Real-Time RCP Solutions for Power Electronics and Power Systems

Accelerate Control Engineering Design and Reduce Cost with OPAL-RT Solutions

OPAL-RT TECHNOLOGIES

From Imagination... to Real-Time

Accelerate Control Engineering Design

Jean Bélanger
President & CEO

OPAL-RT provides high-performance Rapid Control Prototyping (RCP) systems optimized for advanced power electronic systems using fast switching technologies and innovative converter topologies.

Our flexible RCP solutions help design the most sophisticated controllers required for new multi-level converted topologies used in photovoltaic and other grids-connected industrial drives. Our solutions also provide the performance of modern digital signal processors (DSP) and field programmable gate array-based (FPGA) power electronic controllers. These controllers are commonly employed in new - more electrical - aircraft and modern hybrid vehicles requiring the use of sophisticated high-speed converters to reduce weight, space and harmonics.

For more than 10 years, OPAL-RT's RCP and HIL systems have interfaced high-end multi-core processors with large FPGAs. This multi-rate CPU-FPGA-I/O architecture, where all I/O converters are directly controlled by the FPGA chips, is very flexible. It leads to the highest effectiveness expected from the most sophisticated controller hardware used in actual systems.

OPAL-RT also wants to serve the market of RCP systems used to design small and distributed power electronics systems. Specialists designing such small but high-performance and interconnected controllers used in PVs and micro-grids are addressing a very price sensitive market. They must therefore have access to cost-effective and small high-performance RCP systems with the capability to communicate with each other as well as with a main control center.

OPAL-RT addresses this challenge with the development of the OP4000 RCP and HIL compact product serie.

This product family includes sophisticated cost-effective RCP systems capable of emulating complex motor drive, wind turbine, PV and micro-grid controllers. A new line of RCP systems will soon be developed to take advantage of the decrease in price and the technological evolution of FPGA, combining the ARM with the KINTEX FPGA in the same chip. This will help develop a new class of RCP systems. In fact, this RCP technology will be much closer to the technology used in actual systems.

At the other end of the spectrum, OPAL-RT will also continue to offer very high-end multi-processor/FPGA RCP systems integrated with HIL simulators. Such tools are optimized for the design of multi-converter systems used in complex military and off-highway vehicles, trains, ships, aircraft and multi-levels multi-converter systems used in industrial plants, micro-grid and AC/DC grids.

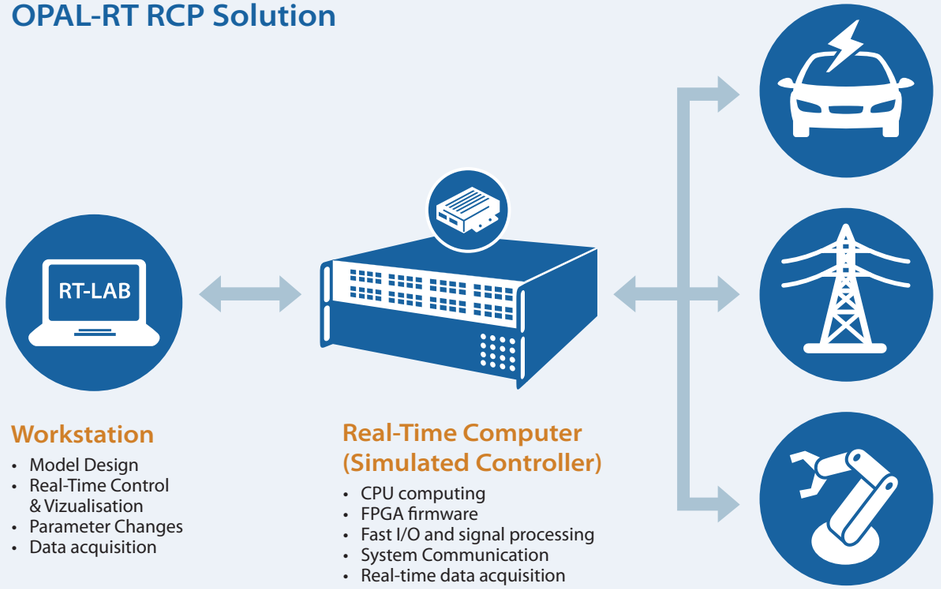
In the near future, we foresee that all entry-level and high-end systems will be extremely scalable and will share the same architecture with a sophisticated user interface, all with the goal of providing user-friendly and powerful solutions for better systems monitoring. This way, control specialists can focus on algorithm development and testing with peace of mind.

Why Use Rapid Control Prototyping

RCP decreases development time by allowing corrections to be made early in the product process. By giving engineering a look at the product early in the design process, mistakes can be corrected and changes can be made while they are still inexpensive.

- To allow early verification of control specifications in the form of a model.
- To avoid the time-consuming and expensive development of controller prototypes.
- To enable rapid innovation and shorten test cycle.
- To increase effective communication between teams.
- To decrease development costs and save tremendous amounts of time.
- To decrease costly mistakes.
- To minimize engineering changes.
- To implement and test advanced synchronization and data acquisition function without building complex DSP/micro controller/FPGA boards.

OPAL-RT RCP Solution



Workstation

- Model Design
- Real-Time Control & Vizualisation
- Parameter Changes
- Data acquisition

Real-Time Computer (Simulated Controller)

- CPU computing
- FPGA firmware
- Fast I/O and signal processing
- System Communication
- Real-time data acquisition

Actual Drive, Grid & Mechatronic Systems (or HIL systems)

Our Key Strengths

OPAL-RT's unique combination of technologies, expertise and flexibility enable us to effectively meet today's challenges in terms of rapid control prototyping.

System scalability

OPAL-RT differentiates itself by being able to provide a PCI express architecture that allows you to connect hundreds of I/O channels in order to represent large controllers systems. Customers can simulate complex systems with ever increasing precision and execution speed.

FPGA expertise

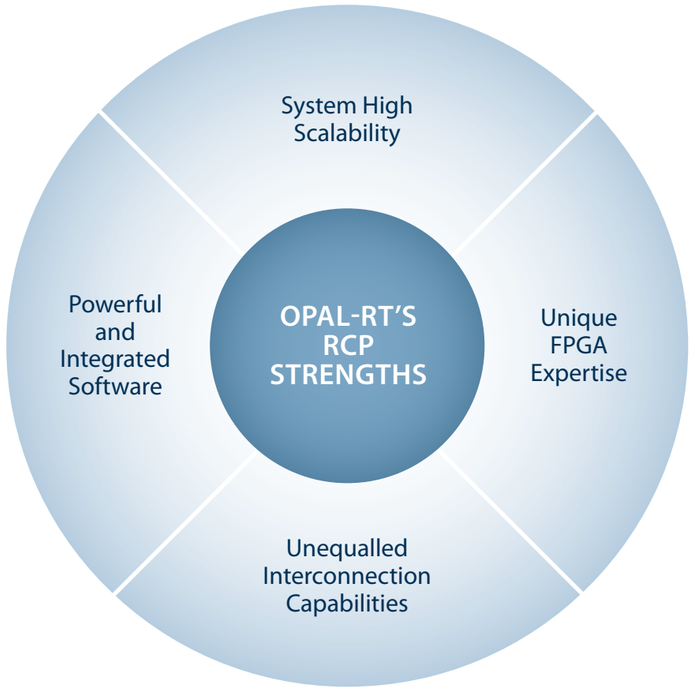
OPAL-RT's FPGA allows greater simulation power and precision, as well as greater flexibility for data acquisition and specific timing functions. Communications between functions implemented on the FPGA are made easy and open.

Unique software for real-time simulation

OPAL-RT offers a suite of powerful simulation software HMI such as RT-LAB and TestDrive providing a complete real-time experience for model edition, vizualisation and test programmation. Our renown mathematical solvers and models are specially designed for accurate simulation of power electronic systems and electrical grids.

Interconnection

The open architecture of OPAL-RT allows for a smooth integration with third party hardware, making an RCP solution more complete and powerful.



Our Solutions

Our unique technologies and capabilities are regrouped into two product lines for electrical applications.

RCP-Drive

RCP-Drive solutions that are geared toward electric drive control engineering, with all types of motors and converter topologies. These include:

- Electric drives for low voltage applications, such as PMSM and BLDC
- High Power industrial drives found in marine applications, oil & gas systems, trains, and off-highway vehicles
- Teaching and professional training laboratories

RCP-Grid

RCP-Grid systems are ideal for the design, prototyping and testing of complex control, protection and measurement used in modern power systems as well as grid-connected power electronics systems. Applications include:

- Renewable energy resources, storage, and smart home automation
- Smart grid systems such as protection relay, phasor measurement units, energy management systems
- High voltage power electronics, used in transport or interconnection applications, in particular, recent power electronics systems with modular multi-level controls

Electric drives

- Hybrid electric drive
- Electric steering
- Electric actuators

Renewable Energy

- Renewable energy resources
- Storage
- Smart home automation

High Power Industrial Drives

- Multi-machine drives
- Multi-phase drives
- Marine oil & gas
- Off-highway vehicles
- Trains

Power System & Smart Grid

- Protection relay
- PMU
- SCADA
- Energy management systems

Teaching Laboratories

- 250W electric drive kit
- Doubly fed induction 2KW generator kit

High Voltage Power Electronics

- HVDC interconnections
- Meshed DC grids
- MMC HVDC systems
- Facts and SVCs

RCP-Drive Applications

With RCP-Drive, OPAL-RT provides a rapid control prototyping solution tailored to the needs and requirements of electric motor control, for all types of motors and electric power conversion topologies.

Rapid control prototyping for motor controls:

The trend towards mechatronic integration means that electric motors are gaining in popularity. However, their advantages are accompanied by a higher workload for integrating the additional control algorithms into the respective controller. The result is more complex controller software, which usually leads to increased development times. This drawback can be countered by using model-based design along with rapid control prototyping (RCP) to accelerate design iterations of the control algorithm on the real object.

OPAL-RT developed specific features to meet new motor control challenges:

- Simplicity, flexibility and high precision on the gate pulse generation, thanks to dedicated control functions implemented on FPGA.
- FPGA firmware providing configurable I/Os for many types of sensors used in the industry.
- Tested and proven with various types of motors (AC, DC, PMSM, BLDC, SRM,..)
- Can be fully integrated with OPAL-RT eDRIVEsim HIL simulator.
- Power management strategy involving other global system devices through CAN or other communication protocols.

Rapid control prototyping for energy conversion

We find power conversion control strategies in all kind of industries. OPAL-RT's flexible plattform can adapt it's simulation parameters and sensors to any type of power and configuration.

Main RCP features include:

- Ability to control demanding cases with tight cycle times and complex topologies
- Tested and proven with inverters of many types: 2-level, 3-level, 3-level NPC, matrix converters, multi-phase frequency converters or multi-drive configurations.
- Possibility of inserting high voltage and high current sensors.

We serve many industries and energy conversion configurations such as:

Electricity into motion
- Compressors
- Propellers
- Rolling mills
- Pumps

Motion into electricity
- Wind turbines
- Turbo generators
- Hydro power
- Wet renewables

Electricity into electricity
- Wind/solar PV
- Railway substations
- Pulse power supply
- Soft starters

RCP-Grid Applications

With RCP-Grid, take advantage of the best solution to design control, protection and measurement of modern power systems.

Protective relay, PMU and SmartGrid IED prototype

The rise of model-based systems engineering is a benefit to the power system industry, allowing faster development, and the ability to cope with increasing software complexity.

OPAL-RT delivers industry-first solutions, which enable the rapid development and trial of protective relay, PMU and SmartGrid IED logic:

- Automatic translation of MATLAB/Simulink monitoring, control or protection algorithms
- Compatible with various protocols, such as IEC 61850 Goose and SV, for protection testing and electrical substation automation, C37.118 for PMU/PDC interfacing and DNP3 to interface process automation and SCADA systems
- Support of external time reference (GPS synchronization)
- Can be used independently for controller emulation and stand-alone protection systems development using CPU or FPGA processors
- Can be integrated with eMEGAsim simulator by dedicating processor cores and I/O modules on the RCP functions and other CPU and I/O for the power system model; this feature is essential to develop complex wide area control and protection system

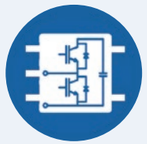
Modular multi-level voltage source converter (MMC VSC) prototype controller

Developing open and closed-loop controls for MMC VSCs can be a daunting task, requiring high performance control systems that are able to handle a very large amount of synchronized I/O signals, data and complex models.

OPAL-RT delivers a unique rapid control prototyping solution for MMC converters, which enables faster development, cost and risk reduction. This solution features exclusive characteristics to rapidly build a demonstration prototype, validate control algorithms, de-risk control design, detect design faults, and ensure lean implementation afterwards:

- Automatic translation of MATLAB/Simulink control algorithms for real-time execution and testing of high-level pole controllers and low level MMC cell controls
- Ability to implement voltage balancing control of each cell capacitor by reading back each individual capacitor voltage

Electrical power conversion
- MMC
- FACTS
- HVDC



Power monitoring and control
- Smart grid
- PMU
- Wide-area control and protection

Renewable energy storage and distribution
- Micro grid
- Controls and protections
- DER (Distributed Energy Resources)

OPAL-RT Products Highlights for RCP Applications

OPAL-RT provides hardware, software, and firmware for a complete RCP solution.

Software

RT-LAB, fully integrated with MATLAB/Simulink® and Xilinx system generator, is the open real-time simulation software environment that has revolutionized the way model-based design is performed. RT-LAB's flexibility and scalability allow it to be used in virtually any simulation or control system application, and to add computing-power to simulations where and when it is needed.

TESTDRIVE User Interface

HMI (Human-Machine Interface)

TestDrive user interface uses the best of two tools: RT-LAB for developing real-time application with Simulink® and LabVIEW, one of the most complete and well known system design platforms. It offers features like:

- Connection to any models compatible with RT-LAB.
- Direct assignment between RT-LAB signals and Labview control and acquistion widget.
- Simplified and integrated scripting using Python.
- Different permissions controls for all type of users; from run-time application to development.

Communication Protocols

EtherCat, OPC, IEC 60870-5-104, IEC 61850, MODBUS, Serial Protocol (RS-232, RS-485), CAN, LIN, ARINC, DNP 3.0, C37.118, MIL-STD-1553, etc.

Hardware

OP4500

CPU: QuadCore
FPGA: Kintex-7 325T
I/O: 96 channels max

OP5600

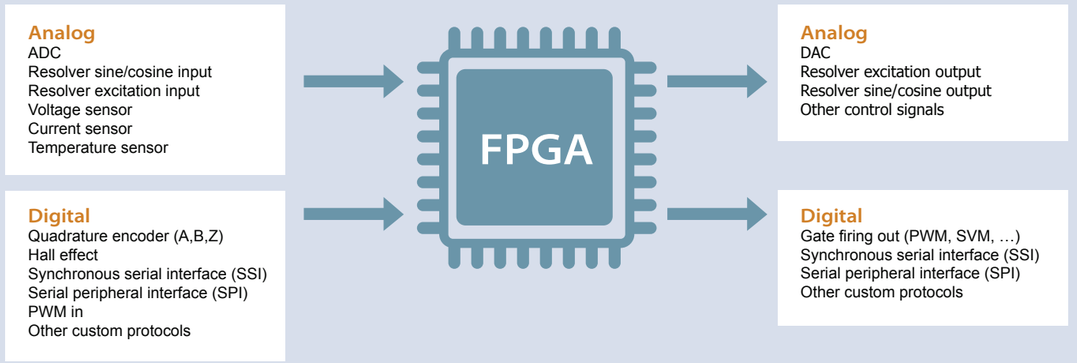
CPU: From 2 to 32 cores
FPGA: Spartan 3, Virtex 6 or 7
I/O: 256 channels max

Firmware

FPGA Firmware is a technology that allows versatility and fast computation for high speed algorithms that are used for signal processing, controls or protections.

It also allows compatibility with a wide variety of sensors needed for Rapid Control Prototyping (RCP) applications. Given that RCP testing activities deal with efficient devices (power electronics, electrical motors, ...), the FPGA firmware also needs to show security features that allow secure test performances.

Users can develop their own FPGA firmware using Xilinx system generator, fully integrated with RT-LAB XSG, or use OPAL-RT standard firmware.



RCP Showcase

Auto HEV
RCP-Drive

CONTEXT: The mission of the powertrain systems at Valeo is to develop innovative powertrain solutions aimed at reducing fuel consumption and CO2 emissions. These innovations cover a complete product range, from the optimization of internal combustion engines to the varying degrees of electrification of vehicles, from stop-start systems to the electric car. In this case, Valeo is aiming at developing a new power electronics system for us in electric vehicle applications.

CHALLENGE: The R&D department in Creteil (France) had to study the system, design new algorithms and control laws and to test their efficiency on a prototype. This type of demonstration is very time consuming and costly because, traditionally, computer code must be written and implemented. This approach is inflexible and does not allow engineers to quickly modify/correct control loops; it also requires programming knowledge and investigating problems is complicated.

SOLUTION: The customer works with Simulink for their preliminary tests. OPAL-RT provided and RCP-Drive system that allows the user to automatically load a Simulink model on a real-time platform equipped with the I/O interfaces required for the project (PWM, voltage/current measurement, speed sensor, etc.).

BENEFITS: VALEO saved numerous work hours that would have proved very costly for them and would have impacted other industrial projects required by their customers. A quick and practical, Human-Computer Interaction (HCI) and datalogging solution lets users assess problems more quickly and in greater detail without needing extra tools. PWM management is both fast and accurate and can be configured using Simulink software, which makes it very flexible and allows users to test in greater depth. New control laws were tested and allowed VALEO to demonstrate new electric automobile concepts and respond to today's challenges.

A global leader in power and automation technologies

Power Conversion Industry
RCP-Drive

CONTEXT: Our customer develops frequency variators for electric drives. They research new techniques to be used by it's business units and also do their own development.

CHALLENGE: Our customer wanted to research new low voltage drive systems for their automation line. Until now, development was done on boards connected to the company's automation systems. Researchers had to implement these DSP / FPGA boards either manually or using Simulink blocs with automatic generation. This process was time consuming (generating firmware requires a great deal of time), required advanced programming knowledge and was difficult to correct.

SOLUTION: OPAL-RT suggested an RCP-DRIVE system that had the advantage of directly integrating with Simulink, without requiring any other software environment.

BENEFITS: The customer wants to simplify and speed up R&D while using the latest tools to support an ambitious R&D policy.

MMC
RCP-Grid

CONTEXT: Development of new MMC type (pole and VBE) controls for VSC and HVDC. The university research team is very active in the field of power conversion. Their research is being applied in the fields of future transportation, renewable energy systems, industrial manufacturing systems and electrical power distribution. Jon Clare's team is one of the most renowned in the UK, on the cutting edge of research in this field and a leader involved in some of the largest European research projects.

CHALLENGE: As part of a commercial contract, the team must develop a new generation of sophisticated controls to manage hundreds of IGBT in a multi-level, modular architecture, with significant timing constraints and synchronization of thousands of signals. The solutions already developed by the university are limited in terms of the number of signals supported and are complicated to implement (DSP/FPGA programming knowledge is required) and allow only minimal reuse of the software code developed.

SOLUTION: By choosing the RCP-Grid solution, Nottingham University's PEMC group is equipped with one of OPAL-RT's latest innovations for rapid control prototyping of power electronics. The system is not only completely integrated into MATLAB/Simulink and able to manage thousands of channels (analog and digital) to drive IGBT and read values received from current and voltage sensors, it also lets developers access a wealth of functions to facilitate development and speed up validation and adjustment of existing models.

BENEFITS: Thanks to the RCP-Grid platforms provided, the PEMC group gives demonstrations of their scope both in their laboratories and at the new EPSRC CENTRE, inaugurated in 2013. The results of these demonstrations are highly anticipated for offshore wind farm development and HVDC links currently expanding in the UK (as well as for DC and supergrid network projects). The research proposal for industrials is widespread and well supported, thanks to information sharing with industrial or academic partners using the standardized MATLAB/Simulink file format.

Other Customers (partial list)

ABB · ALSTOM · DENSO · EATON · GE · HITACHI · Johnson Controls · KTH · Mitsubishi Electric · Panasonic · Rockwell · Schneider Electric · SIEMENS

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OPAL-RT
Corporate Headquarters

1751 Richardson, Suite 2525
Montréal, Québec, Canada H3K 1G6
Tel: +1 514-935-2323
Fax: +1 514-935-4994

USA

OPAL-RT Corporation
26 Summit Street, Brighton
MI 48116, USA
Phone: +1 (734) 418-2961
Fax: +1 (866) 462-5120

EUROPE

OPAL-RT Europe S.A.
196 Houdan Street
92330 Sceaux, France
Phone: +33 1 41 73 40 80
Fax: +33 9 67 23 07 84

INDIA

OPAL-RT India Pvt Ltd
100 ft road, Binnamangala
Bangalore - 560 038, India
Phone: +91.80.2520.0305
Fax: +91.80.2520.0105

OPAL-RT TECHNOLOGIES

About OPAL-RT TECHNOLOGIES

OPAL-RT is the world leader in the development of PC/FPGA Based Real-Time Digital Simulator, Hardware-In-the-Loop (HIL) testing equipment and Rapid Control Prototyping (RCP) systems to design, test and optimize control and protection systems used in power grids, power electronics, motor drives, automotive industry, trains, aircrafts and various industries, as well as R&D centers and universities

www.opal-rt.com

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