Hardware-In-the-Loop Measurement System for Global Prosumer Characterization

STORE&GO

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Background

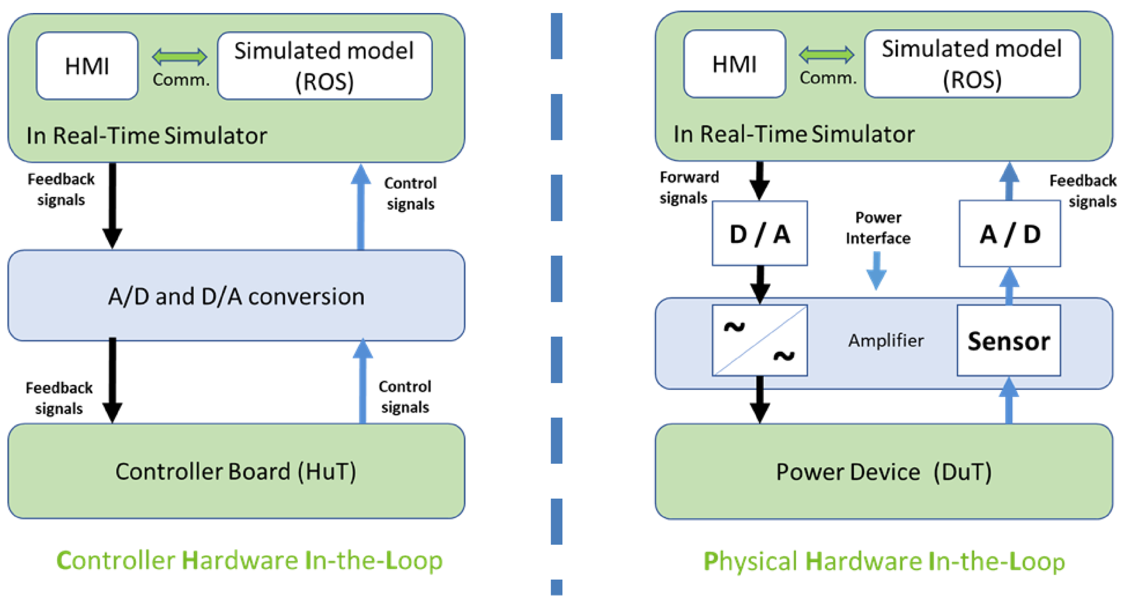
New technologies and approaches are widely developed and proposed to be implemented in real energy systems to meet the objectives. However decision making meant to select the best solutions in terms of performance, efficiency, and economic feasibility require evidence based tools. These tools should be reliable, robust, and capable of demonstrating the behavior and impact of newly developed devices or algorithms in different pre-defined scenarios. Therefore, new approaches and technologies need to be tested and verified using a safe laboratory test environment.

Methodology

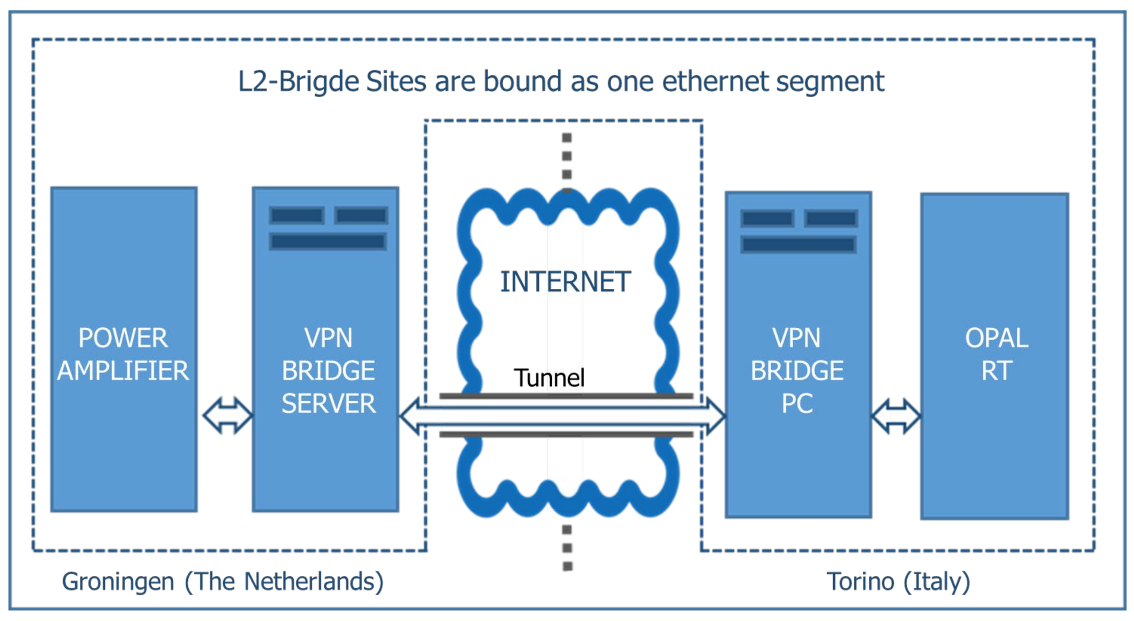
We started with the local characterisation of a PV-Field and a PEM-electrolyzer at Entrance Groningen by logging and measuring the electric behavior and dedicated device parameters. Goal was to integrate and convert these into working mathematical models of a 'PV-Field and Electrolyzer prosumer'.
After testing and evaluating these models by comparing the results with the real-time measurements these test and modelling are also generated from the remote laboratory in Torino.
To achieve dynamical physical hardware we also made dynamic mathematical models with real-time functionality to interact directly with the remote electrolyzer.
To connect both the laboratories with full duplex communication functionalities between physical hardware and models, we have also realized a network with is able to share network resources on both local- and remote sites. With the complete setup we achieved to put remote hardware in the loop of a local simulation.

Hardware in the loop

To test and validate the performance of a device prototype or to tune or characterize a newly manufactured hardware like an electrolyzer before installing and connecting it to power grid, a so-called hardware-in-the-loop is carried out using digital real-time simulators. In case, the device is a controller which retrieves some measurements or alarms and produces some command signals as a feedback to the rest of system, there is no need to exchange power; hence off-the-shelf digital real-time simulator can be directly coupled with the device, performing Control Hardware-in-the-loop (CHIL).



At an energy source (solar panel, wind turbine, fuel cell, etc.) or a consumer (Electrolyzer, etc), an interface is required to enable power exchange. In such cases, a power amplifier is used to perform a Power Hardware-in-the-loop (PHIL). The above figure illustrates both types.
The power interface is the most important element in PHIL experiments. The interface consists of a power amplifier and a set of sensors that control the Device under Test (DuT). The power amplifier acts as a source or consumer to respectively generate or absorb power (4 quadrants).

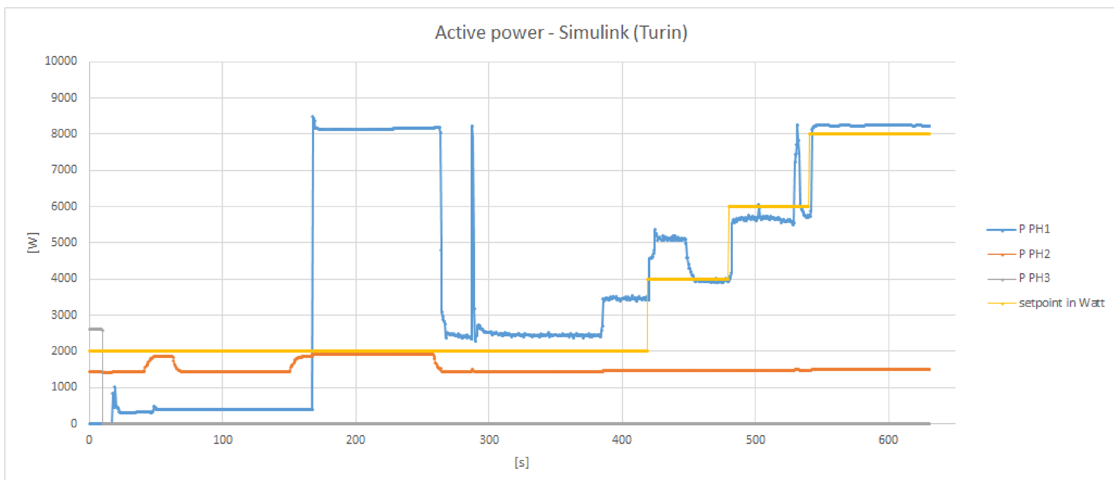


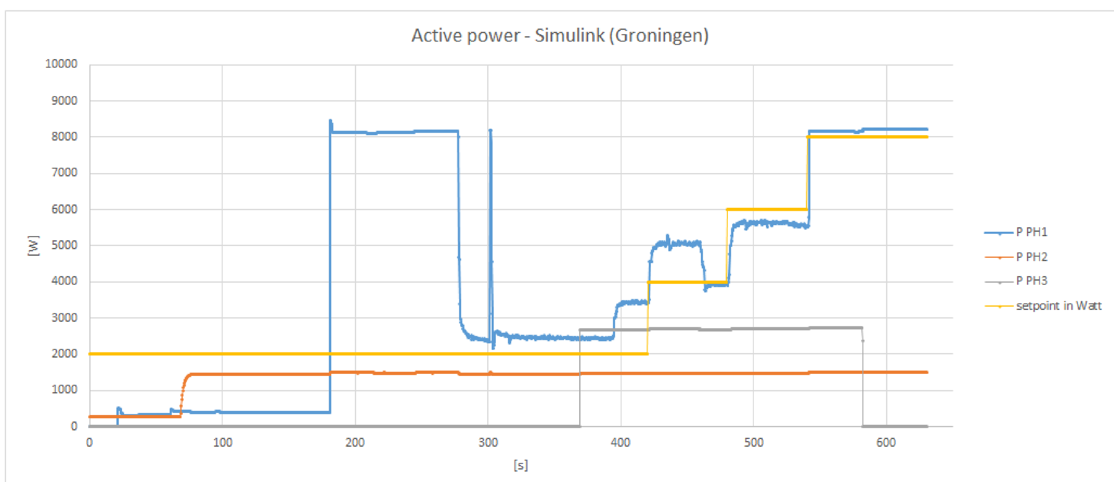
Communication

The realization of remote hardware in the course uses a special infrastructure. With a layer-2 Ethernet bridge, a low latency VPN network has been realized in the same address range. The remote IP basic address is taken as the basis for this. After the connection is established, all are local and remote computers, devices, sensors accessible from any point in the network

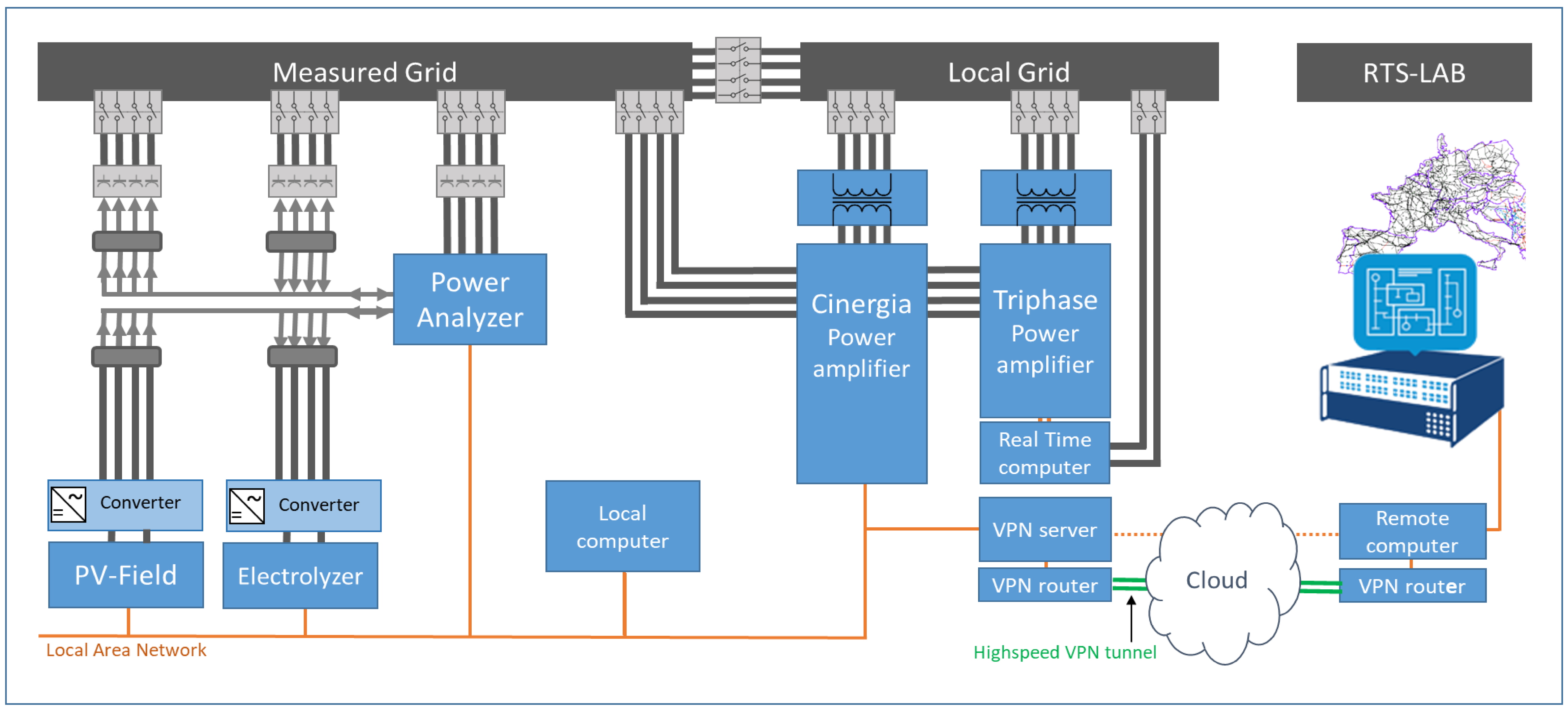
Results

The results obtained for the active power in three phases are shown in the upper figure (local measurement), and in the lower figure (model executed from Turin). It is clear that the dynamic behavior of the electrolyzer is the same both locally and remotely. both figures show how the electrolyzer after the start-up phase then the steady state at 25, 50, 75 and 100% of full load, with an almost stepwise change between them.
The measured values at each time step are the average of the actual data within the considered interval by the use of a Matlab function. If the Simulink model performs a Matlab function during the simulation, the model is temporarily paused. Simulink blocks the interface with the respective Matlab file that executes the code to read / write data to and from the instruments. If the Matlab values are available in Simulink, the simulation is continued





By integrating the read / write functions of the measuring and control equipment in Simulink code, a lower simulation time step is possible.



Real-time grid / devices setup installed at Entrance / Hanze Groningen.

The Real-Time Grid laboratory, is a test site that has been designed and built for the purpose of Energy transition- and PtG grid integration- experiments. The laboratory setup is directly connected with transition sources (PV and all the additional components necessary to investigate the integration of hydrogen production by electrolysis with renewable energy sources). With this setup we have realized characterization of this sources, comprising an electrolyzer, PV panels and others, through the acquisition of appropriate data in order to produce mathematical models based on the real-time and dynamic measurements. Second aspect is that the complete setup has now been configured to be accessible through a low latency data connection by remote use. Beside this the lab is equipped with two power amplifiers. This allows to establish a communications between the grid laboratory and a specific Global Real-Time Simulation Lab (G-RTSLab) located at the Politecnico in Torino. In this way, the laboratory equipment in Groningen can be accessed from Turin for the purpose to remotely collecting real-time data to use into large-scale grid models and the realization of a distributed real-time co-simulation with the power amplifiers.

Conclusion

The developed and tested method was applied to a small-scale plant setup but demonstrates the ability to use the same infrastructure to collect information (in real time) from larger plants, such as those installed on the Store & Go -demo sites. This opens the possibility to use the data for research purposed, but also to act in remote on the infrastructure in case of particular test (for example the acceptance test).

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