MATLAB EXPO 2018

Developing Battery Management System using Simulink

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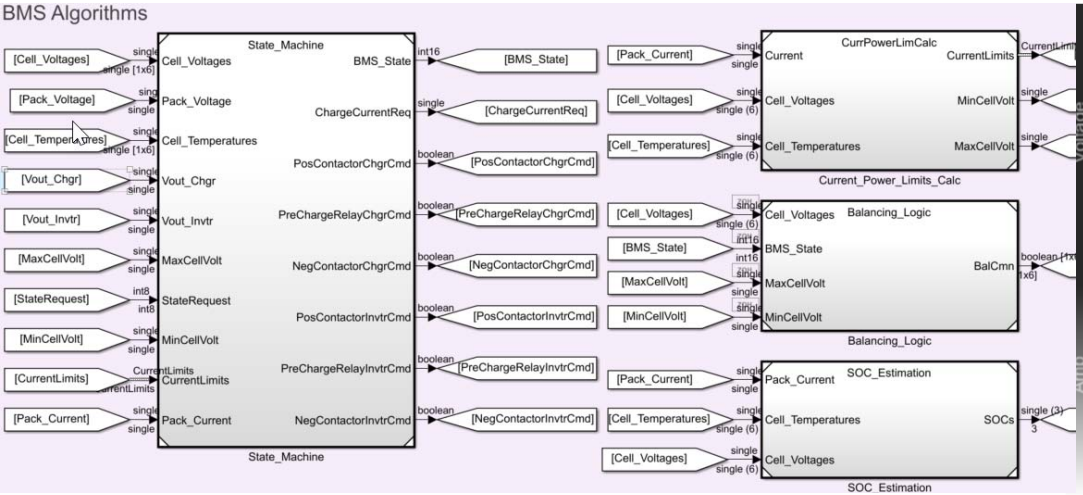
MathWorks

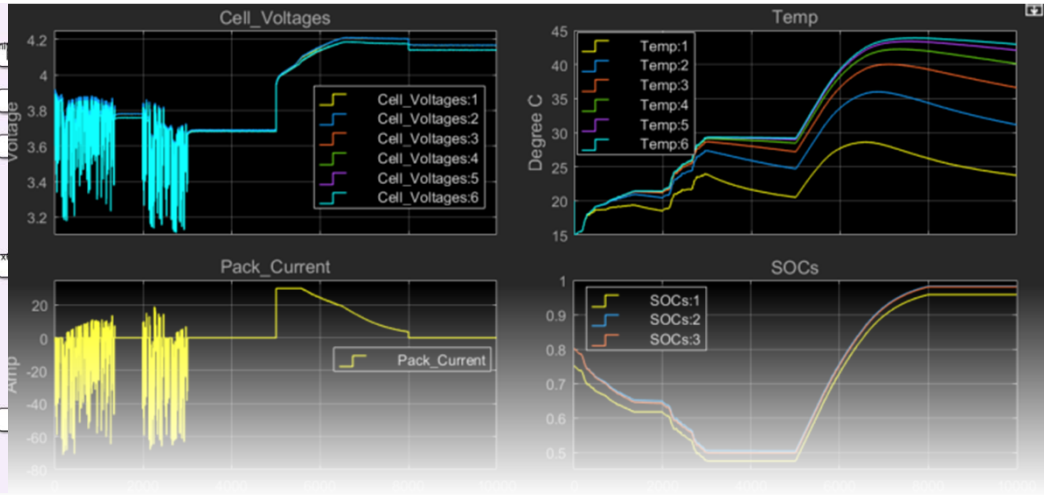
Motivation

Collaboration

Short Iteration Cycles

Safety Critical System





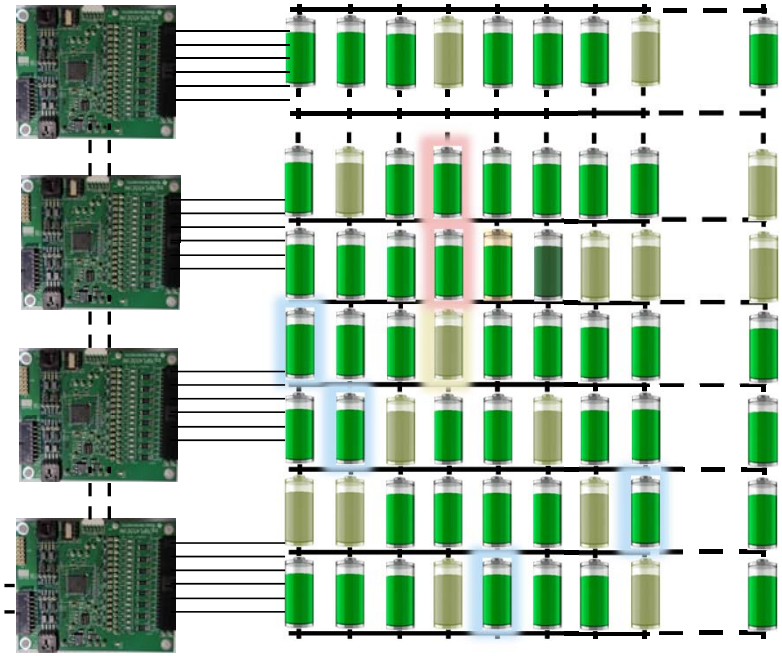
What is BMS?

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

Demo

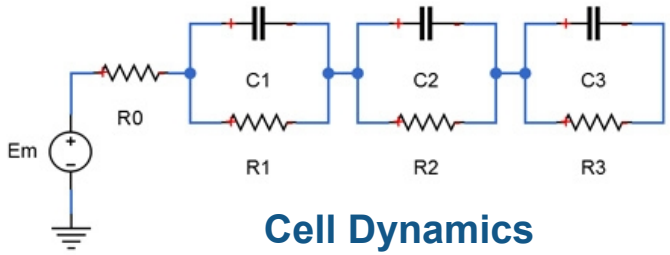
```
if (((uint32_T)State_Machine_DW.temporalCounter_i3) < 15U) {
  State_Machine_DW.temporalCounter_i3 = (uint8_T)((int32_T)(((int32_T)
    State_Machine_DW.temporalCounter_i3) + 1));
}

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

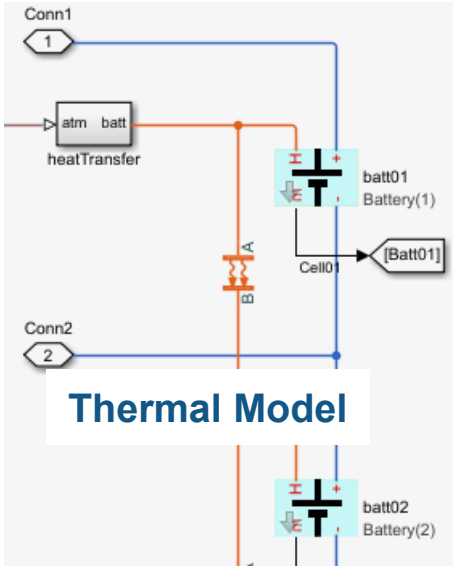


Block Voltage,
Temperature Measurement
Cell Diagnostic
Cell Balancing

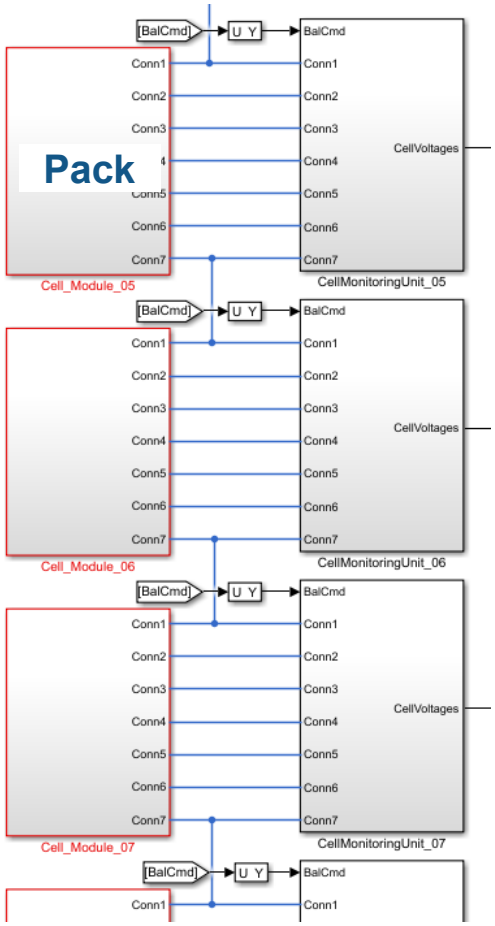
Start with Simulation
Capture Dynamics of Battery Cell → Large Battery Pack

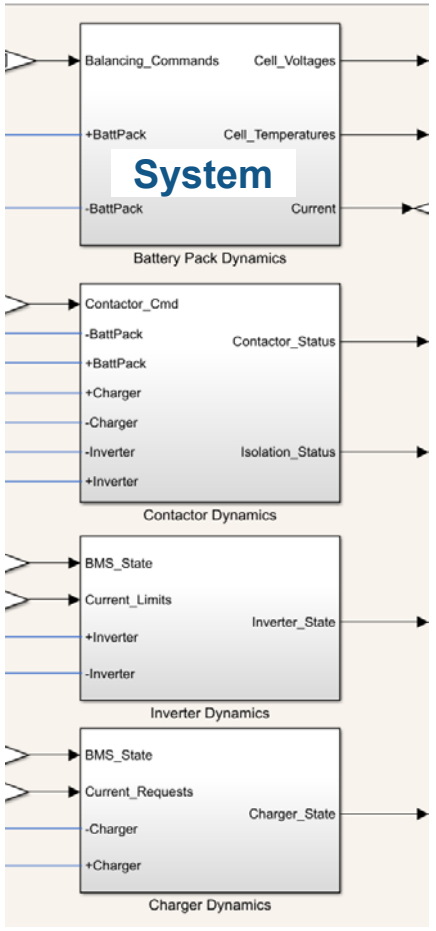


Cell Dynamics

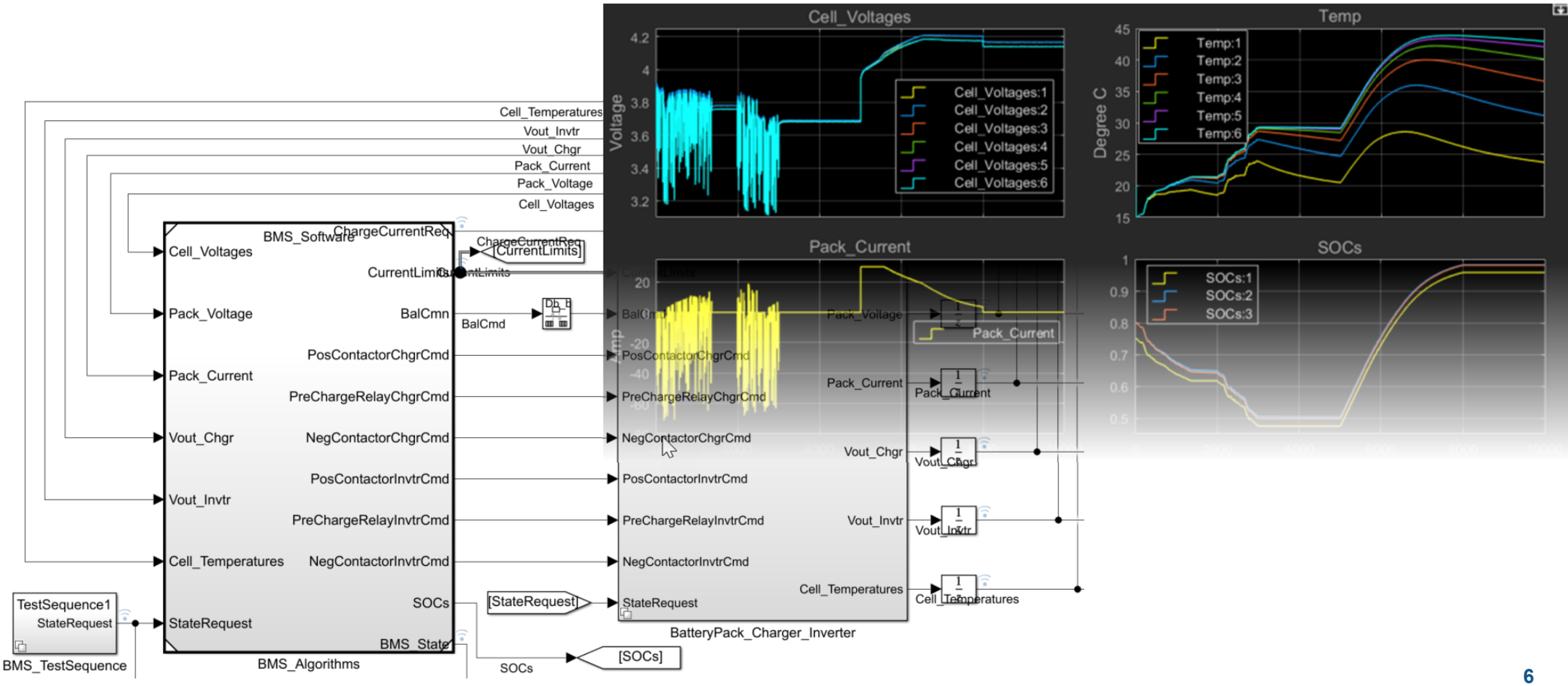


Thermal Model

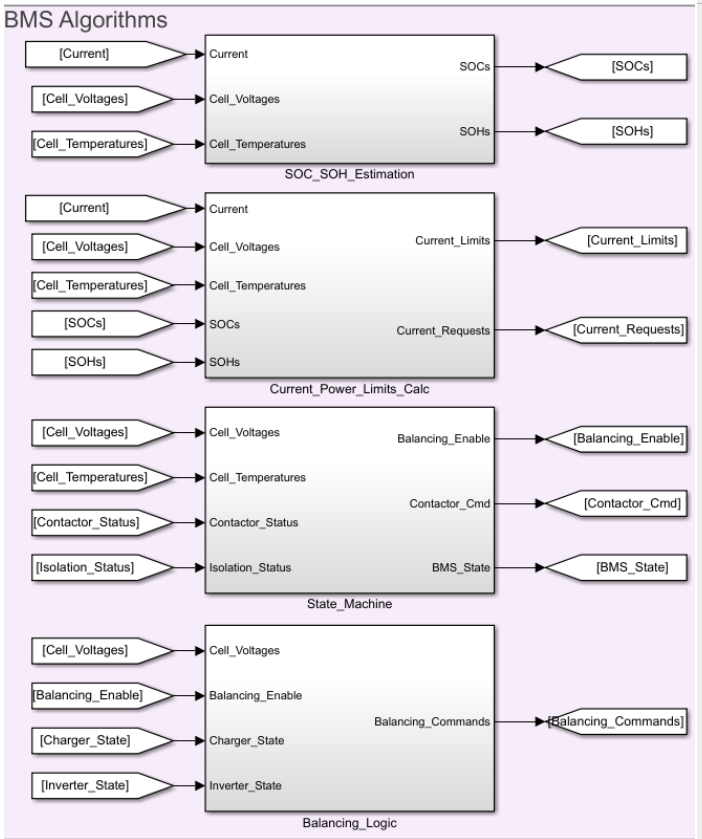


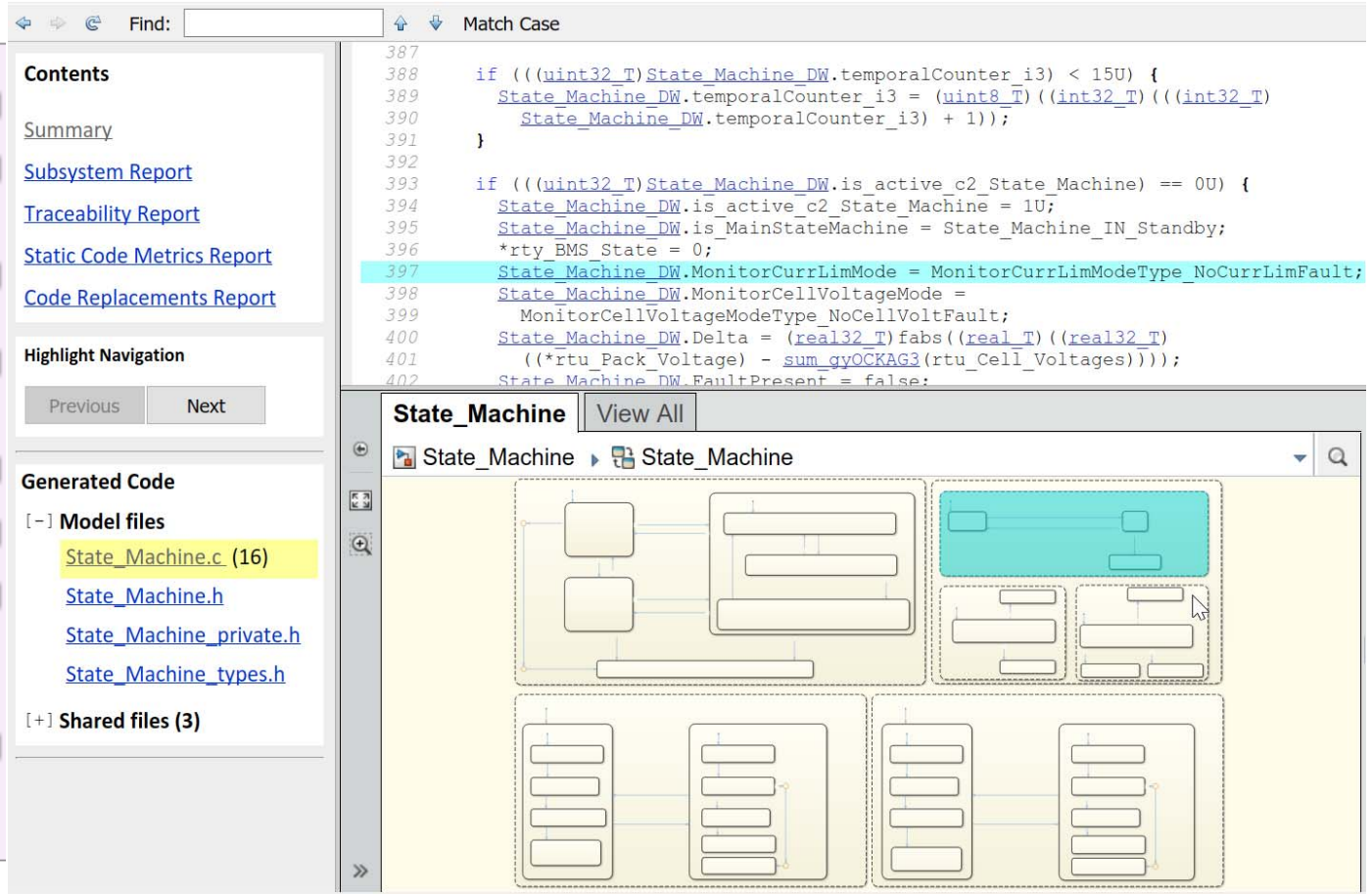


Develop Battery Management Algorithms in Simulink

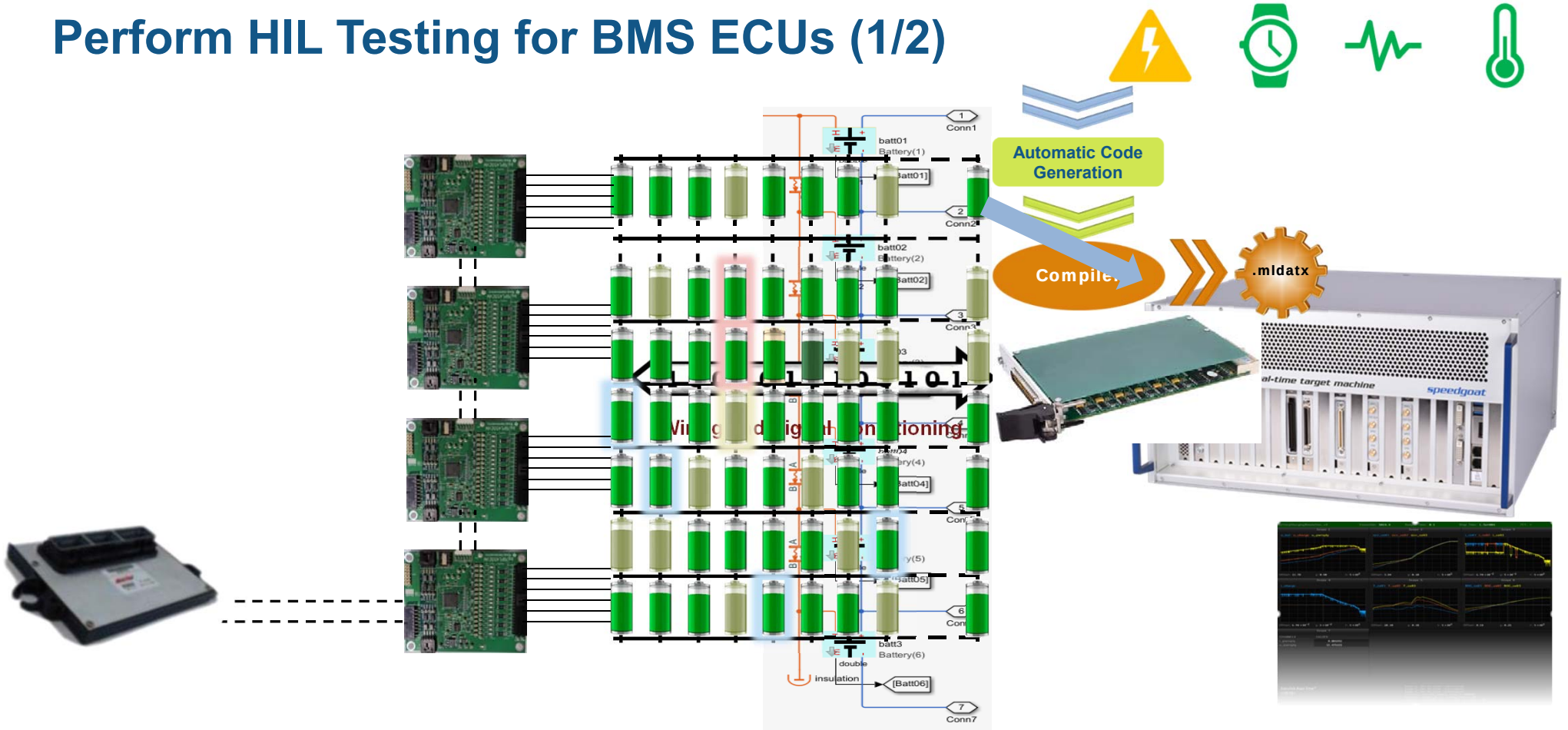


Generate C/C++ Code From BMS Algorithm Models





Perform HIL Testing for BMS ECUs (1/2)



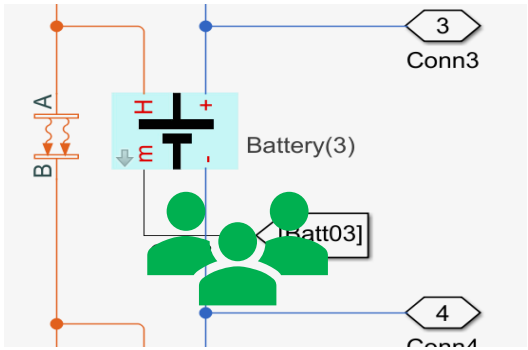
Perform HIL Testing for BMS ECUs (2/2)
IO991: Battery Emulation I/O Module

Key Features

- 6 independent isolated channels
- Architecture allows series and parallel battery stack 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

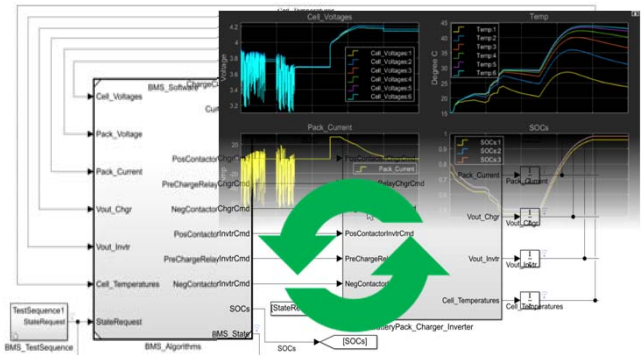
Summary

Multi-Domain



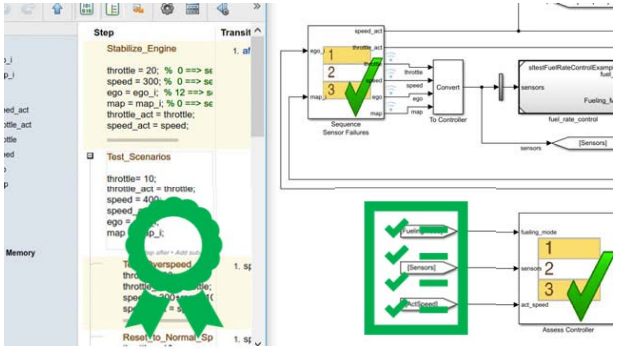
Collaborate Across Domains

Long Iteration Cycles



Reduce Iteration Time

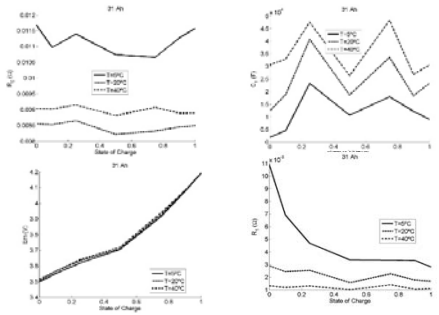
Safety Critical System



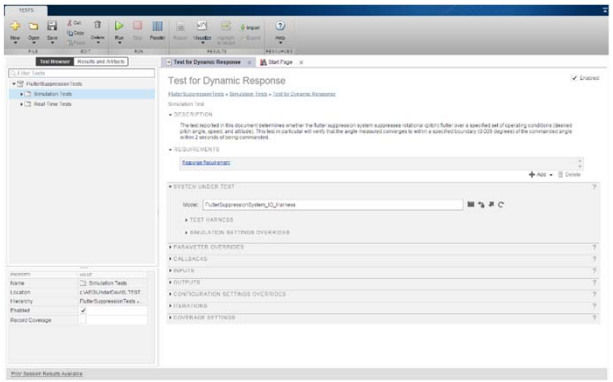
Functional Safety Certification

Taking It Further

Parameter Estimation

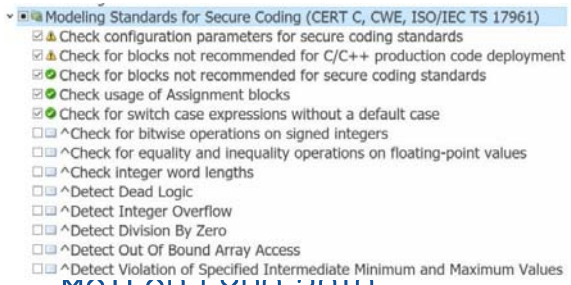


Test Automation

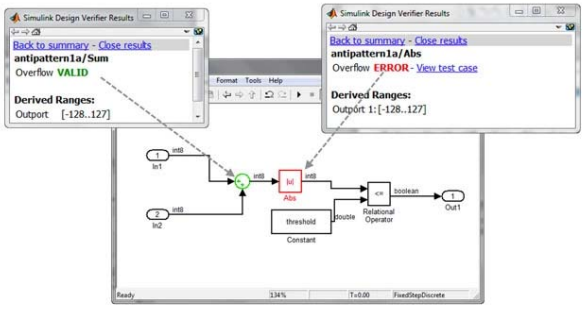


HDL Code Generation

Model Checks



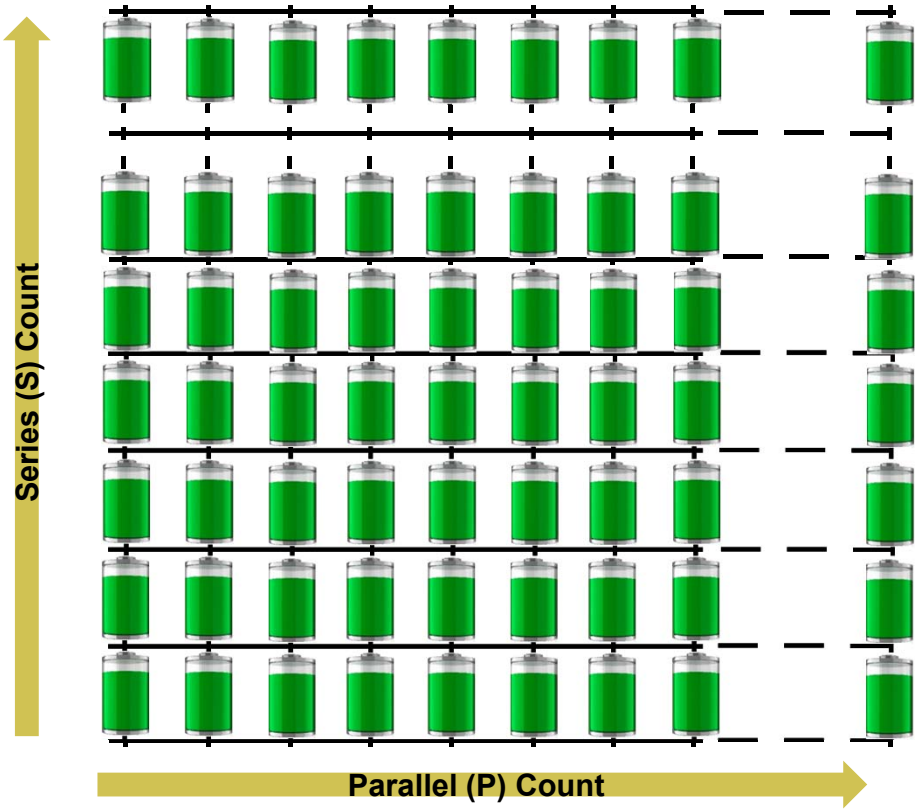
Design Error Detection



Model Coverage

An Example BMS Architecture (1/2)

- Cells connected in parallel to match Ah capacity requirement
  - a **Block** is one row of P number of cells in parallel
- Blocks are connected in series to match DC Bus voltage
- Cells are assembled, soldered and packaged in smaller Modules
  - A **Module** is typically 6 to 16 **Blocks** in series
- An Example 54kWh Pack Configuration
  - Cell: Nominal 3.6v with Capacity 3.4Ah
  - 46Cells in Parallel; Block of 156.4Ah Capacity
  - 98Cells in Series; 6-S Module; Total 16 Modules
  - Pack of 4416 cells with ~54kWh Capacity



An Example BMS Architecture (2/2)

Central Controller
supervisory tasks, SoC/SoH estimation, contactor management, isolation monitoring, fault detection and recovery

Isolated Serial Communication

Module# n+1

Module# n

Block Voltage Measurement
Temperature Measurement
Optional Current Measurement
Cell Diagnostic
Cell Balancing
Isolated Serial Communication

Module# n-1