Accelerating Energy Transition: HIL Testing for Smarter Utility-Scale BESS

Validation de l'intégration et de l'incidence de convertisseurs de puissance dans un réseau en prenant pour exemple des unités de stockage par batteries

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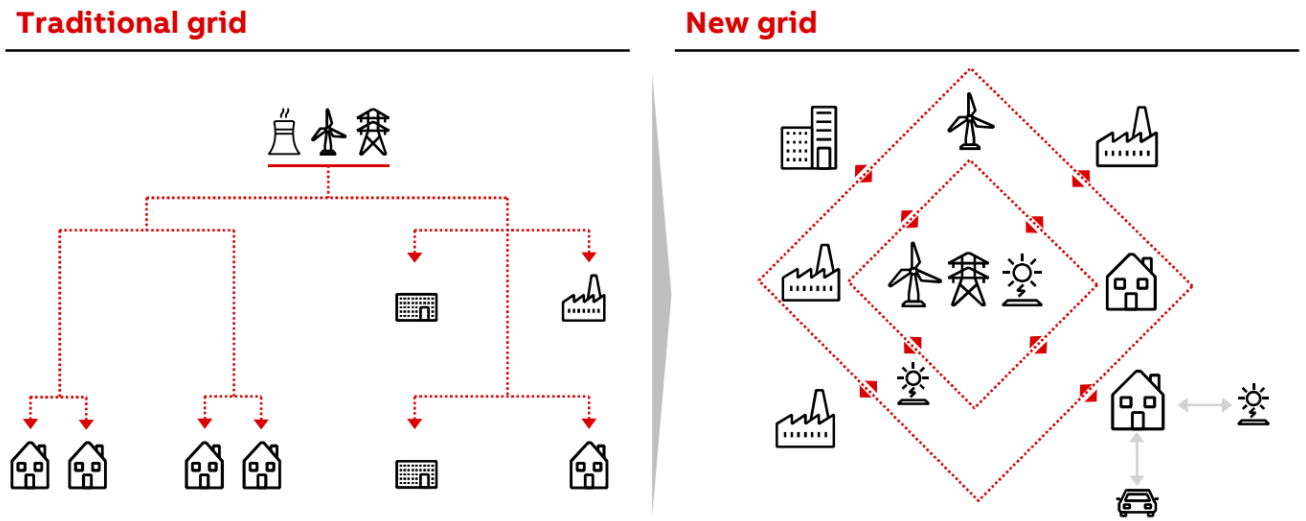
Accelerating Energy Transition

Transition from a centralized to a distributed grid

- The integration of distributed generation (DG) in the distribution system poses technical constraints for the electrical power system. The addition of relatively large amounts of generation to the distribution system challenges the historical setting principles and design assumptions made in developing protection and control strategies based on overcurrent protection.
- The necessity and complexity of additional protection and control measures increase as the aggregate DG capacity within a potential island approaches or offsets the load within that island. In addition, the varying nature of DG availability and fault current capability must also be considered.
- As the distribution system evolves to accommodate more DG, the design and implementation of the feeder protection must also evolve.



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General challenges due to power electronic based DERs: an overview

- ☐ Reduced System Inertia
- ☐ Fault Current Characteristics
- ☐ Bidirectional Power Flow
- ☐ Islanding and Unintentional Islanding
- ☐ Voltage Regulation Challenges
- ☐ Harmonics and Power Quality Issues
- ☐ Coordination Complexity

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How to solve the problem: Grid Forming vs Grid Following

- **Grid-Following (GFL) Converters**
  - Synchronizes to grid voltage using PLL
  - Operates as a current source
  - Requires strong external grid
- Application examples
  - Solar PV inverters
  - BESS connected to strong grids
  - Wind turbine inverters (with DFIGs)

- **Grid-Forming (GFM) Converters**
  - Generates its own voltage waveform
  - Operates as a voltage source
  - Can control frequency and voltage autonomously
- Application examples
  - BESS in weak grids or microgrids
  - Inverter-based resources replacing thermal plants
  - Critical for high-renewable penetration grids

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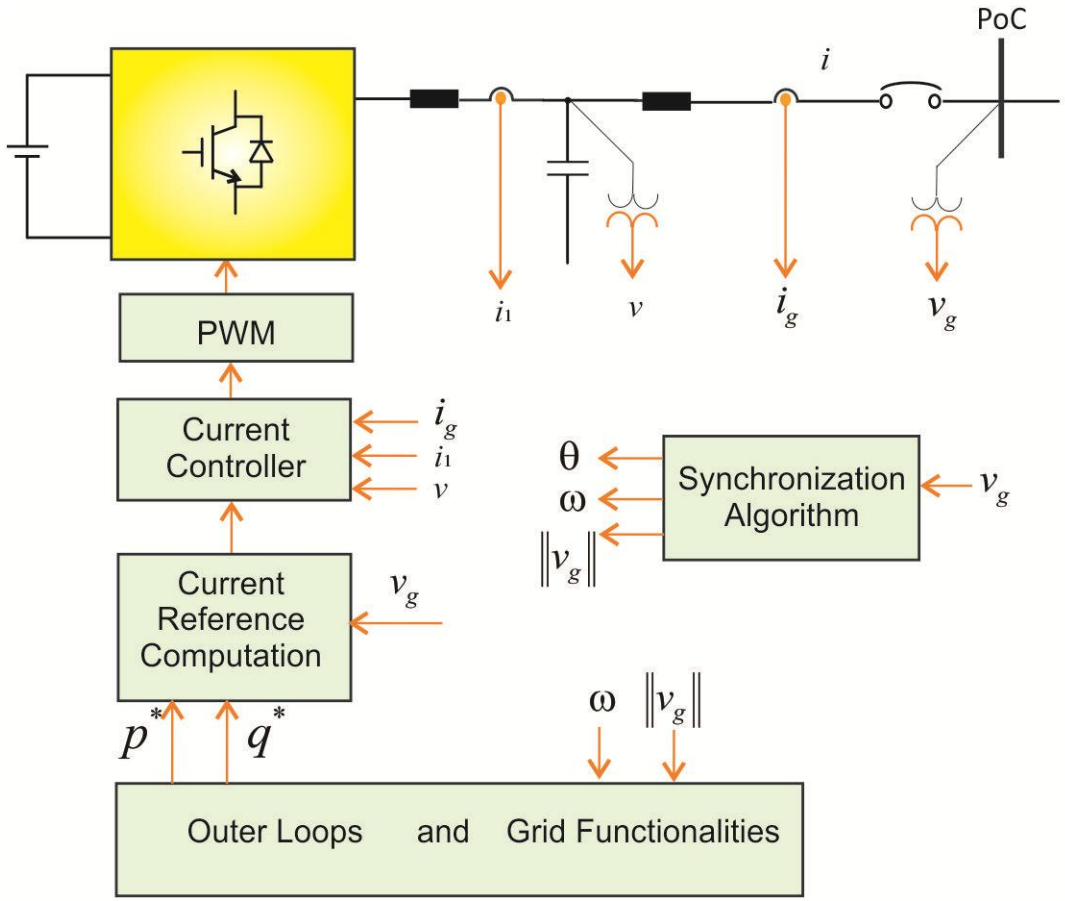
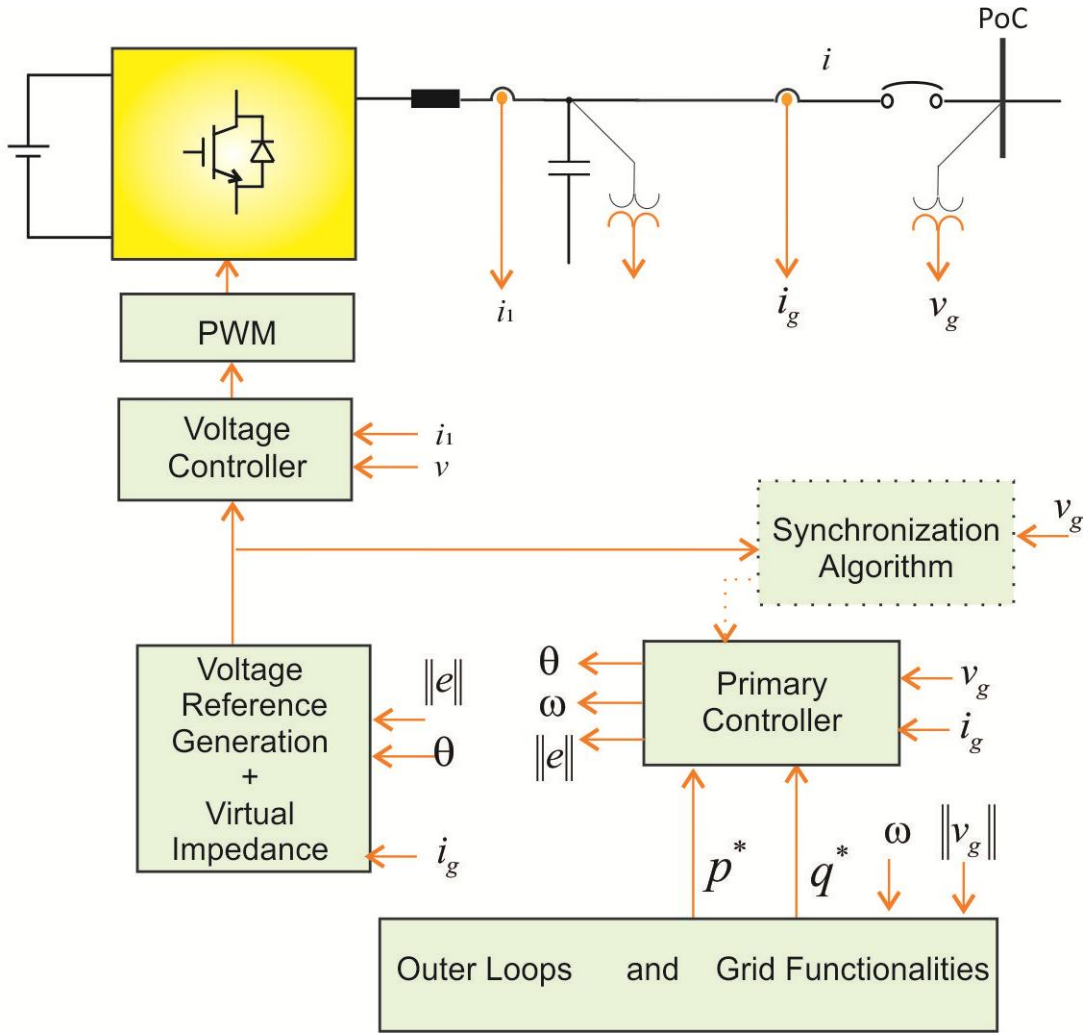
How to solve the problem: Grid Forming vs Grid Following

Grid-following mode



Grid-forming mode



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How to solve the problem: grid scale BESS

- The most established solution to overcoming the grid stability issues arising from the increasing penetration of Inverter based distributed energy resources (IBDER) is installing grid scale BESS, as standalone or as part of a hybrid plant at the same location of a large PV or Wind park.
- A Grid-Scale BESS can support grid by means of:
  - Inertial Response
  - Frequency Stability
  - Voltage Stability
  - System Resilience
  - DER Integration
- The Power Plant Controller (PPC) has the central control functions in a large BESS plant.

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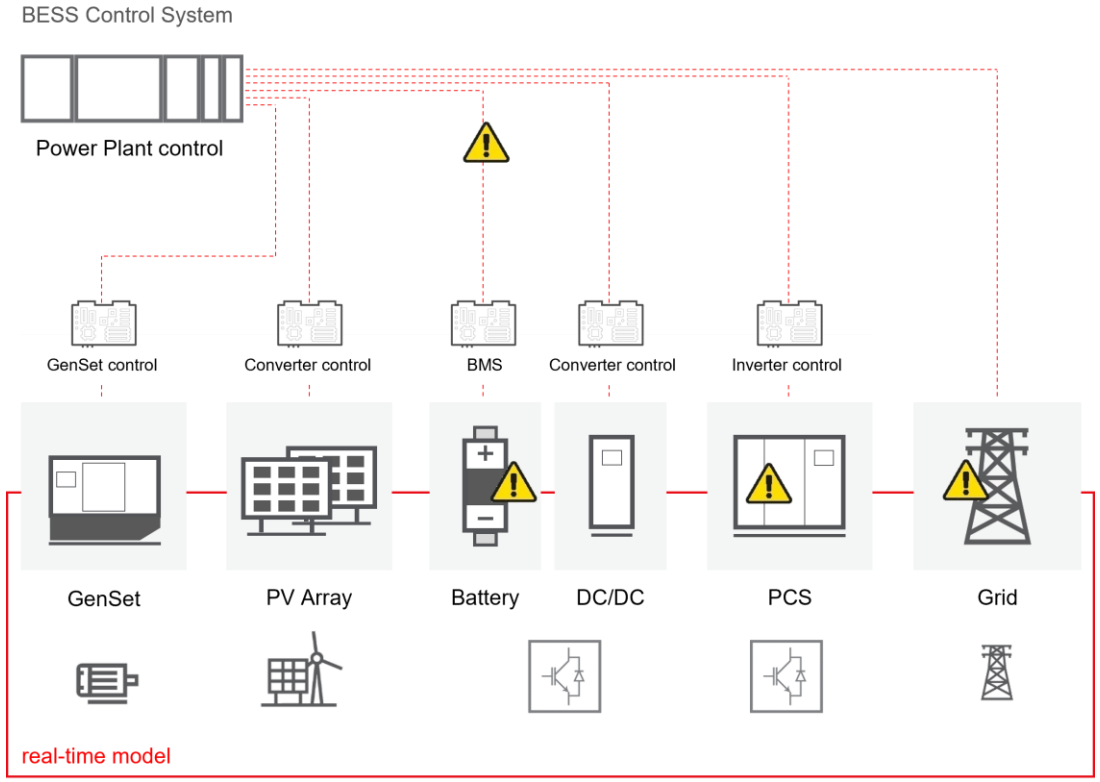
PPC/EMS Development : Test your plant controller logic on a simulated power system

- In the initial stages of a controller development, it is often enough to rely on average models.
- Power Plant Control
  - Testing during development
  - Performance validation
- Communication testing
  - Validation of communication interfaces
- Performance testing
  - BESS control system functional testing
- Fault testing
- Operational support



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PPC/EMS Development : What happens when you move from development to commissioning phase

- BESS integration
  - Different OEMs for the BESS subsystems
  - New OEM combination every project
  - Battery chemistry (e.g. NMC vs LFP)
  - Intense digital communication
- BESS grid connection
  - Interoperability
  - System stability
  - Grid support performance
  - Intense digital communication
- Pre-commissioning
  - Validation
- Commissioning / Operation
  - High service cost
    - Downtime
    - Field engineering
  - Relationship with OEMs
  - Performance optimization

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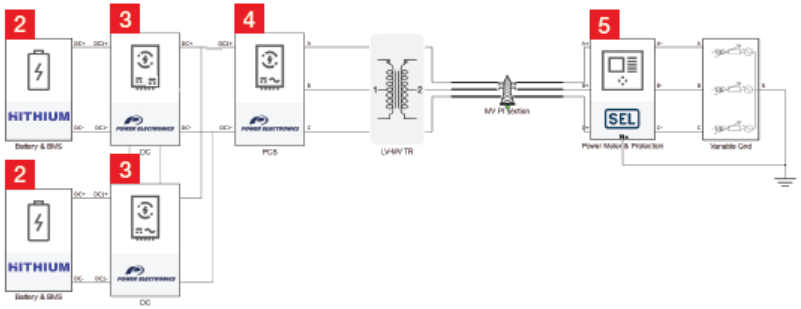
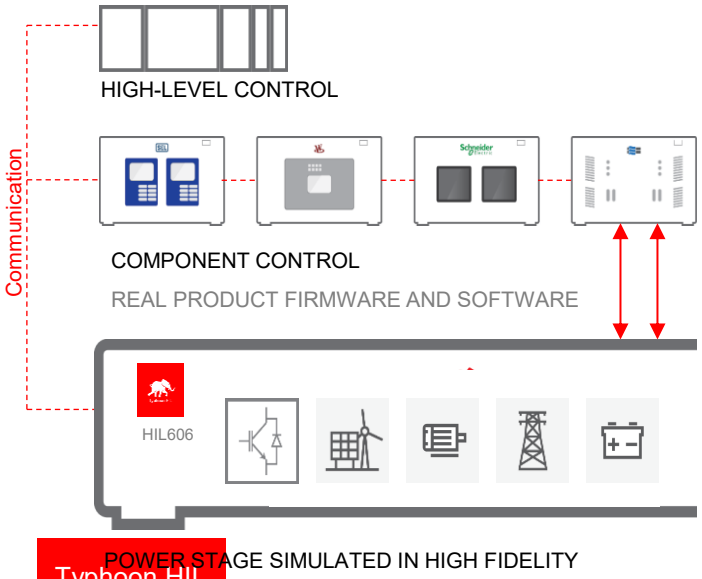
BESS integration testing: one step before field deployment

Real control. Field-grade firmware. No power.

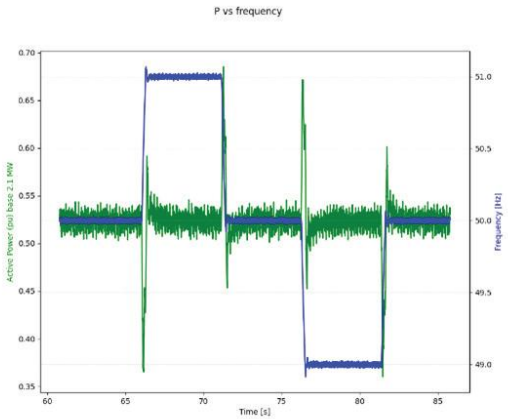
Controller HIL digital twins developed in close collaboration with PCS suppliers, Battery and Relays OEMs.



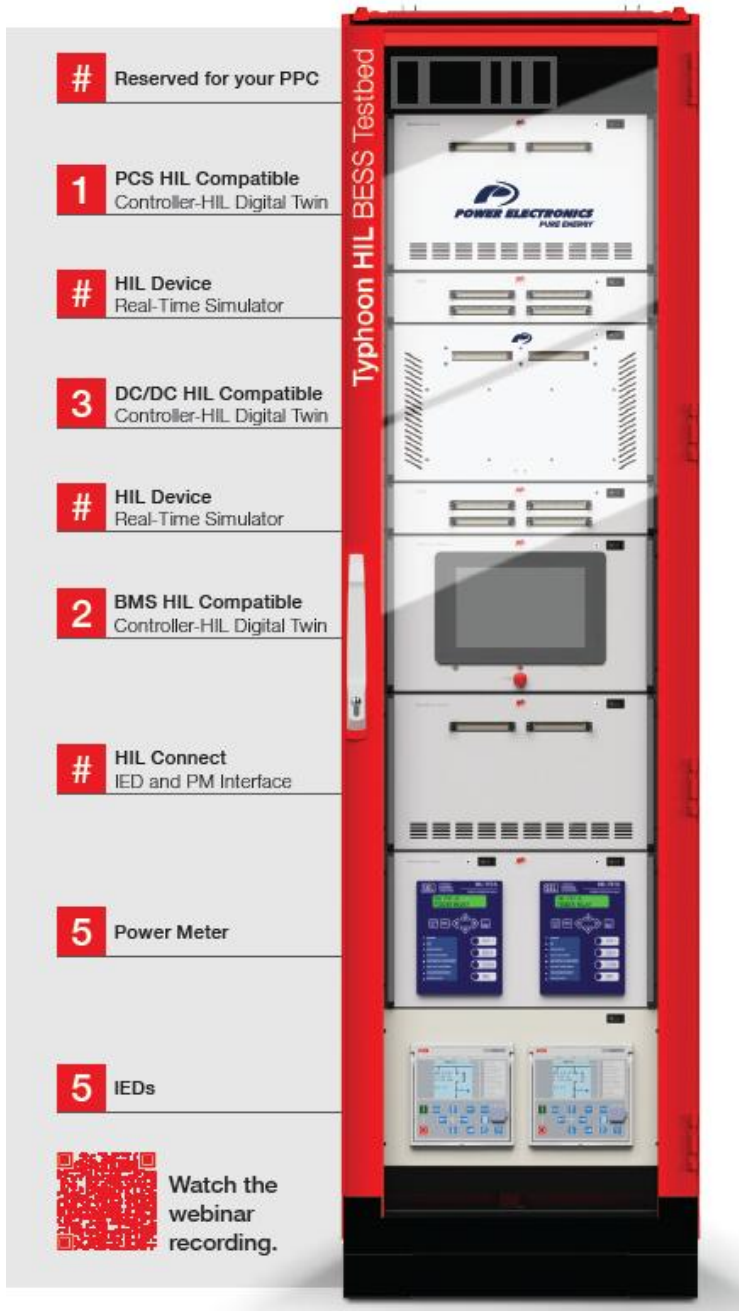


Complete lifecycle coverage.

From PCS and BMS vendor qualification, to grid-code compliance testing and decades long operational support.



Real signal captured with fully automated test procedures. In accordance with AEMO, UL1741, EN50520, etc.



Typhoon HIL

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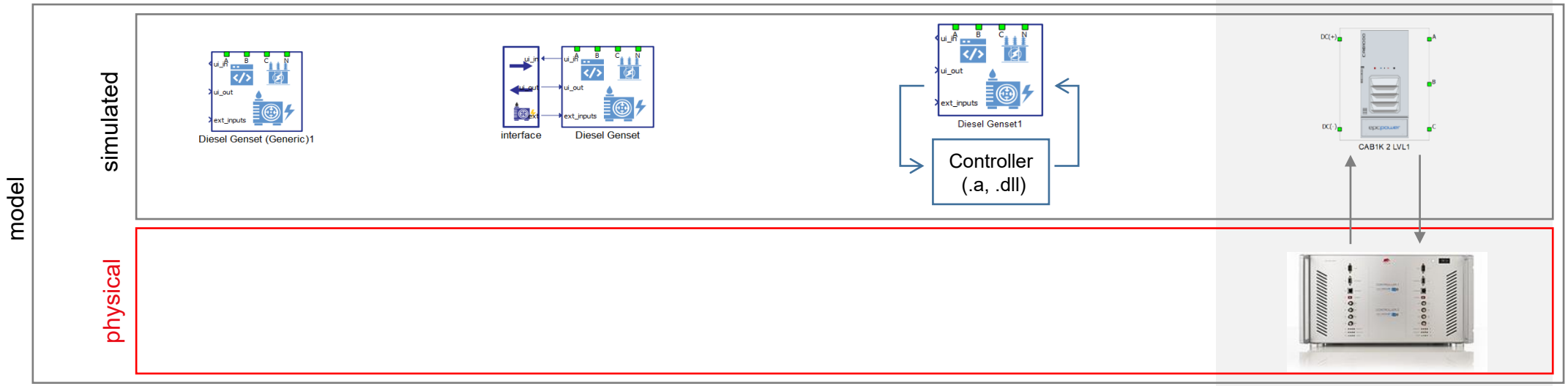
Smart Models: Single model set used for design, testing, validation, and system integration.

Generic models

OEM Communication Models
OEM communication interface, generic behavior

"SIL type Models"
OEM Control Models
Controller model binaries (.a, .dll) in the loop with generic model

Productized Models
(aka "HIL Compatible")
High-fidelity power stage model with actual controller



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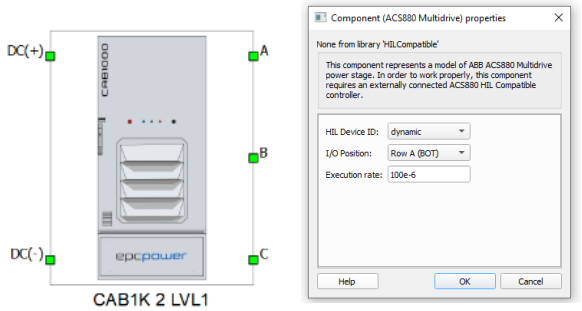
Productized model packaging

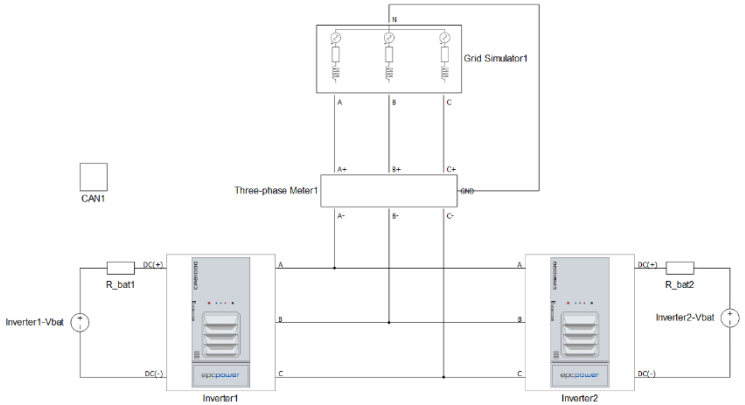
☐ Packaged controller

☐ Model library

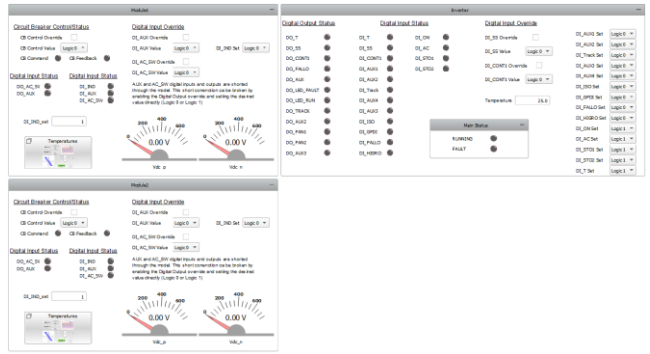
Executable in real-time with sub µSec resolution



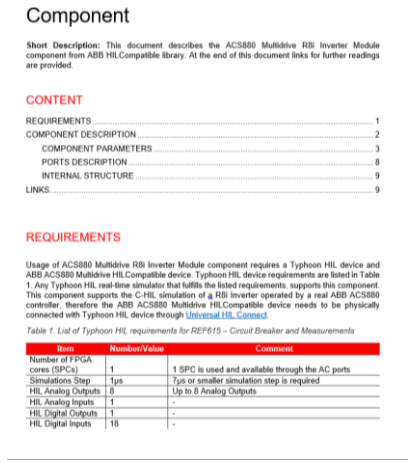
☐ Application examples



☐ Simulation dashboard



☐ Documentation



Component

Short Description: This document describes the ACS880 Multidrive RBi Inverter Module component from ABB HILCompatible library. At the end of this document links for further readings are provided.

CONTENT

REQUIREMENTS

Usage of ACS880 Multidrive RBi Inverter Module component requires a Typhoon HIL device and ABB ACS880 Multidrive HILCompatible device. Typhoon HIL device requirements are listed in Table 1. Any Typhoon HIL real-time simulator that fulfills the listed requirements, supports this component. This component supports the C-HIL simulation of a RBi inverter operated by a real ABB ACS880 controller, therefore the ABB ACS880 Multidrive HILCompatible device needs to be physically connected with Typhoon HIL device through Universal HIL Connect.

Table 1. List of Typhoon HIL requirements for REF615 – Circuit Breaker and Measurements

Item	Number/Value	Comment
Number of FPGA cores (SPCs)	1	1 SPC is used and available through the AC ports
Simulations Step	1µs	7µs or smaller simulation step is required
HIL Analog Outputs	8	Up to 8 Analog Outputs
HIL Analog Inputs	1	-
HIL Digital Outputs	1	-
HIL Digital Inputs	18	-

Typhoon HIL

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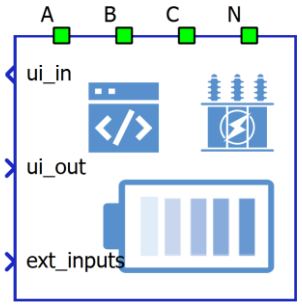
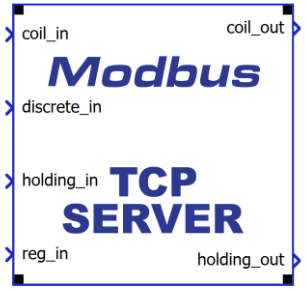
Typhoon's solution for BESS

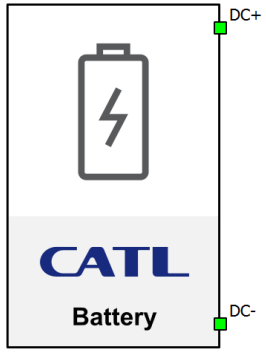
- Real-time simulation of the electrical dynamics of all parts of the system
  - Different fidelity levels representation of the BESS components.
    - Average models (generic)
    - Surrogate (generic + OEM based communication)
    - High-order (switched, HIL Compatible)
- Extensive communication protocols support
  - Modbus, DNP3, C37, IEC 61850, …
- HIL Compatible
  - BMS, PCS, Protection
- EASE OF USE!
- CUSTOMER SUPPORT!!



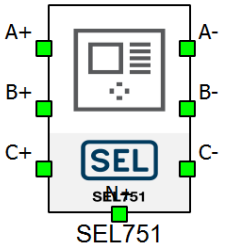
Battery ESS (Generic)



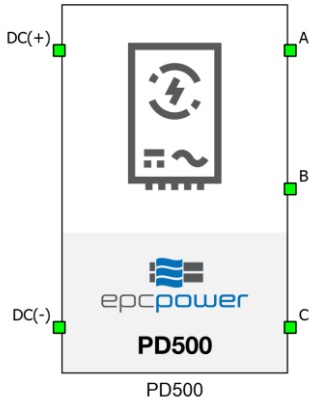
ModBus Device



CATL Battery



SEL751



PD500

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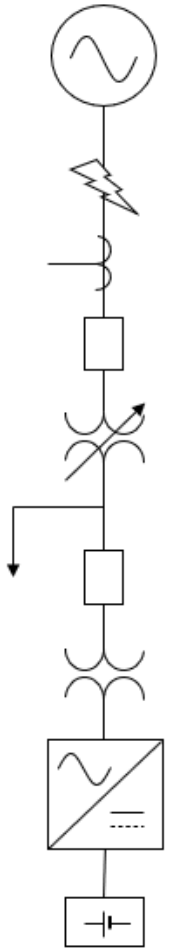
Typhoon’s solution for BESS: Example 1

- ☐ Integration studies
  - ■ Power Electronics GEN3
  - ■ OEM Power Quality Meter
  - ■ Comparison with PSCAD model
  - ■ Voltage disturbances mismatches
- ☐ Operation HIL
  - ■ HIL testbed as a tool for reproducing on-field events
- ☐ Communication pre-validation



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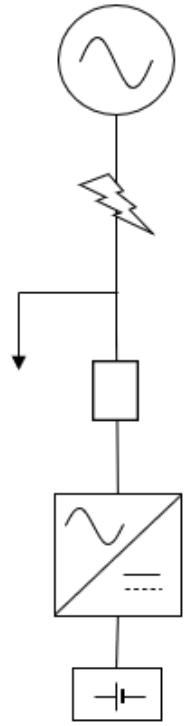
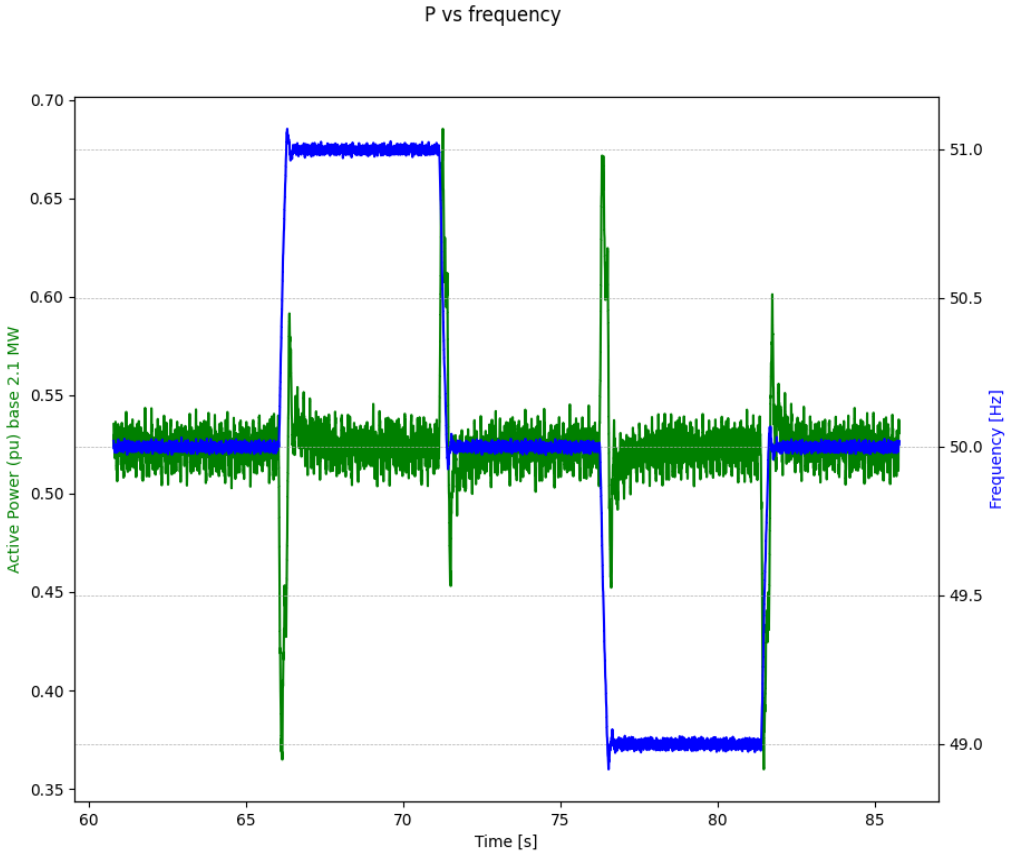
Typhoon’s solution for BESS: Example 2

- Integration studies
  - Multiple PCS (Power Electronics GEN3, EPC Power)
- Test according to the Australian and United Kingdom grid requirements





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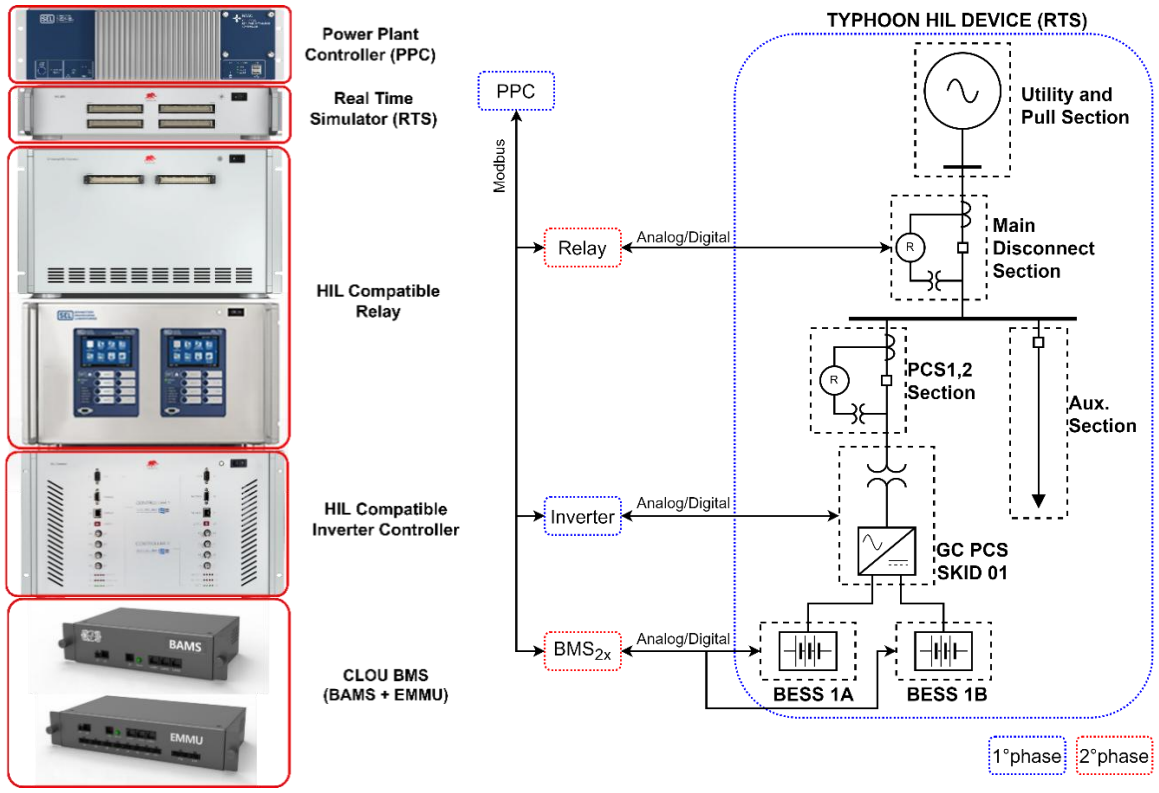
Typhoon's solution for BESS: Example 3

- Integration studies + EMS validation
  - OEM IED for Power Monitoring
  - OEM IED for Feeder / Point of Connection protection
  - OEM Industrial Controller operating as EMS
  - OEM Power inverter + Comms)
  - Virtual BMS
- BMS studies
  - OEM BMS surrogate model
  - SOC dependent battery resistance
  - Generic battery array model for multi-cell representation



Doosan GridTech

Powering Performance: How Hardware-in-the-Loop (HIL) Revolutionizes Battery Energy Storage Systems (BESS)

Partnering with Typhoon HIL has transformed our approach to energy storage system development. Their real-time simulation technology allows us to rigorously test and optimize our Battery Energy Storage Systems (BESS) in a controlled environment, ensuring seamless integration with renewable energy sources and grid infrastructure. This collaboration not only accelerates our deployment timelines, but also enhances system reliability and safety, ultimately delivering greater value to our customers.

Steve Hummel
Chief Technology Officer
DOOSAN

Typhoon HIL Read more https://www.doosangridtech.com/blog/how-hil-revolutionizes-bess.

IHI Terrasun

Deploy Energy Storage Systems Safely and Efficiently

“The Typhoon HIL Simulation provides means to quickly, safely, and cost effectively test Energy Storage Devices and Energy Storage Systems (ESS). IHI Terrasun can safely simulate failure cases on a Typhoon HIL System that would normally cause serious equipment damage on a real system and unsafe conditions for personnel.

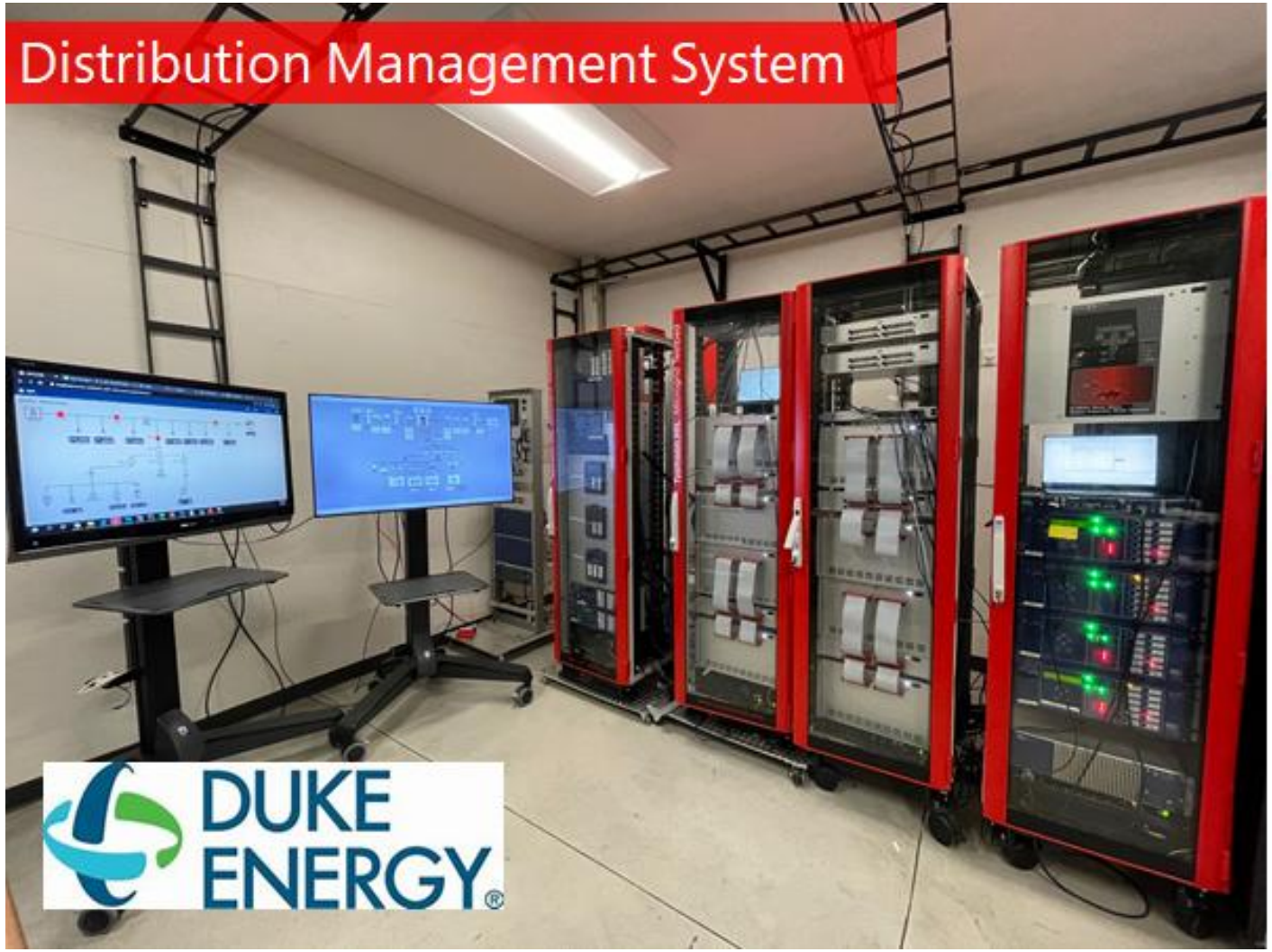
Jim Cleveland
Senior Controls and QA manager
IHI Terrasun

IHI terrasun

Typhoon HIL Read more https://www.typhoon-hil.com/blog/ihi-terrasun-energy-storage-systems/.

Duke Energy

Integration testing with productized models



Controllers in the Loop

- ABB PCS100
- SEL RTACs X 4
- SEL751
- SEL787
- SEL700G
- SEL651RX3
- SEL351
- SEL451
- Beckwith Capbank
- Beckwith Tap Changer
- EATON CL7
- EATON CBC8000
- Hitachi Powerstore *

Real Time Emulators

- 6 X Typhoon HIL604

Signal Conditioning

- 7 X HILConnects

Typhoon HIL

Selected Case Studies on Interoperability and Integration

Special Report

How Hardware in the Loop Addresses Challenges of Microgrid System Integration

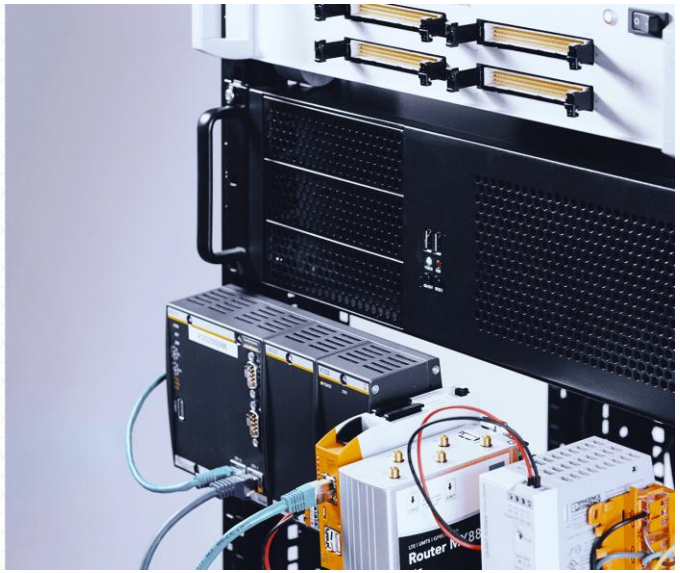
MICROGRID KNOWLEDGE

Case Study MICROGRID KNOWLEDGE

Reducing surprises in the field

in Microgrid System Integration

Rolls-Royce mtu



Case Study MICROGRID KNOWLEDGE

Increasing confidence with HIL testing

in Microgrid System Integration

DUKE ENERGY.

Case Study MICROGRID KNOWLEDGE

Complying with standards

in Microgrid System Integration

Hitachi Energy

Typhoon HIL

Read the blogs with the Special Report and the case studies with Duke Energy, Rolls Royce, and Hitachi Energy to learn more.

Thank you for your attention!