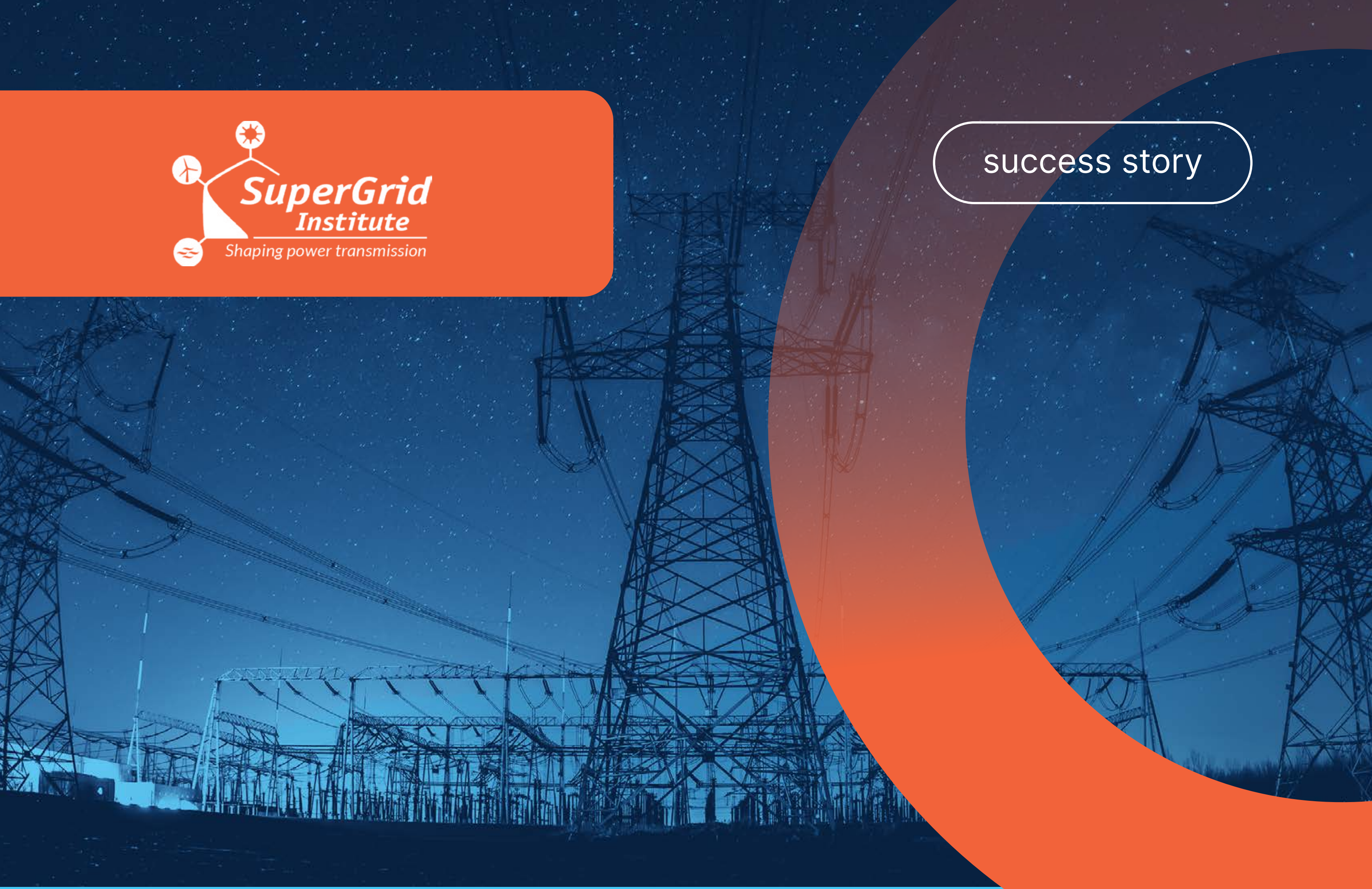
SuperGrid Institute
Shaping power transmission

success story



Digital twin of innovative MVDC system for breakthrough linear photovoltaic power plants

SuperGrid Institute builds an MVDC demonstrator for solar energy production

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SuperGrid Institute

SuperGrid Institute is a privately owned company with expertise in high and medium-voltage direct current (HVDC & MVDC) systems and technologies—key components of future energy networks. Based in Greater Lyon, France, the company actively contributes to the energy transition by removing the technical barriers associated with the deployment of future power grids and the massive integration of renewables.

The company has proven expertise in real-time simulation covering a full scope of medium & high voltage testing for algorithms, controllers, mock-ups and converters in a realistic power system environment. SuperGrid Institute's teams are regularly called upon to contribute their expertise to collaborative projects, providing in-depth, highly accurate simulations to validate designs quickly and cost-effectively. One such project is OPHELIA, funded by the French Environment and Energy Management Agency (ADEME).

> The unique constraints of the demonstrator meant the consortium had to develop many new components and technologies exclusive to the project. Due to the innovative nature of the linear electrical architecture being built, we cannot fall back on standard industrialised products. The validation process therefore becomes extremely critical to understand the behaviour and interaction between these new pieces of equipment before integrating them into the demonstrator. A high level of complex modelling is required to carry out this validation.

Laurent Chedot
Research group leader - Control & protection prototyping and validation

LAURENT CHEDOT

OPHELIA: Building an MVDC demonstrator for solar energy production

OPHELIA

This project was funded by the French State as part of France 2030 operated by ADEME

The OPHELIA demonstrator, «ViaSolaire du Colombier», will be installed above a 900-metre stretch of the ViaRhôna cycle path.

While the demands to produce more renewable energy are increasing, the photovoltaic (PV) industry is faced with a scarcity of land available for new projects. The OPHELIA project addresses this problem by promoting the development of linear photovoltaic power plants on narrow plots of land that have already been designated for other uses (dikes, spaces alongside railways, roads, cycle paths, etc.), leaving natural spaces as they are.

The long distances involved in these PV power plants means traditional AC collection architectures are ill-adapted to collecting the energy produced. The project consortium (CNR, Nexans, Schneider Electric, SNCF and SuperGrid Institute) is developing a linear PV park demonstrator, in the form of a solar canopy over a cycle path, to validate an innovative medium-voltage direct current (MVDC) collection network which minimises electrical losses.

Complex real-time simulation: SuperGrid Institute's speciality

BUILDING & MAINTAINING A REAL-TIME DIGITAL TWIN OF THE LIVE MVDC DEMONSTRATOR

Digital twins are a powerful tool to validate that a system and its equipment will function as expected. They can also be used to uncover unexpected results which in turn show how to improve equipment or troubleshoot during a network's development phase. The value of this tool is now widely accepted but few real project demonstrators have been linked to a digital twin today.

Using their Hardware-in-the-Loop (HIL) platform, the SuperGrid Institute team built a real-time digital twin of the MVDC OPHELIA demonstrator network. The digital twin will run for 2 years. During this period, it will be used to troubleshoot the day-to-day running of the network and will also provide valuable information about the digital twin tool itself, making it possible to develop more advanced versions in the future.

VALIDATING & TESTING CONTROLLERS

The unique MVDC electrical architecture developed in the OPHELIA project brought with it numerous challenges for the validation process. Different levels of models, average & detailed, were required to properly and efficiently model the behaviour of each element in the network. The various controllers within the network used different communication protocols meaning the team had to develop interface cards for each control and work with multiple communication protocols to achieve a global vision of the whole system in the real-time simulator.

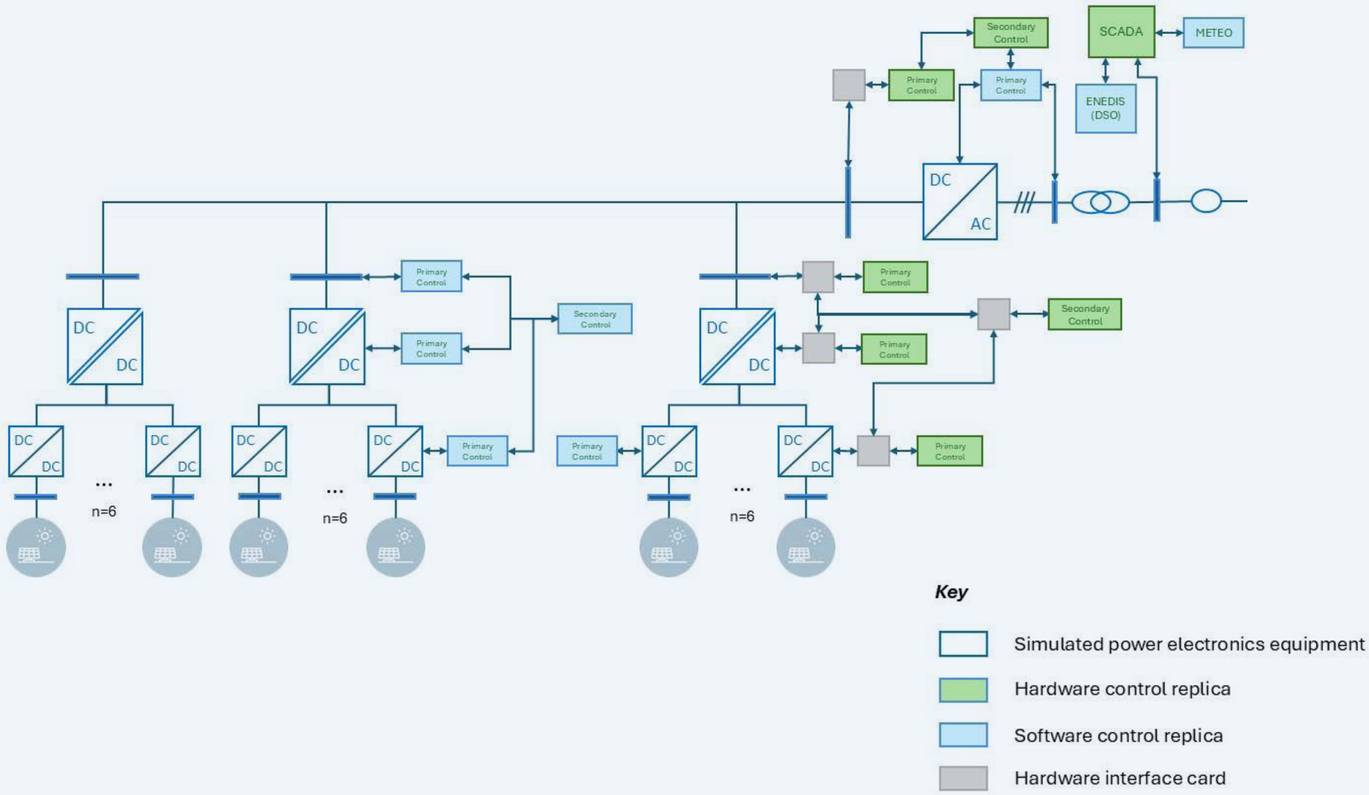
The test bench also had to integrate both software and hardware elements, ranging from elements developed in-house to black box models with no access to their code. SuperGrid Institute's expertise lies in being able to combine each of these complex modelling requirements into one global vision of the overall network.

The real-time digital twin functional architecture

The digital twin's architecture incorporates power conversion stages, control strategies, and interfacing components, enabling hardware-in-the-loop (HIL) and software-in-the-loop (SIL) simulation. The photovoltaic power system with DC grid integration was simulated on the OPAL-RT simulator environment in real time. The software controllers (blue) are either blackbox models that were directly integrated into the system or models developed from specifications while the hardware controllers (green) are the controllers which will be installed in the on-site converters. In order for the physical controllers to be interfaced with the simulator, the SuperGrid Institute team designed, developed and integrated interface cards (gray) into the test bench. The communication between all entities was achieved through a combination of wired communications (analog and digital), CANopen and ModBus TCP/IP.

This setup makes it possible to test different control strategies for PV power production like the maximum power point tracking (MPPT) algorithm for the PV DC/DC converters and the voltage regulation for the intermediate isolated MVDC converters. The MVDC bus is connected to the DC/AC conversion stage for grid synchronisation and management from ENEDIS with supervisory SCADA control, which interacts with external weather data (Meteo).

The real-time digital twin functional architecture



OPAL-RT provides advanced solutions and tailored software development

OPAL-RT's solutions are the facilitator behind SuperGrid Institute's simulation expertise. In the OPHELIA project, OPAL-RT's advanced technologies provided the functionalities required by the SuperGrid Institute team to develop the very realistic models required by the project. OPAL-RT's compatibility with multiple communication protocols allowed the team to integrate these protocols into their real-time simulator and run simulations to understand exactly how the system's different elements would interact.

The SuperGrid Institute team also drew upon OPAL-RT's personalised software development offer which in turn made it possible to achieve a very high level of precision in modelling for this specific outcome.

Test bench technical setup

The technical setup consisted primarily of three layers:

The first layer was made up of the simulated components. Various developed models were installed on the OPAL-RT real-time simulator, which incorporated:

- ✓ Averaged models for certain converters
- ✓ Detailed switched models for specific converters, using the eHS solver from OPAL-RT
- ✓ Models for transmission lines and circuit breakers
- ✓ A communication setup using two protocols: CAN and Modbus TCP
- ✓ Controller models
- ✓ Black-box control models, representing specific controller components developed by a project partner

The second layer consisted of interface cards, developed by the SuperGrid Institute HIL team, to enable the real-time simulator to communicate with external hardware.

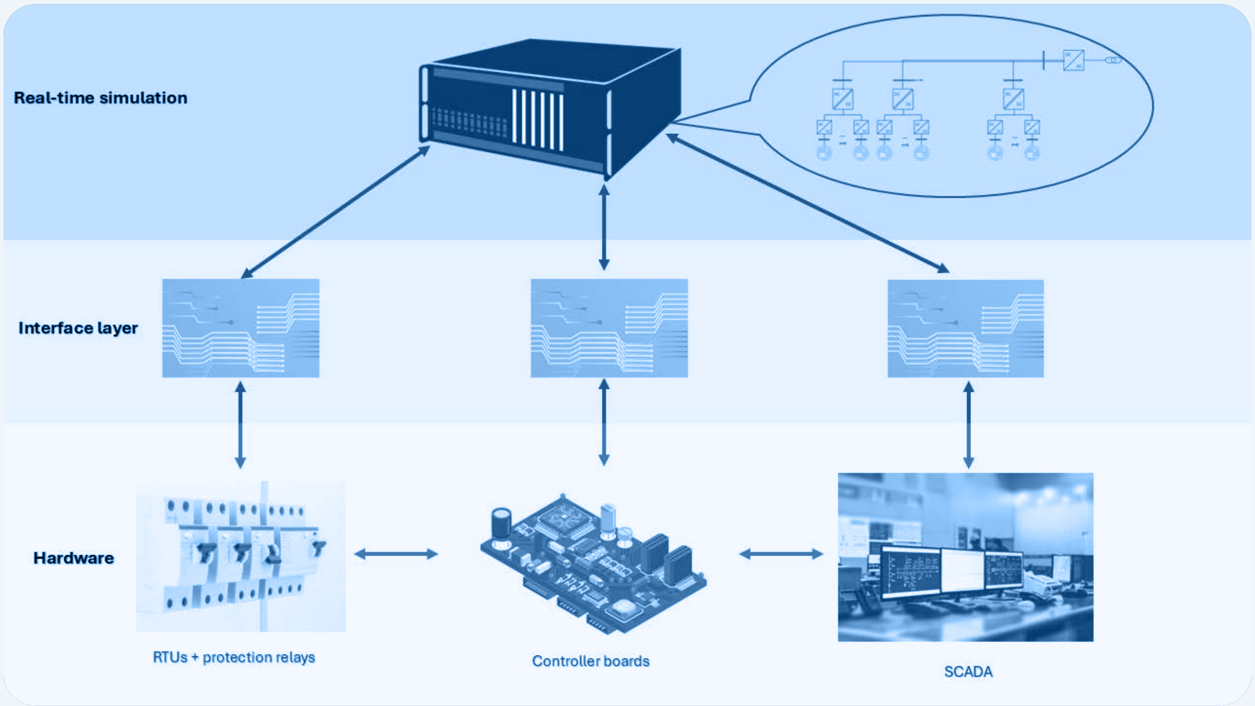
The third layer was the hardware layer made up of three types of hardware components:

- ✓ Controllers, responsible for high-voltage and medium-voltage control in the network
- ✓ Protection relays and RTUs (Remote Terminal Units)
- ✓ The network SCADA system

Each hardware component communicated with the real-time simulator through the interface layer using various communication protocols.

The OPHELIA digital twin setup at SuperGrid Institute

After a year's work, our real-time test bench is now fully operational and ready for the controllers' validation phase where it will be used to validate the functionality of major controllers in the demonstrator system.



Once this phase is complete, the control software is up to date and the controllers have been installed in the demonstrator, the test bench will evolve into the digital twin of the project's entire network. This digital twin will be maintained throughout the duration of the rest of the OPHELIA project and will notably be used to:

- Carry out future technical analysis
- Test new features and controllers
- Continue research and development
- Diagnose potential faults
- Perform economic analysis (energy produced)
- Test and validate protection algorithms
- Development energy and power management systems

Ready to innovate?

For over two decades, OPAL-RT TECHNOLOGIES has been a global leader in real-time simulation and hardware-in-the-loop (HIL) testing. Since 1997, OPAL-RT has empowered engineers and researchers with accessible, innovative, and customized simulation technology—bridging the gap between modeling and real-world applications. By leveraging high-performance computing, OPAL-RT accelerates the development of advanced solutions in energy, automotive, aerospace, and beyond. With our ISO 9001:2015 certification and a strong commitment to sustainable development, we're not just developing technology—we're building a better future, together.

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