HIL Testing

Unlike conventional power systems, microgrids operate with limited inertia and often integrate inverter-based resources (IBRs) at higher penetration levels. As a result, frequency and voltage regulation in microgrids requires smarter, adaptive control strategies tailored to specific operational conditions. The unique challenges of microgrids highlight the need for rapid control prototyping, as these systems demand faster and more efficient controllers designed for a diverse set of applications.

To address these needs, a real-time simulation environment capable of interfacing both legacy and prototype controllers is essential. This environment must support the following objectives:

- Accelerate computer-based simulations
- Enable Hardware-in-the-Loop (HIL) testing, including Controller-HIL (CHIL) and Power-HIL (PHIL)
- Facilitate Rapid Control Prototyping (RCP)

Modern terrestrial grids and military operations increasingly depend on the availability of high-quality, reliable electrical power. Power system design and evaluation rely heavily on computationally intensive simulations, which must be supported by validation through physical experiments. To support these efforts, a Real-Time Digital Simulator (RTDS) Novacor 2.0 system has been procured through an Army grant and integrated into the Center for Electromechanics (CEM) power system testbed.

This system is complemented by amplifiers for CHIL, as well as communication protocol modules to interface with legacy controllers and protection relays such as Woodward and SEL devices using analog I/O and digital protocols like IEC 61850, Modbus and others.
The RTDS enables high-fidelity, real-time simulation of complex power systems and facilitates closed-loop interaction with physical controllers and relays. This setup allows for the development, validation, and de-risking of control systems under realistic operating conditions.

When operated in HIL mode, the RTDS executes power system models in real time, directly supporting controller design and testing. In PHIL mode the RTDS interacts with real hardware such as energy storage systems, loads, and distributed energy sources by driving them through power amplifiers. The hardware's dynamic response is then fed back into the simulation loop, creating a fully integrated cyber-physical test environment for power systems.

Importantly, the RTDS platform supports models developed in PSCAD, an industry-standard tool for simulating electromagnetic transients. This compatibility allows previously developed PSCAD models to run in real time on the RTDS without requiring code modifications, streamlining the transition from simulation to experimentation.

Additionally, the RTDS platform is modular and scalable. It serves as a foundational component for a larger real-time computational facility, with the capability to expand by incorporating more processors and I/O interface modules as research demands grow. A layout of the system with available hardware is shown in Fig. 1.

The University of Texas at Austin
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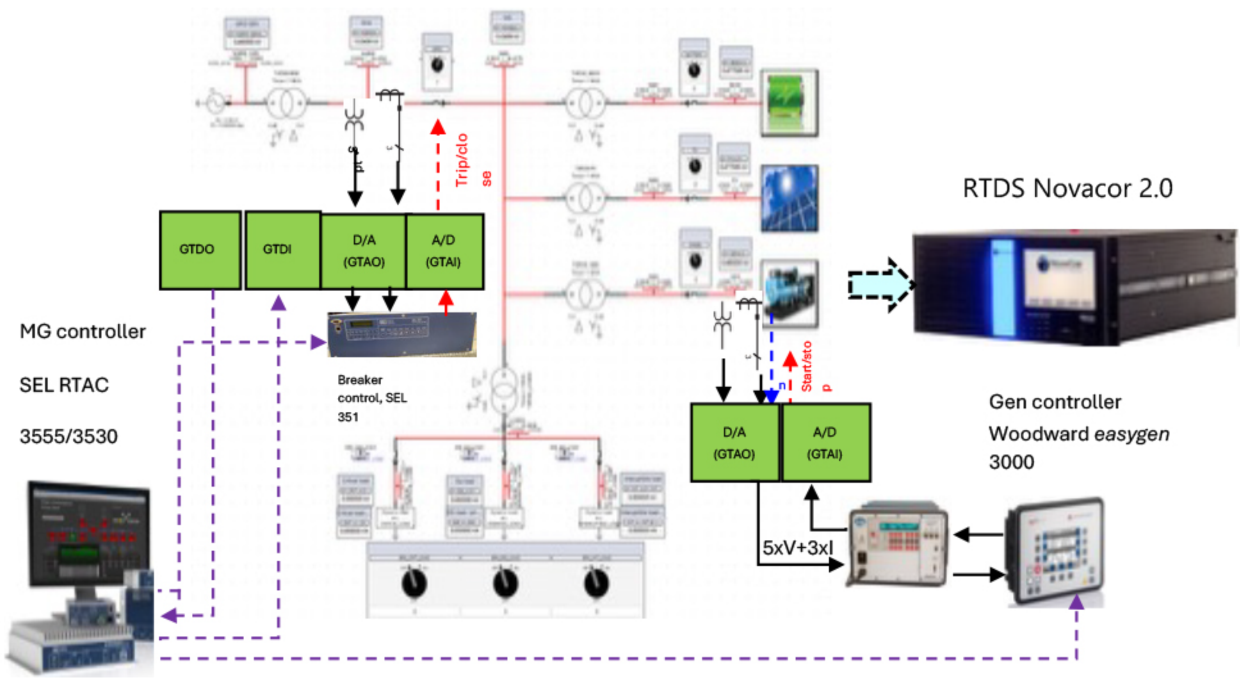
Beyond its role in supporting Army-funded research, the RTDS system is also used for broader investigations into:

- Grid controller design for integrating renewables and energy storage
- Optimization of electric distribution architectures
- Machine design tailored for tactical and terrestrial microgrids

As a core component of CEM's power system testbed, the RTDS enables research into critical power architecture challenges, from both theoretical and experimental standpoints. It facilitates the validation of control strategies in real-world conditions, supporting the development of more resilient and responsive energy systems for military and civilian applications alike.



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