Harvest™ by Schneider Electric

success story

# OPAL-RT HIL Simulation for Variable Frequency Drive R&D

Harvest uses OPAL-RT's HIL solution to overcome key challenges in the development of Medium Voltage Variable Frequency Drive (MV VFD), accelerating control verification while reducing costs.

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OPAL-RT TECHNOLOGIES

# Harvest: Schneider Electric Global MV VFD R&D Center and Production Base

Founded in 1998, Harvest is one of the leading manufacturers specializing in the R&D, production, and sales of Medium Voltage Variable Frequency Drive (MV VFD) in China. For 27 years, the company has been focusing on the R&D and production of MV VFD. Its production base is located in Yangfang Industrial South Zone, Changping District, Beijing, with over 400 employees. In 2011, Harvest joined Schneider Electric (a Fortune Global 500 company in 2011), becoming its global R&D center and production base for medium voltage variable frequency drive.

In early 2024, OPAL-RT China partnered with Harvest to provide a comprehensive HIL simulation testing solution for medium voltage variable frequency drive designed for a variety of motor types.

OPAL-RT has over 20 years of deep expertise in electromagnetic transient real-time simulation for power electronic topologies. In particular, it has accumulated a wealth of HIL simulation experience for Cascading H-Bridge (CHB) topologies, applicable to: Variable Frequency Drives (VFD); Voltage Source Converters (VSC); Modular Multilevel Converters (MMC); Static Var Generators (SVG); High-voltage energy storage systems.

* Harvest Ultra High Power Water-Cooled MV VFD - HAR9000

Harvest offers a range of products with output voltages from 3.3kV to 13.8kV and output capacities up to 52MVA, including air-cooled, water-cooled, and four-quadrant regenerative MV VFD. Harvest MV VFDs feature vector control for both asynchronous and synchronous motors, compatible with various loads and are widely used in: Power generation, Oil and gas, Chemicals, Mining, Water and wastewater treatment, Building materials, Test benches, Hydraulic engineering New energy applications, etc.





# Addressing multifaceted technical challenges in VFD modeling and testing

## Computationally Intensive EMT Simulation

On the inverter side of the VFD model, the switching frequency of each single full-bridge submodule ranges between 500-1000 Hz. Each phase consists of 1-8 cascaded full-bridge modules. Due to the phase-shifting between multi-level modules and PWM dead-time, the overall switching frequency per phase can reach up to 10 kHz.

Compared to a simple cascaded full-bridge topology, the VFD model is significantly more complex due to the inclusion of a front-end phase-shifting transformer and rectifier section - particularly the phase-shifting transformer. Taking a typical 3-phase 8-chain system as an example: there are as many as 72 connection wires between the transformer's secondary side and the rectifier section, along with 24 3-phase full-bridge modules. This results in a highly coupled complex model comprising up to 96 switches, over a hundred model states, and numerous electrical nodes.

This complexity significantly increases the computational load of the electromagnetic transient model. Even on the most advanced current processors (CPU, GPU, FPGA), real-time simulation cannot be achieved using traditional algorithms.

## Multi-Motor and Sensor Simulation Demands

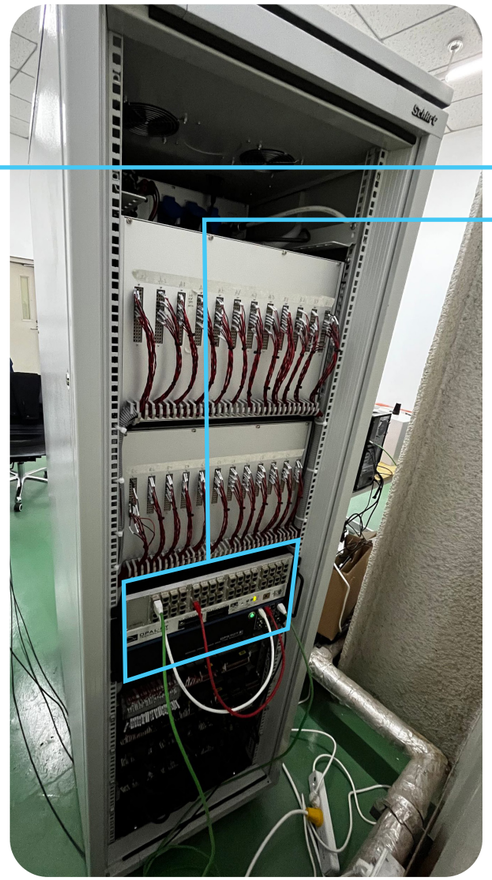
Beyond the complex transformer and power electronics topology, the final stage of VFD testing involves motors and sensors—such as induction machines, permanent magnet synchronous machines (PMSMs), and electrically excited synchronous motor, as well as sensors like incremental encoders. Thus, the real-time simulation system is required to support a wide variety and quantity of motor models and sensor types.

## Safety Risks and Maintenance Complexity

Traditional testing of physical inverter prototypes involves high-power systems and large-scale test benches, while entailing "blow-up" risks and safety hazards. The cascaded full-bridge structure increases prototype maintenance complexity, and high-risk operating condition testing further slows down the overall testing phase.

# Benefit from OPAL-RT's Scalable, high-speed simulation design

For the hardware implementation, OPAL-RT's High-end simulator OP5707XG is deployed. Its stand-alone electrical I/O interfaces can meet the requirements for 3-phase 8- to 13-cascaded full-bridge or converter topologies. For higher-level topologies, such as 50+-cascade full-bridge systems, optical fiber communication transmits switching signals and voltage/current measurements.





**HARDWARE SOLUTION** • Success Story — Harvest

# OP5707XG: Maximum flexibility and precision

### Modularity

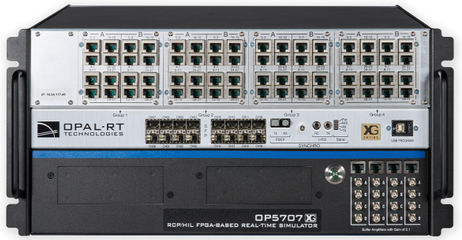
Connect your devices and systems without limitation. Onboard expansion slots accommodate up to 8 analog and digital I/O modules, with signal conditioning to support a combination of up to 128 fast analog or 256 digital channels.

### Scalability

Supports up to 16 SFP multi-mode fiber-optic modules and LVDS/fiber optic synchronization for high-speed communication and synchronization. Easily expand simulation and I/O capacity using other OPAL-RT FPGA and I/O expansion units.

### Monitoring and HIL interfacing

Convenient RJ45 and mini-BNC monitoring connectors are also available at the front of the simulator and standard DB37 connectors at the back for simple and efficient HIL interfacing.




OP5707XG FRONT


OP5707XG REAR

> The OPAL-RT hardware-in-the-loop test platform relieves the pressure on the test prototype occupancy to some extent and accelerates the validation session of the control algorithm, which is also in line with the R&D concept of Harvest.

Software Engineer at Harvest

# Leveraging OPAL-RT's toolboxes to expand real-time simulation capabilities

Addressing Harvest's requirements and the aforementioned challenges, OPAL-RT China leverages over a decade of solution experience with cascaded full-bridge topologies to recommend the adoption of OPAL-RT's eHS and ARTEMiS at the software level.


### eHS

**FPGA-based power electronics toolbox**

The industry benchmark for simulating high-speed switching and converters with high precision.

- Ultra-fast solvers for converters & inverters
- Ideal for HIL testing of power converters


### ARTEMiS

**CPU-based electrical toolbox**

Compatible with MATLAB/Simulink®, enabling accurate simulations of power systems and converters on CPU.

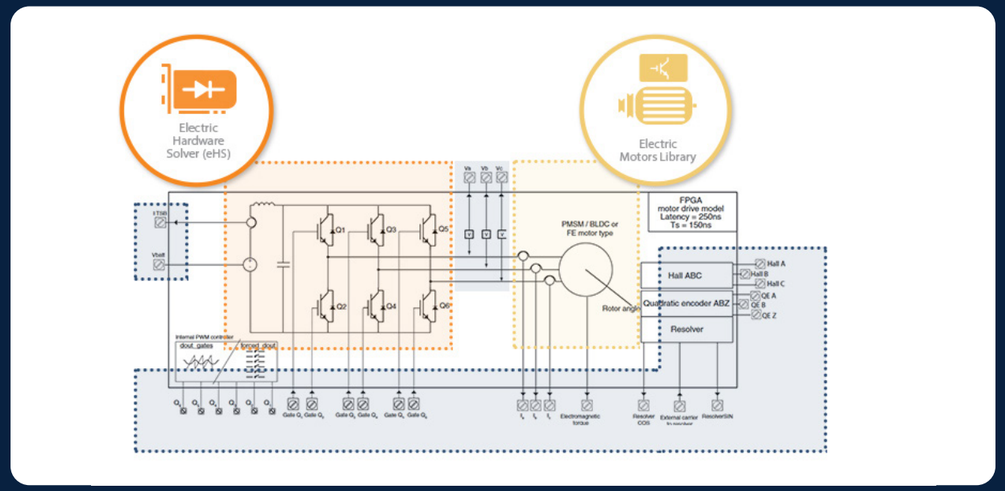
- Realistic switching behavior in CPU-based solvers
- Reduce numerical oscillations and improve model fidelity



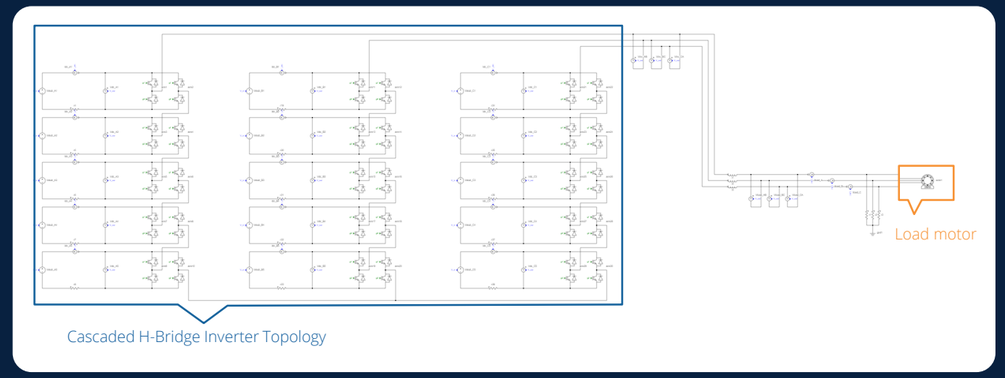
**SOFTWARE SOLUTION** • Success Story — Harvest

## eHS | FPGA-based Power Electronics Toolbox

eHS provides FPGA-based computation capabilities for power electronics models along with a wide range of motor models. It allows users to build highly customizable power electronic topologies within software, supporting high switching frequencies (notably including above 200 kHz) and solving them with time steps as small as the nanosecond level. Power electronics models running on the FPGA can be edited and modified without requiring recompilation—once saved, they can be directly deployed to the FPGA for execution. This enables digital power electronic topologies to replace physical prototypes in testing scenarios.

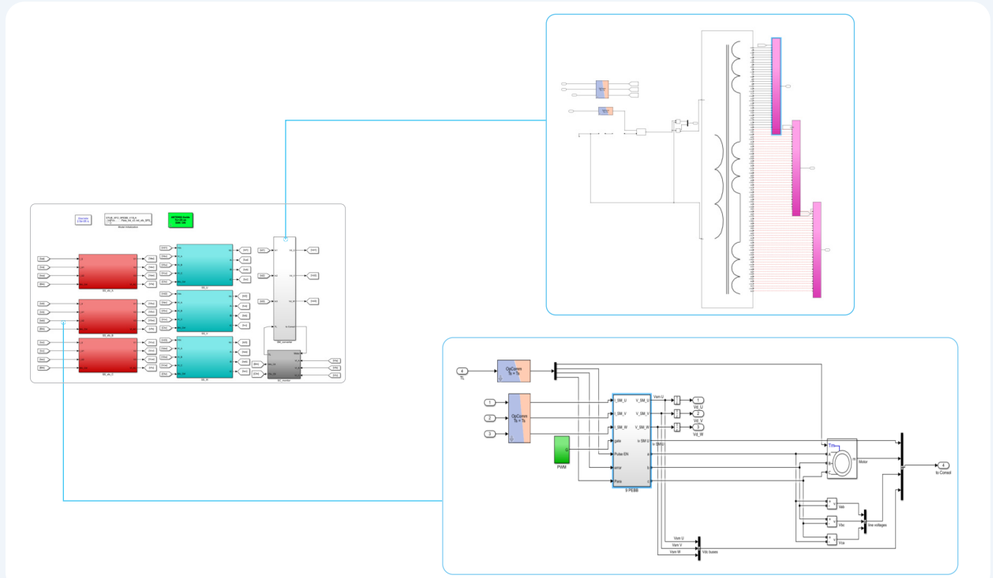



In addition, for VFD application scenarios, eHS offers a wide variety of motor models, including commonly used permanent magnet synchronous motors (with fixed parameters and lookup tables for variable parameters) and induction motors, as well as incremental encoders and resolvers. Furthermore, eHS also provides FPGA-based models for electrically excited synchronous motors, six-phase motors, and switched reluctance motors.



## ARTEMiS | CPU-based Electrical Toolbox

ARTEMiS is a CPU-based electromagnetic transient model solver that applies the State-Space Nodal Solver method to decouple and partition large-scale power systems or power electronic models without introducing artificial delays. This approach optimizes simulation time steps and improves computational accuracy. Additionally, ARTEMiS supports multi-rate execution within a single model, allowing users to assign different time steps based on the system's frequency response characteristics for more efficient allocation of real-time simulation resources.



In the Harvest's application, although the rectifier does not use high-frequency switching and hence a time step at tens of microseconds is sufficient, the Artemis-SSN solver is still essential to decouple those more than twenty converters from the multi-winding transformer to meet the timing constraints for real-time computation. Also, simulating the rectifier on the CPU is more cost effective without compromising its accuracy, as it does not need another FPGA.

### Simscape Electrical™ models enhancer

ARTEMiS brings Simscape Electrical/SPS models to real time with minimal effort.

### Simulate complex motor drives and converter topologies

Provides advanced converter models for the real-time simulation of large drives.

### Extended library of optimized real-time models

From transformers and machines to lines, every model is adapted for precise simulation and real-time performance.

### Run large power system models

Provides several options and methods to parallelize electrical models to run on OPAL-RT multiprocessor platforms.





# Local service: Full-Cycle Escort for HIL Deployment

OPAL-RT China provides a full range of local services:

## Project Integration

In this project, local engineers were involved in the design of an integrated cabinet based on specific model parameters provided by the customer, interfaces of the controller to be tested, and other information.

## Model Development

Prior to customer on-site debugging, OPAL-RT Application Engineers complete the development of RT-LAB simulation models and conduct open-loop testing to verify:

(1) alignment of simulation results with expectations, (2) rational utilization of hardware/software resources, and (3) absence of timeouts or anomalies.

This preparatory work significantly reduces the learning curve and debugging timeline for first-time RT-LAB users, paving the way for accelerated HIL testing deployment.

## Technical Support

Field Integration and Technical Support Services

- **Essential Maintenance:**

Technical support response within 48 hours, support by email and phone, knowledge base, latest software, free firmware transfer to new hardware platforms, support for project software upgrades as well as free firmware upgrades.

- **Premium Maintenance:**

Make OPAL-RT technical support engineers part of your team. This maintenance program includes additional options and advanced services required on critical application scenarios on top of the base program. Often, real-time simulation testing is a core element of mission-critical product development: in such cases, downtime or troubleshooting efforts can be very costly for OPAL-RT customers, and the Premium Maintenance program includes the following benefits:

1) Designate two local technical support engineers to follow up the progress of the customer's project for a long period of time; 2) For the two sets of test models specified by the customer, cooperate with the completion of the real-time and modification work; 3) Extra hardware warranty extension;  4)Additional discounts on secondary hardware upgrades or purchases.

# Revolutionizing VFD testing with OPAL-RT HIL Solution

The ARTEMiS and eHS provide customized and optimized motor models covering induction, permanent magnet synchronous and electro-excited synchronous motors, etc., and sensor models containing rotary transformers and incremental encoders, etc. Replacing real motors with digital motor models greatly accelerates the validation session of control algorithm.

## RESULTS

### Control Algorithm HIL Verification

The control strategy algorithms for VF control, inductive vector control, and non-inductive vector control of asynchronous motors and permanent magnet synchronous motors based on simulation models are completed and verified respectively by using HIL bench and accessing the mature physical controllers on the production line.

### Fault Condition Protection Testing

Fault condition tests were introduced to verify the protection control strategies for fault conditions such as synchronous switching with/without reactor, single-phase output voltage grounding protection, out-of-phase detection, bus voltage overvoltage and undervoltage, etc., which greatly reduces the risk of testing in the extreme conditions.

### On-Site Issue Lab Reproduction

The lab environment in the R&D center allows for timely reproduction of on-site feedback issues, reducing the need to travel to the model lab or customer site.

### Accelerated Product Development

Accelerates the development of new products and functions and reduces the dependence of software development on hardware platforms.

### One Bench, Multi-Motor Test

Facilitates testing of different motor types on the same bench, simplifying the expense and time cost of test rig setup.

### Reliable Simulation Results

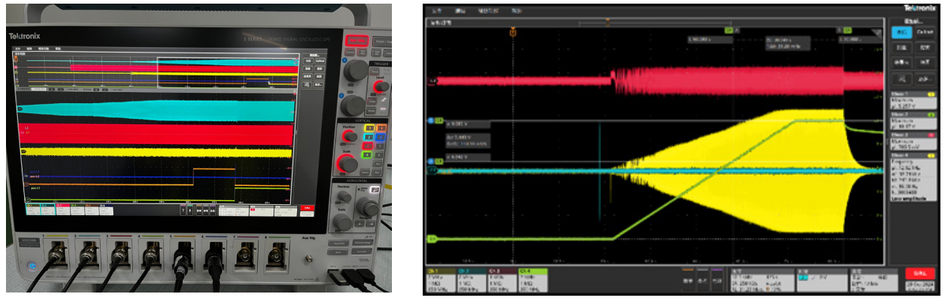
The simulation results and waveform data are highly reliable and can replace the dynamic hardware-involved simulation platform to complete most tests.

### Early Defect Exposure

Control program issues are exposed and iterated early in the development process.



**CONCLUSION** • Success Story — Harvest




Waveform of PLC switching (operation and cut-off)

> According to varying on-site requirements from customers, we offer MV VFD products with varying voltage, current, and power levels. However, it is impractical to test all models during R&D. Similarly, the diversity of motors and load types at customer sites makes it difficult to reproduce specific scenario issues on the R&D side. Additionally, extreme condition tests are costly and potentially dangerous. To address these challenges, we introduced OPAL-RT's HIL simulation platform into our R&D."

**Software Engineer at Harvest**

# Ready to innovate?

For over two decades, OPAL-RT TECHNOLOGIES has been a global leader in real-time simulation and hardware-in-the-loop (HIL) testing. Since 1997, OPAL-RT has empowered engineers and researchers with accessible, innovative, and customized simulation technology—bridging the gap between modeling and real-world applications. By leveraging high-performance computing, OPAL-RT accelerates the development of advanced solutions in energy, automotive, aerospace, and beyond. With our ISO 9001:2015 certification and a strong commitment to sustainable development, we're not just developing technology—we're building a better future, together.

## Explore our other success stories

Discover how industry leaders achieve engineering excellence with OPAL-RT's solutions.

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