OPAL-RT TECHNOLOGIES

POWER IN MIND

NEWS • INNOVATION • BREAKTHROUGHS

VOLUME 5 - FALL 2023

A Word from the Editor

As we launch our first-ever simulation-focused publication that we call Power in Mind, I am immensely proud to now work with four hundred amazing employees who are at the OPAL-RT offices all over the world. From France to Germany, from Brazil to India, Detroit, and of course our headquarters in Montreal.

At OPAL-RT, we engineer inspiration. We champion versatile solutions. We foster profound connections with our clients. Our dedication revolves around fueling the dreams of engineers, visionaries, and creators, today and in the era of global electrification.

OPAL-RT is a pioneering force at the forefront of real-time simulation and hardware-in-the-loop testing solutions. With a commitment to excellence and innovation, we are a trusted partner for industries seeking to push the boundaries of simulation technology and redefine the way we understand and interact with complex systems.

We are a high-performance company. We take on the challenges that our competitors are afraid to tackle. This is what makes us unique. But this is no secret.

From HIL to SIL, to, DIL, even pioneering PHIL, OPAL-RT has been and continues to be on the forefront of leveraging the power of simulation to not just accelerate innovation but to disrupt the status quo.

By leveraging the processing power of a cloud-based network, we can increase simulation power to the point where we can monitor entire grids in real-time – preventing issues before they occur.

Leveraging the full potential of simulation, we can remove the need to physically prototype and thus remove an entire step from the design process.

By revolutionizing the design process, we can use simulation to dramatically increase time to market, and once in the market, monitor performance to seek continuous improvement and innovation.

And let us not forget that the world needs cleaner energy in renewables and the ability to better store energy as we generate at the microgrid level and share this energy across the grid.

All of this, we will continue to lead and discuss here in each edition of Power in Mind.

I hope that you find this edition, and all future quarterly editions of OPAL-RT's Power in Mind magazine educational, entertaining, and most of all, inspirational as we work together to bring the world the technology it wants, and needs.

Our role is to support you in conquering intricate engineering endeavors and fostering thriving enterprises. This is the OPAL-RT way.

Etienne Leduc,
Head of Energy Market

Etienne Leduc is a highly accomplished professional in electrical engineering and power systems at OPAL-RT TECHNOLOGIES. With expertise in real-time simulation and hardware-in-the-loop testing, Etienne has made significant contributions to power system simulation and control technologies. He is dedicated to promoting green energy solutions, particularly in renewable energy integration and grid modernization.

In this Edition of Power in Mind

Behind the Cover

The freeze light spiral across the landscape exemplifies the interplay between real-time simulation technologies and the environment, illuminating the path towards sustainable progress, and a future where technology coexists seamlessly with the natural world.

Image credit: Artur Harutyunyan

Front page design: Maija Baroni

R&D Behind the Scenes

In the first of a series of short interviews with OPAL-RT's R&D experts and leaders, we sat down with Fred Monfet, VP of Technologies, to ask him a few questions regarding the future of OPAL-RT's innovative technology roadmap.

Question 1: *What drives the team to innovate? What is the driving source of passion?*

Frederic Monfet: I think for me and the team, what drives us the most is the expertise we have. It's extremely rewarding to see that our applications are used by our clients to develop these green energy products. People always want to push themselves so that we can provide products that enable much cleaner energy. That's why I get up in the morning and want to work at OPAL-RT. We can see the direct correlation between our products and how our customers use them in world-changing innovative ways.

Question 2: *What are some of the biggest obstacles or challenges that you face, or the industry and customers face when it comes to knowing which products to put on our roadmap?*

Frederic Monfet: One of the challenges we face internally is finding the right balance of which features to push forward with the technology, which to maintain, and which to deprecate. For our customers, the challenge is that they don't know exactly what they need because they're in the middle of developing it, so the needs quickly emerge. We pride ourselves as always being the company that can help our customers solve the newest or most unique challenge but, we also must commit to supporting that large portfolio of custom needs into the future.

Question 3: *What excites you or the team about future opportunities, be it a year, five years, or ten years out?*

Frederic Monfet: I think the biggest opportunity we face in the future is how to simulate the unpredictable nature of renewable energy sources such as solar panels and wind turbines. Our customers need to maximize these resources and ensure a smooth transition when facing unexpected changes in weather or energy production. This is a big challenge that we are working to address.

Question 4: *What can you tell us about some big projects on the horizon?*

Frederic Monfet: We have a vision of migrating our tools to web-based interfaces to make our products easier to use and cater to the new generation of engineers. We also want to collaborate with other technologies to make our products more compatible and versatile.

Bonus Question: *What's your favorite feature you've released this past year?*

Frederic Monfet: One of the most exciting new features is standalone simulation, which decouples the UI from the simulation, allowing users to efficiently run simulations with different parameters in the cloud. This expedites the process and enables users to test various scenarios before running real-life simulations, representing a significant step forward in utilizing cloud services effectively.

Frederic Monfet, Vice President Technologies
Photograph: Romain Guilbault

Introducing the **OP4800 Series**: A Quantum Leap in FPGA Technology for Power Electronics Simulation

In the ever-evolving realm of power electronics simulation, OPAL-RT consistently leads the charge, expanding the boundaries of what's achievable. We're thrilled to introduce the latest addition to the FPGA real-time simulator technology landscape: the **OP4800 Series, powered by the AMD VERSAL™ FPGA.**

With this groundbreaking release, OPAL-RT is poised to reshape the future of power electronics simulation, ushering in unmatched precision, agility, and near-zero latency, redefining the industry.

It empowers engineers and developers to tackle complex power electronic circuit topology, including power converters, free from the constraints of conventional decoupling methods. This state-of-the-art technology not only empowers but also doubles simulation capacity, enabling agile development and innovative control strategies, revolutionizing the landscape of power electronics.

Taking eHS to New Heights:

Elevate your power electronics simulations to uncharted territory by harnessing the full potential of OPAL-RT's eHS FPGA Power Electronics Toolbox. The OP4800 Series introduces the **Advanced Performance Add-on,** known as eHS Gen 5, acclaimed as the fastest FPGA-Based Power Electronics Toolbox in the industry.

With eHS Gen 5, you can:

- Cater to specific applications like Dual-Active Bridge (DAB) Converters, providing engineers with the tools needed to tackle complex challenges.
- Bid farewell to the complexities of decoupling as the OP4800 Series offers a decoupling-free approach, streamlining your simulation process.

The OP4800 Series, powered by the AMD VERSAL™ FPGA, marks a revolutionary milestone in power electronics simulation, underscoring OPAL-RT's commitment to innovation. It is the vanguard of a new era in FPGA technology, poised to outperform competitors and function as the linchpin for high-performance FPGA applications in the years ahead. Embrace this future with OPAL-RT, your steadfast partner in pioneering technology.

OP4800

Series

Unleash power electronics simulation potential with Versal™ FPGA Technology

Embrace **complex power electronics circuits**, such as power converter, without the constraints of yesterday's decoupling techniques. **Double your simulation capacity** for agile development and innovative control strategies with **unparalleled precision** and near-zero latency.

Experience the future of power electronics with our cutting-edge innovations, **tailored for applications like Dual-Active Bridge (DAB) Converters and On Board Charger**.

HIGH SPEED

Lightning-fast analog sampling rates of up to **10 MSPS**

CONNECTIVITY

140 I/O - 12 High Speed SFP

MINIMUM TIME STEP
90ns

SAMPLING RATE
625ps

eHS

Leverage the full power of **eHS Gen5**

WHY VERSAL

Instead of UltraScale

- Increased logic cell capacity & expanded ULTRA RAM
- DSP with 58-bit capability
- Enhanced FPGA simulation frequency (highest logic density 7nm platform)
- 4 ARM processors (upcoming)

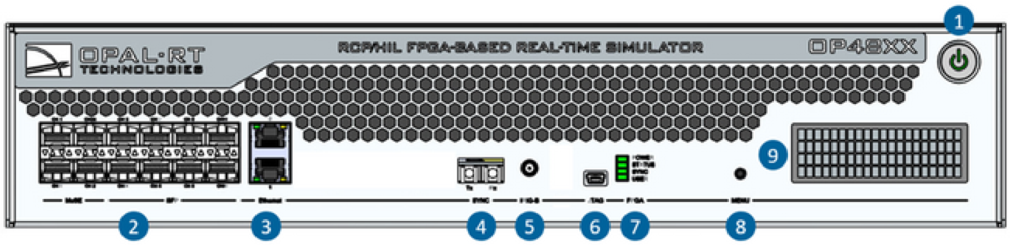
OP4800 SERIES SPECIFICATIONS

OP4800 Series Compute Engine	
OP4810-IO	AMD Versal™ Prime VM1302 Adaptative SoC 703 K logic cells adaptable engine (FPGA)
OP4815-IO	AMD Versal™ Prime VM1402 Adaptative SoC 1,238 K logic cells adaptable engine (FPGA)
Fast I/O Module (2 modules installed)	
Digital I/O (DIO)	64 channels, 8 banks of 8 channels configurable as inputs or outputs, TTL 3,3/5 V
Analog Inputs	32 channels at 5 MSPS, ± 10 V, 16 bits
Analog Outputs	32 channels at 10 MSPS, ± 10 V, 16 bits

FPGA Processor and I/O Expansion Unit

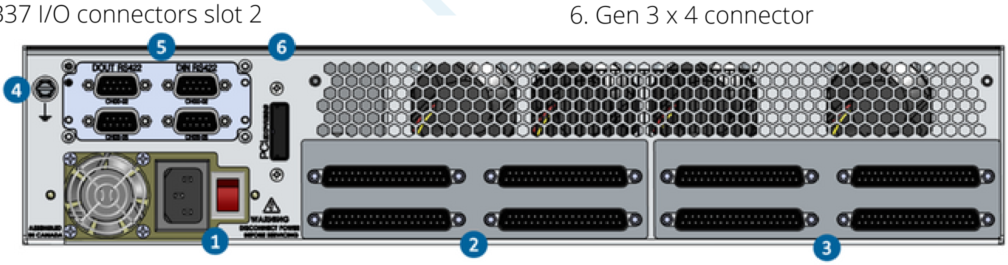
Front view

1. Power and Reset push button with LED indicator
2. 12 SFP sockets @ 5 Gbps
3. 2 Ethernet RJ45 ports at 1 Gb/s
4. Optical synch connectors
5. IRIG-B @ 1 PPS
6. USB port for JTAG programming
7. FPGA unit status indicators
8. LCD menu button selection
9. LCD display



Rear view

1. Power cord plug and master power on/off switch
2. DB37 I/O connectors slot 1
3. DB37 I/O connectors slot 2
4. Ground screw
5. RS-422 DB9 connectors with 6 Rx and 6 Tx
6. Gen 3 x 4 connector



https://www.opal-rt.com/op4800-series/

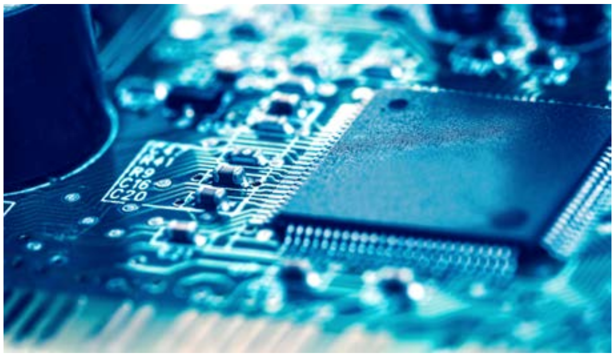
Advancing Real-Time Simulation for High-Frequency Power Electronics

In the dynamic realm of power electronics, the quest for higher power density and converter efficiency remains paramount. While multilevel converters promise advantages, traditional topologies persist due to reliability. Silicon carbide switches usher in higher switching frequencies, enhancing power density and efficiency but presenting design and validation challenges. This article explores a pioneering real-time simulation development, addressing power switch gating and time-constant discretization for high-frequency applications.

The Challenge of High-Frequency Power Electronics

In recent years, the fundamental structure of converter topologies has remained relatively unchanged, with industries tending to favor established designs. Nevertheless, the components employed in these converters have evolved significantly. Silicon carbide switches, capable of switching at hundreds of kilohertz, have ushered in a paradigm shift, allowing for the downsizing of magnetic components and, consequently, converters themselves. However, the design and validation of such converters are fraught with challenges, primarily due to their exceedingly high switching frequencies.

Conventional real-time simulation tools face limitations when tasked with accurately modeling these fast-switching converters. The issue lies in the granularity of power switch gating signal sampling and the ability to handle extremely small time constants in real-time applications. Existing methods involve approximating power switches with parasitic inductances and capacitances, resulting in unrealistic reactive losses during switching events. While some techniques aim to mitigate these losses, they persist to some extent, affecting simulation accuracy.



Our Real-Time Simulation Solver

To address these challenges, the authors propose a novel real-time simulation solver that adopts a state-space approach and utilizes a 9th-order discretization method. Unlike traditional backward Euler methods, which can overdamp oscillations and distort time constants, this solver employs Padé approximation to achieve precise results even when the time step closely approaches the smallest time constant of the simulated circuit.

One significant advantage of using a higher-order solver is that it enables accurate simulations even when the time step matches the time constant of the circuit. This flexibility is crucial for modeling highly nonlinear power electronic applications and capturing the higher harmonic spectrum of signals under study.

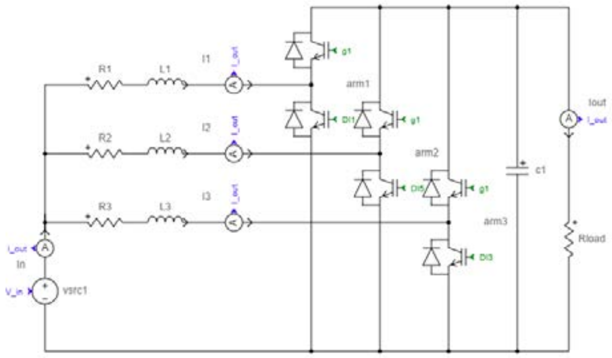
Gate Oversampling and FPGA Implementation

The proposed implementation also addresses the issue of gate signal oversampling. By taking advantage of FPGA technology, the solver samples gating signals every 625 picoseconds using over-clocking but routes only their average duty cycle through the design. This high-precision gating event sampling is crucial for applications like LLC converters, where precise frequency control is essential to avoid output voltage fluctuations.

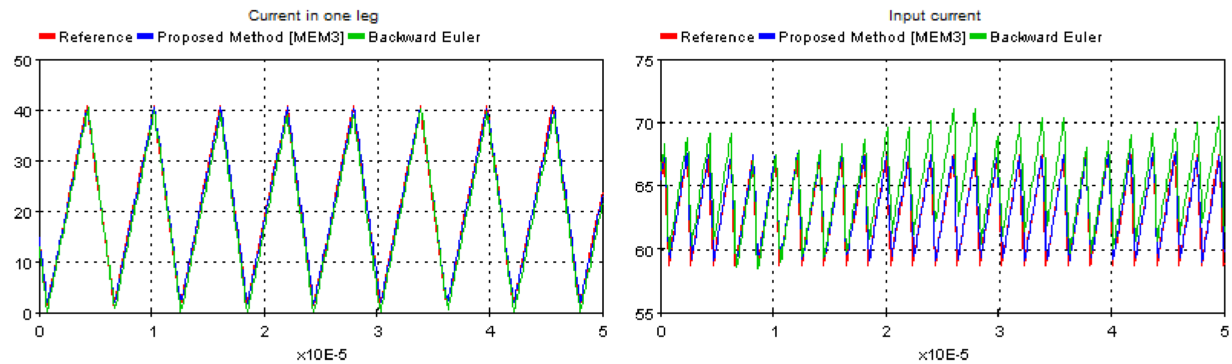
Furthermore, the solver is designed for FPGA implementation, capitalizing on parallelization and pipelining capabilities. FPGA's application-specific nature allows for the rapid execution of operations required for solving specific equations, resulting in minimal latency. With a minimum latency of 38 tics, or 95 ns at 400 MHz, the solver achieves remarkable performance.

Simulation Results and Future Prospects

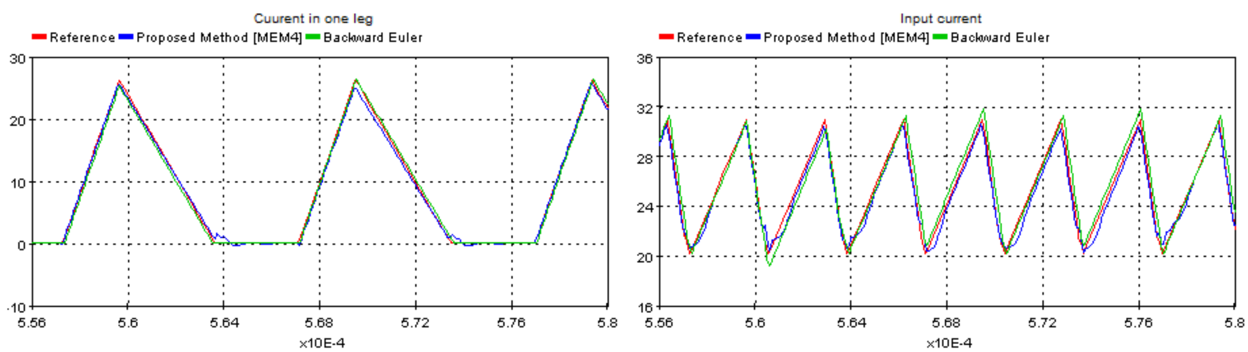
The article demonstrates the effectiveness of the proposed solver through a three-phase interleaved-boost converter at 169.25 kHz. Results show that it outperforms traditional methods, eliminating oscillations and providing accurate simulations even under challenging conditions.



Three-leg interleaved boost



Boost current during continuous mode



Boost during discontinuous operation

In conclusion, this article highlights a pioneering development in real-time simulation, addressing high-frequency power electronics challenges. Our solver offers precise modeling capabilities, gate oversampling, and FPGA implementation, revolutionizing converter design and validation. Future work will aim to further reduce simulation sampling times, possibly through hardware upgrades or alternative numerical representations, pushing real-time simulation boundaries in power electronics. ♦

Hardware-in-the-loop Simulation of MMC DC-DC Converters for HVDC Applications

DC grids increase the flexibility of existing AC grids and provide a solution for the integration of large-scale renewable resources which are characterized by their intermittence and far location from the power consumption centres. The development of high voltage (HV) DC grids will require new technologies. One of them are HV DC-DC converters. These circuits will enable the interconnection of DC systems with different characteristics such as voltage level or grounding schemes.

The CIGRE working group WG B4.76 has analysed the role of DC-DC converters in HVDC transmission grids, evaluating their feasibility, motivations, and applications [1].

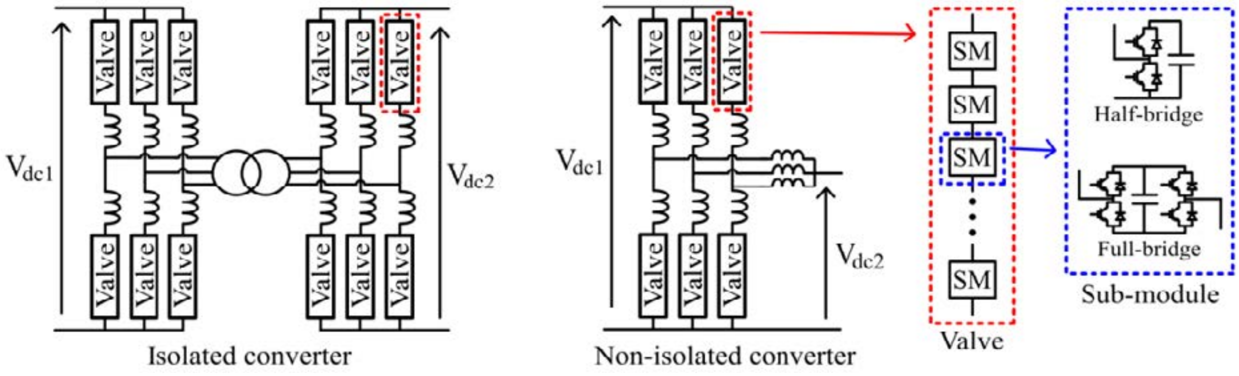


Figure 1. Modular Multilevel DC-DC converters for HVDC

Two converter topologies have been identified as benchmark topologies (Figure 1). They are based on the Modular Multilevel Converter (MMC). In the WG, both converters have been tested for a system design of 600 MW and 320 kV. The circuit design, control and off-line simulation have been addressed.

To go beyond from the theoretical analysis of these circuits, and approximate to a real implementation, different obstacles should be overcome. Some of them are related to the control design and evaluation of these structures in a real network scenario. Hardware-in-the-loop (HIL) simulation can help to solve these issues speeding up the development process. This paper explores the use of HIL simulation for HV DC-DC converters. The two topologies identified by the CIGRE WG B4.76 are tested in HIL using a multi-rate time step implementation in FPGA and CPU for normal and fault conditions.

The simulation approach is shown in Figure 2. The simulation model for each converter valve is based on [2]. It includes the dynamics of all sub-module (SM) capacitor voltages, and the control signals of all the switches. The MMC valve model is implemented on an FPGA with sub-μs time steps. The voltage inserted by each converter valve is sent to the CPU where the converter valves are simulated by controlled voltage sources in series with diodes to simulate the freewheeling path of the current in case of SM blocking. The valve current measurement is sent back to the FPGA to calculate the capacitor voltages. The model supports different types of SMs in the same valve and is suitable for testing the converter behaviour for DC fault ride through.

Concerning the converter control, it is separated in high-level control implemented on the CPU and low-level control implemented on FPGA. The low-level control implements the modulation and a voltage balancing algorithm for the SM capacitors. The measurements and control signals are sent between the converter model and the controller using a high-speed serial protocol by optical fibres as a real implementation including the delays of the protocol and hardware.

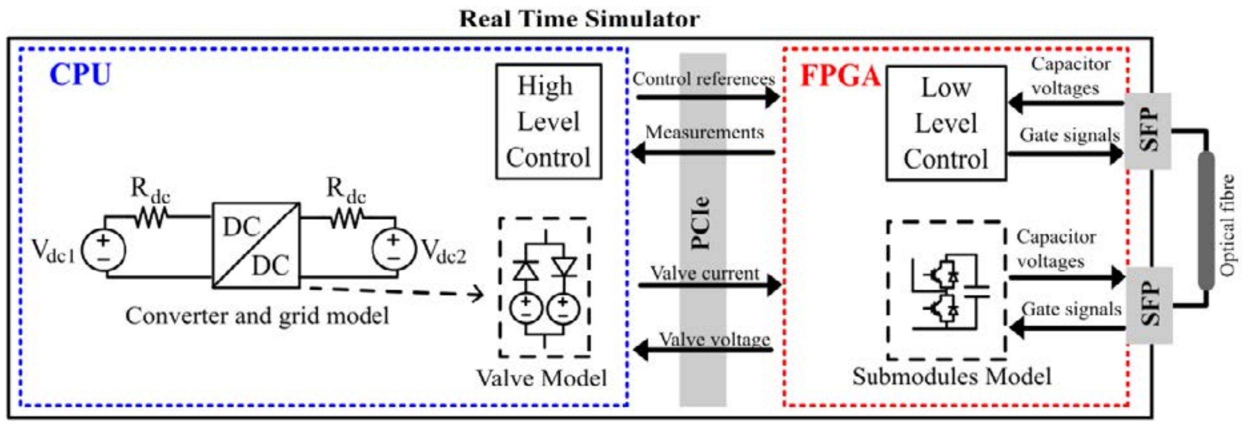


Figure 2. HIL Simulation of HV Modular Multilevel DC-DC converters

Juan Paez Alvarez, Ancha Satish Kumar, Shijia Li, Wei Li

Full article here:

Fast and Real-Time EMT Simulations for HIL Controller Performance Testing

Second Place at the 2023 CIGRE Canada Conference & Exhibition, Best Papers Awards

Full title: Fast and real-time EMT simulations for Hardware-in-the-Loop controller performance testing and for on-line transient stability analysis of large-scale low-inertia power systems.

The increase in Inverter-Based Renewables (IBRs), Flexible AC Transmission System (FACTS), and High Voltage Direct Current (HVDC) systems, coupled with the retirement of synchronous generating plants, is significantly reducing inertia in large-scale power systems. Fast controllers of IBRs should stabilize these systems, but they are highly sensitive to fast transients, harmonics, and system imbalances. Research findings indicate that relying solely on simplified positive-sequence simulations is inadequate for evaluating the transient stability of extensive power grids equipped with a substantial number of IBR controllers. In this context, detailed Electromagnetic Transient (EMT) simulations are becoming essential for the seamless integration of renewable energy sources such as wind and solar. The capability to perform fast simulations in Software-In-The-Loop (SIL) mode with generic or real-code controllers is indeed useful to determine the worst contingencies in the shortest time to develop the equivalent circuit required for real-time Hardware-In-The-Loop (HIL) simulation to test and optimize control performance. Naturally, fast EMT simulation of large-scale power systems will also become essential for online transient stability assessment to aid system operators, planning, and IBR integration analysis. However, EMT simulation of large-scale power systems with complex power electronic systems is computationally intensive. Moreover, it involves managing a significant amount of data and interfacing HVDC, FACTS, and IBR plant controller models, which are often delivered as black box codes without any interoperability standard, with grid simulation tools. This paper describes solutions to achieve real-time or near-real-time EMT simulation of large-scale power systems with high IBR penetration. The proposed techniques implement fast parallel simulation either based on in-house clusters of high-performance computers or cloud servers.

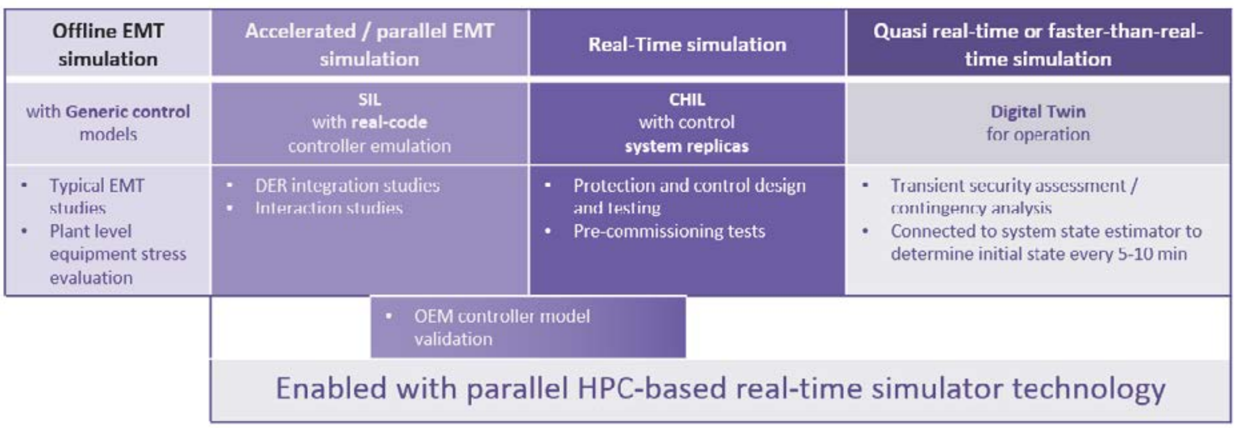


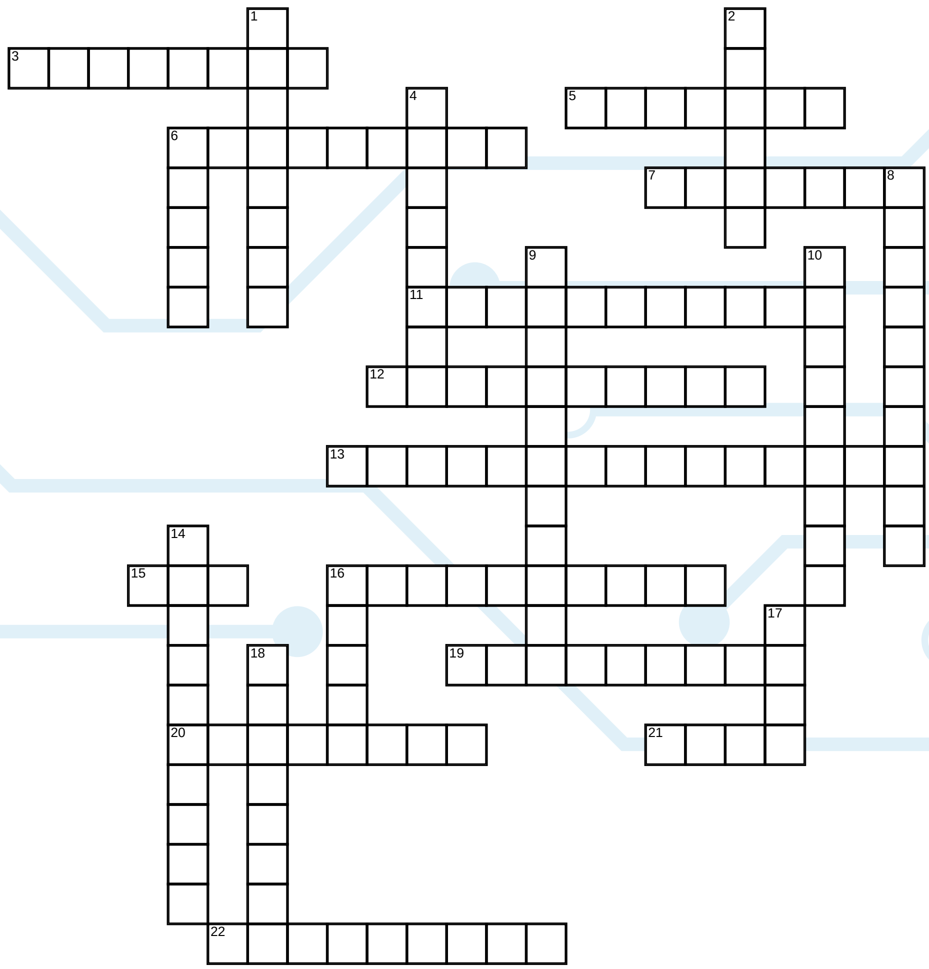
Figure 1. Study-simulation matrix with real-time simulator technology

The proposed solution further simplifies the design and testing of Wide Area Monitoring, Protection and Control Systems (WAMPAC) through near-real-time fully digital Software-In-The-Loop (SIL) tests with virtual wide area controllers or in real-time with the actual hardware controller equipment typically used in the control room. Most importantly, it will aid system owners and operators in performing online transient stability assessments at much higher speeds and with high-fidelity models, including OEM control emulators.

S. Li, J. Bélanger, M. Cervantes, M. Kazemtabrizi, J.N. Paquin, V. Lapointe, W. Li, J. Paez-Alvarez

Full article here:

Crossword: Test your Knowledge on Real-Time Simulation



Across

3 Limits current flow.
5 Electrical potential difference.
6 AC current's rate of cycles.
7 Storing electrical energy.
11 Changes voltage in AC circuits.
12 Detecting and mitigating faults.
13 Coordinating devices.
15 Testing technique that interfaces physical components with a simulated environment.
16 Grid's ability to recover from disruptions.
19 Converts mechanical energy to electricity.
20 Studying power system data.
21 Electrical devices connected to the grid.
22 Steady state of a power system.

Down

1 Creating system representations.
2 Representing waveforms.
4 Converts DC to AC power.
6 Abnormal condition in a system.
8 Effective energy use.
9 Adding renewables to the grid.
10 Temporary system behavior.
14 A process of modeling real-world scenarios.
16 Detects and responds to faults.
17 An interconnected network of power distribution.
18 Total loss of power.

Answers

ACROSS
3 Resistor
5 Voltage
6 Frequency
7 Storage
11 Transformer
12 Protection
13 Synchronization
15 HIL
16 Resilience
19 Generator
20 Analysis
21 Load
22 Stability

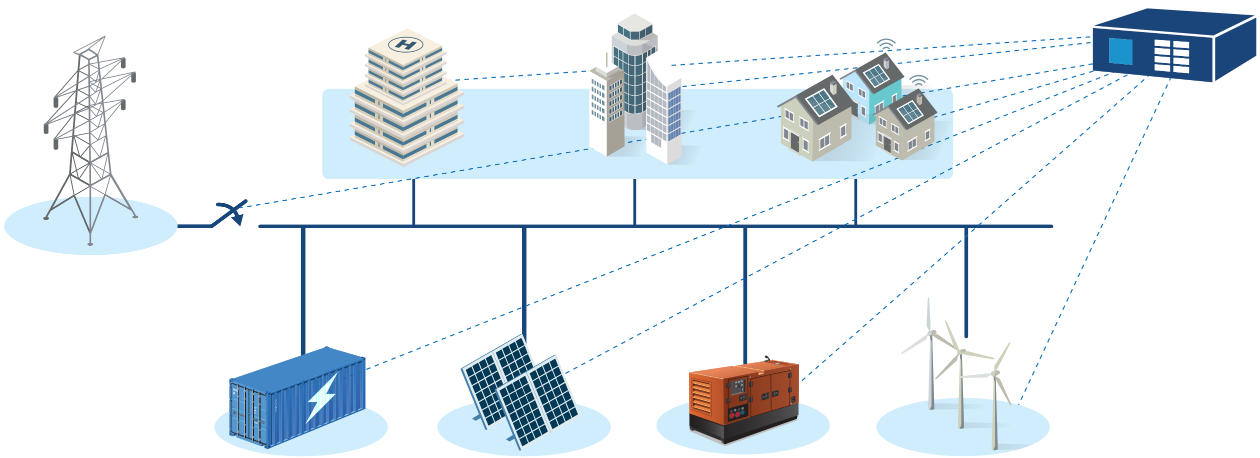
DOWN
1 Modeling
2 Phasor
4 Inverter
6 Fault
8 Efficiency
9 Integration
10 Transient
14 Simulation
16 Relay
17 Grid
18 Blackout

Product News | Microgrid Library

Microgrid Simulink Library: all the typical Distributed Energy Resources (DER's) and Control functions present in microgrids **Available** and **Ready to Use.**

HIL Simulation and The Future of Microgrid Controls with Renewables

The Microgrid Control Library is a MATLAB-Simulink control library developed with all the typical Distributed Energy Resources (DER's) and control functions present in this type of system. It includes active, reactive, and curtailment power controllers, protection functions, and certain configurable grid support functions, such as Volt-Var, and Droop.



Included in RT-LAB Coming soon for HYPERSIM

Turnkey

Save time and money with a ready-to-use solution.

Trustworthy

Developed by OPAL-RT experimented company, according to IEEE standards.

Versatile and Adaptable

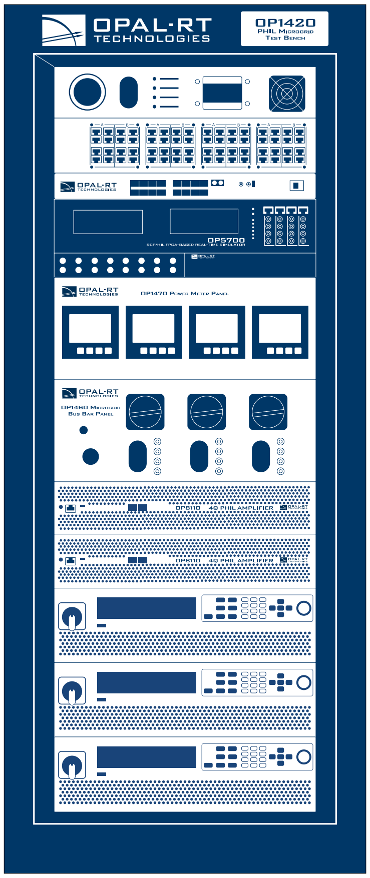
Components are available as Simulink subsystems. Easy to customize. Easy to extend.

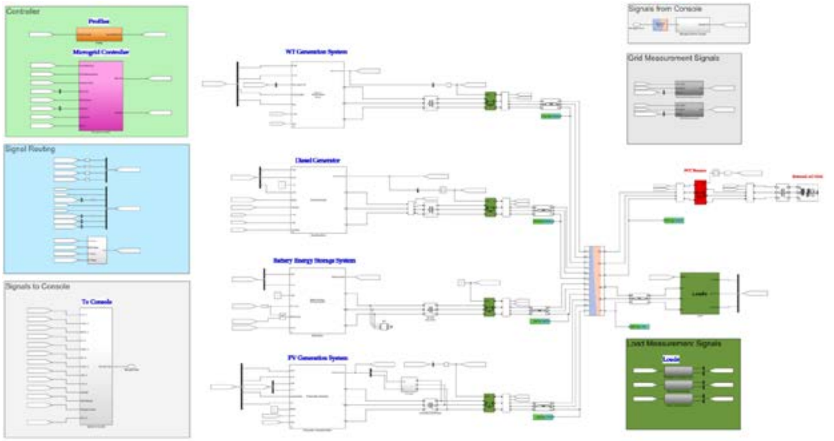
- Active/Reactive Power Control
- Curtailment Power Control
- Load Management Control
- Islanding Control
- IBRs (BESS, WT, PV, Diesel, ...)

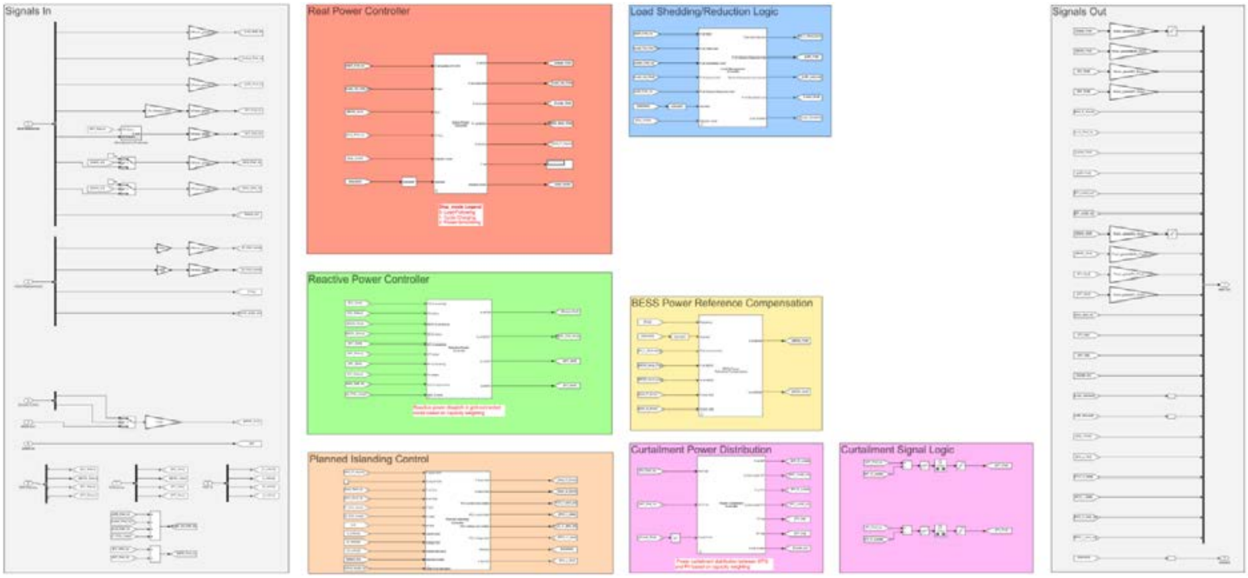
Microgrid library, which was previously only available with OP1420 PHIL Microgrid Testbench, is henceforth accessible as a standalone ARTEMiS add-on for HIL real-time testing.

Available with RT-LAB 2023.2 and ARTEMiS. The library for HYPERSIM will be available in 2024.

To help engineers get started faster, the Microgrid Simulink Library is shipped with a validated **Microgrid Model** built using the world's best real-time power system simulators.







Celebrating Success: Havana Nights at IEEE Power & Energy Society General Meeting

On July 18th and 19th, OPAL-RT played host to a dazzling VIP hospitality suite at the IEEE Power and Energy Society General Meeting 2023, held at the exquisite Descend 21 Lounge within the Hyatt Regency Orlando, Florida. Guests were treated to an evening of sheer opulence at the Havana Nights Party, replete with an air of camaraderie, entertainment, and invaluable insights.

From 6:00 PM to 10:00 PM, attendees relished the electrifying atmosphere and savored an array of appetizers and cocktails while mingling with the crème de la crème of the power and energy industry. Our team of OPAL-RT experts was on hand to discuss the latest advancements and innovative solutions, making it a truly enlightening experience for all present.

The Havana Nights Party was nothing short of a resounding success, thanks in no small part to our incredible partners and the vibrant, enthusiastic attendees who graced the occasion. It was a celebration of innovation, where the brightest minds in the field came together to exchange ideas and insights.

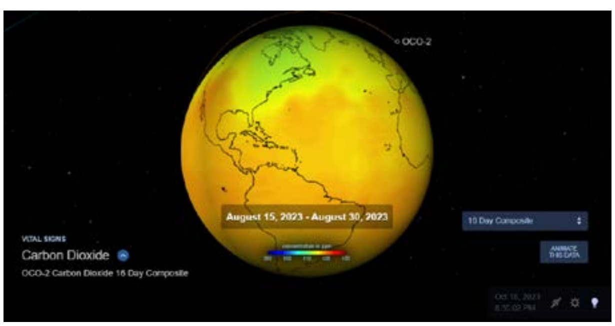
Furthermore, the event also featured a career fair where we had the pleasure of meeting some of the most remarkable individuals in the industry. This opened doors to exciting future collaborations and partnerships that hold the promise of pushing boundaries even further.

We invite you to stay connected with us as we look forward to more exciting events on the horizon. Together, we will continue to push the boundaries of technology, innovation, and collaboration. Your support is our driving force, and we are excited to see where our shared journey will lead.

Collaborative Innovations: Paving the Way to CO_2 Reduction in the Technology Industry

In the dynamic realm of technology, our commitment to a greener and more sustainable future is at the forefront of our mission at OPAL-RT TECHNOLOGIES. We not only provide unmatched expertise to diverse industrial and academic projects but also actively contribute to a sustainable world.

At our RT23 annual user conference, we channel our dedication into the "CO2 Reduction Contest", a competition that mirrors our core values and visionary outlook. This contest invites university students and teachers to highlight their achievements in using real-time simulation to combat climate change. It serves as a platform for collaboration and underscores the pivotal role of real-time simulation in advancing sustainability. By encouraging young minds to harness this technology, we sow the seeds for innovative solutions that can transform the energy landscape.



Source: Nasa OCO-2 Jet Propulsion Laboratory

Real-time simulation technology offers a unique advantage in environmental preservation. It enables precise and efficient testing and refinement of models and devices aimed at reducing carbon emissions, resulting in faster development cycles and more reliable energy transmission systems.

In tandem, our OPAL-DDD initiative, "Democratiser le développement durable un quartier à la fois," is a commitment to democratize sustainable development, one neighborhood at a time. It comprises two main components: Environment and Community.

OPAL DDD | Démocratisation Développement Durable

The Environment component supports renewable energy solutions through research projects, while the Community component collaborates with businesses to invest in charitable organizations and youth-oriented activities. This multi-faceted approach aims to promote green energy integration, reduce poverty, enhance education, and improve living conditions.

Overall, OPAL-DDD seeks to democratize sustainable development by combining renewable energy integration with community engagement, poverty reduction, and educational advancement.

We believe that collaboration within our industry is vital to mitigating carbon emissions and achieving a more sustainable future. These initiatives reflect our commitment to sustainability and innovation, pushing the boundaries of what is possible and fostering open collaboration to address the pressing issue of climate change.

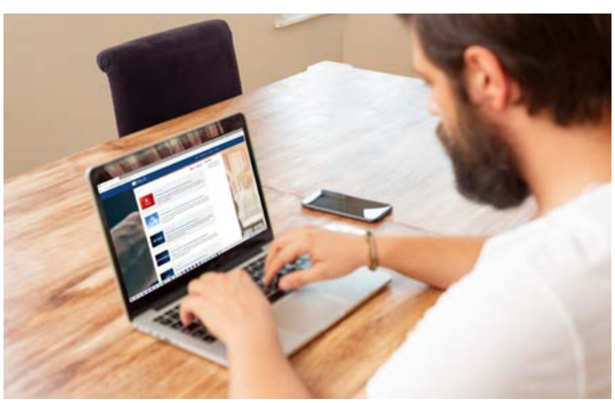
OPAL-RT E-Learning Platform: Empowering Customers with Knowledge

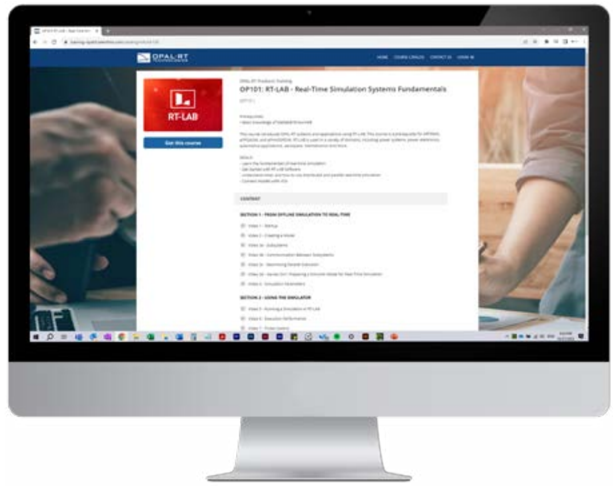
Given the high-speed technological landscape of today, staying ahead of the curve is paramount for engineering professionals. At OPAL-RT Technologies, we have always been committed to providing our customers with the tools and knowledge they need to excel in the field of real-time simulation and hardware-in-the-loop (HIL) testing. We are thrilled to announce the launch of our newest initiative - the OPAL-RT E-Learning Platform, designed to empower our customers and enhance their skills.

Our E-Learning Platform is a valuable resource that offers OPAL-RT customers an opportunity to access high-quality training flexibly and conveniently. The platform is easily accessible and completely free of charge for customers, ensuring that knowledge and expertise are readily available to all our valued clients. Users can request their free access via the following form: opal-rt.com/training-request-form

Key features of the OPAL-RT E-Learning Platform include:

- **Comprehensive Training:** Users can access a range of courses designed to cater to both beginners and experienced professionals. From introductory sessions to advanced topics, our platform covers a broad spectrum of OPAL-RT software products and their applications.





- **Self-Paced Learning:** We understand that time is a precious resource. Our platform allows users to learn at their own pace, making it easier to balance their professional commitments with ongoing education.

- **Certification:** Upon successful completion of specifically designed certification courses, users will receive certifications, validating their expertise in using OPAL-RT software. These certificates can enhance their career prospects and professional credibility.

We passionately believe that empowering our customers with knowledge is the key to their success. The OPAL-RT E-Learning Platform is a testament to our commitment to excellence and innovation.

OPAL-RT
E-Learning

E-Learning
Catalogue

On-Board Chargers in Electric Vehicles: Advancements and Future Prospects

The electric vehicle (EV) revolution has sparked significant interest in on-board chargers (OBCs), particularly in bidirectional charging, a cornerstone of **Vehicle-to-Grid (V2G) technology**. This innovation enables EVs to both draw energy from the grid and serve as power sources for off-grid loads or grid energy return. Advanced power electronics and control algorithms are pivotal, facilitating efficient energy exchange in both directions.

Technical Evolution

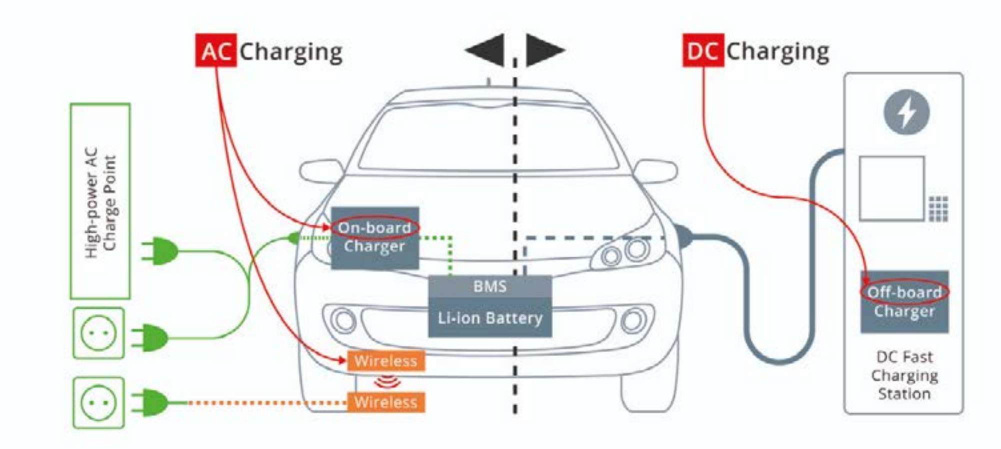
Technical advancements are marked by the growing use of Silicon Carbide (SiC), Gallium Nitride (GaN), and silicon in the three-level NPC/ANPC topology. This topology minimizes device stress, reduces Electromagnetic Interference (EMI), and is complemented **by totem-pole PFC converters, known for their efficiency and compact design**.

Integration and Bi-directionality

Incorporating bi-directional charging not only facilitates energy exchange but also empowers EVs to stabilize the grid and support renewable energy. Applications like peak shaving and load leveling are transformative, easing grid stress and enhancing resilience.

Challenges and Real-time Simulation Implications

Integrating OBCs with various vehicle systems, including battery management and charging infrastructure, is essential. Robust fault-handling mechanisms and complex control algorithms add to the challenge. **Real-time simulations like Hardware-in-the-Loop (HIL) testing are vital, enabling early-stage validation, reducing reliance on physical components, and ensuring compliance with communication standards like ISO 15118.**



On-Board Chargers in Electric Vehicles
Image: Courtesy of DC Charging the Electric Vehicle (EV) Infrastructure, January 10, 2022

OBCs consist of two primary components: an AC-DC converter for grid energy conversion and a DC-DC stage providing galvanic isolation and voltage adjustment for the high-voltage (HV) battery. **Dual-Active Bridge (DAB) and LLC resonant converter topologies have gained prominence due to their efficiency, reliability, and EMI management**.

The OBC landscape is rapidly evolving, driven by bi-directional energy exchange, advanced power electronics, and seamless grid integration. Real-time simulation tools, such as HIL testing, will be indispensable for engineers and researchers to navigate challenges and unlock the full potential of these advanced charging systems.

ABOUT US

Founded in 1997, OPAL-RT TECHNOLOGIES is the 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 simulators are used by engineers and researchers at leading universities, manufacturers, utilities, and research centres around the world.

OPAL-RT's unique technological approach integrates parallel, distributed computing with commercial off-the-shelf technologies.

The company's core software, RT-LAB and HYPERSIM, enables users to rapidly develop models suitable for real-time simulation, while minimizing initial investment and their cost of ownership. OPAL-RT also develops mathematical solvers and models specialized for accurate simulation of power electronic systems and electrical grids. RT-LAB, HYPERSIM and OPAL-RT solvers and models are integrated with advanced field programmable gate array (FPGA) I/O and processing boards to create complete solutions for RCP and HIL testing.

OPAL-RT TECHNOLOGIES

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