Real-time simulation for HVDC interoperability – first experience with the InterOPERA project

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Inter OPERA
Enabling multi-vendor HVDC grids

Co-funded by the European Union

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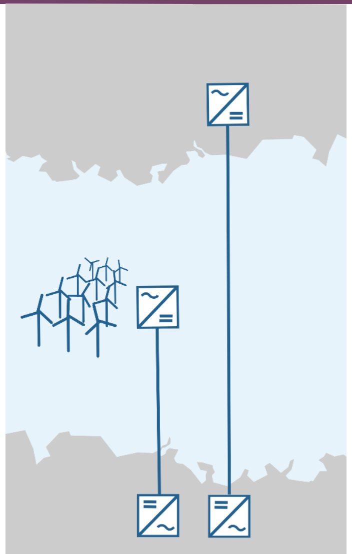
EC objective for climate neutrality & energy independence

= massive deployment of 300 to 450 GW of offshore wind by 2050

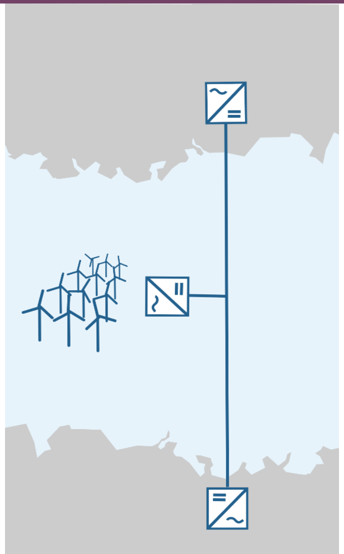
Where we are now

Connection through **point-to-point HVDC transmission**



Suitable for connection far from the shore
Power flow control
System stability support

First multi-terminal hybrid HVDC systems being deployed, but as **single vendor**



Increased market coupling, reduced societal costs
Reduced footprint, increased social acceptance

Gap

Multi-vendor HVDC interoperability

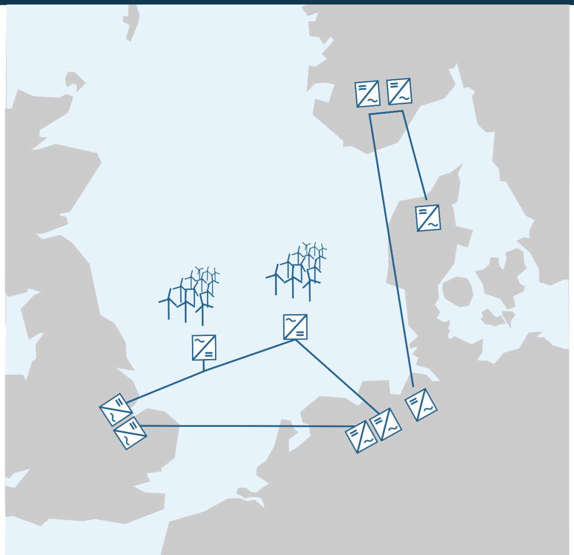
with grid forming capability

Procurement framework

InterOPERA
Enabling multi-vendor HVDC grids

Where we need to be

Scalable multi-terminal HVDC systems serving the connection of offshore wind generation to onshore consumption centres



Higher renewables integration capacity
Higher resilience and efficiency
Potential increased speed of deployment

InterOPERA
Enabling multi-vendor HVDC grids

Start date
1 January 2023

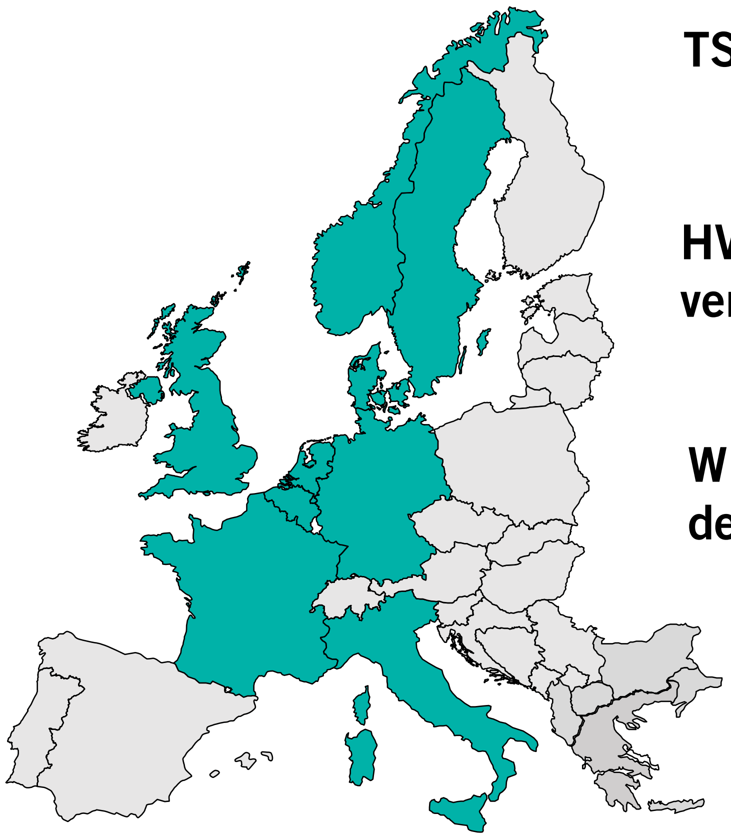
End date
30 April 2027

Enabling multi-vendor HVDC grids

Interoperability standards
Real-time physical demonstrator
Procurement framework

Total cost ~ 70 M€

EU contribution
~ 50 M€



TSOs
amprion, Rte, ENERGINET, TenneT, 50hertz, Terna Driving Energy, Statnett

HVDC vendors
SIEMENS energy, GE, Scibreak, Hitachi Energy, T&D europe

Wind developers
Wind EUROPE, Ørsted, equinor, VATTENFALL

WTG vendors
Vestas, SIEMENS Gamesa

Research & innovation
university of groningen, SuperGrid Institute (Shaping power transmission), TU Delft

InterOPERA Objectives

2023 | PHASE 1 | 2025 | PHASE 2 | 2027

WP1 – Standardised interaction study processes
- Standard process for interaction studies (O2)
- Minimum technical requirements for HVDC and PPMs models and replicas (O2)
- Functional specifications for standardised offline and real-time simulation platforms (O2)
- Guidelines to limit interoperability issues (O2)

WP2 – C&P functional framework and integration tests
- Basic functional requirements for multi-vendor HVDC Grid Systems and Subsystems, integrating PPMs (O1)
- Recommendations to Grid Codes and technical standards (O1)
- Multi-vendor benchmark and verification test system (O6)

WP3 – Multi-vendor multi-terminal demonstrator
- Real-life inspired and forward-looking offshore grid design, demonstrator definition and guidance for coordinated HVDC system planning(O4)
- Multi-vendor HVDC Grid physical demonstrator (O3)
- Validated detailed functional spec. for the demonstrator (O1)

WP4 – Multi-vendor cooperation framework
- Preliminary multi-vendor cooperation framework (O6)
- Multi-vendor cooperation framework (O6)

WP5 – Procurement strategy and future projects preparation
- Usable procurement documents and tender processes (O4)

TODAY

WP1 objectives

- To define **documented interface and requirements** for manufacturers converter models and C&P cubicles
- To provide **functional specifications** for a standardized platform to perform interaction studies, before implementing and validating it.
- To establish a **standard process** for **interaction studies**
- To adapt and generalize **the approaches, requirements and processes** developed for multi-vendor HVDC system

WP1 content and planning

M1 | M6 | M12 | M18 | M24

Task 1.1 – Specifications of models / replicas, sim. platforms and studies

- Subtask 1.1.1 – Definition of interfaces and requirements for models and C&P replicas
- Subtask 1.1.2 – Requirements for simulation platforms to perform interaction studies
- Subtask 1.1.3 - Definition of standard process for interaction studies

Task 1.2 – Preparation of models and simulation platforms - Dry-run of system integration tests and interaction studies

- Subtask 1.2.1 - Provision of template models and control cubicles by vendors
- Subtask 1.2.2 - Development of simulation platforms to perform offline and real-time interaction studies
- Subtask 1.2.3 – Dry run of interaction studies

Task 1.3 – Development of practices and guidelines to limit interoperability issues

Model and interactions studies for MVMT

New challenges for models and replicas for interaction studies

Long-term use:
- extension of the grid
- replacement
- post-event analysis
- validation

Performing tests with different vendors' provision at the same time with the same simulation tool

Sharing models and results

-Tool independant C&P models and replicas

Documentation of interfaces for models:

Use of the IEEE/ CIGRE JWG B4.82 *Guidelines for Use of Real-Code in EMT Models for HVDC, FACTS and Inverter based generators in Power Systems Analysis*

-Validation against different references

Balance between confidentiality *(to respect vendors' IP)* and accessibility *(for the system integrator to perform the tests)*

→Clear requirements on data accessibility

Task1.1
Specifications of models / replicas, sim. platforms and studies

- Requirements for EMT offline models, SiL models and C&P replicas
  - AC/DC converter stations,
  - DC switching stations,
  - Power Park modules
  - DC Grid controller,

- Type of models, Frequency range of validity, level of details
- Modularity, multiple instantiation, simulation time step, accessibility
- Format of C&P offline models: Tool independant → DLL approach with documented interface*

→Fulfilment of requirements are tested with PSCAD, EMTP, RTDS and HYPERSIM

*IEEE/CIGRE DLL interface from Cigre B4.82 (“Guidelines for Use of Real-Code in EMT Models for HVDC, FACTS and Inverter based generators in Power Systems Analysis”)

Building an MVMT system demonstrator

Minimum requirements proposal for C&P physical replicas

A full set of requirements has been written to describe

- Functions to be included in replicas
- Confidentiality management in the HiL platform
- How the interfaces with the Real-time simulators should be documented

The target is to build a real-time simulation test setup as shown on the figure

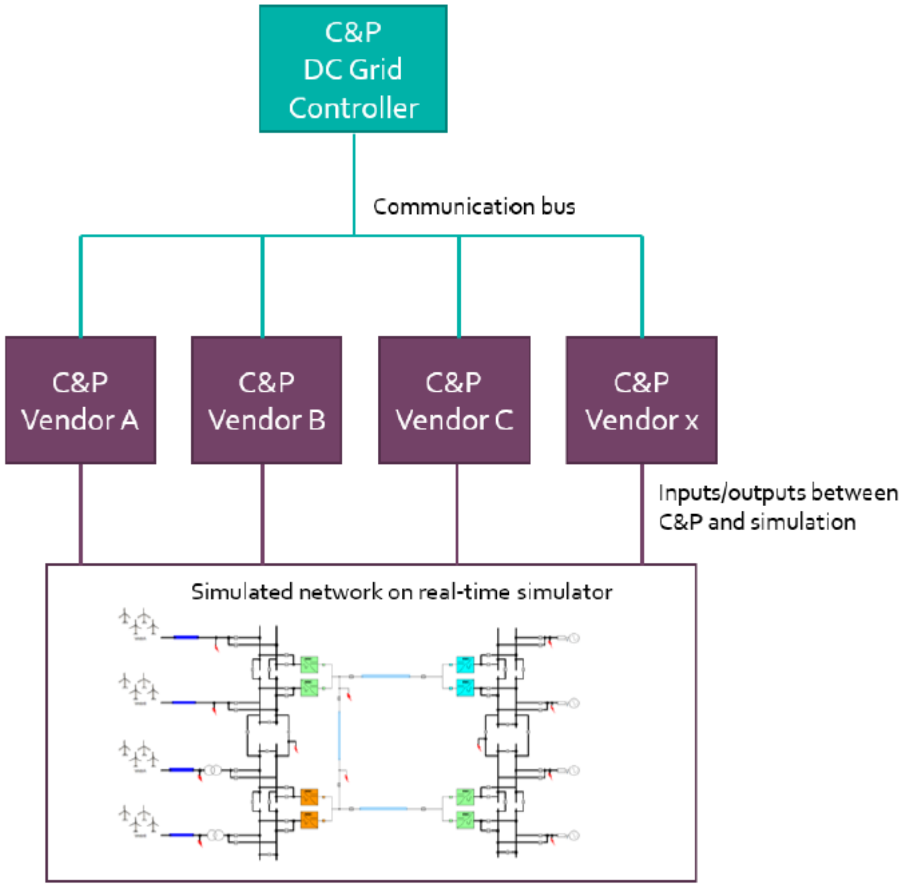
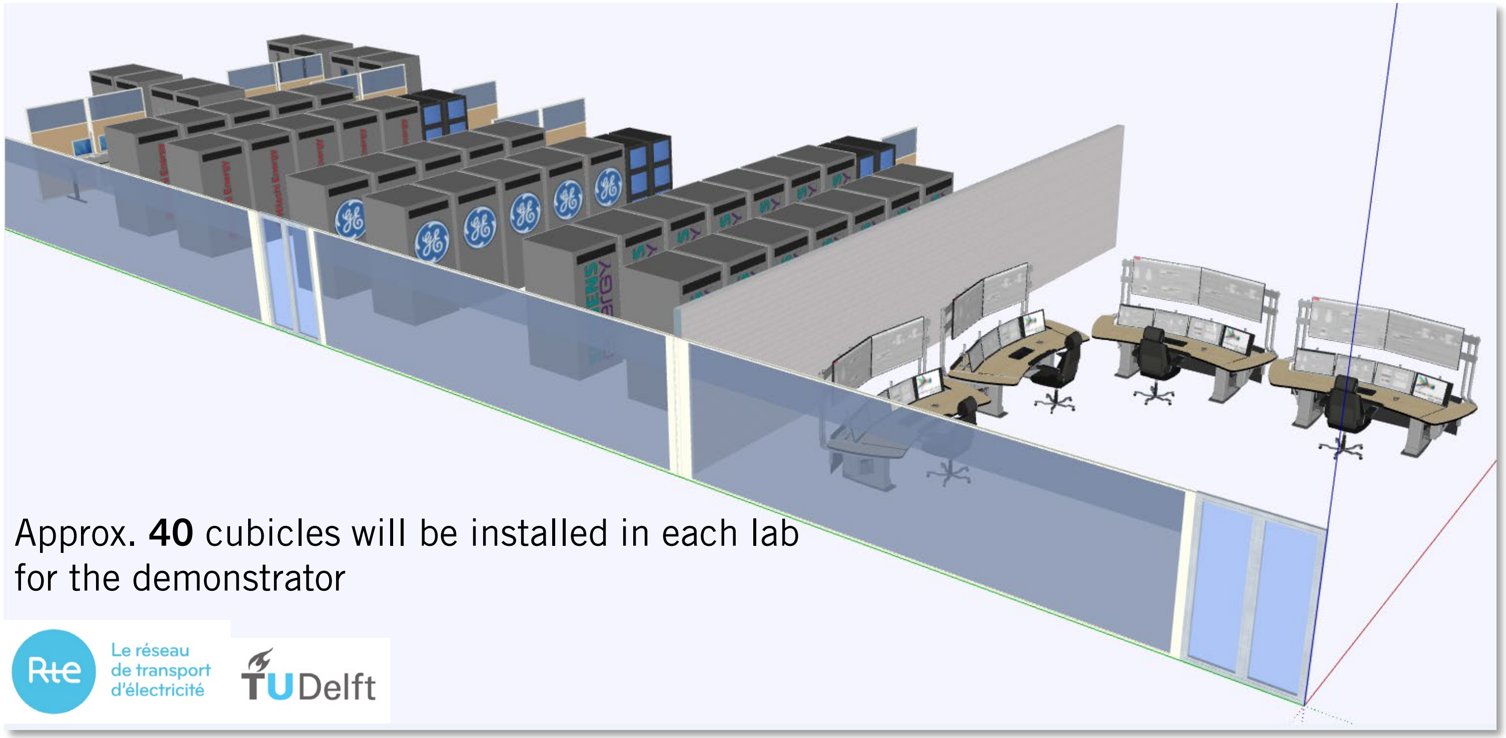


Figure 10 – Principle of the real-time simulation test setup

Building an MVMT system demonstrator

Development of a real-time demonstrator in InterOPERA



Approx. **40** cubicles will be installed in each lab for the demonstrator

Rte Le réseau de transport d'électricité

TU Delft

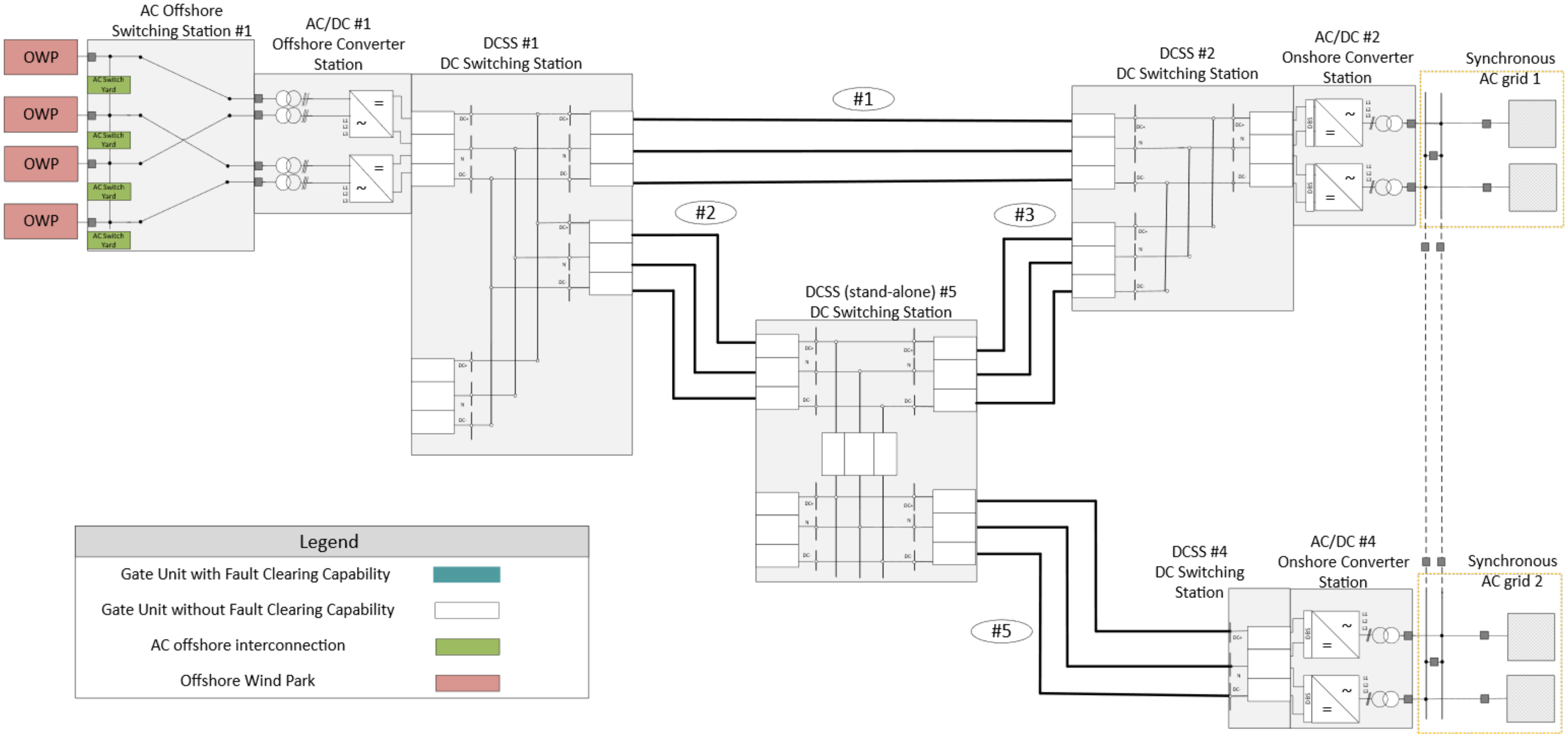
Replicas, as Hardware-in-the-Loop
or as Software-in-the-Loop
will be provided by:

Hitachi Energy | Siemens Energy | GE Vernova
Scibreak | SuperGrid Institute
Vestas | Siemens Gamesa Renewable Energy

to demonstrate the MTMV concept in real-time

Demontrator topology

Base topology (variant 2)



Offline models and HiL/SiL solutions planning for development and dry run tests

Jan 24 → Dec 24

Offline

- Vendor internal activities
- Test program preparation
  Tool preparation
- Single-vendor tests
- Multi-vendor tests
  - Not electrically connected
- Some interaction tests

Real-time

- Vendor internal activities
- Testing activities @vendor facility
- Installation – commissioning
- Lab facility preparation
- Single-vendor tests
- Multi-vendor tests
  - Not electrically connected

Offline models and HiL/SiL solutions – Dry run tests

- Checking adequacy with requirements established in the WP1
- Testing models separatly (offline and realtime)
- Type of tests performed:
  - System energisation
  - Change of operation setpoint (active / reactive power, voltage regulation)
  - Grid disturbances (grid frequency ramp, non-permanent fault, grid phase shift)
  - Permanent fault to check protection system

Building an MVMT system demonstrator

Siemens Energy has delivered replica cubicles on July 2024

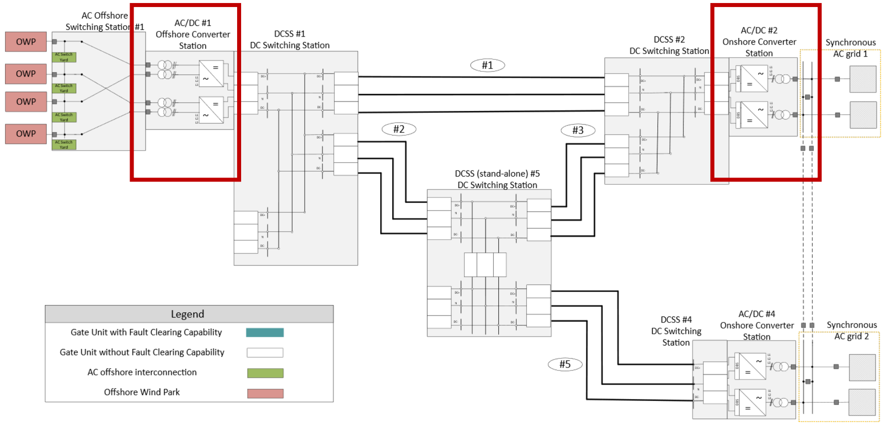
Supergrid Institute has delivered the DC grid controller in September 2024

Hitachi Energy's cubicles to be delivered on Oct 9th, 2024

Siemens' replica has been connected to RTDS and Hypersim simulators with identical interfaces

SIEMENS Energy C&P replica installed in RTE lab in July 2024 for InterOPERA project

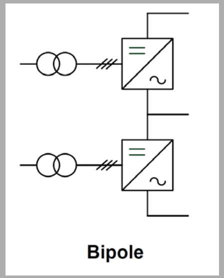
The C&P replica can control an offshore or an onshore station



Interfaces between Siemens Energy replica and the RTS

Realtime Simulator

Digital / Analog signal hardwired interface



Aurora protocol

Breaker & tap position commands ←

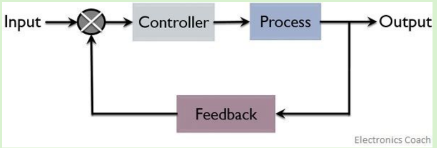
Voltage and current measurement (AC & DC) →

Number of SM blocked (1/valve)
Number of SM to insert (1/valve) ←

→ *Equivalent SM capacitor voltage (1/valve)*

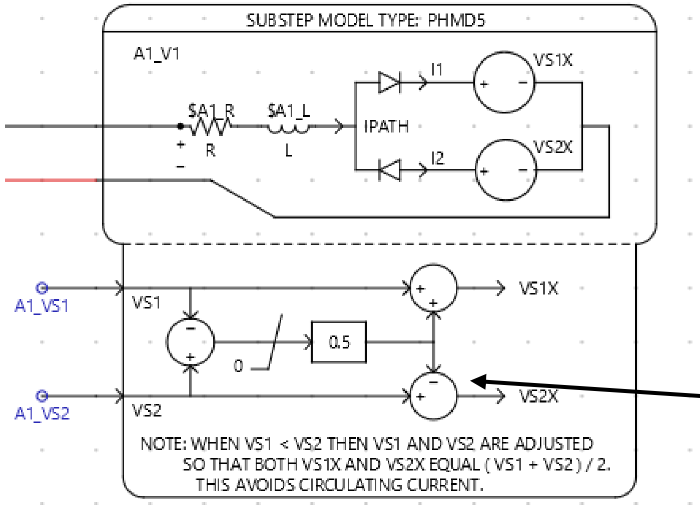
C&P System
Replica

Digital / Analog signal hardwired interface



Aurora protocol

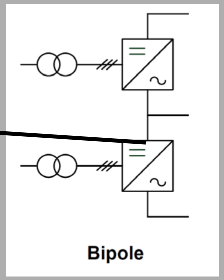
Interfaces between Siemens Energy replica and the RTS



Valve aggregated model [1]

Realtime Simulator

Digital / Analog signal hardwired interface



Aurora protocol

Breaker & tap position commands

Voltage and current measurement (AC & DC)

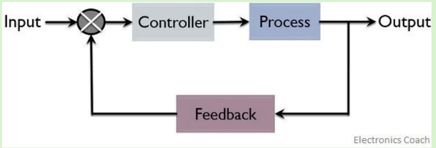
Number of SM blocked (1/valve)
Number of SM to insert (1/valve)

Equivalent SM capacitor voltage (1/valve)

C&P System

Replica

Digital / Analog signal hardwired interface

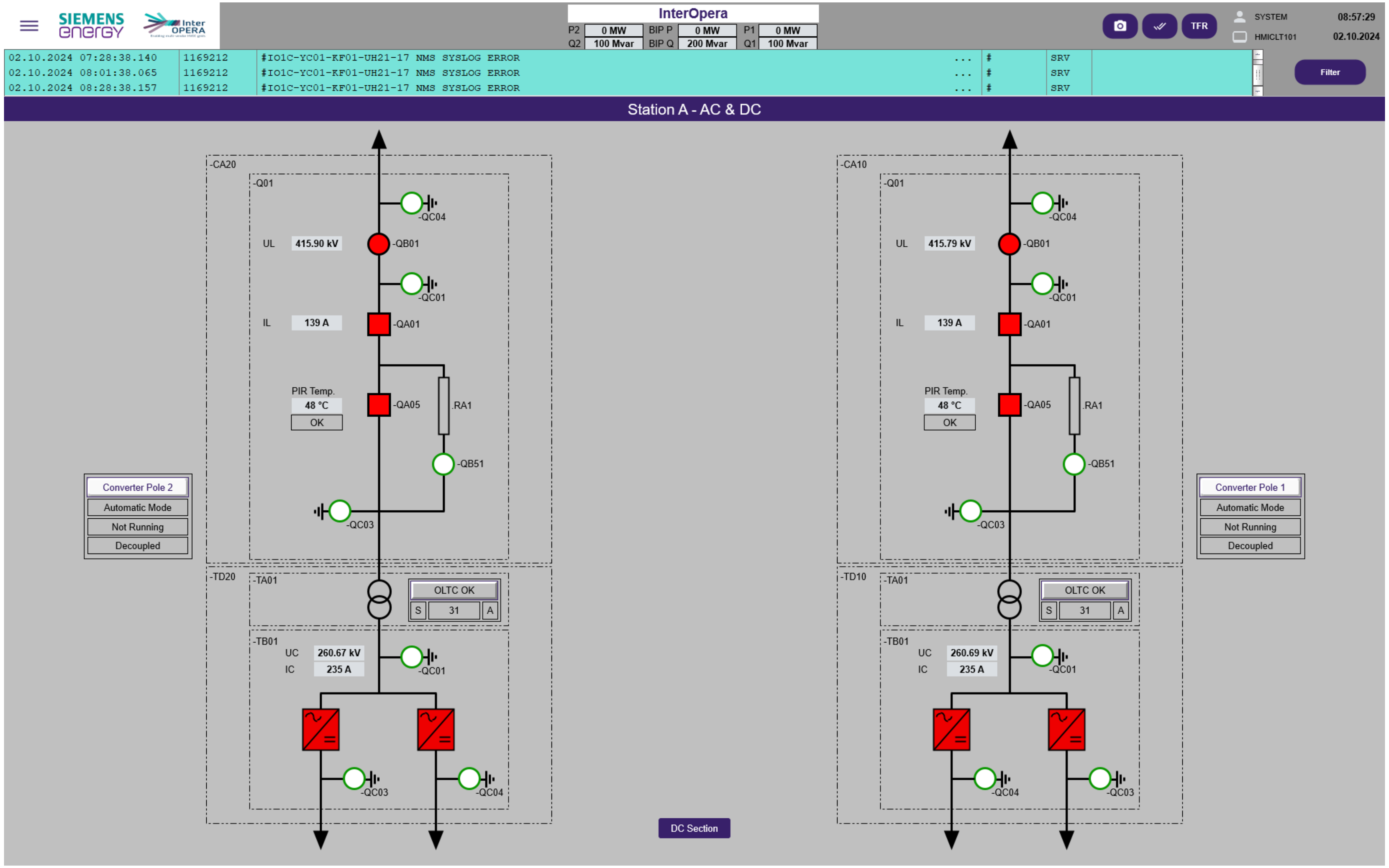


Aurora protocol

[1] Venjakob, Otmar et al. "Setup and Performance of the Real-Time Simulator used for Hardware-in-Loop-Tests of a VSC-Based HVDC scheme for Offshore Applications." (2013)

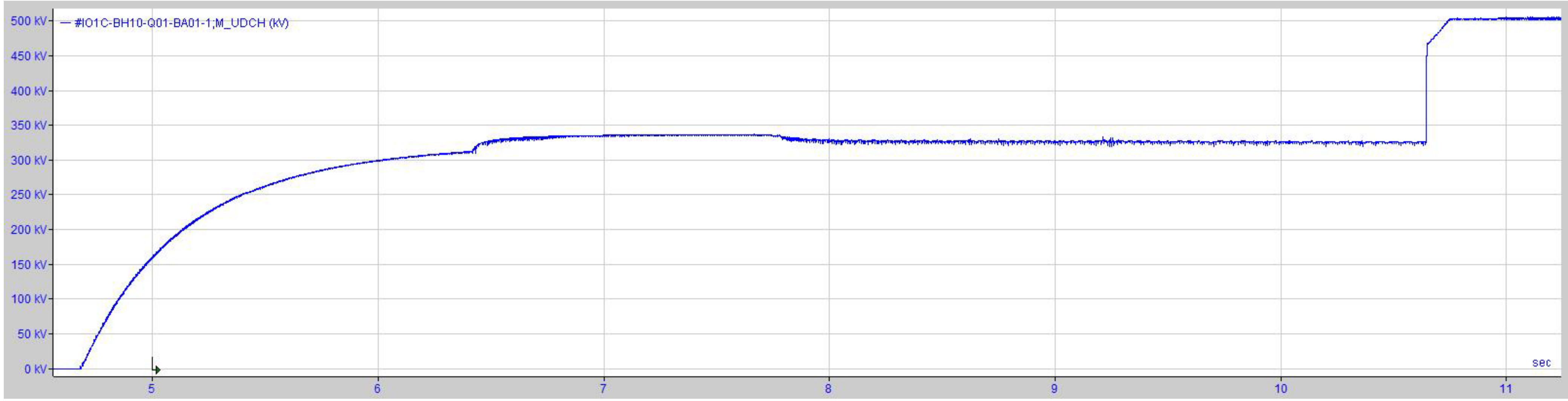
Siemens Energy replica

BIPOLE CONVERTER (HMI view)

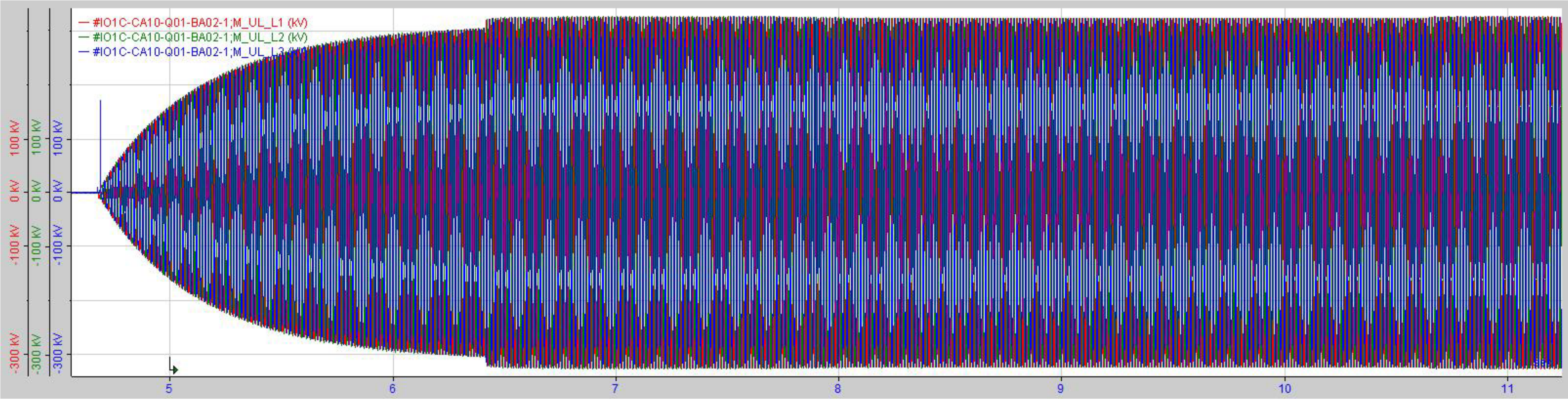


Single vendor tests: pole energisation (STATCOM operation)

Positive Pole dc voltage

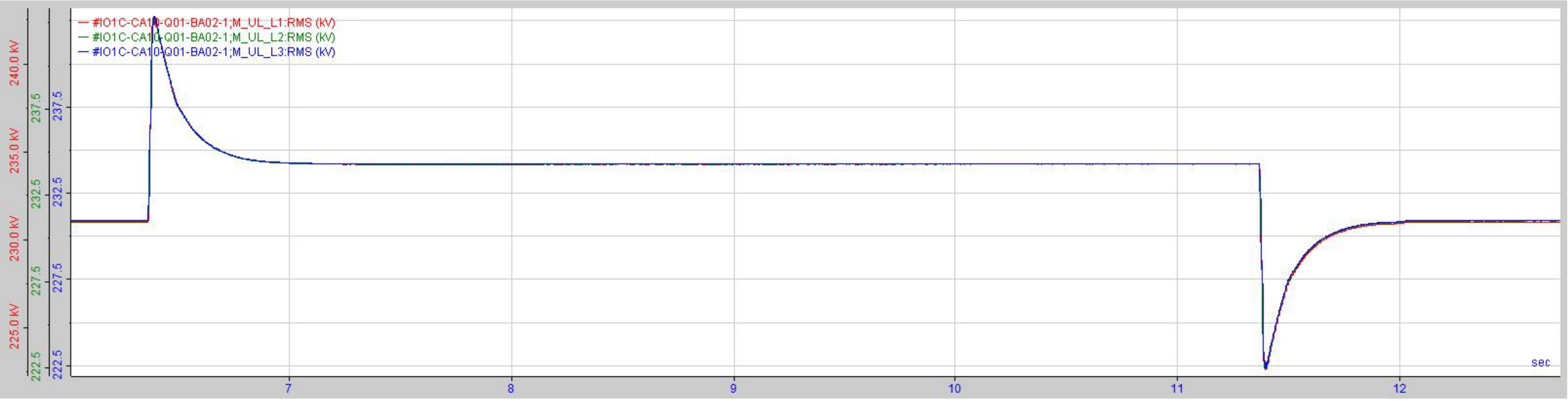


Primary AC grid voltages

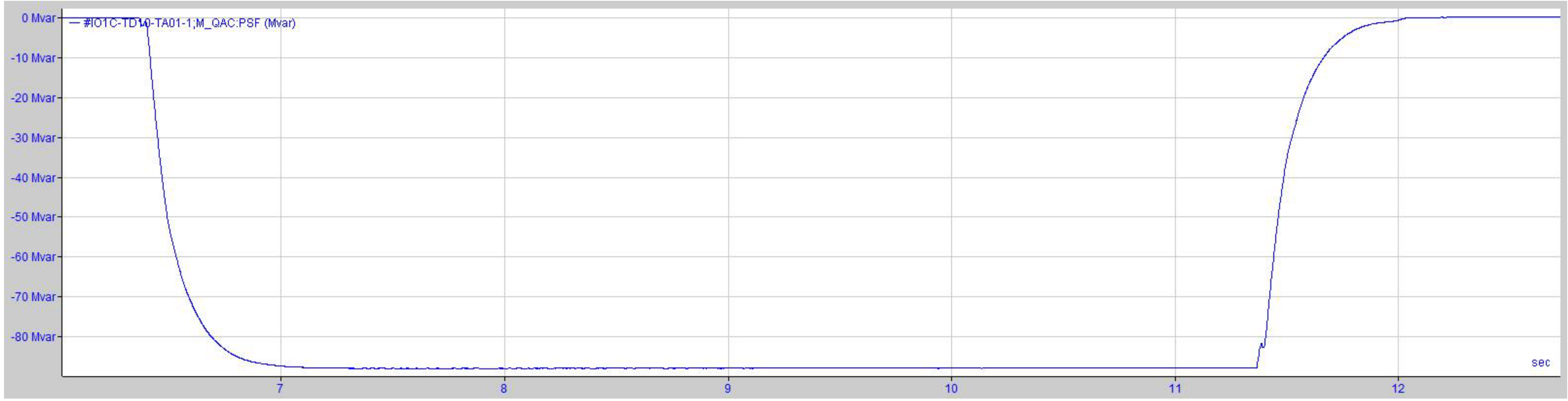


Single vendor tests: voltage control (weak grid)

RMS
Grid LG voltages



Reactive power response



Next steps

- Dry run tests of other vendor's replicas with RTDS and HYPERSIM
- Interface all replicas to a single simulator and test of their interface with the DC grid controller
- Implementation of the 3-terminal realtime demonstrator
- Performing the interaction studies

Thank you for your attention

source: interopera.eu