HYBRID ENERGY PRODUCTION AND MANAGEMENT SYSTEM (FUEL CELL AND BATTERY)

HEL – HYBRID ENERGY LAB SYSTEM

GREEN HYDROGEN, RENEWABLE ENERGY, ELECTROCHEMICAL SYSTEMS, SMART BUILDINGS

The Hybrid Energy Lab (HEL) is a versatile training and research platform designed to simulate and study advanced energy systems integrating hydrogen fuel cells, battery storage, and power electronics. Manufactured by Heliocentris Academia International GmbH, the system includes the following components. The system also includes a water electrolyzer that produces hydrogen using electricity generated by the solar house's PV panels. This electrolyzer was added to the standard commercial HEL unit to extend its functionalities.

HYDROGEN LOOP SYSTEM

- A 1.2 kW air-cooled PEM fuel cell stack (Nexa® 1200, 36 cells)
- Two types of batteries: Li-Ion (10 Ah) and Lead-acid (18 Ah / 7.2 Ah)
- Three metal hydride hydrogen storage canisters (3 × 600 Nl at 15 bar, H_2 purity: 99.999%)
- A water electrolyzer that produces hydrogen using electricity generated by the PV panels of the solar house (added to the standard HEL unit)
- A hybrid energy management module with DC/DC and DC/AC inverters
- A programmable electronic load for charge/discharge simulation
- Integrated sensors (temperature, pressure, hydrogen, state-of-charge) and data logging
- Touch-screen control panel and dedicated HEL software for visualization and real-time control

OPERATIONAL MODES & SAFETY FEATURES

The Hybrid Energy Lab offers multiple configurable operation modes, making it adaptable for a wide range of research and training scenarios. These include:

- Hybrid Operating Mode (fuel cell + battery combination)
- Unregulated DC Output Mode (direct energy supply)
- AC Output Mode (up to 1500 W at 110/230 V AC)
- Off-Grid / Autonomous Power Mode
- UPS (Uninterruptible Power Supply) Mode

These modes are accessible through the system's touch panel PC and Nexa® Training Software, which also enables real-time monitoring and data acquisition.

INTEGRATED SAFETY MECHANISMS

Given that the system works with compressed hydrogen, HEL is equipped with robust safety protocols:

- Emergency Stop Button instantly shuts down fuel cell and disconnects hydrogen supply
- Hydrogen Sensors detect any leakage in both the storage and fuel cell modules
- Safety Chain automatic shutdown triggered by fault conditions
- Pressure Relief Valve safely vents excess hydrogen above 16 bar
- Ventilation and grounding requirements lab must comply with ventilation rate of ≥10 air changes/hour

POSSIBLE ANALYSES OR EXPERIMENTAL APPLICATIONS

- Dynamic behavior analysis of fuel cells and batteries under different load conditions
- Energy flow control and optimization in hybrid systems
- State of charge (SoC), state of health (SoH), capacity (Ah) and Peukert coefficient evaluation
- Modeling and data fitting for different battery chemistries
- Efficiency measurement, energy loss quantification, and system diagnostics
- Case studies simulating UPS systems, net-zero energy buildings, and grid support scenarios

ASSOCIATED PROJECTS AND USES

- Integrated into training and research activities at Concordia University
- Part of a MITACS-funded project in collaboration with NERGICA (Gaspé, QC)
  - Compare research-scale equipment (HEL) with commercial systems under development at NERGICA
  - Site visit to Gaspé planned for October, with initial technical exchanges underway
- Key component in the upgrade of the Solar House at the Concordia Field Research Facility for Buildings of the Future, focusing on investigating the potential of using hydrogen as an energy vector for nano and microgrids under low temperatures, in addition to smart building integration.

ACCESSIBILITY

Available upon request for academic research, student projects, industry-academic collaborations, and demonstrations. Training is required before operation.

RESPONSIBLE

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