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OPAL-RT TECHNOLOGIES

SNCF Voyageurs: HIL Simulation for Rolling Stock Vehicles

SNCF VOYAGEURS

Application

- Railway

Related Products

- RT-LAB
- FPGA-based Power Electronics Toolbox (eHS)

Type of Simulation

- Hardware-in-the-Loop (HIL)

SUCCESS STORY

Photo: Letizia Le Fur / SNCF

INTRODUCTION

The *Société Nationale des Chemins de Fer Français* is France's national state railway company. Founded in 1938, it operates the country's national rail traffic, including the TGV, on France's high-speed rail network. Every day, the SNCF Voyageurs runs 15,000 commercial trains and transports more than 5 million passengers—along with more than 250,000 tonnes of goods.

The SNCF Voyageurs' Matériel Department, in turn, has the daunting responsibility of maintaining a fleet of 17,000 rolling stock, in order to provide the means of transport for both people and goods. To guarantee high availability and security in this high stakes context, this department relies in particular on the Equipment Engineering Centres (called Clusters), one of which is located near Lyon, France. This Engineering Cluster specializes in the maintenance of traction chain control electronics , with the aim of improving its validation processes through digital simulation.

The project code name SimHIL (an acronym for SIMulated Hardware In the Loop) that aimed to integrate SNCF Voyageurs' operations with rigorous HIL testing had as a central goal nothing less than to uniformly improve the maintenance of electronic command and control on trains through using digital simulation. The following is a look behind the scenes at a multi-partner project led jointly by SNCF Voyageurs and Innovation & Research.

OPAL-RT is grateful to the authors and publishers of the two primary references listed below, and used in the preparation of this material.

"I can tell you that through my experience using OPAL-RT's real-time solution for several years, it is essential that you enumerate your needs as well as possible from the start of the project. This may seem a basic idea, but it nevertheless determines the proposed solution from the ground up, as well as the type of technical support required to support the project. A subsequent follow-up would be to remain alert on the software and hardware evolution paths that OPAL-RT are developing: our requirements are constantly evolving in power electronics simulations--as are OPAL-RT's technical proposals."

Florent Chabrier, Coordinateur de l'activité « MCO des outils de tests et validation » at SNCF Voyageurs

Alex Profit; / SNCF

CHALLENGE

All railway traction chain control electronics must follow a strict validation process, requiring online tests that can be extremely expensive, even dangerous if tests at limit conditions (operational edge or corner cases in terms of equipment demands, high/low temperature thresholds, strong accelerations, mechanical shocks, software modification, etc.) are required. Engineers use HIL simulation systematically in order to test these electronics, and, in so doing, prevent risks and significantly reduce the costs and delays of this essential testing process.

The initial motivation was always to provide the SNCF Voyageurs with a virtual tool capable of testing the impact of changes made to on-board computers on the behavior of trains, without having to mobilize rolling stock and above all in real time. But why would companies fuss with virtual models when they had many (and superior) real-world trains for test campaigns?

Therein lies the chief advantages of HIL testing: real-time hardware simulators with highly-specialized platform software and solvers are used to 'spoof' or convince the equipment into believing it is cabled, connected, and operating under current physical conditions. The configuration is observed performing closely to how it would in the real world. Quite simply, there is little difference and high accuracy is enabled when testing between the real and virtual in this way. Additionally, real trains are extremely expensive: it can cost thousands of euros for a train to be immobilized for a week, not to mention the costs and risks associated with dynamic, possibly damaging or destructive tests.

CHALLENGE

In this case, then, the HIL simulation and modeling tools are set up to replicate an electromechanical traction chain, capable of interacting in real time with the on-board computers tested. The controls and feedback are fed in both directions, and the closed HIL 'loop' is achieved.

"The challenge for us at SNCF Voyageurs, is to develop simulation models that are representative enough to test control electronics as closely as possible to operating conditions. Many internal Material Engineering's skills are therefore at work to allow the development of the various models needed to represent train powertrains. In addition, the constraints imposed by real-time HIL simulation were also taken into account. This is why the SNCF Voyageurs definition of the simulation platform required a long study and comparative analysis phase.

Now that the platform is defined, each new powertrain studied requires hardware and software development to adapt to the constraints of the control electronics tested", said Florent Chabrier, Coordinateur de l'activité « MCO des outils de tests et validation » at SNCF Voyageurs.

SNCF Voyageurs team in front of the simulator control station

SOLUTION

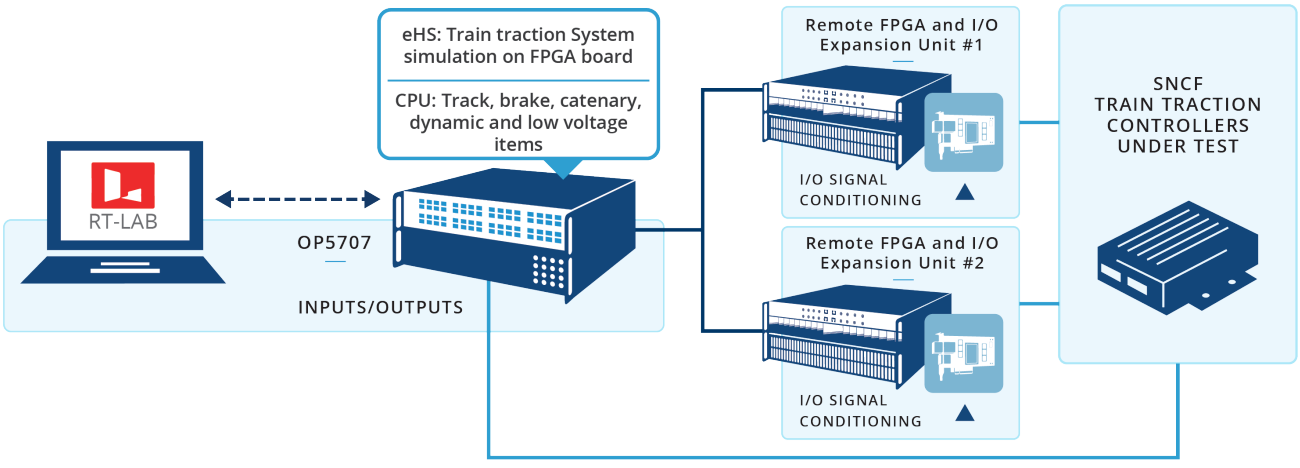
OPAL-RT was first called on in 2013 as part of this research project, the aim of which was to develop a real-time simulation platform able to deal with the operating realities of the real TGV (Train Grande Vitesse). The TGV, in particular, was selected from a series of machines from SNCF Voyageurs' rolling stock fleet because it was among the most complex and recent at the time.

Given that SimHIL's primary motivation was to provide SNCF Voyageurs with a tool capable of modeling with sufficient precision the power diagram of a chain of traction, the goal was to faithfully virtualize the unique signature harmonic of diffuse current on the catenary, which varies according to the laws of motor control and traction. The second central motivation was to simulate the impact of the distribution of energy (substation, catenary, etc.) in the functioning of the machine model.

After extensive consultation between SNCF Voyageurs and OPAL-RT, a real-time computer with a multi-core processor was acquired and development was underway. Significant research and modeling efforts were required in order to achieve a first, or draft, level of HIL performance--since the power electronics models of a drivetrain can understandably be astonishingly complex. Tools like OPAL-RT's ARTEMiS/SSN, in their turn, made it possible to achieve an optimized calculation time step—this interaction was required to determine that commands and feedback were faithfully flowing back and forth ('in the loop') once the fourth element of time was introduced to the simulation.

SimHIL, in a very concrete way and outside of the all-digital simulation realm, also consists of control bays--the 'H' in 'HIL' is for hardware. They interact with the simulator which model the train behavior, the whole being controlled by a supervision PC. Behind this deceptively simple description beats the vital R&D heart of a multipartner project. SimHIL can be broken into three parts: the Power and Dynamics model, the Low Voltage model, and the software/hardware integration, all of which required considerable leveraged expertise, collaboration and iterative, accumulated 'lessons learned' during the process.

At the same time, OPAL-RT has developed its power electronics modeling offer on FPGA components with its eHS (FPGA-based Power Electronics Toolbox); It was at the end of 2018 that the SimHIL real-time simulation platform switched to this technology, making it possible to achieve the calculation time-steps necessary for the pre-specified objective of virtual certification. In this context, the accurate representation of the models is paramount; SNCF Voyageurs is counting on OPAL-RT to support it in this further development process.



Alex Profit, / SNCF

RESULTS

The use of the simulator is increasing, and its further development continues apace! Having conceived of the configuration as flexible, scalable and modular since its inception, SNCF Voyageurs Equipment Engineering now has a tool that allows it to position itself to interface with traction chain controllers other than those studied until now. (OPAL-RT has long leveraged modular, expandable components in an effort to enable a growth and development path for clients as their needs evolve.) Combined with the simulator's performance, OPAL-RT's competent team and its full R&D support, SimHIL presents persuasive arguments for the companies' customers who ask increasingly for virtual solutions. The idea is to reduce the costs of physical tests, while minimizing the risks related to safety, both for the installation and personnel.

In addition, rail regulations, which were initially cautious with regards to simulation tools, are beginning to be revised due to the changing and positive judgments regarding HIL technology in this context. Administrators and engineers in these facilities clearly perceive that these tools are becoming essential--in particular to optimize the performance and energy consumption of powertrains as we evolve together towards a greener future.

Further effort is being invested in giving confidence back to these same authorities, by demonstrating that a large part of the online tests may be carried out through HIL simulation. As these tools further evolve, they will improve exponentially on the current tools, which are already sufficiently powerful, and the models representative of the challenging circumstances of the SNCF Voyageurs' reality.

The technological challenges of the future include achieving ever-smaller time-steps, and the uses of these simulators will be only more numerous as they prove themselves in ever-widening circumstances. HIL simulators and their configuration installations are of great interest to various SNCF Voyageurs entities in order to bring about new projects, on time and on budget, and meeting the steep exigencies that SNCF Voyageurs deals with on a daily basis.