Driving Solar Energy Innovation: How Sungrow is Leveraging OPAL-RT TECHNOLOGIES Real-Time Simulators

OPAL-RT TECHNOLOGIES SUNGROW

Application

- Power Converter System Testing
- Power Plant Controller Testing
- Battery Management System Testing
- Controller Blackbox Validation
- AI Model Training
- Black Start Studies

Related Products

- RT-LAB
- OP5700 Series

Success Story

Introduction

Sungrow, a global leader in renewable energy technology, has pioneered sustainable power solutions for over 28 years. As of December 2024, Sungrow has installed 740GW of power electronic converters worldwide. The Company is recognized as the world's No. 1 on PV inverter shipments (S&P Global Commodity Insights). Its innovations power clean energy projects in over 180 countries.

Sungrow HIL Lab

Sungrow's HIL Simulation Lab is one of the core departments of the Sungrow Power Electronics Research Center. It plays a key role in projects related to renewable energy power conversion system modeling and simulation, development and verification of advanced power electronic converter control strategies, grid construction, and AI-assisted power electronic system design. Currently, Sungrow is equipped with more than 20 OPAL-RT real-time digital simulators.

Sungrow HIL Lab	
Real-time simulators	▪ OP4510 x 1 ▪ OP5700 x 20
I/O & communication interfaces	▪ DI: 64 channels Max. ▪ AO: 48 channels Max. ▪ Modbus-TCP、IEC104、CAN
Simulation scale & step size	▪ Maximum number of IGBT simulated 128 ▪ Maximum switching frequency 40 ~ 60K ▪ 100+MW power plant simulation

" We rely heavily on OPAL-RT's OP5700 series simulators in our HIL labs, and thanks to their superior FPGA simulation performance, our engineers are able to realize converter simulations with switching frequencies as high as 40 ~ 60KHz."

—— Yuanze Zhang

Deputy Director, Power Electronics Research Center of Sungrow

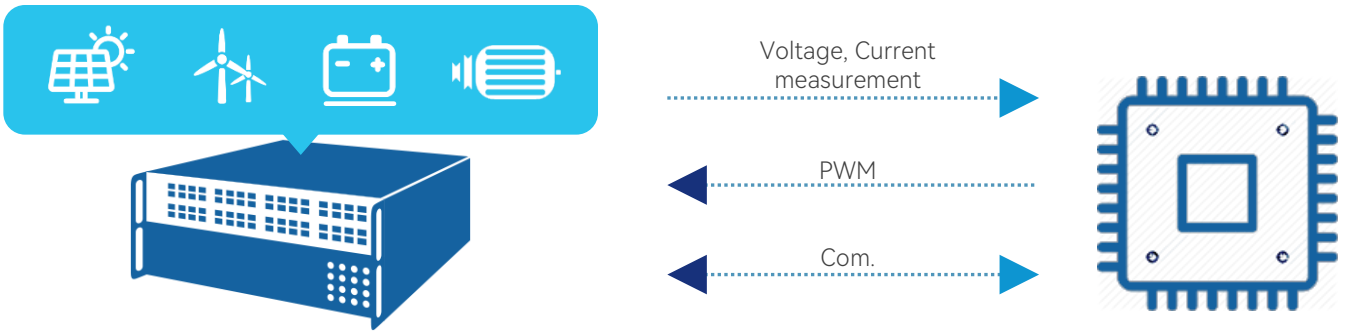
HIL Testing

Currently, Sungrow's HIL Simulation Lab primarily conducts two types of simulation testing:

1. Equipment-level Controller HIL Simulation for Power Electronics Converters;
2. Large-scale HIL Simulation for New Energy Power Stations and Power Systems.

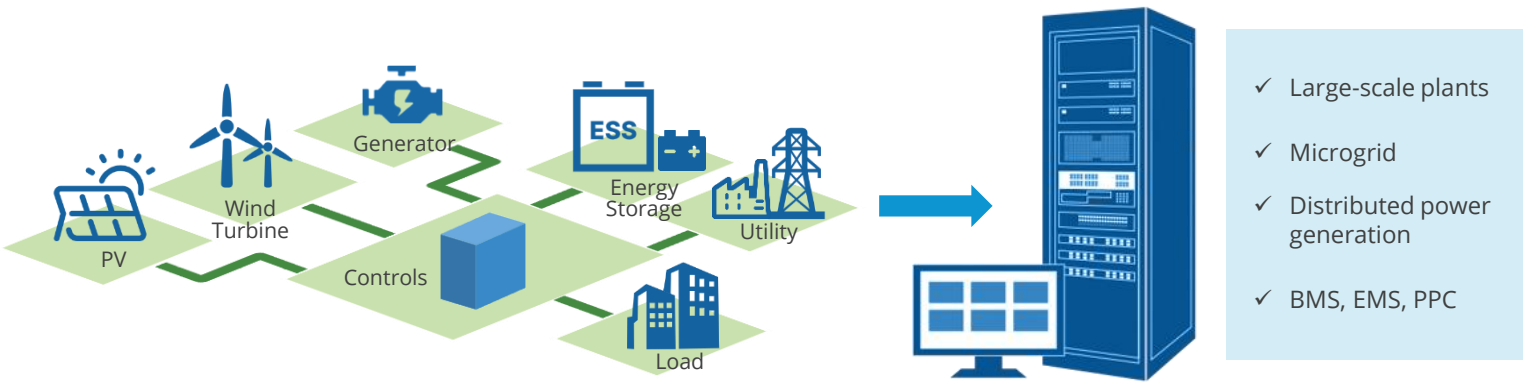
Power Converter System (PCS) HIL Simulation

The Devices Under Test (DUT) commonly used at Sungrow include photovoltaic converters, wind power converters, energy storage converters and EV motor drive controllers. First, the DUT's controlled object model is built in the real-time simulator, and the converter controller is connected to the OPAL-RT simulation platform through I/O and communication protocols to form a closed loop HIL test.



Power Plant Controller (PPC) HIL Simulation

Microgrid or large-scale power plant models are built in the OPAL-RT simulation platform, and then EMS or PPC real controller are connected to the system to test their control algorithms.



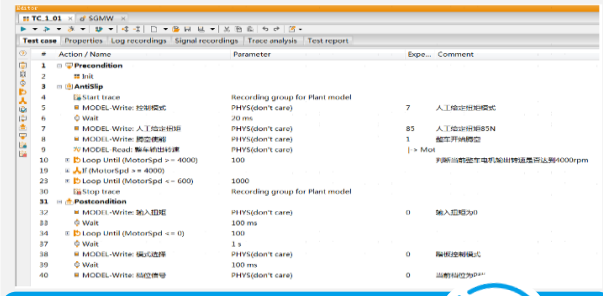
- ✓ Large-scale plants
- ✓ Microgrid
- ✓ Distributed power generation
- ✓ BMS, EMS, PPC

"Based on RT-LAB's powerful Python API, automated testing can be easily performed. Pressing the start button at the end of the day, and when you come to the office the next day, the system has already completed hundreds of tests, even the test reports are ready. This is very helpful to increase our testing efficiency and coverage. In a recent product pre-research project, project, we successfully completed over a hundred software functionality tests using RT-LAB's automation features, saving approximately 50% of the testing time compared to traditional physical test benches."

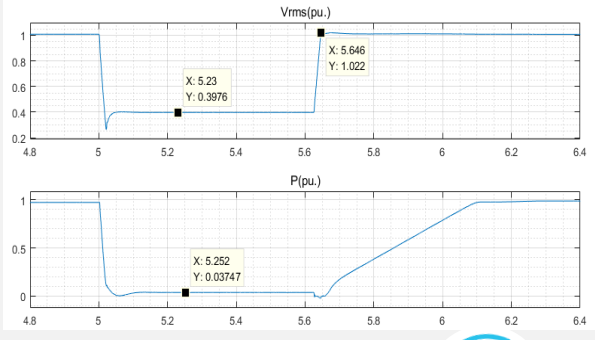
—— Yuanze Zhang

Automatic HIL Simulation and Test

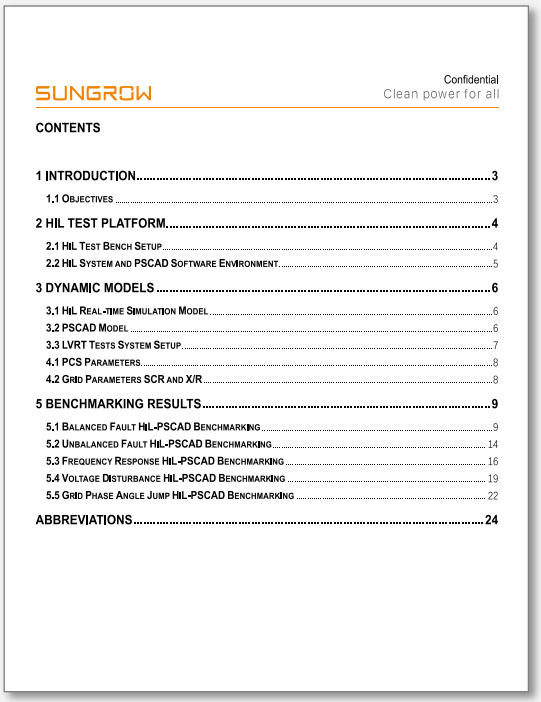
Thanks to RT-LAB's comprehensive Python API, testing engineers can easily implement automated testing by integrating data analysis scripts into test cases. This helps to verify whether the controller's performance meets the required specifications during testing, without manual intervention. Additionally, this tool facilitates the generation of large amounts of data for AI model training.



Professional automatic test case management system



Automatic data collection, analysis and figure plotting

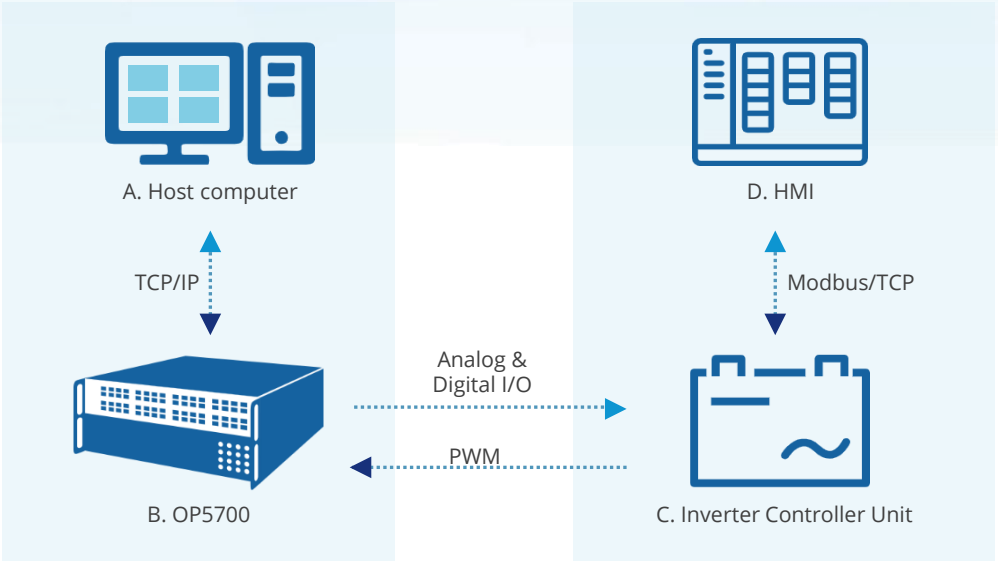


Automatic test report composition

HIL Simulation Cases

PCS HIL Simulation System

The SC2500UD HIL test platform meets the requirements in IEEE Std 1547.1-2020 5.10.2.3. The test platform consists of:



Digital Real-Time Simulator (DRTS)

A. A host computer which is used to build system model;

B. An OPAL-RT 5700 real-time simulator to run the simulation in real-time;

Equipment Under Test (EUT)

C. SC2500UD controller unit that consists of: a DSP controller board, a signal conditioning board, a smart communication unit;

D. A human-machine interface website.

Based on the weak grid HIL simulation platform, Sungrow HIL simulation lab is able to test the performance of inverters/PCS and their control strategies. The platform allows:

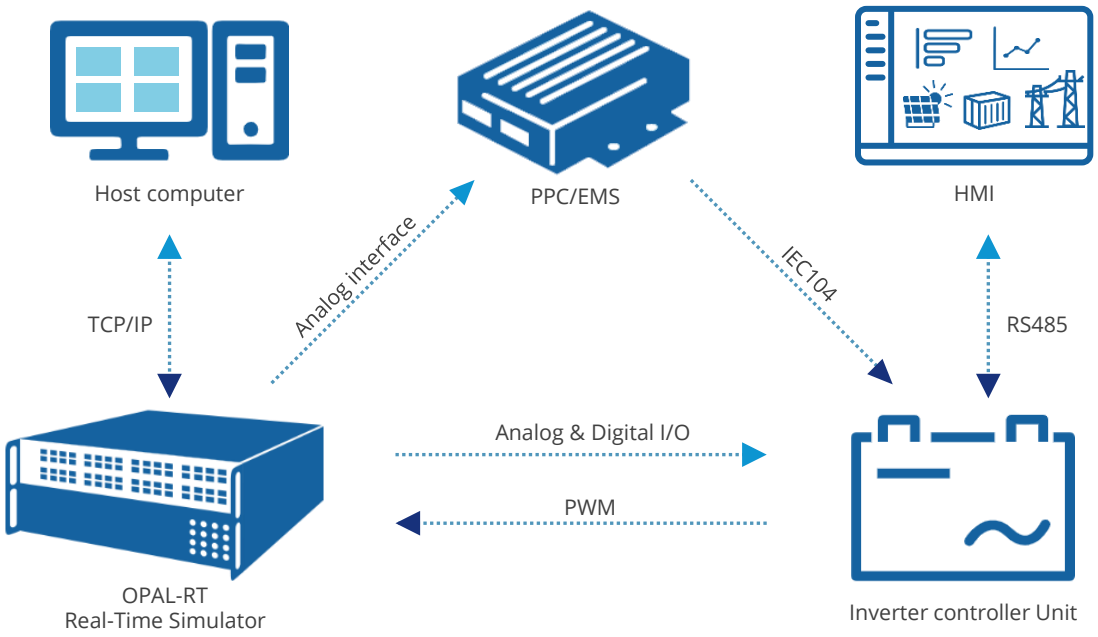
- ✔ Extreme low SCR: test the lowest SCR at which the inverter can operate properly;
- ✔ Consecutive HVER & LVRT;
- ✔ Frequency response;
- ✔ Inverter impedance scanning;
- ✔ Maximum Q compensation factor.

"Building a real power plant to test the PPC functionality is obviously not practical. In the past, the control functions of the PPC in an actual power plant could not be verified during the R&D phase. Now, with this powerful testing platform, we are able to simulate a complete power plant and conduct numerous PPC functionality tests, which is crucial for ensuring the safe, reliable, and efficient operation of the power plant and its equipment."

—— Yuanze Zhang

Power Plant Controller (PPC) HIL Test

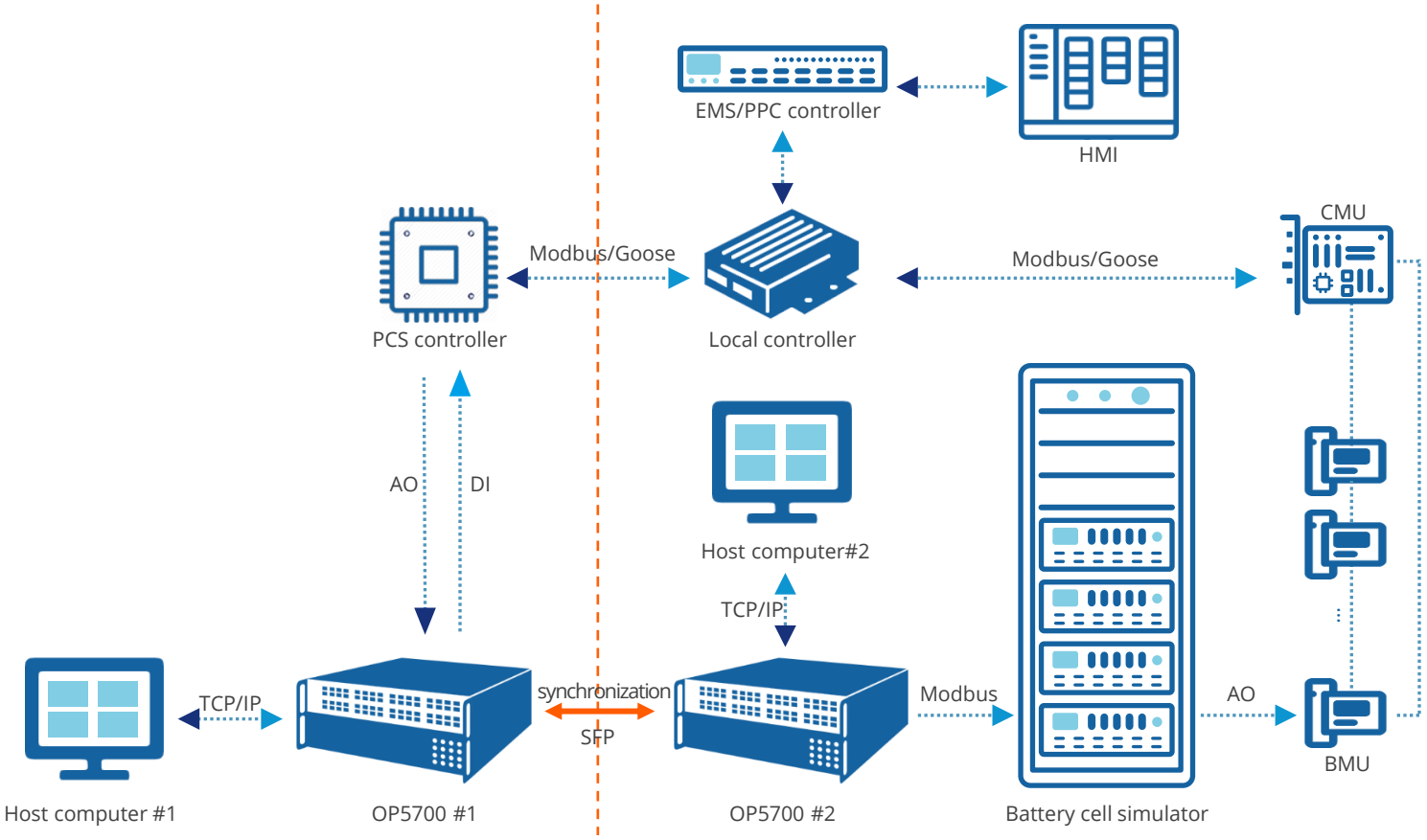
Based on the previous HIL test, an additional Power Plant Controller (PPC) or Energy Management System (EMS) is included. It is connected to the controller via IEC104 or GOOSE communication protocols. The voltage and current values at the POC are then measured and sent to the smart meter. The PPC, connected to the smart meter, generates a control algorithm based on the grid voltage and current measurements and sends dispatch signals to the inverter controller.



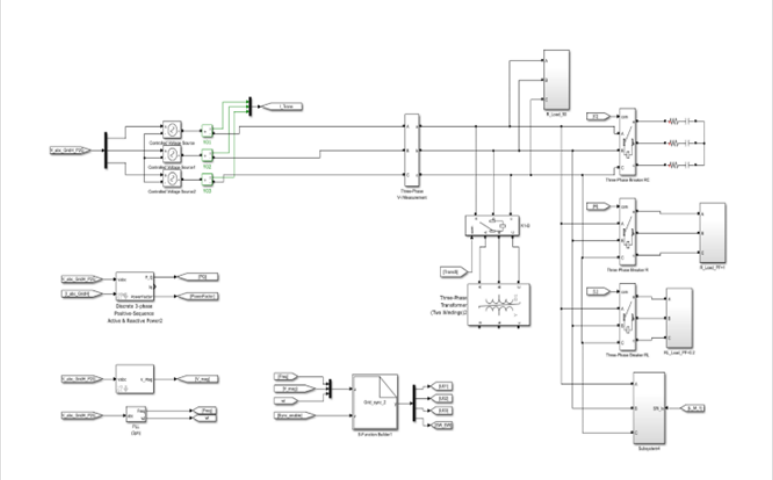
- PPC and inverter controller are real hardware under test;
- Industrial communication protocols (Modbus/TCP, GOOSE, IEC104) between PPC and inverter controller;
- Use single inverter to emulate the whole plant by scaling up power output.

BMS+PCS BESS System HIL Simulation

This use case is mainly used to test Sungrow's BMS, utilizing two independent real-time simulators to simulate the BMS and PCS separately. The two systems communicate and synchronize via a high-speed fiber optic protocol. The system is capable of simulating thousands of battery cells and synchronously simulating the BMU, PPC, PCS, and local controllers, among others. This helps study the impact of renewable energy grid integration on the power system and accelerates the research and development work to improve the efficiency of renewable energy grid integration.



BESS based Power Plant Black Start



Sungrow's black start project for a BESS power plant in North America involves the energy storage inverter forming the grid, supplying power to local loads, and providing power to the steam turbine generator. Before on-site deployment, the entire process is run in advance on the HIL simulation platform.

The HIL test setup consists of: RT-LAB + Simulink + Energy Storage Inverter Controller.

Off-grid black start procedure:

1. Multiple PCS start up in sync;
2. Main transformer Excitation;
3. Resistive load cut in;
4. Motor cut in;
5. Steam turbine starts up;
6. PCS change from VSG mode to grid following mode.

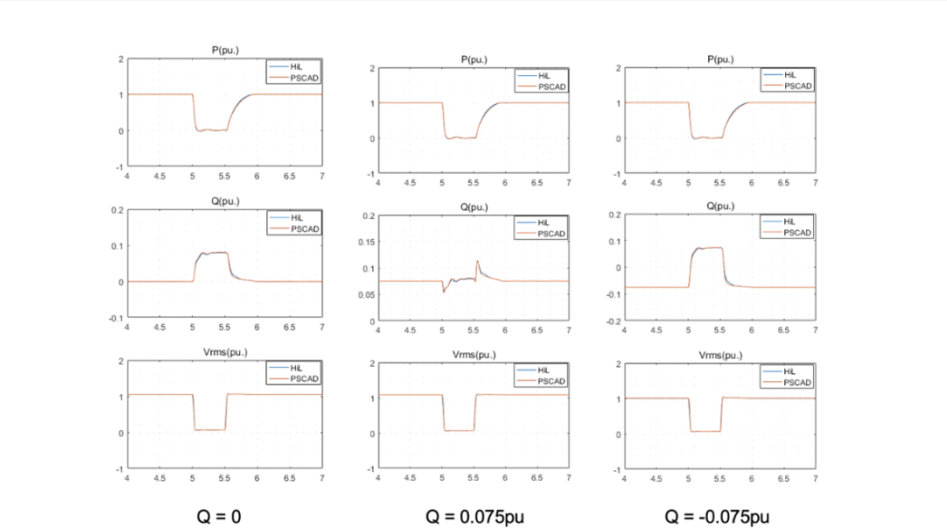
"Through HIL testing, we identified and fixed some control issues before going on site. When the team arrived at the site, it took only a few days to get the system running smoothly. In the highly competitive energy storage market, reliable and efficient project deployment means competitive advantage, which cannot be achieved without the help of OPAL-RT HIL testing platform."

——Yuanze Zhang

Model Validation Using HIL

The results of Hardware-in-the-Loop (HIL) testing can represent the actual performance of the product controller, making it a benchmark testing tool for model validation in various industry applications. For example, in power system applications, HIL can be used to verify the EMT-type digital simulation model's adequacy to represent the real-world operation of the power conversion system under various grid and operating scenarios.

The following diagram compares HIL simulation with other digital models:



▲ LVRT Test Digital Simulation VS HIL Benchmarking

This article is excerpted from the presentation by Dr. Yuanze Zhang of Sungrow in the webinar "Industry Insights: The Role of HIL in IBR Development and Integration".

Watch webinar