InterOPERA

Enabling Interoperability of Multi-Terminal Multi-Vendor HVDC Grids

2025 EMTP International User Conference

Carmen Cardozo – RTE, France

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ABOUT INTEROPERA

The InterOPERA project will define technical frameworks and standards for electricity transmission and accelerate the integration of renewable energy. Ensuring that HVDC systems, HVDC transmission systems or HVDC components from different suppliers can work together – making them "interoperable"- is a top priority to accelerate Europe's energy transition.

Co-funded by
the European Union

DISCLAIMER:

PROJECT DETAILS:

Duration: 1 January 2023 – 30 April 2027
Grant agreement: 101095874

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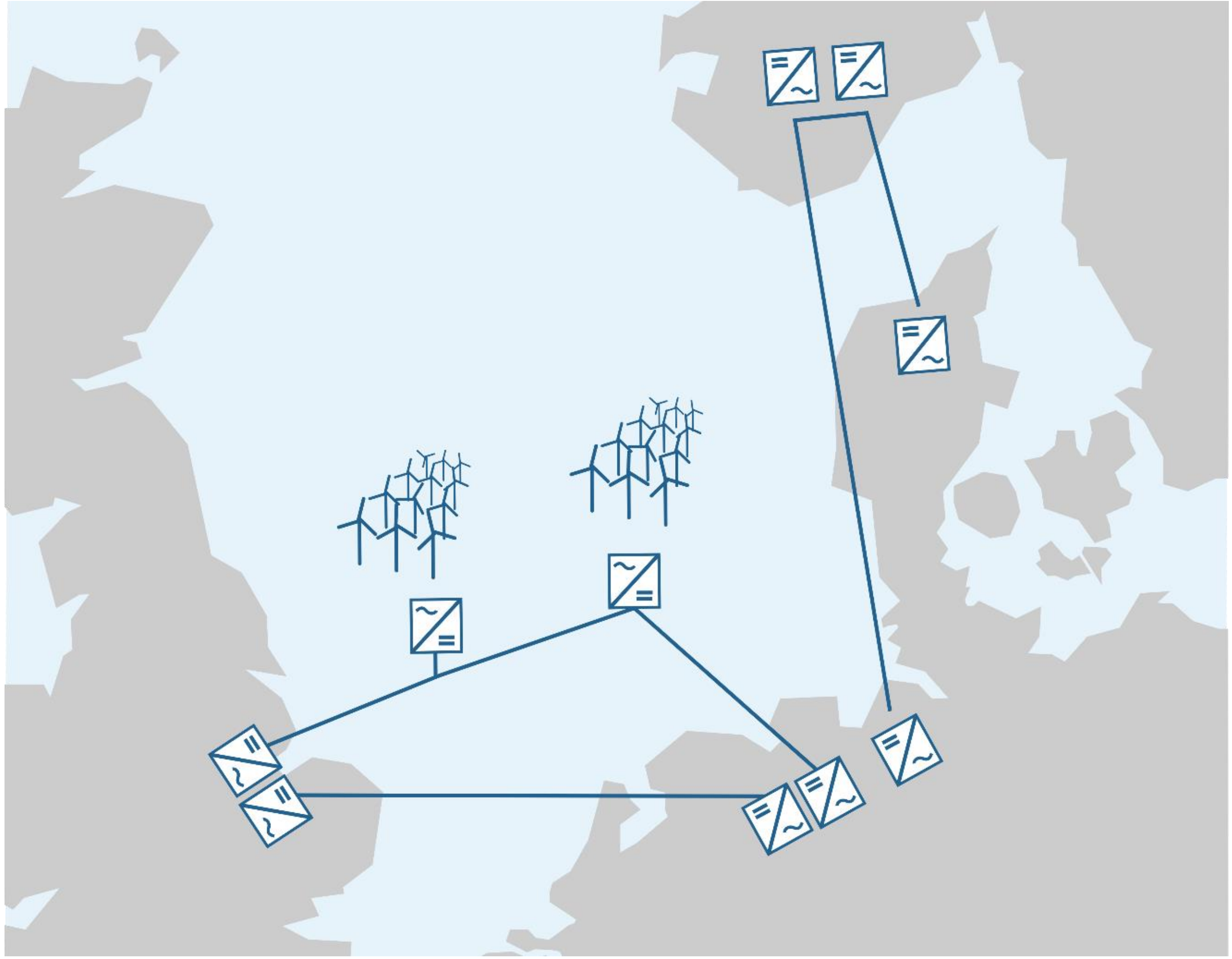
Agenda

1. InterOPERA project: objectives, partners, WPs, Demo & key outcomes

2. Functional requirements for Multi-terminal Multi-vendor HVDC grids

3. The role of EMT simulation in HVDC interaction & grid design studies

4. Takeaways



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InterOPERA project

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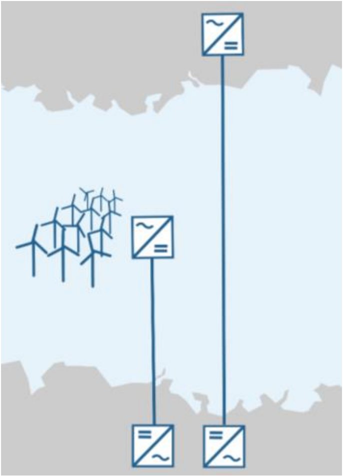
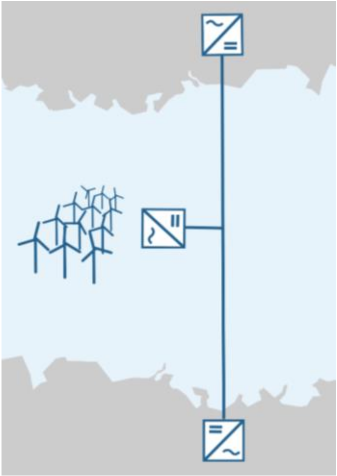
EC objective for climate neutrality & energy independence = massive deployment of 300 to 450 GW of offshore wind by 2050

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



Connection far from shore
Power flow control
System stability support

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



Increased market coupling and social acceptance.
Reduced costs & footprint

Multi-vendor HVDC interoperability

Grid forming capability

Procurement framework

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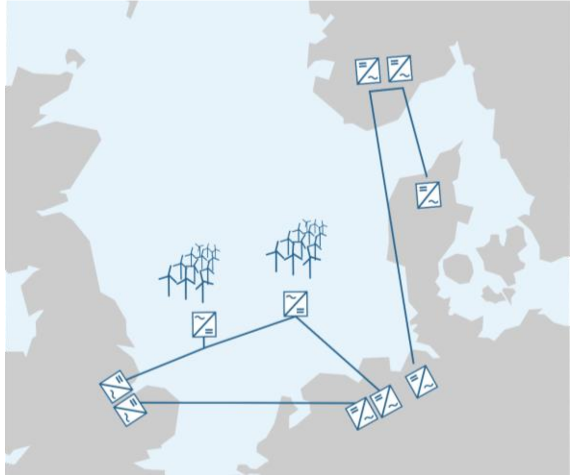
Scalable multi-terminal HVDC systems serving the connection of offshore wind generation to onshore consumption centres



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

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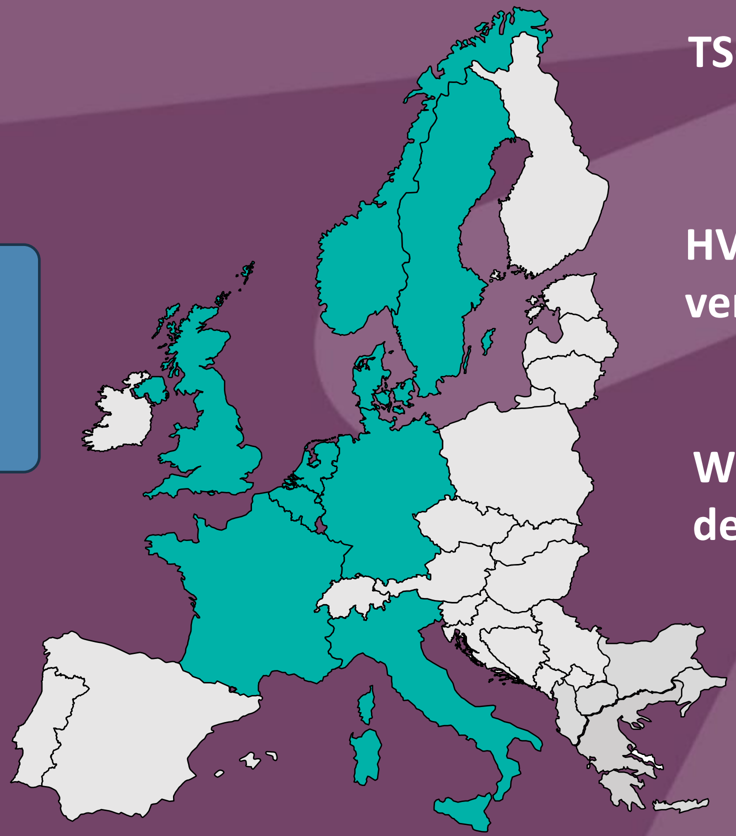
Start date
1 January 2023

End date
30 April 2027

Main target:
To enable multi-vendor HVDC grids in Europe

70 M€ budget

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

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Coordinated by SuperGrid Institute (France)
Grant Agreement 101095874

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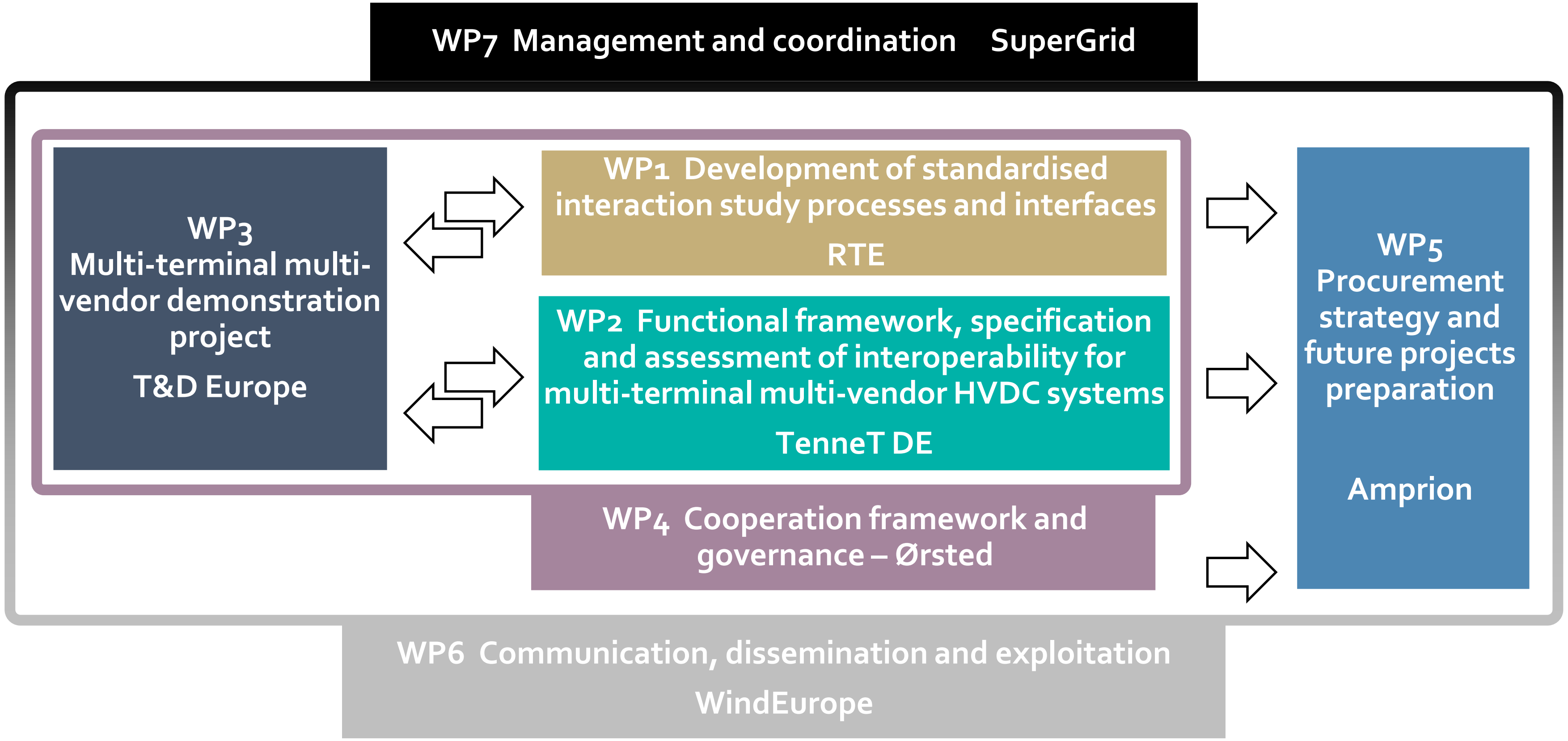
Work packages



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Multi-terminal (MT) multi-vendor (MV) HVDC demonstrator

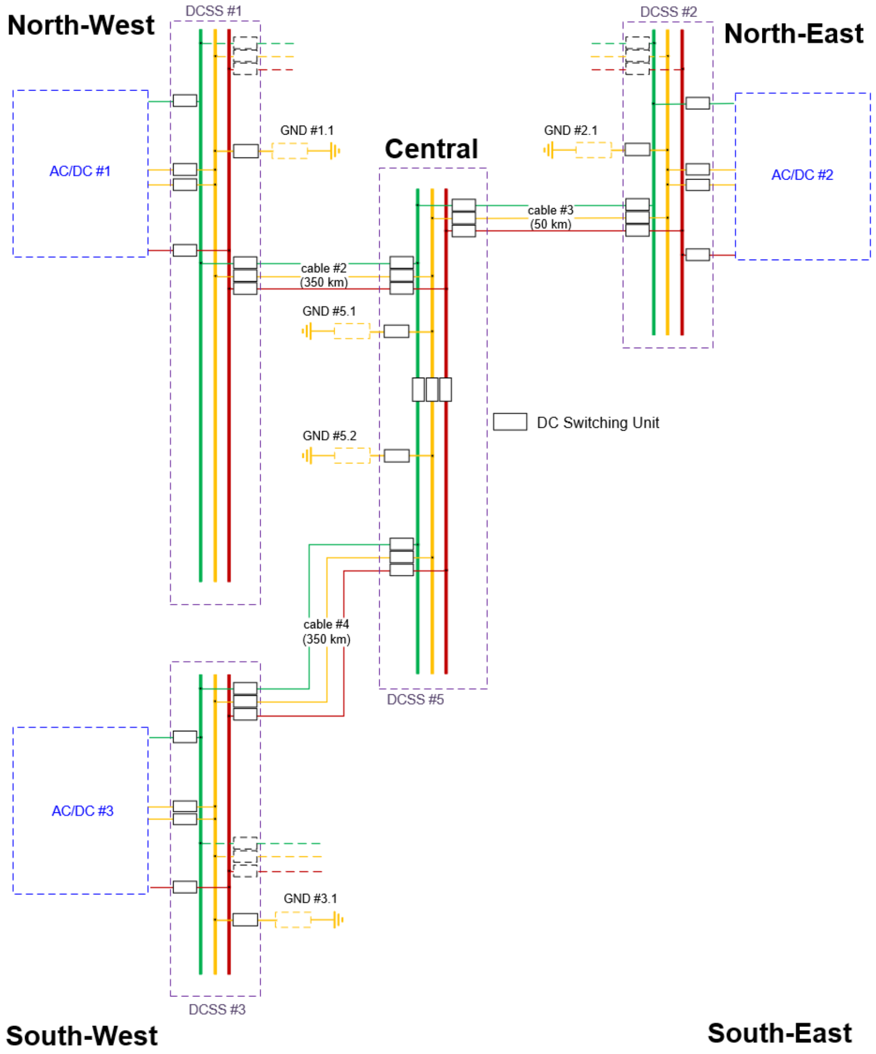
Two DC side topology: 3T (base case) & 5T (full extent, offline only)

Building blocks from different vendors:

- 3 AC/DC Converter Station 2GW – 525 kV
  - Able to operate as onshore & offshore

Configuration	North West	South West	North East
GGG	Onshore	Onshore	Onshore
GGW	Onshore	Onshore	Offshore
WWG	Offshore	Offshore	Onshore

- 4 DC Switching Station (DCSS)
- 4 Power Park Modules (PPM)
- 1 DC Grid Controller



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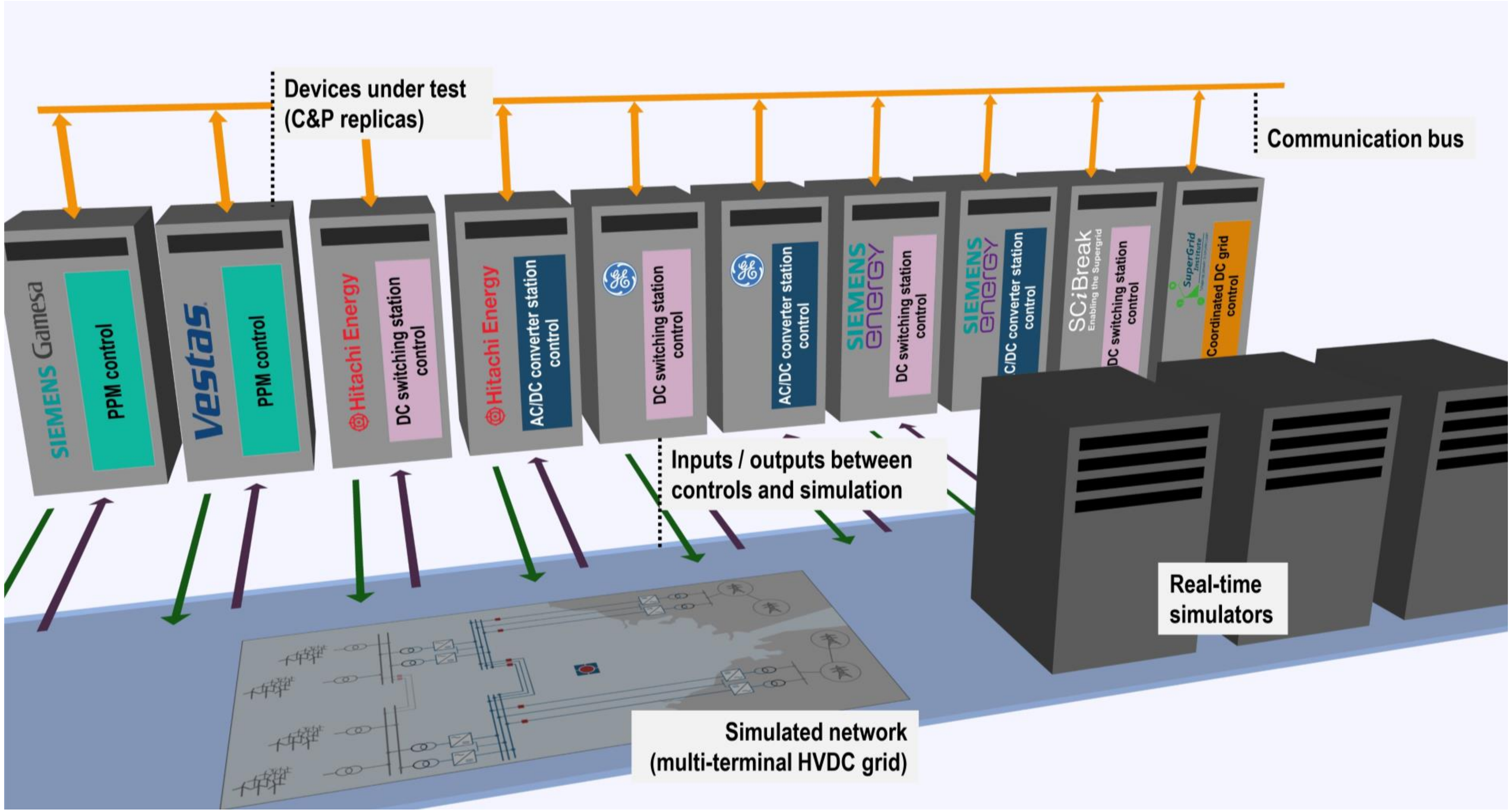
MT MV HVDC Real-Time (RT) Demonstrator



Deliverables available for download

WP1 Development of standardised interaction study processes and interfaces
RTE

Among others:

- **D1.1**: Requirements for AC/DC converter stations, DC switching stations, Power Park Modules and DC Grid controller offline models, SIL models and C&P cubicles
- **D1.2**: Platform requirements for offline and real-time simulations
- **D1.3**: Definition of a standard process for interaction studies with EMT simulation in multi-vendor project
- **D2.1**: Functional requirements for HVDC Grid systems and subsystems
- **D4.2**: Multi-Party Cooperation Framework – Draft version

WP2 Functional framework, specification and assessment of interoperability for multi-terminal multi-vendor HVDC systems
TenneT DE

WP4 Cooperation framework and governance – Ørsted

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Requirements for MT MV HVDC grids and subsystems

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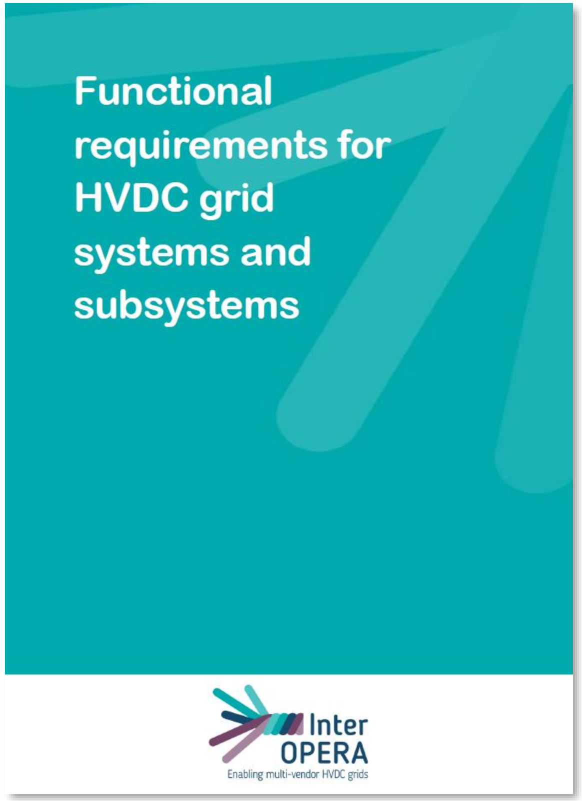
Functional framework [D2.1]

Functional Requirements for HVDC Grid Systems and Subsystems


Functional requirements for HVDC grid systems and subsystems

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Structured in four sections:

1. Sequential control
2. Continuous control
3. DC grid protection
4. AC/DC security and dispatch

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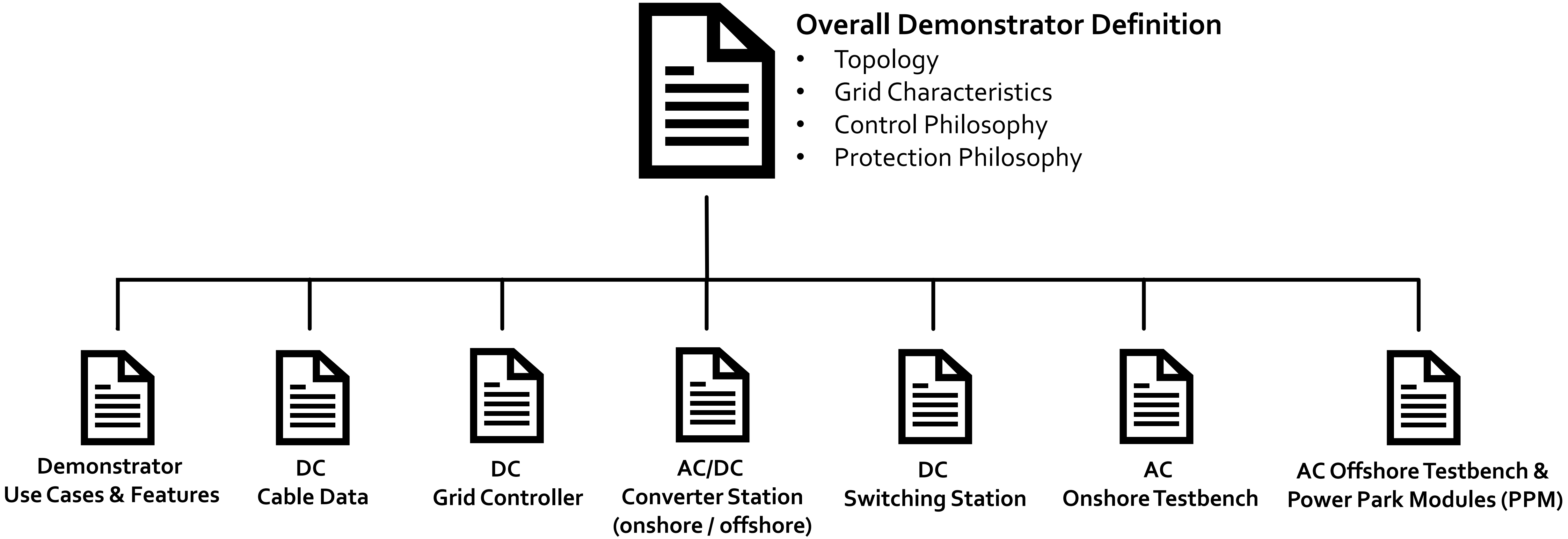
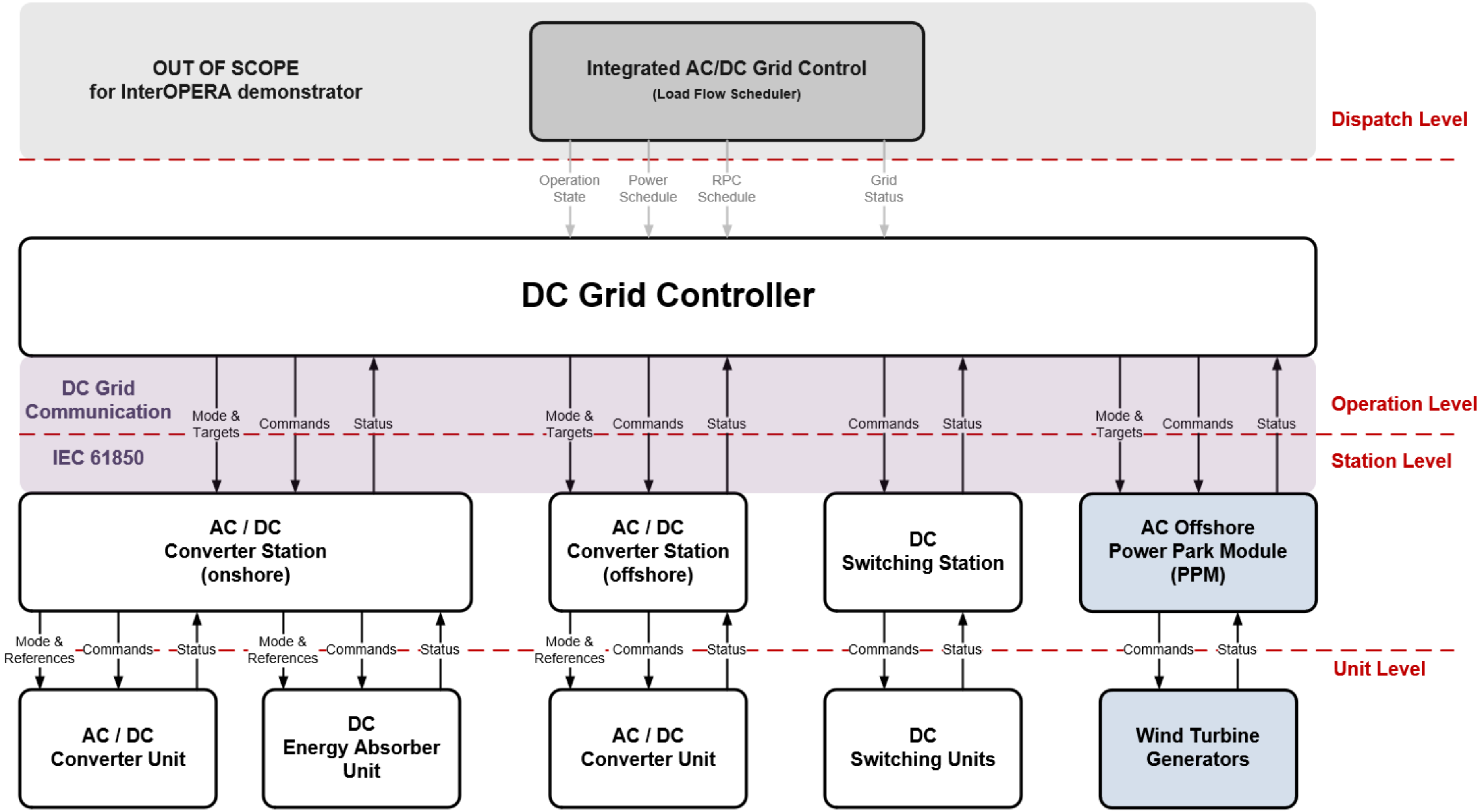
Technical specifications [WP3]



Demonstrator control hierarchy



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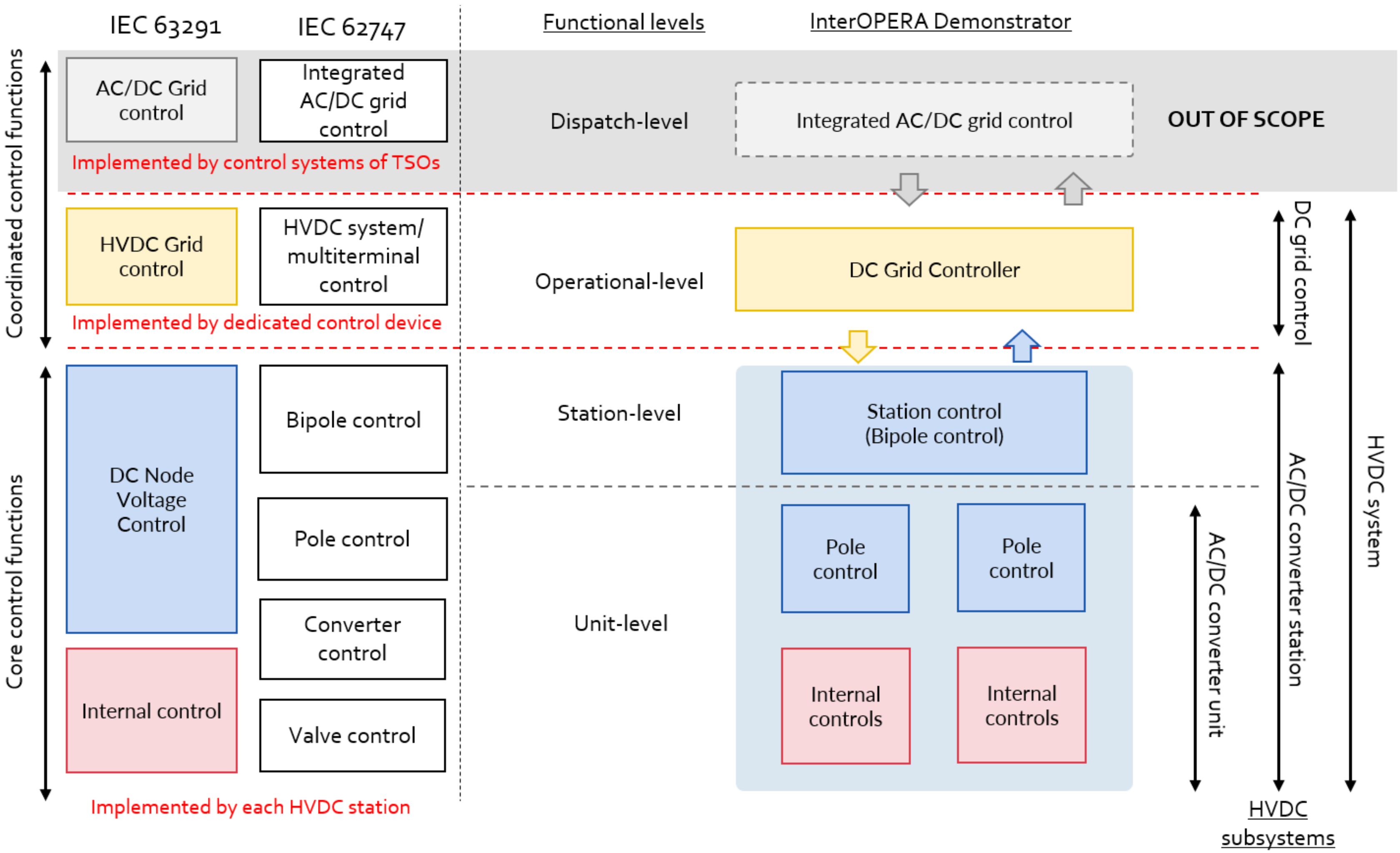
Focus on continuous control



Example of continuous control definitions [D2.1]

Operating ranges, control modes…

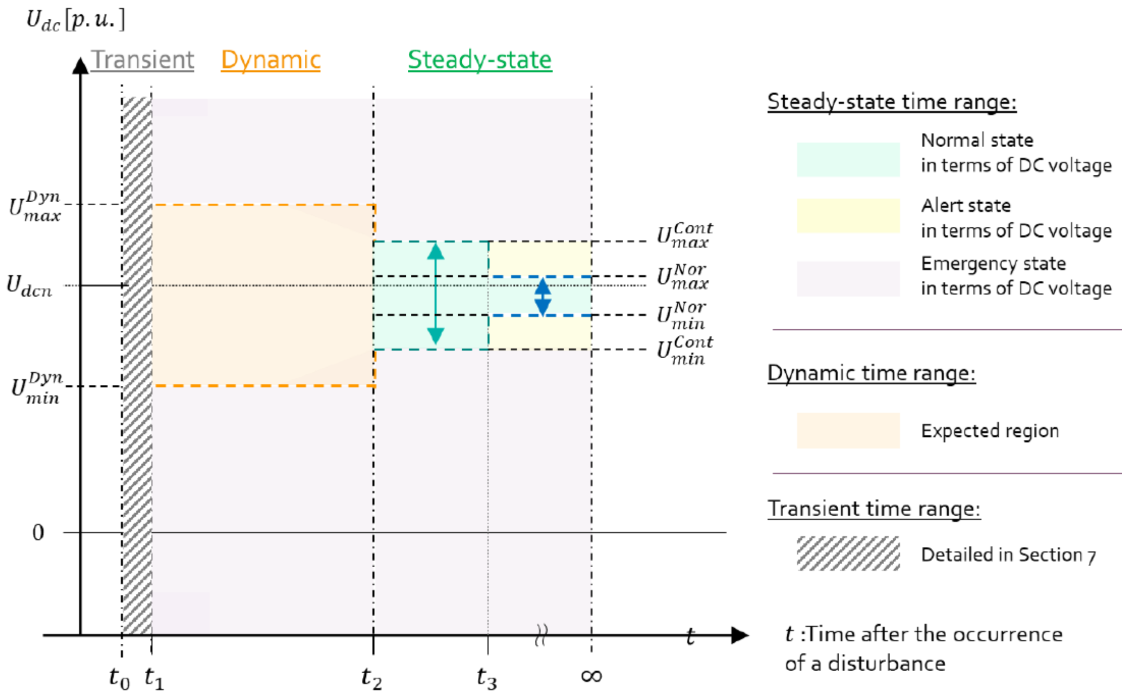
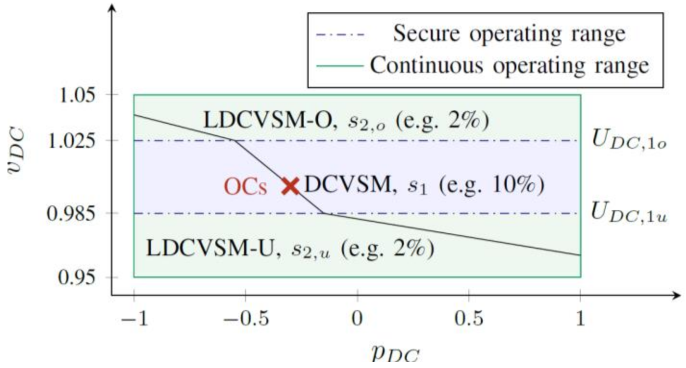


FIGURE 15: General illustration of system-level DC voltage profile.

Primary DC voltage control capabilities provided by AC/DC converter stations

- Onshore stations DC voltage – power droop
  - DC voltage sensitive mode (DCVSM)
  - Limited DCVSM (LDCVSM-U/O)



$$P_{dc} = P_{dc}^{*} + \frac{1}{S_i}(V_{dc}^{*} - V_{dc})$$

$$\forall i = 1u, 1o, 2u, 2o$$

  - Power liming mode (PLM)
  - DC voltage limited mode (DCVLM)
- Offshore stations constant active power

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Focus on DC grid protection

DC-FRT [2.1] & Fault separation zones

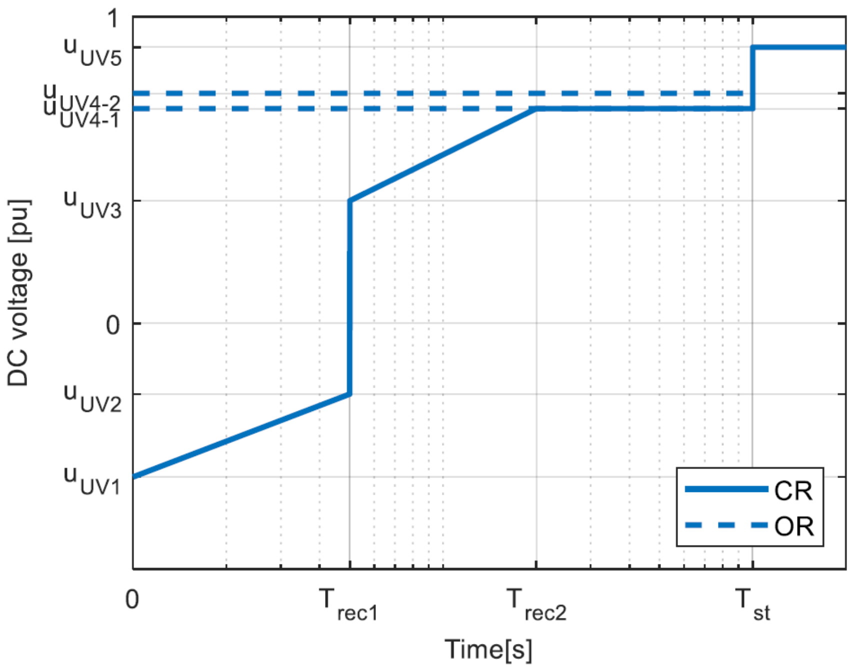
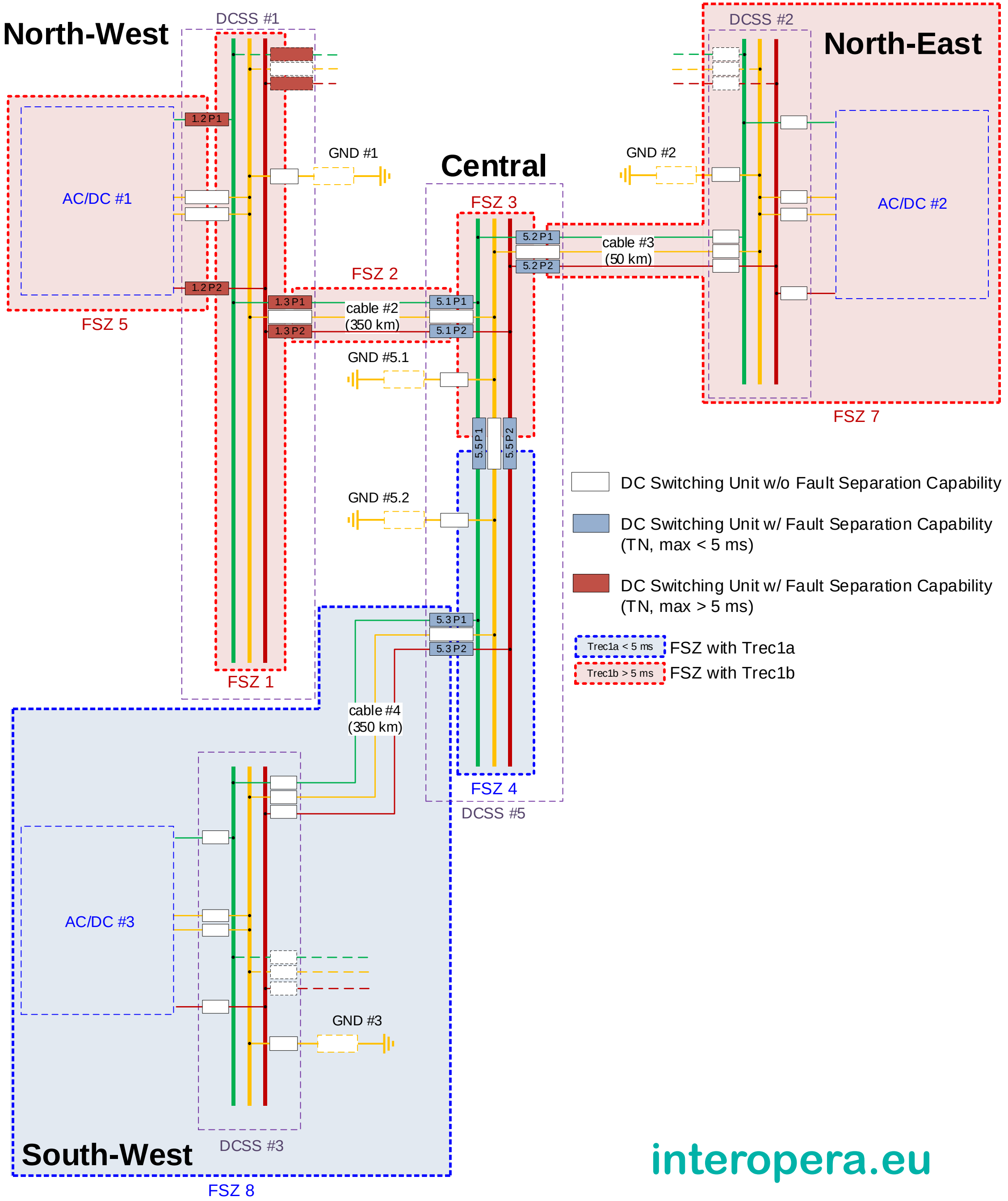


FIGURE 54 DC undervoltage FRT profile at DC-PoC for connection requirement definition, Pole-to-Ground voltages



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3

The role of EMT simulation in HVDC interaction & grid design studies

Interaction studies

Among others:

- **D1.1**: Requirements for AC/DC converter stations, DC switching stations, Power Park Modules and DC Grid controller offline models, SIL models and C&P cubicles
- **D1.2**: Platform requirements for offline and real-time simulations
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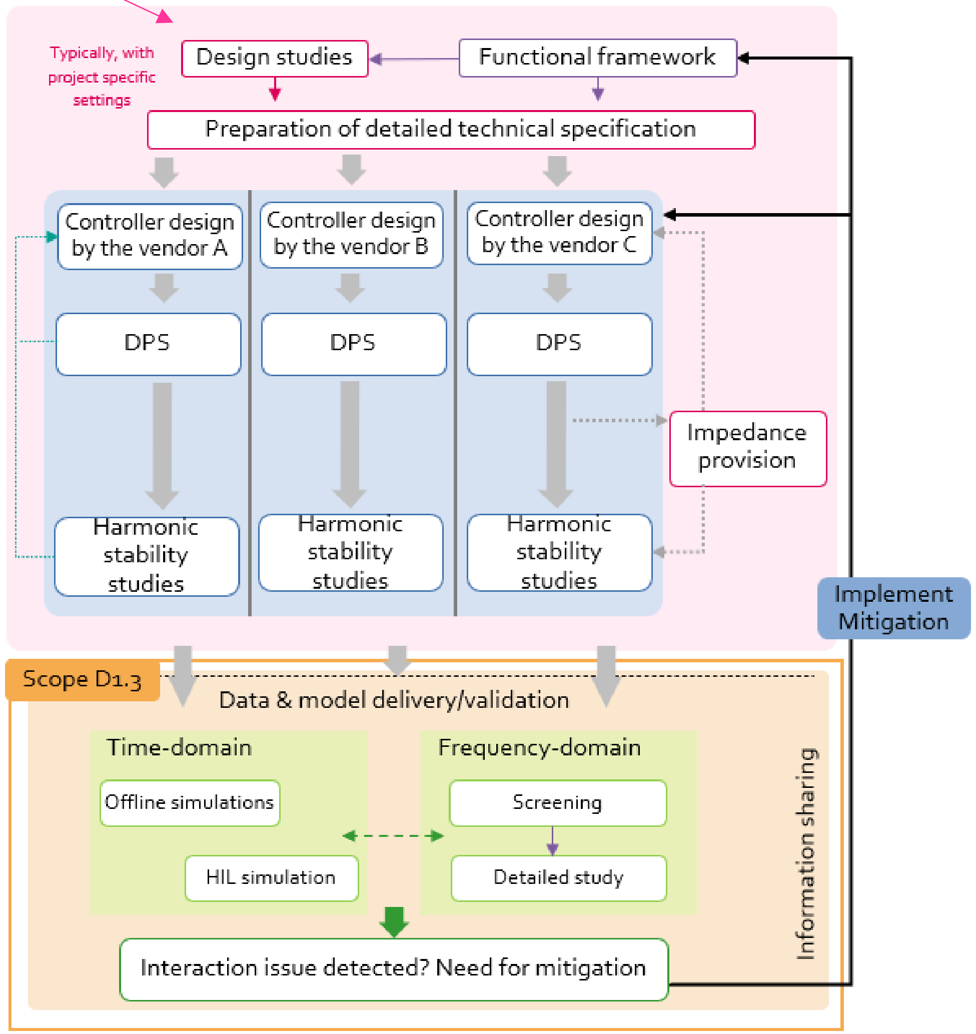
HVDC interaction & grid design studies

Various study packages at different project phases, as well as the required multi-party organisation. For **interactions studies**:

1. Near steady-state studies
2. Energisation, de-energisation and grid reconfiguration studies
3. Withstand studies
4. Small-signal stability studies

Need for *suitable* models!



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WP1 Model and platform requirements

Among others:

- **D1.1**: Requirements for AC/DC converter stations, DC switching stations, Power Park Modules and DC Grid controller offline models, SIL models and C&P cubicles
- **D1.2**: Platform requirements for offline and real-time simulations
- **D1.3**: Definition of a standard process for interaction studies with EMT simulation in multi-vendor project
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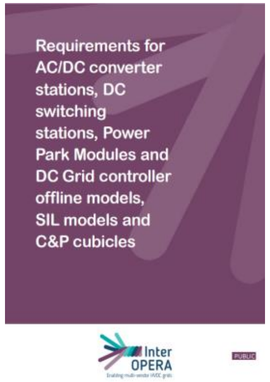

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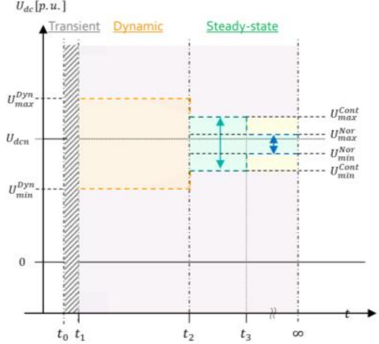
Key messages on model & platform requirements

WP1 addresses the need for requirements consistent among all stakeholders

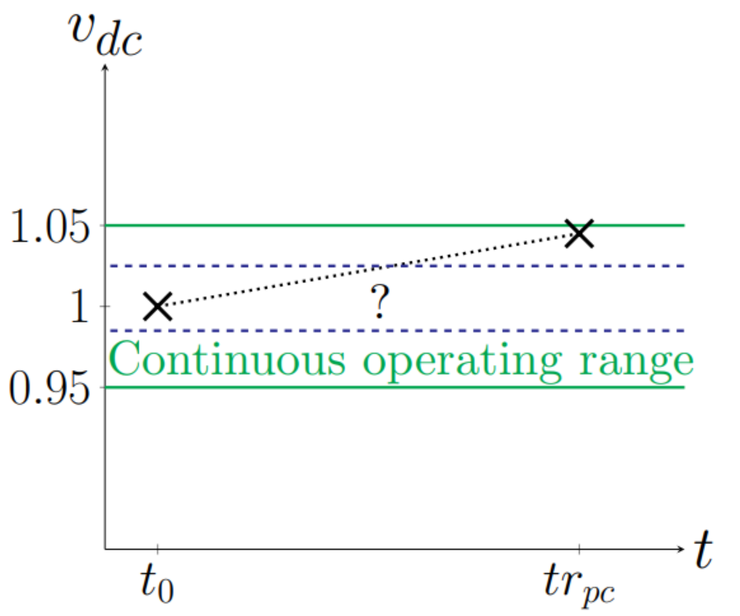
- Models shall be provided as open-box, with few exceptions defined—e.g. control and protection (C&P), valve, wind turbine electrical and mechanical model— which can be provided as a black-box IEEE/CIGRE DLL.
- Tool-independent DLL concept, based on the CIGRE TB 958, has been validated with several vendors proving smooth integration in two EMT tools and is being now applied to commercial projects.
- Dry-run tests are ongoing to validate the relevance of the requirements and prepare interaction studies. First, in a single-vendor setup; then, in a multi-vendor environment with no electrical connection.
- Interface documentation is the cornerstone of successful integration!
- More challenges in RT, e.g. setting step requires a trade-off between the RT simulator (RTS) capability, the C&P system capability & the desired accuracy. Software in the loop (SIL) is not mature for RTS tool-independence.

The requirements defined in D1.1 have proven to be relevant for tool-independency and multi-vendor use. Only few improvements are expected for the sake of clarity

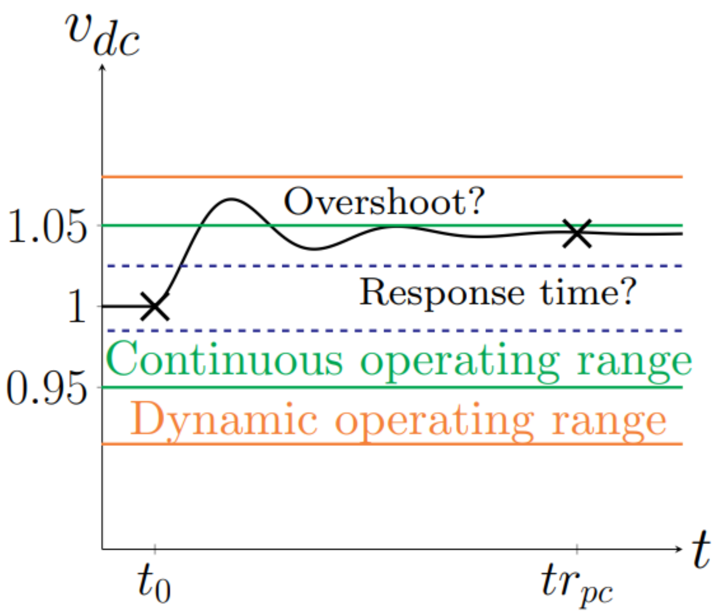


HVDC grid design studies: three packages

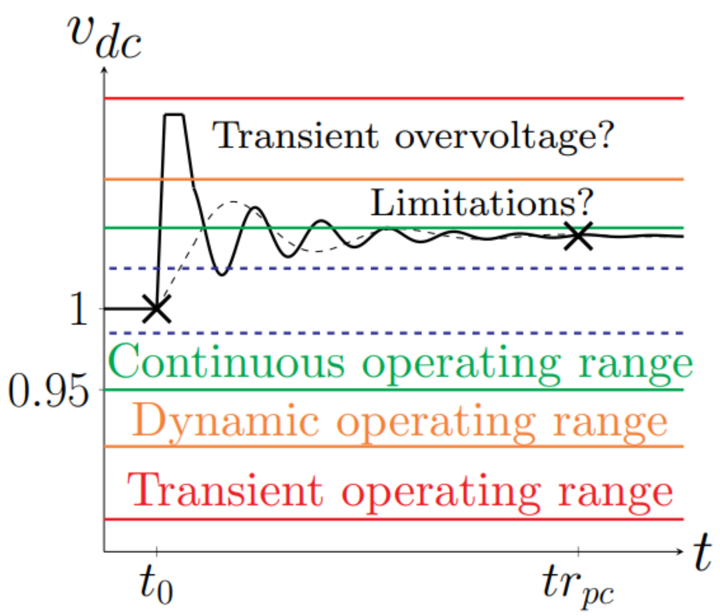
LF & Contingency analysis



Dynamic studies



Transient studies



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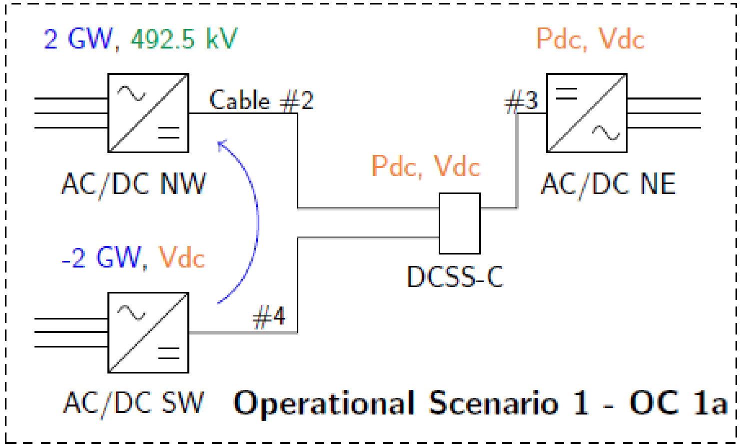
HVDC grid design studies: overall methodology

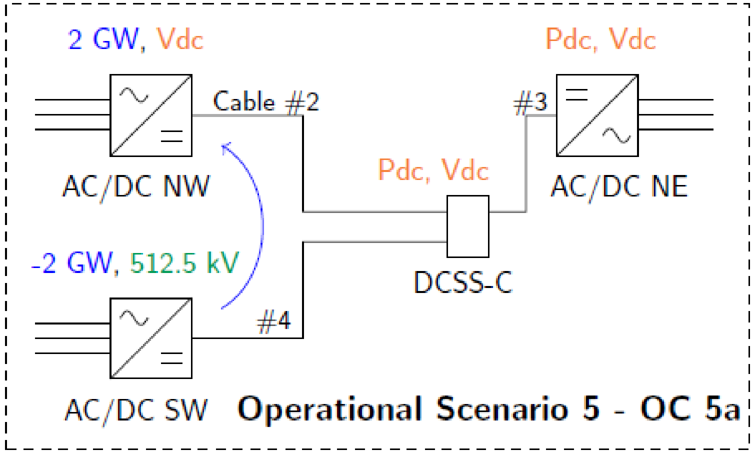
1. Define equipment capabilities: typically, continuous operating ranges.
2. Define design criterion: typically, N-1 rule
   - The system must remain within its operational security limits (OSL=continuous operating range) following predefined contingencies.
3. Define relevant scenarios: N situation & contingencies.
   - N situations must cover all possible initial operating conditions (power flow & voltage profiles)
   - Contingencies may be *ordinary* (single outage) or *extraordinary* (double outage with common cause)
   - Permanent or temporary (fault within FRT), on the AC or DC side.
4. Set modelling assumptions aligned with the study purpose & phenomena of interest
5. Conduct DC load-flow calculations (final state) & dynamic simulations (trajectory)

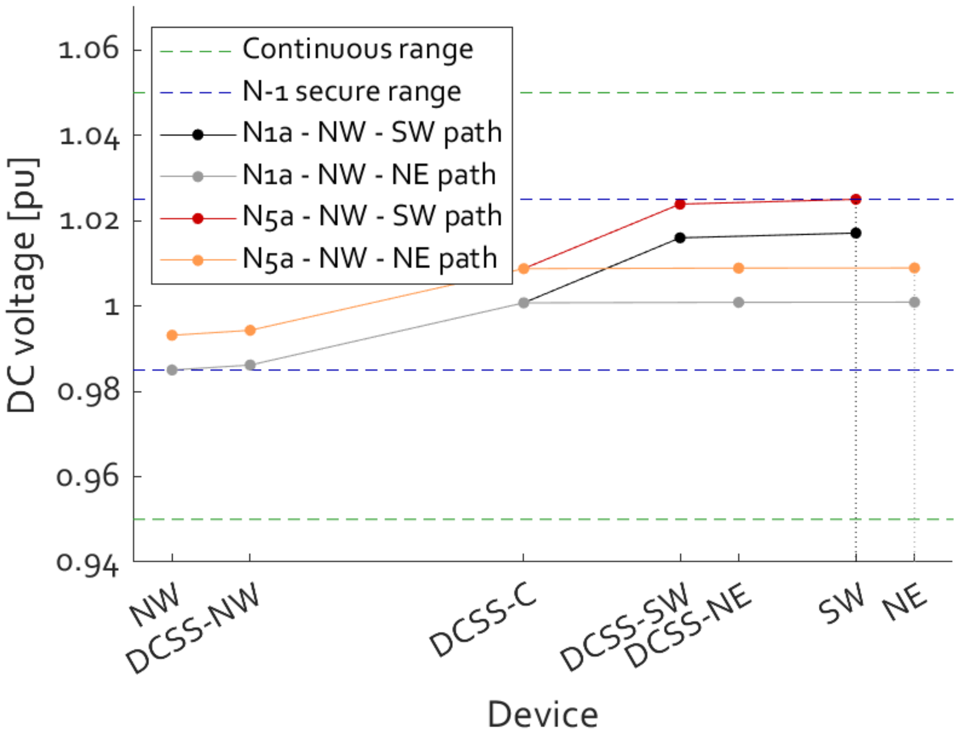
HVDC grid design studies: using EMTP

Applying the proposed methodology to the InterOPERA 3T base case

1. DC load flow & contingency analysis example: defining N situations



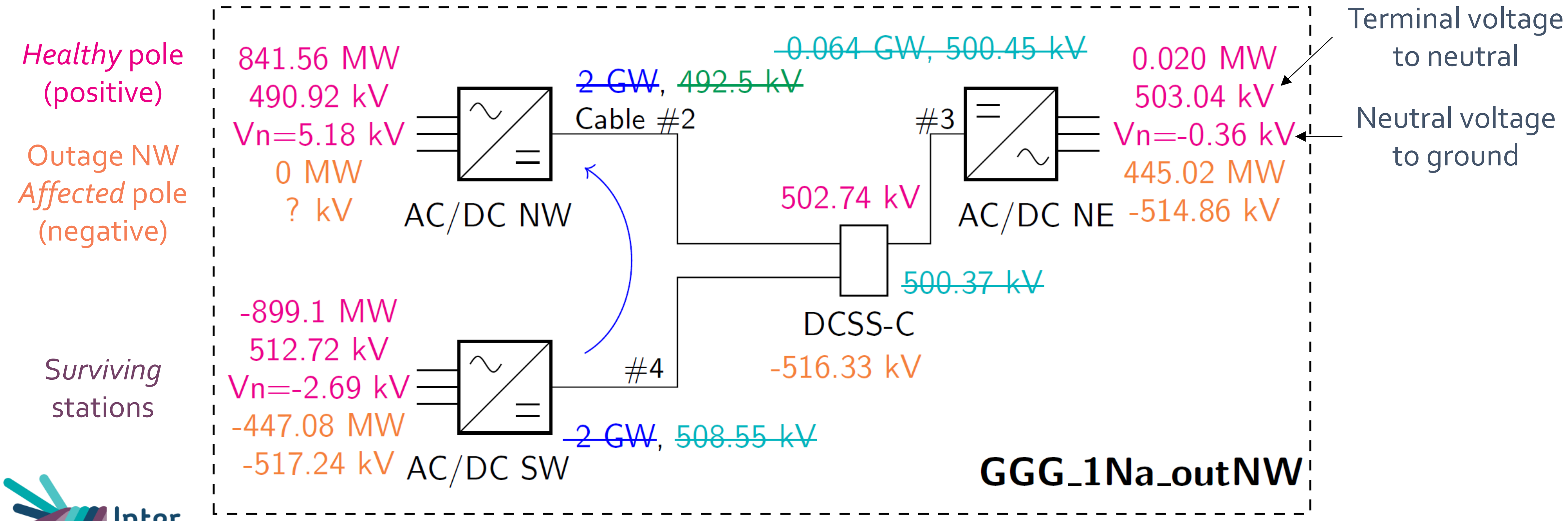




HVDC grid design studies: using EMTP

Applying the proposed methodology to the InterOPERA 3T base case

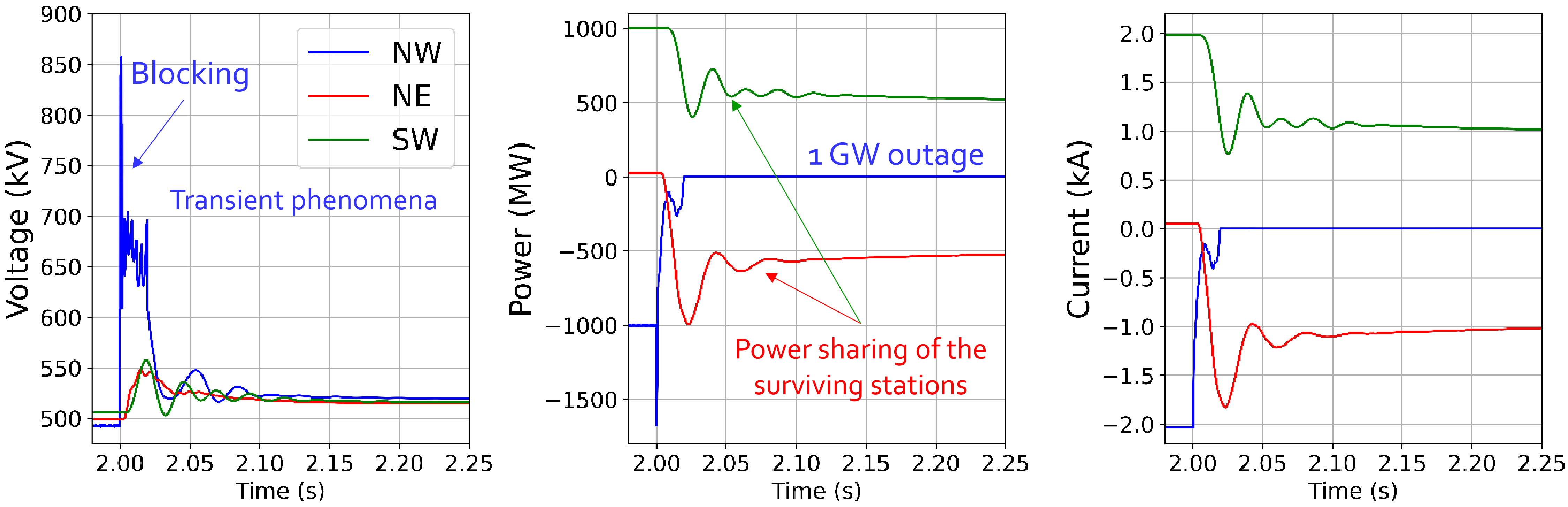
2. DC load flow & contingency analysis example: final state following outages



HVDC grid design studies: using EMTP

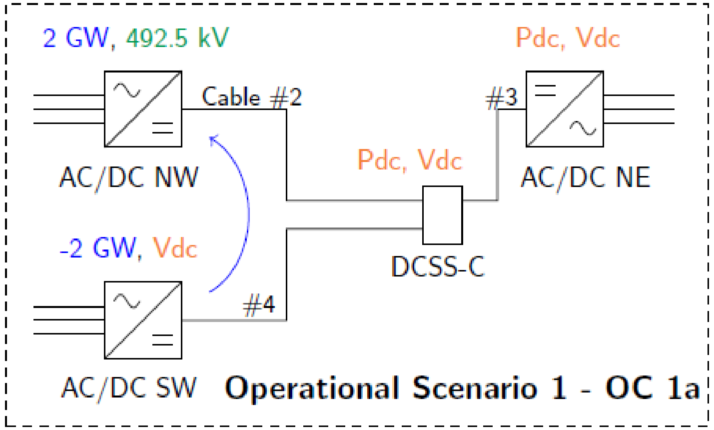
Applying the proposed methodology to the InterOPERA 3T base case

3. Contingency analysis example: dynamic response following a converter unit



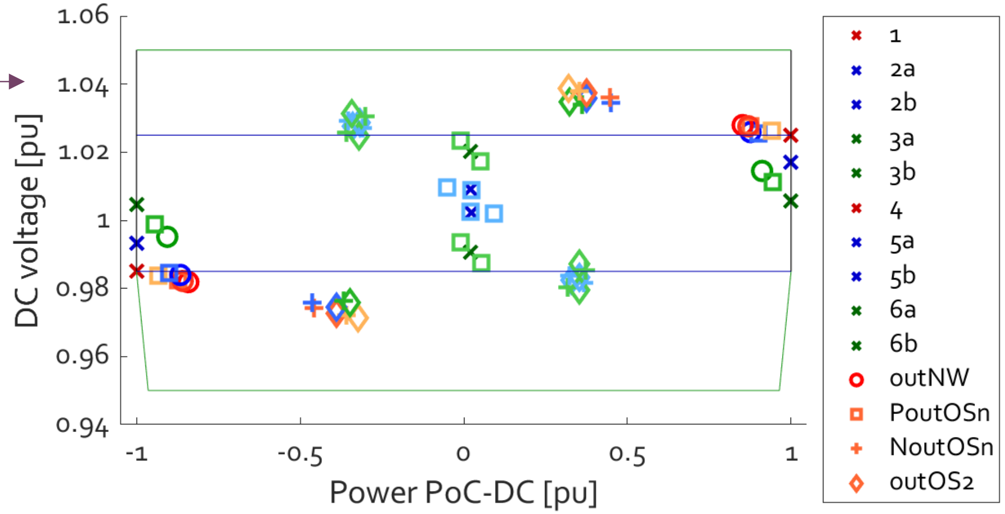
Affected (negative) pole. Final state aligns with LF study outcomes

InterOPERA HVDC grid design studies



For the 3T base case InterOPERA demonstrator
3 configurations and 12 N situations

Configuration	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b
GGG	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
GGW	✓	✓	✓	✓	×	×	✓	×	✓	×	✓	✓
WWG	×	×	×	×	✓	✓	✓	×	✓	×	✓	✓



EMTP has allowed to investigate:

- DC LF 136 scenarios (pole & bipole outages)
- 136 blocking cases + 120 AC faults on the grid side
- 22 DC fault events at DC PoC, DCSS busbar and along DC cable (528 scenarios)

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Takeaways

Takeaways & next steps

- **Functional requirements** for HVDC grids and subsystems define necessary capabilities to implement the proposed operational, control and protection principle while maximising interoperability by design.
- **Detailed technical specifications** instantiate those requirements within a specific project.
- Different system wide-studies, at the design and integration stage, must still be conducted:
  - **HVDC grid design studies** have supported the definition of the InterOPERA demo specifications, which have been drafted based on **generic models**. No vendor models have been delivered yet.
  - **Interaction studies** will be conducted in **Phase 2 with vendor models** to validate that final system performance aligns comply with the technical requirements and aligns preliminary results.
- To conduct those studies, appropriate **models and simulation platform** are required.
- InterOPERA will also provide guidance on suitable **procurement strategies** for MT MV HVDC systems.

THANK YOU

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