# BMS HIL Test System Helps Jaguar Land Rover Shorten Time-to-Market for Hybrid and Electric Vehicles

A White Paper by: Peter Blume, President, Bloomy
Dr. Miguel A. Gama, Principal Engineer in Advanced Hybrid Controls, Jaguar Land Rover
Steven Hoenig, Battery Test and Simulation Unit Manger, Bloomy
Sue Slater, Product Lead Next Gen Energy Storage, Jaguar Land Rover
Duncan Holden, Principal Systems Engineer, Vayon Energy Storage

R091216

# Table of Contents

Abstract ..... 3

Accurate and Advanced BMS Firmware Algorithms ..... 4

The BMS HIL Test System ..... 5

Application Benefits ..... 6

Conclusion ..... 7

About Bloomy Controls, Inc. ..... 8

# Abstract

Jaguar Land Rover, the UK's largest automotive manufacturer, and Bloomy, a National Instruments (NI) Platinum Alliance Partner were tasked with developing a system providing the ability to design and validate battery management system (BMS) firmware algorithms on prototype hardware, and safely test the unit with various battery chemistries, fault scenarios, and drive profiles. Bloomy developed a hardware-in-the-loop (HIL) test system based on NI PXI, EtherCAT hardware, LabVIEW software, VeriStand software, DIAdem software, and Bloomy's Battery Simulator 1200 instruments to simulate a 24-cell advanced-chemistry, hybrid- and electric-vehicle battery, with each Bloomy instrument powered by Single-Board RIO and the LabVIEW FPGA Module.

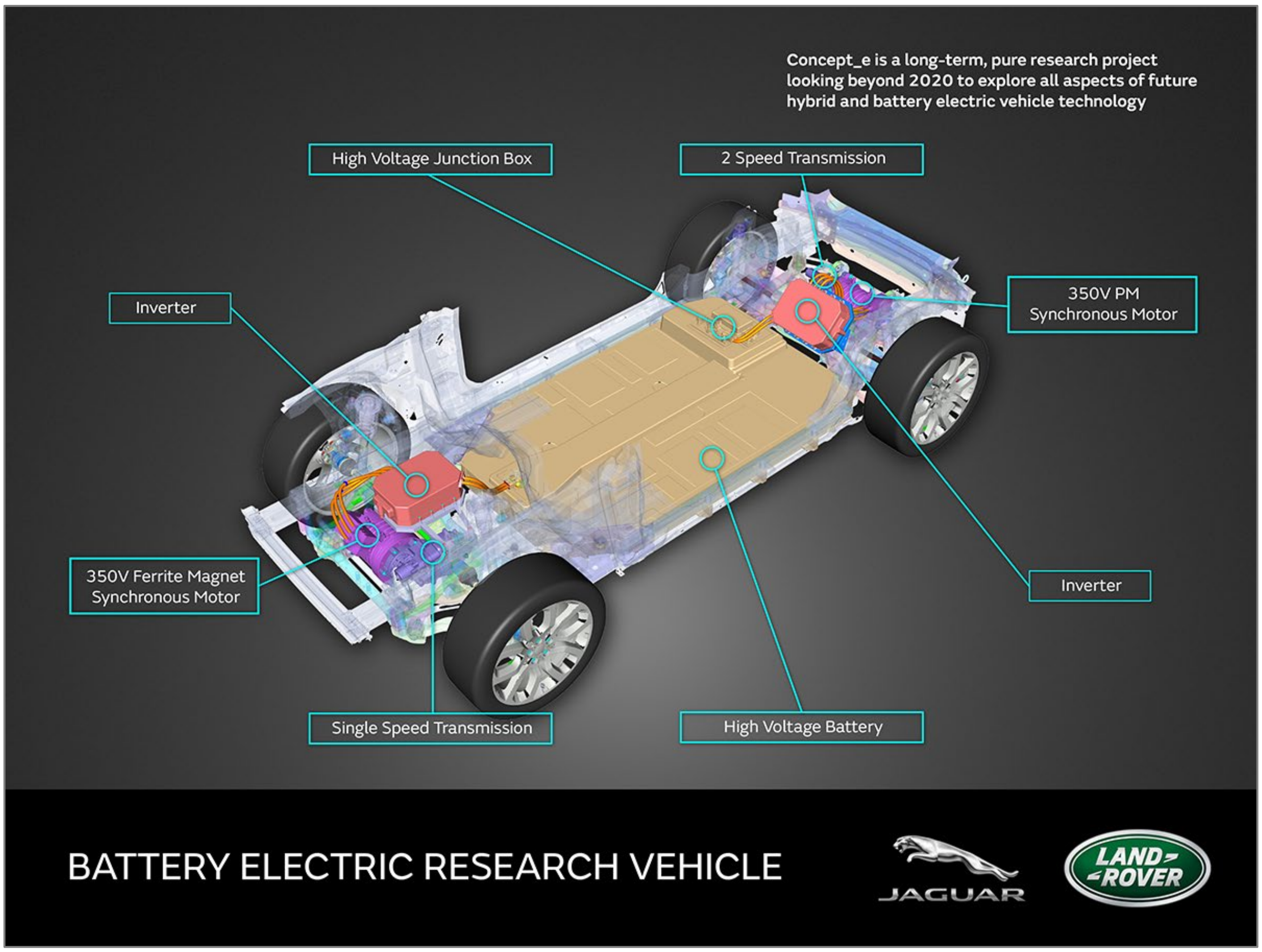


*Figure 1. Jaguar Land Rover Battery Electric Research Vehicle*

## Accurate and Advanced BMS Firmware Algorithms

As automotive manufacturers race to disrupt the transportation industry and shape the future with high-performing zero- or low-emission hybrid and electric vehicles (xEVs), BMS firmware algorithms are critical for extending electric range, minimizing charge times, and maximizing battery life, while ensuring the safety of lithium-ion (li-ion) and other advanced chemistry batteries. Moreover, as a premium luxury and sport utility vehicle manufacturer, Jaguar Land Rover (JLR) must ensure the driving performance that the industry has come to expect from the JLR brand, without sacrificing range and efficiency. Developing BMS algorithms is a tedious process, and developers must evaluate how well the BMS performs under real-world driving conditions. However, Li-ion batteries are expensive, require time and energy to charge and discharge, decay over time, and present safety hazards during product development. For example, over-voltage, over-current, and over-temperature are routine conditions handled by the BMS, but it would be dangerous to force real batteries to generate these faults for testing the corresponding safety interlocks. Rather, the iterative nature of BMS algorithm development requires a safe, configurable, and repeatable BMS test platform.

JLR and Vayon Energy Storage contracted Bloomy to provide a BMS test platform that simultaneously simulates all battery I/O, including 24 individual battery cells, CAN communication, relay inputs, and temperature sensors, in a safe, convenient, and reconfigurable manner. The simulated signals must be realistic such that the BMS functions as if connected to a real battery in a xEV. The system must run the simulations deterministically, in real time, to properly emulate the timing and responses of real cells. The system also must be capable of recreating fault scenarios, such as over-voltage, under-voltage, over-current, over-temperature, and cell imbalances. Additionally, for the test system to grow with the changing requirements of the BMS, it has to be easy to update with new battery and drive-train configurations and models. In particular, the system must accommodate substantially different BMS hardware architectures used for a wide range of xEV programs, from hybrid through fully-electric vehicles. This includes different high-voltage buses, relays, current sensors, and voltage monitors, using both centralized and master-slave BMS topologies, with varying numbers of slave boards.

## The BMS HIL Test System

Bloomy's BMS HIL Test System consists of a PXI chassis and controller running a real-time OS and VeriStand software. Along with PXI I/O and bus communication modules, the PXI chassis connects to two Bloomy Battery Simulator 1200 units and an EtherCAT extension to provide the full set of required simulation signals, which includes battery cells, relay inputs, thermistors, and bus communication. VeriStand runs 24 asynchronous cell models implemented using The MathWorks, Inc. Simulink® software. A high-speed CAN interface is used to command the Battery Simulator 1200 units to produce the simulated cell voltages. Bloomy's Battery Simulator 1200 is a commercial, off-the-shelf instrument specifically designed for safe and efficient BMS testing. Each unit includes a Single-Board RIO device with a custom mezzanine board that produce the commanded cell voltages. The Single-Board RIO FPGA quickly and deterministically controls the output voltage levels at the end of the cable harness where it connects to the BMS, ensuring very high accuracy and response times. A novel design featuring specialized power electronics allow the Battery Simulator 1200 to sink and source current under the test BMS's control. All of the BMS HIL Test System's I/O are made accessible through CPC connectors. This standard connector interface facilitates fast changeover of the test BMS.

*Figure 2. BMS HIL Test System - System View*

Bloomy used NI products to leverage the tight integration between hardware and software that is critical for an HIL application. For example, using a PXI chassis in conjunction with VeriStand empowered JLR to easily deploy and run Simulink models, and update those models on the fly as needed to execute cell models of various chemistries. Similarly, JLR implemented both industry-standard and custom drive cycles using the VeriStand Stimulus Profile Editor. The ability to use the same programming language and environment (LabVIEW) on the PC, RT, and FPGA levels enabled faster development and debugging.

The greatest challenge we faced on this application was the requirement for 24 channels of cell simulation, with sink-and-source capability to exercise cell balancing, as well as high-voltage isolation to enable expandability in cell count. This highly-specialized need could only be addressed using Bloomy's Battery Simulator 1200. The product contains a Single-Board RIO embedded controller, selected at product inception because it encourages extremely rapid product development, which eliminates the need to develop custom real-time and FPGA circuitry. In addition to the simulation of cell voltages and balancing currents, the unit provides 500V of continuous working isolation and 1,000V withstand isolation, voltage and current readback sensing, instrument-level safety, and has FCC and CE certifications. As of this writing, energy storage companies on three continents have deployed many Battery Simulator 1200 units for battery, xEV, and power grid BMS test applications.

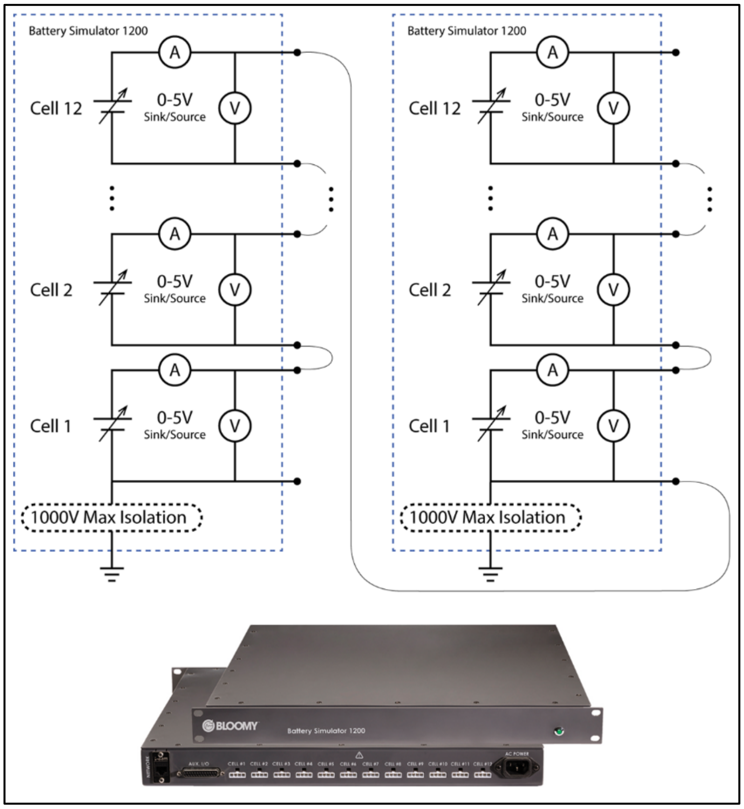


*Figure 3. Two Series-Connected Battery Simulator 1200 Instruments Provide 24 Cells of Battery Simulation*

## Application Benefits

In recent years, HIL techniques have become widely accepted for testing electronic control units (ECUs) in the automotive industry. Today, automakers have taken advantage of the flexibility, repeatability, and convenience of HIL systems to develop the next generation of xEVs faster and more economically than ever before. Moreover, HIL systems are especially useful when the HIL simulator replaces hardware that is difficult and dangerous to work with, such as li-ion batteries. As stated previously, batteries require significant time and energy to charge and discharge, degrade over time, and can be hazardous if improperly managed.

JLR uses Bloomy's BMS HIL Test System to more rapidly develop and test the BMS firmware, leading to higher performing xEVs, and shorter time to market. Using this system, JLR can more readily respond to changing requirements such as cell chemistries, battery configurations, and drive profiles, by simply updating battery models and stimulus profiles. Indeed, JLR quickly evaluated and selected a cell chemistry with the company's early use of the system. Currently, JLR uses the system to evaluate new drive cycles, reproduce track behavior in the lab environment, and qualify battery performance under JLR's expected driver use, which is substantially more rigorous than industry standards.

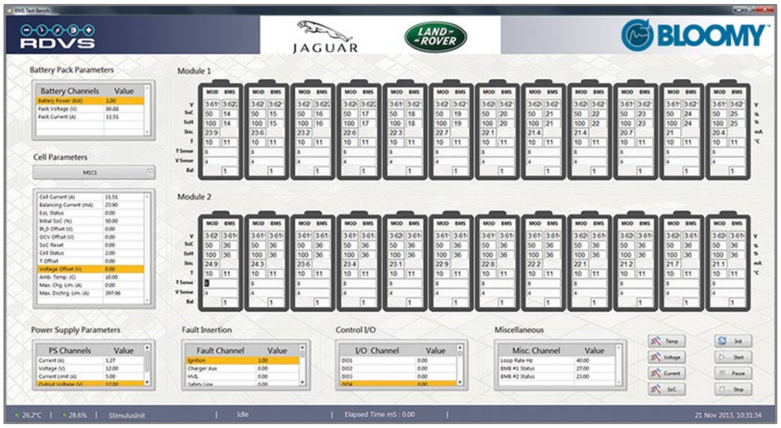


*Figure 4. BMS HIL Test Stand Software View*

Additionally, JLR uses the BMS HIL Test System's modularity and standard connector interface to test different BMS hardware platforms targeting a number of different xEV programs. Most importantly, the BMS HIL Test System facilitates full regression testing, for which all BMS functions are comprehensively retested every time there is any change made to any aspect of the firmware. Regression testing ensures that any change to the BMS firmware does not unintentionally effect any of the other functions. All of JLR's firmware revisions are comprehensively tested on the BMS HIL Test System prior to release. The flexibility and tight integration of NI software and hardware made this powerful configurability possible.

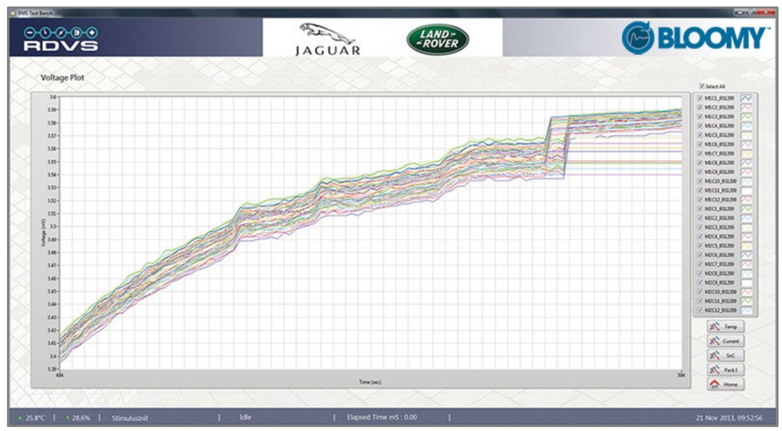


*Figure 5. BMS HIL Test Stand Plot View*

## Conclusion

The BMS HIL Test System delivers a flexible test platform that facilitates rapid design and testing of the BMS firmware, thereby accelerating development of JLR's prototype hybrid and fully-electric vehicles. JLR has used the system to validate four different BMS hardware architectures, including both centralized and master-slave topologies, with substantially different high-voltage architectures. JLR can use the standard connector interface to quickly changeover the test stand to test different xEV programs during the same day. The power of real-time PXI with a connected EtherCAT extension, the speed of an FPGA, and the flexibility of LabVIEW and VeriStand combine for a platform that meets both JLR's performance and configurability needs. Moreover, the Battery Simulator 1200 provides necessary cell simulation capabilities with high-voltage isolation, offering future scalability to larger cell-counts. As a result, JLR can achieve first-time right performance quicker.

"Major BMS firmware releases can now be rolled out within one week with good confidence of success, whereas similar projects in the past used to take well over a month, and with substantially less confidence."—Miguel Angel Gama-Valdez, Principle Engineer, Jaguar Land Rover

## About Bloomy Controls, Inc.

Bloomy Controls, Inc., (Bloomy) provides products and services for battery test and simulation, electronics functional test, and avionics real-time test. We also provide world-class LabVIEW, TestStand, and VeriStand application development. Achieving success throughout all stages of the battery management system (BMS) product lifecycle, we have delivered enterprise solutions for hybrid and electric vehicles (xEVs), power grid energy storage, and battery manufacturers, which include OEMs, contract manufacturers, researchers, and test labs. We are an NI Platinum Alliance Partner with NI embedded control and electronic design specialties. For more information, please visit our BMS test web page, online resources, or contact us.