OPAL-RT TECHNOLOGIES

POWER ELECTRONICS SOLUTIONS FOR ON-BOARD CHARGER (OBC) DEVELOPMENT

Valeo

Application

- On-Board Charger (OBC)

Related Products

- RT-LAB
- eHS Gen5 | FPGA-based Power Electronics Toolbox
- OP5707

Type of Simulation

- Hardware-in-the-Loop (HIL)

SUCCESS STORY

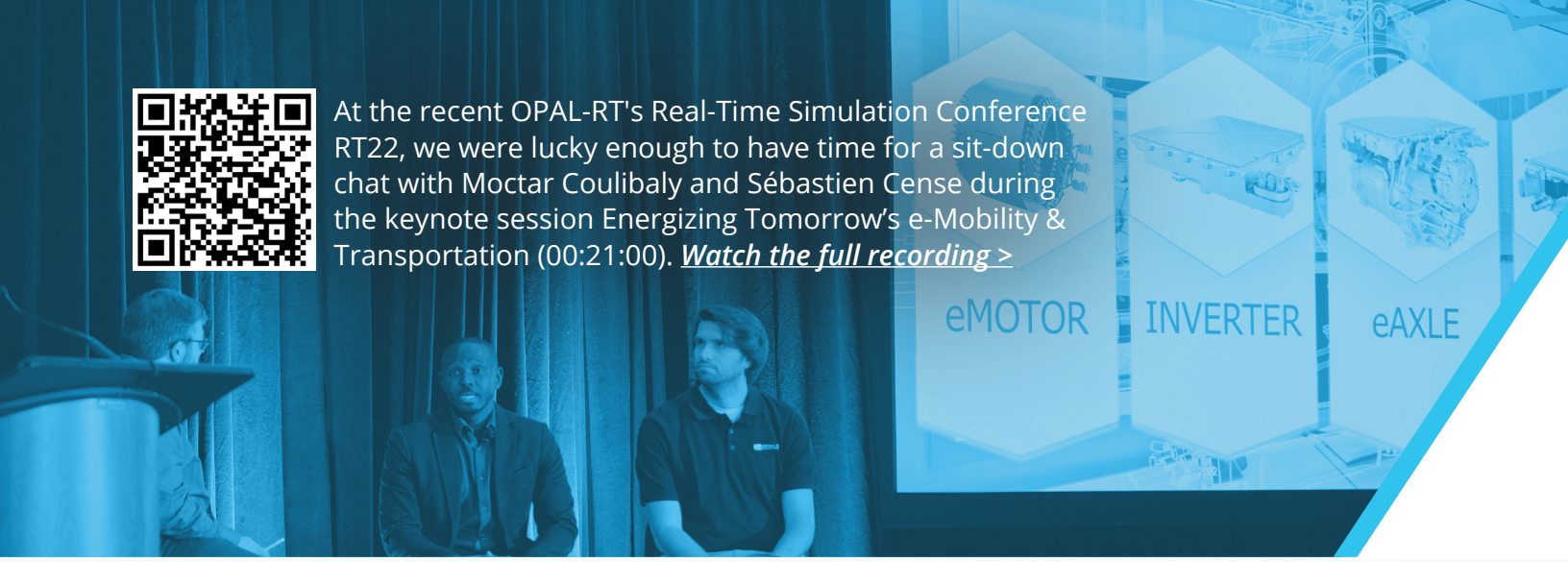
INTRODUCTION

As a technology company, Valeo is a partner to all automakers worldwide and to new actors in mobility, working together to create mobility that is cleaner, safer and smarter through its innovations. Valeo is focused on four key domains – electrification, advanced driver assistance systems, reinventing interior experience and lighting. Valeo is listed on the Paris Stock Exchange. In 2021, Valeo generated 17.3 billion euros in sales and invested 8.7% of turnover in R&D. As of Dec. 31, 2021, Valeo has 103,300 employees in 31 countries, 185 production sites, 21 research centers, 44 development centers and 18 distribution platforms.

Moctar Coulibaly, OBC and DCDC R&D Platform Director at Valeo Powertrain Electrified Mobility in France, and his team are responsible for oversee the development and introduction to market for Valeo's On-Board Charger (OBC) and Combos, including DCDC, for HV products—and he brings to his work his more than 17 years of experience in power electronics, grid stability control and filtering as well as Variable frequency converters and Control and System Design.

As electric vehicles (EVs) continue to emerge ever more powerfully as consumer- and government-validated transportation vectors towards our mutually greener future, they have of course—as with all modern technologies—faced immense challenges. These are additionally multi-faceted and complex challenges since, for example, fast EV charging of EVs at any time—the goal of the consumer—must be mediated against a widely expanding and consistently challenged larger power network.

The figure below shows the diverse range of over 90 EV models equipped with Valeo EV hardware and the variety of products Valeo develops, evaluates, and resells:



At the recent OPAL-RT's Real-Time Simulation Conference RT22, we were lucky enough to have time for a sit-down chat with Moctar Coulibaly and Sébastien Cense during the keynote session Energizing Tomorrow's e-Mobility & Transportation (00:21:00). ***Watch the full recording >***

CHALLENGE

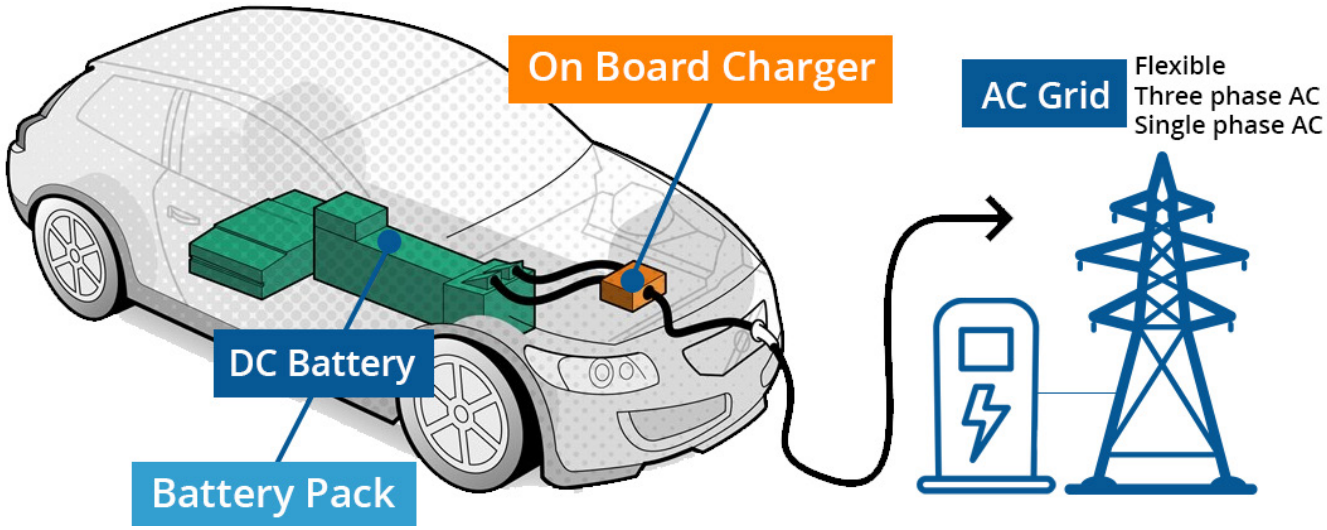
The On-Board Charger (OBC) remains one of the highly researched areas, as better OBCs will in turn improve consumer usability and speed the rollout of EVs to those same consumers waiting to use them. OBCs are no longer 'just chargers'—they are used for both AC Charging Power Conversion and Communication, as well as for DC Charging Communication, and their use applies to both Plug-in Hybrids as well as Full Electric Vehicles. The OBC acts as the interface between the car and the public grid and converts energy from the network grid AC source to the DC voltage of the car HV Battery. Since EVs initiate large volume transactions with the public network, they must inherently be designed and used in respect with the public grid and its regulations.

Valeo's challenges included development taking dynamic elements into account, such as:

- Variable grid / Line impedance
- Voltage dips / Harmonics / Load profiles
- Harmonics injections and immunity

New functionalities are being brought to V2X as well, each necessitating their own stringent requirements:

- Vehicle to grid V2G and
- Vehicle to home/to Load V2H and V2L



OBC SIMULATION SYSTEM REQUIREMENTS

Each main component of the OBC itself faced its own R&D challenges and design issues:

The AC/DC Power Factor Correction (PFC) required that testing and considerations be made for:

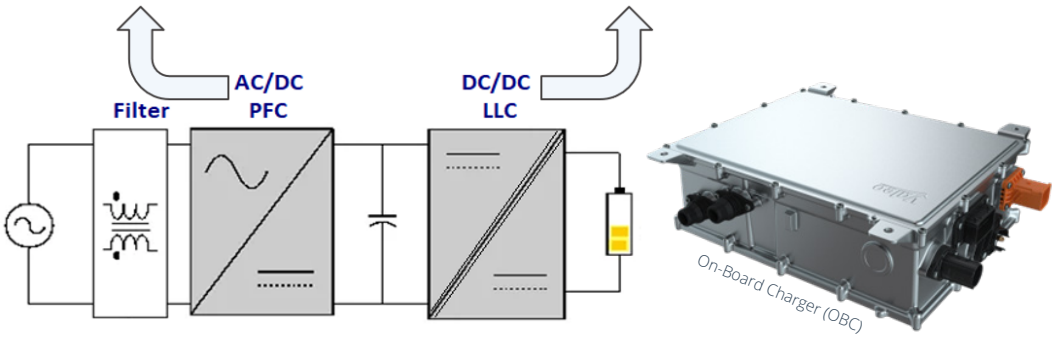
- Up to 80kHz switching frequency
- IEC tests regarding grid Voltage and Frequency variations, harmonics, Voltage drops
- Fidelity of system & grid dynamics
- Detection of High current variations

It requires: Time step of the plant model in real-time (running on FPGA) must be small enough--below 200ns

The DC/DC LLC Resonant Converter required that testing and considerations be made for:

- Up to 400kHz switching frequency & high-resolution PWM
- Sharp gain curve at operating frequencies (close to resonance)
- Diode conduction plays a key role (secondary)

It requires: Accurate sampling, interpolation, detection of gate pulses, and time step of the plant model in real-time be small enough--below 100ns



"eHS Gen5 is about reaching the limit of the FPGA's computational performance to achieve the maximum resolution. We are now able to achieve a 100 ns time step and a resolution of 625ps on the gating events--which makes it the fastest simulation platform in the world."

Sébastien Cense, Energy Conversion Offering Manager at OPAL-RT

SOLUTION & DEVELOPMENT

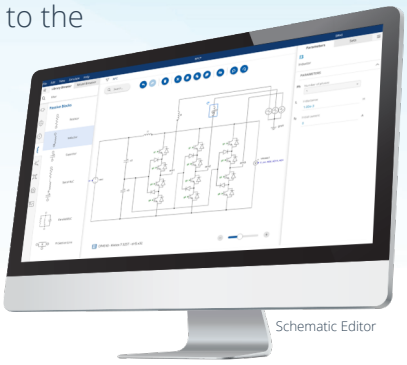
Valeo's team determined that the resolution of PWM detection in LLC was primary, since:

- This resolution means the smallest possible change in frequency detection is observed,
- The smallest possible frequency change detection, mapped to the gain curve of LLC, reflects the smallest possible change in the gain of the converter,
- If the slope of the gain curve is high (around the resonance frequency), the smallest change can be significant.

When Sébastien Cense sat down with Moctar, among the specifications they drafted for what they hoped would meet all their testing needs were these extremely ambitious goals:

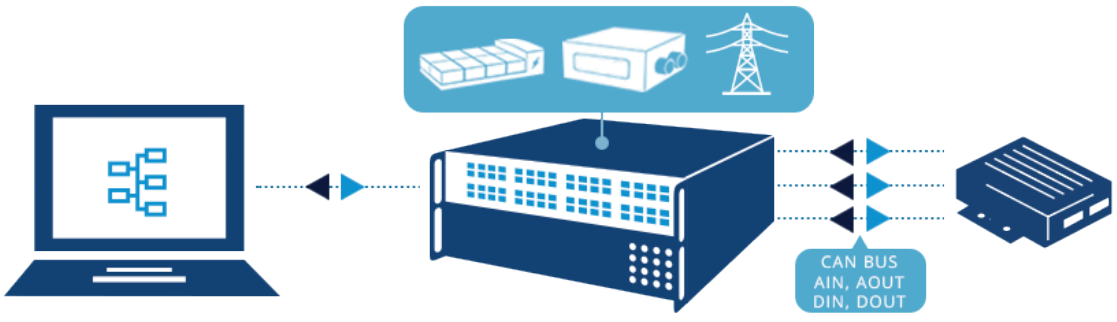
- Deliver the world's fastest Power Electronic real-time simulator,
- Providing a possibility to run simulations of a 100ns time step,
- And leveraging 625ps of gate sampling.

Finally, the eHS Gen5 delivers a focus on user experience and reliability, a streamlined workflow in Simulink, and the possibility of the Model being configured in seconds. Usabilityimprovements such as direct access to the Schematic Editor (OPAL_RT's intuitive user interface for building power electronics) is provided, and workflow is centered around what is essential to the user.


Schematic Editor

As a response to the stringent demands during development, in terms of PWM detection resolution, **OPAL-RT provided at least 4,000 points per switching cycle**, which is an excellent ratio compared to Valeo's highest switching frequency.

And as a result of **using a time step when running the plant model between 100 and 200 ns**—astonishingly fast—Valeo was able to experience a good ratio for simulating dynamics of the system. Simulating diode conduction can be improved further, but we must leave some future features for future versions.



RT-LAB
eHS Gen5 FPGA-based
Power Electronics Toolbox

REAL-TIME SIMULATOR (OP5707)
- Battery Pack
- On Board Charger (OBC)
- AC Grid

DEVICE UNDER TEST
OBC Controller

Watch Moctar Coulibaly's presentation on "Onboard Charger High PWM Resolution and Immunity to AC Grid Harmonic" during RT22, OPAL-RT's Real-Time Simulation Conference.
Watch now >

RESULTS

The new generation of the FPGA-Based Power Electronics Toolbox (eHS Gen5) helped improved the robustness of the On-Board Charger, as well as the entire system including the connection point. And equally, eHs Gen5 was needed for dynamic behavior of the resonant converter LLC/CLLC and the Grid and PFC control—so the collaboration on the project bore fruit for Valeo as well as OPAL-RT.

PWM resolution below 1ns was found to be key to reach the acceptable level of Battery current ripple in the Model, to validate customer requirements. On field events were easy to reproduce using the same On-Board Charger control to interface with the Simulator.

Moctar and OPAL-RT started working together a while ago, with him and his team, when he was at GE Energy. So, he knew OPAL-RT's expertise and collaborative approach would be crucial to the success of a such custom and complex project. Partnerships that introduce the world at large to problem-solving, sometimes long conceived of innovations while helping us drive our core competencies and platforms forward, are truly a solution where everyone benefits.

"The eHS Gen5, in this HIL context, provides advanced real-time simulation, allowing faster evaluation of new concepts before developing Power Hardware, a costly and time-consuming process, and so one worth streamlining and shortening," says Moctar Coulibaly. *"We saw a strengthening of the development cycle through introducing all possible system variations such as grid impedances, harmonics, voltage variations in the control law design and tests before the final product—doing a thorough troubleshooting ahead of all this."*

Moctar Coulibaly, R&D Platform Director at Valeo Powertrain Electrified Mobility