OPAL-RT TECHNOLOGIES

Shape the Future of Microgrids: Hybrid DC-AC PHIL Test Bench

Québec   RQEI Réseau québécois sur l'énergie intelligente   ÉTS Le génie pour l'industrie   GRÉPCI

Applications

- Grid-Forming and Grid-Following Converters
- DC/AC Microgrids with Islanding and Ancillary Services
- Energy Storage and Grid-Tied EV/V2G Integration
- Microgrid Cybersecurity and Power Quality Analysis
- Distributed Energy Resource Management Studies

Type of Simulation

- Power Hardware-In-the-Loop (PHIL)
- Control Hardware-In-the-Loop (CHIL)
- Software-In-the-Loop (SIL)
- Digital Twins

SUCCESS STORY

PHIL's Role in Microgrid Integration

Microgrids offer a sustainable solution that enhances energy reliability, integrates renewable resources, and strengthens grid resilience. By facilitating local adoption of renewables like solar and wind, microgrids reduce dependence on fossil fuels and support carbon reduction goals. They also drive innovations in smart grids and energy storage, serving as platforms for developing decentralized power systems.

However, despite their advantages, microgrids face significant technical challenges that hinder widespread adoption and effective operation. Integrating diverse renewable energy sources, such as solar PV, wind turbines, and batteries into a cohesive ecosystem, introduces complexities related to compatibility, reliability, and scalability. Coordinating these technologies requires sophisticated control systems capable of optimizing performance under varying load conditions and fluctuating energy inputs. Additionally, ensuring seamless grid interconnection for both grid-tied and islanded modes is crucial for maintaining power quality and stability, necessitating precise synchronization and protection coordination.

The Power Electronics and Industrial Control Research Group (GRÉPCI) at École de Technologie Supérieure (ÉTS) leverages its expertise in power electronics, power systems, smart control, renewables, and real-time simulation to develop innovative solutions that enhance the design, operation, and integration of microgrids, effectively addressing challenges such as power flow management, resource compatibility, system reliability, cybersecurity, and grid stability. To overcome key obstacles in achieving their research objectives, OPAL-RT has recently developed a Power Hardware-in-the-Loop (PHIL) test bench for GRÉPCI. This cutting-edge facility will enable this research group to refine microgrid design, operation, and integration strategies, ultimately contributing to the advancement of resilient and efficient energy systems.

" The Hybrid DC-AC PHIL developed by OPAL-RT, provides a platform to test and validate novel IBR/DER topologies, their control, and their piece-wise integration to large Microgrids. It serves as an invaluable tool for the researchers at ÉTS to address several areas of research ranging from microgrid cyber-security studies, grid-tied EV, V2G, DER energy resource management, etc. In addition, the remote controllability of the testbench allows access to other remote research communities in Quebec and elsewhere too."

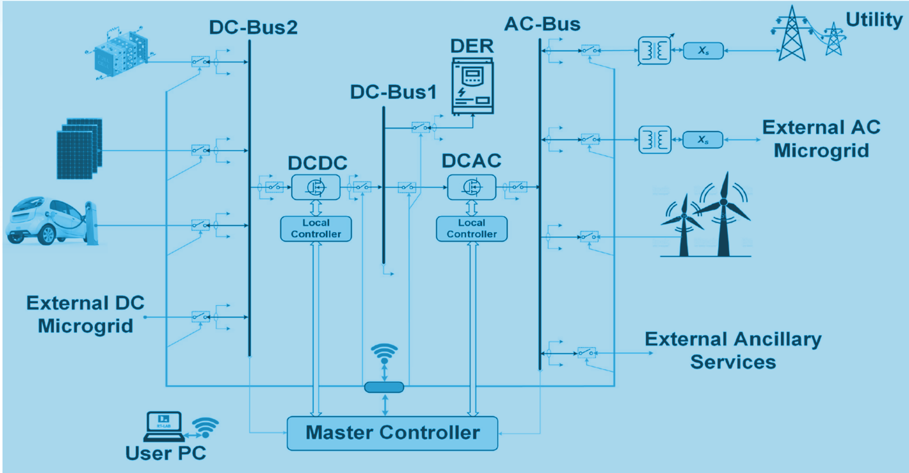
—— Prof. Kamal Al-Haddad, ÉTS

Solution Highlights

To shape the future of microgrid systems and address the challenges they pose, discover the highlights of the **Hybrid DC-AC PHIL Test Bench** developed by OPAL-RT Technologies.

Innovative Testing

Incorporates Hardware-In-the-Loop (HIL), Control Hardware-In-the-Loop (CHIL), Power Hardware-In-the-Loop (PHIL), Rapid Control Prototyping (RCP), and Real-Time Simulation (RTS) to accelerate testing and validation.



Controlled Environment

Creates a controlled and flexible environment with several protection layers for evaluating multiple system configurations.

Diverse Energy Resources

Incorporates various DC and AC distributed energy resources and emulators.

Renewable Energy Integration

Drives progress in integrating renewables and enhancing grid resilience.

Efficiency Improvement

Supports efficiency improvements and standardized protocols for microgrid operations.

Cybersecurity Studies

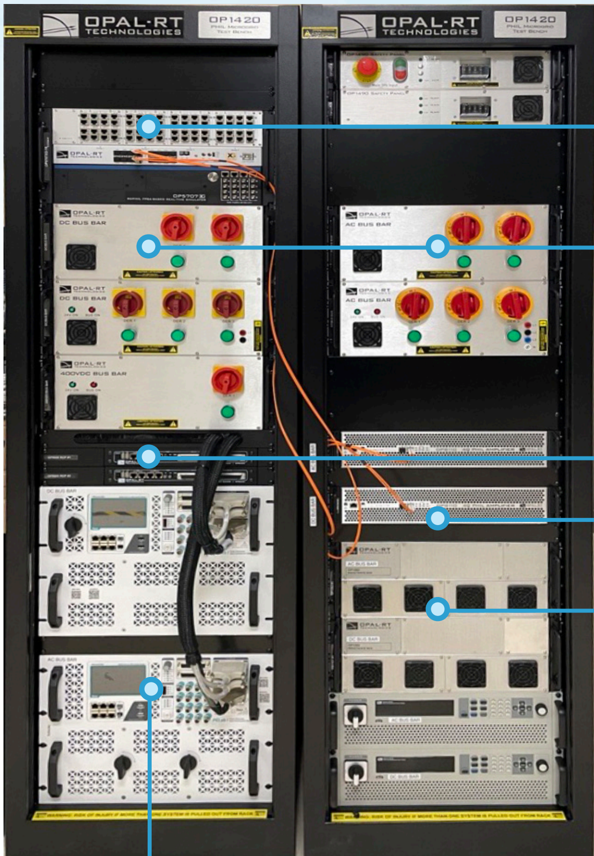
Facilitates research on cybersecurity measures to protect microgrids from potential threats and vulnerabilities.

Remote Access

Remote control of the test bench improves research efficiency and collaboration without the need for physical presence.

Structure Overview

Two 40U cabinets for housing the components.



Real-Time Simulator

- The entire bench is managed using a powerful real-time simulator from OPAL-RT like the OP5707XG.
- This simulator operates as the master controller over the bus bar boxes, amplifiers, and RCP units.
- A model is developed based on MATLAB® and implemented on the simulator using RT-LAB, enabling users to control and monitor the entire system.

Bus Bar Boxes

- This test bench incorporates one AC and two DC bus bars to manage and distribute power flow between the AC and DC sides, facilitating interaction with external resources, loads, and microgrids.
- The AC and DC bus bar boxes are equipped with multiple layers of hardware and software protection, ensuring secure and reliable operation. Additionally, these boxes enable users to control power flow remotely and investigate cybersecurity issues within microgrid environments.

RCP Controller

- The OP8666 DSP controller board, benefit fully from the RCP functionality while providing maximum integration and communication options.

Power Amplifiers

- OPAL-RT power amplifiers with advanced protection and control features are incorporated to the test bench to mimic the behavior of various AC and DC systems.
- The amplifiers can be configured and controlled as distributed energy generators, emulators of the grid, motors, energy storage systems, loads, EV chargers, active power filters, STATCOMs, and more.

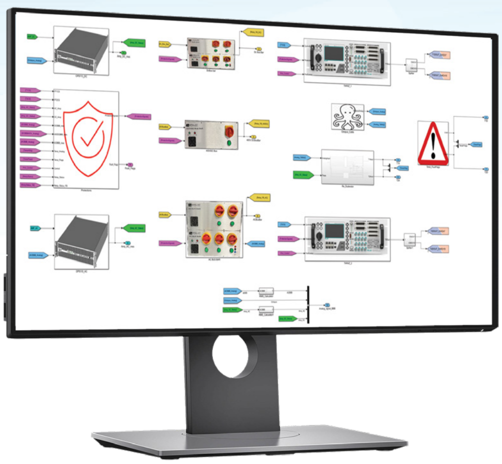
Inductor Boxes

- Inductor boxes are added to the bench to replicate the grid impedance for power system studies.

Converters

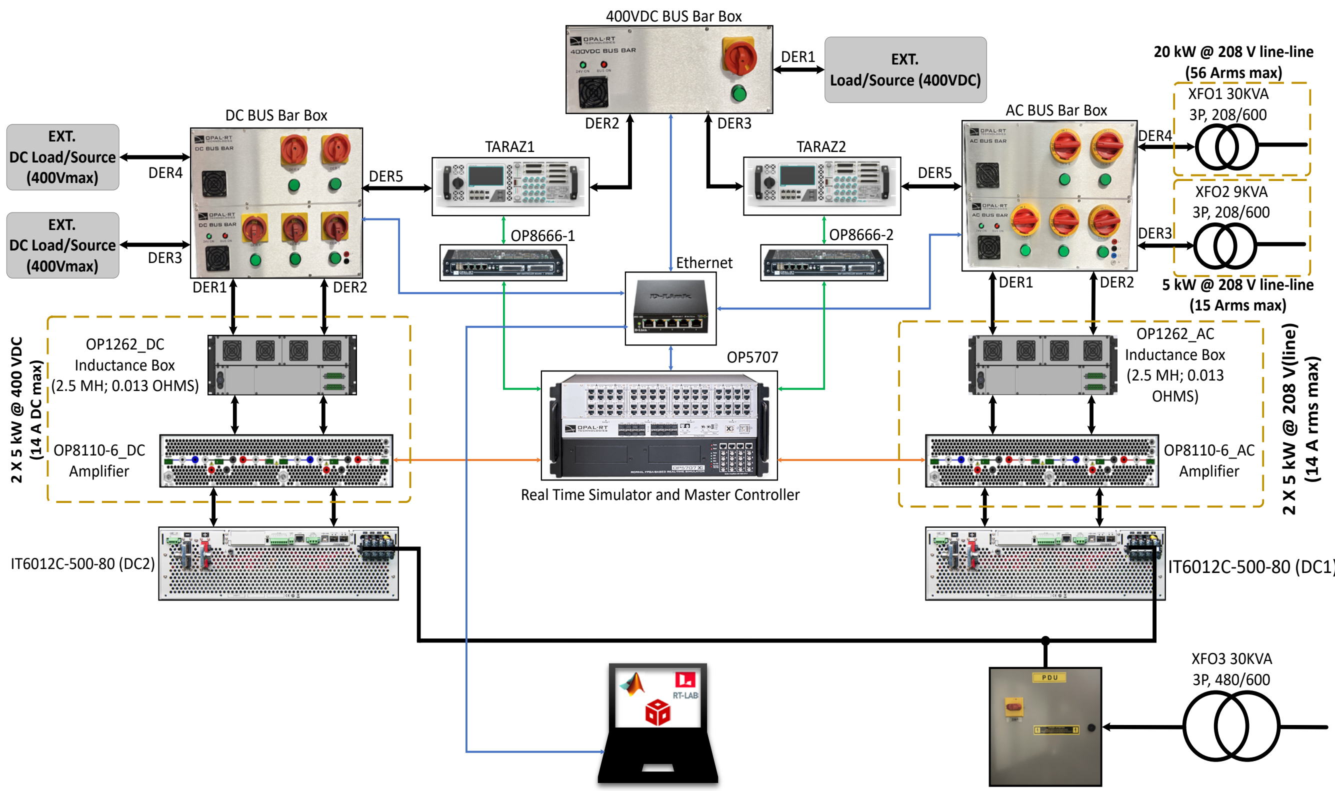
- The power is exchanged between the AC and DC bus bars using two converters provided by a modular power electronics development system, which are locally controlled by an OPAL-RT simulator or an RCP unit.
- Based on the power electronics modules, different DC-DC, DC-AC, AC-DC, and AC-AC inverters and converters can be implemented according to user needs.
- Each module is well-protected against over voltage and currents, short circuits, and over temperature, which is ideal for research purposes.

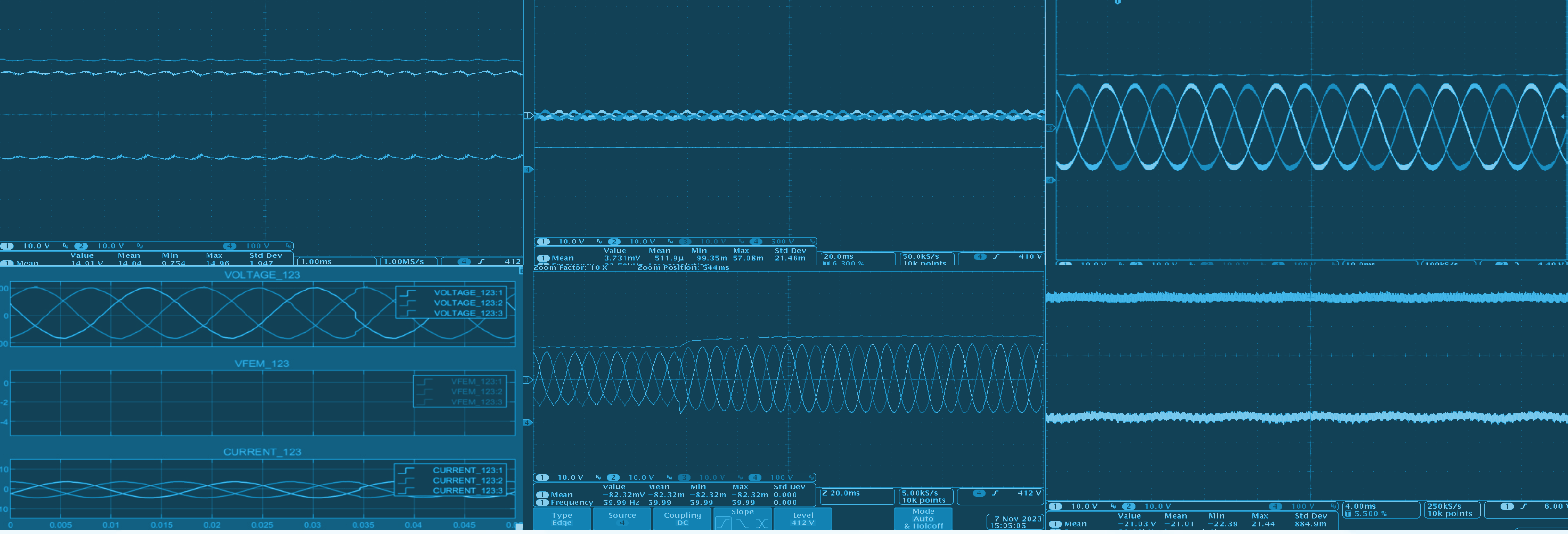
Structure Overview



An advanced protection algorithm is developed and integrated into the master model to protect the hardware of the microgrid system against damaging inrush currents, voltage fluctuations, overvoltage, and interrupted communications. This algorithm provides the user with a comprehensive monitoring dashboard to debug the system with minimum effort and time.

Given the processing power of the simulator and the additional AC and DC terminals available in the variable bus bar boxes, this integrated test bench can be scaled up in both size and power to emulate a larger microgrid environment. Its modular design, supported by the advanced simulation, control, and protection tools, makes it ideal for the research and development of both DC and AC microgrids.





Results Summary

With a rigorous on-site commissioning and Site Acceptance Tests (SAT), the test bench, including its two cabinets, was successfully delivered to the client.

During the commissioning process, the Hybrid DC-AC PHIL Test Bench was evaluated in both AC and DC-AC modes. In AC mode, only the AC side was tested, while the DC-AC mode involved testing both the AC and DC sides.

Part of the on-site interaction also included hands-on training, where the client's researchers learned how to best use the system.

The commissioning was successfully completed, and the bench is now operational at the GRÉPCI laboratory, where it is being utilized to meet the client's research needs.

" We appreciate the dedicated training and successful commissioning of the Hybrid DC-AC PHIL Test Bench by OPAL-RT. This advanced platform significantly enhances our research capabilities at GRÉPCI, allowing us to explore the challenges of microgrid integration and renewable energy with greater depth. We are excited to utilize this tool to drive forward our mission of developing sustainable energy solutions."

—— Mojtaba Ayaz & Eric Laurendeau, GRÉPCI