NHOA ENERGY

success story

Enhancing BESS performance and reliability with C-HIL simulation

A success story with NHOA Energy

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OPAL-RT TECHNOLOGIES

NHOA Energy in a nutshell

NHOA Energy is a **global leader in the supply of energy storage systems**, making green energy reliable and competitive. NHOA Energy operates across five continents, with over **2.6 GWh** of systems either in operation or in advanced stages of construction.

NHOA Energy develops, manufactures, and delivers **Battery Energy Storage Systems (BESS)** for large-scale industrial applications, ensuring a reliable and competitive energy supply while promoting the transition toward a world powered by 100% renewable sources.

NHOA Energy offers fully integrated, turn-key storage solutions that combine advanced power electronics solutions with top-tier battery technologies, carefully selected from the most trusted global manufacturers. At the core of its offering is **NHEXUS**, a plug-and-play platform that seamlessly integrates conversion, control, and energy management systems. Engineered for performance, reliability, and cost-effectiveness, NHEXUS delivers optimized storage solutions tailored to the evolving needs of grid operators, utilities, and energy developers.

NHOA Energy deployed Control-Hardware-in-the-Loop (C-HIL) with OPAL-RT to de-risk and accelerate BESS development and commissioning. The project focused on validating plant controls and grid-code compliance, optimizing PCS–battery interactions, and troubleshooting corner cases in a safe real-time environment—thereby improving performance before Site Acceptance Tests and supporting robust O&M after delivery.

Control-Hardware-in-the-Loop (C-HIL) technology

A key pillar of NHOA Energy's success is its **efficiency in project execution.** To achieve this, the company has implemented strategies aimed at accelerating and de-risking the commissioning phase and delivering exceptional after-sales services. Among these, the integration of high-fidelity real-time simulations of BESS through **Control-Hardware-in-the-Loop (C-HIL) technology** stands out as a critical innovation, enabling both **precision engineering** and robust **system validation** across the entire project lifecycle.

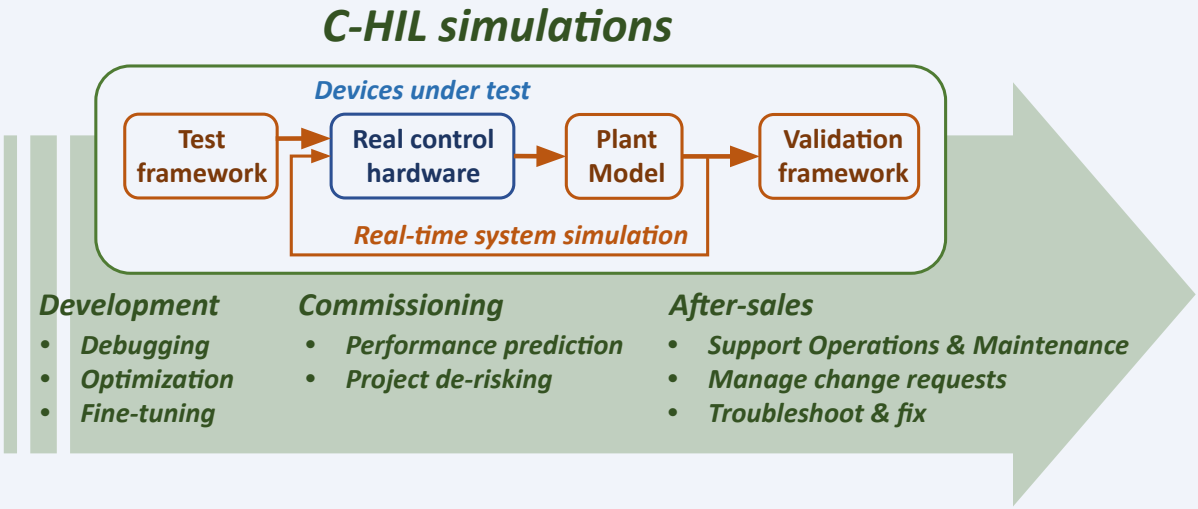
Benefits of C-HIL simulations

C-HIL is a powerful engineering tool that enables **real-time, high-fidelity simulation** of BESS behavior. This framework offers significant advantages across all project phases, from development and commissioning to after-sales support.

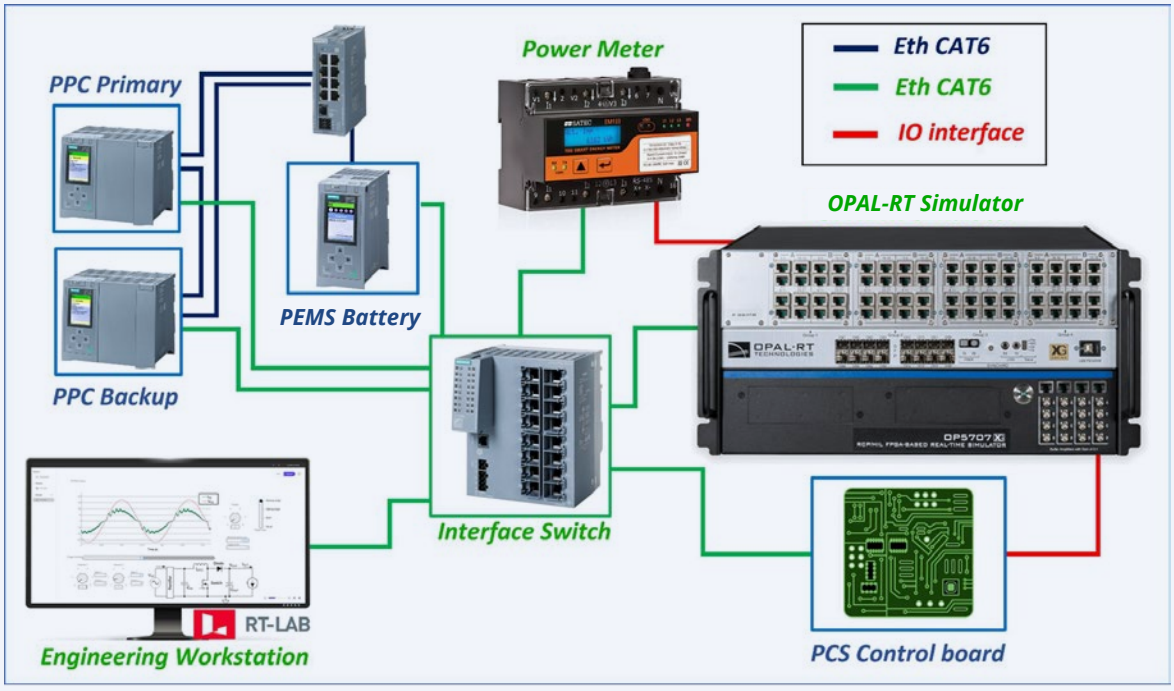
During development, the C-HIL framework is used to debug, optimize, and fine-tune complex systems involving multiple Devices Under Test (DUTs). By replicating complete system behavior in a safe simulated environment, NHOA Energy can identify issues early, **refine hardware interfaces** and communication delays, and adjust system parameters to align with expected performance.

C-HIL simulations

During commissioning, C-HIL simulations accurately predict system performance before on-site acceptance testing. This significantly reduces risk and accelerates the overall commissioning process.



Post-deployment, the C-HIL simulation serves as a digital twin of the delivered plant. This virtual replica is used to manage change requests by testing updates safely before live implementation. It also facilitates troubleshooting by simulating potential malfunctions and supports operation and maintenance (O&M) tasks—such as modeling plant behavior during high-voltage switching operations—for enhanced safety.



C-HIL architectural design

NHOA Energy's BESS control system follows a modular design philosophy centered around the concept of Power Islands (modular generating units). A central power plant controller (Master) oversees the entire system and coordinates multiple distributed Power Island controllers (Slaves), with the number of these units depending on the size of the BESS.

C-HIL architecture is designed to maximize simulation accuracy and fidelity. At its core is the flagship OP5707XG real-time simulator, used to model the grid and power systems. All relevant BESS control hardware is physically interfaced with the simulator, including:

NHOA Energy Power Plant Controller (PPC)

Serving as the BESS's brain, this redundant central controller handles communication with energy markets, computes aggregate active/reactive power setpoints, and dispatches optimized commands to generating units while preserving the health and longevity of the assets.

NHOA Energy PEMS Battery (Power Island's distributed controller)

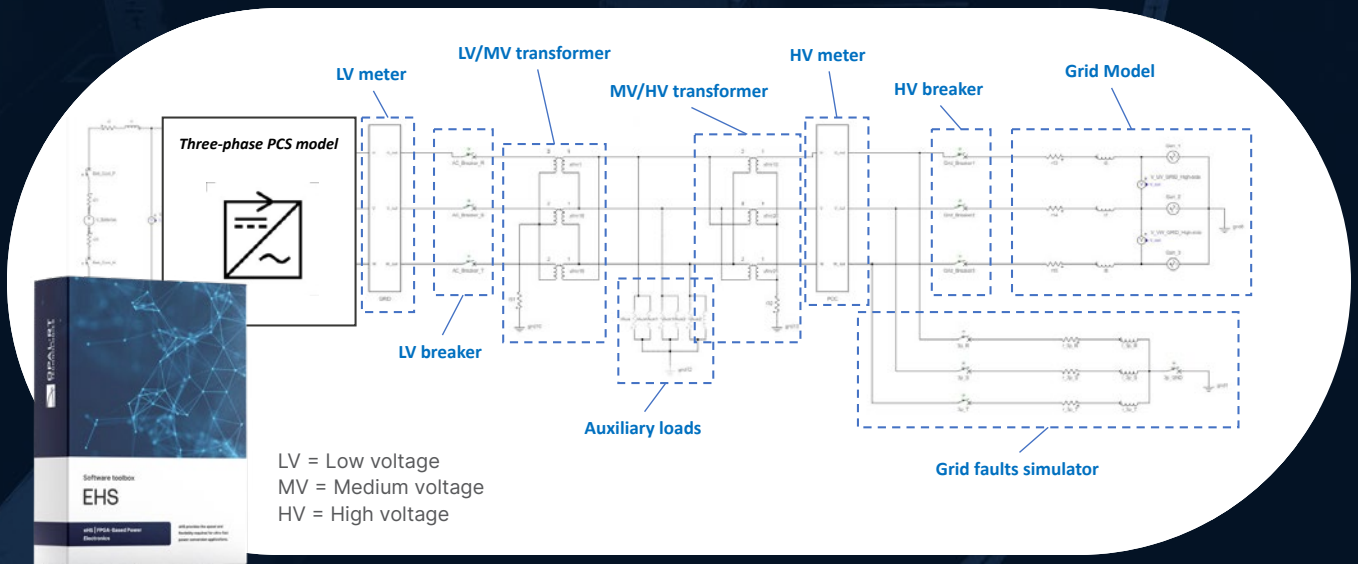
This controller manages the individual generating unit, receiving local setpoints from the PPC and ensuring optimal operation of the Power Conversion System (PCS) and batteries.

PCS Control Board

The low-level controller that manages energy flow between batteries and the grid. It generates modulation signals for the PCS power model (e.g., IGBT legs), interfaced directly with the simulator through a dedicated IO interface.

Power Meter

Measures electrical quantities at the Point of Connection (PoC)—such as voltages, currents, frequency, power factor, and harmonic content—via analog signals exchanged with the real-time simulator. These readings are polled by the PPC to complete the power control loop.



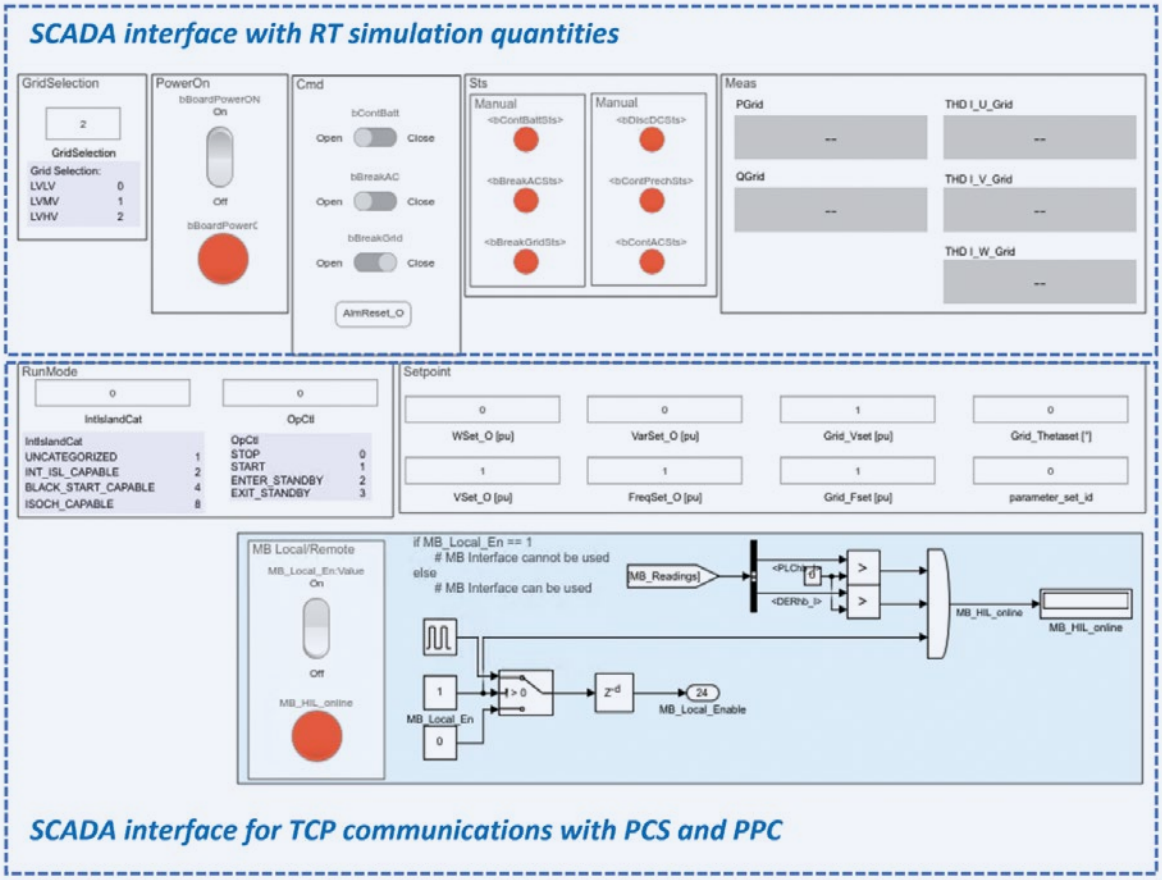
BESS Power Model Using eHS

The simulated power model developed by NHOA Energy employs a single Power Island configuration, representing the BESS as a single generating unit. This includes the DC side (emulating batteries), the DC/AC conversion stage (the PCS) and the AC output filter.

The PCS interfaces with the grid through an AC circuit breaker located on the Low-Voltage (LV) side. A low-to-medium-voltage (LV/MV) transformer connects the LV side to the Medium-Voltage (MV) level, where the plant's three-phase auxiliary loads are modeled. The MV side is further connected to the High-Voltage (HV) side via a medium-to-high-voltage (MV/HV) transformer. Transformer losses, auxiliary loads, and the grid short-circuit power (SCP) are appropriately scaled to align with the single-PCS approximation.

At the proof-of-concept, a real-time-controlled HV circuit breaker enables or disables the connection to the grid. A grid fault simulator allows for the emulation of various fault types—including single-phase, three-phase, and line-to-line faults—with configurable short-circuit impedance.

The model incorporates a Thevenin-equivalent grid, represented as a three-phase voltage source with adjustable series impedance, to simulate different SCP conditions. The simulation is executed using the eHS solver toolbox, offering ultra-high time resolution.



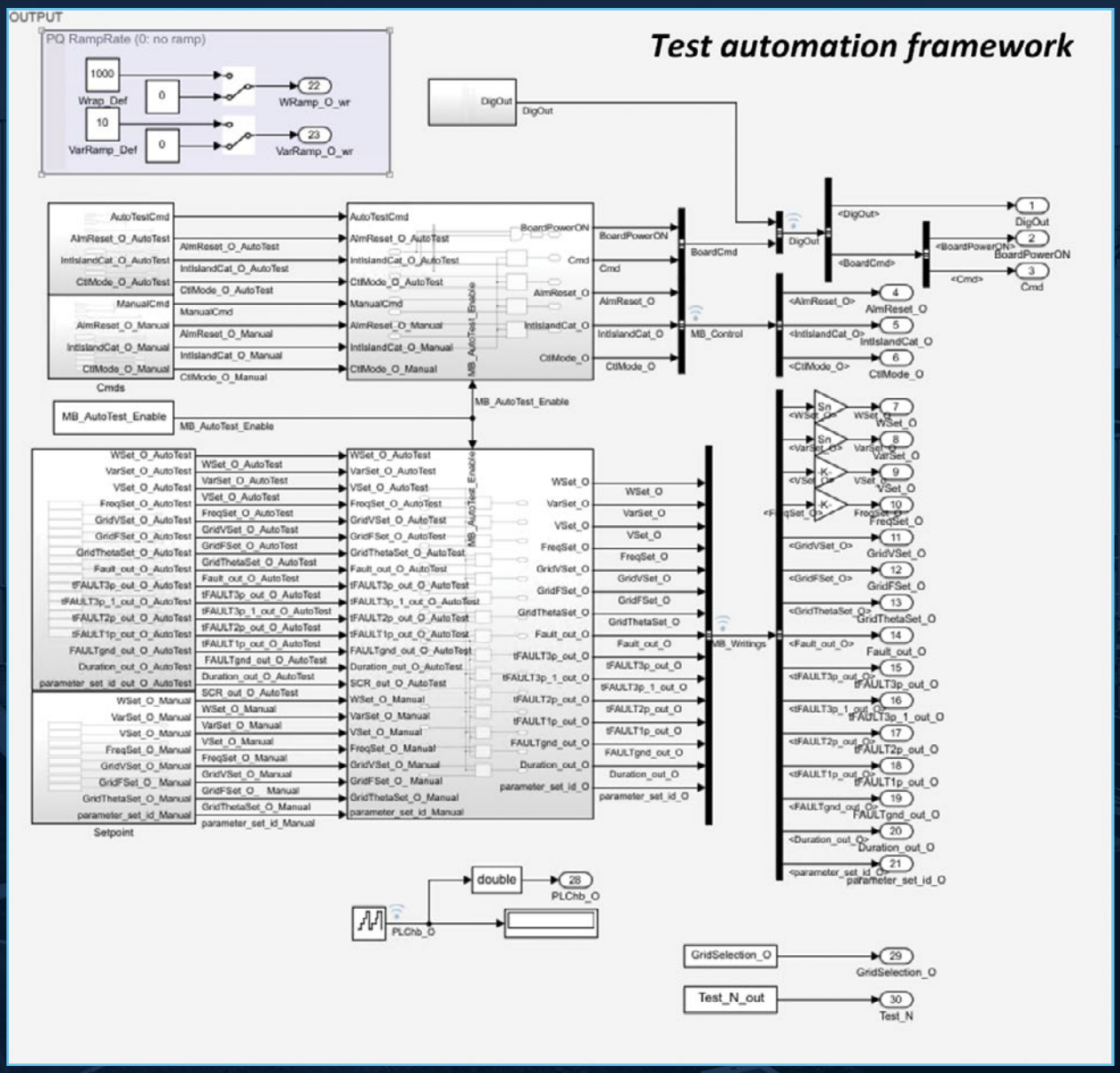
Simulation SCADA Interface

NHOA Energy's real-time simulation is complemented by a custom Supervisory Control and Data Acquisition (SCADA) interface developed in Simulink within the RT-Lab environment. Key functionalities include:

Real-time control of simulation parameters such as breaker status and fault impedance, grid SCP.

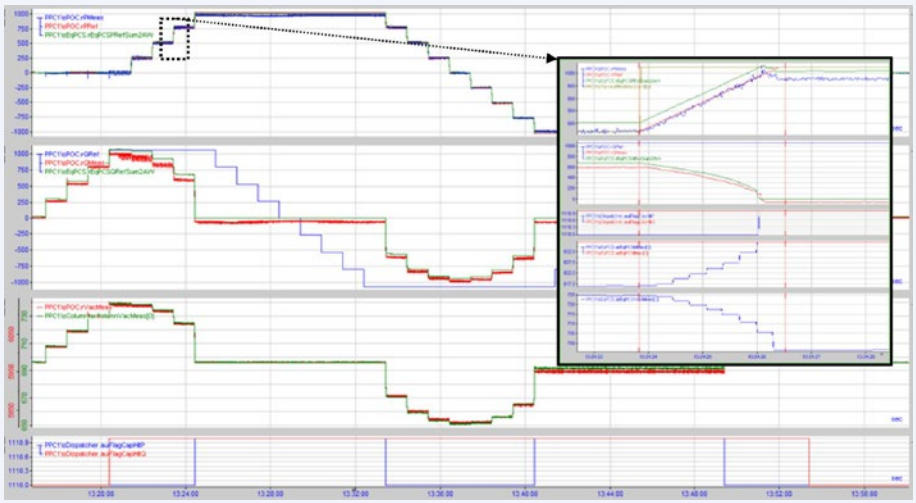
TCP-based communication with the PCS control board and the PPC, supporting command exchange and modular component testing.

Execution of standardized automated test procedures to assess subsystem (e.g., PCS) and full system (e.g., PPC) performance under various market and grid conditions, including grid faults.



Results and conclusions

A reported sample test includes issuing predefined active/reactive power setpoints to the PPC via the SCADA interface—**pushing the system to its power capability limits to validate overall performance.**



- **High-resolution simulation data** is collected and analyzed with a proprietary post-processing tool. This allows NHOA Energy to fine-tune system behavior and optimize performance ahead of Site Acceptance Tests (SAT). Post-SAT, actual plant data is compared with the simulation outputs, **confirming the high fidelity of the C-HIL framework** in both transient and steady-state conditions.

- **C-HIL simulations are a key enabler of NHOA Energy's engineering success.** They accelerate development, bring speed and confidence to the commissioning phase, and allow efficient and reliable plant management after delivery.

- In today's rapidly evolving grid and energy markets, C-HIL is one of the cutting-edge technologies we are leveraging to drive innovation, deliver high-quality solutions, and ensure seamless after-sales service.

> C-HIL with OPAL-RT is a key pillar of our innovation—enabling exploration of corner cases, accelerating development, ensuring grid compliance, and delivering reliable, high-performance energy storage systems from simulation to operation.

Dr. Stefano Pane
Control Engineer at NHOA Energy

STEFANO PANE

Ready to innovate?

For over two decades, OPAL-RT TECHNOLOGIES has been a global leader in real-time simulation and hardware-in-the-loop (HIL) testing. Since 1997, OPAL-RT has empowered engineers and researchers with accessible, innovative, and customized simulation technology—bridging the gap between modeling and real-world applications. By leveraging high-performance computing, OPAL-RT accelerates the development of advanced solutions in energy, automotive, aerospace, and beyond. With our ISO 9001:2015 certification and a strong commitment to sustainable development, we're not just developing technology—we're building a better future, together.

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