PHIL Tests the Integration of Energy Technologies in the Energy System under Realistic Conditions.

The Power Hardware-in-the-loop Laboratory

The testing capability

- 1 MVA Egston Power Amplifier
- 3 linear power amplifiers of up to 45 kW power
- 1 DC emulator of up to 250 kW power and up to 1 kV DC voltage
- Digital real-time simulators, able to simulate thousands of electrical nodes in real-time (i.e. time step 0 <50 µs)

Available energy technologies

- 120kW high-speed flywheel,
- 500kW supercapacitor energy storage system
- 3.5kW electrical and 15kW thermal power micro gas turbine
- 50kW hydrogen-based energy storage system, that is currently under construction (first operation in 2024)

The Power Hardware-in-the-loop (PHIL) Lab is a large testing facility that allows the testing of high-power energy technologies with the highest

flexibility and accuracy. With a power capability of 1MW and a voltage up to 1.5kV, the PHIL Lab enables validation of energy technologies under realistic grid conditions, connecting the real hardware during testing with a real-time simulated grid by means of a power interface.
PHIL testing offers the flexibility of rapidly changing testing conditions and varying the simulated system characteristics, while keeping high experimental testing fidelity by using the real technology hardware. This feature can help researchers, manufacturers, and system operators to analyze, develop, and test future solutions for the energy system.

Micro gas turbine testing operations:
Installation of water mass flow sensors

The Power Hardware-in-the-loop Laboratory

Stornetic high-speed flywheel:
Internal view of the plant with the flywheel (green), power converter (on the left), and cooling system (on the right)

Real-time modelling of multi-modal components: The micro gas turbine case

In the future energy systems, components that can connect different energy carriers, such as electricity, heat, and gas, will play a fundamental role in the energy management.

In the Power Hardware-in-the-loop Lab, a 3.5kW electrical and 15kW thermal power micro gas turbine setup has been developed and equipped with electrical, heating, and gas sensors.
This micro gas turbine works as a combined heat and power generation system, enabling a final energy efficiency of 90%. Its main application lies in autarkic electrical networks (i.e., without connection to the main power system) control and energy management.

In this setup, we develop data-driven models of gas turbines, starting from field measurements, and optimize them for real-time simulations, reducing their execution time, while keeping high accuracy standards.

Power Hardware-in-the-loop testing of a high-speed flywheel

Due to the need of coping with highly volatile energy production and consumption, fast frequency regulation will be a fundamental task in the future energy systems. Flywheel energy storage systems can provide such fast frequency control. In the PowerHardware-in-the-loop Lab, the performance of a120kW high-speed flywheel from the company Stornetic has been evaluated by means of Power Hardware-in-the-loop testing. A standard microgrid benchmark is implemented in the digital real-time simulator OPAL-RT, and the flywheel has been "virtually" connected to the simulated grid by means of the 1 MVA Egston power amplifier interface. The performance of the flywheel in providing grid frequency support services has been assessed, integrating several strategies to manage the frequency control in microgrids in the flywheel controllers. The results clearly show improvements in the grid frequency management, decreasing both the frequency deviation and its derivative with respect to a base case without flywheel.

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