



The Bern University of Applied Sciences relies on a HIL lab environment for the realistic and reproducible testing of system components found in modern private households. The dSPACE MicroLabBox is used to control individual systems and the emulation environment.

Give and Take

Lab Testing of Load Flow Management for Prosumer Households

Modern households are becoming more and more complex due to advancements in connectivity. Photovoltaic systems, storage batteries, heat pumps and, energy management systems (EMS) all interact with each other and consequently increase the self-consumption of the generated energy. These types of households are called prosumers because they consume electrical energy while also producing their own energy at the same time. Energy management systems used to intelligently control the flow of energy will enable prosumers to play a more active role in the future electrical energy market. For example, these management systems can control the energy input or output of batteries, or even switch heat pumps on or off. To do this, however, they require access to various interfaces and communication protocols. In addition to optimizing energy consumption in the home, an EMS can also stabilize the voltage quality in low-voltage grids. The research, development, and certification processes of relevance to both proven and innovative components for modern households have to be completed in controlled environments on test benches that support the integration and grid connectivity of various electrical devices.

These laboratory environments are ideal for examining and optimizing the interaction of components and their impact on low-voltage grids in realistic scenarios.

Modern Households as HIL Test Benches

The Prosumer-Lab at the Bern University of Applied Sciences replicates a modern household in a laboratory environment. The hardware-in-the-loop (HIL) test bench supports the analysis, comparison, and development of system components under controlled and reproducible conditions. This is possible thanks to a combination of software simulation and hardware emulation using system components such as batteries and inverters that are readily available in the market. Researchers are able to replicate the flow of electrical and thermal energy in a household equipped with a photovoltaic system, heat pump, storage battery, and energy management system right up to the grid access point with real voltage and current. The following questions are of interest to university researchers: How can the flow of energy inside a building be guided and controlled intelligently with an energy management system? How do decentralized energy sources and storage batteries

impact the stability of power grids? How can decentralized prosumers be integrated in the low-voltage grid in ways that are feasible in the market?

Modular Test Bench with High Flexibility

The computers in the Prosumer-Lab emulate household appliances (heat pump, hot water heater, cooking stove, etc.) and their consumption within the laboratory grid up to a maximum power level of 50 kVA – this emulation is reproducible. Another emulation device is used to create an electrical power grid in which voltage quality parameters such as harmonic oscillation or voltage dips can be set to take effect at any particular time. Eight photovoltaic (PV) emulators with up to 5 kW each are used to emulate PV systems in various roof positions. Additional components such as the storage battery, the PV inverter, and the EMS are real and installed on-site so that they can be tested under real-life conditions. The simulations in the test bench are specifically intended for use in the computation of thermal profiles and the simulation of thermal components, which cannot easily be integrated in the test bench in ways which are real and reproducible. A thermal building simulation, for example, determines >>



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Batteries, emulators, and circuit and control technology for load flow management.

“Thanks to its many analog and digital interfaces, various communications protocols, and bus systems such as Ethernet, the MicroLabBox offers enormous flexibility for the huge number of fast-changing requirements in today’s research environment.”

Steffen Wienands, Bern University of Applied Sciences

the profile for room temperatures, hot water requirements, heat pumps, or energy losses in thermal storage units. Figure 1 shows the intentionally modular and flexible design of the test environment that supports an easy activation and deactivation of components. This concept enables the emulation of households with various system components in the Prosumer-Lab. The emulation devices and the real system components are equipped with a wide and diverse range of interfaces and communication protocols. Connecting all of the test devices to build a network is a major challenge. Furthermore, an overarching control program has to be written

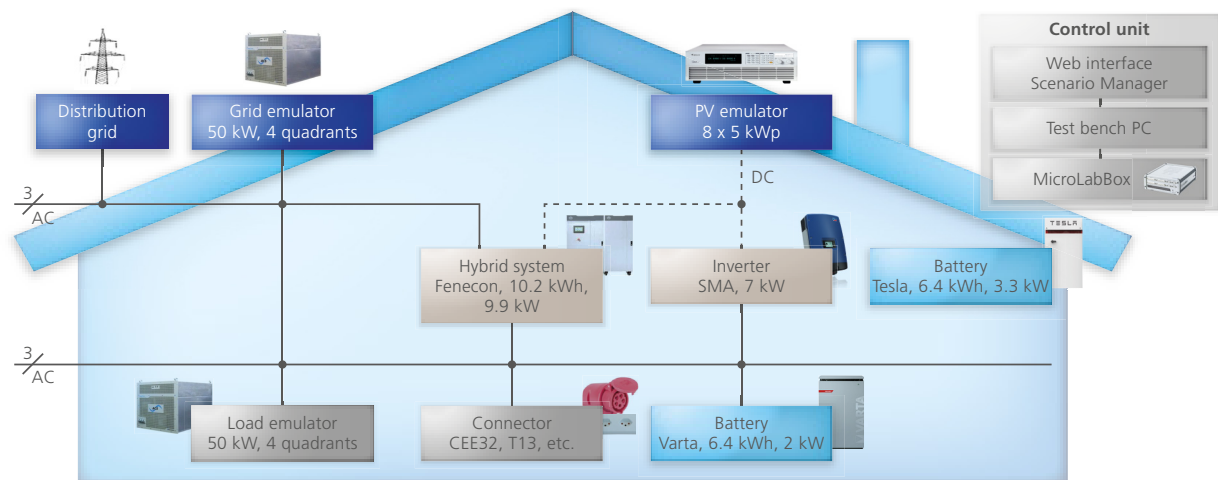
for managing all of the individual emulation devices. This program must function in real time and run with a resolution of 10 kHz.

Central Control of the Test Bench Hardware

The MicroLabBox provides a high level of flexibility for the test bench thanks to its many interfaces for Ethernet and RS485, as well as analog and digital I/O. Figure 2 shows the large number of diverse interfaces that enable the MicroLabBox to manage the devices of the test bench. The values defined for the devices are computed by the Scenario Manager or the simulation software before they are applied to

the test bench via the MicroLabBox. Once a comprehensive system has been completed, the control algorithm for the load emulator is quite easy to implement in MATLAB®/Simulink®. The control algorithm increases the precision of the defined target value on the emulators and enhances their functions to enable the application of electrical current and voltage characteristics. The 10 kHz resolution required to do this is achieved without the need for any FPGA programming. The MicroLabBox serves as the central control unit for all of the test bench devices – it communicates the target values to the devices and reads the actual output values from the devices.

Figure 1: Electric current flows and modular concept of the Prosumer-Lab test bench.



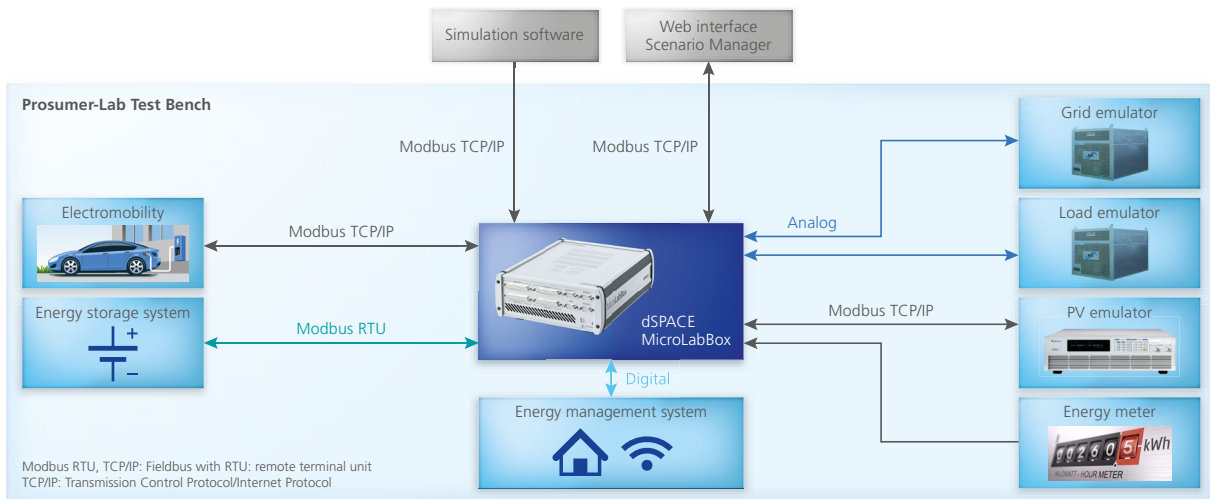


Figure 2: External access to the real-time system.

External Access to the Real-Time System

To make data easily available, a web application was created, which sets up a server-client structure. The MicroLabBox is integrated into this structure via ASAM XIL API. By using the ASAM XIL MAPort (Model Access Port), the program can access application values during ongoing operations and process the data, which can then be displayed directly or exported to other analytic processes.

Start-Up Phase Completed

The start-up phase of the test bench was completed with a performance analysis. Special attention was placed on controlling the load emulator with 10 kHz via the MicroLabBox along with external measuring and analytic devices. Results indicate that controlling the load emulator through the MicroLabBox leads to a significant boost in performance. The load emulator control features outstanding flexibility and high precision across the entire performance range.

Summary and Outlook

Thanks to the real-time system, it was possible to connect various kinds of test bench devices within the environment and to create a central control unit. Access to the MicroLabBox is possible at any time via the ASAM-XIL standard. The HIL test bench can

be used to test system components at the early stages of development and even those that are scheduled for market launch – the testing includes the interfaces, communication protocols, and control algorithms, not to mention the realistic interaction of components in the prosumer household. Once the test bench was set up and put into operation, the first tests of energy management systems were conducted immediately in the Prosumer-Lab. The future lab agenda includes further and more detailed tests as well as the development of a new EMS algorithm. Projects with interested partners from industry and research are planned for energy management

systems, charging stations for electromobility and storage batteries. ■

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