HIL TEST AUTOMATION FOR MODULAR MULTILEVEL CONVERTERS

OPAL-RT TECHNOLOGIES

SIEMENS energy

Application

- FACTS & HVDC
- CI/CD Pipeline

Related Products

- RT-LAB
- eHS | FPGA-based Power Electronics Toolbox

Type of Simulation

- Hardware-in-the-Loop (HIL)

SUCCESS STORY

INTRODUCTION

Grid Solutions: A Leading Provider of FACTS & HVDC Systems

Grid Solutions, a business unit of Siemens Energy, leads the advancement and provision of cutting-edge solutions for power transmission and distribution worldwide. Offering a wide portfolio of products, systems, and services, Grid Solutions is at the forefront of enhancing the efficiency, reliability, and sustainability of global power grids.

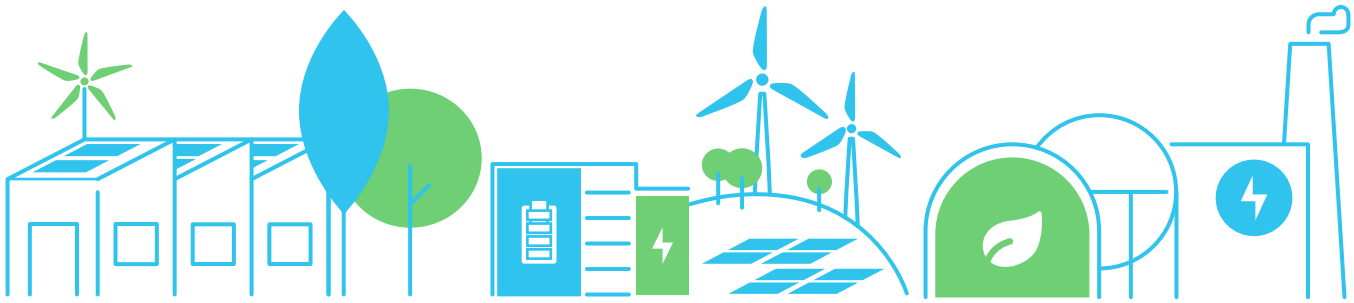
Central to Grid Solutions' operations is the seamless integration of renewable energy into the power grid. The company specializes in developing and delivering solutions that facilitate and support the incorporation of renewable energy sources into the grid. These include innovative systems designed to predict and control the power generation of wind and solar power plants, ensuring the stability and efficiency of the power grid.

FACTS (FLEXIBLE AC TRANSMISSION SYSTEMS)

FACTS (Flexible AC Transmission Systems) are **power converter systems** used in **power transmission and distribution** to **improve the stability and efficiency** of the power grid.

HVDC (HIGH-VOLTAGE DIRECT CURRENT)

HVDC (High-Voltage Direct Current) is a technology that enables **more efficient transmission of power over long distances** and is also used for **power exchange between different countries**.



"One of the advantages of OPAL-RT is the seamless interaction with MATLAB/ Simulink, which enabled us to work in our usual development environment to setup the simulator software. Thanks to the competent support of the OPAL-RT team, we were able to familiarize ourselves quickly with the simulator and could develop together solutions for our use case."

Frank Schuhmann, Senior Development Engineer at Siemens Energy AG

OBJECTIVE

Ensuring Quality of Converter Control Through Automation for FACTS & HVDC Systems

FACTS and HVDC systems, powered by the advanced **Modular Multilevel Converter (MMC)**, are pivotal to controlling the power flow in high-voltage transmission. With such critical functions, **very high demands are placed on the quality and reliability of the MMC's control**. Additionally, the control software must be flexible and adaptable for different projects and transmission lines.

Therefore, **testing the software on real hardware across diverse projects is crucial for early fault detection** in the software development of the converter controls. For this purpose, it's essential to develop an easily usable HIL test bench capable of automated test execution to enhance efficiency.

The simulator for the HIL test bench should:

- ✔ Use an existing Simulink plant model
- ✔ Provide the necessary performance for the simulation with a time step below the microsecond for the converter
- ✔ Have interfaces fitting to the control hardware

Project-specific variants of the converter control software require **thorough testing**, while the simulator's plant model must remain flexible and readily adaptable to **various project configurations and parameters**. Likewise, it is necessary to integrate the test bench with the simulator into a GitLab CI/CD pipeline to automate the test execution. New software versions can then be tested automatically so that the developer gets prompt feedback whether the correct function is still being fulfilled.

Consequently, **OPAL-RT simulators enabled Siemens Energy to meet these requirements seamlessly, while aligning with their workflow and toolchain**.

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CONTINUOUS TESTING INTEGRATION

Leveraging OPAL-RT's FPGA-Based Power Electronics Toolbox

First, it was crucial to **adapt the existing plant model**, constructed with Simulink and the electrical circuit with Simscape Specialized Power Systems, to run seamlessly on the simulator. Through close collaboration with OPAL-RT's local team in Germany, necessary modifications were **swiftly identified and implemented,** enabling **rapid integration of the plant model onto the OPAL-RT simulator**.

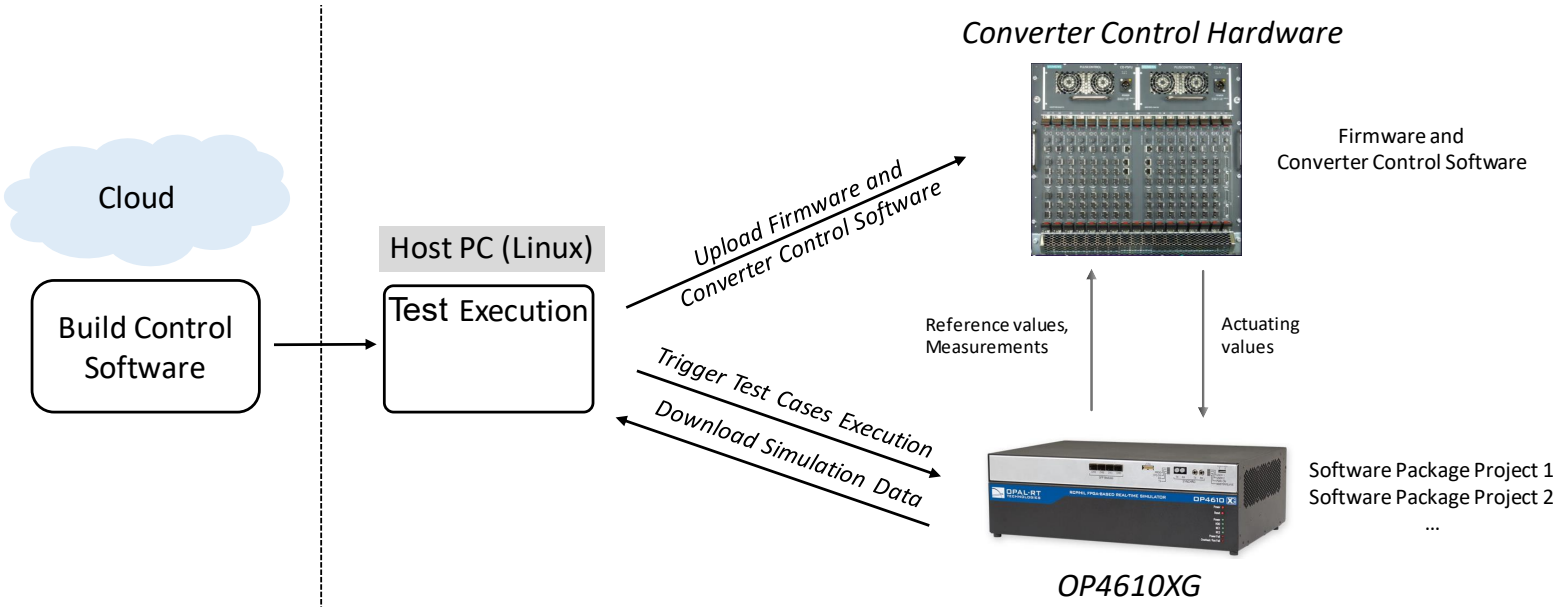
- The eHS solver enables the execution of the electrical circuit on the FPGA with an impressive execution time of less than 1us, eliminating the need for time-consuming synthesis.
- A Simulink-based control algorithm is executed on the simulator's CPU, achieving an execution time step of 10 us.

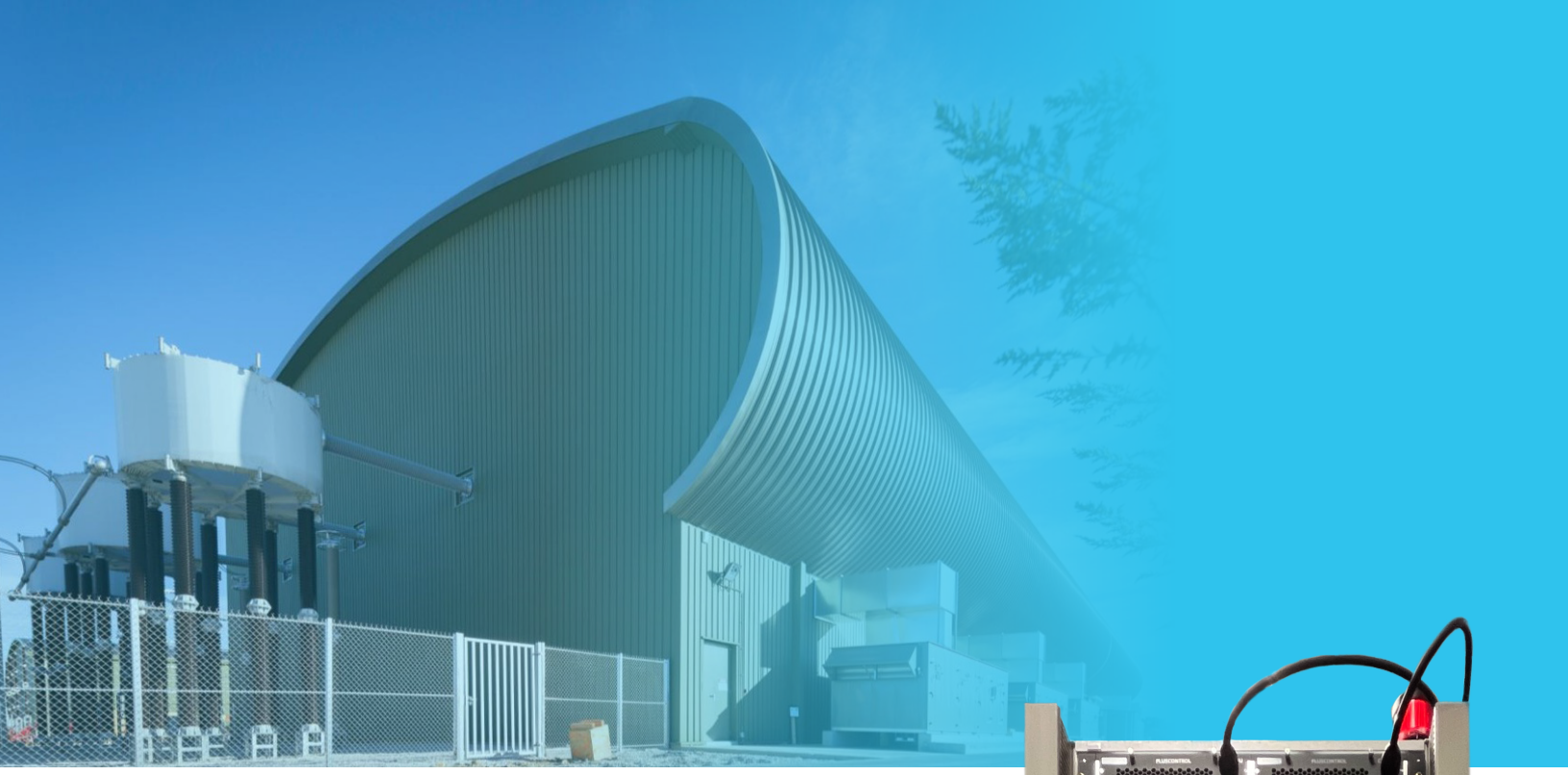
Automation with RT-LAB's Python API

To support various configurations and parameterizations of the plant model, **multiple software packages are created with the corresponding plant model and transferred to the simulator**. Each software package includes:

- The fully generated simulator models
- The test sequences
- The Python scripts, which control the test execution

Thanks to RT-LAB's Python API, the creation of the software packages for the simulator can be fully automated.





"OPAL-RT's technology allowed us to bring our existing Simscape Specialized Power Systems model to the FPGA while requiring only minor changes. Since OPAL-RT's eHS solver can be used without having any in-depth knowledge of FPGAs, we could swiftly proceed to integrate the test bench into our CI/CD pipeline."

Alexander Sinn, Senior Development Engineer at Siemens Energy AG

Integration with GitLab CI/CD Pipeline

Triggered by a **Linux host PC, which is integrated into a GitLab CI/CD pipeline**, the firmware and control software is loaded on the control hardware and the appropriate software package with the test cases is then executed directly on the simulator. Finally, the recorded data is downloaded from the host PC to **check the test criteria in MATLAB/Simulink.**

Thus, it is possible to execute the test cases defined for the control of MMC's for FACTS and HVDC systems with each GIT commit before a merge is executed or with a manual trigger, depending on the requirements of the development process.

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CONCLUSION

Advancing MMC Control Software Testing with OPAL-RT Simulation Technology

Thanks to a successful collaboration with OPAL-RT, the integration of the Simulink plant model into the simulator was swift. Additionally, leveraging the FPGA-based Power Electronics Toolbox of OPAL-RT, Siemens Energy **easily harnessed the performance benefits of FPGA technology for the modeling of plants in HIL environment**.

The HIL test bench, powered by the OPAL-RT simulator, **facilitates comprehensive testing of the MMC control software on actual control hardware**. Test cases are executed **directly on the simulator**, enabling independent operation irrespective of the host PC's operating system. This allows Siemens Energy to utilize a Linux OS, simplifying integration into the GitLab CI/CD pipeline and paving the way for future automation using Docker containers.

With each update to the control software, Siemens Energy's converter control development team receives **immediate feedback from the HIL test bench**, ensuring functionality remains intact and automatically verifying performance requirements such as execution times.

"By using the test bench, we can catch any issues between the control software and hardware firmware early on. This means we can fix them before they become problems for our projects in execution, and later on, for the customers. The test bench also helps us make sure all the control functions are working smoothly across different processing cores. We keep an eye on execution times too, spotting any slowdowns early and tweaking things to make them run smoother. It's been a big help in the latest development of new functions."

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