OPAL-RT TECHNOLOGIES

Global RT-Super Lab: A real-time co-simulation across the Atlantic

Sandia National Laboratories

University of South Carolina

Colorado State University

Politecnico di Torino

NREL National Renewable Energy Laboratory

INL Idaho National Laboratory

RWTH Aachen University

Washington State University

Application

- High-voltage, direct current (HVDC)

Related Products

- RT-LAB

Type of Simulation

- Hardware-in-the-Loop
- Power Hardware-in-the-Loop

INTRODUCTION

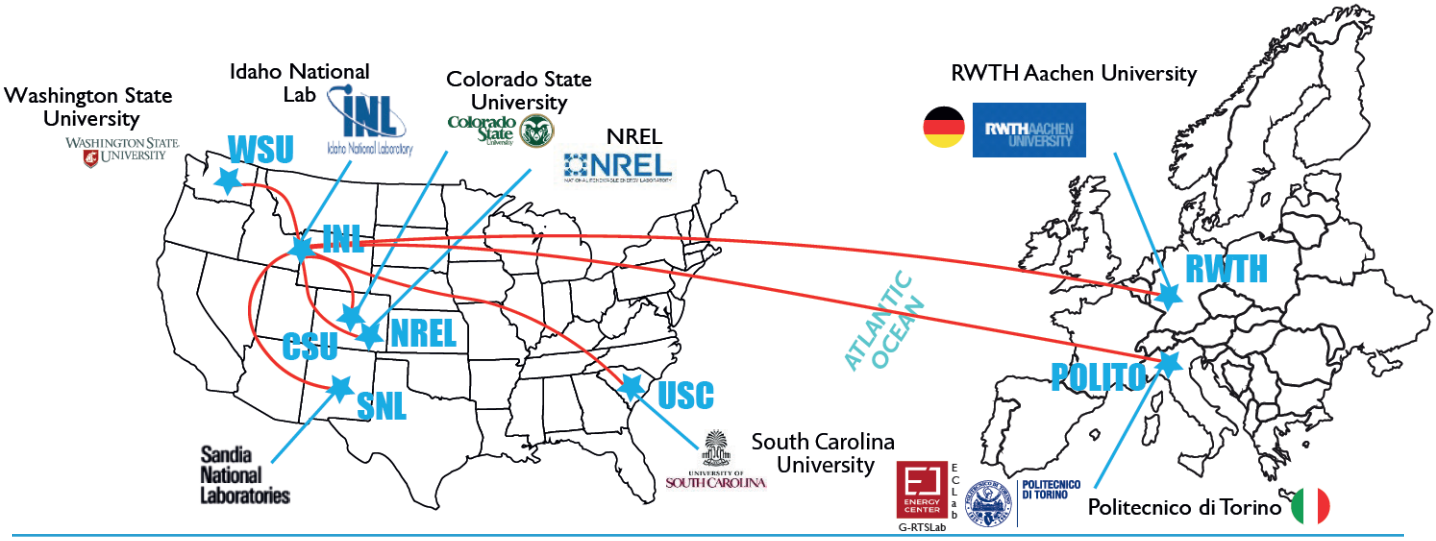
Globally connected grids are becoming a reality, and OPAL-RT is proud to be associated with some of the most interesting, challenging and promising transcontinental electrical and electronic network research work that will take utilities and consumers into the 21st century and far beyond. In this case, we cover the Global Real-Time Super Lab.

To say the electric grid is changing is a massive understatement. But in particular, power electronics are significantly transforming power systems around the world. The gradual installation of Distributed Energy Resources (DERs) is driving this change as they make their way into power electronics-based interfaces. The low-inertia grid that results, chiefly power electronics-driven, represents a transformation from the way things have always worked for as long as we've known them. Portions of grids with solely power electronics-driven sources are already possible.

The Global Real-Time Super Laboratory (Global RT-Super Lab) represents a vendor-neutral distributed platform, established in 2017, and based on the virtual interconnection of Real-Time Simulators and Hardware-In-the-Loop (HIL) setups, hosted at eight geographically distributed laboratories located in the USA and Europe.

The labs' geographical areas and their sponsoring institutions were as follows:

CATEGORY	NAME
National labs	Sandia National Laboratories (Sandia)
	National Renewable Energy Laboratory (NREL)
	Idaho National Laboratory
US universities	Colorado State University (CSU)
	University of South Carolina (USC)
	Washington State University (WSU)
EU universities	RWTH Aachen University (RWTH)
	Politecnico di Torino (POLITO)



OBJECTIVE / CHALLENGES

The challenge presented to the developers of the SuperLab was to integrate Geographically Distributed Real-Time Simulation (GD-RTS)—a relatively new concept—with a co-simulation platform that allowed great trans-Atlantic distances, multiple vendors and platforms, and various universities and facilities to communicate. It is difficult to overstate the complexity of this undertaking.

Today electric grids faces challenges that are from unknown threats such as cyberattackers and forces of nature, to the variability of generation and loads that leads to an excess of energy that is not utilized. Having an integrated system that allows sharing energy resources globally helps to enhance reliability and resiliency and improve the efficiency in the energy generation and consumption.

The best collaborations involve a common purpose and dedication to a shared goal—and this rapidly becomes staggeringly complex in projects involving multiple research entities, geographical locations and budgets. The final outcome of this project was nothing less than the culmination of a large-scale virtual infrastructure. These next generation global power grids break new ground and lay the groundwork for the future.

Simulation models of Global RT-Super Lab

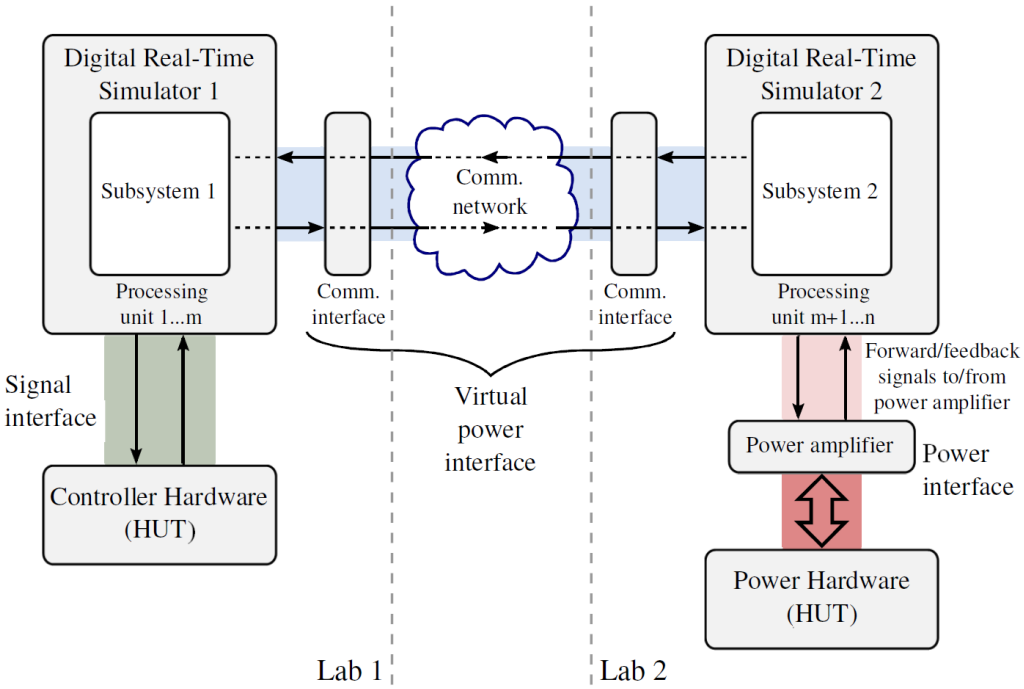
NAME	GRID	# BUSSES	HIL	SIMULATOR
Sandia National Laboratories (Sandia)	Distribution grid	7	PHIL for PV inverters	OPAL-RT
National Renewable Energy Laboratory (NREL)	Distribution grid	3	PHIL for wind turbines	Other vendor
Idaho National Laboratory	WSCC	9	-	OPAL-RT + 2 vendors
Colorado State University (CSU)	IEEE distribution test feeder	13	-	OPAL-RT
University of South Carolina (USC)	IEEE distribution test system	123	Controller HIL, Network Emulation	OPAL-RT
Washington State University (WSU)	Simplified CERTS microgrid	9	-	Other vendor
RWTH Aachen University (RWTH)	CIGRE HV	12	-	Other vendor
Politecnico di Torino (POLITO)	CIGRE MV	14	-	OPAL-RT

SOLUTIONS & DEVELOPMENT

The networking of real-time simulation, Power Hardware-In-the-Loop (PHIL), novel test benches and hybrid co-simulation frameworks created a comprehensive research infrastructure that allowed the partnering of resources and enabled largescale and multi-domain experiments. Virtually interconnected infrastructures served as a flexible framework for collaboration with realization of joint experiments and studies based on indirect data sharing without presenting confidential details of individual research groups, industries, and utilities. The collaboration and joint research studies that leverage competences across research groups, industries, and utilities, are feasible even in case of confidentiality constraints.

In September 2017, the largest geographically distributed real-time simulation of a large power system was performed as the Global Real-time Super Lab Demonstration. In total, eight laboratories utilizing ten digital real-time simulators from OPAL-RT, RTDS and another vendor were interconnected over the Internet using the previously presented VILLASframework.

Geographically Distributed Real-Time Simulation[1]



Global RT-Super Lab aimed to provide several advantages to the scientific community:

• Enhancing computational capability of each lab without further investment;

• Sharing of hardware/software facilities in a cost effective way, without the need for the same equipment to be replicated locally;

• Use of available hardware/software resources in remote laboratories, in case they are not available locally, and allowing the sharing of models and simulation tools;

• Pooling of expertise in a collaborative super-resource for various use cases and studies, without physical exchange of personnel;

• Keeping national data confidential, while running a co-simulation that integrates such data safely.

RESULTS

The concept of virtual interconnection of laboratories is called here Geographically Distributed Real-Time Simulation, or GD-RTS. GD-RTS refers to a concept of partitioning a monolithic simulation model into subsystem models that are simulated concurrently on multiple DRTS units located at geographically dispersed facilities. Interconnection and data exchange between DRTS systems is typically realized via a shared communication network, such as the Internet. Therefore, comprehensive real-world testing of interconnection and interoperability between novel technologies and existing power grid can be performed without having the diverse HIL setups located at the same facility.

Similarly core to this solution's working is the smooth and cooperative inter-operability of various real-time simulation vendors. Information exchanged between DRTS units are variables defining power, typically current and voltage. The paramount requirement for an accurate GD-RTS is conservation of energy at the interface. There must be neither generated nor stored energy where the interfaces between simulated subsystems intersect. If this principle is violated, the stability and fidelity of the simulation cannot be ensured and the results are not valid.

The collaborative efforts towards the planning and successful demonstration of Global RT-Super Lab produced something that until that point had not existed: a large-scale distributed platform established based on virtual interconnection of DRTS systems and HIL setups hosted at eight geographically distributed laboratories located in the USA and Europe.

The co-simulation framework, named VILLASframework, and its roles in establishing and utilizing the Global RT-Super Lab platform were the tools upon which this platform was built. In the bigger picture, the demonstration included transatlantic HVDC interconnection of the benchmark transmission systems (of the USA and European grid) with local transmission-distribution interactions and capability assessment of distributed generation units to support the grid operation. The ambition and reach of this project left their influence on subsequent projects—and indeed the way these things will be simulated for years to come.

[1]Monti, Antonello, Stevic, Marija, Vogel, Steffen, De Doncker, Rik W., Bompard, Ettore, Estebsari, Abouzar, Profumo, Francesco, Hovsapian, Rob, Mohanpurkar, Manish, Flicker, Jack David, Gevorgian, Vahan, Suryanarayanan, Siddharth, Srivastava, Anurag K., and Benigni, Andrea. *A Global Real-Time Superlab: Enabling High Penetration of Power Electronics in the Electric Grid*. United States: N. p., 2018. Web. doi:10.1109/MPEL.2018.2850698.