CASE STUDY: DATA CENTERS

DATA CENTER DEVELOPER DE-RISKS DESIGN WITH HIL TESTING AT NATIONAL LABORATORY OF THE ROCKIES

THE FACILITY: A SIMULATION-BASED TESTBED AT THE USA'S PRIMARY NATIONAL LAB FOR ENERGY SYSTEMS

Demand for data centers is increasing faster than we can develop the power grid infrastructure required to securely supply them. New solutions are direly needed to address the massive power demands of AI workloads and hyperscale cloud growth. That's where the National Laboratory of the Rockies (NLR) comes in.

As the US Department of Energy's primary national lab for energy systems, NLR provides a myriad of research programs, collaborative research facilities, technologies, and partnerships to foster innovation and enhance the security and reliability of the grid. They operate an impressive RTDS® Simulator laboratory with hardware-in-the-loop (HIL) testing capabilities - a key approach for de-risking and accelerating important new power system technologies.

NLR collaborated with Verrus™, a developer of flexible and grid-aware data centers, to model, test, and validate Verrus' data center design using NLR's real-time simulator.

The RTDS Simulator used for data center testing at NLR
Photo from Verrus

WHY DATA CENTER LEADERS ARE ADOPTING HIL TESTING

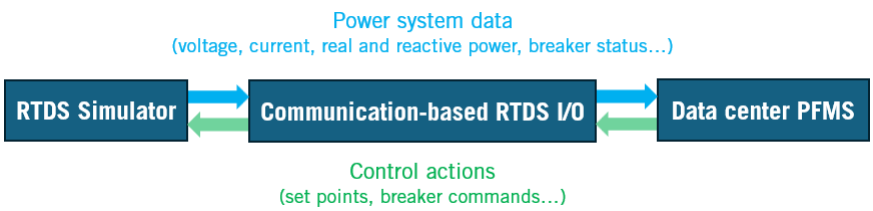
The RTDS Simulator runs detailed simulations of the data center's electrical architecture. In HIL testing, control and protection devices are connected to this simulated power system in a lab environment. This lets developers and utilities verify secure and reliable data center operation prior to deployment.

- **Accelerate project timelines by demonstrating grid code compliance with real hardware in the lab**
- **Verify control and protection behaviour, including fault ride-through, before issues occur in the field**
- **Increase stakeholder confidence by exposing real equipment to a wide range of operating conditions**

THE CHALLENGE: ENHANCING GRID STABILITY WITH ADVANCED DATA CENTER ELECTRICAL ARCHITECTURE

In the Verrus approach, the data center functions as a flexible asset to the grid rather than just a passive load. Verrus integrates a utility-scale battery energy storage system at the medium voltage bus, which can support the grid by responding to utility dispatch requests. Additionally, Verrus' unique StabiliGrid™ control architecture enables fast response of the battery inverters in grid-forming mode during contingency events. This helps to extend the ride-through capabilities of the data center, reducing the chances of an islanding event, and supports rapid recovery - making the data center a truly flexible large load and a better citizen of the grid while also meeting requirements for uptime.

HIL testing of Verrus' unique power flow management system (PFMS) enables rigorous validation of these functions in the safety of the lab.



"The RTDS Simulator has been instrumental in accelerating our data center design process. Hardware-in-the-loop testing eliminates surprises in the field that could delay commissioning or incur major costs during operation."

Ben Wheeler, VP, Product Development at Verrus

MODELLING AND TEST SETUP: INSIDE THE HARDWARE-IN-THE-LOOP TESTBED FOR DATA CENTERS

A model of the Verrus data center electrical architecture was developed in RSCAD™ FX - the RTDS Simulator's user-friendly software. Simulated components include:

- **IT loads:** Time-varying load behaviour including fast transient behaviour associated with AI workload
- **UPS and BESS:** Grid-forming and -following modes supported; ability to test low-level firing pulse controls if required; support for vendor-specific control model integration if required
- **Cooling loads:** Sensitivity to voltage and frequency; detailed control logic and operational sequences
- **Protection and control:** Any functions not included in device(s) under test can be simulated with library components for protective relays and control logic

The RTDS Simulator's network interface card creates a closed-loop interface between the simulation and the data center controls via the **DNP3 communication protocol**.

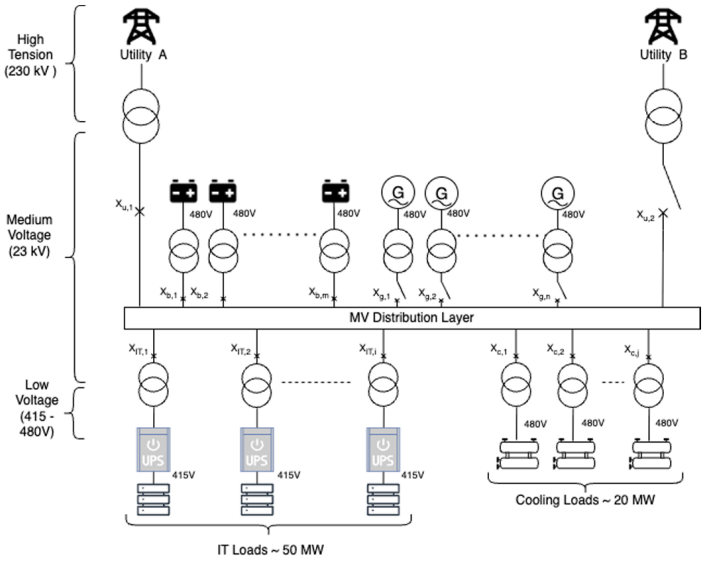
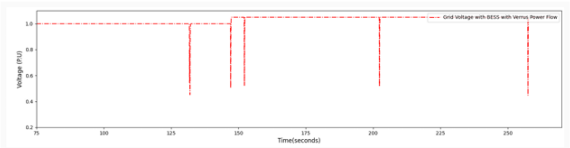
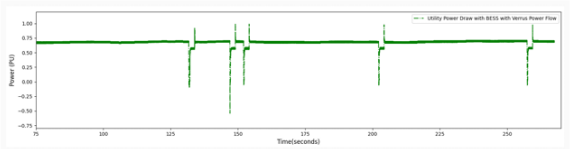


Diagram of the simulated data center power system

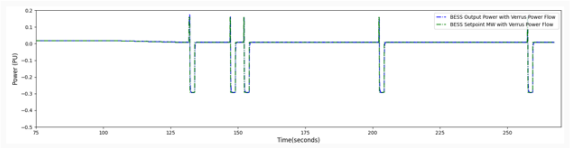
Image courtesy of NLR



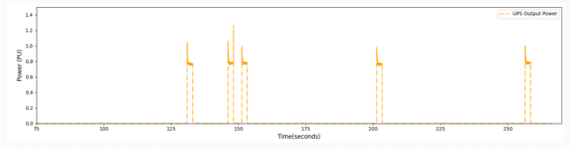
(a) *Grid voltage*



(b) *Utility power import*



(c) *BESS output power*



(d) *Data center UPS load*

Response of the data center during repeated undervoltage events (200 seconds elapsed)

Image courtesy of NLR

OUTCOMES: DEPLOYING WITH CONFIDENCE

HIL testing demonstrated the successful performance of the Verrus data center in many scenarios:

- Fault ride-through for short-duration contingencies
- BESS dispatch in response to utility request
- Transition to islanded mode for longer utility outage
- Load-shedding of interruptible workloads
- Dispatch of long-duration power backup in case of BESS charge depletion
- Grid reconnection after utility recovery

The RTDS Simulator also allowed NLR to recreate a real voltage event that resulted in large load loss (the disconnection of ~1,500 MW of data center load) in Northern Virginia in 2024. The question was: would Verrus' data center design change the outcome for the power system?

When faced with the cascaded voltage event at its terminals in the simulated environment, Verrus' design prevented premature disconnection of the data center and allowed fault ride-through, thanks to coordinated control and grid-resilient protection settings. This is how HIL testing increases confidence in novel technologies that have a positive impact on the power system.

HIL testing with the RTDS Simulator demonstrated the effectiveness of Verrus' unique data center design in a realistic lab environment. The developer goes into the build knowing the design has been stress-tested, and utilities have evidence of the facility's dynamic response to events.

LEARN MORE ABOUT DE-RISKING DATA CENTERS AT RTDS.COM / APPLICATIONS / DATA-CENTERS