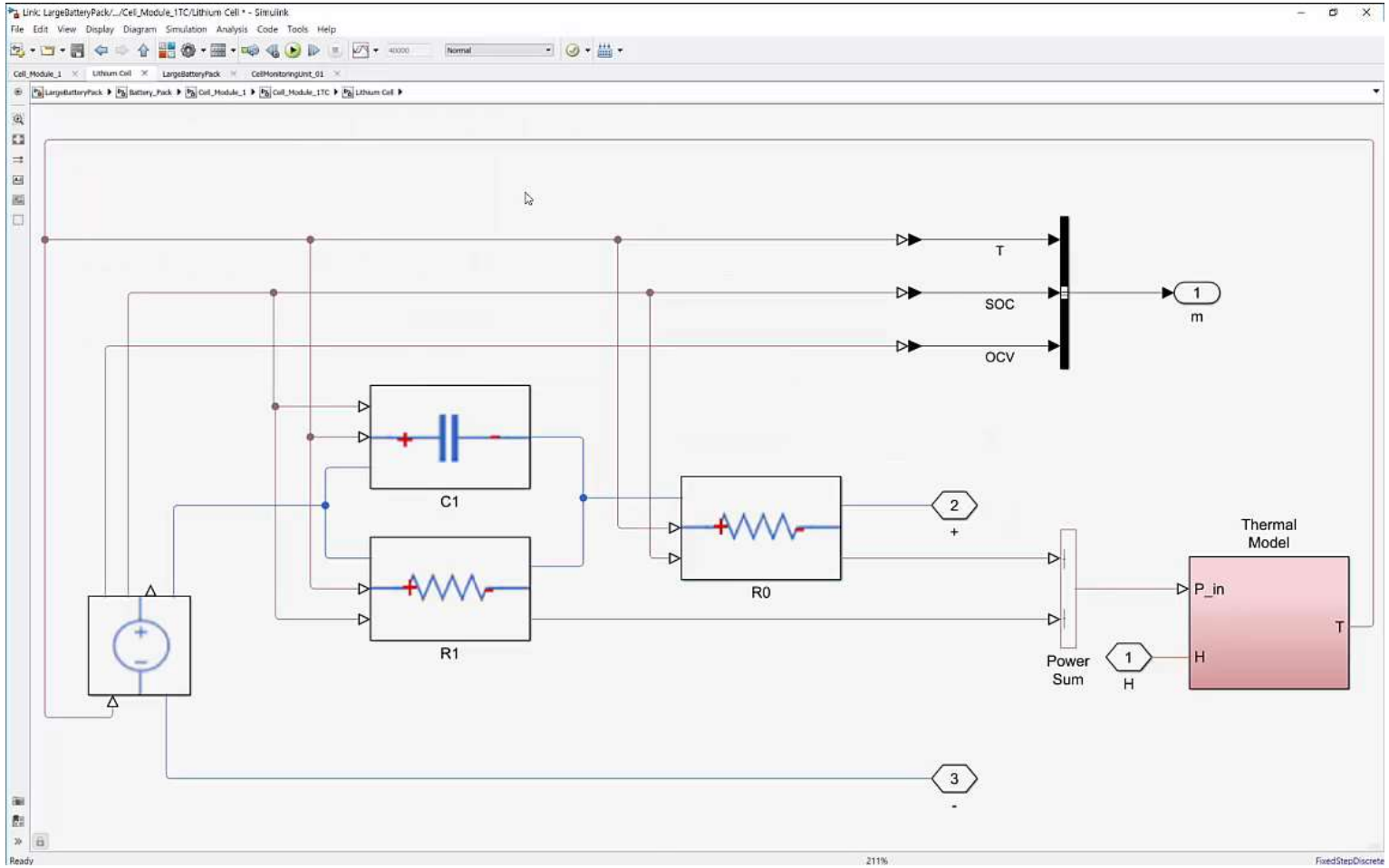
Javier Gazzarri, Robyn Jackey
MathWorks
39555 Orchard Hill Place, Suite 280
Novi, MI 48375 USA
robyn.jackey@mathworks.com

Abstract— The growing need for accurate simulation of advanced lithium cells for powertrain electrification demands fast and accurate modeling schemes. Additionally, battery models must account for thermal effects because of the paramount importance of temperature in kinetic and transport phenomena of electrochemical systems. This pa-

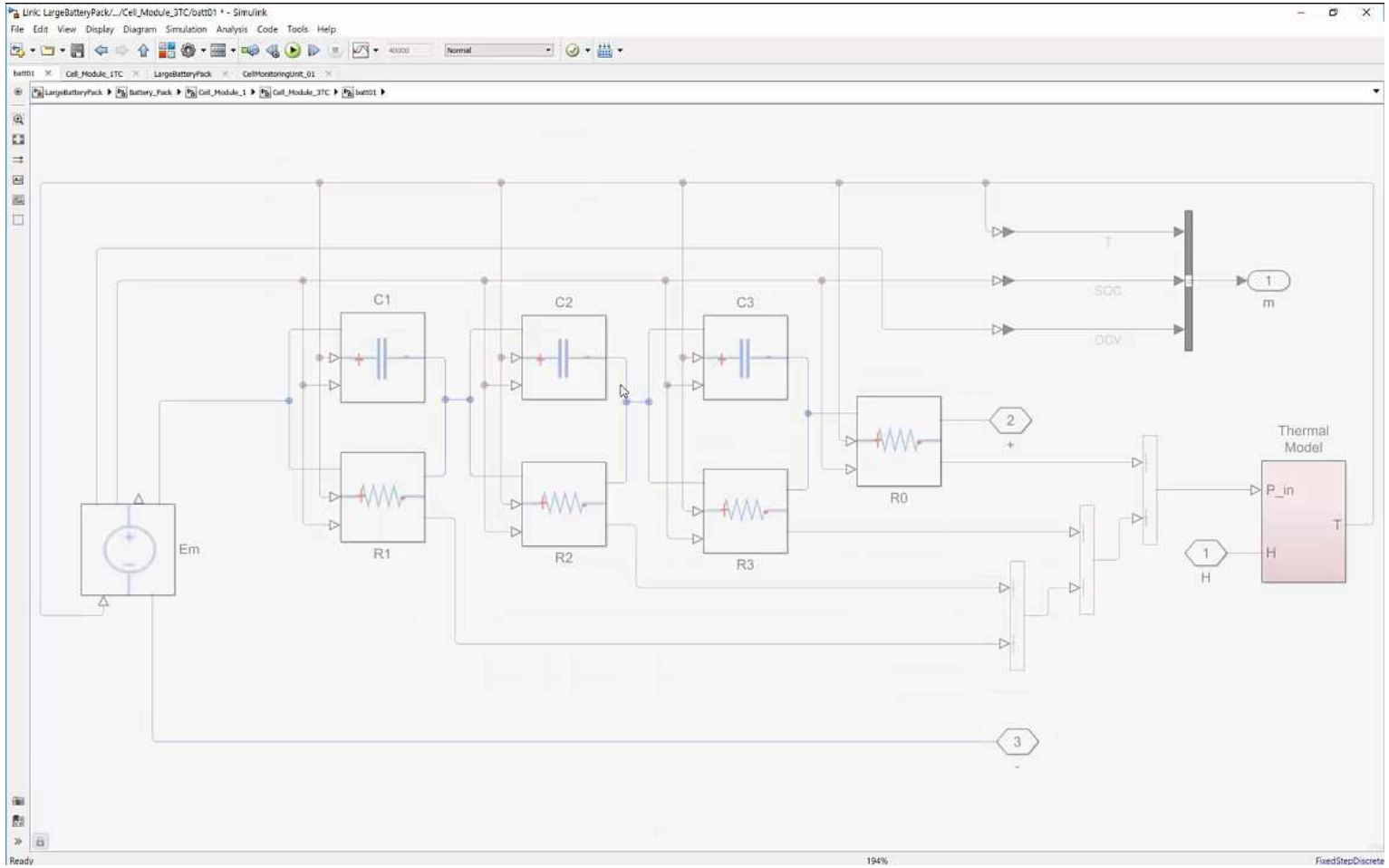
OCV	open circuit voltage (V)
P_s	power dissipated inside the cell (W)
Q_e	extracted charge from cell (Ah)
R_n	resistor n, where n is a natural number (Ω)
R_T	convection resistance ($W^1\ m^{-2}\ K^{-1}$))

2012 IEEE INTERNATIONAL ELECTRIC VEHICLE CONFERENCE

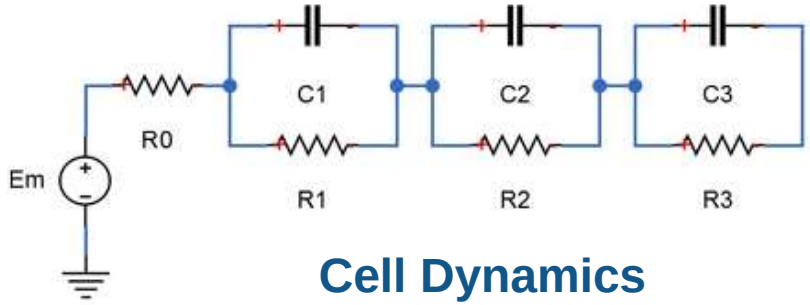
Cell Modeling Using 1RC circuit



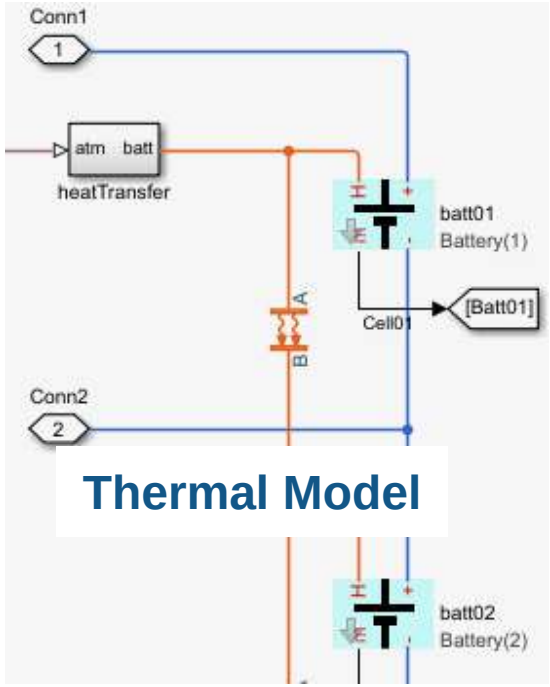
Cell Modeling Using 3RC circuit



Battery Cell ←→ Large Battery Pack

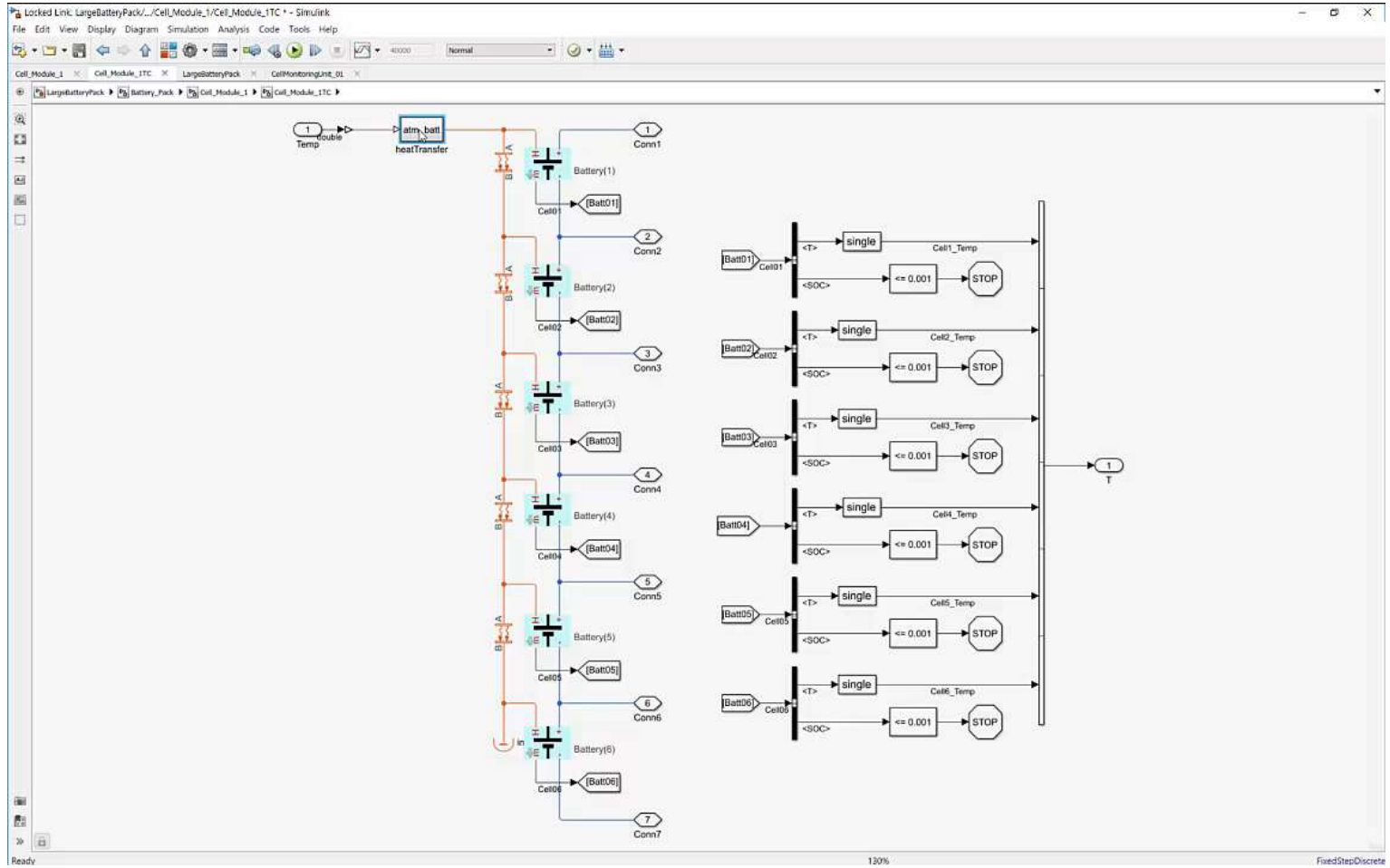


Cell Dynamics

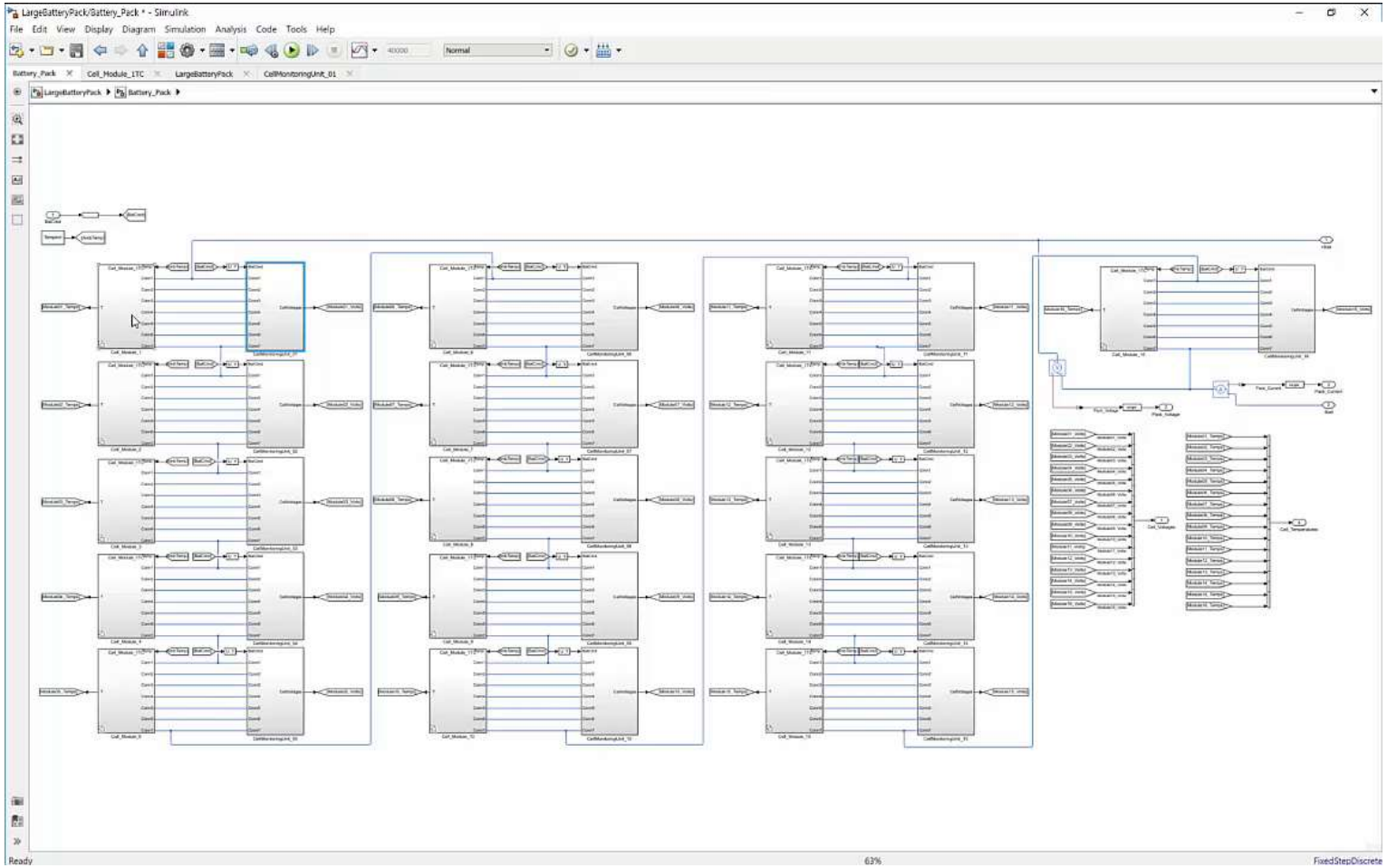


Thermal Model

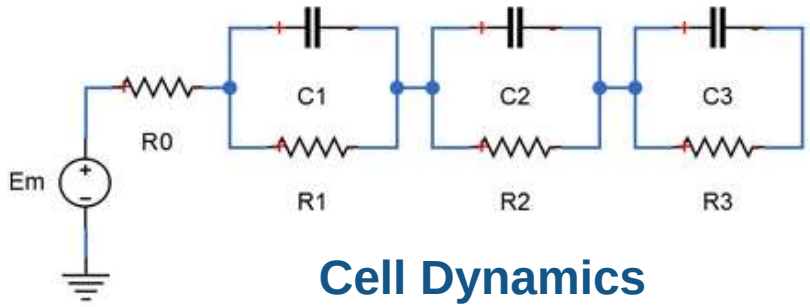
Battery Pack Modeling with Thermal Dynamics



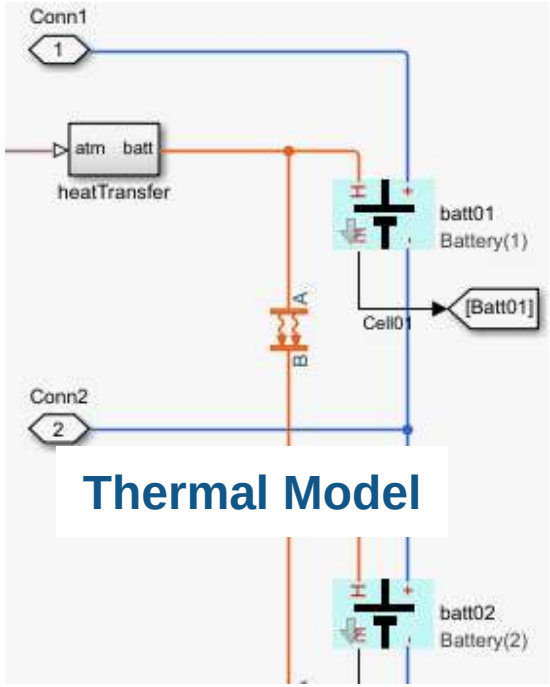
Large Battery Pack Modeling



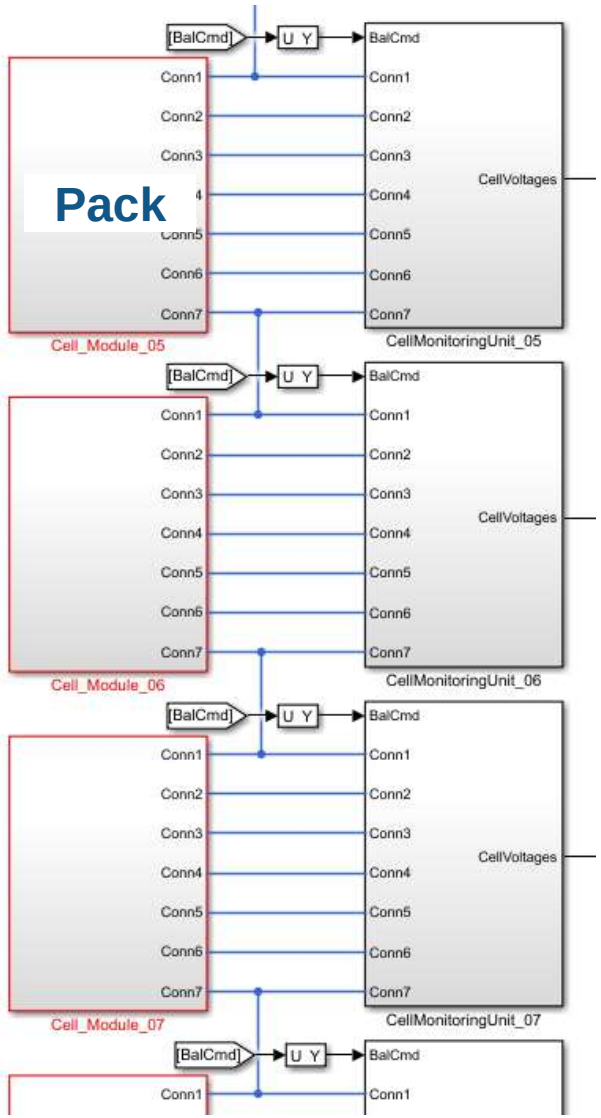
Battery Cell ←→ Large Battery Pack

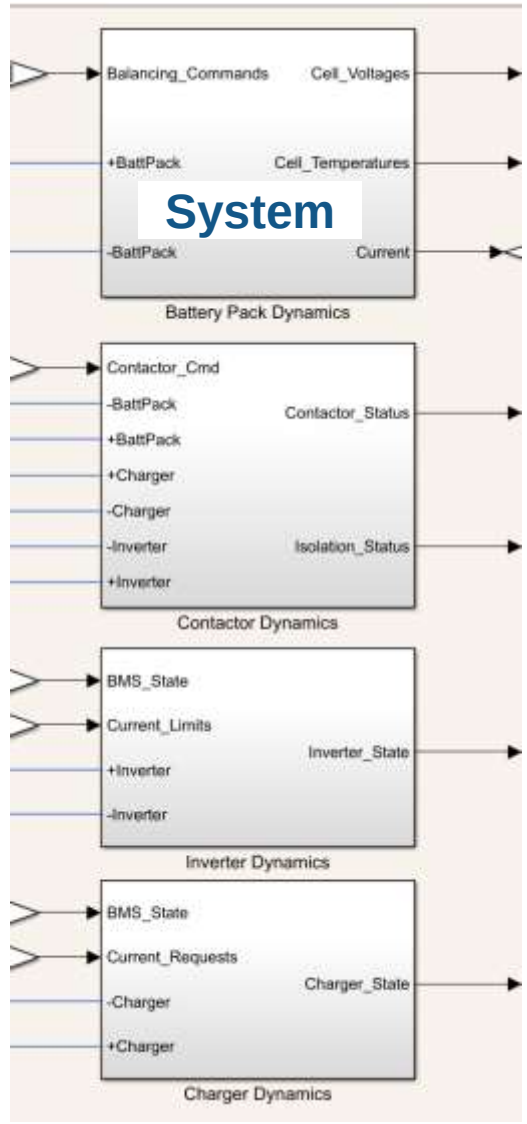


Cell Dynamics

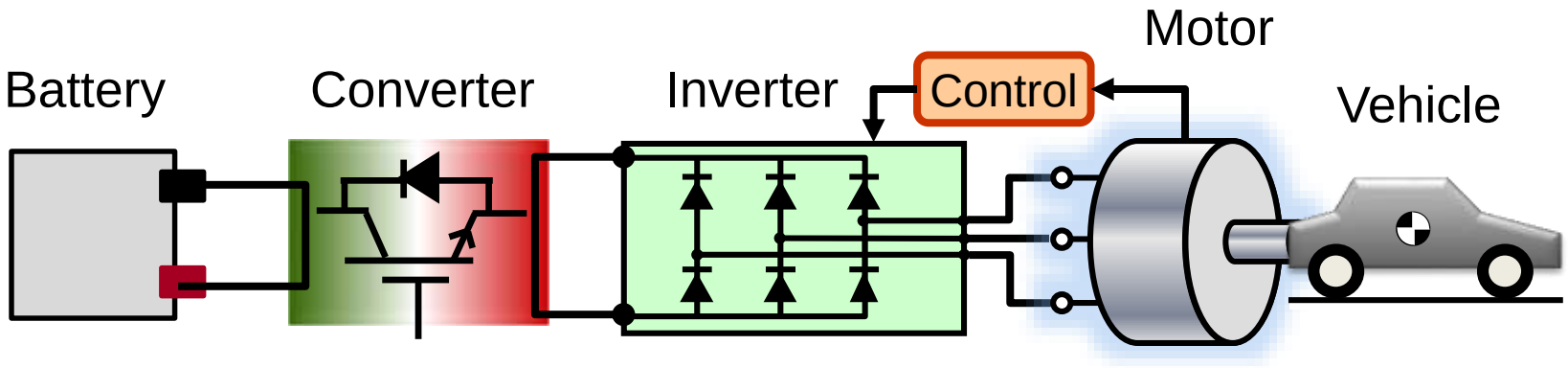


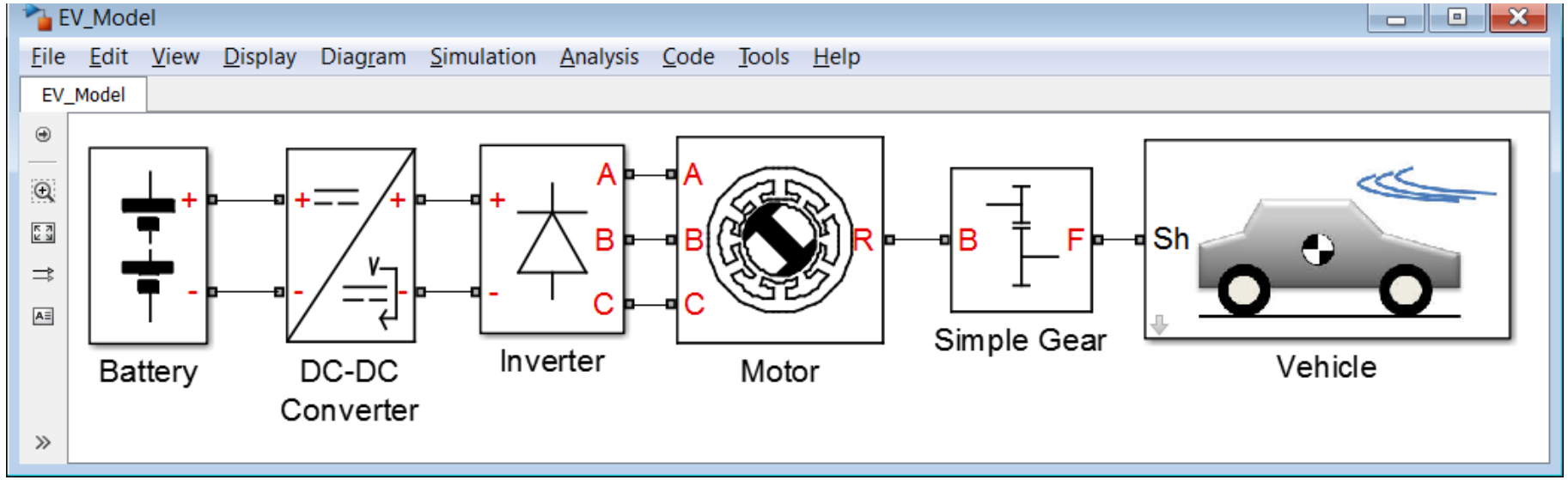
Thermal Model



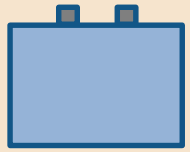
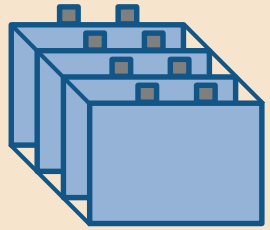
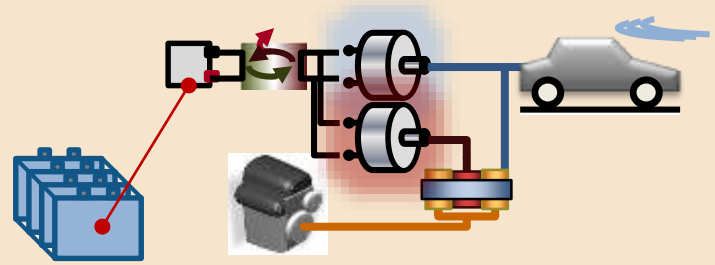
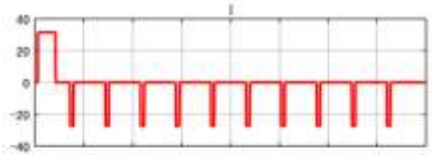
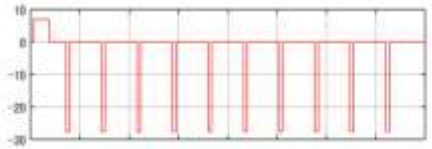
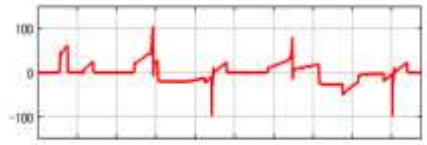
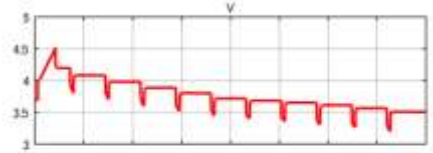
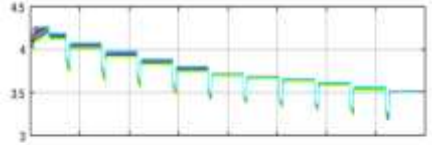
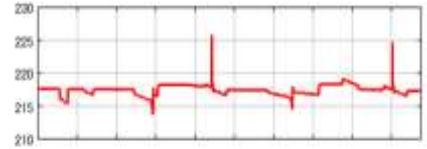
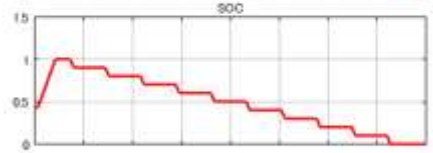
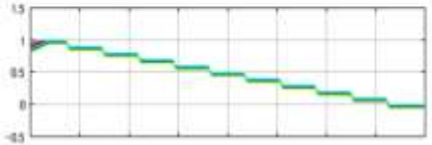
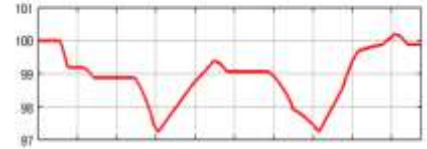
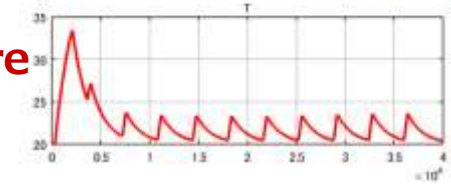
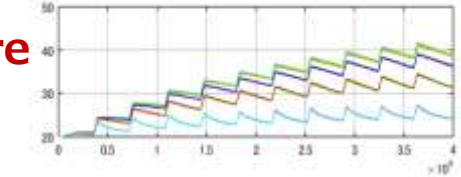
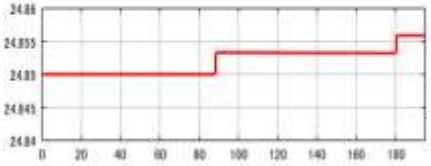


System Level Simulation - Collaboration





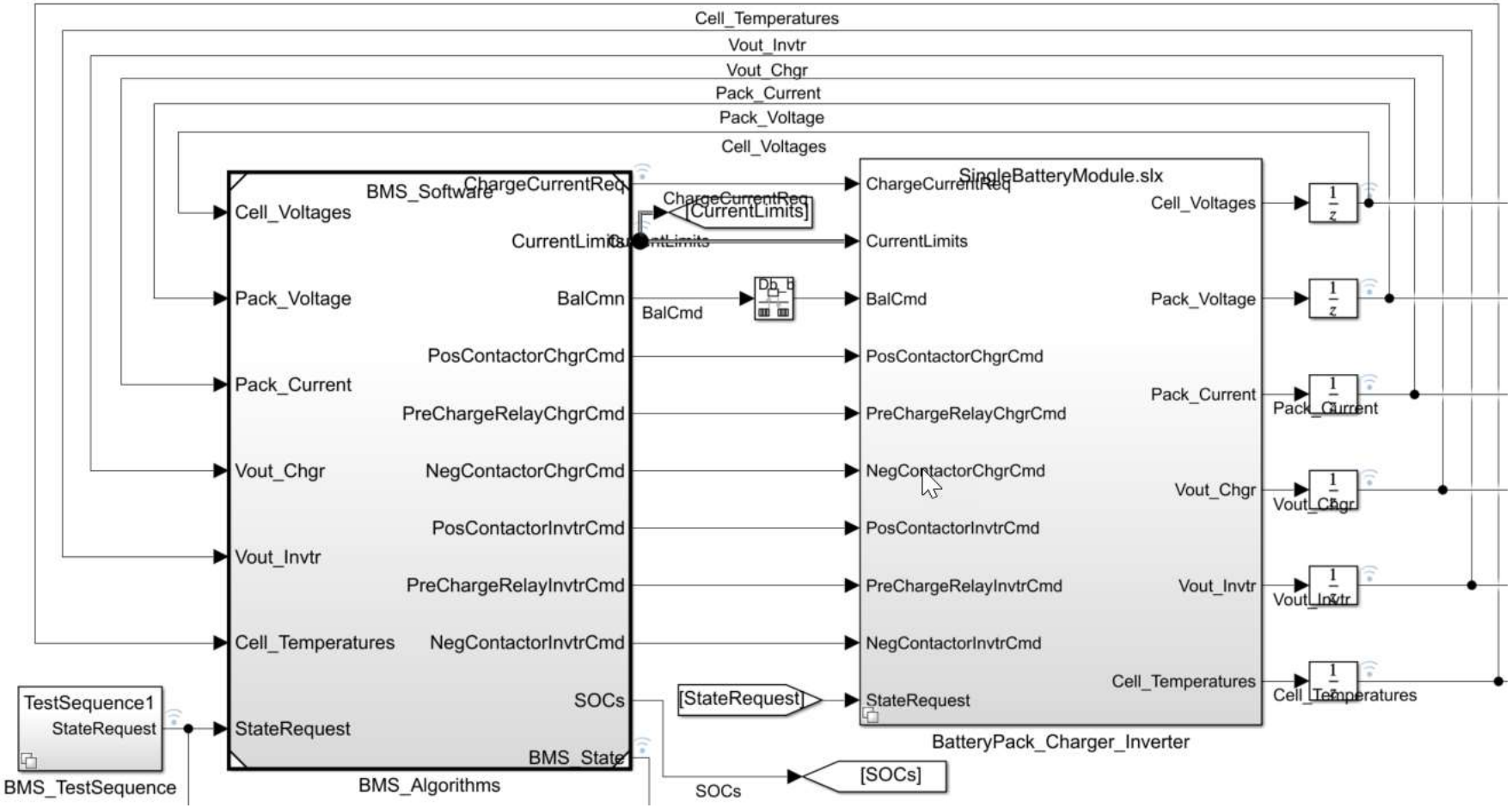
Simulation Level

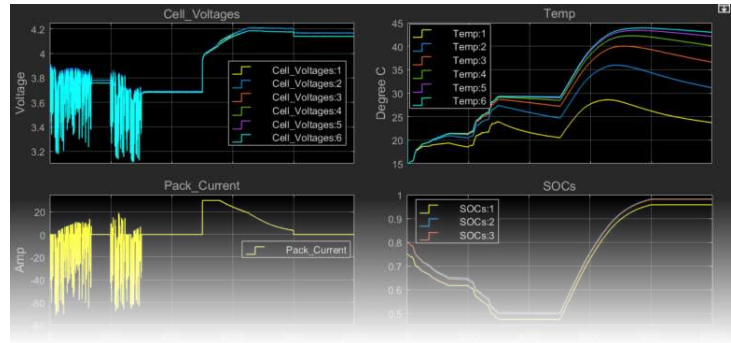
Cell Level	Pack Level	System Level
		
Current 	Current 	Current 
Voltage 	Voltage 	Voltage 
SOC 	SOC 	SOC 
Temperature 	Temperature 	Temperature 

Agenda

- Battery Modeling
  - Equivalent Circuit Model
  - Expansion of Physical Model
- Algorithm Development
  - Algorithm Modeling
  - Code Generation
- Hardware-In-the-Loop Test

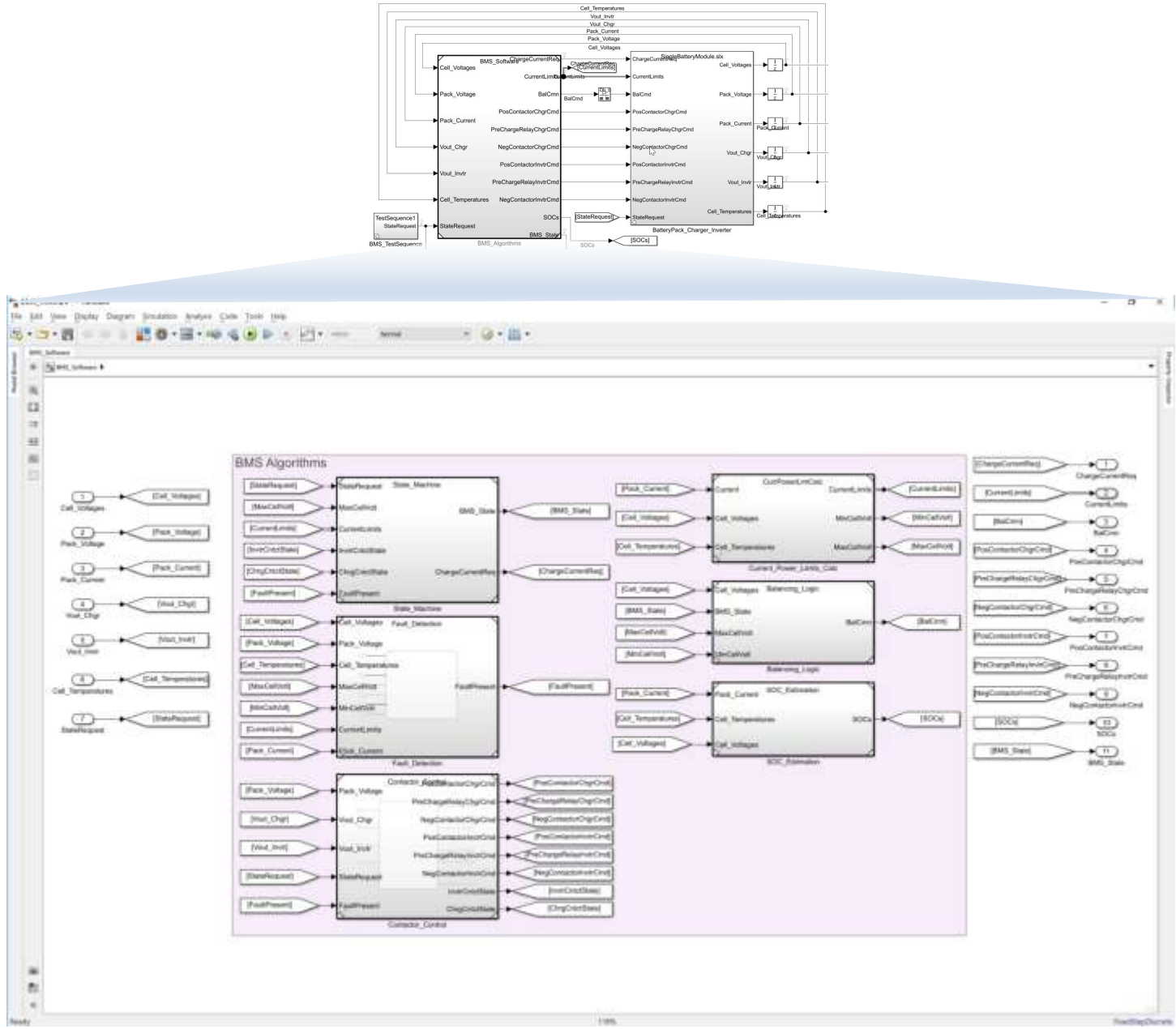
Develop & Test Algorithms in Simulink



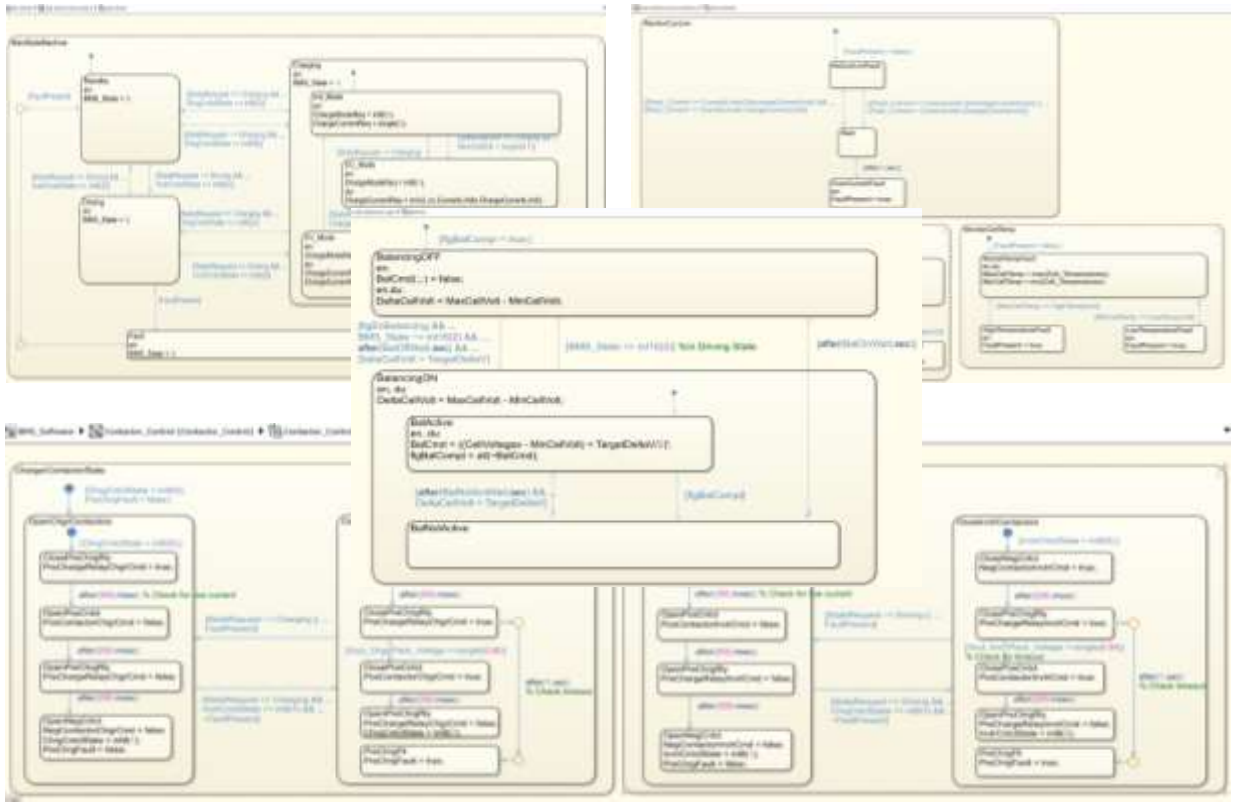


BMS Algorithm

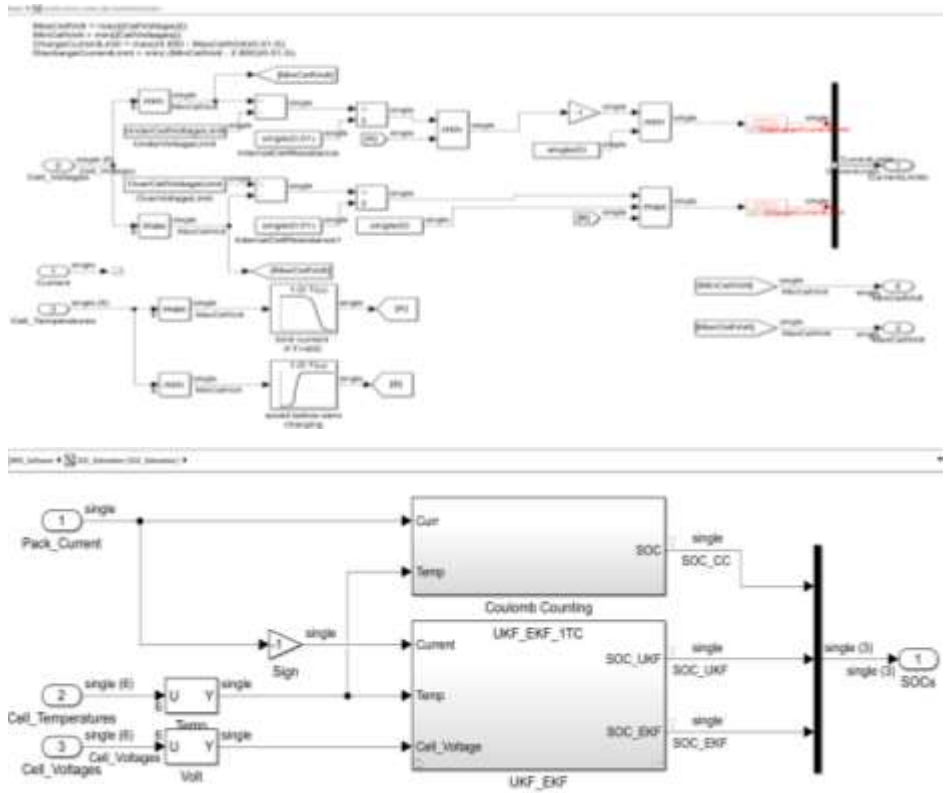
- Supervisory control
- Fault detection and recovery
- Contactor management
- Current & Power Limits
- Cell Balancing
- SOC estimation



Make it easy to design algorithms

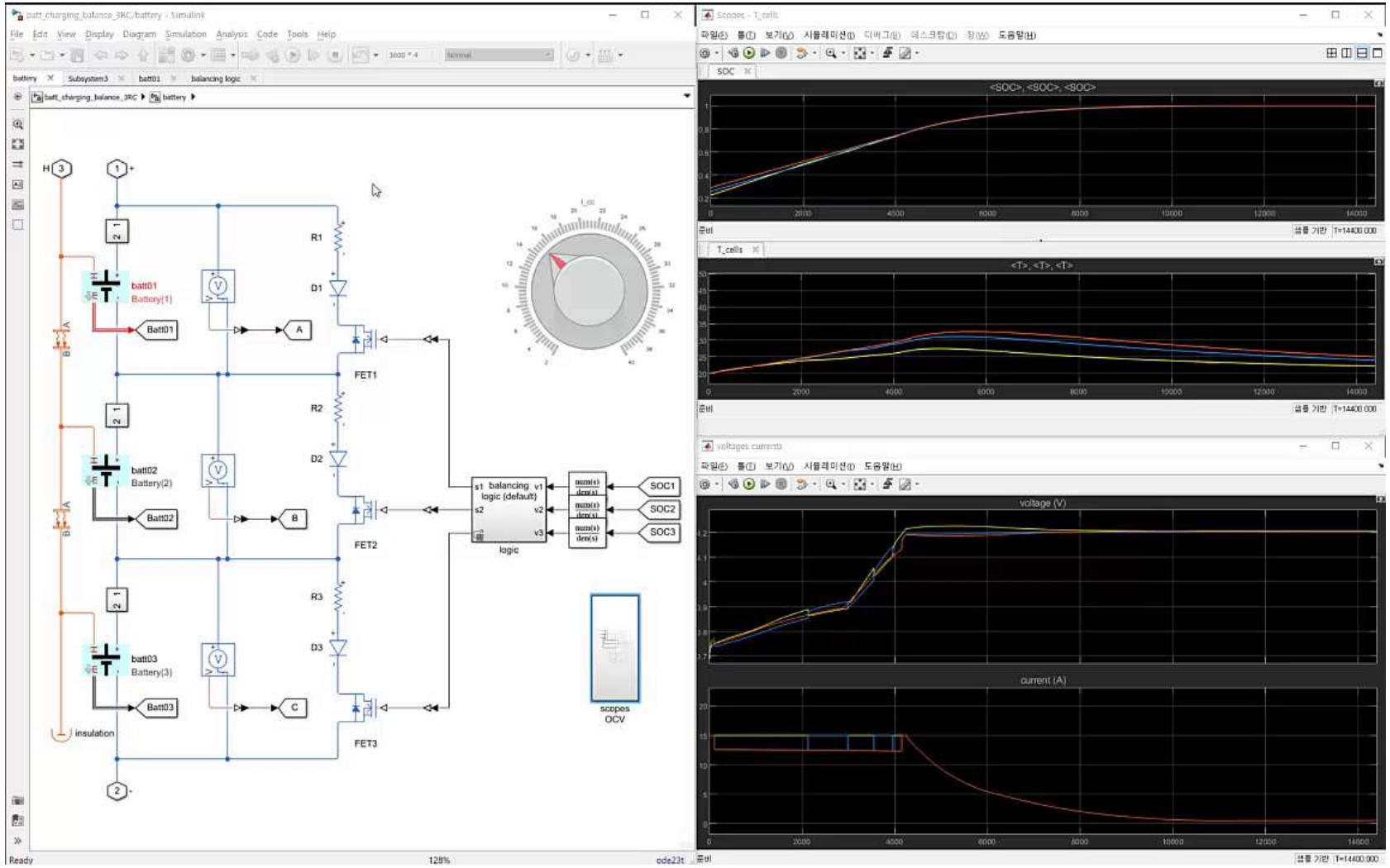


Stateflow

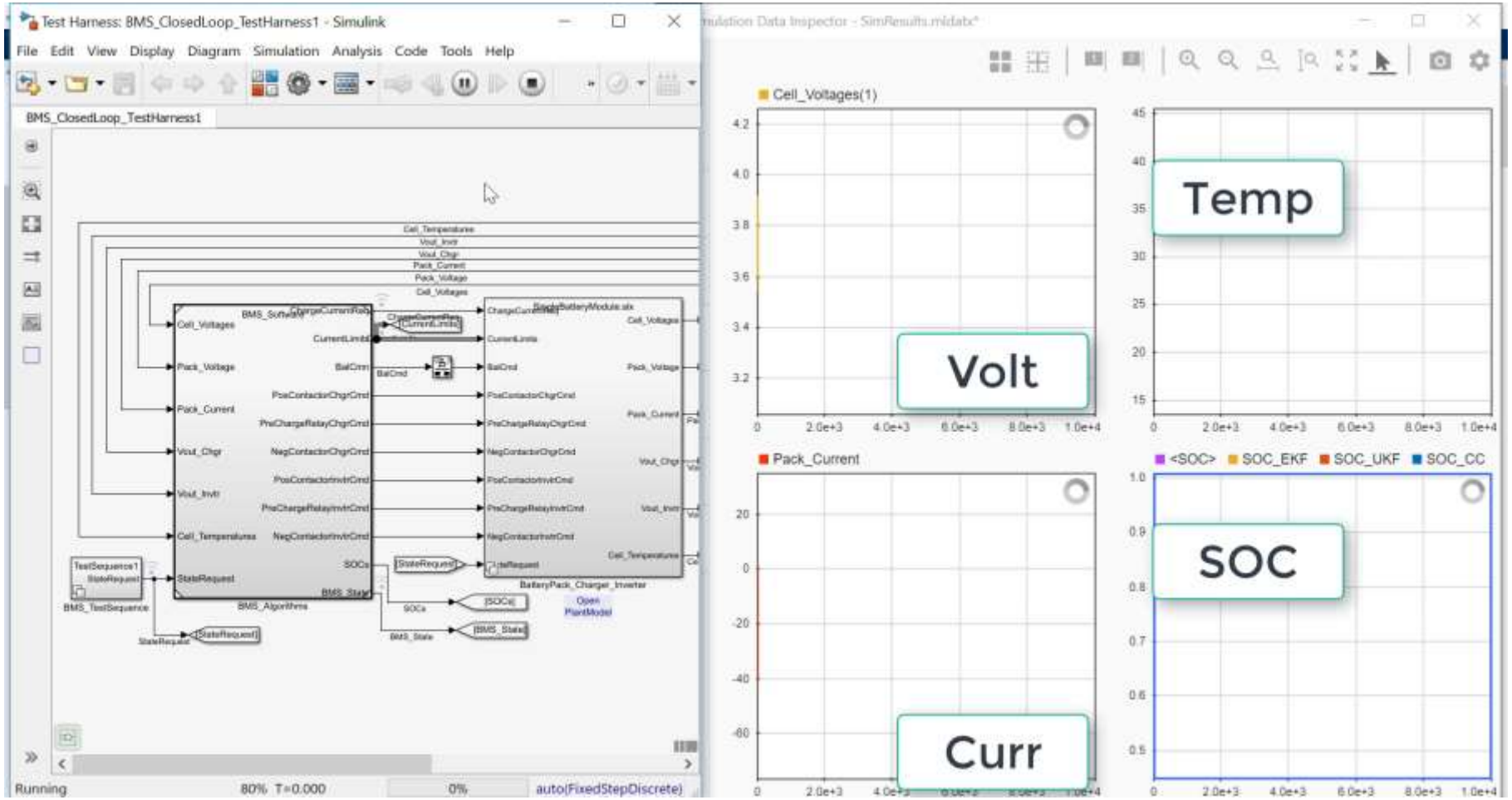


Simulink

Passive Cell balancing

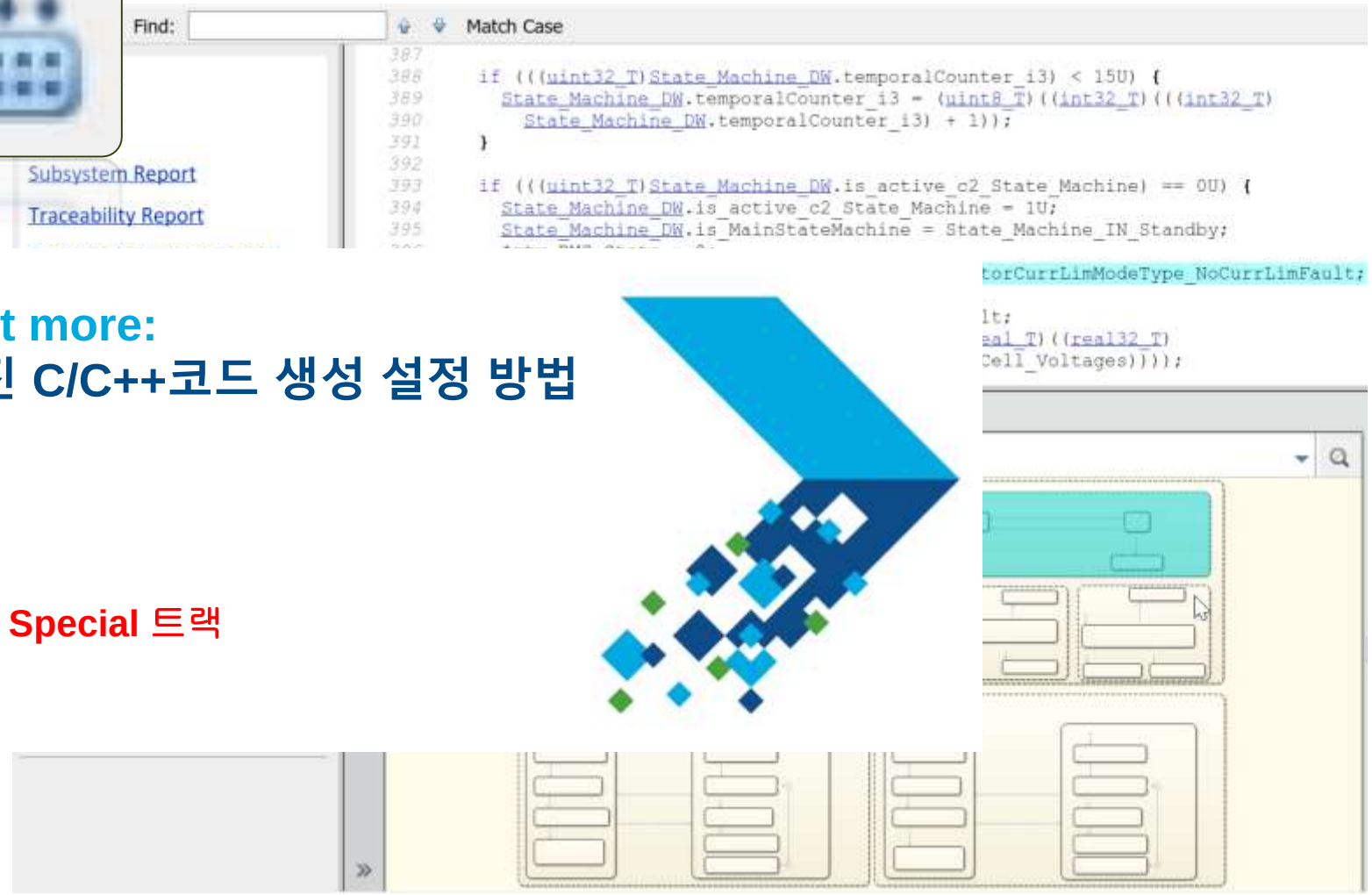


Test with Algorithms



Test with Algorithms using Simulink Test

Generate C/C++ Code From BMS Algorithm Models



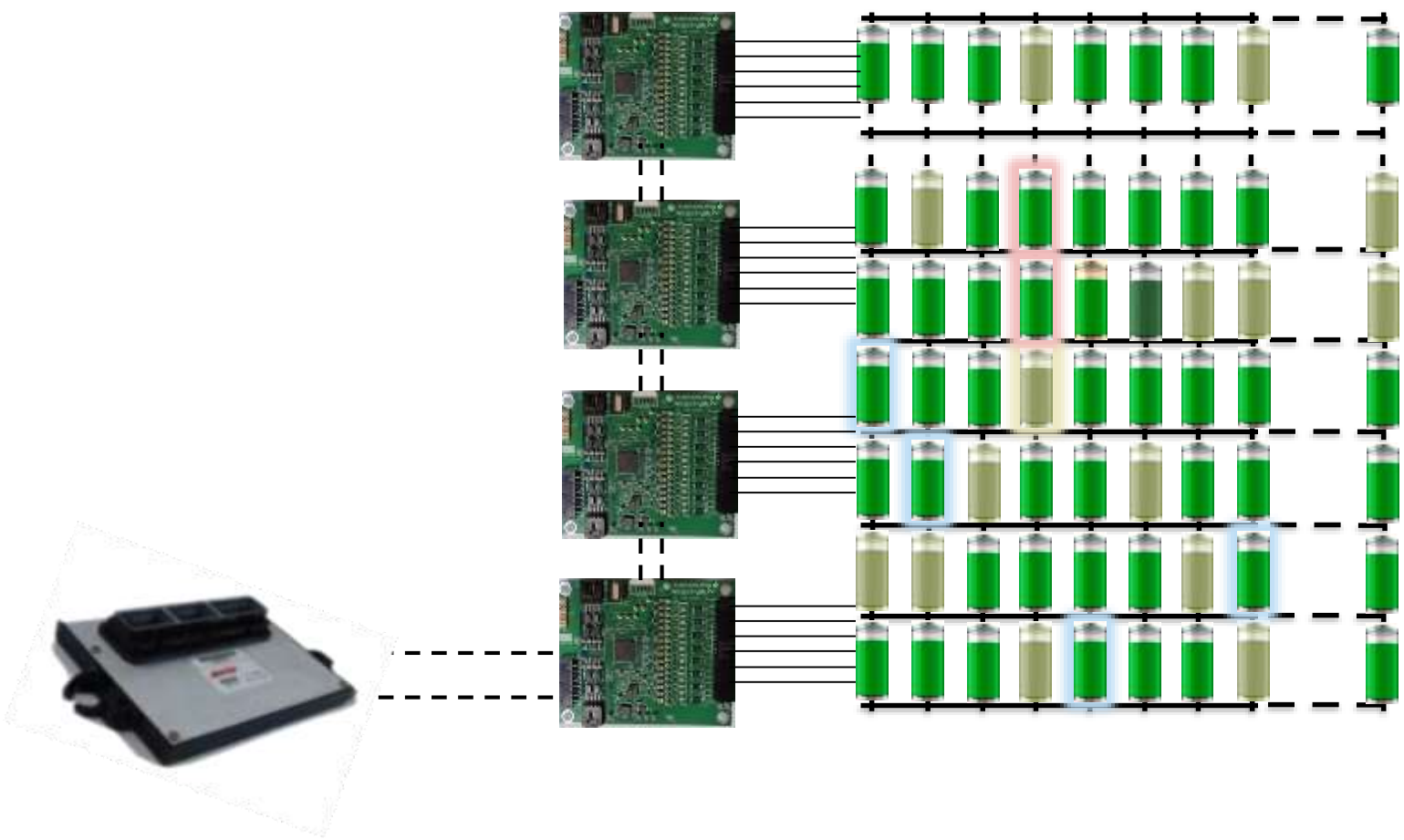
Find out more:
간편해진 C/C++코드 생성 설정 방법 소개

Tech Talk Special 트랙
유재흥

Agenda

- Battery Modeling
  - Equivalent Circuit Model
  - Expansion of Physical Model
- Algorithm Development
  - Algorithm Modeling
  - Code Generation
- Hardware-In-the-Loop Test

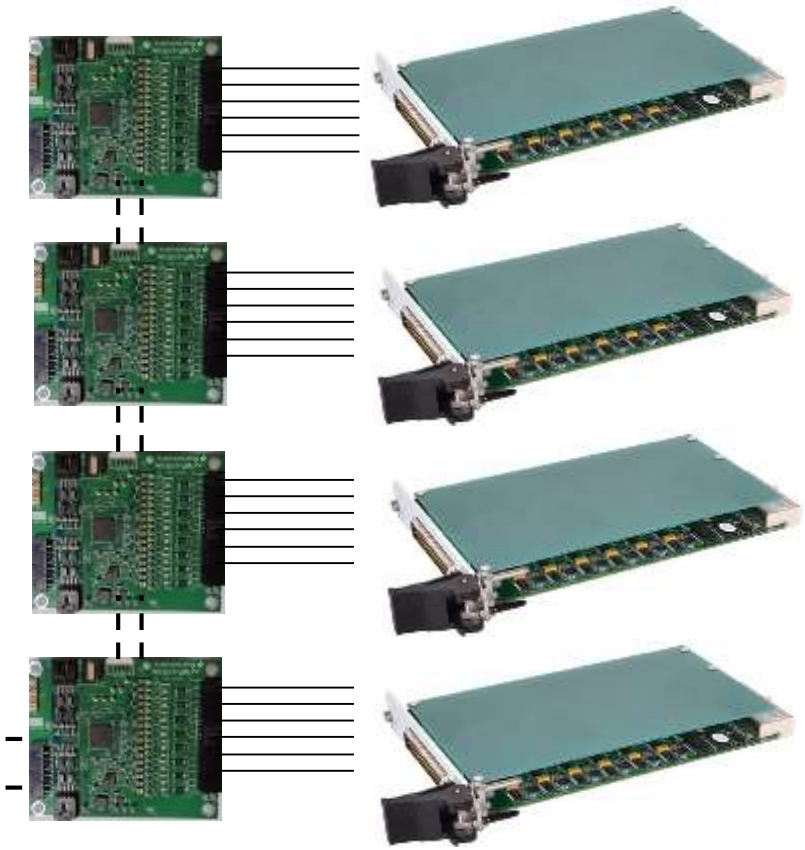
Perform HIL Testing for BMS ECUs (1/2)

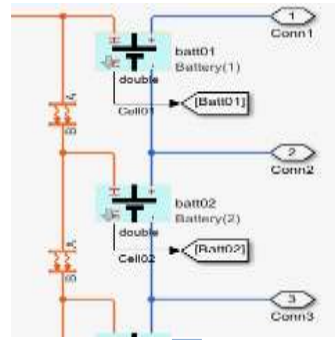


Testing ECUs with Battery Cells

- Longer test cycles
- Difficult to reproduce results
- Limited test automation
- Difficult to test fault conditions

Perform HIL Testing for BMS ECUs (2/2)



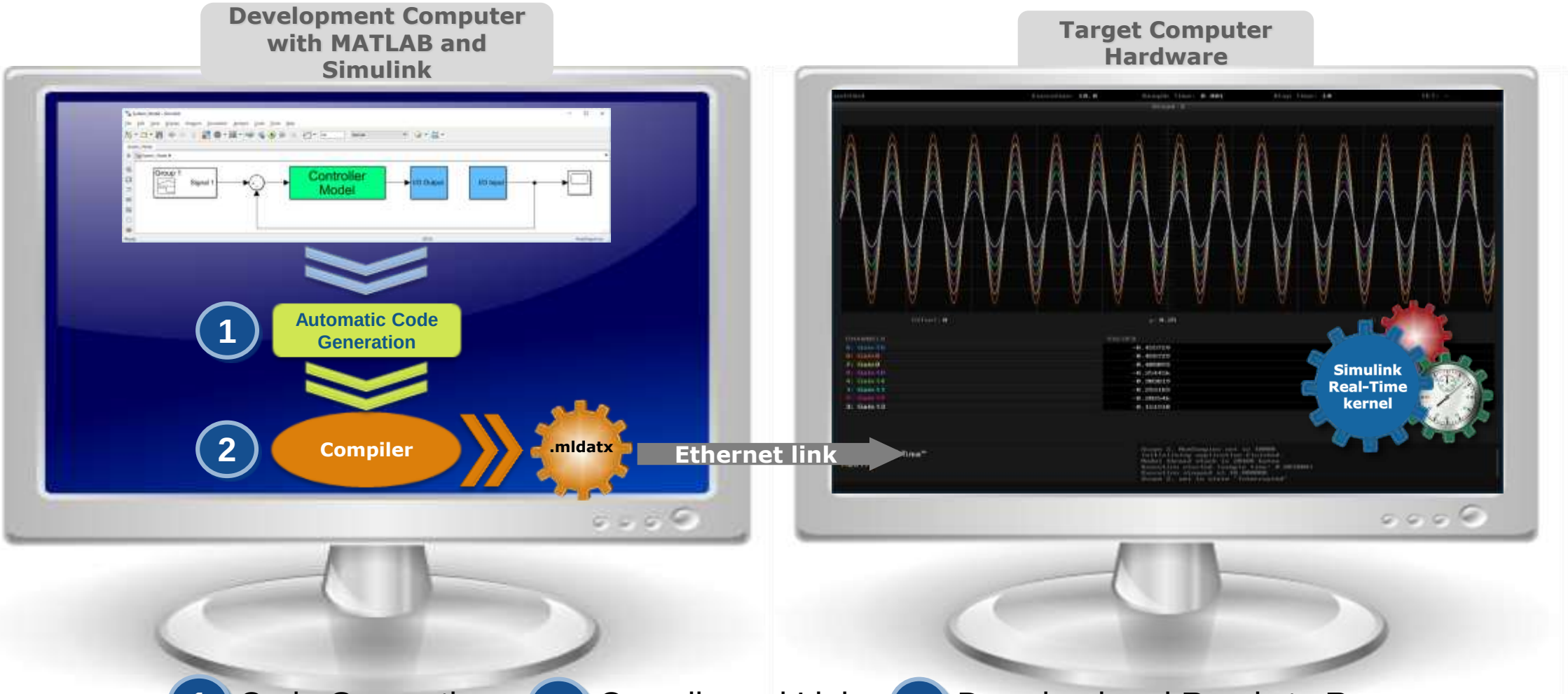


Automatic Code Generation

Wiring and Signal Conditioning

What is Simulink Real-Time?

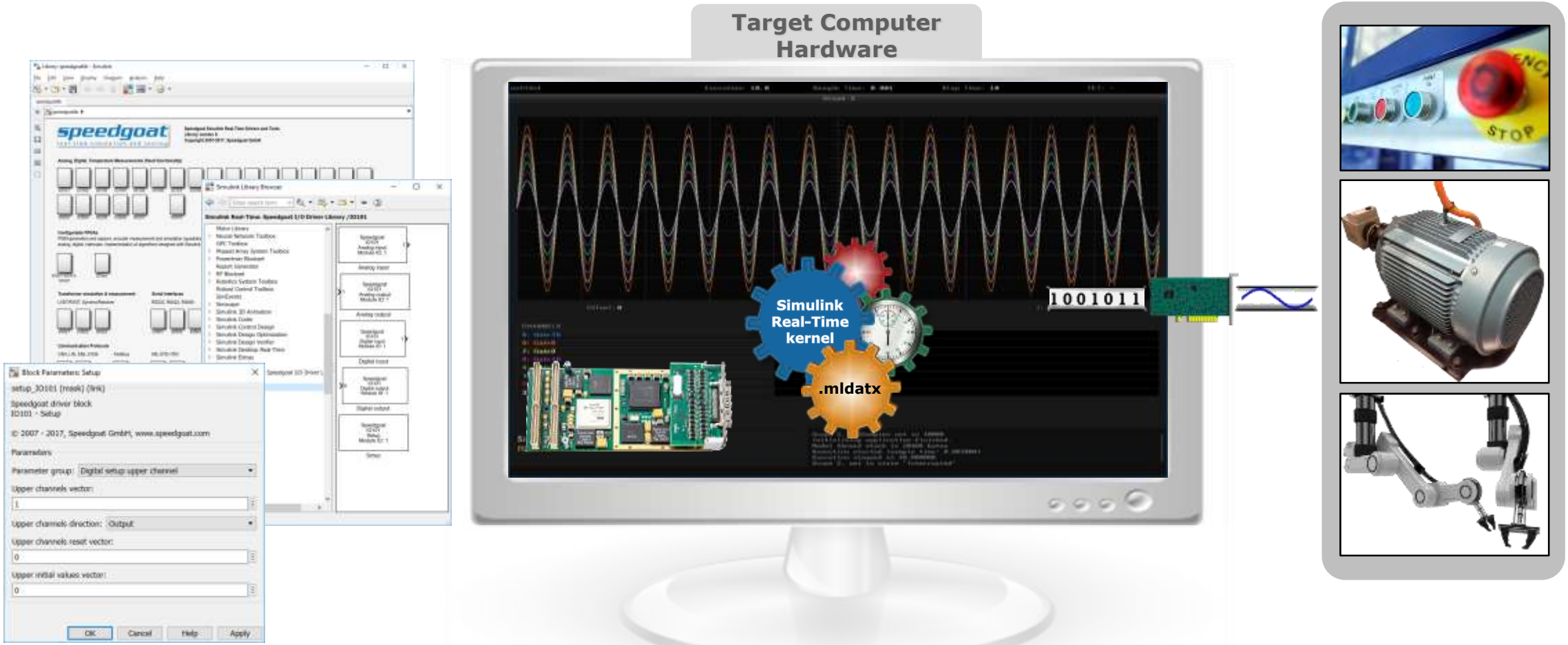
From Desktop Simulation to Real-Time Execution



1 Code Generation 2 Compile and Link 3 Download and Ready to Run

What is Simulink Real-Time?

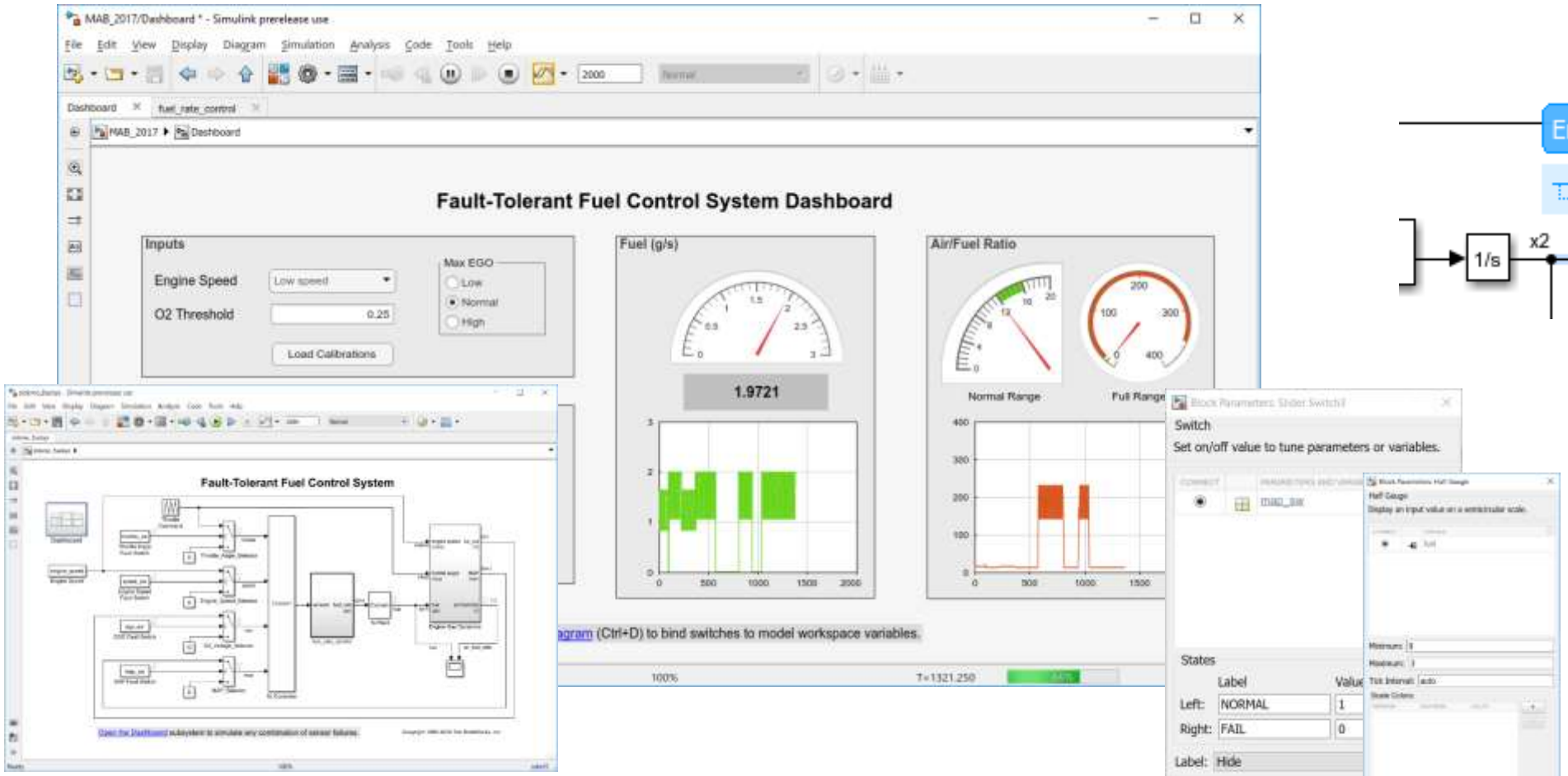
Connect to Your Physical System

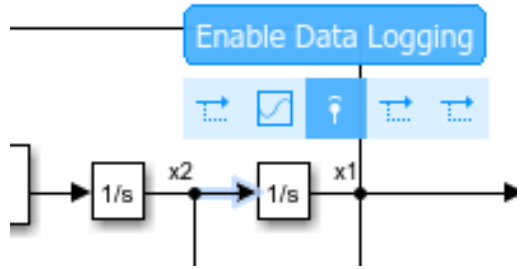


- Support for a broad range of I/O types and communication protocols
- Easy drag and drop and configuration within a Simulink model

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



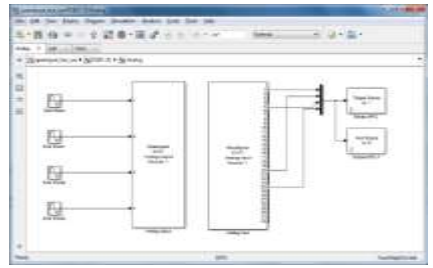


Speedgoat Machine

Real-time target machine

I/O modules installed in target machine

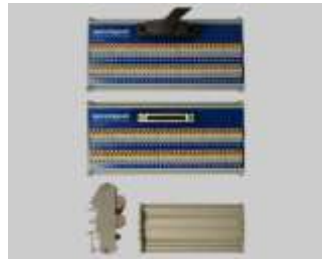
Simulink driver blocks



Simulink test models

- 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

I/O cables



Terminal boards

Documentation

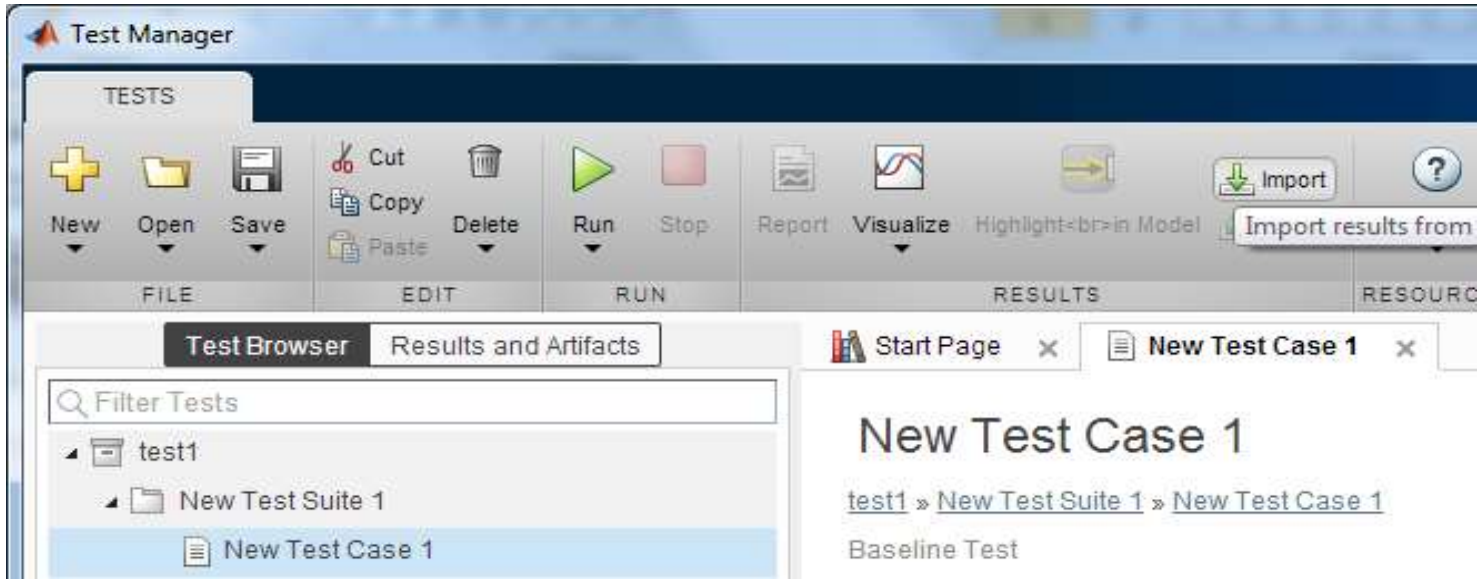
Support, Training, Consulting, and Warranty Services

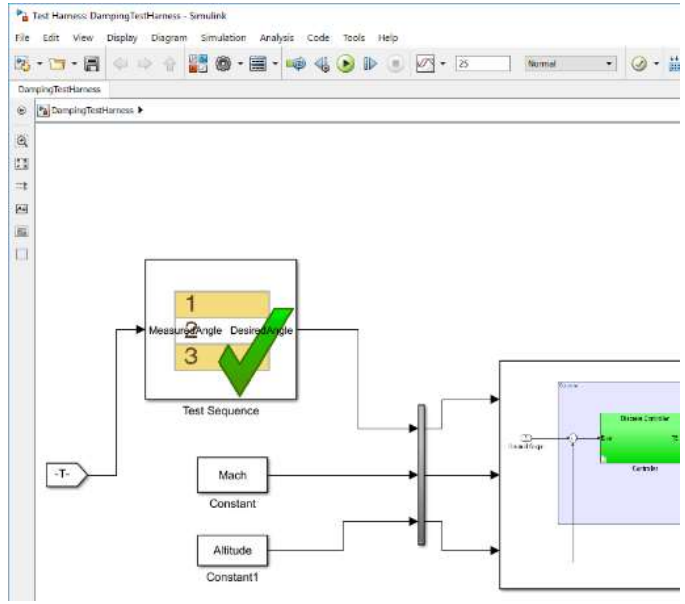
IO991: Battery Emulation I/O Module

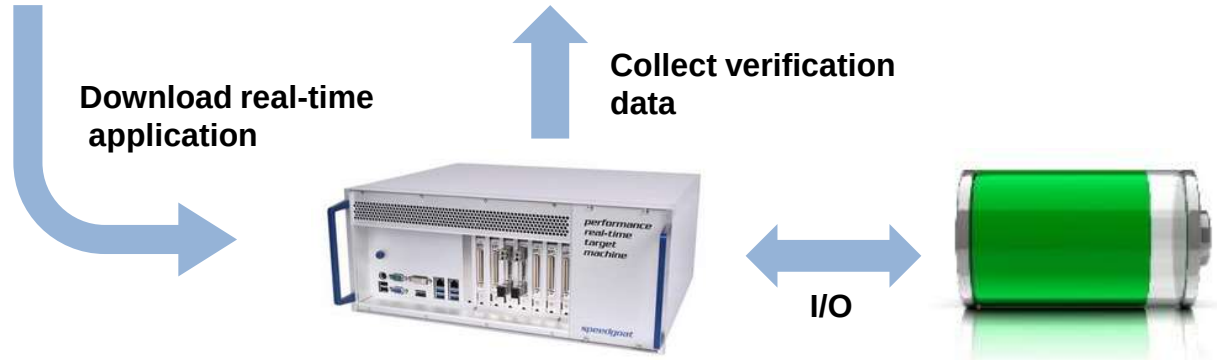
- Key Features:
  - 6 independent isolated channels
  - Architecture allows series & parallel combinations
  - Independent power and sense lines
  - Voltage range of 0-7 V with 14-bit resolution
  - 300 mA source to load
  - 100 mA sink adjustable in 16 steps
- Enables:
  - Test automation and repeatable testing
  - Fault testing safely
  - Reuse testcases from earlier desktop testing

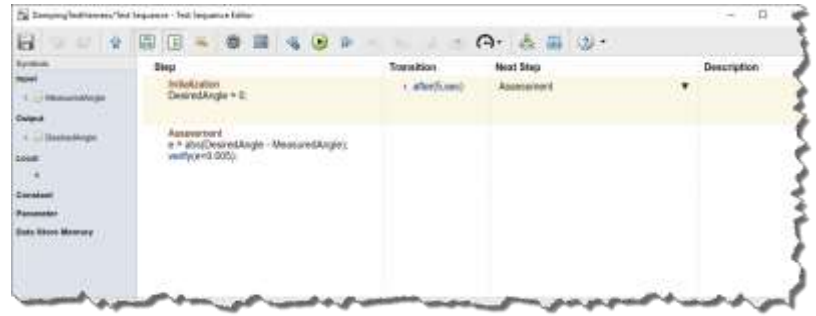
Automated Testing with Simulink Test

Real-Time Test Automation, Ideal for Hardware-in-the-Loop









LG Chem Develops AUTOSAR - and ISO 26262 - Compliant Software for a Hybrid Vehicle Battery Management System

Challenge

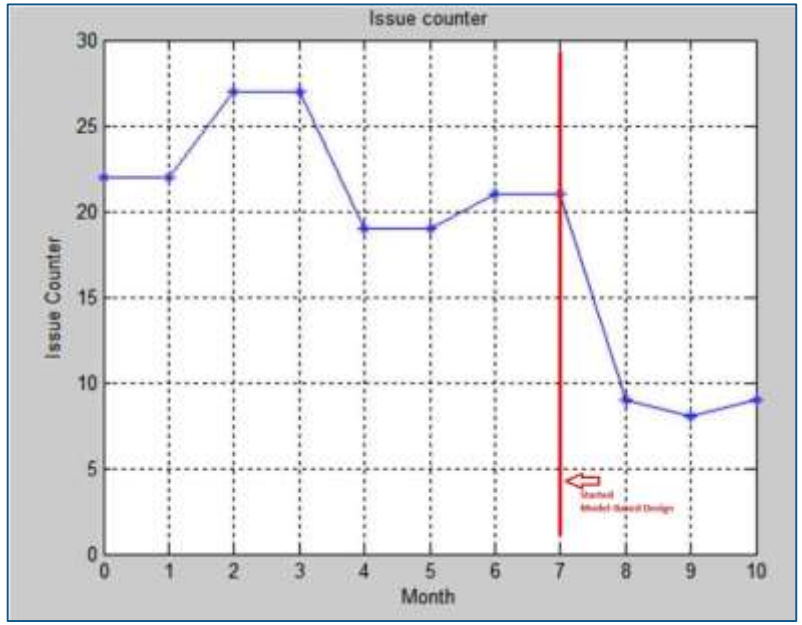
Design and implement production battery management system (BMS) software for the Volvo XC90 plug-in hybrid

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 languages
- Software issues reduced by more than 50%
- ISO 26262 ASIL C certification achieved



Issue counts for software releases before and after the adoption of Model-based Design.

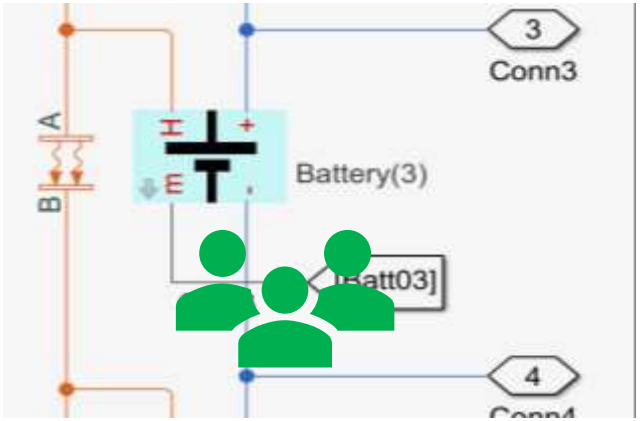
"Model-Based Design with MATLAB and Simulink] enables us to increase component reuse, reduce manual coding, improve communication with our customers, and ultimately deliver higher-quality BMS in less time."

- Won Tae Joe, LG Chem

Link to technical article

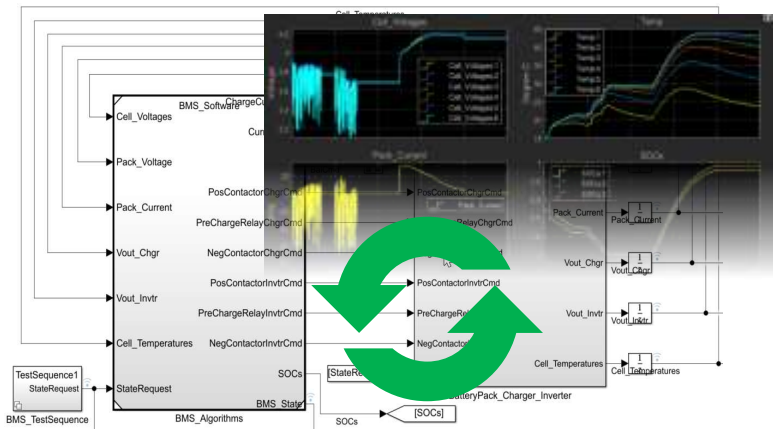
Summary

Collaboration
Physical Modeling



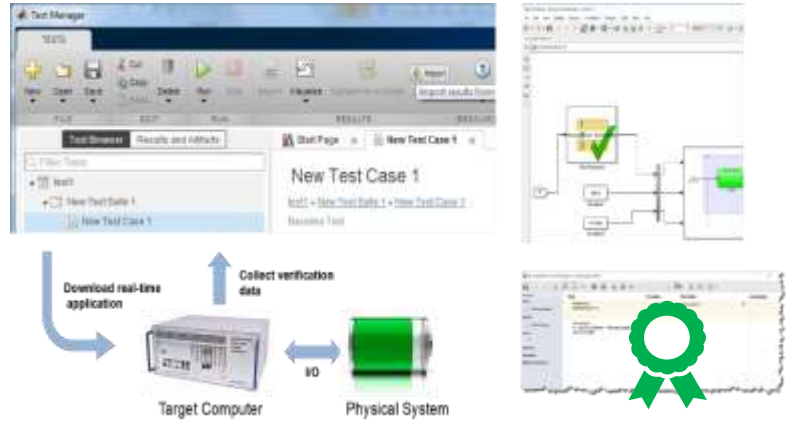
Collaborate Across Domains

Short Iteration Cycles
Virtual Prototyping



Reduce Iteration Time

Safety Critical System
HIL Testing

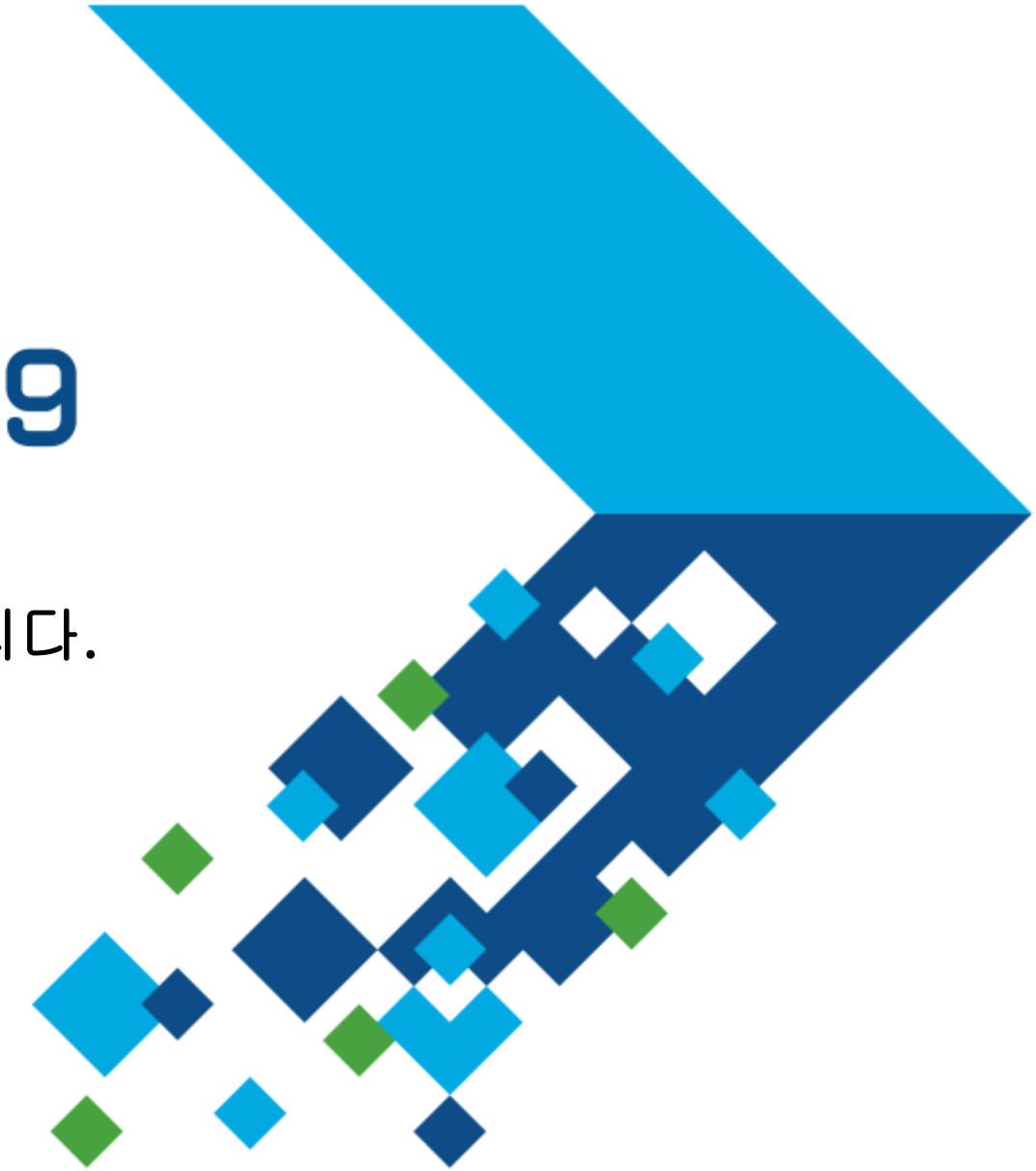


Functional Safety Certification

MATLAB EXPO 2019

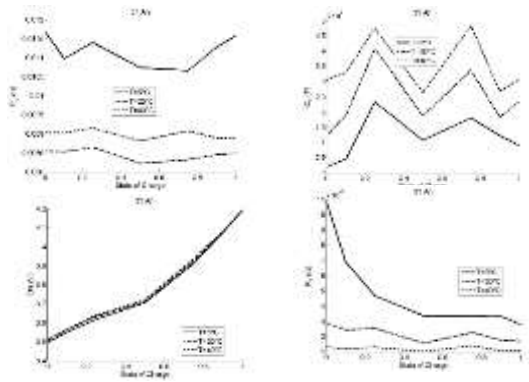
데모 부스와 상담부스로 질문 하시기 바랍니다.

감사합니다

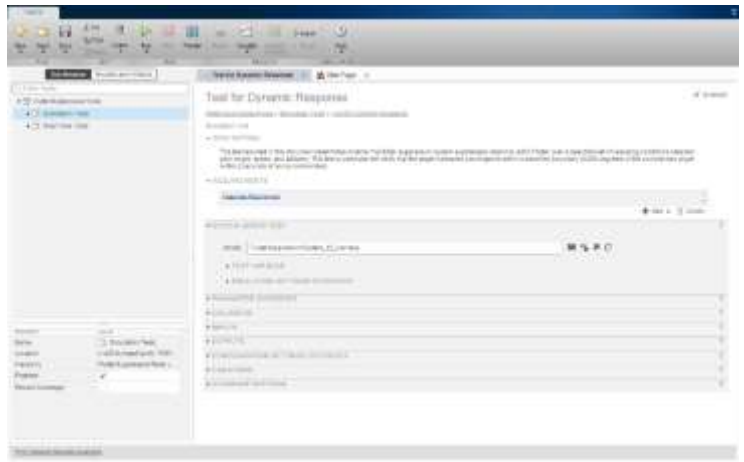


Taking It Further

Parameter Estimation

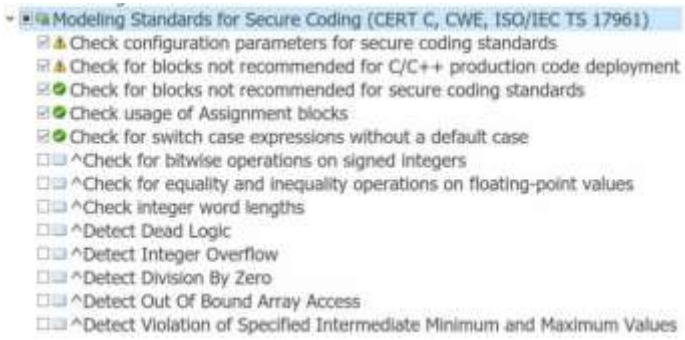


Test Automation

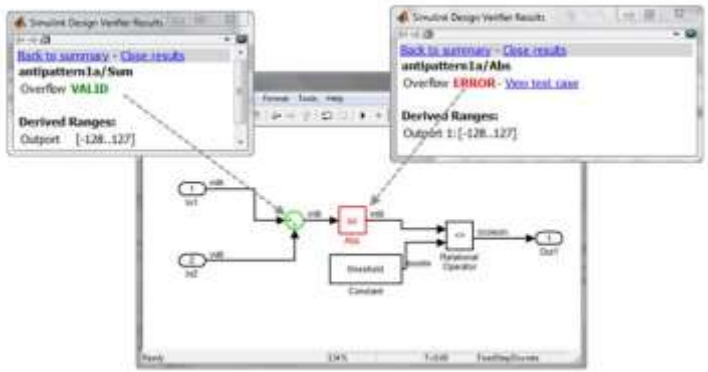


HDL Code Generation

Model Checks



Design Error Detection



Model Coverage

Learn More about Battery Management System