Inter OPERA
Enabling multi-vendor HVDC grids

READY4DC

Joint Event

CIGRE B4-Colloquium, Vienna

13 September 2023
8.00 – 12.30 CEST

Agenda

08:00 – 08:15	Registration & welcome coffee
08:15 – 08:20	Opening
08:20 – 08:35	READY4DC project overview
08:35 – 09:15	Framing the future European Energy System: presentation of main findings
09:15 – 09:30	Coffee break
09:30 – 10:30	READY4DC: main findings of the final whitepapers of Working Groups 1, 2 and 3
10:30 – 10:45	Coffee break
10.45 – 11:00	InterOPERA project overview
11:00 – 12:25	InterOPERA: the European way for Multi-Vendor Multi-Terminal HVDC grids
12:25 – 12:30	Closing remarks

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Inter OPERA
Enabling multi-vendor HVDC grids

READY4DC project overview

Getting ready for multi-vendor and multi-terminal DC technology

Dr. Ilka Jahn, RWTH Aachen University

Sept 2023

Basic Facts

- **Expected Outcome:** The call is intended to support all the preparatory phases among all stakeholders (HVDC systems manufacturers, TSOs, wind turbine manufacturers and windfarm developers) leading to a demonstration project to de-risk the technology to enable the installation in Europe of the first Multi-Vendor Multi-Terminal HVDC system with Grid Forming Capability.
- **Type**: CSA
- **Budget:** 1 million €
- **Duration**: ~~18~~ 20 months (Nov. 2023)

Partners

Research Institutions

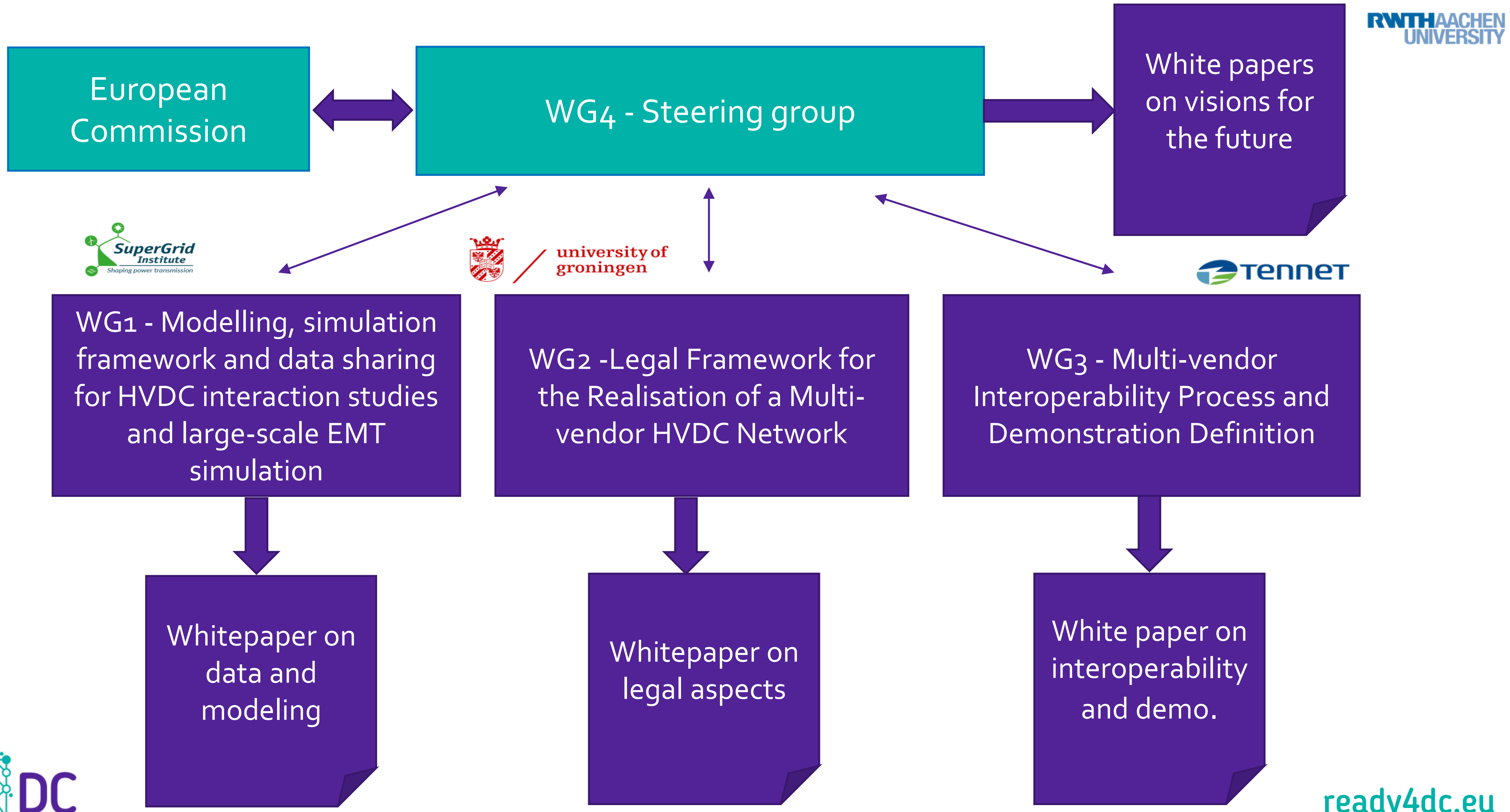
Stakeholders associations

Major TSO active in two countries

Scope

- Preparatory tasks
  - → **lead to a global agreement among stakeholders**
  - → **lead to detailed planning** for the full-scale industrial demonstrator
- Coordination and organization of a **platform involving all stakeholders**
- Compatibility of **modelling tools**
- Model sharing between TSOs: **legal framework**
- **Roles and responsibilities**

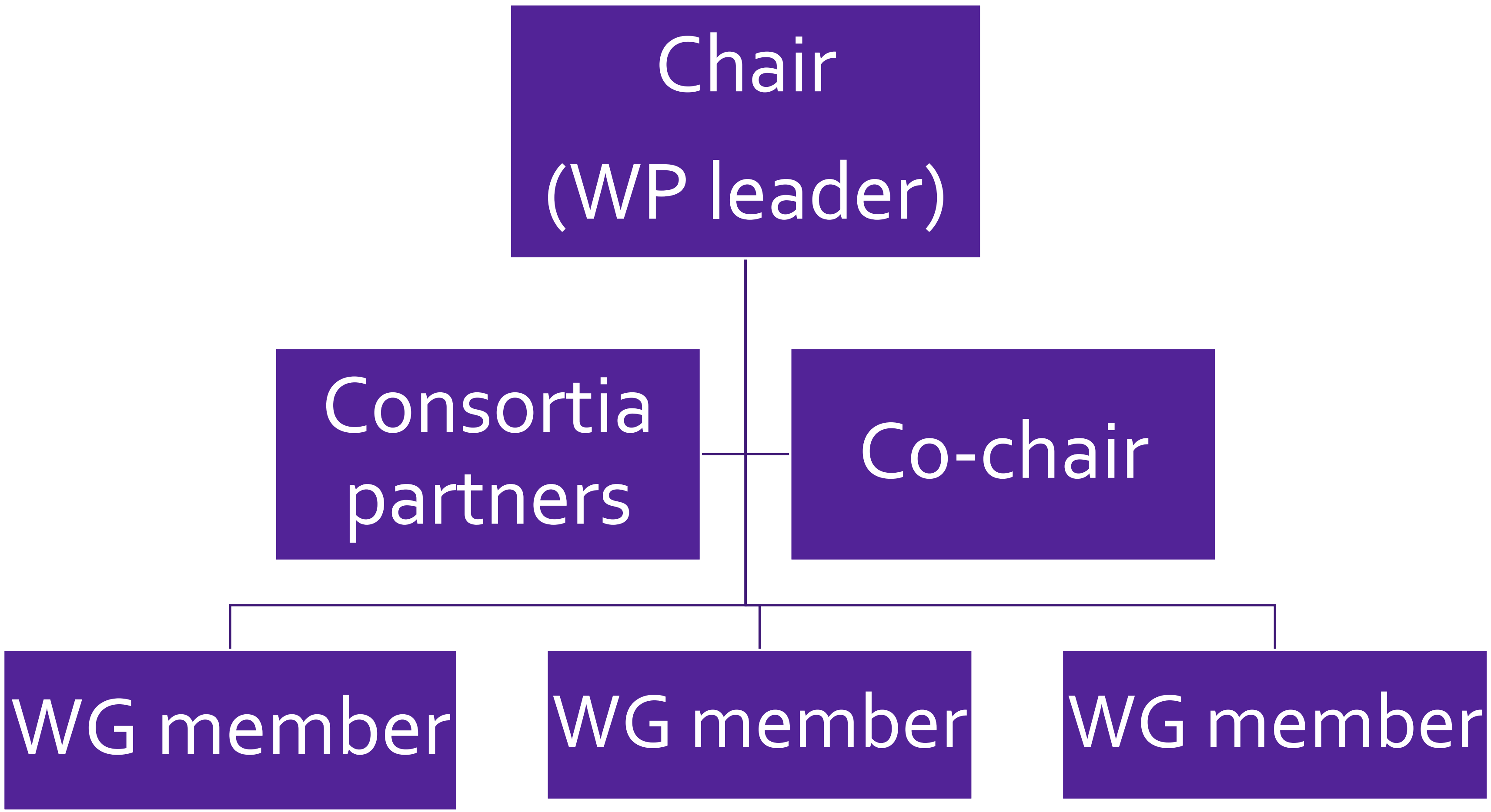
Project Concept



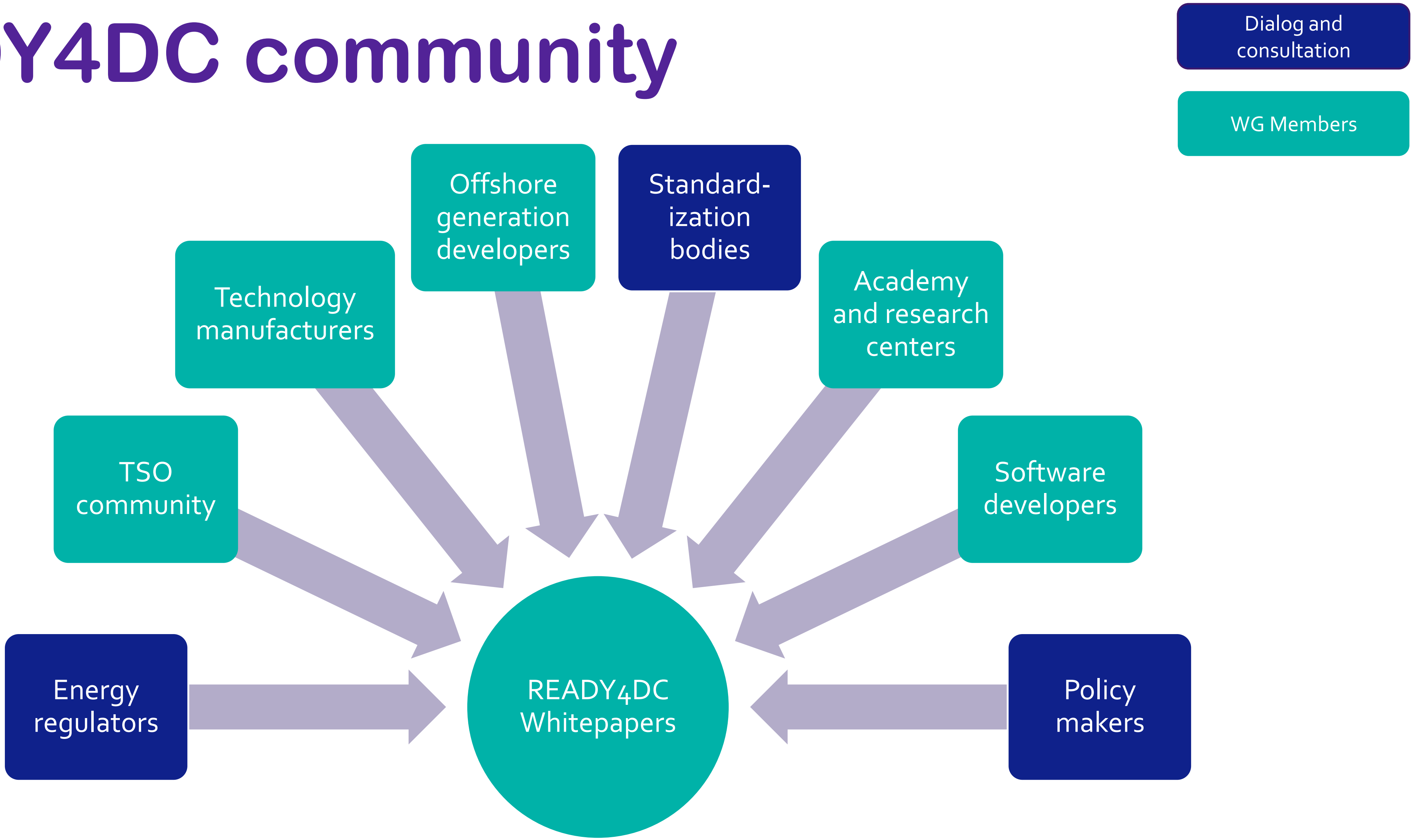
Process per WG

WG1 Modelling, simulation framework and data sharing for multi-vendor HVDC interaction studies and large-scale EMT simulation	• Modelling framework and process • Legal aspects of data sharing • Integration with simulation tools
WG2 Legal Framework for the Realisation of a Multi-vendor HVDC systems	• Analyse the current status of legislation and regulation • Addressing the gaps in the legislative framework • Legal framework for coordination and governance of multi-vendor, multi-terminal HVDC networks
WG3 Multi-vendor Interoperability Process and Demonstration Definition	• Planning the first multi-vendor HVDC demonstration project • Placing demonstrators in the European grid • Going beyond a demonstration project
WG4 Framing the future European energy system	• Technical Coordination • Vision for the short-term impact of the project • Vision for the long-term impact of the project • Involvement in BRIDGE and SetPlan activities

WG governance structure (example)



READY4DC community



READY4DC whitepapers

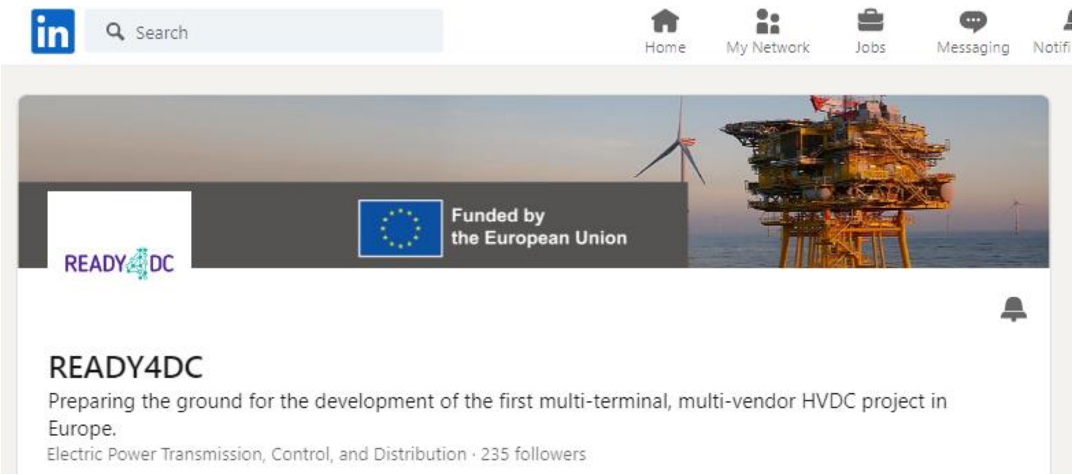
- **Published**
  - Modelling, Simulation Framework and Data Sharing for MVMT HVDC Interaction Studies and Large-scale EMT Simulations **Update coming!**
  - MV Interoperability Process and Demonstration Definition **Update coming!**
  - Report on the State of the Art of Regulation and Legislation and Gap Analysis
  - Preliminary conclusions: Legal and Regulatory Aspects of a MVMT HVDC Grid **Update coming!**
  - How to unlock investments for the first full-scale MV HVDC systems demonstration
- **More upcoming**
  - Long-term view for HVDC technology
  - Framing the European energy system (on- off-shore) architecture and topology: future role of meshed DC structures and barriers for such technology to kickoff

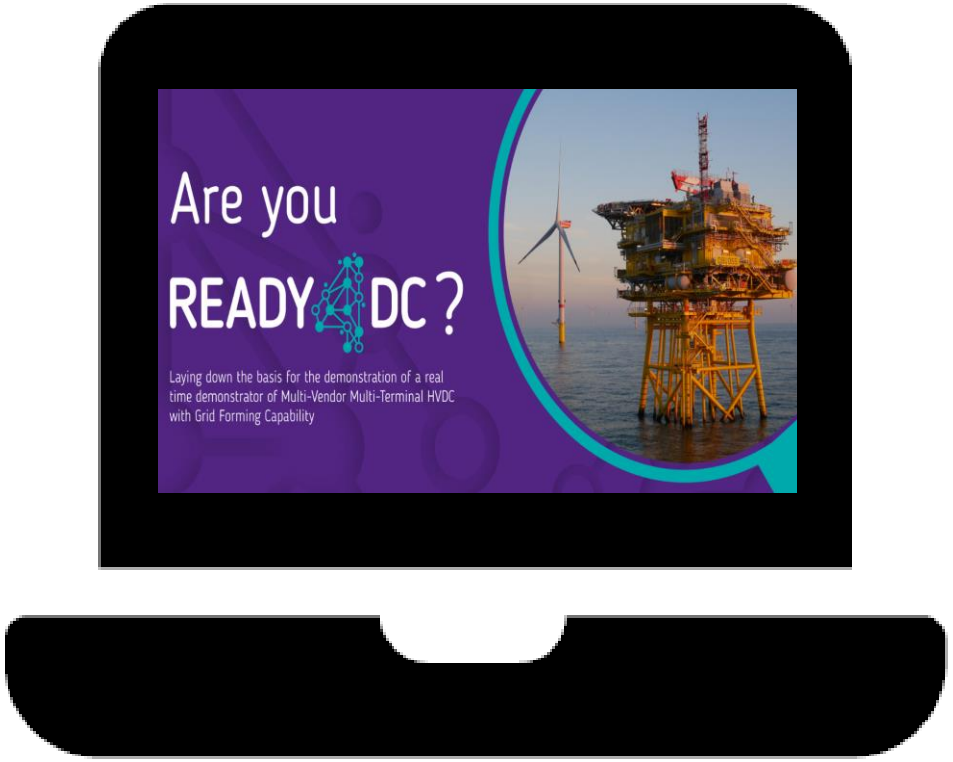
Other efforts towards multi-vendor multi-terminal HVDC

- **CIGRE B4.81:** Interactions: VSC-HVDC, FACTs, HV power electronics, and conventional AC equipment
- **CIGRE B4.85:** Open-source HVDC Control & Protection
- **PROMOTioN:** Technical and commercial readiness (road map) for HVDC grids (2020)
- **COMPOSITE:** Multi-infeed studies for offshore HVDC grids
- **CENELEC / IEC 63291**: HVDC Grid functional requirements / parameters
- **IEC 63471**: DC Voltages for HVDC Grids
- **InterOPERA** EU-funded project

It is not too late to join the READY4DC community!

- Subscribe to mailing list
- Follow us on LinkedIn





THANK YOU

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ready4dc.eu

WG4 on Framing the Future European Energy System (Lead: RWTH Aachen University)

Ilka Jahn (Chair), Jaqueline Cabañas Ramos, Marc Moritz

Co-chairs: Dimitar Kolichev, Nuno Souza e Silva

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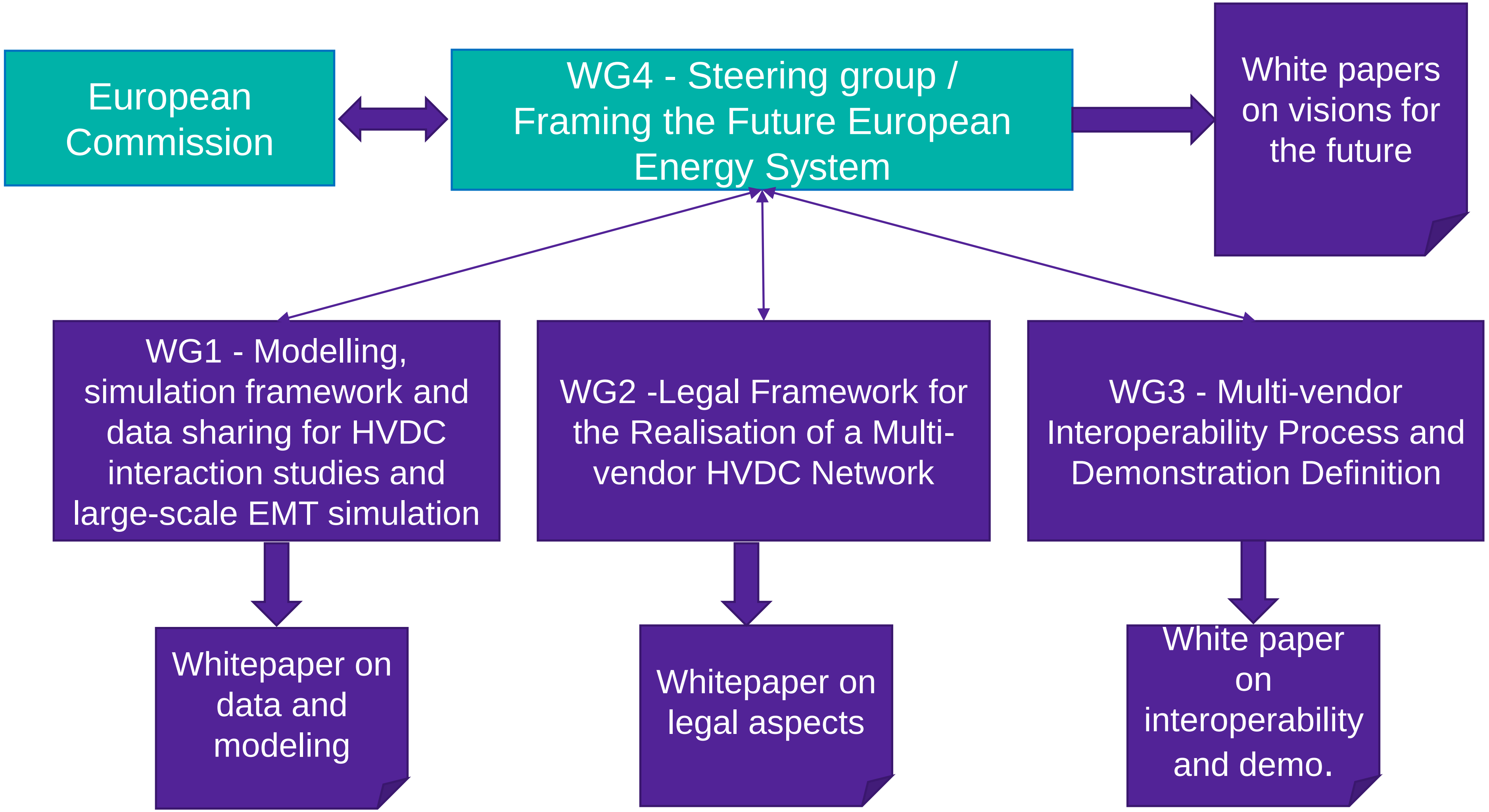
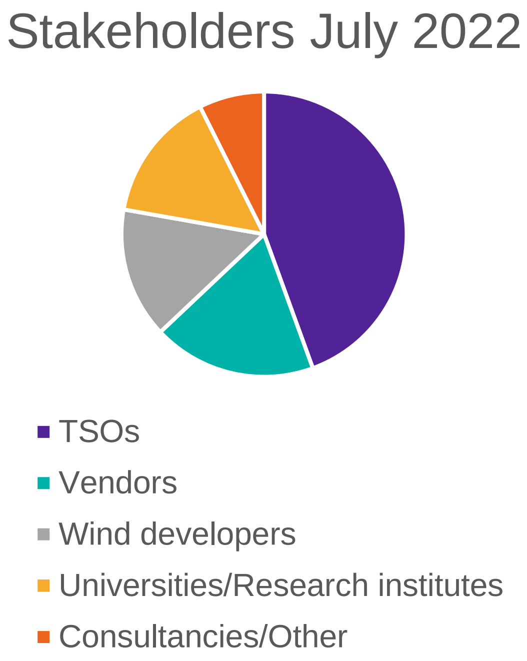
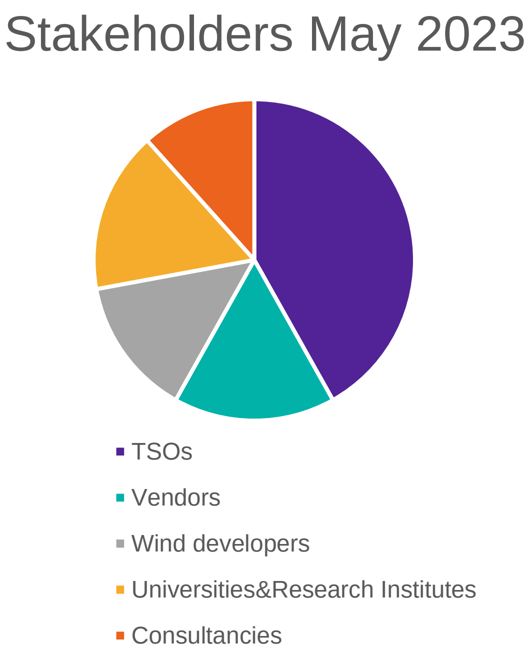
Project Structure

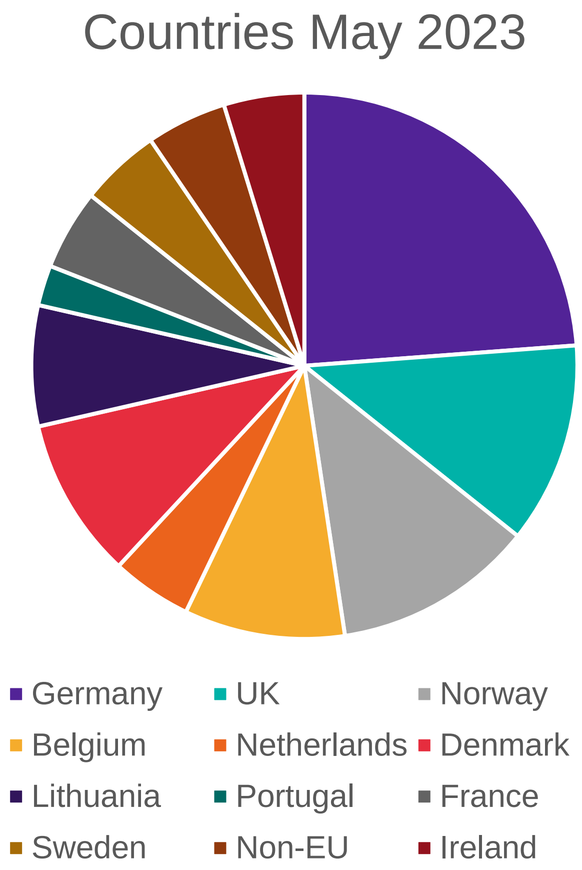


Member Statistics

WG4 list: 49 persons
Meeting attendance: 6-21 persons







Timeline

<table>
<tr><td>April 2022</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>March 2023</td><td></td><td></td><td></td><td></td><td>Sept 2023</td><td></td><td></td></tr>
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<tr><td colspan="11">Whitepaper: How to unlock investments</td><td colspan="3">Review</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td colspan="18">White paper: Framing the European energy system / role of DC + barriers</td><td colspan="2">Review</td></tr>
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Additional: Involvement in BRIDGE and SetPlan activities

Whitepaper: Unlocking Investments

- Investment Options
- Investment Volume and Sustainability of Supply
- Blocks for Investing into the First MTMV HVDC Demonstrator
- Financial Decision-Maker Experience
- Plan to Unlock Investments

Whitepaper: Unlocking Investments --- Magnitude of an Example FOAK HVDC Component

- Size of initial FOAK (first-of-a-kind) projects may be high and outside (national) support schemes

- DC circuit breaker bypass (case study in PROMOTioN)
  - Onshore, connect two single-vendor p2p HVDC links
  - 17 million € … 38 million €
  - “Single piece of equipment„
  - Positive cost benefit yet risk considered too high

Whitepaper: Unlocking Investments --- Potential Subsidy and Funding Options

- Most likely finding for a FOAK will be with EU CEF/PCI (project of common interest)
- Open questions around anticipatory investments
  - Over-scaling of hardware, return to EU ownership?
- "FOAK Europe„ for technology with strategic importance
  - Could consider technology integration aspects that can be different outside Europe
- Public/Private partnership could be a good option for financing and sharing risk (compare Neuconnect)

Whitepaper: Unlocking Investments --- Investment Volume and Sustainability of Supply

Survey in READY4DC community December 2022

- The teams' workload (during writing of this paper) ranges from 60% to 250% with
  - 15% of employees judging their team being loaded 200-250%
  - 20% of employees judging their team being loaded 130-150%
  - 41% of employees judging their team being loaded 90-120%
- More than half the teams are currently hiring 20-40% of their size.
- One year from now, most teams need 0%-60% extra staff.
- Five years from now, the teams need between 0%- up to more than 200% extra staff.

Timeline

April 2022												March 2023					Sept 2023		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Whitepaper: How to unlock investments											Review								
White paper: long-term view for HVDC technology																		Review	
White paper: Framing the European energy system / role of DC + barriers																		Review	

Additional: Involvement in BRIDGE and SetPlan activities

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Whitepaper: Long-term view for HVDC technology

- WGs outputs
- State of the art of HVDC Technology
- Socio-economic aspects
- R&D priorities
- End of life

Whitepaper: Long-term view for HVDC technology

- WGs outputs
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- Socio-economic aspects
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- End of life

Whitepaper: Long-term view for HVDC technology – Socio-economic aspects

- Benefits of HVDC technology:
  - Key solution for connecting large-scale offshore wind farm. One example is: German North Sea project
  - Ease congestion and enable offshore wind farms to link multiple grids
  - Allows for the connection of independent grids that cannot be merged into a single synchronous system→ The North Sea Link is an example
- Impact on Energy Market
  - Example: Caithness-Moray link- enhance grid stability and reduce curtailment

Whitepaper: Long-term view for HVDC technology – Socio-economic aspects

- Infrastructure investment and job creation
  - Cross-border and national investments play a vital role
  - The TYNDP studies : an additional 64 GW of cross-border reinforcements for 2030 would be cost-efficient ⟶ contribute significantly to the region's socio-economic welfare
  - National investments also play a vital role by connecting stronger areas with weaker ones, achieving a similar effect.
  - 2050: 4x electricity, 3x transmission, big investments, jobs

Whitepaper: Long-term view for HVDC technology – Socio-economic aspects

- Integration of HVDC in Energy Policies and investment:
    - NeuConnect project →policy scenario based also on third parties projections (TYND,FES ,NECP among others)
    - Their source of funding includes private investment and their operate under Ofgem's "Cap and Floor" regulations
- Social acceptance
    - Success relies on public acceptance

Whitepaper: Long-term view for HVDC technology – Socio-economic aspects

- Circular economy-Challenges and opportunities in HVDC Technology

  Raw material

  - Grid expansion → Key minerals needed (including aluminum and copper among others)
  - Robust steel platform construction, extendable
  - Environmental-friendly insulation for copper cables
  - Aluminum remains a costly metal to produce and recycle

  Remanufacturing and Refurbishment

  - DCCB: Quick Replacement for Maintenance Benefits

Whitepaper: Long-term view for HVDC technology – Socio-economic aspects

- Circular economy- Challenges and opportunities in HVDC Technology

  Design for circularity

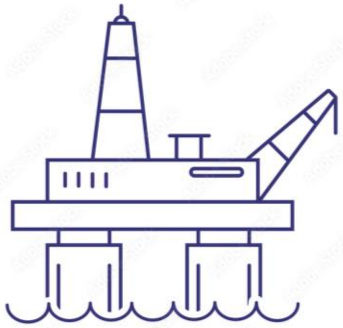
  - Modular design facilitates component replacement.
  - SF6 switchgear challenge: Advocacy for Air Insulation
  - Circularity design of power transformers by replacing conventional oils with renewable or re-refined oils

Whitepaper: Long-term view for HVDC technology – Socio-economic aspects

- Circular economy- Challenges and opportunities in HVDC Technology

  Waste management/recycling and decommissioning

  - Recycling Offshore Equipment Conserves Resources → Example : Offshore oil and gas platforms in the North Sea decommission report demonstrates that a substantial portion of the assets and equipment can be considered for re-use, re-sale, or recycling.



R&D priorities

- Screening OFGEM / SET / PROMOTioN reports on R&D priorities
  - General agreement
  - But also much increased targets

- READY4DC puts special emphasis on
  - "Getting infrastructure up-and-running"
  - Grid extension
  - Training

Whitepaper: Long-term view for HVDC technology – End of life

- Developed Structures for End-of-Life Assets
- OWFs Lifetime Extension Preferred for Decommissioning→challenge cable Lifetime Mismatch
- Cable Removal Obligation in International Law
- End of Life in Legislation and Contracts

Q&A

Whitepaper: Framing the European Energy System

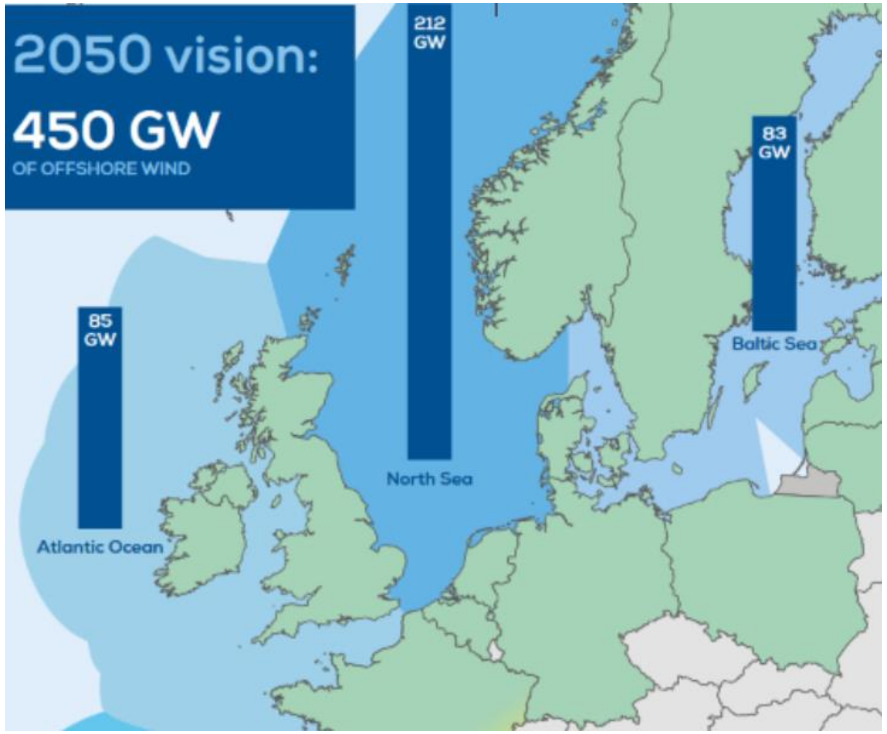
- Role of HVDC Onshore and Offshore
- HVDC Grids in Overal Infrastructure
- Sustainability of DC Grids
- Beyond HVDC

Whitepaper: Framing the European Energy System - Role of HVDC Onshore & Offshore

Ambition of North Sea countries' goals

- Status Quo:
  - 30 GW offshore wind installed capacity in EU + UK
  - 3% of electricity demand covered by offshore wind
- EU targets (2020):
  - 300 GW offshore wind installed capacity by 2050
  - 60GW by 2030
- Ostend Declaration of North Sea countries (2023)
  - >120 GW offshore wind capacity by 2030
  - >300 GW by 2050

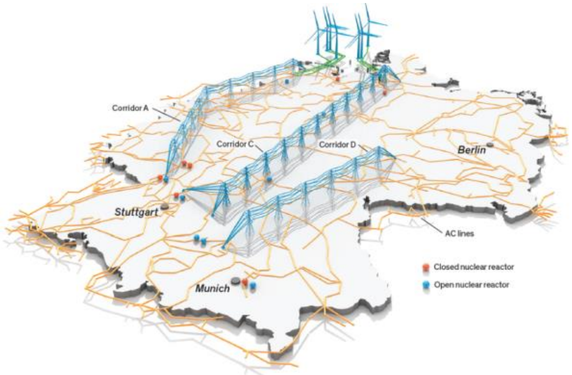
➢Goals are ramping up!



Source: *Our Energy, our future*, WindEurope, 2019

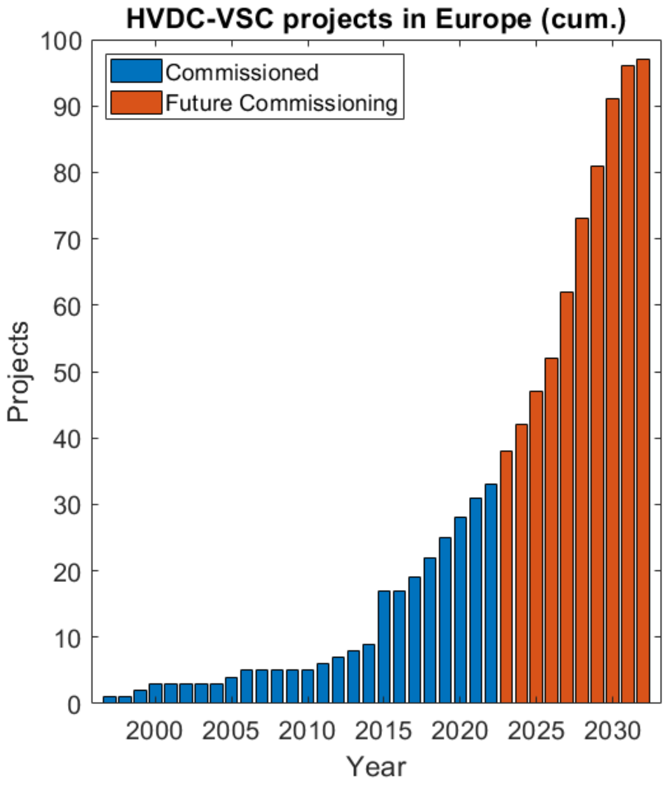
Whitepaper: Framing the European Energy System - Role of HVDC Onshore & Offshore

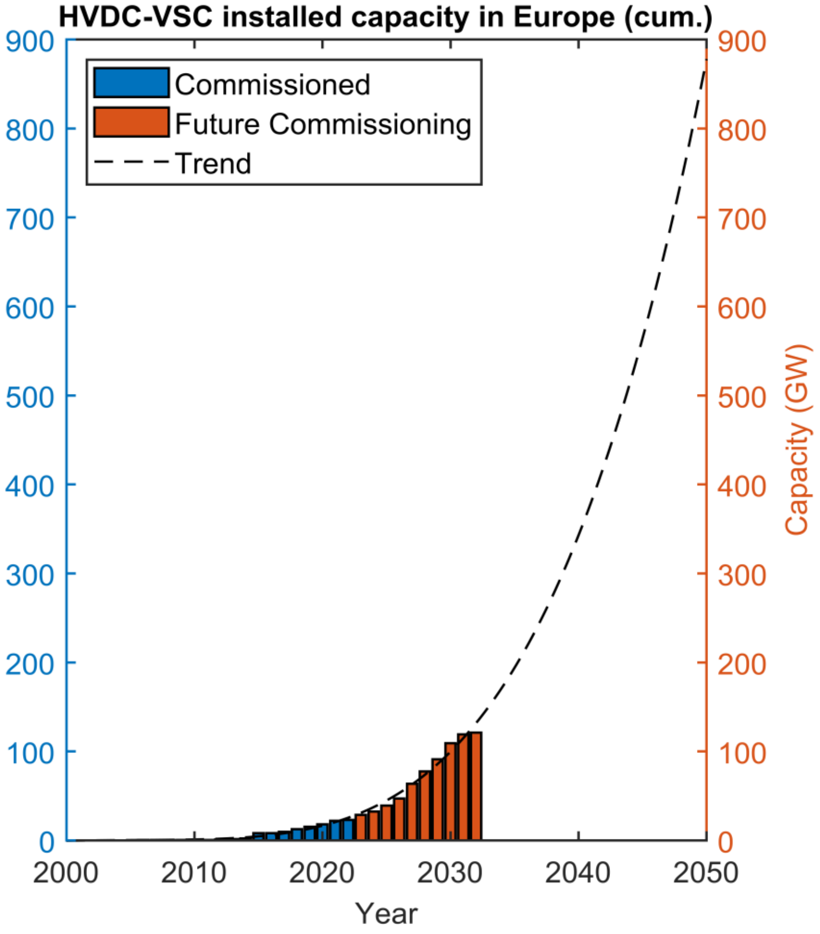
- HVDC offshore
  - Main technology for offshore wind power transmission
  - Cross-country interconnections
    - Onshore-to-onshore
    - Offshore hub-to-hub
    - Hybrid projects
    - Offshore hub to onshore
- HVDC onshore
  - Long distance transmission
  - Cross-country interconnections - System Needs
  - Replace functionalities of existing AC assets



Source: TU Graz

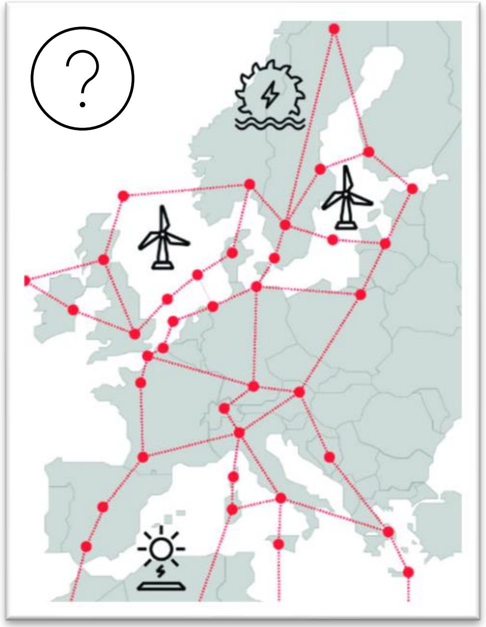
Whitepaper: Framing the European Energy System - Role of HVDC Onshore & Offshore





HVDC Grids in Overall Infrastructure

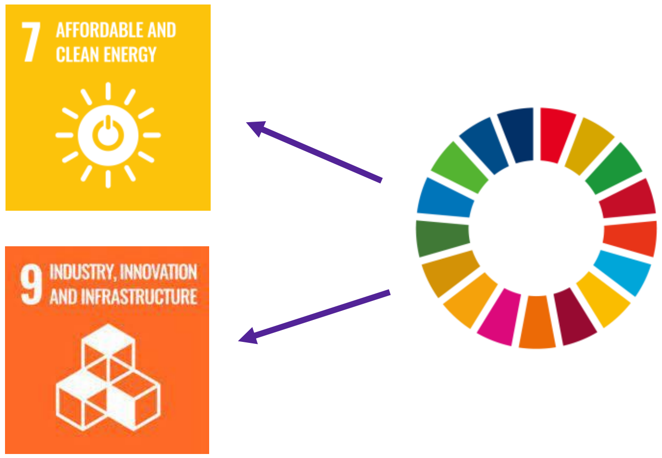
- **Visions for HVDC Grid development:**
  European Supergrid vs. Incremental Approach
  - ➢ 2030 is close
  - ➢ Regulation challenges
  - ➢ Engineering skills gap / Staff scarcity
  - ➢ Supply chain challenges



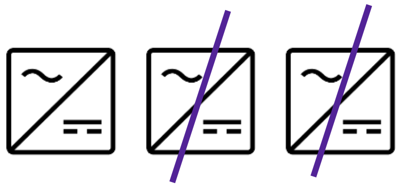
- AC transmission grid reinforcements necessary

Vision for Sustainability of DC Grids

- Sustainable Development Goals and HVDC
  - SDG 7: reduction of emissions & increasing energy efficiency
  - SDG 9: DC transmission as reliable, resilient infrastructure



- Meshed DC grids vs. P2P DC transmission
  - Approximately #DCnodes converters needed vs. 1.5 * 2 * #DCnodes



Vision for Sustainability of DC Grids

- How to build sustainable DC Grids?
  - ➢ Grid extensibility
  - ➢ Interoperability & modularity
  - ➢ Repurposing of existing infrastructure

Your Input needed: Which direction should we focus on

Beyond HVDC

Planned topics:

- Attracting more engineers for the HVDC Industry
- MVDC & LVDC
    - Use cases and potential
    - Technology challenges
    - Are there synergies /common features with HVDC?

Main Points – Q&A

- Contribution of HVDC links & grids to AC grid stability
- Sustainability of DC grids
  - Vision
  - How to build sustainable DC Grids?

Thank you!

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COFFEE BREAK

Modelling, Simulation Framework and Data Sharing for **MTMV HVDC Interaction** Studies and Large Scale EMT Simulations

Working Group 1

READY4DC

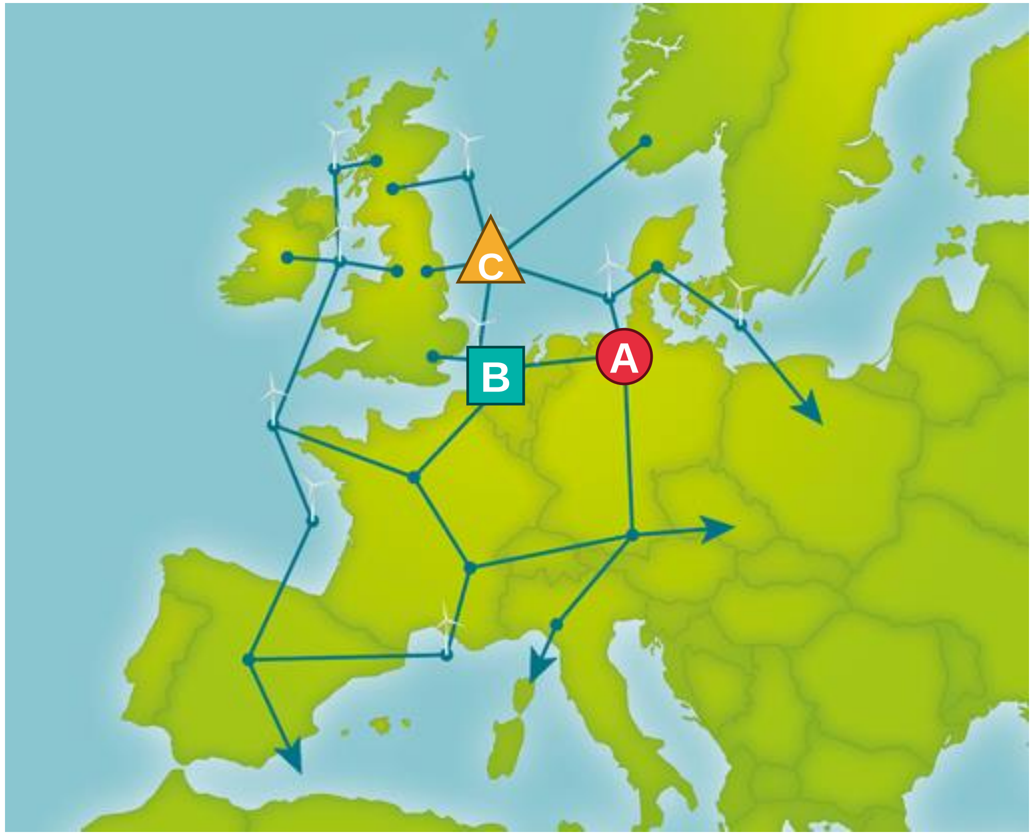
William LEON GARCIA

13 September 2023

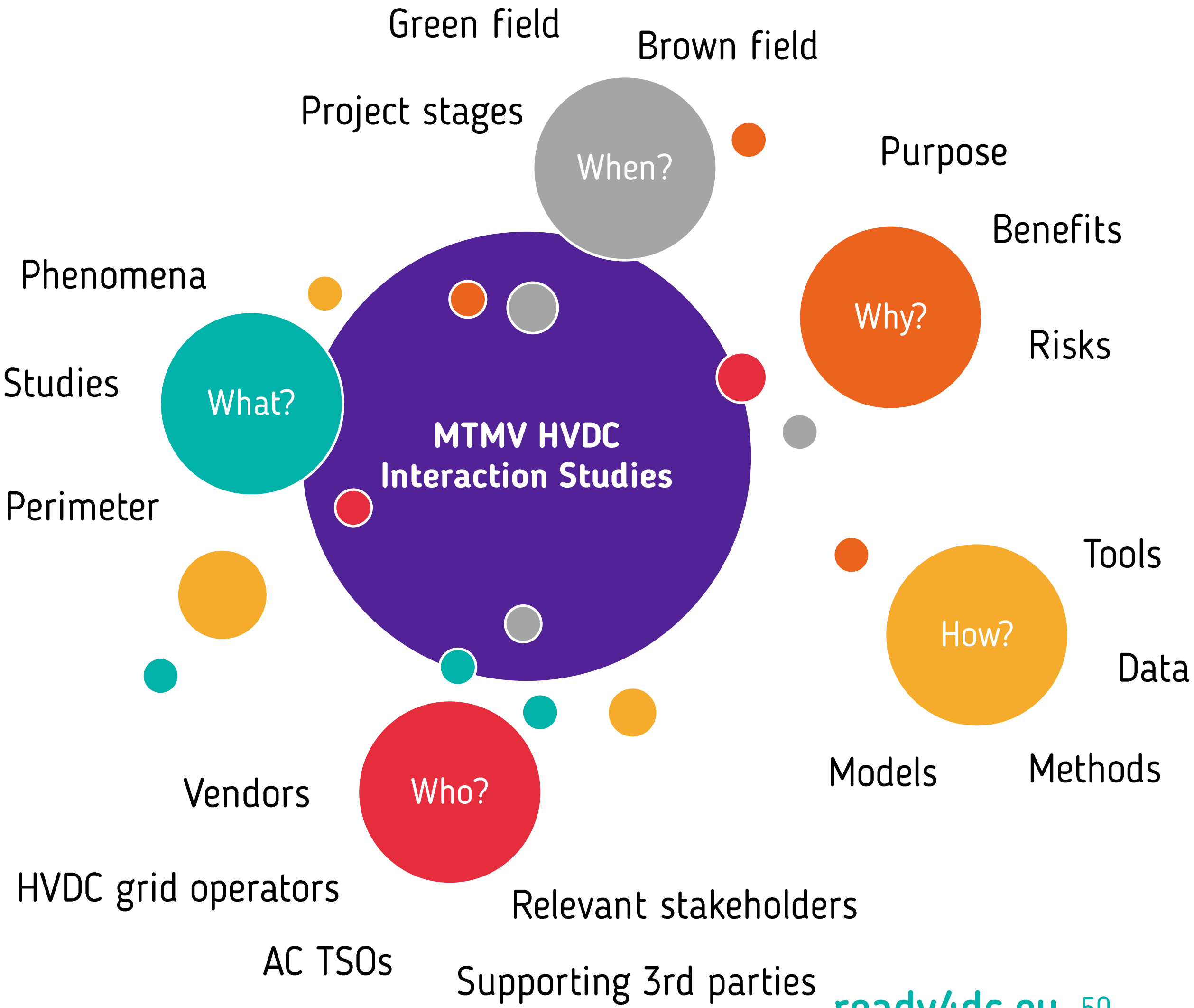
Table of contents

Introduction

Introduction



Multi-terminal multi-vendor HVDC system vision (Corbett, 2020)



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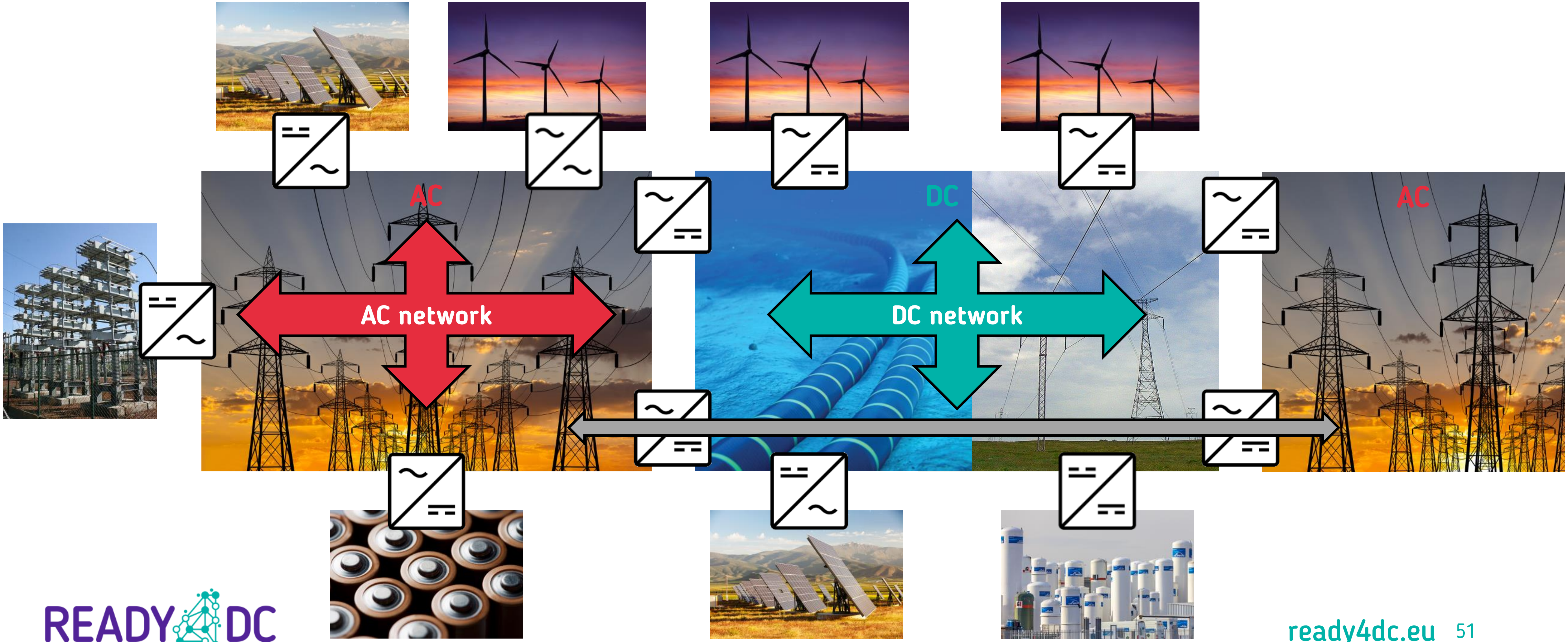
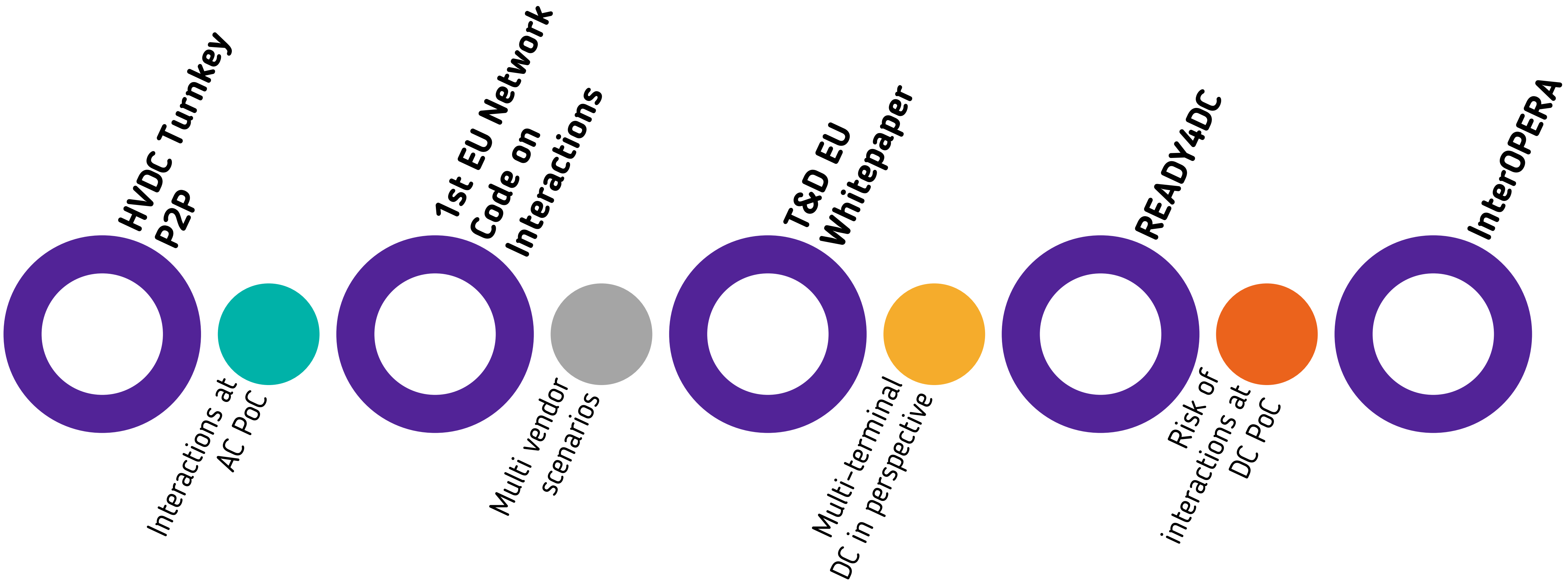
Motivation

Network codes shall anticipate new interactions, through new tools/methods and R&D



Context

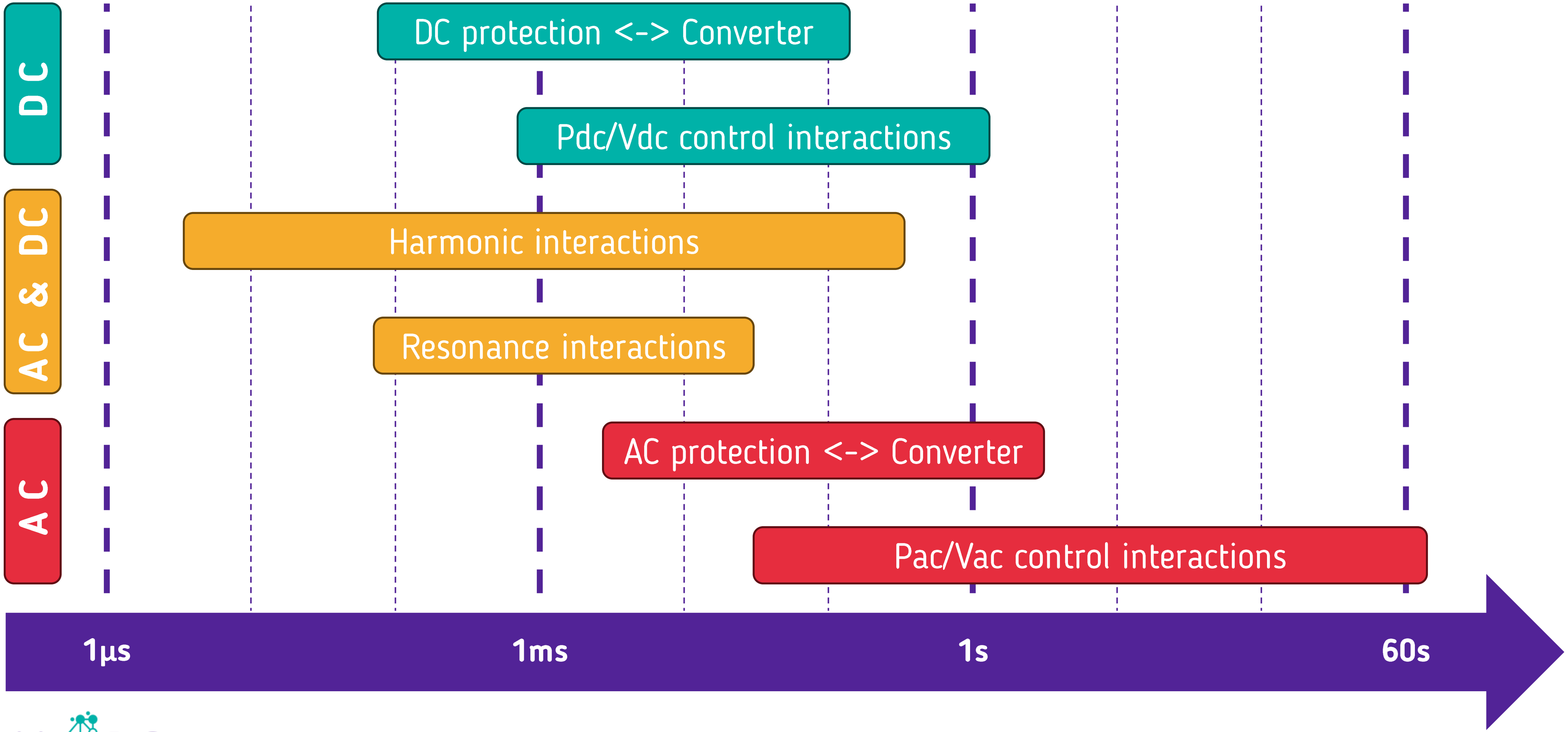

HVDC Turnkey P2P
Interactions at AC PoC
1st EU Network Code on Interactions
Multi vendor scenarios
T&D EU Whitepaper
Multi-terminal DC in perspective
READY4DC
Risk of interactions at DC PoC
InterOPERA

Chapter 1

Interaction Phenomena

Interaction phenomena

Facing the risk of new and more interactions: more converters, new environment (DC)



Chapter 2

Workflow for interaction studies

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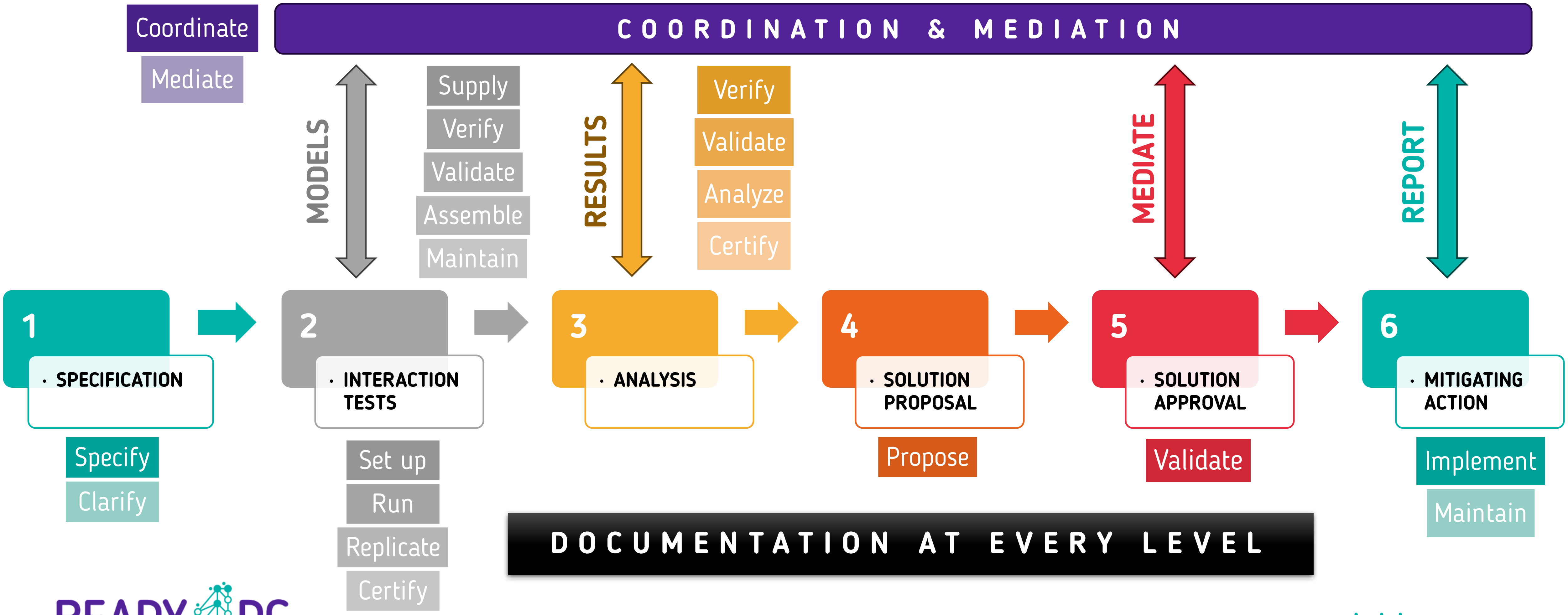
Workflow for interaction studies

A couple dozen roles (27) identified among all stages



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Chapter 3

Roles assessment

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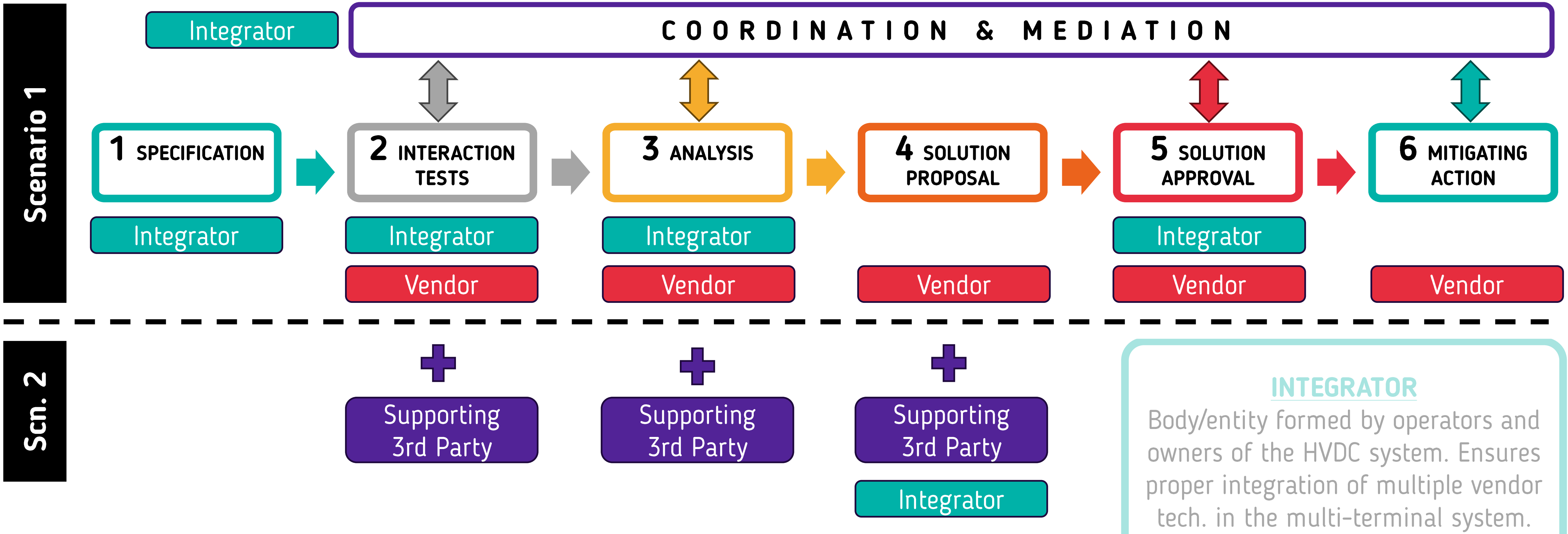
Role's assessment

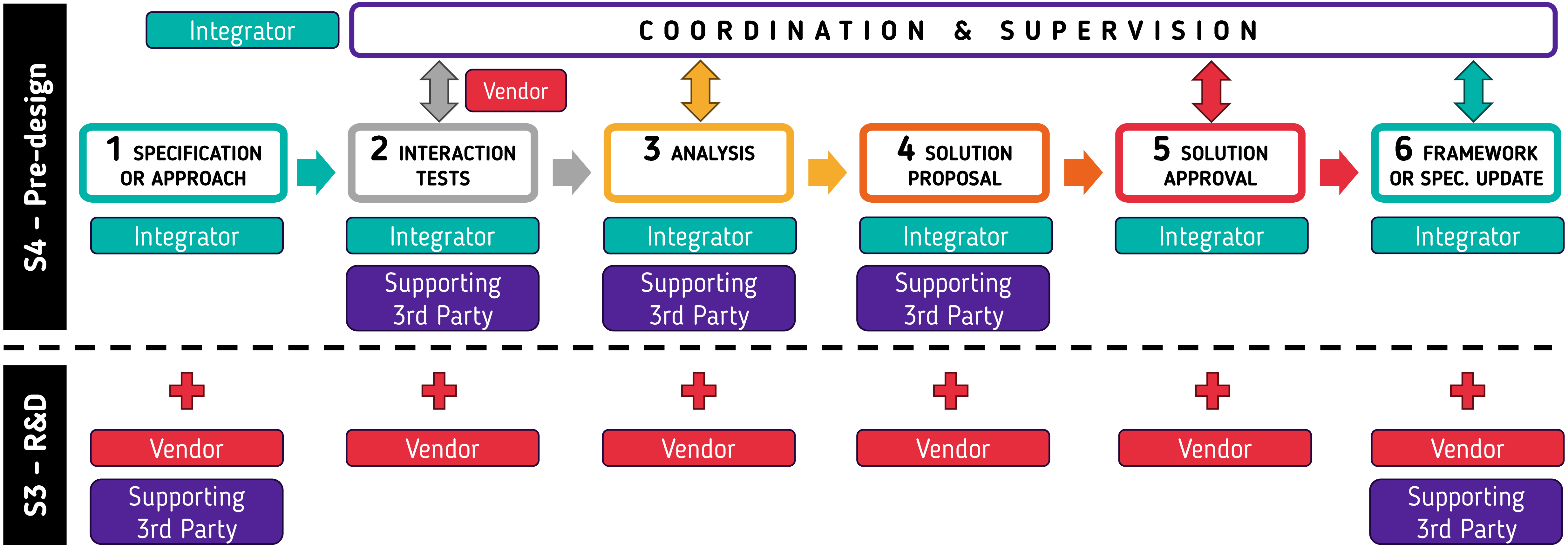
Interaction studies remain priority **AFTER MTMV HVDC projects awarded**



INTEGRATOR
Body/entity formed by operators and owners of the HVDC system. Ensures proper integration of multiple vendor tech. in the multi-terminal system.

Role's assessment

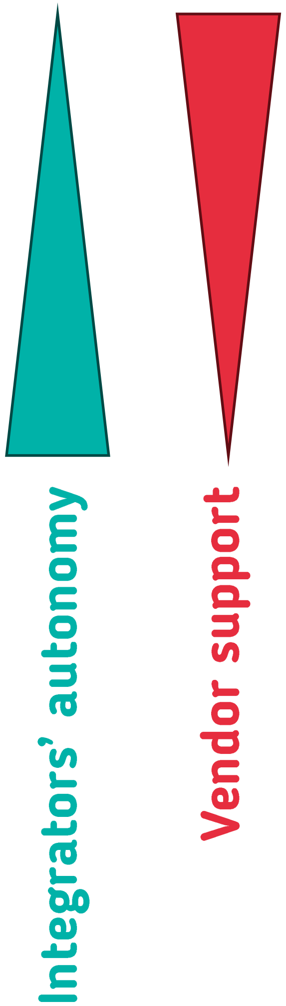
Prospective scenarios for **BEFORE** contract awarding



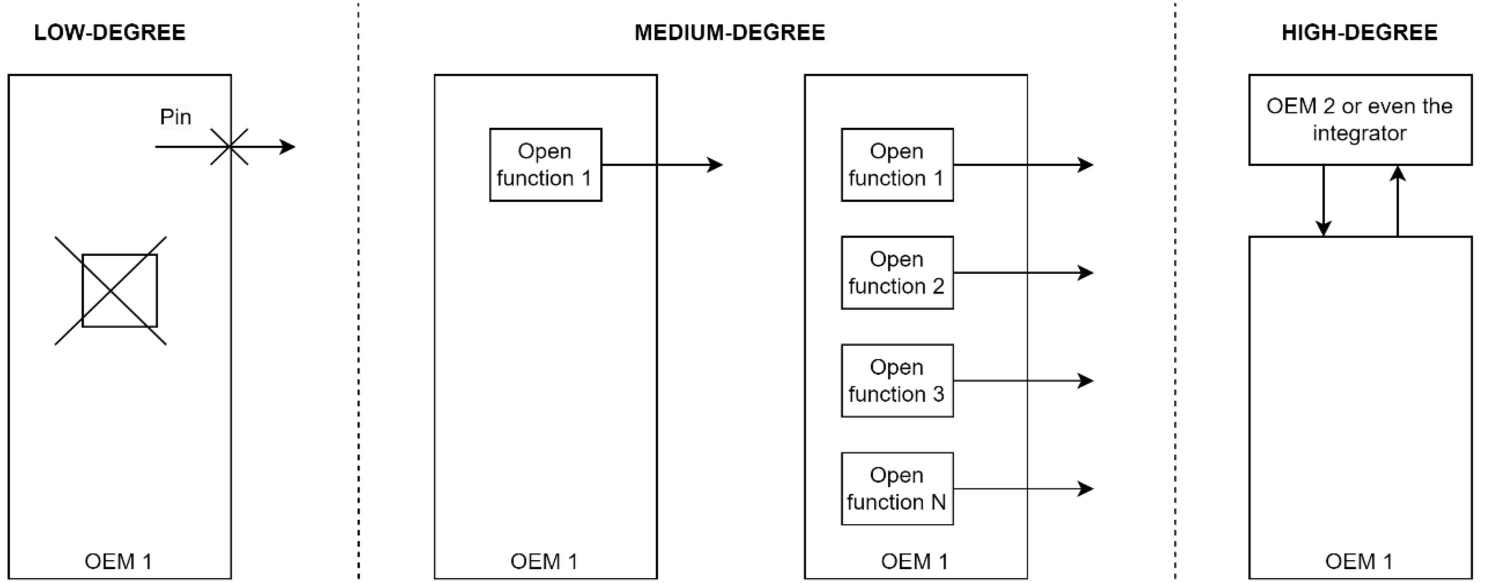
Chapter 4

Effects of converter openness

Openness of (certain) converter functions



- **Low-degree**
  Maintains the interface between converter functions and the overall system via vendors, prioritizes the safeguarding of vendor IP and leverages their converter control expertise. But it limits the integrator.
- **Medium-degree**
  Greater but still limited control, vendor support still needed to clarify how much the converter functions can be adjusted.
- **High-degree**
  Offers total access to certain functionalities, simplifying troubleshooting and decentralizing interactions. But it demands the integrator a certain know-how and prompts questions about accountability.



Chapter 5

EMT simulation tools

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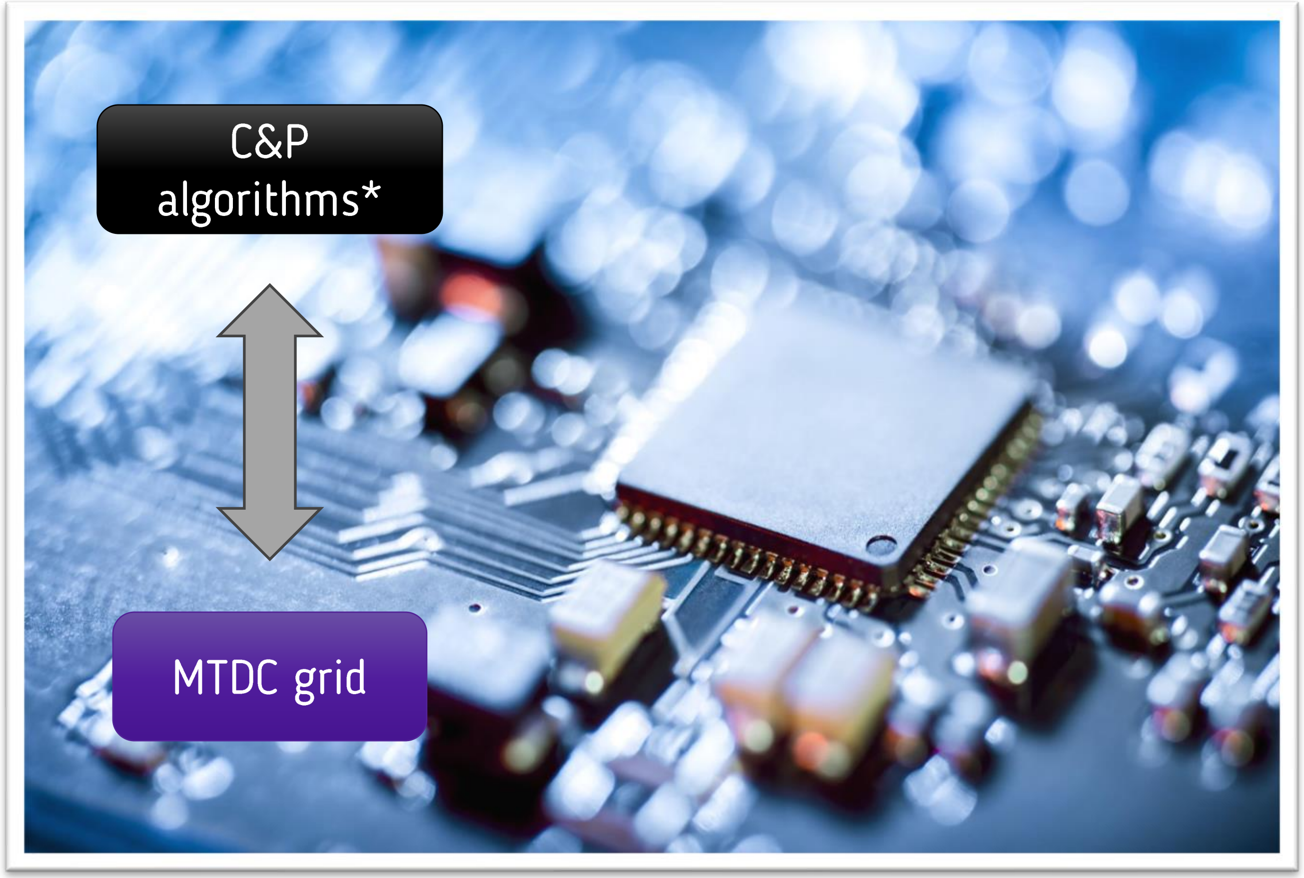
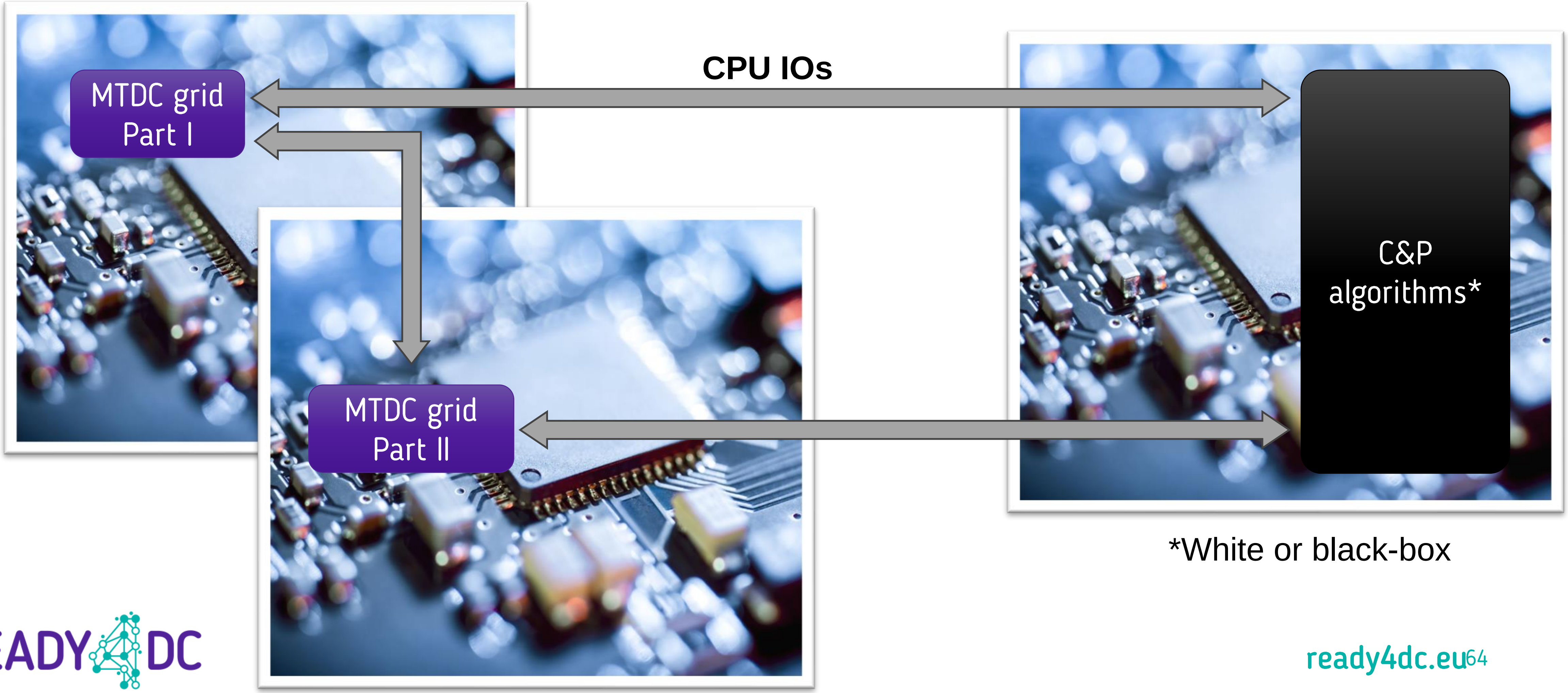
SIL Offline



*White or black-box

SIL with parallel CPUs, Offline+ or Real-Time



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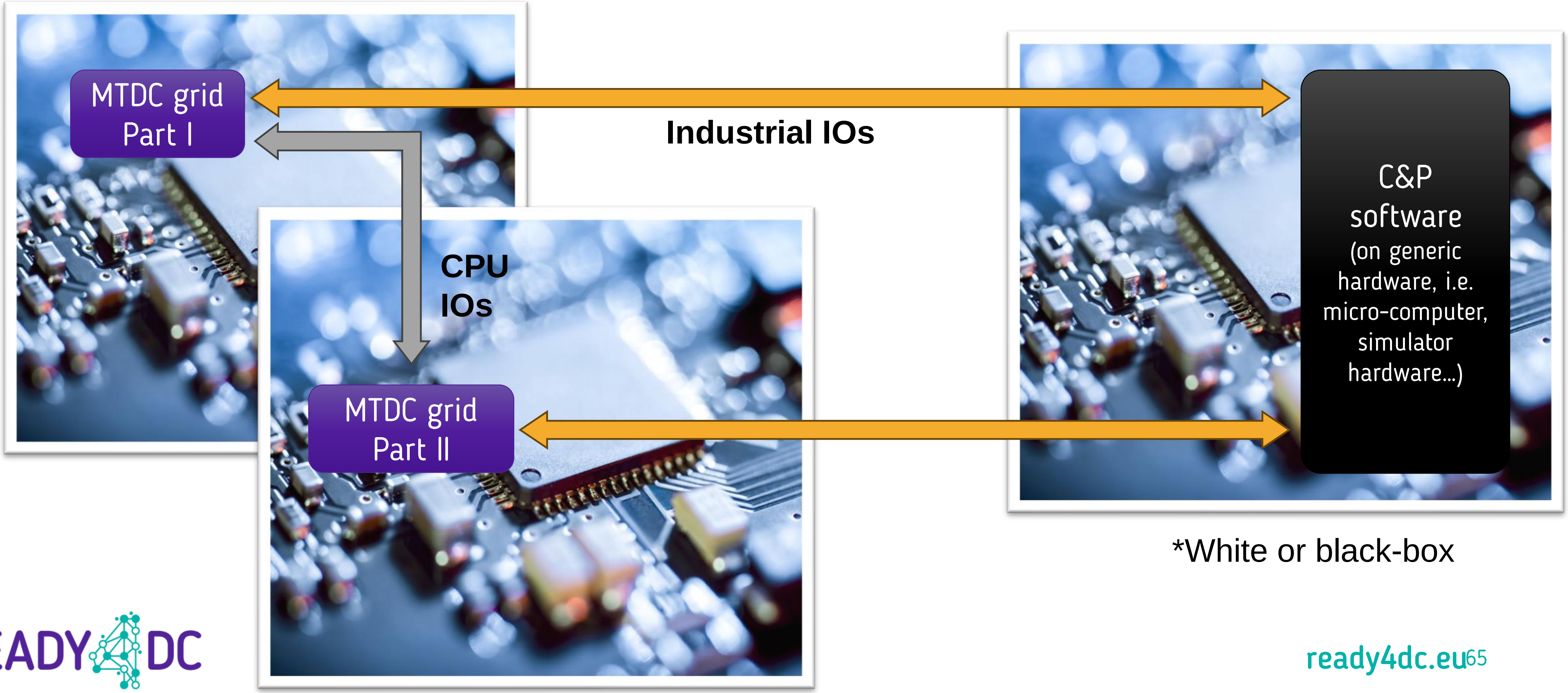
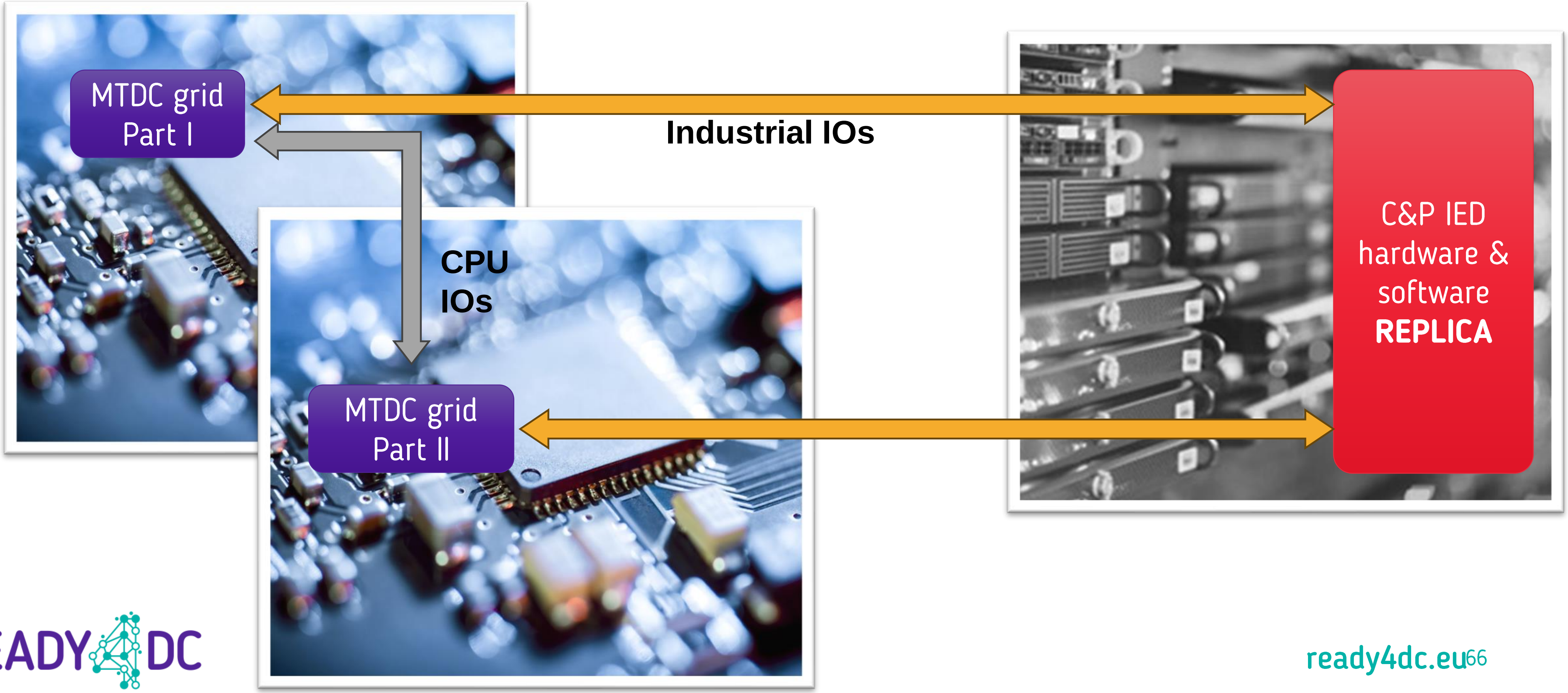
SIL with industrial IOs, Real-Time+

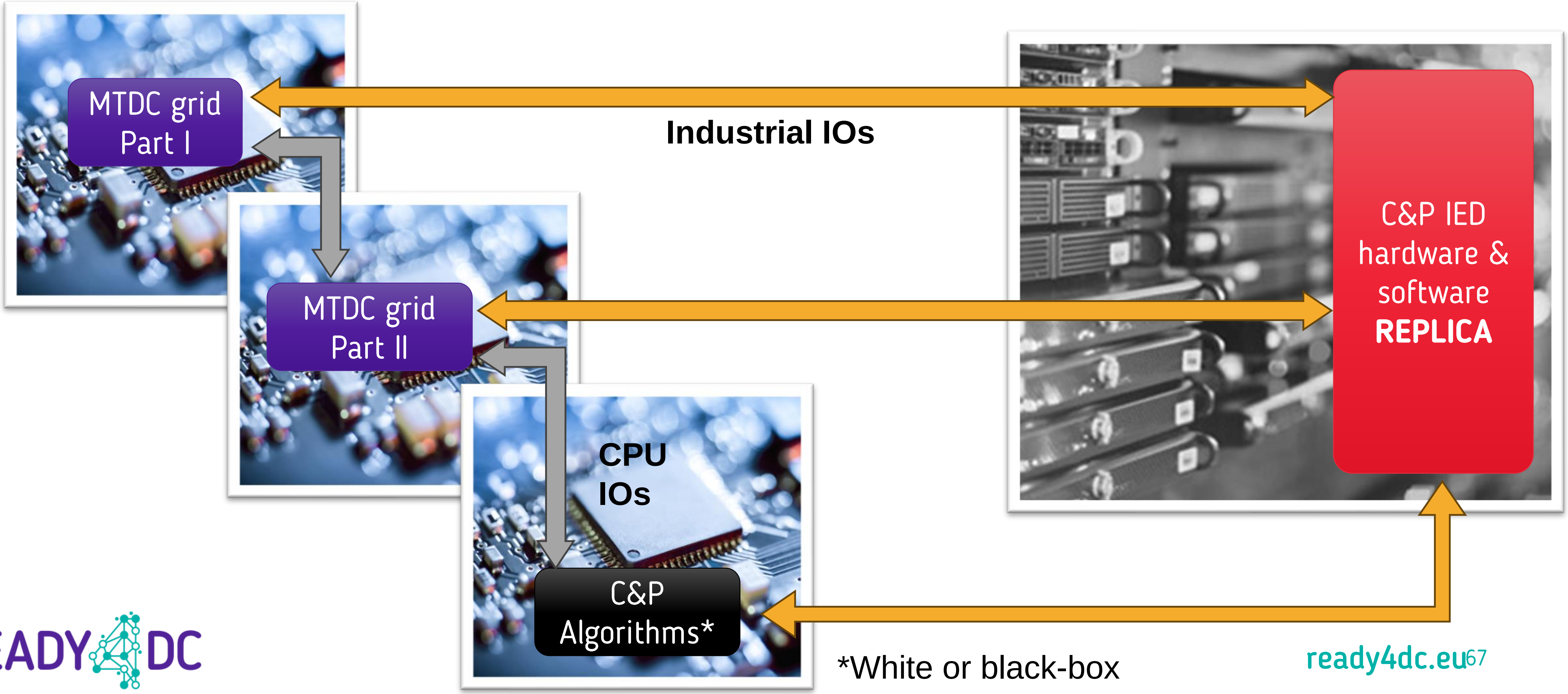


*White or black-box

HIL tests (real-time is implicit)



Hybrid SIL/HIL tests (real-time also implicit)



*White or black-box

Comparative analysis

A great power, requiring great responsibilities

	Simulation hardware	Type of interface	Type of model/replica	HIL-ready	Market availability	Setup complexity	Cost	Fidelity to... ...real software	...real hardware	Reusability of models/replicas	Model/replica maintenance complexity	Compatibility with FPGA-based models
SIL OFFLINE	Standard computer	Virtual IOs	Vendor or generic	No	Common	Standard	Standard	No	No	High	High	No
SIL OFFLINE +	Advanced computer	Virtual IOs	Vendor or generic	No	Common	Standard	Standard	No	No	High	High	No
SIL RT	Advanced or Dedicated	Virtual or Generic IOs	Vendor or generic	No	Uncommon	Moderate	Moderate	No	No	Moderate	Moderate	Maybe
SIL RT +	Dedicated	Industrial IOs	Vendor or generic	Yes	Uncommon	Moderate	Moderate	Maybe	No	Moderate	Moderate	Maybe
HIL	Dedicated	Industrial IOs	Generic	-	***NOT EXISTING***	*High*	*High*	*Maybe*	*No*	*High*	*Moderate*	*Maybe*
HIL +	Dedicated	Industrial IOs	Configurable hardware	-	***NOT EXISTING***	*High*	*High*	*Yes*	*Maybe*	*High*	*Moderate*	*Yes*
HIL ++	Dedicated	Industrial IOs	Vendor replica	-	Common	High	High	Yes	Yes	Low	Low	Yes

7

Take-aways

Main take-aways

- The overall AC/DC system will face the risk of new and more interactions…
- Network codes shall anticipate them,
  integrating new methodologies and tools for interaction studies
- Interaction studies remain priority after MTMV HVDC projects awarded, when vendors support availability is at its highest
- Prospective studies at R&D and pre-design stages appear in the landscape
- Converter functions openness under exploration by experts, but still far from practical implementations
- Different EMT tools for different scenarios, but **SIL (offline) and HIL** using **vendor models and replicas** respectively are current trend for interaction studies in design phases for green field MTDC HVDC development.
- Hybrid SIL/HIL as an option for large EMT and brown field MTMV HVDC development

Thank you

For your attention and feedback on D1.2

READY4DC

READY4DC WG 3 Multi-vendor Interoperability Process and Demonstration Definition

Joint READY4DC-InterOpera Dissemination Event

READY4DC

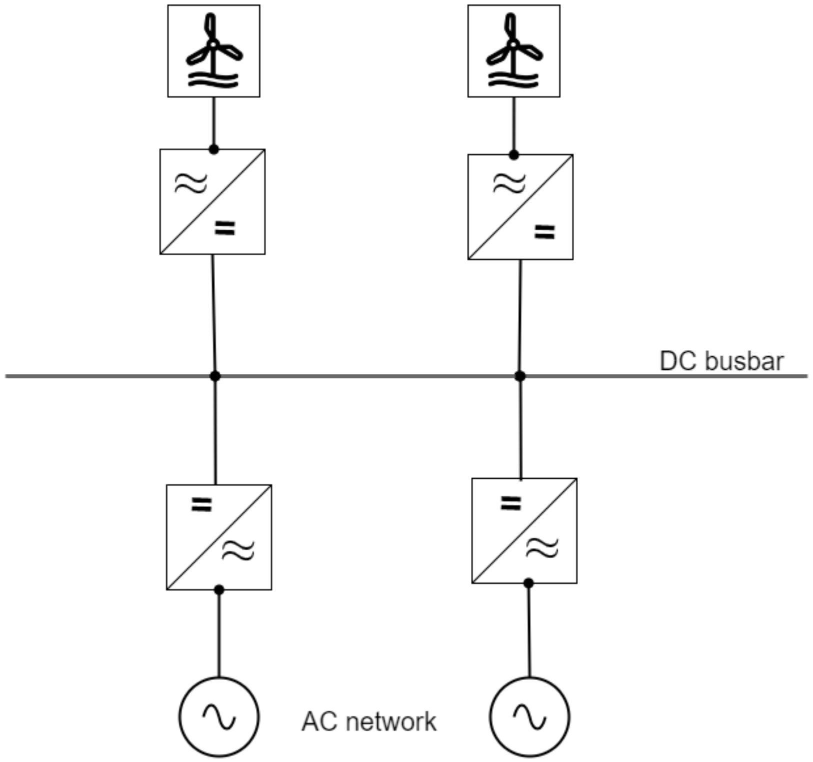
Nico Klötzl (TenneT)

13th September 2023

Motivation

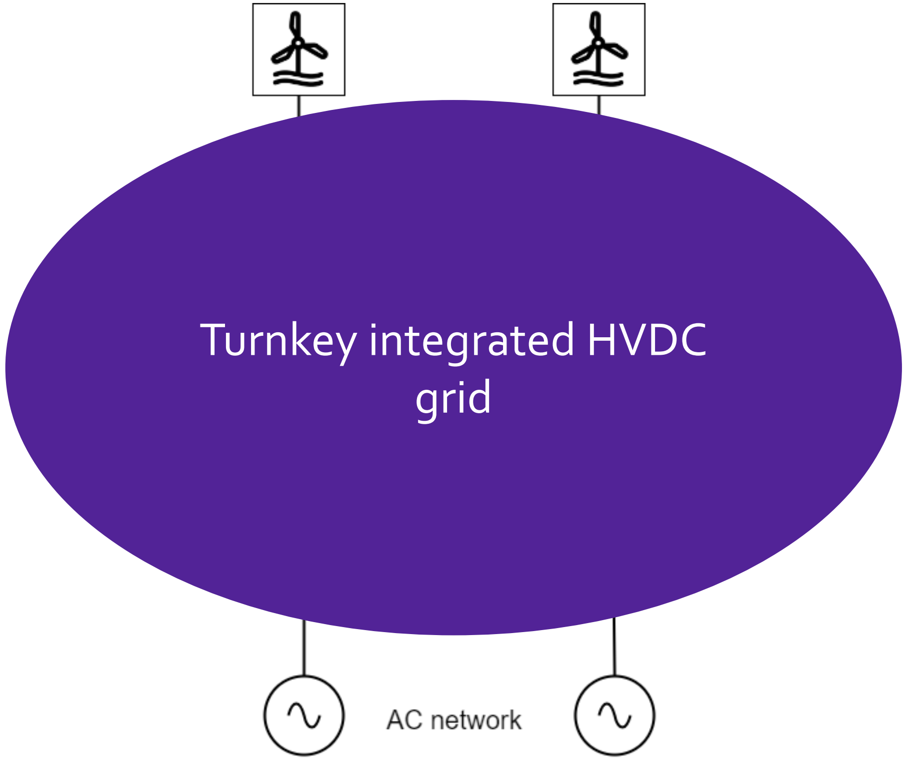
Current status

As is: Single Vendor – Multi Terminal



Current status

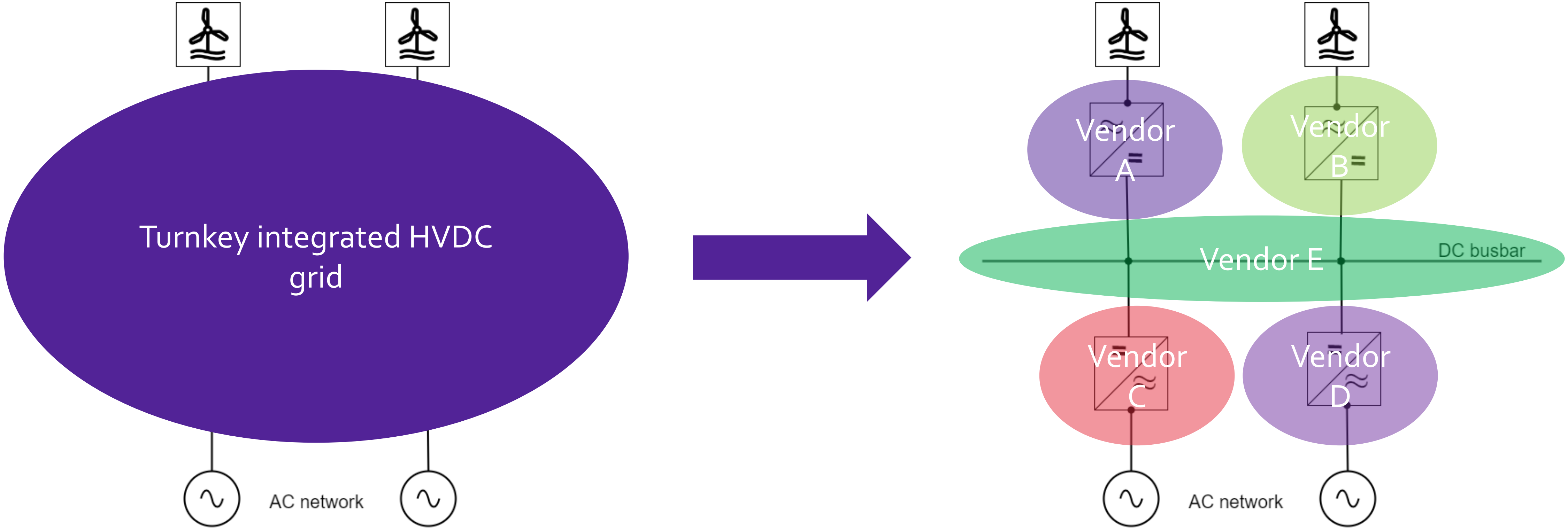
As is: Single Vendor – Multi Terminal



Aim: Modular and interoperable HVDC building blocks

As is: Single Vendor – Multi Terminal

To be: Multi Vendor – Multi Terminal



WP3 Objectives

Guidelines for demonstration project

- **Selection criteria** for the first MTMV demonstrator
- Proposal of potential (type of) **candidate projects**

Procedure for **selecting functional specifications**

Key milestones in implementing a first MTMV demonstrator

Roadmap future expandability beyond demonstration project

→ Mention what needs to be thought of

→ Give recommendations

2

Definition of selection criteria

Selection criteria for the first MTMV demonstrator

- Functional requirements
  - Compliance to system operation guideline (SOGL)
  - Fulfilment of transmission request
  - Provision of grid services
  - Grid Forming Capability
  - Improvement of ancillary services
  - Redundant coupling
  - Functions requiring use of technology components currently of low technology readiness level
  - Reduction of technical complexity/risk

- Design impacts
  - DC fault protection
  - DC control

Selection criteria for the first MTMV demonstrator

Design impact: DC fault protection

- Introduction of DC-FSD recommended
- Enable connection of new terminals recommended

Design impact: DC control

- minimising the dependencies on communication
- behaviour is predictable

Selection criteria for the first MTMV demonstrator

- Functional requirements
  - Compliance to system operation guideline (SOGL)
  - Fulfilment of transmission request
  - Provision of grid services
  - Grid Forming Capability
  - Improvement of ancillary services
  - Redundant coupling
  - Functions requiring use of technology components currently of low technology readiness level
  - Reduction of technical complexity/risk

- Design impacts
  - DC voltage options
  - Selection of active power per converter station

Selection criteria for the first MTMV demonstrator

Design impact: DC voltage options

- 320kV or 525kV
- DC control easier with one voltage level

Design impact: Selection of active power per converter station

- TRL level for 2GW considered market ready
- No specific power rating recommended
- For verification purposes minimum active power rating of some hundreds MW

Selection criteria for the first MTMV demonstrator

- Functional requirements
  - Compliance to system operation guideline (SOGL)
  - Fulfilment of transmission request
  - Provision of grid services
  - Grid Forming Capability
  - Improvement of ancillary services
  - Redundant coupling
  - Functions requiring use of technology components currently of low technology readiness level
  - Reduction of technical complexity/risk

- Design impacts
  - Trade offs in converter station function selections across DC network
  - Submodule technology selection
  - Topology selection
  - Overplanting of windfarms and deloading below MPP
  - Offshore AC connection
  - Include technologies not being operated in the European transmission grid up to now
  - Demonstrator project for first MTMV project doesn't aim to solve all issues from the beginning

3

Selection of potential candidate projects

READY4DC

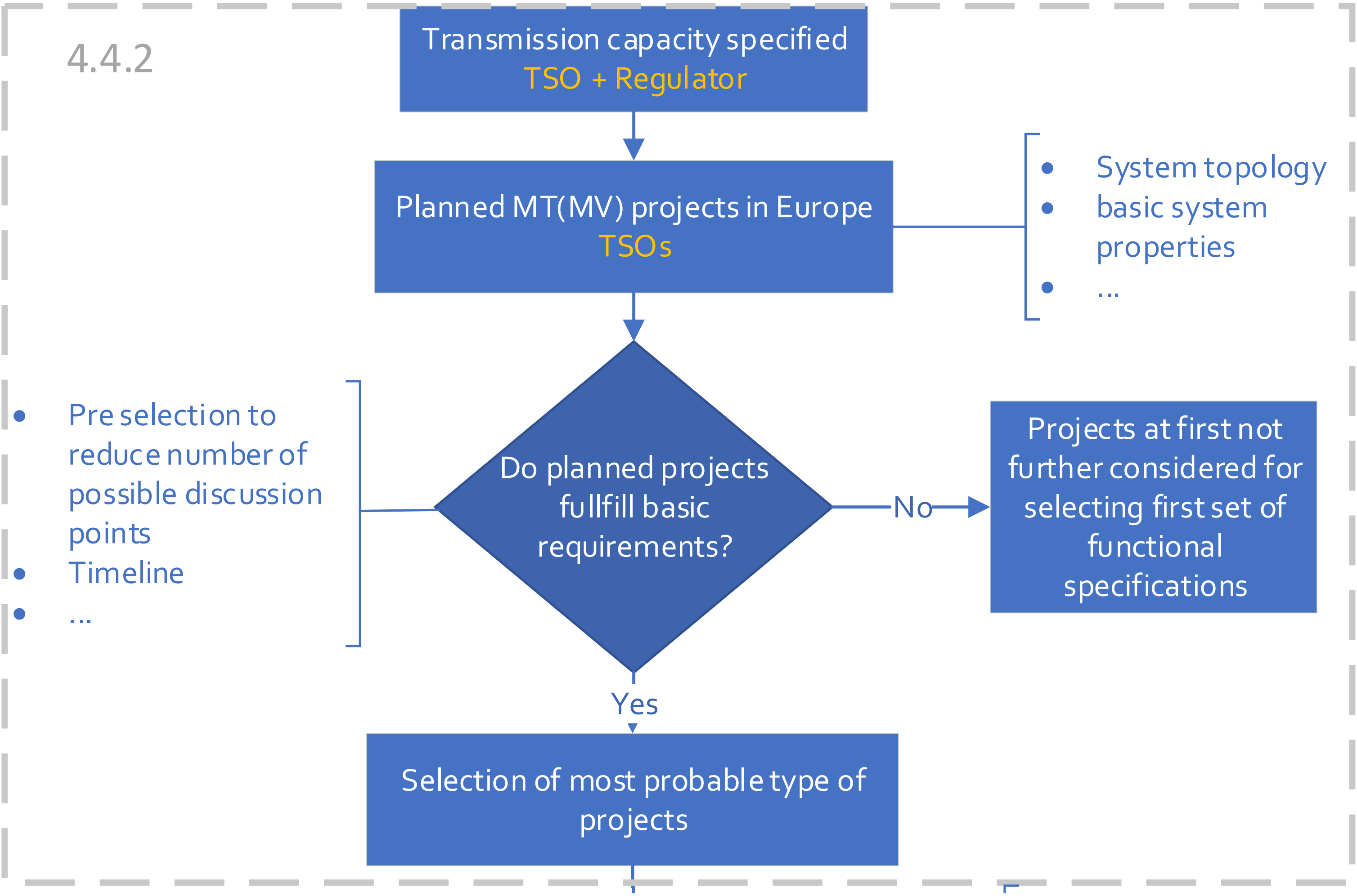
Selection of potential candidate projects

1. Bornholm Energy Island
2. North Sea Energy Island
3. Project Aquila
4. Generic MTMV system

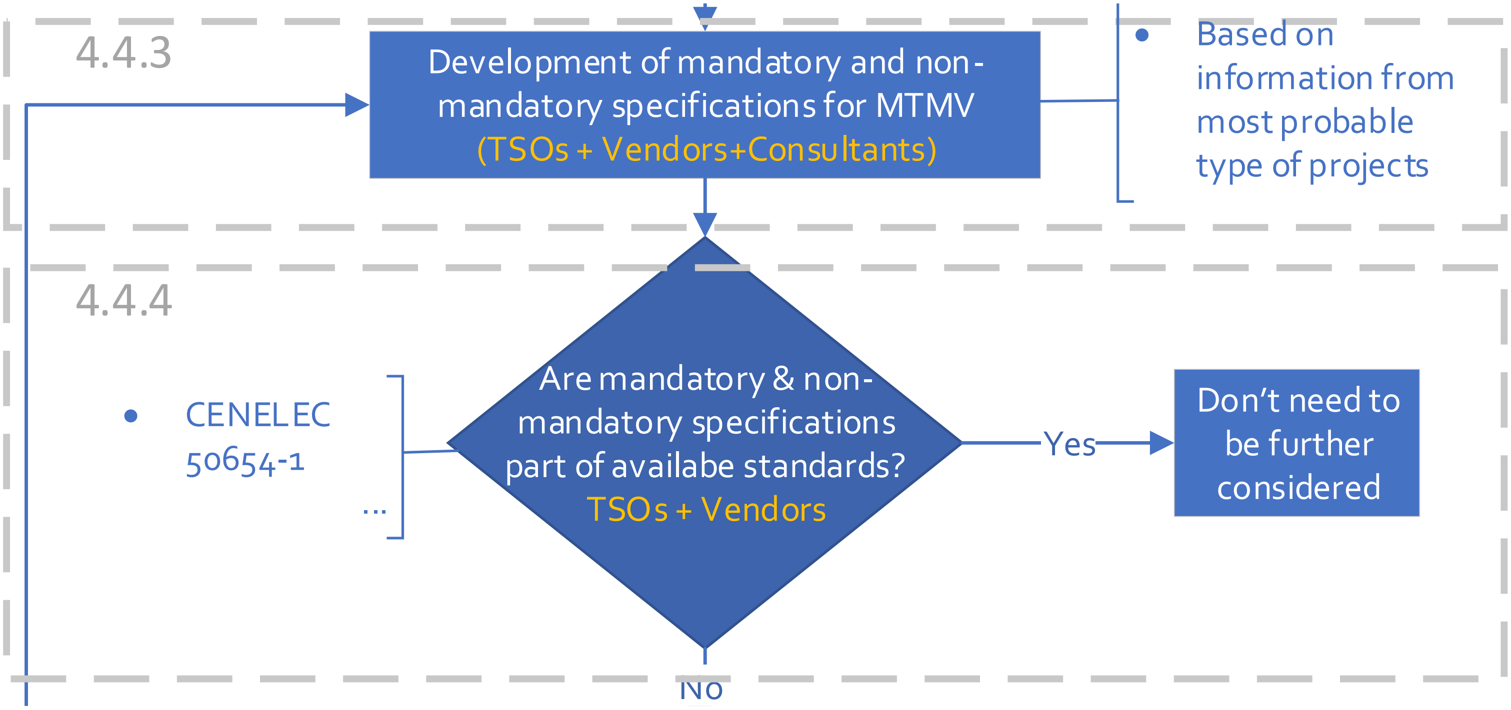
4

Procedure for selecting functional specifications beyond the first demonstrator

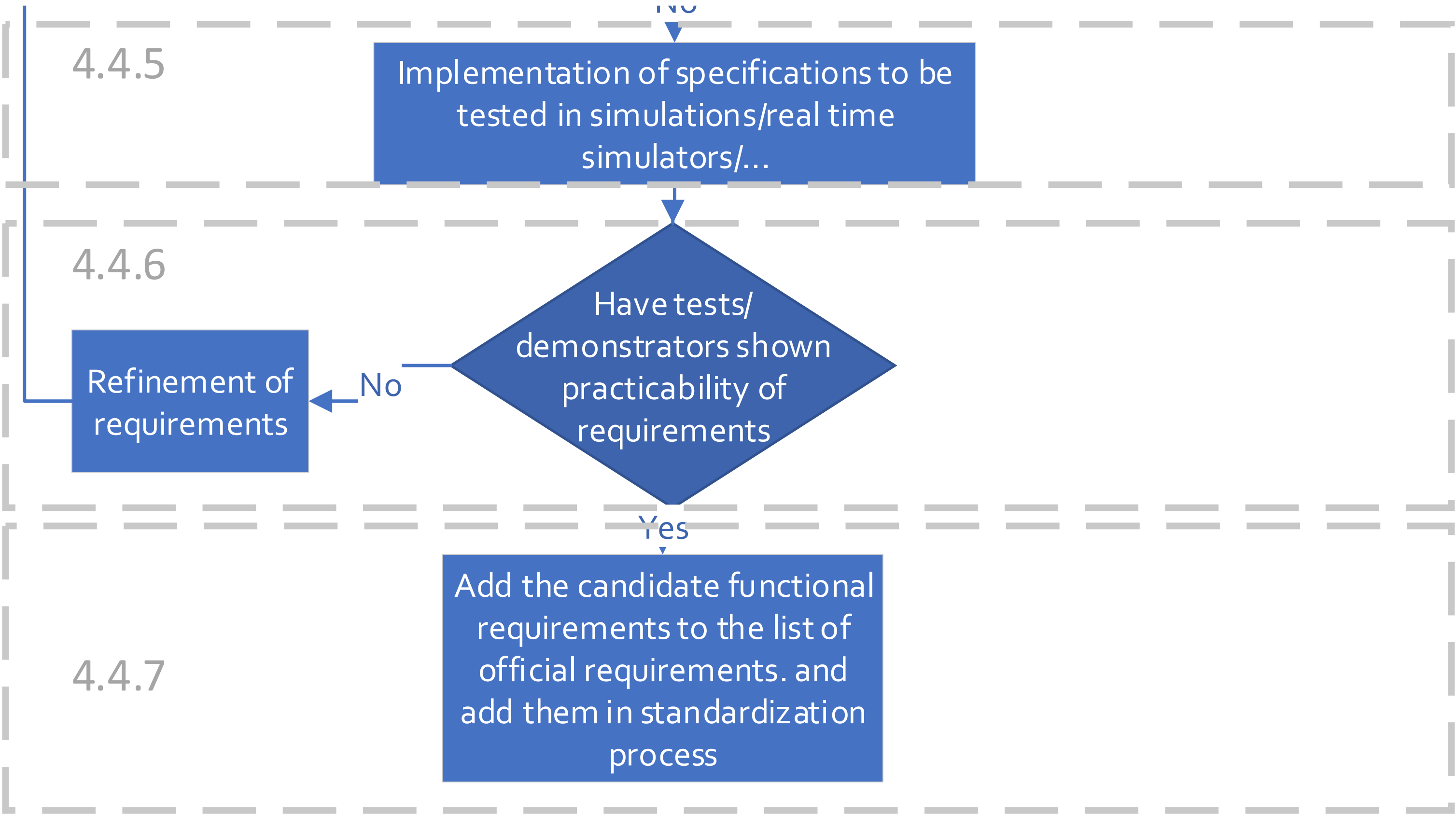
Procedure for selecting functional specifications



Procedure for selecting functional specifications



Procedure for selecting functional specifications



5

Key milestones in implementing a MTMV demonstrator

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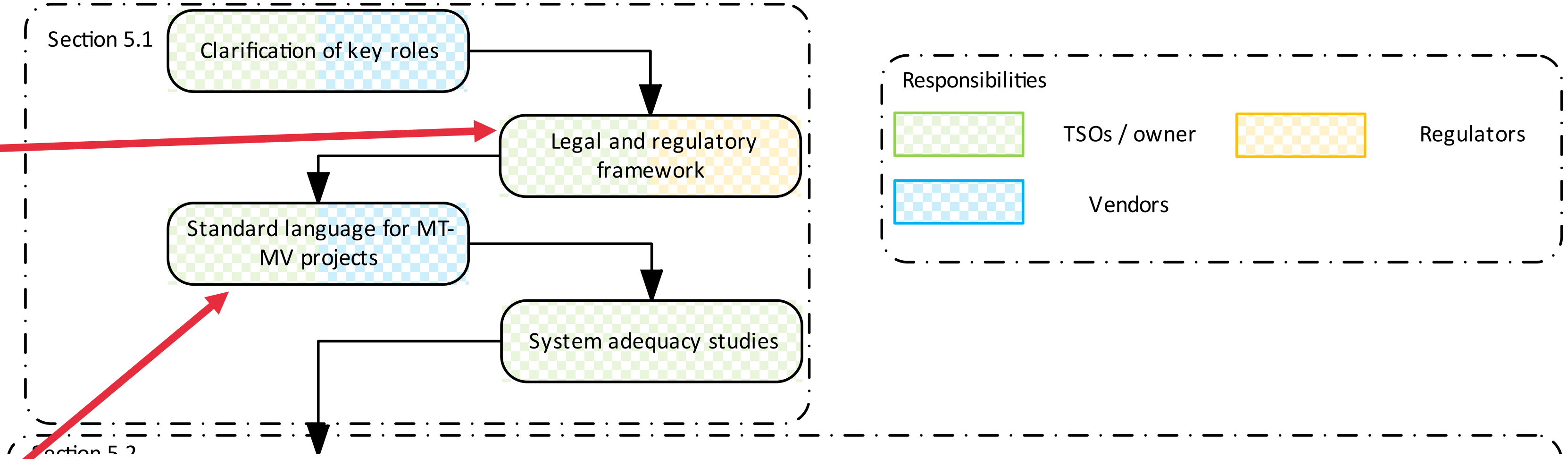
Key milestones implementing a MTMV demonstrator – Preconditions and assumptions before planning phase

- include MT-MV demonstrator as project of common interest (PCI) in TYNDP or within grid development plan
- Alignment of different system operation guidelines

- Two interfaces: a.) Model sharing b.) grid and station level control



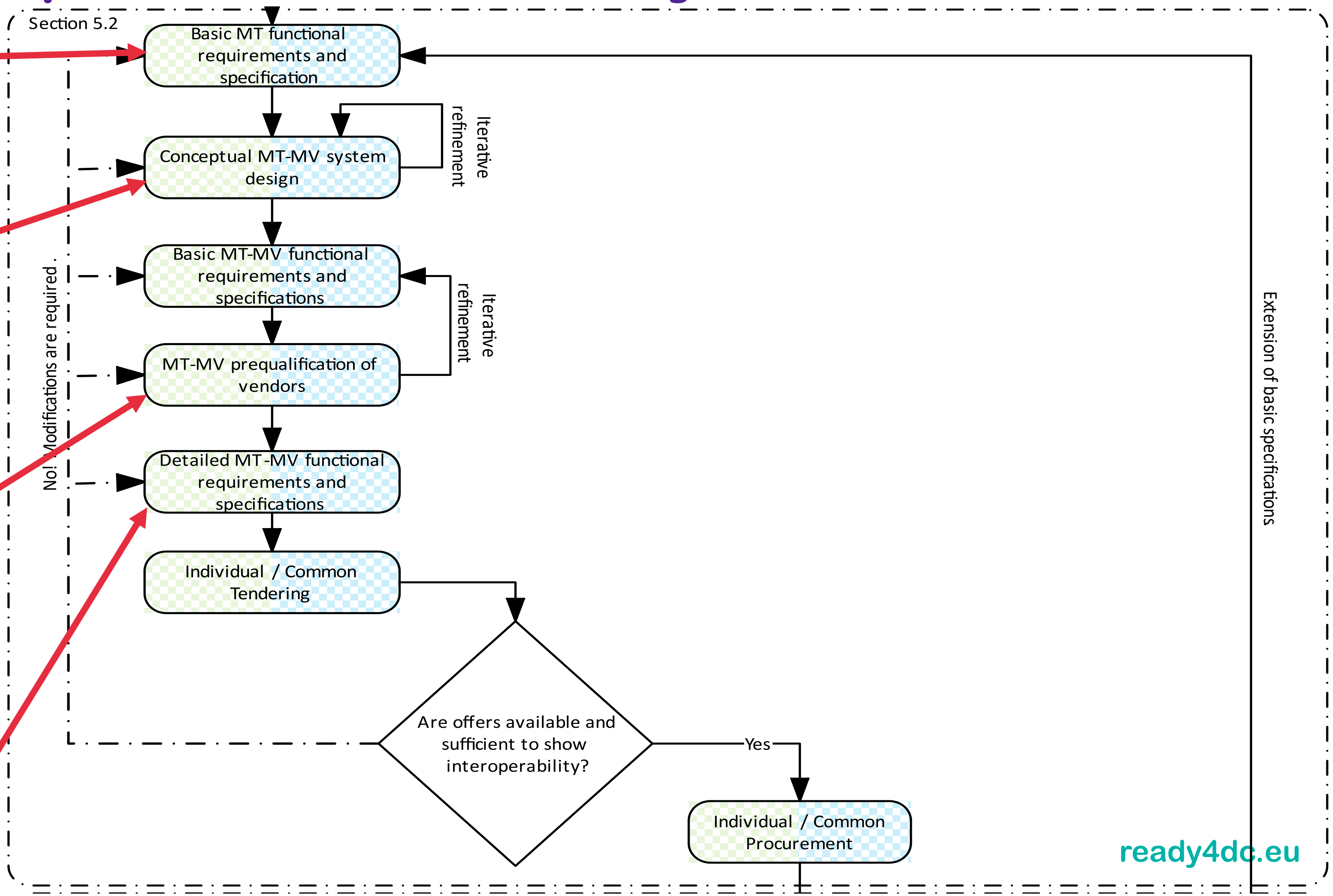
Key milestones implementing a MTMV demonstrator – Planning & Development of a MTMV system

- Recommendations from Chapter 4 may be used

- First draft by TSOs, reviewed by vendors
- Screening and initial dynamic performance & interaction studies

- examine if vendors can fulfil MTMV interoperability with defined functional specifications
- Possible iterative adjustments of the specifications

- Operating requirements
- Energization/shut down
- Protection concepts
- Coordinated control
- …



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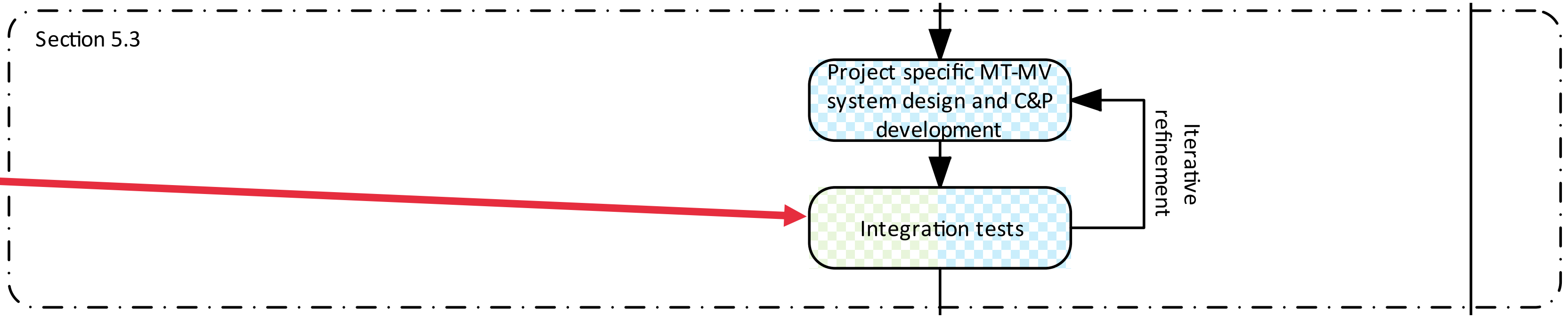
Key milestones implementing a MTMV demonstrator – From a conceptual to a project specific design

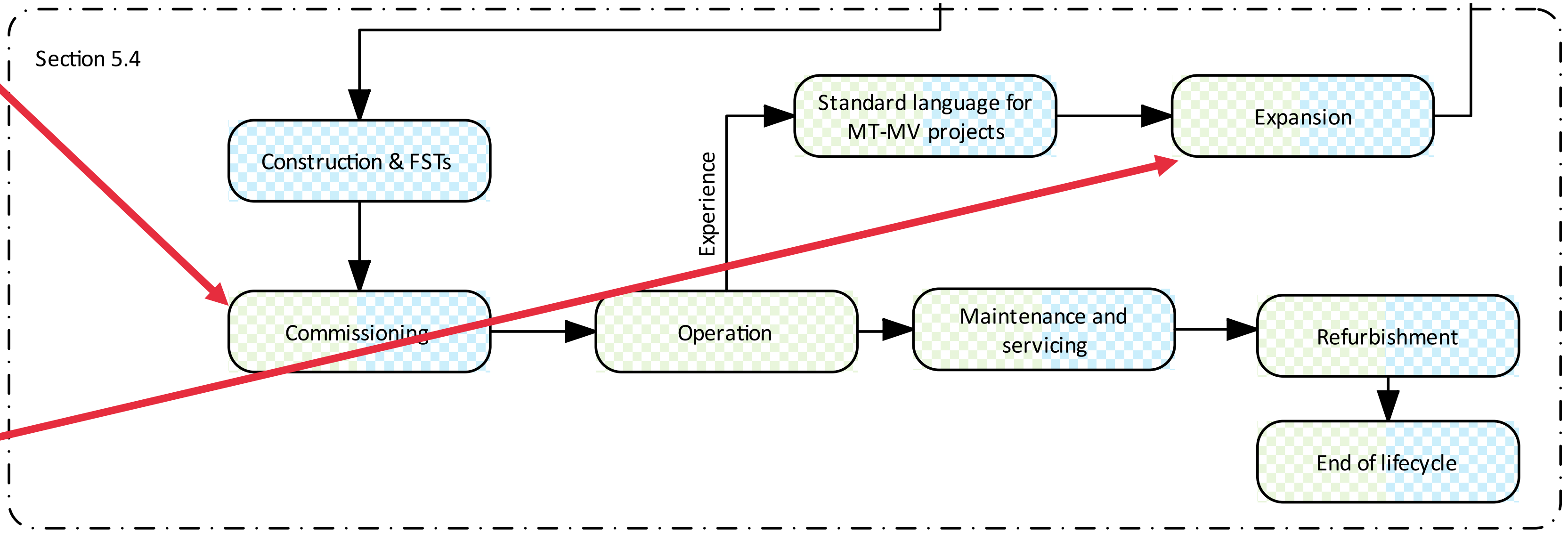
Functional and dynamic performance will be demonstrated by offline, software-in-the-loop and hardware-in-the-loop system testing



Key milestones implementing a MTMV demonstrator – Final steps from construction to end of lifecycle

Sufficient training for operators needed

- possible new functions, software upgrades, cubicles and new technologies such as fault separation devices and DC-DC converters
- the system shall be classified as expandable at the beginning of the planning phase



6

Providing a roadmap towards rolling out future expandability

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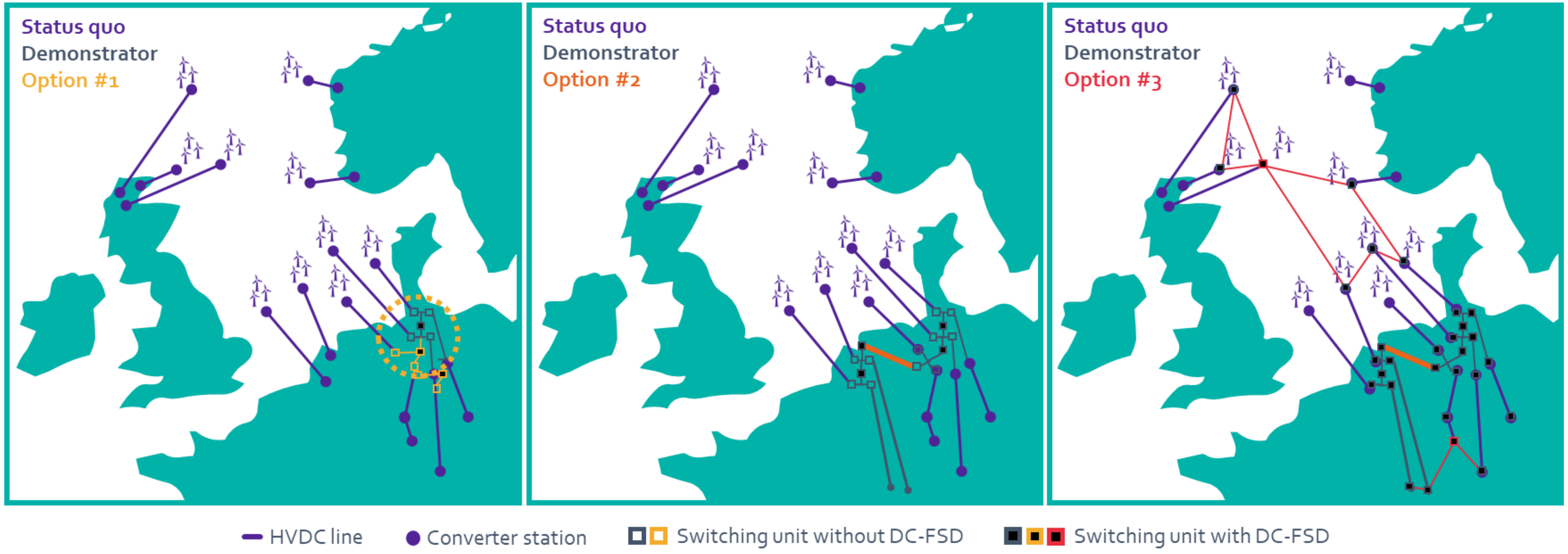
Providing a roadmap rolling out future expandability – Phases

- Phase 1: Gaining experience from the first MTMV HVDC demonstrator
  - Interoperability is proven
  - Necessary adjustments can be made to the existing requirements so future linking of hub projects is enabled
- Phase 2: Development of an overall system design
  - No consensus so far about the potential options for further development. But it is possible to distinguish between three topics, based around various priorities
- Phase 3: Standardisation to modular sub-systems
  - standardize technical and regulatory requirements to ensure modular expandability of the system
  - compatibility of converter stations and separate DC switchgear
  - modular protection design
  - overall goal is to achieve modular HVDC building blocks with standardized I/O interfaces which include interoperability by design

Providing a roadmap rolling out future expandability – Phases



Providing a roadmap rolling out future expandability – Essential requirements

<u>Technical requirements:</u>

- System rating
- Power flow control
- Dynamic stability
- Protections and Equipment
- Etc.

<u>Roles of key actors:</u>

- Policy makers
- Energy regulators
- Standardization bodies
- Academy and research centres
- TSOs
- Vendors
- Consultants

<u>Planning standards:</u>

- Definition of technical terms and descriptions
- Strategy of potential interfaces for the exchange of signals and data
- Standardization of integration studies for future projects
- Standardized regulations for network connection
- …

<u>Further requirements:</u>

- External threats
- Cyber security
- Cost

Providing a roadmap rolling out future expandability – Planning standards

Regulatory bodies

Connection
- Grid forming
- Integration studies
- Interfaces for old and new devices
- AC-PoC requirements

Operations
- Operational limits (e.g. voltage bands)
- Voltage and power flow control
- System defence and restoration
- FRT requirements

Market
- Market coupling of European countries
- Harmonisation and Standardisation
- …

Cybersecurity
- Interfaces between converters and communication
- Risk mitigation and monitoring
- Protection against external threats

Thank you!
Q&A

READY4DC

ready4dc.eu

READY4DC WG 2
Legal and Regulatory

CIGRE Vienna – READY4DC/InterOPERA Joint Event

READY4DC

Dr. Ceciel Nieuwenhout

13-9-2023

Whitepaper

Legal and Regulatory Aspects of a Multi-Vendor Multi-Terminal HVDC Grid

READY4DC

Introduction

- WG2: Whitepaper almost ready – your input counts!!
- Governance
- Cooperation between companies
- Standardisation
- IP
- Risks & Liability

Governance

READY4DC

Coordination on a larger system level needed

- Coordination in public law
  - EU electricity market regulation & directive
  - Is it the same as AC?
  - Tariff model
  - Network Codes

- Private law
  - Umbrella agreement
  - Model Bilateral agreement

- Standardisation agreements
  - Between public & private
  - Essential for interoperability

Roles & Responsibilities currently not clear

- Roles and responsibilities will change over the lifetime of assets
- Not all parts of the system will have the same division of roles and responsibilities
- Responsibilities should be placed there where the risks that come with it can best be mitigated
- Short Term vs Long Term

Cooperation

Between companies

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Cooperation between companies

- Governed by competition law
- Agreements should not be anti-competitive / disrupt the market
- Guidelines for when this is the case
- Application to HVDC grid development
- 101(3) TFEU exceptions and safe havens

Standardisation

- Large group of companies (large market share)
- Open & transparent process
- Voting rights
- Objective reasons for choosing a certain standard
- Standard Essential Patents: FRAND
- Excessive Pricing: what is excessive?
- Static or Dynamic Standards

IP Rights and HVDC Standardisation

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Patents and Trade Secrets

- What’s the difference?
- Why does it matter?
- Shift from turnkey to MVMT
- Can it still be blackboxed?

Relevant considerations

- The price of a license / access to a patent
- How to apply FRAND to trade secrets?
- Individual licensing or patent pool?
- Protection of IP rights differs per country
- Interpretation may differ per country

Risks & Liability

READY4DC

Introduction

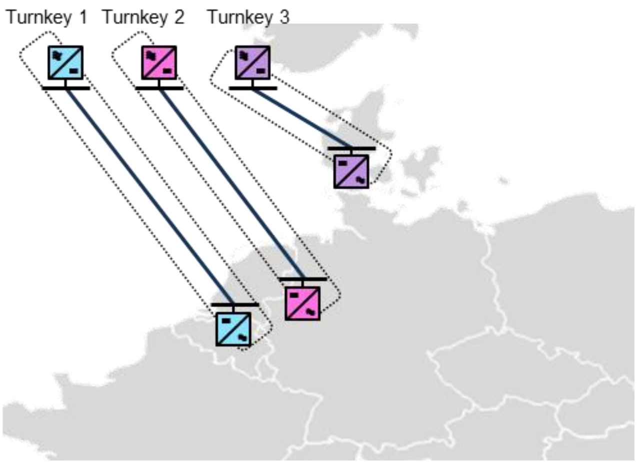
- Multi-Terminal Multi-Vendor HVDC systems are complex and involve multiple stakeholders and vendors.

- Defining liabilities and risk allocation is crucial to ensure **accountability** and avoid disputes in case of system **malfunctioning and interoperability issues**.

- Within Ready4DC principles and considerations for defining liabilities and risk allocation in such systems were outlined.

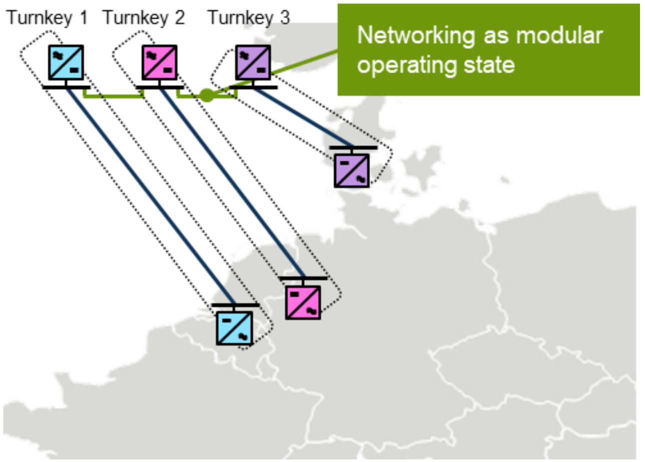
From Turn-key to Multi-Vendor Systems

Status Quo – Point-to-Point HVDC Systems



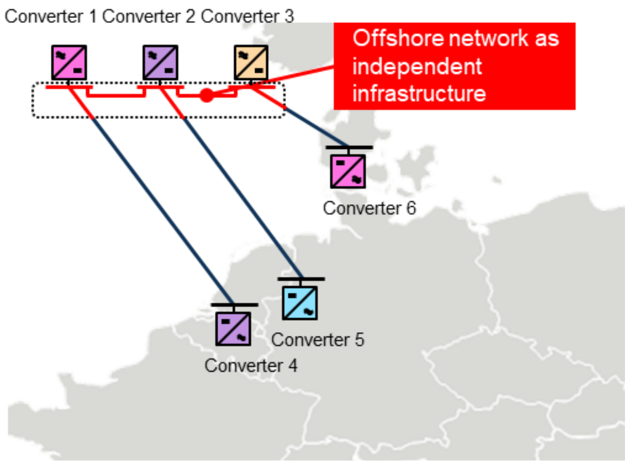
- Turn-key systems by a single vendor

DC-side connection of Multi-Vendor-Point-to-Point Systems



- Network based on the connection of turn-key systems
- Turn-key systems as fallback

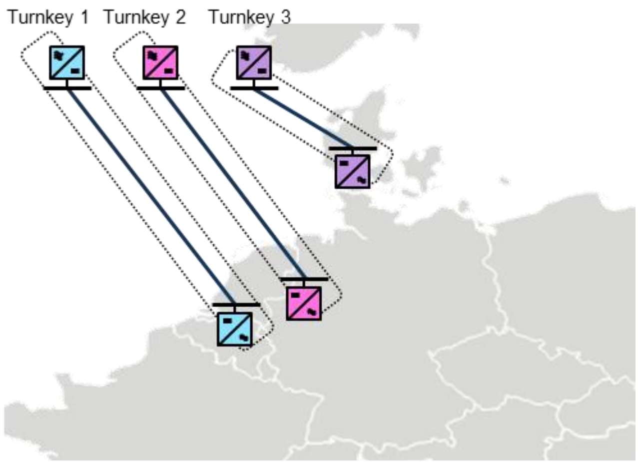
Distributed Multi-Vendor Multi-Terminal Systems



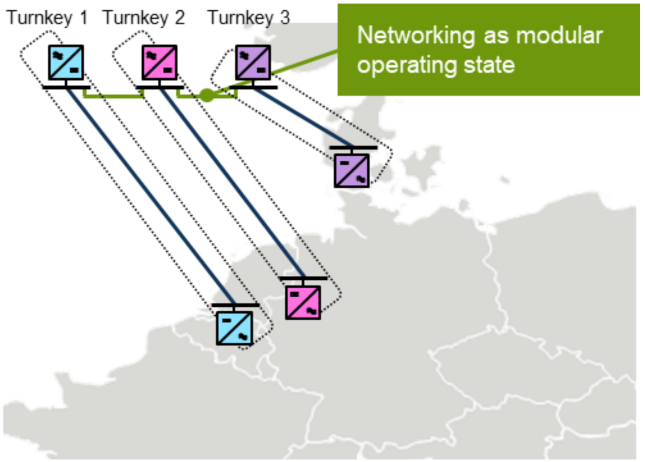
- Fully modular MT/MV system
- Full responsibly on the system operator(s)

From Turn-key to Multi-Vendor Systems

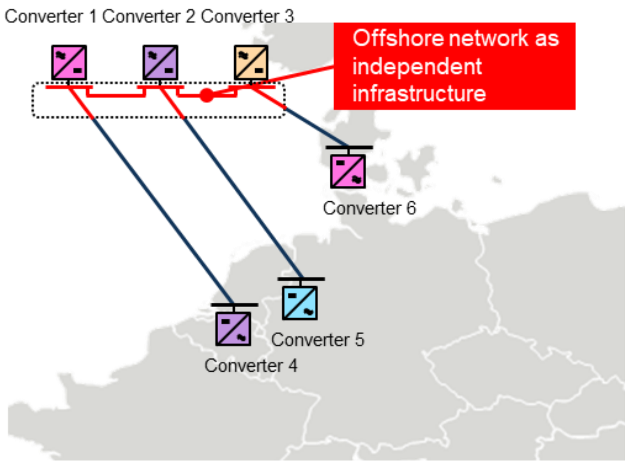
Status Quo – Point-to-Point HVDC Systems



DC-side connection of Multi-Vendor-Point-to-Point Systems



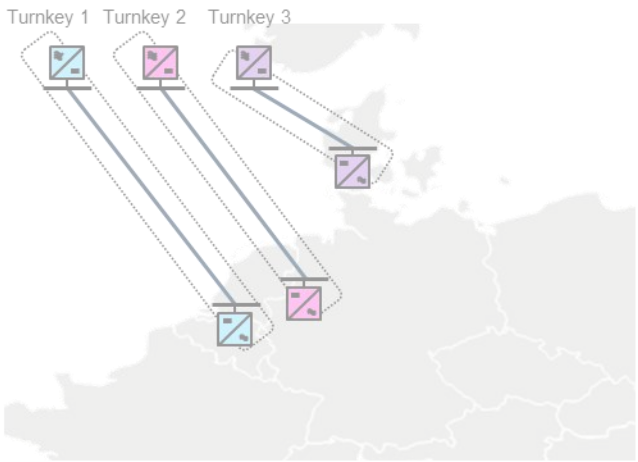
Distributed Multi-Vendor Multi-Terminal Systems



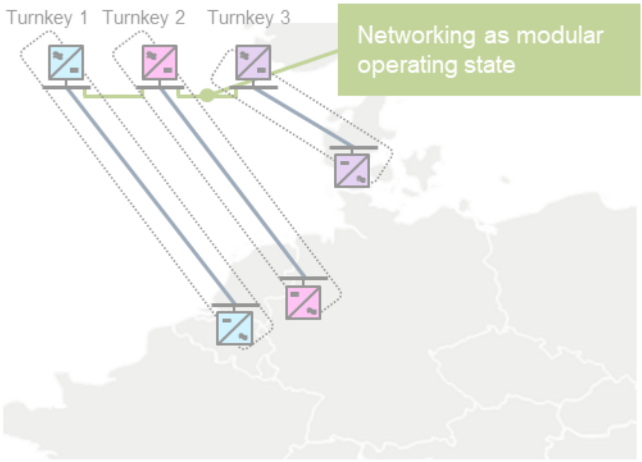
System responsibility shifts from the manufacturer to the TSO or system developer, increasing the design risk for the latter.

Methodology to

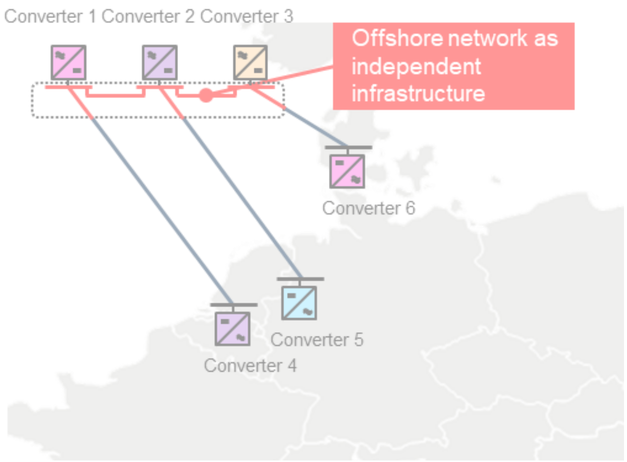
Status Quo – Point-to-Point HVDC Systems



DC-side connection of Multi-Vendor-Point-to-Point Systems

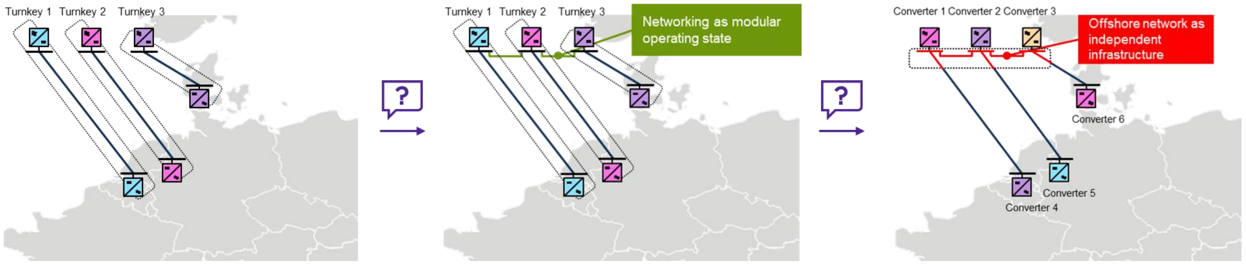


Distributed Multi-Vendor Multi-Terminal Systems



Identification of the MT/MV scenarios to be assessed → Identification of the MT/MV specific risks for all scenarios through the project phases → Proposals on how to distribute risks and liability

Project Preparation



System Design

- **Responsibility for design shifts** from the vendor(s) to TSOs or system developers, increasing the design risk for the latter.
- The system developer will take on the role of the **system designer**, including the definition of functional and specific requirements at the DC connection points.
- The design of components, such as converter stations, will remain the responsibility of the HVDC vendors
  - Vendors are liable for malfunctions against the system designer's requirements

➢ Connecting turn-key systems can be an **intermediate step** in allocating risks and corresponding liabilities.

Summary and Next Steps

- The shift from turnkey HVDC systems to distributed multi-terminal multi-vendor HVDC systems can impact risks and associated liabilities in several ways:
  - **Turnkey systems:** single vendor responsible for entire project and liable for faults or damages
  - **Multi-vendor systems:** multiple vendors involved, increased risk of interoperability issues and difficulty in allocating liability
- Risk mitigation for early multi-terminal multi-vendor systems:
  - Connection of turn-key point-to-point systems from different vendors
  - Easier management and operation, possibility of separation if issues occur
- Minimization of risks and liabilities
  - clear definition of roles and responsibilities in contracts
  - clear guidelines for system integration and testing
  - thorough testing of interoperability

- Identification of the impact of MT/MV HVDC on liabilities and risk allocation
- Procurement strategy and concepts (templates) for contracts
- Implementation and lessons-learned
- Cross TSO exchange required

Thank you!
Questions?

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Also on behalf of co-authors
Philipp Ruffing and Vincent Lakerink

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READY4DC – InterOPERA

JOINT EVENT

13 September 2023

COFFEE BREAK

READY4DC

Inter OPERA

Enabling multi-vendor HVDC grids

InterOPERA

Introduction

PUBLIC

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

interopera.eu

PUBLIC

In its quest for CO2 reduction and energy independence the EC is promoting technology to support offshore wind generation.

A European Green Deal: climate neutrality in 2050 → Multi terminal HVDC systems serve the connection of offshore wind generation to onshore consumption centres

EC objectives:

- Green Deal: Reduction of GHG emission and climate neutrality by 2050
- REPower EU: Affordable, secure and sustainable energy for Europe

→ **massive deployment of 300 to 450 GW of offshore wind by 2050**
(28% of installed power generation in Europe)

Current approaches:

- **Power Park Modules connected through point-to-point HVDC transmission**

  → the multiplication of point-to-point links would be ineffective and lead to higher societal and environmental costs

- **First multi-terminal and hybrid HVDC systems are being deployed**

  → Locked-in single-vendor proprietary designs

Main needs for cost efficient Grids:

- Multi-vendor HVDC interoperability
- Grid forming capability
- HVDC system scalability

InterOPERA
Enabling multi-vendor HVDC grids

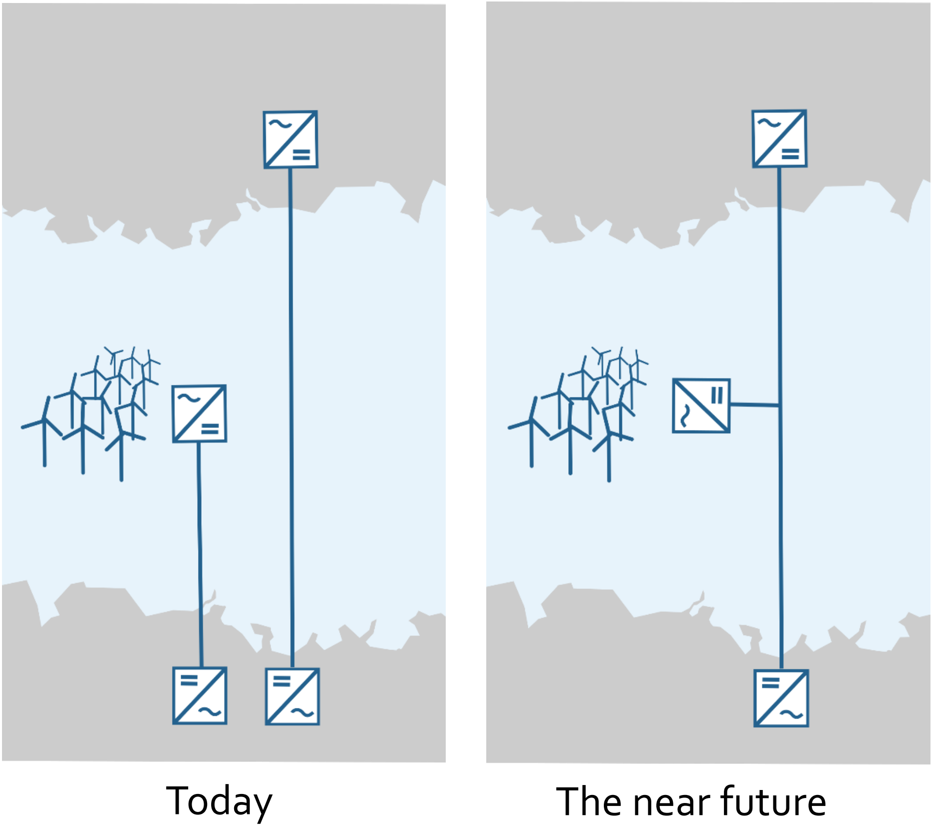
interopera.eu

PUBLIC

Multiterminal HVDC systems are seen as an opportunity for efficient and resilient energy transport

Reducing the footprint and increasing stability of offshore systems→ Multi terminal HVDC systems drive efficiency and resilience in deployment of transmission infrastructure

HVDC features	• Fewer losses over long distances • Power flow control and power system stability support capabilities (grid forming controls)
Multi-terminal systems	• Higher RES integration capacity • Increased market coupling, reduced societal costs • Minimized impact of infrastructure – increased social acceptance
Multi-vendor systems	• Limitation of risks related to one single technology provider • Increased competition and innovation • Potential increase in speed of deployment



Enabling multi-vendor HVDC grids

interopera.eu

Real Multi terminal HVDC systems are planned and being developed

- These help exploit large offshore wind developments
- And support long distance grid infrastructure projects transporting generation to consumption

10 to 15 projects in the next years

Denmark (Energinet & 50Hz)

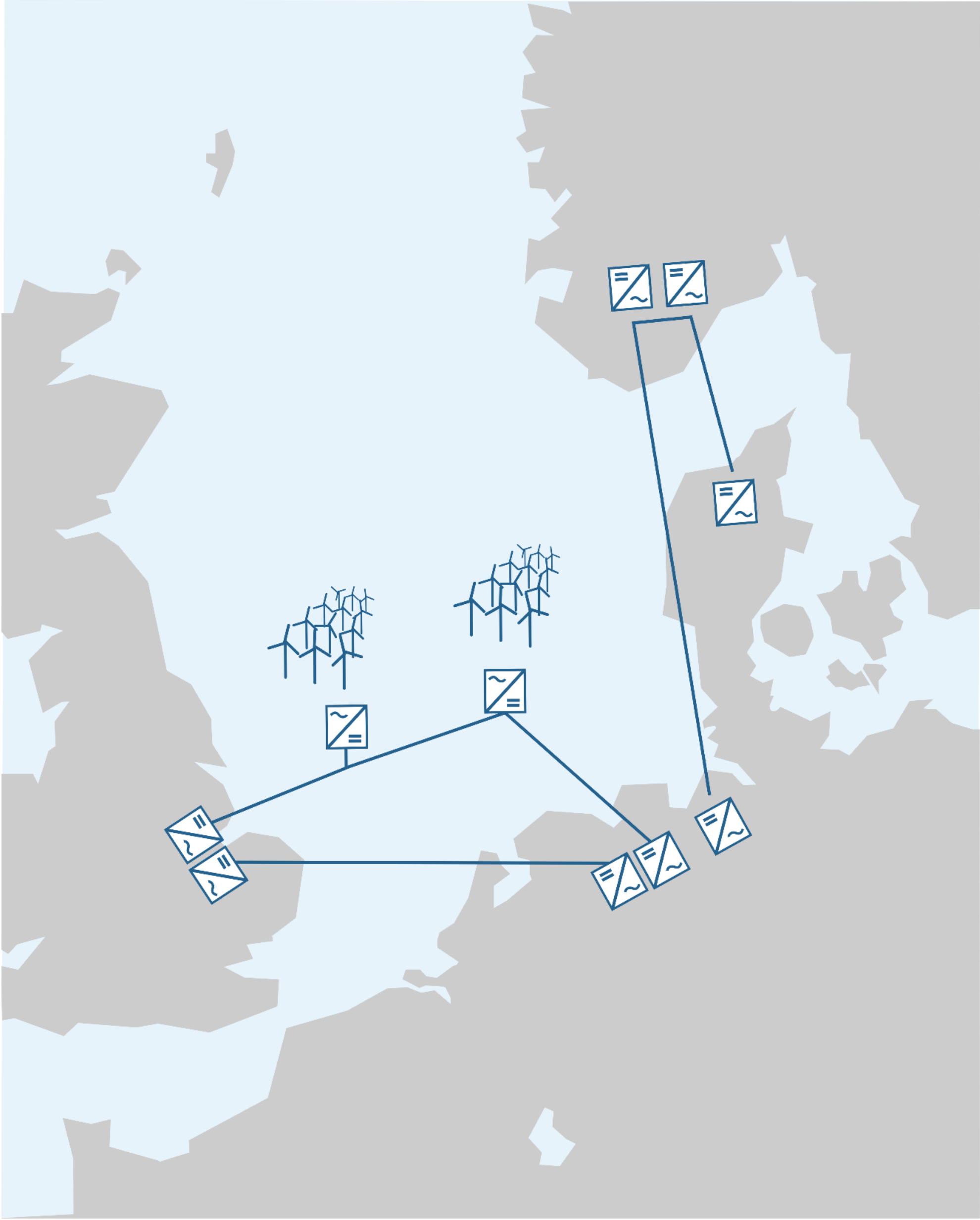
Bornholm Island
North Sea Energy Hub

NL/DE (TenneT & Amprion)

Windconnector
HeideHub
NW-Hub

Others to come…

Princess Elizabeth Island
France Manche
UK and US



InterOPERA
Enabling multi-vendor HVDC grids

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Challenges and ambition

InterOPERA is to de-risk multi-vendor multi terminal technology with grid forming capability

Main challenges

- How to ensure interoperability of converters provided by different vendors?
- HVDC converters and large scale PEIDs for power generation must host grid-forming controls
- How to pave the way for multi-terminal and multi-vendor HVDC projects?
- How to extend multi-terminal multi-vendor systems to larger and larger DC hubs?
- How to expand multi-terminal multi-vendor HVDC grids across countries?

InterOPERA ambition

- Functional technical integration and validation and multi-vendor cooperation frameworks with view to achieving modular and interoperable control and protection systems
- A real time physical demonstrator of a multi-vendor multi-terminal HVDC system with grid forming capability
- A new way of framing the European Grid architecture and topology, through coordinated power system planning
- Open solutions for multi vendor HVDC project procurement, new paths to offshore energy and grid development

What is InterOPERA about?

Multi-vendor HVDC interoperability
Grid forming capability
HVDC system scalability

Require…

Cooperation between vendors, TSOs and developers (+ENTSO-E, WindEurope and T&D Europe) + regional / international coordination

↓

action/intervention from the European Commission

↓

HORIZON-CL5-2022-D3-01-09 –
Real Time Demonstrator of Multi-Vendor Multi-Terminal VSC-HVDC with Grid Forming Capability (in support of the offshore strategy)

InterOPERA is on the critical path towards large-scale multi vendor and multi terminal HVDC systems in Europe – i.e. the future supergrid.

"We are here for the real thing"

InterOPERAs objective is to de-risk the multi-vendor multi-terminal HVDC technology with grid forming capability, to pave the way to the first real-life projects in Europe and to enable the development of the European HVDC grid for offshore wind energy integration

A coordinated approach

- Between TSOs, wind developers, HVDC manufacturers and WTG manufacturers
- 4 years part of the broader roadmap
- Engage with potential stakeholders and parallel activities

Demonstrated interoperability frameworks

- Operational, functional frameworks: modular build and standard interfaces
- Real project organization and procurement strategies
- Legal basis for complex multi-stakeholder cooperation

Enabling real offshore pilot projects

- Full scope of engineering activities
- Deliver a market ready solution
- Potential to facilitate tenders to be launched by 2027

Joint TSOs, HVDC Suppliers and Offshore Developers action

WTG vendors

Vestas
SIEMENS Gamesa

Wind developers

equinor
Wind EUROPE
Ørsted
VATTENFALL

HVDC vendors

Scibreak
Hitachi Energy
GE
T&D europe
SIEMENS energy

TSOs

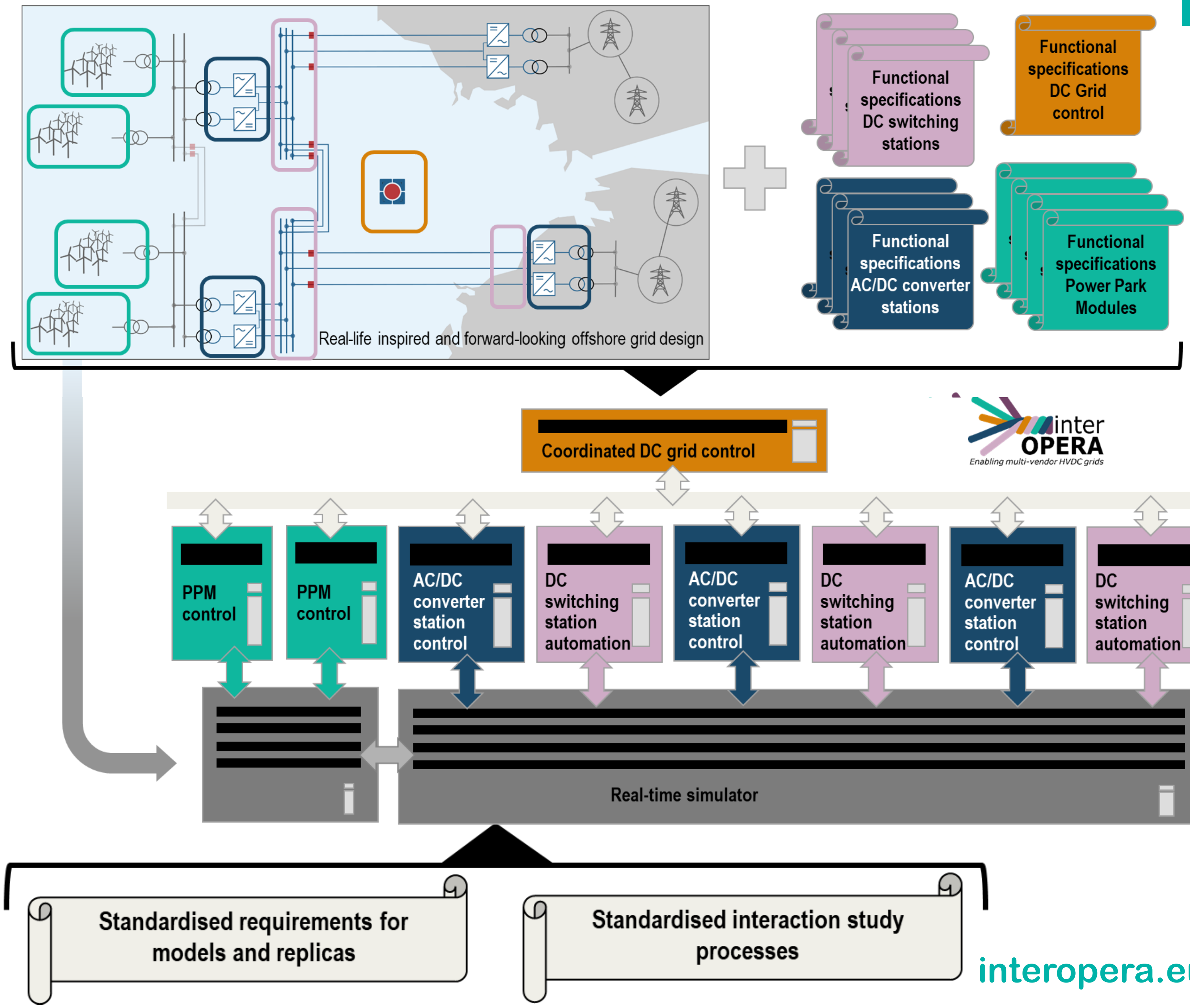
amprion
TenneT
Terna Driving Energy
Rte
ENERGINET
50hertz
Statnett

Consultants, Research & innovation

university of groningen
TU Delft
SuperGrid Institute – Shaping power transmission

Methodology

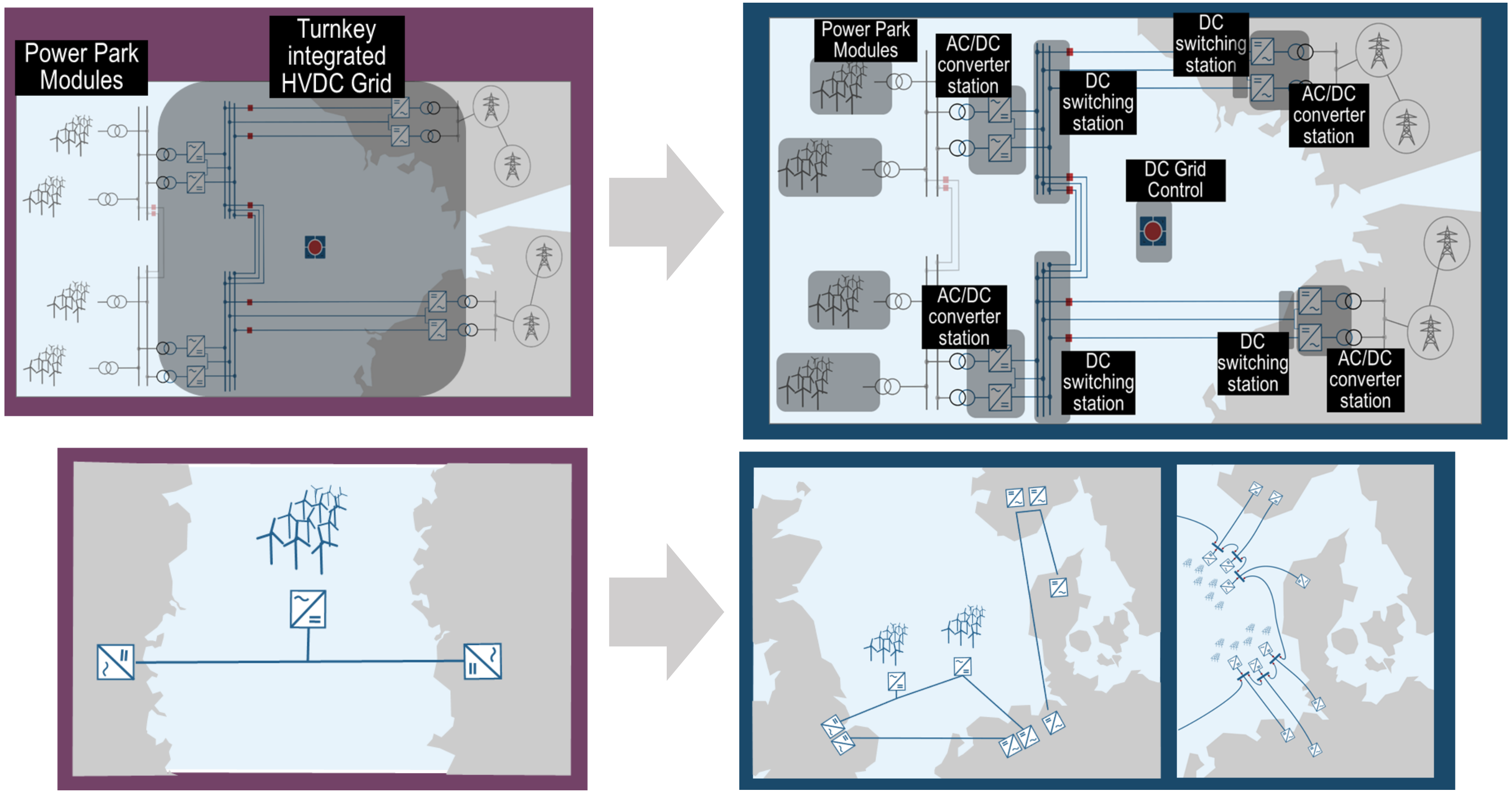
→ Develop relevant frameworks and perform full scope test activities to develop a real time physical demonstrator



PUBLIC

Make grids modular & interoperable by design

→Basic functional requirements for multi-vendor HVDC grid systems and subsystems, integrating PPMs

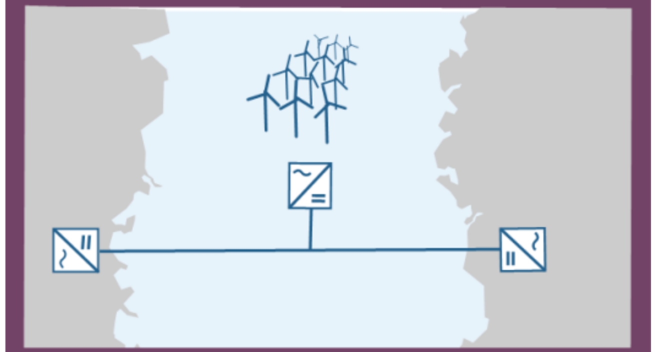


Inter OPERA
Enabling multi-vendor HVDC grids

Pave the way to real-life MV MT HVDC applications ready for future seamless system extension

WP1
WP2
WP3
WP4
WP5
WP6
WP7

→Real-life inspired and forward-looking offshore grid design – Demonstrator definition and guidance for coordinated HVDC system planning

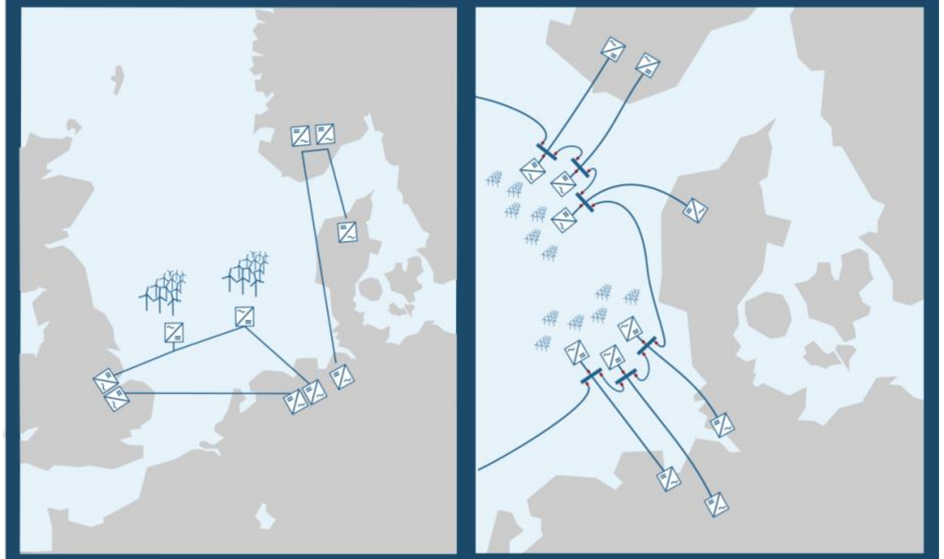


First single-vendor hybrid multi-terminal HVDC links

Expandability hindered by lack of coordination in power system planning

Risk in developing multi-vendor HVDC systems is too high

AS IS



Offshore grid expansion enabled by sufficient level of coordination in system planning - compatibility between HVDC projects

De-risked technical specifications for muti-vendor MT HVDC systems
Future proof and generically applicable procurement documents and processes

TO BE

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PUBLIC

Standardise HVDC and wind power plant models and replicas for assessment of interoperability.

WP1
WP2
WP3
WP4
WP5
WP6
WP7

Non-standard interaction study processes
Diverse quality and accuracy levels for models and replicas

HIL is the only reliable assessment environment
Co-existing proprietary simulation platforms
Models and replicas difficult to port and maintain

AS IS

Standard interaction study processes
Min. technical requirements for models and replicas

Progressive use of offline / SIL / HIL environments
Cross-validated proprietary simulation platforms
Portable and forward-compatible models and replicas

TO BE

Develop Grid forming control features, in support of onshore AC system.

Grid-forming use cases in multi-terminal HVDC systems

- Grid-forming with support from another synchronous area
  - 2 GFM(0H) stations sharing Vdc control duty
  - 1 GFM(H) station 1 Vdc control station
- Grid-forming with support from DC connected PPMs
  - Onshore GFM(0H) with Vdc control duty
  - Onshore GFM(H) with offshore Vdc control duty

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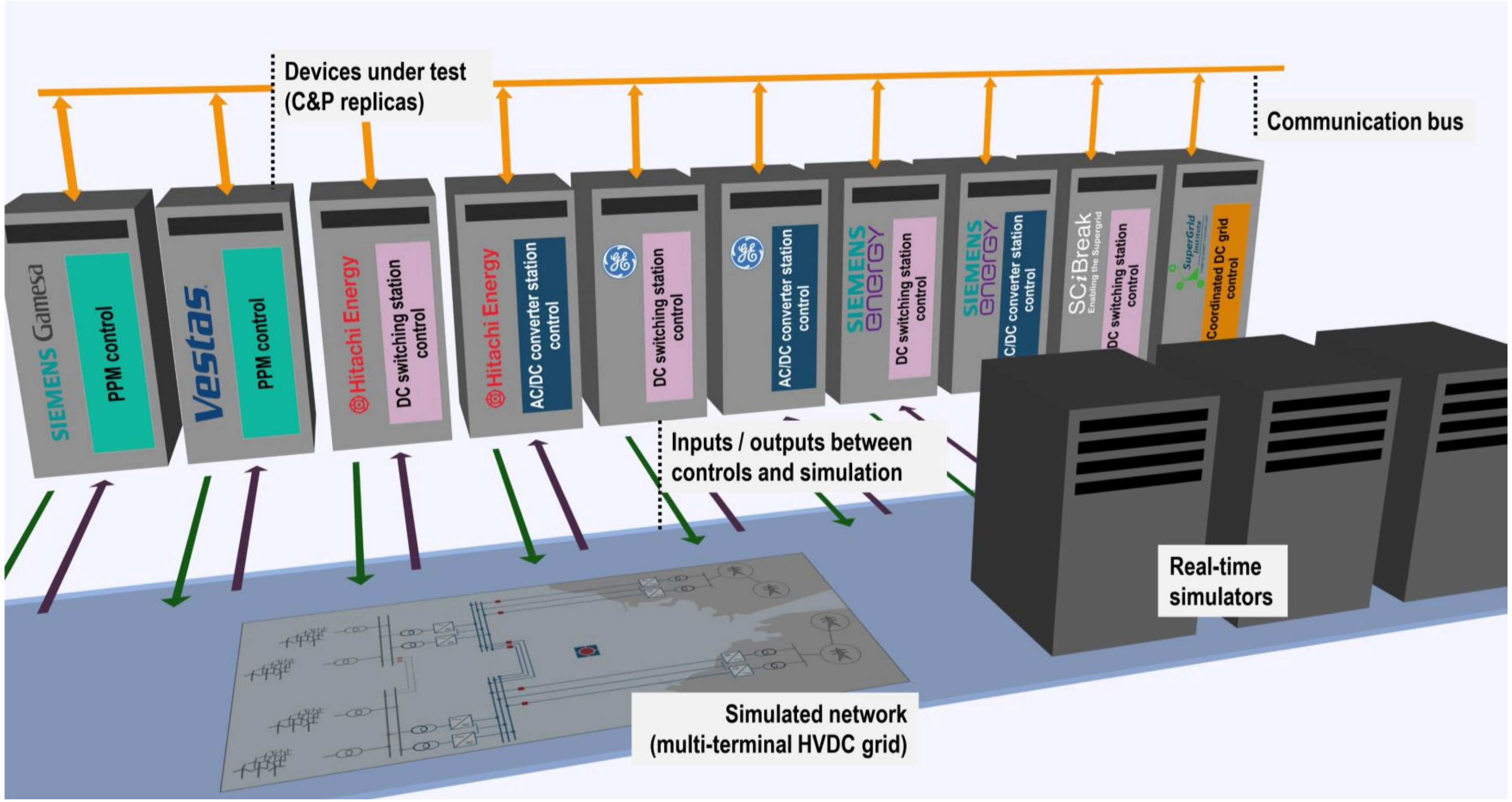
PUBLIC

Perform a real-time physical demonstration of a multi-vendor control and protection system including grid forming

→at least three terminals (AC/DC converter stations) of three different manufacturers with power rating applicable in the current existing real life use cases

WP1
WP2
WP3
WP4
WP5
WP6
WP7



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Secure multi-stakeholder cooperation, build confidence and uptake of the interoperability frameworks

→InterOPERA will share practical experience in Europe and beyond

WP1
WP2
WP3
WP4
WP5
WP6
WP7

Standards
Organisations
Proactive Approach

cigré CENELEC IEC

Executive Advisory Board
InterOPERA seeks advice from Industry specialists

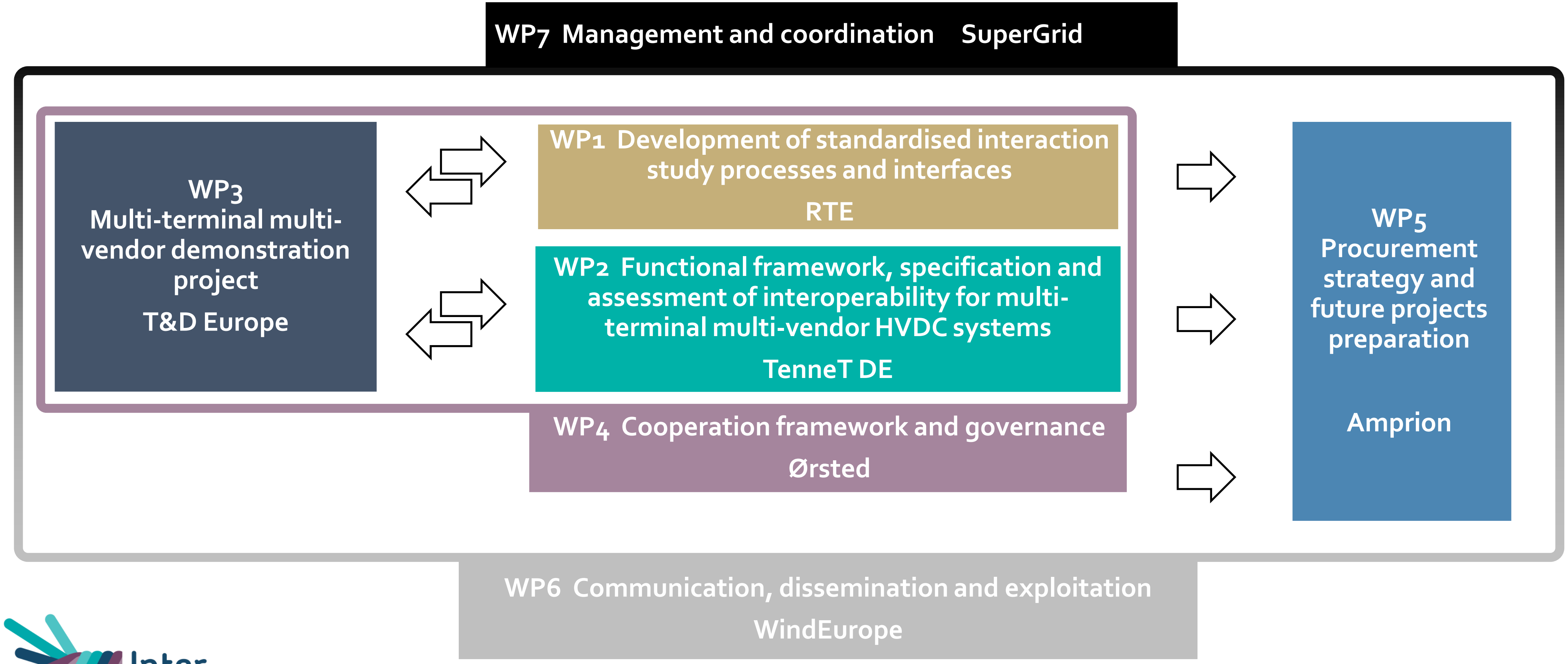
InterOPERA
Communication & Dissemination

Stakeholder Committee
Industry specialists gain early review of InterOPERA findings & recommendations

Multivendor Cooperation Framework

Project structure

Work Packages address current gaps for development of multi-vendor HVDC systems



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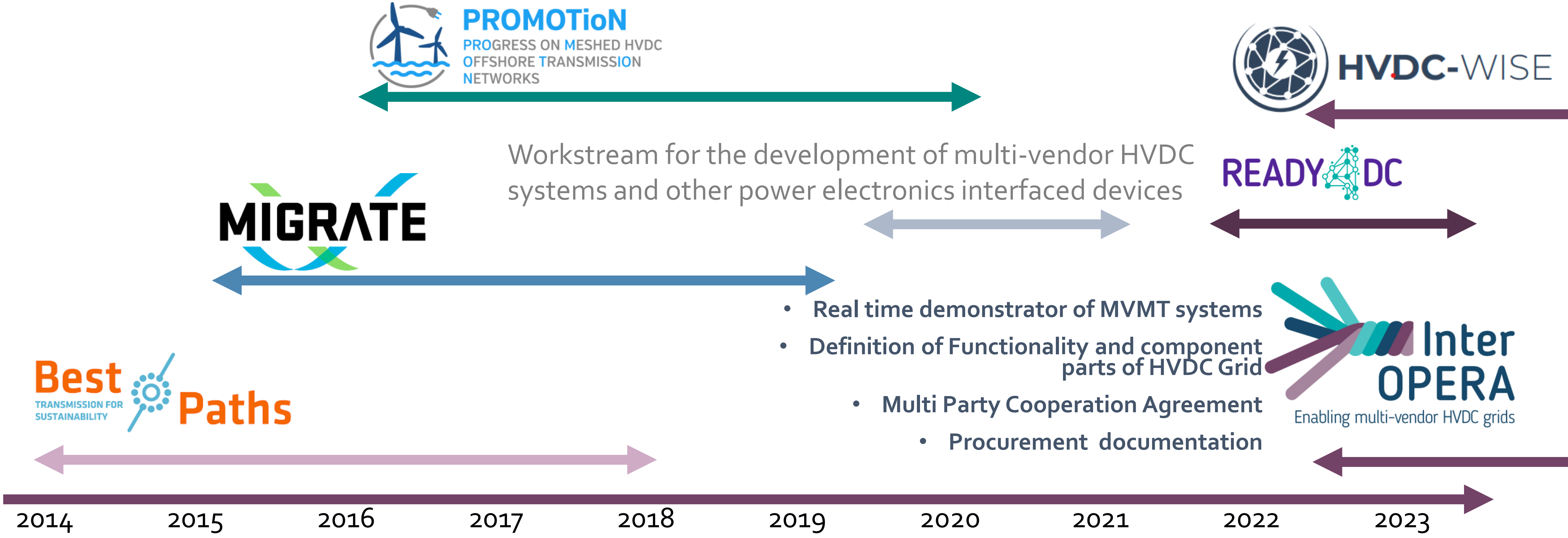
InterOPERA builds on EC funded commitment to develop the technology for cost efficient and resilient evacuation of Wind Power:



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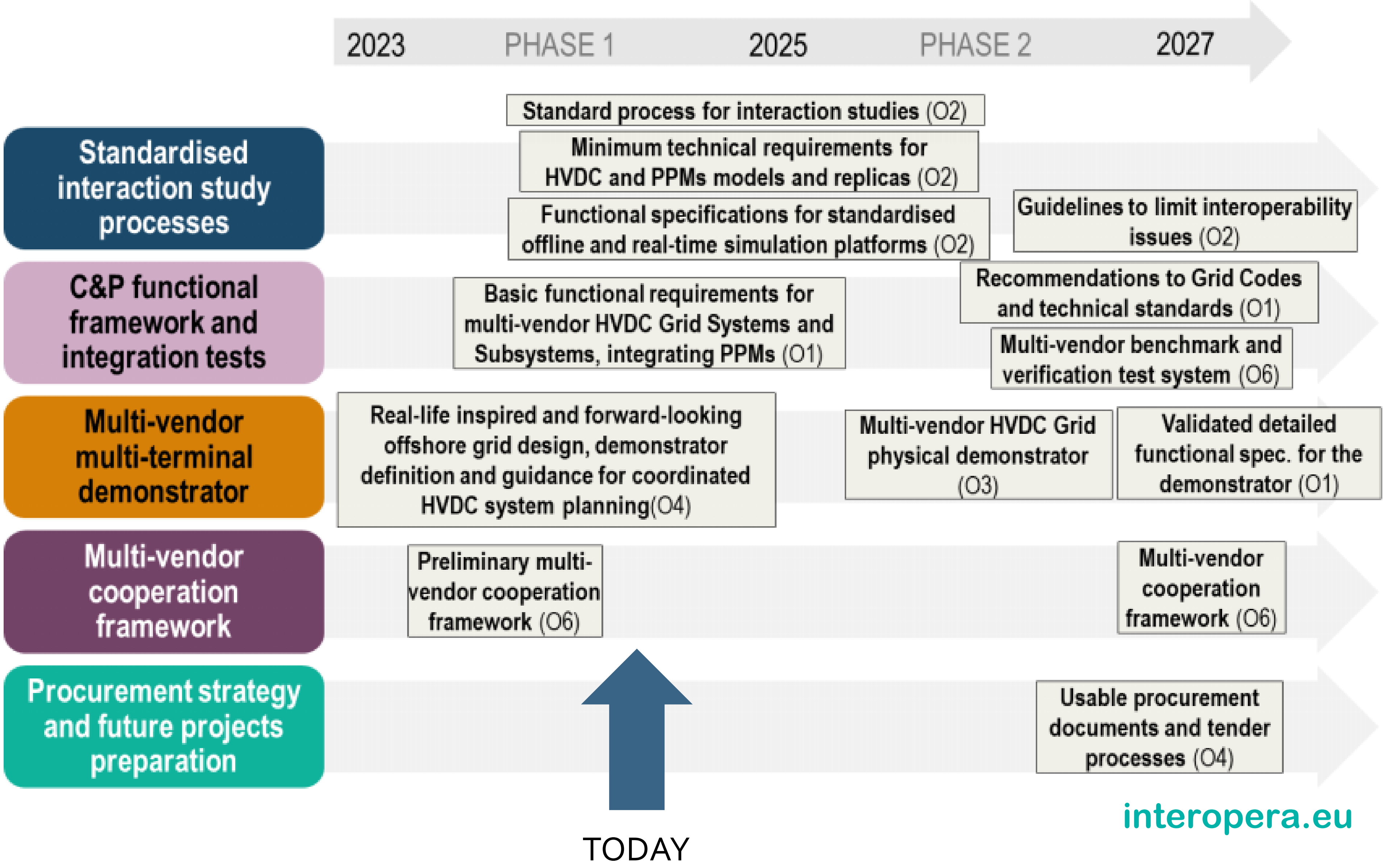
Planning of Activities

Core activities allow InterOPERA to achieve its ambition



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Thank you

John.moore@SuperGrid-Institute.com

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Joint READY4DC InterOPERA event

WP1

Development of standardised interaction study processes and interfaces

S. DENNETIERE - RTE

InterOPERA
Enabling multi-vendor HVDC grids

CIGRE SC B4 Meeting and Colloquium in Vienna,
September 13th, 2023

cigre
SC B4

PUBLIC

WP1 objectives

- To define **standard interface and requirements** for manufacturers converter models and C&P cubicles
- To establish a **standard process** for **interaction studies**
- To provide **functional specifications** for a standardized platform to perform interaction studies, before implementing and validating it.
- 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

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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 offline models,

- 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 will be 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")

PUBLIC

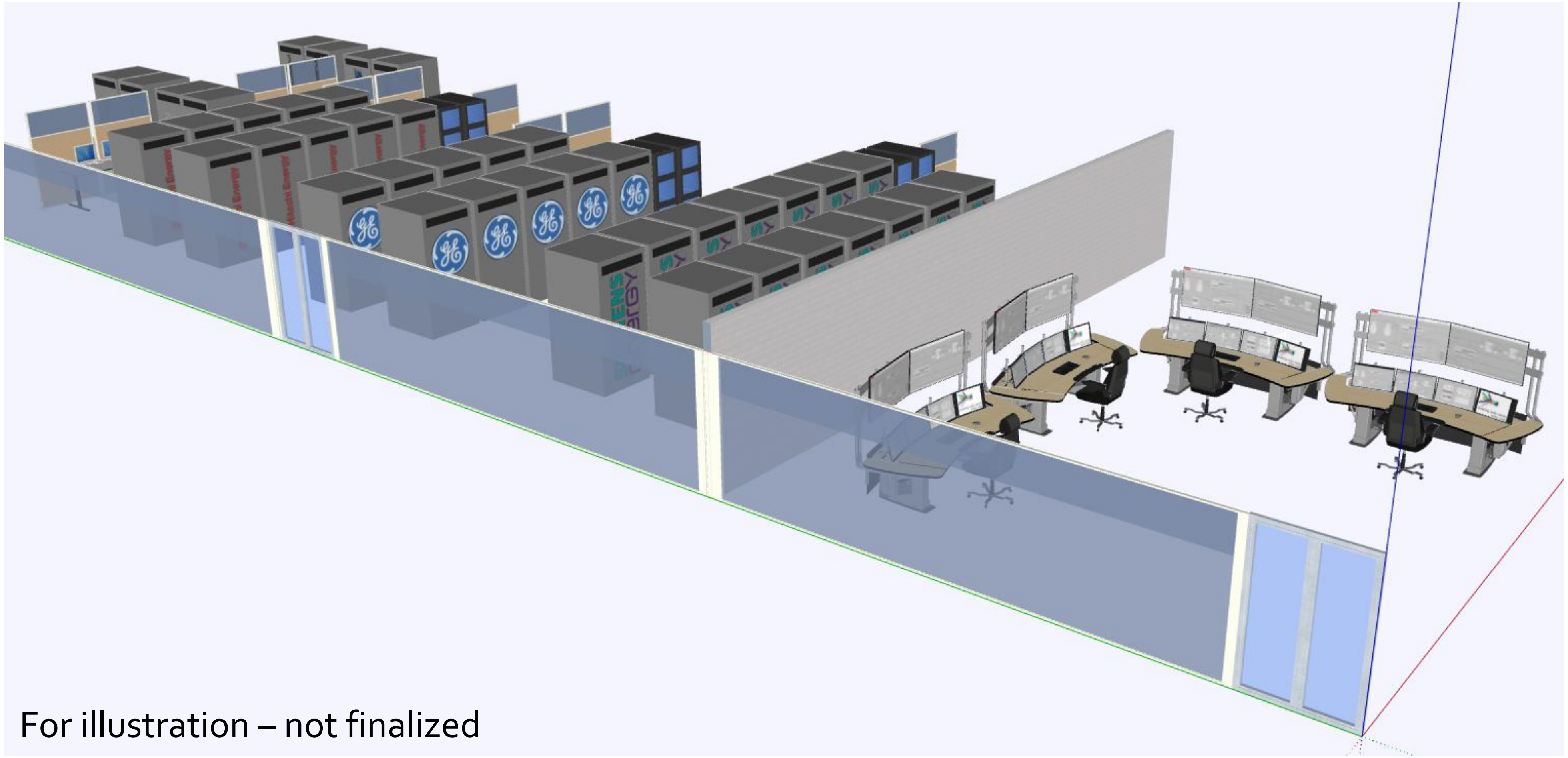
Task1.3 - Definition of a standard process for interaction studies with EMT simulation in multi-vendor projects

- Objective: Adaptation of studies to be performed and study process in a multi-vendor and multi terminal HVDC grid context:
  - Are additional studies needed?
  - Should the studies be categorized and packaged in a different way?
  - How to iterate the studies in a joined cooperation?

- Content:
  - Model sharing and iterations (Worksflow of a single iteration, traceability and quality control)
  - List of studies in project phases (from planning to operation)

- To be applicable for the interOPERA project and for future real-life project

Subtask 1.2.3 – Dry-run with C&P replicas and SiL models



For illustration – not finalized

InterOPERA
Work Package 2

Requirements and assessment of interoperability for multi-vendor multi-terminal HVDC systems

Enabling multi-vendor HVDC grids

Dr. Mario Ndreko (TenneT TSO GmbH)

13.09.2023

RESTRICTED

Work Package Objectives

Objective 1: Develop **functional requirements** at the **DC connection point** and **functional requirements for grid forming capabiliti**es of **HVDC systems and DC-connected PPMs** to enable interoperability by design.

Objective 2: **Perform detailed interaction studies** of the demonstrator system specified in **WP3 .**

The proven standard simulation platforms (offline and real-time) and the **methods** for interaction studies **developed in WP1** will be applied in two labs (TU Delft and RTE).

Objective 3: **Develop verification process based on offline and real time simulations for validating the compliance with the multi-vendor functional requirements** of HVDC systems and DC connected power park modules (At the Connection point, AC and DC).

Objective 4: **Provide recommendations** for connection network codes (NC HVDC) leading to potential new functional requirement for multi-vendor projects (mainly DC side).

Project Phases and tasks

Phase I (2023 - 2024)

Task 2.1 (Super Grid Institute)
Basic functional requirements for multi-vendor HVDC Grid Systems

Task 2.4 (Energinet)
Functional requirements for GFC of HVDC systems and offshore PEIDs

Phase II (2025 - 2026)

Task 2.2 (TenneT NL)
Multi-vendor HVDC grid system integration tests - Execution of Interaction studies at AC and DC connection points

Task 2.3 (Amprion)
Connection network code recommendations for multi-vendor multi-terminal HVDC systems

Task 2.5 (TenneT DE)
Verification process and benchmark for multi-vendor interoperability of HVDC systems

Task 2.1

Basic functional requirements for multi-vendor HVDC Grid Systems and Subsystems

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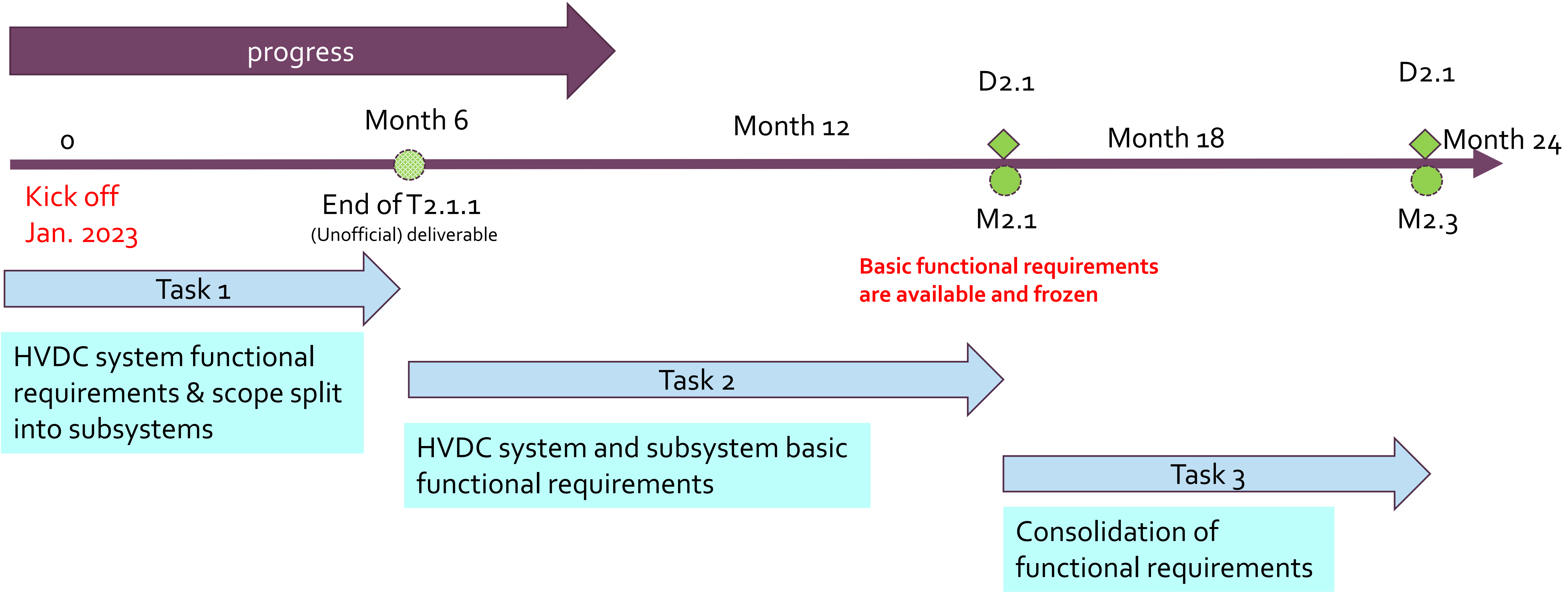
Pascal Torwelle

26th of June

RESTRICTED

RESTRICTED

Timeline of Tasks, milestones & deliverables



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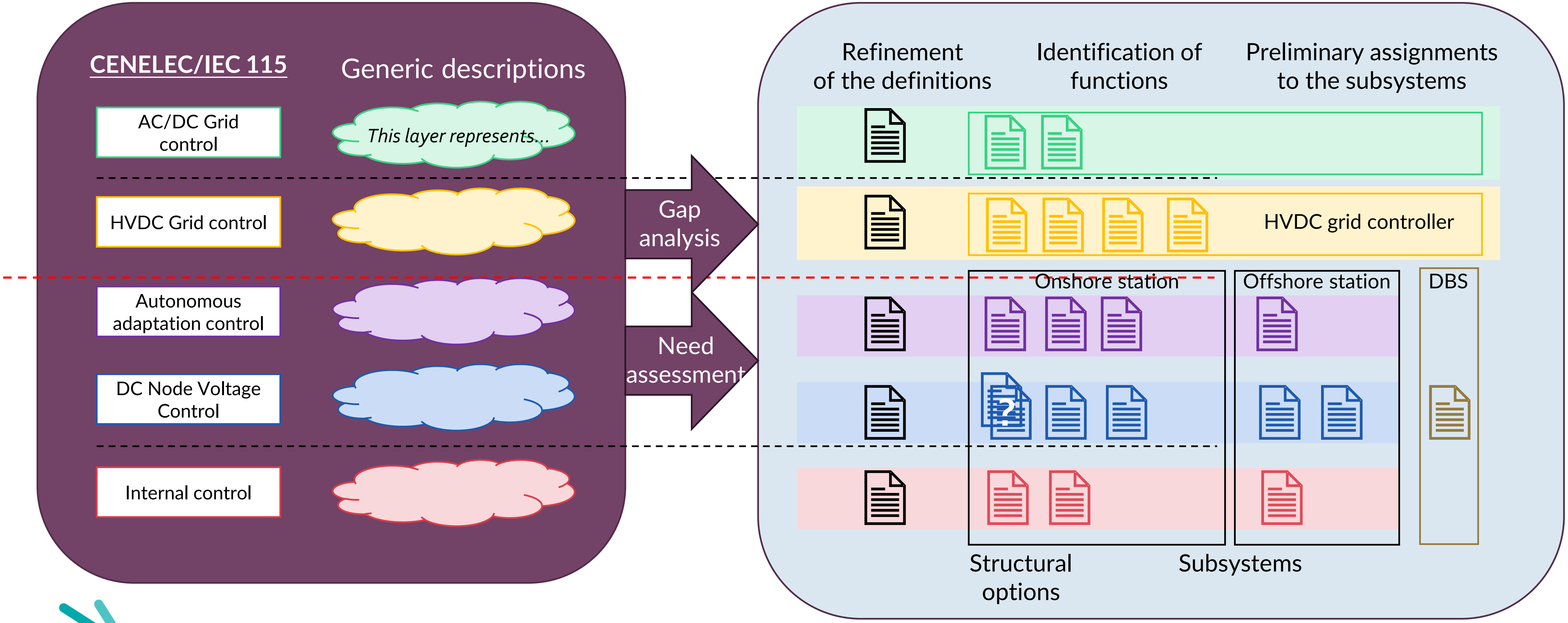
Functional split

❖ Work in progress



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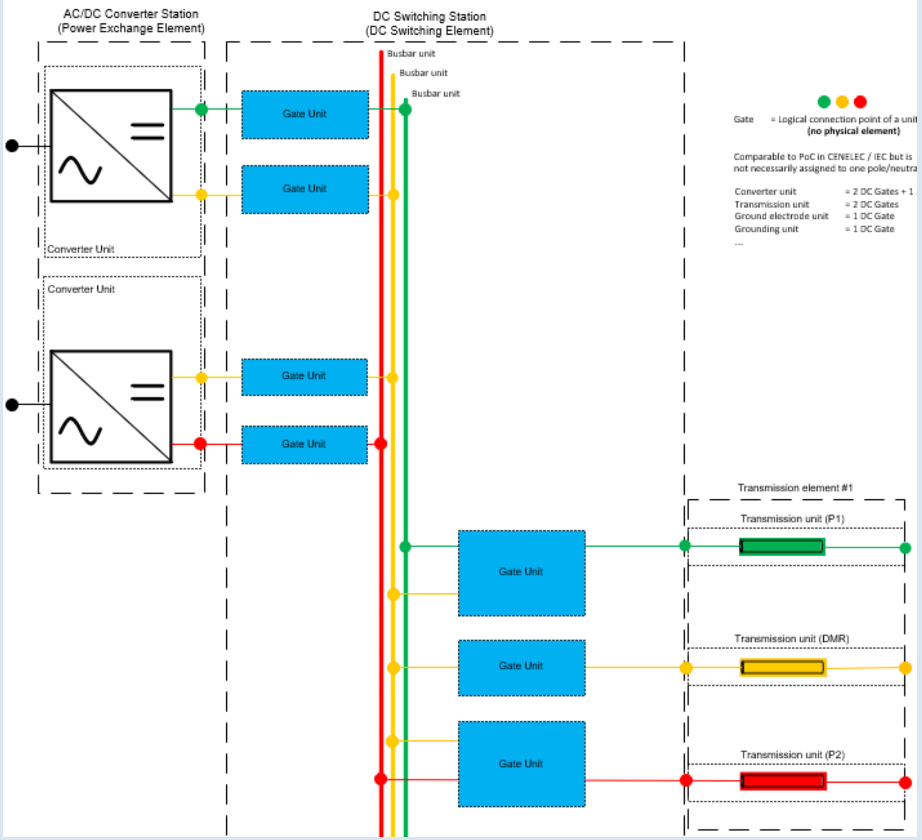
Aggregation of functional elements (in progress)

- DC Switching station
  - Aggregation of all DC switchgear and automation
- DC Switching unit
  - Aggregation of switchgear and automation to execute open and close commands per pole (independent state)
  - Switchgear depends on functional requirements
    - Multiple variations possible (with or w/o current breaking capabilities)
    - HV/LV connection
- HVDC Converter station
- Energy dissipation device



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Take aways from T2.1

- Good progress & agreement of stakeholders on aggregation of the sub-systems and the initial assignment of their functions
  - NC HVDC and IEC/CENELEC standard are taken as initial basis
- Various control functions and sequences are considered
- For AC side, all functions in NC HVDC considered
- For DC side
  - HVDC system protection aspects on DC circuit are included in the functional framework by initial functions:
  - Definition of alert & emergency states for DC grid contingencies
  - Fault handling process
  - Good progress and intense discussions regarding continuous control aspects
    - Balancing control is a current discussion point
    - DC node voltage control layer to be detailed
    - Multi-segment DC voltage droop control principles

Task 2.2

Multi-vendor HVDC grid system integration tests - Execution of Interaction studies at AC and DC connection points

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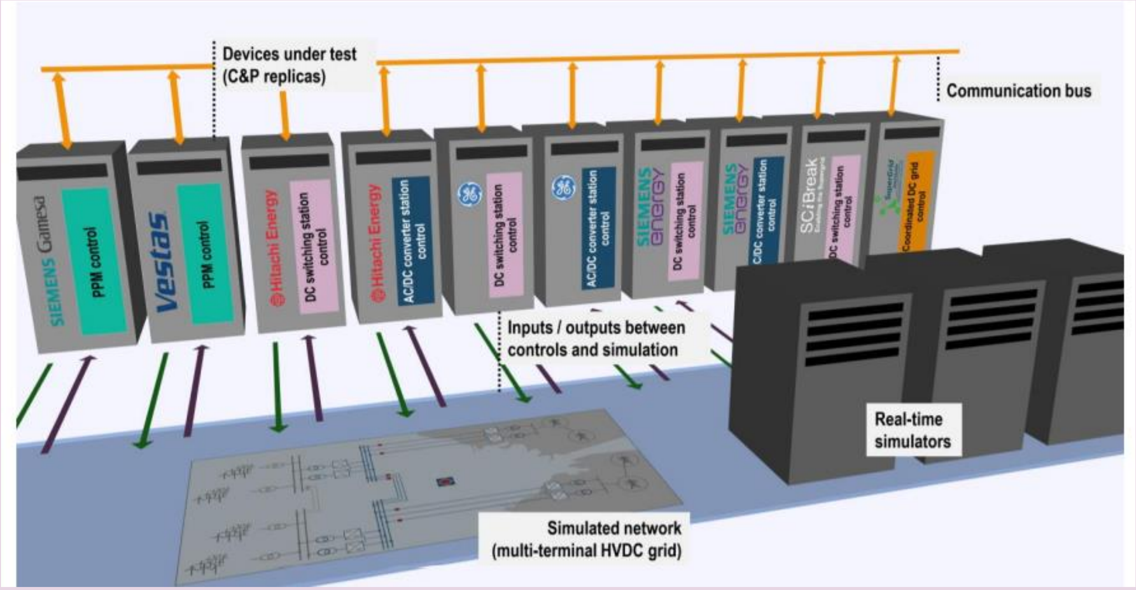
Multi-vendor HVDC System Demonstration

Kick off
Jan. 2025

- **Interaction studies** to be performed at the **AC and DC connection points;**
- The studies will be based **both on offline EMT simulation as well as on real-time HIL simulation**;
- The conclusion of the interaction studies will be used to **provide recommendations for the use of the functional requirements and specifications in future real-life projects**.



RTE

TU Delft

Multi-vendor HVDC System Demonstration

Preparation of the offline EMT simulation setup based on the proven in WP1 model specifications and platfrom

Interaction study using offline EMT simulations

Real-time HIL protection and control testing of the demonstrator set up to assess the interoperability of multi-terminal, multi-vendor HVDC

Assessment of the main finding of the interaction studies

After the completion of this task, the multi-vendor demonstration project detailed specifications will be considered as mature to be used in the construction phase of future multi-vendor HVDC grid projects **(TRL 6-7).**

Task 2.3

Connection network code recommendations for multi-vendor multi-terminal HVDC systems

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Inputs for NC HVDC Amendments and National Implementation

Kick off
Jan. 2025

Simulation model functional requirements from WP1

Basic functional requirements from T2.1

Experience from the real time lab demonstration

- Propose solid and proven DC terminal connection requirements
- The expandability of future HVDC grids would require for DC terminal connection point requirements under the boundary condition of multi-vendor HVDC grid development

Task 2.4

Grid-Forming Functional Requirements

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Enabling multi-vendor HVDC grids

Task 2.4 active contributors

13.09.2023

Deliverables in Progress

T2.4.1

State-of-the art report

✓

T2.4.2

GFM concepts in Multi-terminal HVDC systems with DC connected PPMs

✓

T2.4.3

Functional requirements And connecton network code recommendations

In progress

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Grid forming functionality

No energy storage devices in HVDC converters or PPMs

No oversizing of converters, both HVDC and PPMs

No violation of mechanical constraints of the PPMs

Take aways from T2.4

1. GFM control is crucial to meet the system needs for a secure, reliable and resilient operation of power systems with fast increasing integration of renewable energy.

2. In InterOPERA, GFM functional requirements for HVDC systems and DC-connected PPMs are jointly formulated by TSOs, HVDC vendors, wind power plant developers and wind turbine manufacturers, considering their application in a multi-vendor situation, and will be demonstrated in the project.

3. Common understanding of GFM control has been reached in the group, and GFM functionality have been aligned and formulated in the project.

Thank you

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InterOPERA

Multi-vendor multi-terminal demonstrator project

Carlo Degli Esposti – T&D Europe – WP3 lead

Joint event READY4DC–InterOPERA joint event, Cigré B4 Colloquim 2023 - Vienna 13.09.2023

INTERNAL

Outline

1. Section 1: introducing WP3
   1. Scope of work
   2. Work Package organization (structure, timeline)
2. Section 2: Advancements to date
   1. Main issues tackled
   2. Definition of the topology
   3. Studies to be conducted until end of September
3. Conclusions

1

Section 1: introducing WP3

Scope of work of WP3

WP3 **aims at defining the MV MT HVDC demonstrator project**, to be developed as a representative and relevant case study in the EU context for offshore wind development.

It entails **three main activities**:
- the system-level design,
- the preparation of detailed functional specifications,
- the development of the C&P subsystems by the respective suppliers.

Work approach
1. Integration tests in a multi-vendor environment will be carried out throughout WP2.
2. If integration tests exhibit interoperability issues, their analysis will be conducted within WP2.
3. Required improvements and modifications will be developed within WP3.

Key exploitable results expected from WP3

Key exploitable results	Beneficiaries	Tentative exploitation route
Actual and forward-looking offshore grid design, incl. new topologies for connection of multiple PPMs	System developers and operators, policy makers and industry associations, R&I initiatives and stakeholders	• TSOs and policy makers to integrate the project's results in EU, regional and national level grid planning and HVDC project qualification. • R&I initiatives and academia to use the project's recommended grid design as a reference for ongoing research on power systems.
Full MV MT HVDC C&P system, incl. PPMs	System developers and operators, technology suppliers and integrators	Technology suppliers to develop adapted industrial control and protection products for the roll-out of multi-terminal HVDC projects.

Task organization

- **Task 3.1** – HVDC system design – demonstrator definition
- **Task 3.2** – HVDC grid subsystems pre-design
- **Task 3.3** – Drafting detailed functional specifications
- **Task 3.4** – HVDC grid subsystem control and protection development towards system integration in a multi-vendor environment
- **Task 3.5** – Power park modules control and protection development towards system integration in a multi-vendor environment

Planning of work

	2023 (Y1)				2024 (Y2)				2025-2026
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9-Q16
T3.1									
T3.2									
T3.3									
T3.4									Q11
T3.5									Q11

09/2023

2

Section 2: Advancements to date, focus on T3.1

Status of WP3 / T3.1

Task 3.1 – methodological elements

- Kick-Off 08.02 (CW6)
- Work approach: Project participants alignment on agile working principles and agile framework
- Digital, remote and distributed team established
- Continuous improvement of the final deliverable in sprint cycles
- First unofficial draft of the report consolidated, final draft under way

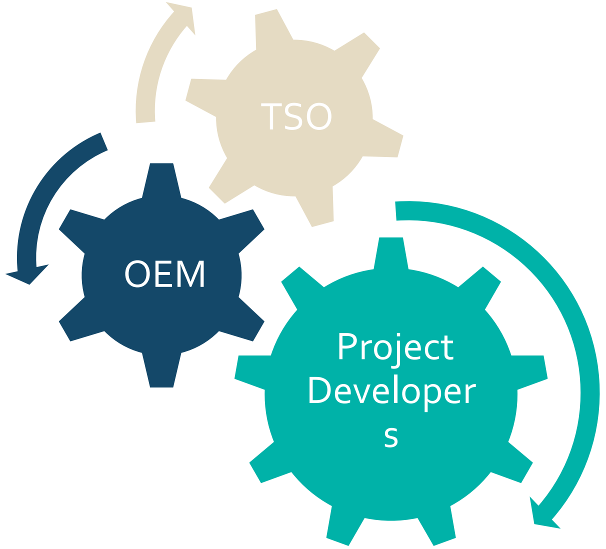
	2023 (Y1)				2024 (Y2)				2025-2026
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9-Q16
T3.1									
T3.2			09/2023						
T3.3									
T3.4									Q11
T3.5									Q11

Approach for the selection of the demonstrator

Task 3.1 actions

- First weekly sessions in CW7 & 8 focussed on the long list of MT-HVDC use cases
- Consolidation of work: setup of a list of MT-HVDC use cases in CW9
- Stakeholder interviews run in CW10 & 11
  - Transmission System Operators & Asset Owners
  - HVDC system OEMs & sub-system suppliers
  - Wind turbine OEMs / project developers
  - External Partners (e.g UK, US, Japan)

After a consultation round and review of all cases, the project presented by the Vendors has been retained as the basis for the demonstrator development



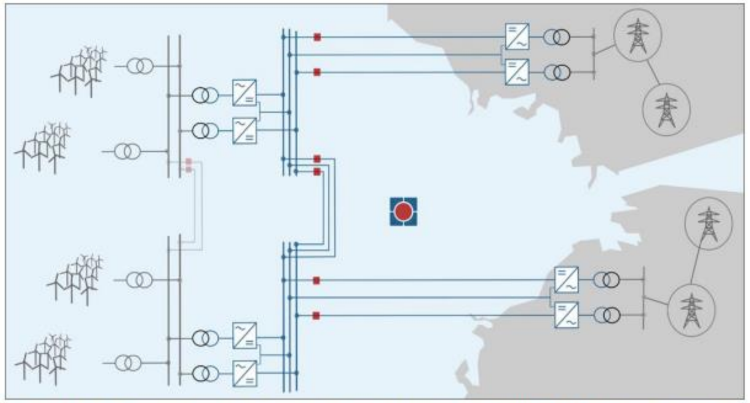
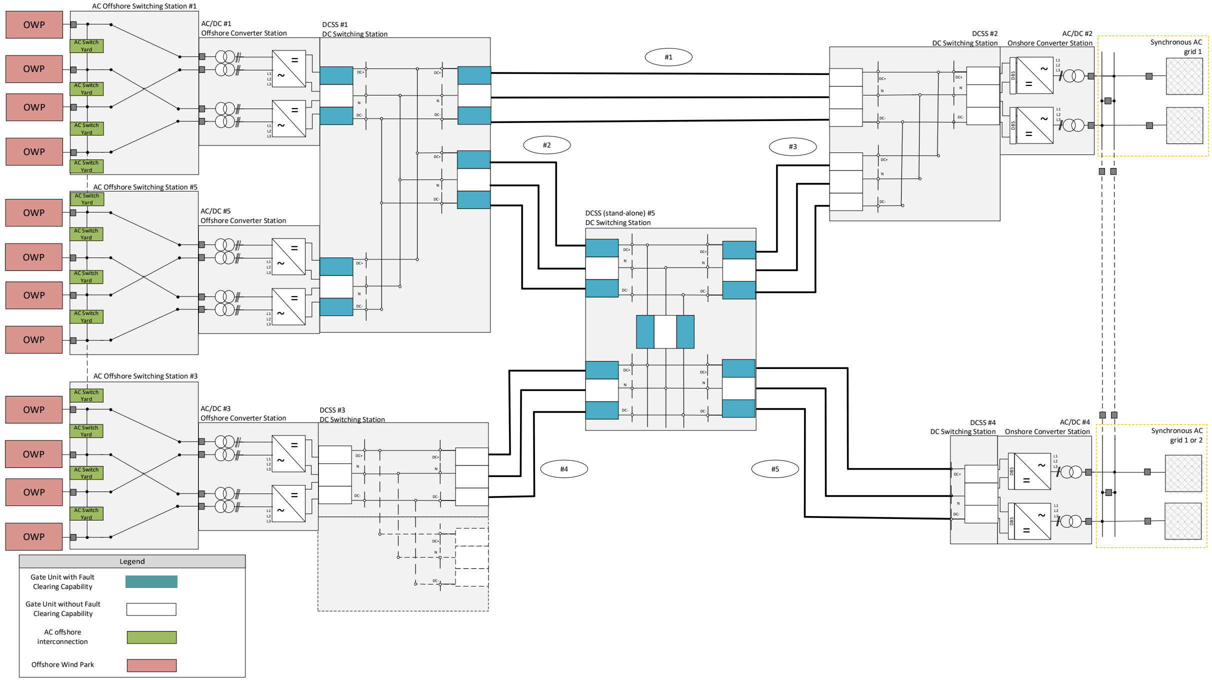
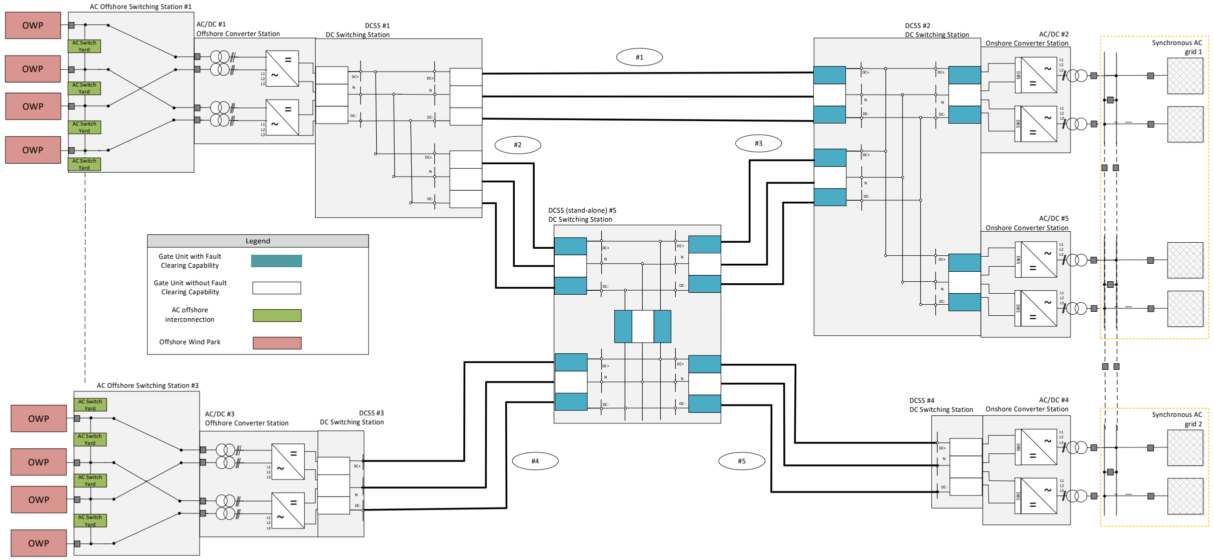


Figure 1.2-G: Demonstrator grid architecture and topology (subject to further optimisation)

The InterOPERA Demonstrator topology under investigation
left: HIL-Base-Case / right: possible extended topology



5MT – Full extent variant 1 with three offshore and two onshore converter stations



5MT - Full extent variant 2 with two offshore and three onshore converter stations

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INTERNAL

Preliminary System Design Studies – What to expect?

- Preliminary system design studies to provide a common basis
  - Step-by-step workflow to give insights into MT-MV DC grid planning
  - Gradual increase of complexity by adding demonstrator stages
  - Keep it manageable!
- Seamless transition and interface to T3.2 (HVDC grid sub-system pre-design)
- Planned workflow:

Collection of input data → Performing a set of system design studies → Consolidate and disseminate the results (D3.1_V2)

Until End of June

Until End of August

Until End of September

Three proposed study packages

Input data	(Quasi-) Stationary	Transient
• AC system data • DC system data • DC switching station • AC/DC converter station	• Loadflow calculations • Definition of steady-state DC voltage bands • Maximum voltage drop under given power flow condition • Quasi-stationary contingency analysis	• Short circuit calculations • Transient voltage calculations • Transient current calculations

List of required inputs for T3.2 to develop subsystems specifications – elements for static analysis

LF analysis

Dynamic response

EMT

Before conducting any LF study, the following items should be aligned and documented

Item #	Description	Comment
1	System Topology	number and type of converter stations + switching stations + grounding type/assumptions
2	Single Line Diagram	simplificiations thereof depending on study purpose (Static/Quasi-Static/Dynamic)
3	Environmental Data	AC system data + topology; DC transmission elements data
4	Modes of operation	DC grid control philosophy (primary + secondary); AC + DC side control modes for converters
5	Contingencies + response	N-1? N-2? Desired reaction on system level
6	System states and restoration strategies	Normal, Alert and Emergency, with the respective actions on/from the converter, HVDC controller and Protection units
7	P-Q-Uac / P-Udc system requirements	AC side + DC side for each mode of operation
8	Global sequences	Example: Initial start-up / energization concept

3

Conclusion and next steps

Several lessons learnt from the development of the first three quarters of work, and more to come!

- Deadlines for the completion of the demonstrator definition exercise are tight but it should be possible to contain the delay (if any!)
- Challenging exercise, first "non-academic" project in the domain, industrial approach and project management required for an effective participation and response from project partners

- Definition of the system functions list still in development: final T3.1 work to be monitored from close to allow the definition of the minimal set of system functions to be implemented for an effective handover to T3.2.

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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Thank you for your attention!

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Enabling multi-vendor HVDC grids

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CLOSING

InterOPERA
Enabling multi-vendor HVDC grids

READY4DC

Joint Event

CIGRE B4-Colloquium, Vienna

Thank you!