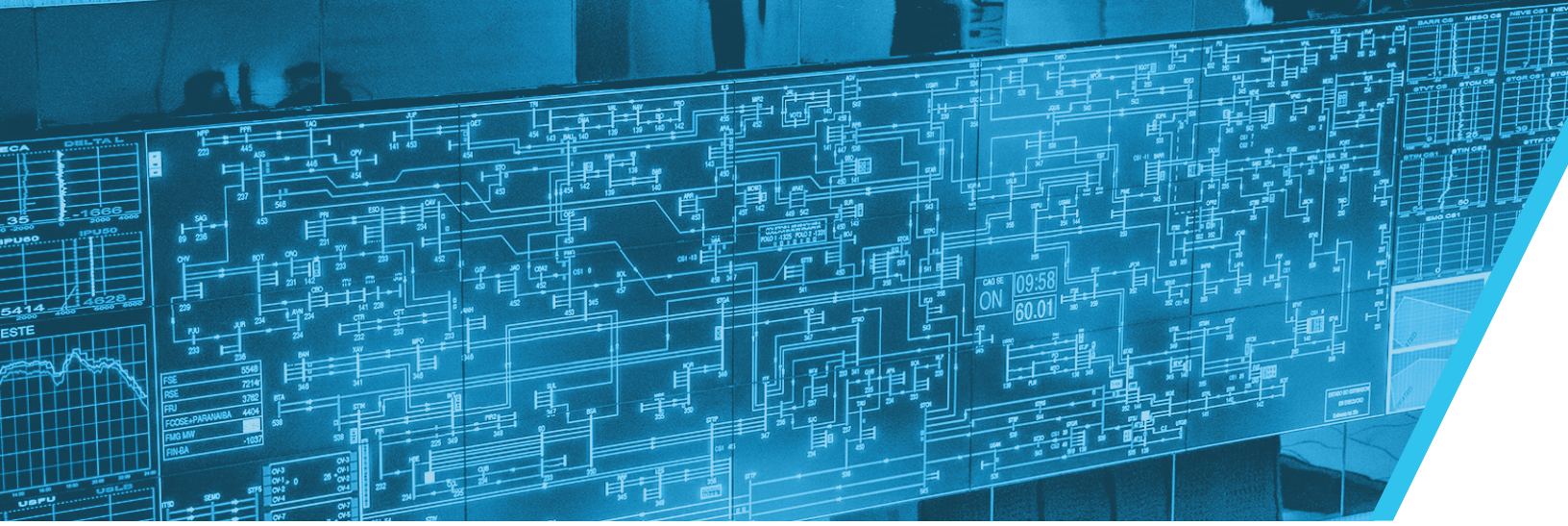


OPAL-RT TECHNOLOGIES

THE IMPROBABLE REAL-TIME CO-SIMULATION BETWEEN HYPERSIM AND RTDS

ONS Operador Nacional do Sistema Elétrico

Application

- High-voltage direct current (HVDC) and alternating current (HVAC) for Simulation Centers

Related Products

- HYPERSIM
- OP5707
- FPGA Aurora-based Communication

Type of Simulation

- Hardware-in-the-Loop (HIL)

SUCCESS STORY

INTRODUCTION

Brazil is the largest electricity producer in South America. Having a generation capacity of 157 gigawatts (GW), the country has the 9th largest electricity market in the world.[1]

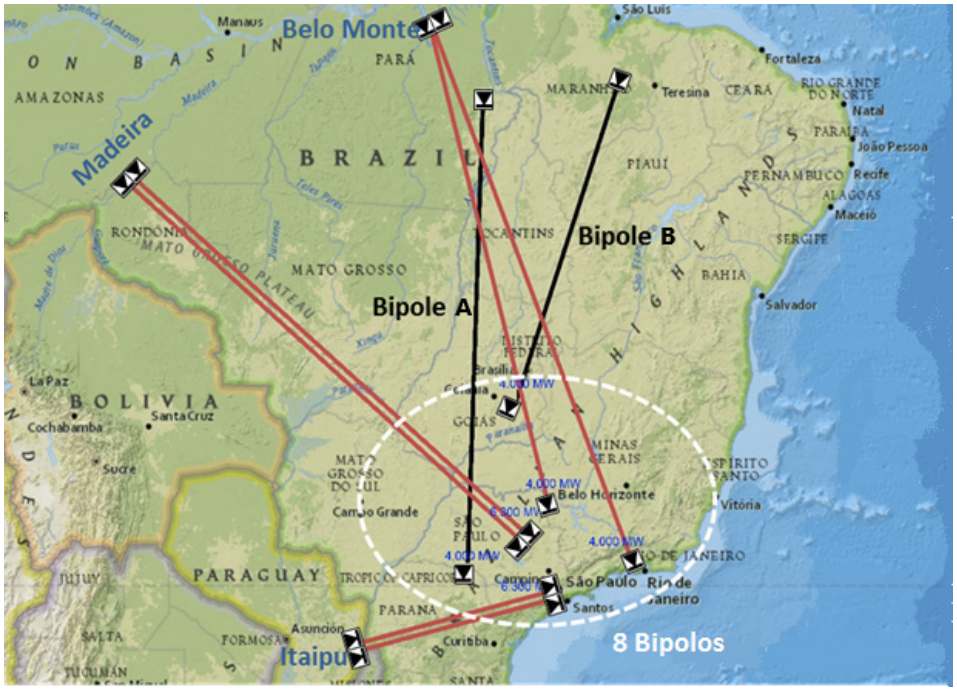
The *Operador Nacional do Sistema Elétrico* (ONS) is the Brazilian entity responsible for the coordination and operation of all generation and transmission infrastructure within the Brazilian Interconnected Power System.

ONS plans and manages various forms of energy generation and transmission to ensure the safety of the system, while maintaining optimization and reducing operational costs. Its mission is also to provide power utilities with access to the interconnected electrical system.

The Brazilian power grid has six HVDC transmission links in bipolar configuration, and one more is expected to be added in this decade. Each one is operated by a different power utility and transfers large blocks of energy from both north and south areas, directing them to the southeast region of Brazil. As the inverter sides of all these links are electrically close to one another, it is mandatory to evaluate their interaction when abnormal operating conditions arise. For this reason, ONS was equipped with a simulation facility where four Control and Protection (C&P) replicas are installed of these six HVDC bipoles.

Employing real-time simulators, studies are carried out to evaluate the individual operation of the bipoles as well as their mutual interaction, whose phenomenon is known by multi-infeed effect. This heterogeneous environment allows the possibility of exploring simulators from different manufacturers in cooperative use.

BRAZILIAN POWER GRID



"Planning studies identify capacity to generate 17,508 MW in three hydrographic basins in the North region.

Bipole A: Network expansion for power transmission from Hydro sources in the North.

Bipole B: Network expansion for power transmission from renewable sources (wind and solar) in the Northeast and Central West.[2]"

THE MOTIVATION

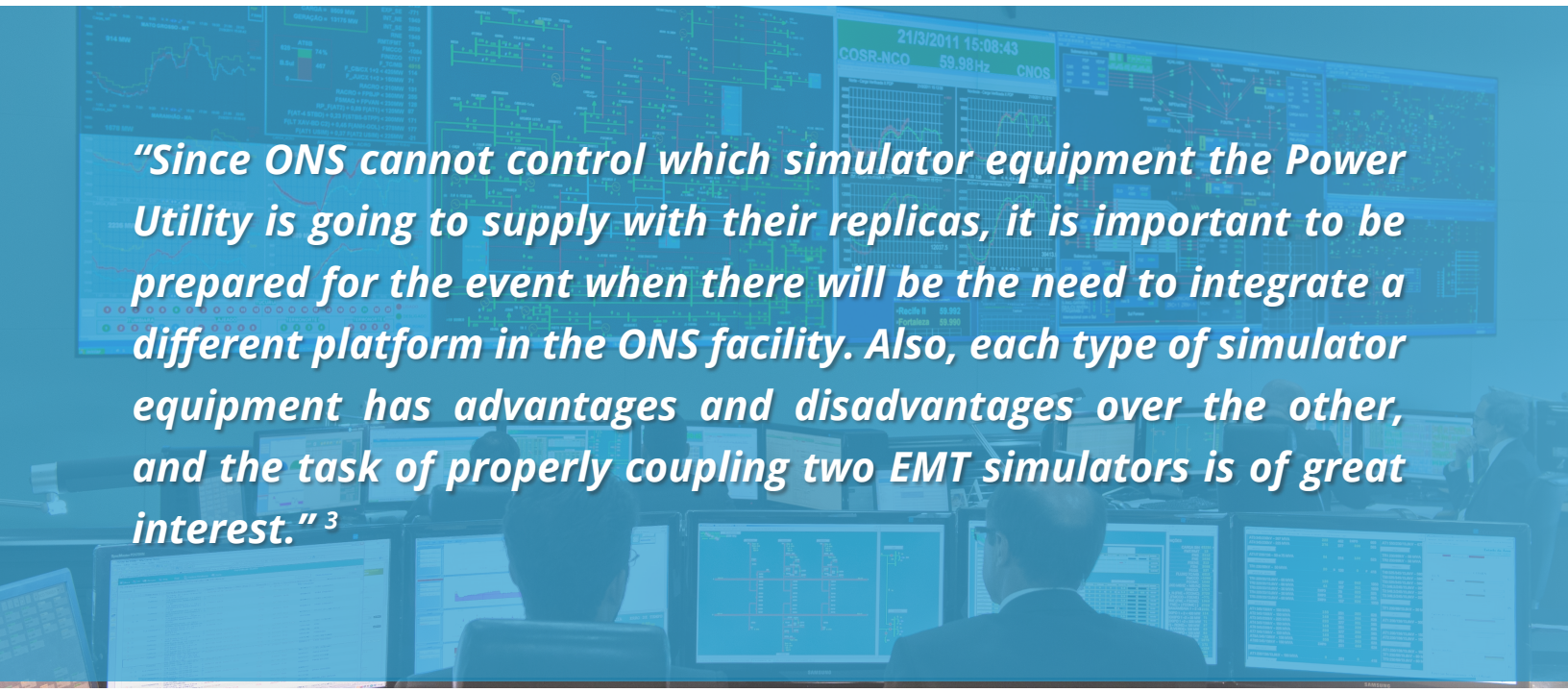
To ensure more accuracy with event analysis, ONS needed to expand and update its real-time simulation facility. Although the deployment of their simulation facility was based upon the RTDS platform, the operator had also considered investing in HYPERSIM, OPAL-RT's real-time simulation platform.

"The initial motivation to adopt HYPERSIM from OPAL-RT was the comparative cost and associated value, as well as expanding the diversity of our suppliers and alternatives--which would ultimately give ONS more commercial and technical possibilities to explore," said Henildo M. de Barros, head engineer at ONS' simulator facility.

In addition, two main advantages finally made a big difference for ONS in terms of its purchasing decision: (i) the creation of any customized model would be considerably easier with HYPERSIM and (ii) both HYPERSIM and "off-line" tool EMTP-RV share a GUI allowing easy database conversion.

Although the benefits were clear to the ONS Simulator crew—who were in charge of getting OPAL-RT technical information during the purchase decision—it was important to clarify to ONS' managers the advantages for adopting an heterogeneous environment and to prove the technical feasibility of co-simulation: indeed, the co-simulation project would be a decisive moment to establish whether it was possible to use simulators from different manufacturers within the same installation.

In early 2018, before ONS had acquired the HYPERSIM tool, a cooperative task between ONS and OPAL-RT began to demonstrate the feasibility of having both simulators working synchronized in co-simulation studies for modeling large electric power systems. The results were presented in the paper *Real-Time Cooperative Simulation Between RTDS and HYPERSIM, Test Results for the IEEE 39 Bus System*, presented in October 2018 during the XIV SEPOPE, an event organized by the CIGRE Brasil.



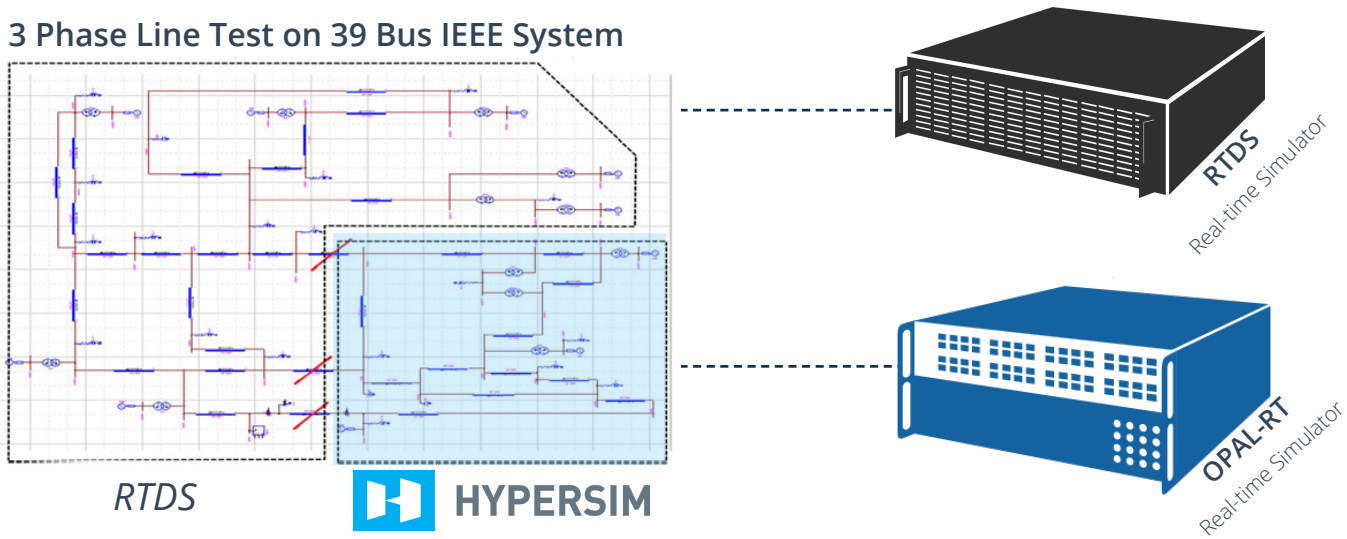
"Since ONS cannot control which simulator equipment the Power Utility is going to supply with their replicas, it is important to be prepared for the event when there will be the need to integrate a different platform in the ONS facility. Also, each type of simulator equipment has advantages and disadvantages over the other, and the task of properly coupling two EMT simulators is of great interest." [3]

THE PROJECT

Implementing a co-simulation solution between OPAL-RT and another supplier created some challenges, such as:

- Adoption of a suitable hardware interface (one that was easy to program and update) for data transfer between the simulators;
- Reliable synchronization between the simulators for recreating the effect of simultaneous subsystems solution;
- Familiarize the ONS Simulator crew with the various hardware and software platforms with the goal of fault diagnosis, predictive maintenance and monitoring of internal signals of C&P logic;
- Operation under two distinct user interfaces, including event scheduling, visualization of results, initial condition adjustment and model initialization, among others.

The project's main goal was to integrate two real-time simulators, the OPAL-RT's HYPERSIM and the RTDS, working in a cooperative way to represent a large power system network in a Hardware-in-the-Loop (HIL) simulation. The proposal was first successfully tested using the IEEE 39 bus benchmark system.



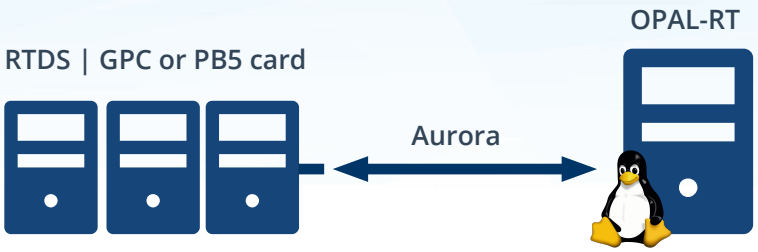
"One cooperative simulation (co-simulation) that is of great importance involves two different EMT simulators for solving a complex power system network in simultaneous and synchronized way. For example, co-simulation can support tests carried out with two different simulators, each one connected to its own HVDC or FACTS control and protection replicas. This is a situation of great importance for the evolution of our understanding: when there is the need to study the interaction between these controllers in scenarios where they are operating electrically close to each other.

There is also the situation where one simulator is used to model a control system and it is connected to the other simulator where the power system is modeled." [3]

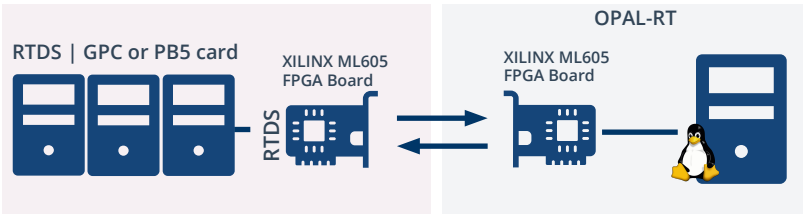
THE PROJECT

COMMUNICATION STRUCTURE FOR CO-SIMULATION STUDIES

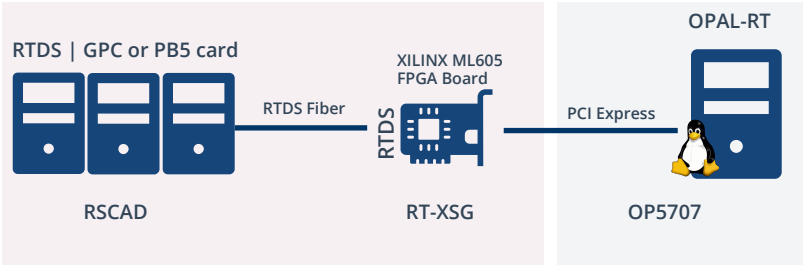
Direct Connection > Aurora Protocol

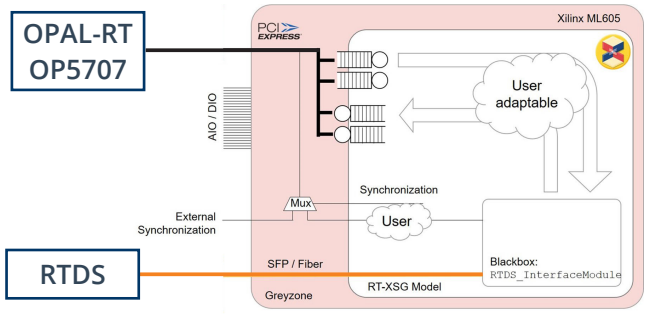


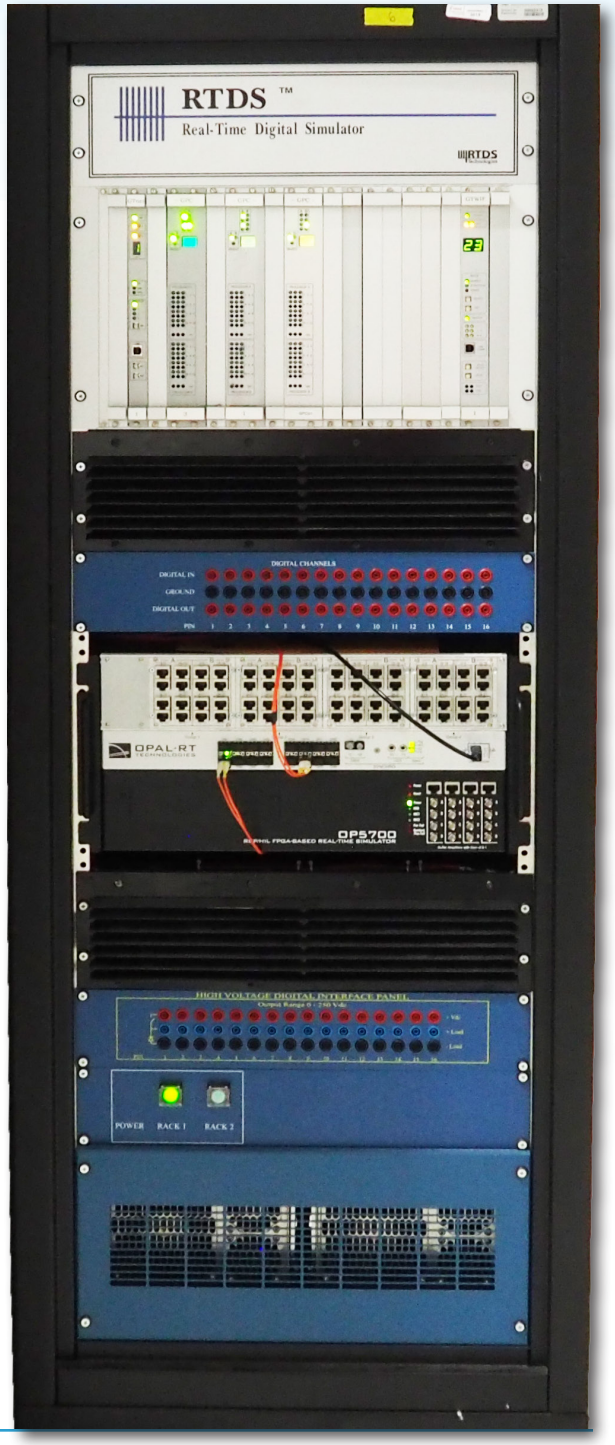
FPGA to FPGA Connection



FPGA Connection







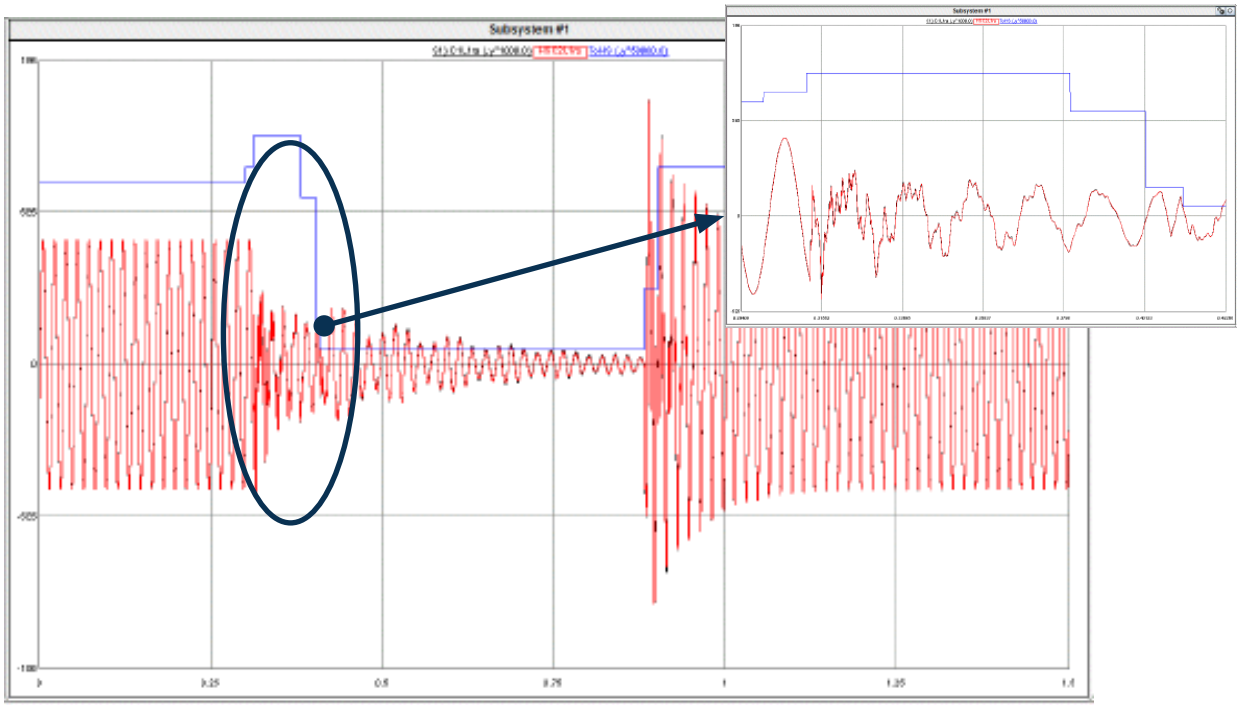
RESULTS

The data flow between the real-time simulators introduces an inherent time delay and this must be taken into consideration in the simulation algorithm. For this reason, the connection between the two simulators must be performed through transmission lines, since the electromagnetic wave requires a time delay or offset to propagate from one side of the transmission line to the other.

To solve this issue, the time delay due to the interface between the two simulators is subtracted from the line delay and compensated for in the mathematical model of the line.

The results are shown below. Here, the red waveform shows the co-simulated result and the blue one shows the single simulator counterpart. The enlarged frame shows how convergent the two sets of results are.

In this way, ONS has enabled the current use of this interface component in order to have the two simulators modeling electrical networks as complex as the IEEE 39 bus system used in the benchmark test of this implementation. The context for this is an integrated heterogeneous environment featuring two simulators from different suppliers, as well as four HVDC C&P replicas from four different manufacturers.



"The successful result of this work opens the possibility to adopt the developed solution for a future integration of ONS facility with other simulation centres placed in the metropolitan region of Rio de Janeiro (CEPEL and Furnas). That way, these centres will be able to share their simulation resources and technical expertise for analyzing multiple HVDC infeed performance and to improve model representation of specific equipment.[3]"

1 https://www.agora-energiewende.de/fileadmin2/Projekte/2019/Brazil_Country_Profile/155_CountryProf_Brazil_EN_WEB.pdf

2 https://blob.opal-rt.com/medias/L00161_0945.pdf

3 J. J. R. Oliveira, H. M. Barros, S. A. Mattar, A. Castro, A. Y. Takahata, A. A. Barbosa, R. N. F. Filho, *Real-Time Cooperative Simulation Between RTDS and HYPERSIM, Test Results for the IEEE 39 Bus System*, XIV SEPOPE 2018.