from imagination to real-time

About OPAL-RT

Founded in 1997, OPAL-RT Technologies is a world leading developer of open real-time digital simulators and hardware in-the-loop testing equipment for electrical, electro-mechanical and power electronic systems. OPAL-RT's simulators are used by engineers and researchers at leading manufacturers, utilities, universities and research centers around the world. OPAL-RT's unique technological approach integrates parallel, distributed computing with commercial-off-the-shelf technologies. Customers perform rapid control prototyping, system integration, and hardware-in-the-loop testing of electric drives, electronic controllers and power distribution networks in a variety of industries including automotive, aerospace, electric ships, power generation, rail, and industrial manufacturing.

OPAL-RT Technologies Inc.
1751 Richardson, Suite 2525
Montréal, Québec, Canada
H3K 1G6
Tel: 514-935-2323
Toll free: 1-877-935-2323
Fax: 514-935-4994

U.S.A.
OPAL-RT Corporation
26 Summit Street, Brighton
MI 48116, USA
Tel: (734) 418-2961
Fax: (866) 462-5120

Middle East - Japan
OPAL-RT Technologies Inc.
Berytech Technological Pole,
Beirut 1107 2240 – Lebanon
Tel.: +961-453.3040 #4013
Fax: +961-453.3070 #1013

Check our website to locate a distributor near you

OPAL-RT.COM

Europe
OPAL-RT Europe S.A.
1, rue traversière
94150 RUNGIS
France
Tel : +33 1 41 73 40 80
Fax : +33 1 41 73 08 49

India
OPAL-RT Technologies Inc.
C-2, J.K.Paradise,
6th Cross, Kaggadasapura
Bangalore - 560 093, India
Tel.: +91.80.6572.6326
Fax: +91.80.4152.5049

China - South East Asia
OPAL-RT Technologies Inc.
Thailand: 66-083-279-6667
China : 86-136-9914-8768

OPAL·RT

BRC-11001-12080-EDS

eDRIVEsim™

Electric Drives and Power Electronics Hardware in the Loop (HIL) Test Benches

OPAL-RT TECHNOLOGIES

opal-rt.com

Real-Time Simulator Solutions for Power Electronic Controller and System Design

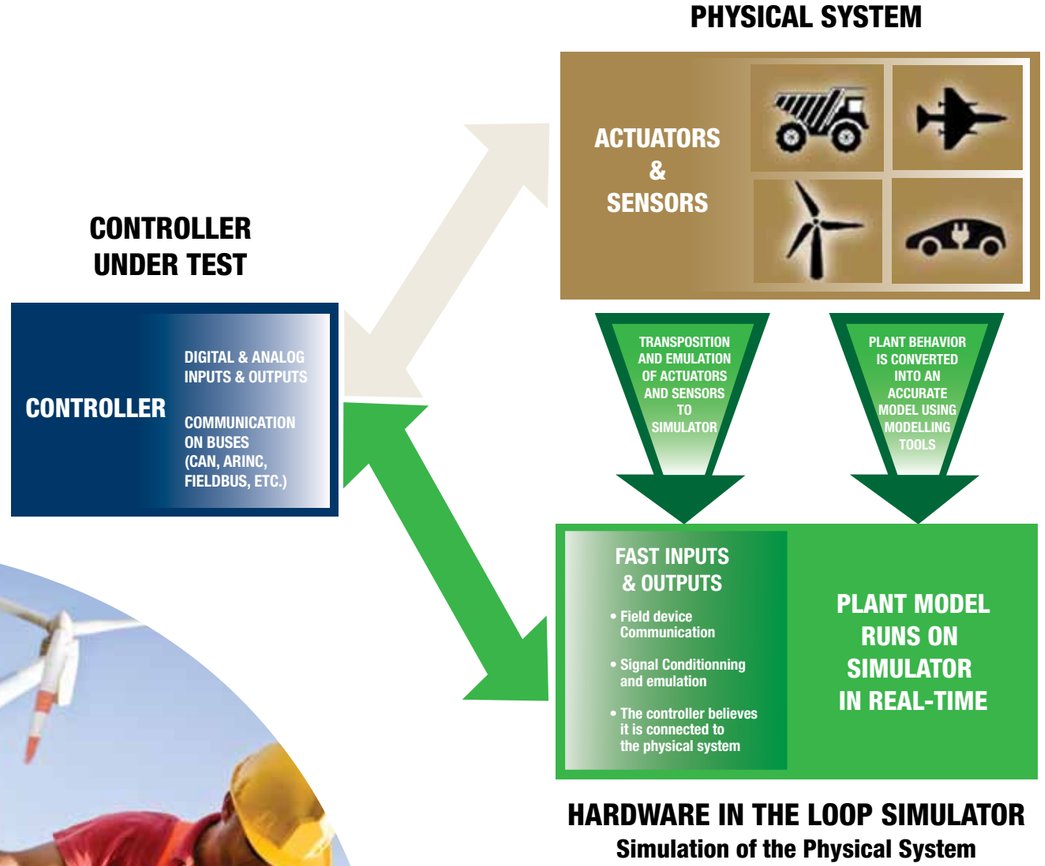
Reduce Cost and Time-to-Market with Full Coverage and Repeatable Testing Tool

Hardware-in-the-Loop (HIL) Introduction

recreating reality

Hardware-in-the-Loop (HIL) Simulation for Developing, Testing Electric Drives and Power Electronics Systems

Hardware-in-the-loop (HIL) simulation is a technique used to develop and test control systems. The goal is to verify and certify the functionality, performance, quality and safety of the controller software program. To achieve that, a physical system's dynamic behavior is converted into a software model that runs on the simulator in real-time. The model accurately simulates the steady-state and transient behavior of the physical system. The controller is connected to the simulator's I/Os which emulate the real actuators and sensors. By recreating reality, the controller is "fooled" into believing it is wired to the real physical system. All the flexibility to test the controller under any operating condition then becomes possible.



Typical e*DRIVE*sim™ Configurations

The following table presents typical e*DRIVE*sim™ configurations. For more information contact your sale representative.

	Description	e*DRIVE*sim C C-1	JMAG C-14	e*DRIVE*sim D D-1	JMAG2 D-12
Real-Time Processor	Main Processor installed on the Real-Time target system	**Consult an OPAL-RT representative for the latest available processors**			
Number of Cores Enabled	Number of enabled processors that can execute parallel computation	1	1	1	1
Remaining No. of processors	Expansion by adding software licenses	3	3	3	5
Spartan III FPGA	User programmable I/O	●	●	●	●
Virtex 6 FPGA	Ideal for advanced co-simulation and user programmable I/O	○	●	○	●
RT-LAB Software Toolboxes					
RT-LAB RTeDRIVE	High precision VSC Power Electronic Drives (IGBT)	●	●	●	●
RT-LAB ARTEMiS	Real-Time Solver for SimPowerSystems	○	○	●	●
RT-LAB *JMAG*	Real-Time Finite Element Motor Model	○	●	○	●
RT-LAB *JMAG* on FPGA	Real-Time Finite Element Motor Model on FPGA	○	●	○	●
Digital Inputs & Outputs With Signal Coditioning		Channels	Channels	Channels	Channels
Static Digital Inputs (DI)	Opto-Isolated (0-30V)	16	24	16	16
Timed Digital Inputs (TDI)	Controlled by FPGA with 10 ns resolution	16	8	16	16
Static Digital Outputs (DO)	Opto-Isolated (0-30V)	16	24	16	16
Timed Digital Outputs (TDO)	Controlled by FPGA with 10 ns resolution	16	8	16	16
Upgrade static to timed DIO	All static DIO can be controlled by FPGA with 10 ns resolution by instaling optional FPGA functions				
Analog Inputs & Outputs					
Analog Inputs	Differential ± 16 V 16 Bits @ 2.5 µs (500 ns optional)	16	0	16	16
Analog Outputs	Differential ± 16 V 16 Bits @ 1 µs	16	16	16	16
Current & Voltage Sensors	Up to 50 Amps / 600 Volts	Optional	Optional	Optional	Optional
Pre-defined FPGA functions available for analog and digital signals Motor Simulator Functions					
Quadrature Encoder	A, B, Z TSDO signals, rotor position	0-5	0-2	0-5	0-5
Hall Effect Sensor Output	TSDO for motor rotor position	0-16	0-8	0-16	0-16
Trigger Wheel Output	TSDO for motor rotor position	0-16	0-8	0-16	0-16
Resolver Output	One carrier input and 2 output signals	0-8	0	0-8	0-8
RVDT /LVDT Output	Rotary /linear Variable Diff. Trfmr out (2 DA)	0-8	0-8	0-8	0-8
Control Proptotyping Functions					
SPWM - TDO	Synchronized PWM Out with dead time	0-16	0-24	0-16	0-16
PWM - TDO	General purpose PWM Out	0-16	0-24	0-16	0-16
Quadrature Decoder	A, B, Z TSDI signals , rotor position	0-5	0-2	0-5	0-5
User defined DO pattern	General purpose TSDO	0-16	0-8	0-16	0-16
Resolver Input	One carrier output and 2 input signals	0-8	0	0-8	0-8
RVDT /LVDT Input	Rotary /linear Variable Diff. Trfmr in (2 AD)	0-8	0	0-8	0-8
User Defined DA waveform	Waveform generation with Simulink	0-16	0-16	0-16	0-16

● **Standard** ○ **Optional**

eDRIVEsim

Why Choose OPAL-RT for Your Real-Time Hardware-in-the-Loop

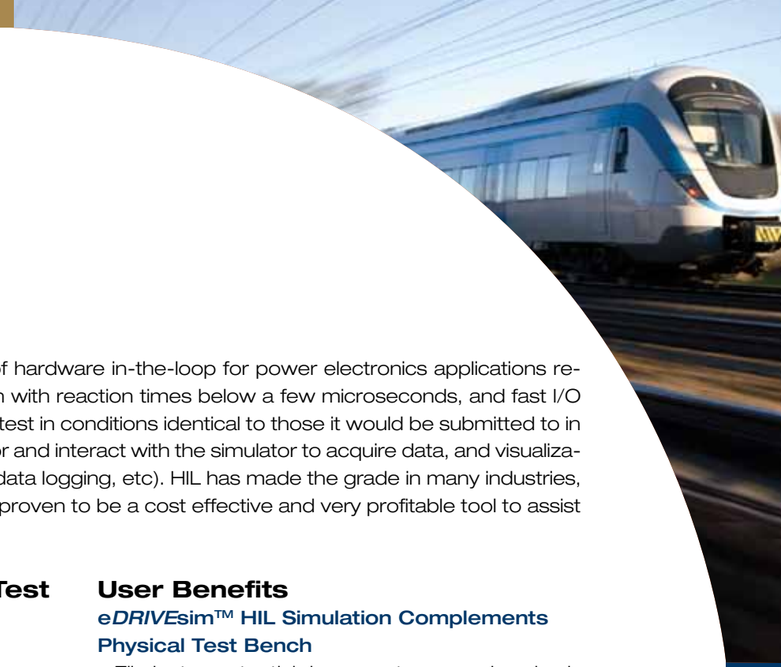
OPAL-RT's approach to hardware-in-the-loop test bench and rapid control prototyping for the electric drive and power electronics industry is simple and unique in that it is scalable, reliable and cost effective. We make no compromise to ensure a successful implementation of your project, minimize risks, and maximize the ROI.

- We offer a full range of standard and custom training on all the elements of a solution to ensure a seamless integration by your team.
- Our solutions are backed by a competent, responsive, and dedicated technical support team that will ensure a successful deployment of your project.
- We have sales and support offices worldwide, ensuring continuity for global customers.
- We offer the highest performance solvers, models, computing platform, and integrate the latest hardware technology to meet the requirements of the most demanding application.
- We provide a complete range of simulation solutions under one roof from 'large-scale turnkey' down to stand-alone HIL and RCP components & services.
- We provide open solutions based on commercial off-the-shelf (COTS) technology, robust and full-featured RTOS and large compatibility with external high fidelity modelling tools already used by customers.

Partial List of Satisfied Customers

ABB Drive
Chrysler
Converteam
Delphi Automotive System
Denso
ETAS
Ford Motor Co.
GE Aviation
GE Converteam
GE Transportation
General Electric
General Motors
Hitachi
HITACHI
Honeywell
MBTech
Mitsubishi
Mitsubishi Electric Corporation (MELCO)
Nari Relay
NREL
Renault
Rockwell
Siemens
SNCF
TM4 Electrodynamics Systems
Toshiba-Mitsubishi Industrial Systems Corp.(TMEIC)
Toyota Industries
Valeos

OPAL-RT recreating reality



The successful and reliable implementation of hardware in-the-loop for power electronics applications requires sound models, fast program execution with reaction times below a few microseconds, and fast I/O communication so the controller is put under test in conditions identical to those it would be submitted to in reality. One also needs a set of tools to monitor and interact with the simulator to acquire data, and visualization tools to interpret results (scope, graphs, data logging, etc). HIL has made the grade in many industries, such as automotive and aerospace, and has proven to be a cost effective and very profitable tool to assist throughout the product life cycle.

Sound Hardware – in the loop Test Systems Integrate:

Hardware

- Processor
- I/OP Interfaces
- Signal Conditioning
- Simulated Loads
- Simulated Faulst
- Fault insertion
- Break-out-Boxes

Software

- Physical System Models
- Model Parameters, test data acquisition and management
- Communication Interfaces

Test Automation

- Test programming environment
- Test Management tools
- Break-out-Boxes

User Benefits

eDRIVEsim™ HIL Simulation Complements Physical Test Bench

- Eliminates potential damages to expensive physical test benches.
- Enables you to prepare and validate test plans prior to their execution.
- Helps to benchmark and interpret test results.
- Helps to validate the effect of extra losses when using scaled-down physical test bench.
- Carries out the bulk of tests while keeping only those critical tests on the physical test bench.

Expand Test Coverage

- Carry out more tests quicker with virtually no set-up time.
- Submit system to extreme faulty operating conditions that are difficult, too dangerous, or simply impossible to perform with physical test benches.
- Enable the testing of several systems without increasing expenses on additional physical test benches.

Quick and Secure Return on Investment (ROI)

- Reduces set-up and test execution time over physical test bench handling.
- Decreases development and test costs and cuts down time to market.
- Develop and test complex systems at early stages while the actual motors and converters are not yet available
- Allows engineering teams to work in parallel without having to build extra test benches, thus reducing time-to-market.
- Provides reusable platform from project to project, and for operator and technician training.
- Helps support proof-of-concept implementation demonstrating and selling new ideas and projects.

e*DRIVE*sim

recreating reality

e*DRIVE*sim™ Overview

e*DRIVE*sim™ is a scalable hardware-in-the-loop simulator that integrates a powerful multi-processor real-time computer, power electronic block set, accurate high speed solvers, and a wide range of fast and versatile I/O modules, that meet the demanding requirements of precise power electronic system simulation.

e*DRIVE*sim™ empowers engineers to efficiently design and test integrated power electronic systems and controls while saving development costs and time to market.

Test and Development Software from Host Sation

e*DRIVE*sim™ Simulator runs Plant Model

Controller under test

e*DRIVE*sim™ Simulator

Integration of FPGA for the Fastest Performance

The computational power required to run complex power electronics models and support the accurate solvers developed by OPAL-RT relies on the latest Field Programmable Gate Array (FPGA) technology provided by Xilinx. The e*DRIVE*sim™ simulator comes standard with an OP5142 equipped with a Spartan 3 FPGA. For ultrafast large model execution in floating point" apr's execution, users can request a Xilinx ML605 board that comes standard with a Virtex 6 FPGA Target.

The OP5600 Simulator Chassis Comes With Spartan 3 or Virtex 6 FPGA

Full Range of Optional I/O Accessories

The e*DRIVE*sim™ chassis can be optionally connected to I/O interface accessories such as mapping boxes, breakout boxes (BOB), screw terminals, DB-37 connectors, fault insertion units (FIU), load simulators, amplifiers, etc.

Typical e*DRIVE*sim™ enclosure with accessories such as Fault Insertion Units (FIUs), Break Out Boxes (BOB) and Mapping Boxes

eDRIVEsim hardware platform

recreating reality

Fast Analog and Digital I/O Interface

e*DRIVE*sim™ includes fast analog and digital I/O modules specifically designed for systems having extremely fast dynamics due to high-frequency switching action of power electronics switches. Their low latency and high sampling rates combined with short time steps ensures the best overall cycle time possible to interface external devices.

Convenient and Flexible I/O Connectivity

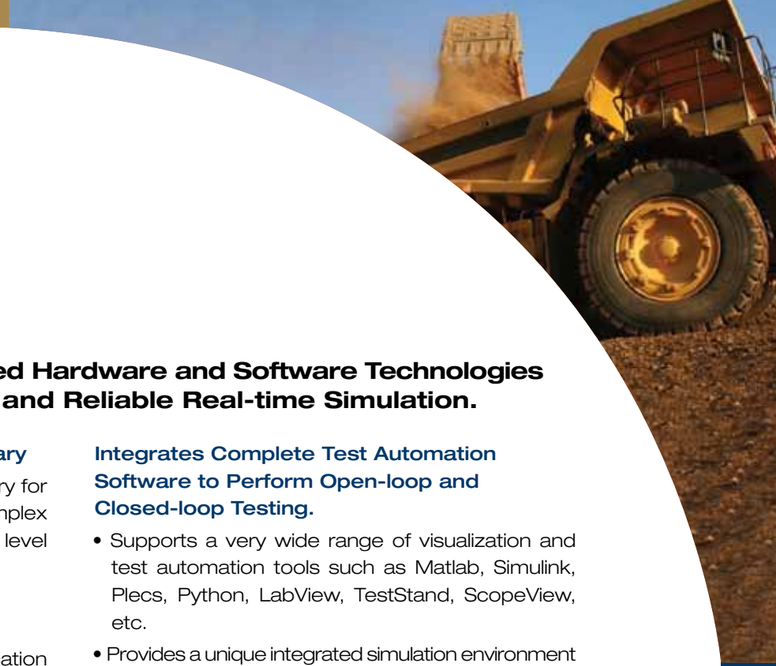
The e*DRIVE*sim™ chassis comes standard with 16 DB37 I/O connectors for convenient, reliable, rapid, and cost effective connection to any external device. It also comes with 6 PCI expansion slots to provide more flexibility to add I/Os and communication devices from other brands (CAN, LIN, FlexRay, ARINC, MIL-STD-1553, RS-232, GPIB, Profibus, reflective memory, etc), as well as to interconnect more e*DRIVE*sim™ simulators in a cluster.

The e*DRIVE*sim™ simulator also provides a wide range of generic I/O functionalities, used for signal acquisition, measurement, processing and generation required by power electronic systems. It includes PWM in/out, quadrature decoder and encoder, Hall Effect sensor, RVDT/LVDT, resolver, etc. e*DRIVE*sim™ also lets you create custom signal generators and data processing algorithms using FPGA-based reconfigurable I/O.

Revolutionary User Friendliness in I/O Monitoring

The e*DRIVE*sim™ chassis comes with convenient connectors for easy connection to analog and digital devices. For additional monitoring convenience, every I/O point is mapped to an array of connectors on the front panel for easy wiring to any one of the 16 mini-BNC terminals provided through differential amplifiers. This adds versatility and flexibility to quickly connect any I/O monitoring device.

OP5600 Simulator Chassis Front and Rear Views



e*DRIVE*sim™ Integrates Advanced Hardware and Software Technologies to Achieve Ultrafast, Accurate, and Reliable Real-time Simulation.

Exhaustive Power Electronic Model Library

- Incorporates an elaborate electric drive library for all motor types (PMSM, IM DQ, etc) and complex voltage source converters (two level, three level and matrix converter, etc).
- Supports JMAG finite-element-based motor models for greater simulation accuracy.
- Simulates AC and DC power electronic application including multi-drive system, medium size grids, multi-winding transformer with saturation, and HVDC and FACTS.
- Interfaces with SimPowerSystems, Plecs, SimScape, AMEsim and Dymola to take advantages of models and solvers available in industry-standard simulation tools.
- Tightly interface with Simulink for control system and user model development.

Advanced Solver for Maximum Accuracy and Flexibility

- Comes with unique solvers that ensure simulation of the highest number of switches while making no compromise on accuracy.
- Simulates the effect of IGBT dead time using a unique solver with time stamping and interpolation.
- Simulates cogging torque due to rotor asymmetry, back EMF harmonics and core saturation.
- Simulates transients and fault conditions difficult or impossible to do on physical systems.
- Optimized for parallel and real-time simulation of interconnected multi-drive systems with hundreds of switches.
- Allows users to implement their own models, solvers and signal processing on FPGA chips to achieve sub microsecond time step.

Integrates Complete Test Automation Software to Perform Open-loop and Closed-loop Testing.

- Supports a very wide range of visualization and test automation tools such as Matlab, Simulink, Plecs, Python, LabView, TestStand, ScopeView, etc.
- Provides a unique integrated simulation environment to perform data acquisition, signal processing, and waveform visualization.

Open and High-Performance FPGA and Multi-core Processing Technologies

- Based on Intel® processors with up to 12 cores per chassis.
- All I/Os are controlled by Spartan 3 or Virtex 6 FPGAs, achieving I/O time stamping with accuracy better than 20 nanoseconds and complex models executed within 250 nanoseconds.
- Comes with fast low-latency analog and digital I/Os equipped with signal conditioning
- A mix of 256 digital I/Os and 128 analog I/Os per chassis. Up to 8192 digital I/Os and 4096 analog I/Os with 32 chassis in expansion configuration.
- Supports a broad range of PCI and PCIe communication interfaces such as CAN, ARINC, MIL STD 1553, etc.
- Includes the widest range of customizable signal generation and signal processing functions such as PWM, quadrature decoders and encoders, time-stamped DIO, frequency/duty measurement, etc.

recreating reality

eDRIVEsim™ is Tailored to Your Needs

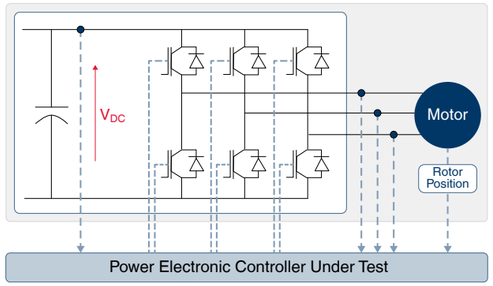
eDRIVEsim™ is a scalable simulation solution that is adapted to your application. Depending on the requirements, technologies to be modeled, and the size of your application, OPAL-RT will recommend the optimal eDRIVEsim™ configuration. As a start, we suggest the C and D series as base packages that can be built on.

eDRIVEsim™ C Series

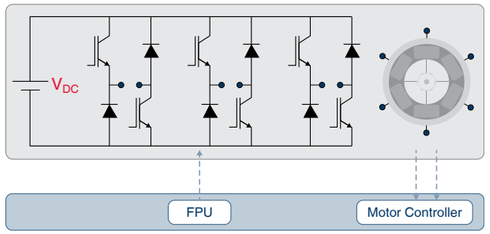
eDRIVEsim™ C series allows you to simulate motors and voltage source converters (VSC) with sub microsecond time steps to achieve maximum accuracy. The C Series can also be used as a rapid control prototy-ping system for conveniently implementing complex controller algorithms using Matlab, Simulink and automatic code generator. It provides the perfect platform to simulate the motor drive and its controller in fast, fully numerical real-time and offline simulation mode.

Some examples of eDRIVEsim™ C series applications:

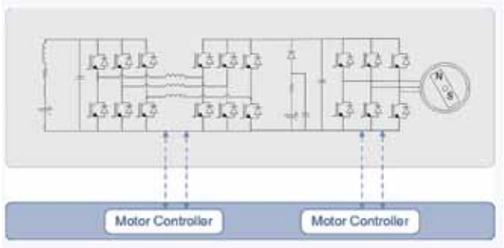
- Electric & hybrid vehicle
- Electrical power steering
- Simple voltage-source converter and motor drives



PMSM Drive



Switched Reluctance Motor Drive



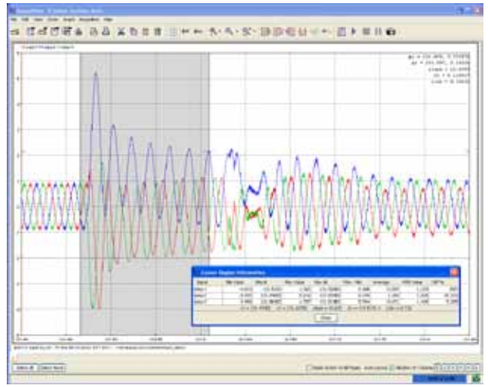
Fuel–cell, Hybrid–Electrical Vehicle Drive

Third-Party Products Connectivity and Integration

RT-LAB™ quickly interfaces to third-party products.

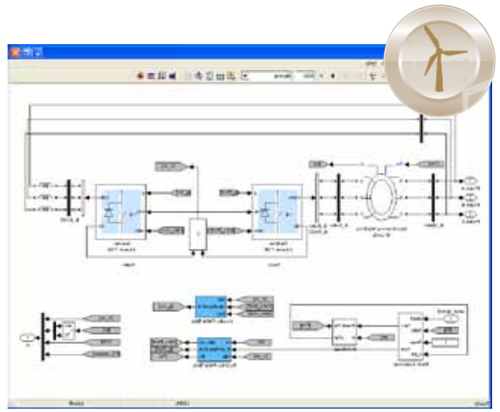
- Modelling tools: Plecs, Dymola, Matrixx/SystemBuild, Statemate, CarSim, TruckSim, EMTP-RV, JMAG, Cruse-RT, Boost-RT, LMS AMEsim, Easy-5, GT-Power, Simulink, SimPowerSystems, SimScape, StateFlow, C/C++, FORTRAN, etc.
- Test automation software: TestStand, Python, SystemTest, etc.
- Visualisation and supervision software: LAbVIEW, ScopeView, Altia, Panorama, PcVue, Wonderware, OPC server, etc.
- Support API languages: C/C++, Java (Matlab), LabView and TestStand.
- Office suite: Word, Excel, etc.

RT-LAB™ is based on the popular Eclipse™ integrated development environment (IDE). The Eclipse community has thousands, of third-party plug-ins that users can add to their RT-LAB™ installation, providing extensions to the environment. Users can further program their own add-ons.



ScopeView Signal Processing Software

eDRIVEsim™ can interface to virtually any MMI using OPC.



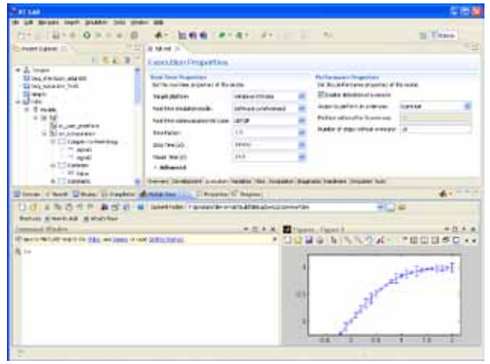
eDRIVEsim™ Takes Full Advantage of Matlab, Simulink and RTW

Test and Development Software Suite

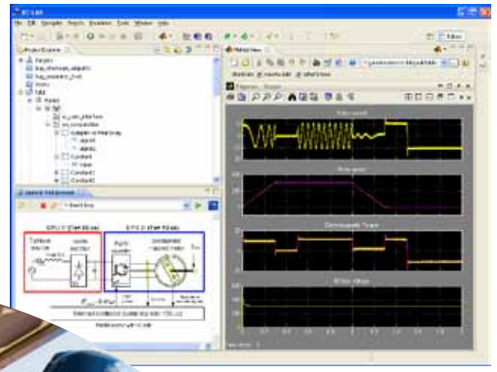
e*DRIVE*sim™'s unique software environment, including the RT-LAB™ integrated simulation environment, is the ideal platform to design and test controller and power electronic and electric drive systems.

RT-LAB Integrated Simulation Environment

RT-LAB™ is OPAL-RT's flagship integrated simulation environment for real-time applications. It enables engineers to conduct distributed parallel computing for real-time simulation of large and complex models for hardware-in-the-loop (HIL) and rapid control prototyping (RCP) applications. With its interactive interface, RT-LAB™ provides all the required functionalities to configure and manage simulator functions and interact with running simulations. On-line parameter adjustment, signal acquisition, data logging and scopes are examples of commonly used features making model development and test easier.



RT-LAB™ Provides All the power and Features For Optimal Smulation Execution



RT-LAB™ Interfaces to Many Modelling Tools

Test Automation Software

e*DRIVE*sim™ comes with a complete set of modules, based on Python, TestStand and Matlab software, to perform reproducible automated test and Monte Carlo analysis. With a minimum of programming skills, users can create open-loop and closed-loop testing of the hardware under test at an early development stage.

- Create complex execution sequences.
- Generate random test vectors to simulate complex transient and fault conditions.
- Generate detailed reports and charts.
- Present and display results with custom user interface in real-time.
- Store data to external database.

e*DRIVE*sim™ D Series

e*DRIVE*sim™' D series features ARTEMiS, a highly precise solver for SimPowerSystems allowing simulation of more complex power electronic systems and motor drives. The D series also provides the ability to simulate large AC and DC circuits on a distributed parallel real-time simulator by taking advantage of multi-core processors.

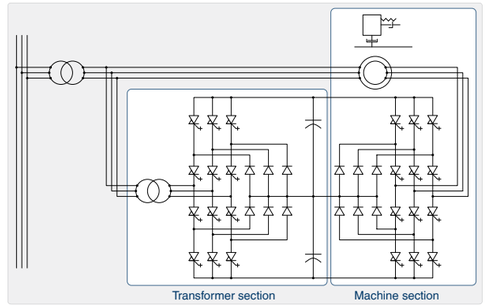
With the e*DRIVE*sim™ D series configuration, one can accurately simulate more complex systems, including:

- Multi-drive systems with 2- or 3-level converters
- Matrix converters and cyclo-converters
- Complex AC-DC front-end rectifier systems with diodes, thyristors or IGBT
- Several interconnected doubly-fed induction generators (wind farms, etc) with multi-level AC-DC-AC converters
- Multi-winding transformers with core saturation effects
- DC and AC filters, choppers and other components
- Several interconnected generators and AC-DC converters
- Power source, transmission lines and cables for simulation of AC feeder systems for industrial and train traction systems

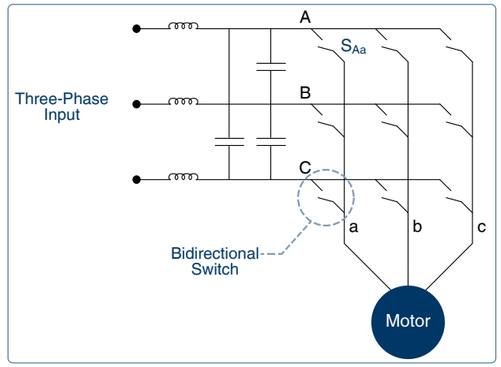
Some examples of e*DRIVE*sim™ D series applications:

- Distributed generation and energy storage as well as renewable energy
- Rectifiers and battery chargers
- Industrial drives and multilevel converters
- Off-road vehicles
- Electrical ship propulsion systems
- Electrical train traction systems
- Aircraft electrical systems

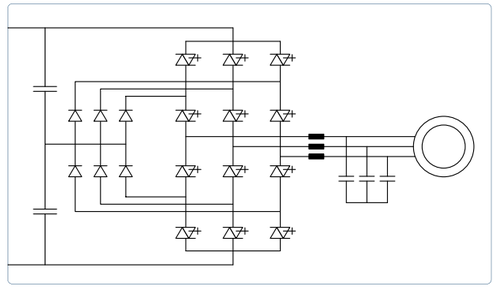
e*DRIVE*sim™ D series can easily be upgraded to OPAL-RT's eMEGAsim power grid real-time simulator which can be quipped with 72 processors or more to simulate very large systems.



Doubly-Fed Induction Machine



Matrix Converter



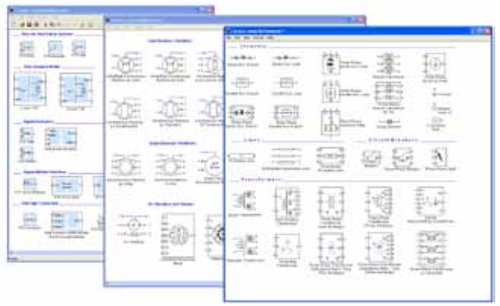
HVDC and Modular Multilevel

Electrical Drive and Power Electronic Models

e*DRIVE*sim™ includes a rich model library that lets you design detailed and accurate models for all components forming the electrical drive and power electronic systems. It includes detailed block components for electrical, mechanical, magnetic and control devices such as motors, voltage source converter, transformer, lines and cables, AC feeder and much more. e*DRIVE*sim™ also provides a complete set of real-time solvers optimized for real-time simulation, allowing you to accelerate simulation but also to simulate complex transient and fault conditions that are difficult or impractical to achieve with a real system.

Motor Models with High Simulation Accuracy for all Applications

e*DRIVE*sim™ supports the complete librairies of motor models included in SimPowerSystems, developed and tested by Hydro-Quebec Research Institute. It includes a wide range of alternating and direct current motor models used in all type of drives (DC, direct DC, single phase AC, poly-phase AC, PWM and variable frequency AC) required in automotive, aerospace, industrial and military applications. Permanent magnet synchronous motor (PMSM), brushless DC (BLDC) and induction DQ motor models are typical examples that could be easily parameterized and tightly integrated into your simulation. Maximum accuracy is achieved by executing the simulation with a time step below 10 microseconds for medium speed motors using standard INTEL processors or below 250 nanoseconds using FPGA chips.



Complex and Detailed Voltage Source Converters

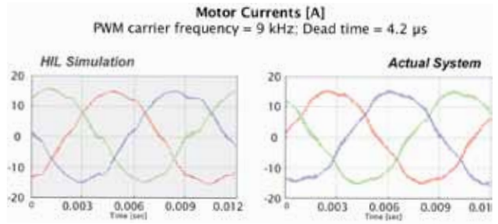
e*DRIVE*sim™ provides unsurpassed precision block set for power electronics and high frequency switching devices used in voltage source converters (VSC) such as two-level and three-level converters, multi-drive systems, and matrix converters. Users can easily develop complex drive and power electronic circuits including filters, RLC components and other electrical devices.

Cogging Torque Simulation with Finite Element Analysis Based Models

With the optional e*DRIVE*sim™ JMAG module, users can readily use commercially available JMAG phase domain finite element analysis (FEA) motor models and put them in a real-time environment. It also provides the ability to simulate the effect of rotor asymmetry, back EMF harmonics, saturation effects and cogging torque.

Simulate Dead Time Effect

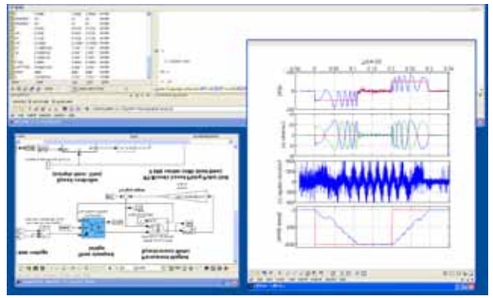
OPAL-RT's toolboxes also let you capture and time stamp inverter gate signals occurring between simulation time steps. The goal being to accurately calculate PWM duty cycle, frequency and simulate dead time effect, without having to reduce the simulation time step. High performance and low computation overhead; this is OPAL-RT's unique modelling algorithms at the service of your application.



Effect of PWM Dead Time on Motor Currents

Simulation of Fault Conditions

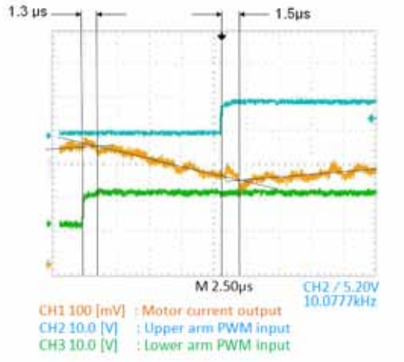
OPAL-RT's advanced and unique solvers allow the simulation of very complex transient and fault conditions on motor terminals and on semi-conductor devices such as IGBT or DC and AC buses. User can also simulate active and natural rectification modes of AC-DC converters.



Results of an Open-Phase Fault Applies on PMSM Motor Terminal

Total Latency Below 1.3 Microseconds

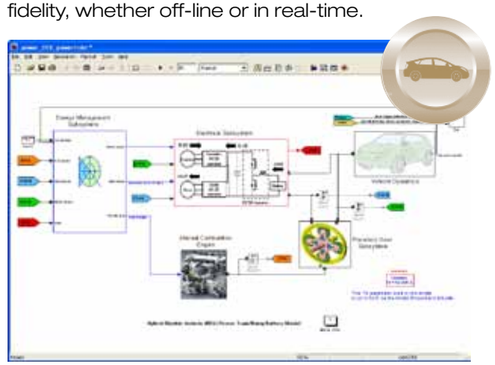
Optional FPGA-based models enable the testing of fast IGBT protections and control by providing a total latency below 1.3 microseconds between IGBT firing signal and effect on motor current outputted of e*DRIVE*sim™ simulator analog output.



Lowest IO latency for the Fastest Cycle Time

Specialized Solvers for Large Applications and Optimal Use of Electrical Models

OPAL-RT produces specific electrical and power electronics simulation solvers whose algorithms take full advantage of parallel computing. Developed by foremost industry experts, e*DRIVE*sim™ solvers help Simulink and SimPowerSystems™ users attain very high computational speed, stability, and fidelity, whether off-line or in real-time.



Hybrid Electric Vehicle (HEV) Power Train Using Battery Model