PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

REVIEW MEETING
BRUSSEL, BELGIUM
20 and 21 MARCH 2017

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© TenneT TSO GmbH

Project Proposal Presentations

Project: PROMOTioN

Contract: 691714

Place: Brussels, 354 Av Van Volxemlaan, Wiels Contemporary Art Centre

Date: 20th of March 2017

Time: 13:00 – 17:00

Attendance: All proposal participants and PMG

13:00	**Start**	
	Introduction	
(5 min)	Welcome of the participants	Project Coordinator
(1 hour)	Explanation of project scope & objectives Explanation of WP8 situation Explanation of liberated budget Explanation of the selection procedure	Project Coordinator
	Presentations of proposals	
(2 hours)	Presentations of proposals - Basic idea - Motivation - Impact - Deliverables - Partners - Budget	All proposal leaders
(20 min)	Presentation of new partner - SCibreak	Project Coordinator & Scibreak
(20 min)	Summary of the proposals in project context	R&D Coordinator
	Conclusions	
(20 min)	Discussion and review Next steps & timeline	PO
17:00	**Close**	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Periodic review meeting

Project: PROMOTioN

Contract: 691714

Place: Brussels, 354 Av Van Volxemlaan, Wiels Contemporary Art Centre

Date: 21st of March 2017

Time: 09:00 – 17:00

Attendance: All partners and PMG

	Start	
09:00	Reception and coffee	
	Introduction	
09:30	Welcome of the participants	Project Coordinator
	Welcome word of project officer	PO
	Review of the: - Overall objectives of the project - Role of each partner - Update on project context	Project Coordinator
	Technical review	
	Review of the work done to date with comparison to the original description of work, milestones and deliverables	All WP leaders
09:50	- WP 1	TenneT
10:30	- WP 2	RWTH Aachen
11:00	- WP 3	DTU
11:30	- WP 4	KU Leuven
12:00	Lunch	
13:00	- WP 5	DNV GL
13:30	- WP 6	University of Aberdeen
14:00	- WP 7	TenneT
14:30	- WP 8	Siemens
15:00	- WP 13	SOW
15:30	Summary of the main achievements to date and results	R&D Coordinator
15:45	Tea break	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

	Management aspects	
16:00	Management of the project: – Collaboration and interaction – Administrative and financial aspects with comparison of financial resources versus original planning	Project Coordinator
	Description of work review Implementation plan next period	
16:20	Proposal for the next period: – Description of work for next period – New proposals – New partner	Project Coordinator
	Conclusions	
16:40	Discussion - Quality assessment - Recommendations - Reporting	PO + reviewer
17:00	**Close**	

Press contact

Stiftung OFFSHORE-WINDENERGIE
Sebastian Boie
Fon: +49 30 275 95 198
Mail: press@promotion-offshore.net

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Proposal Presentations

20th of March 2017 / Brussels

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

CONTENT

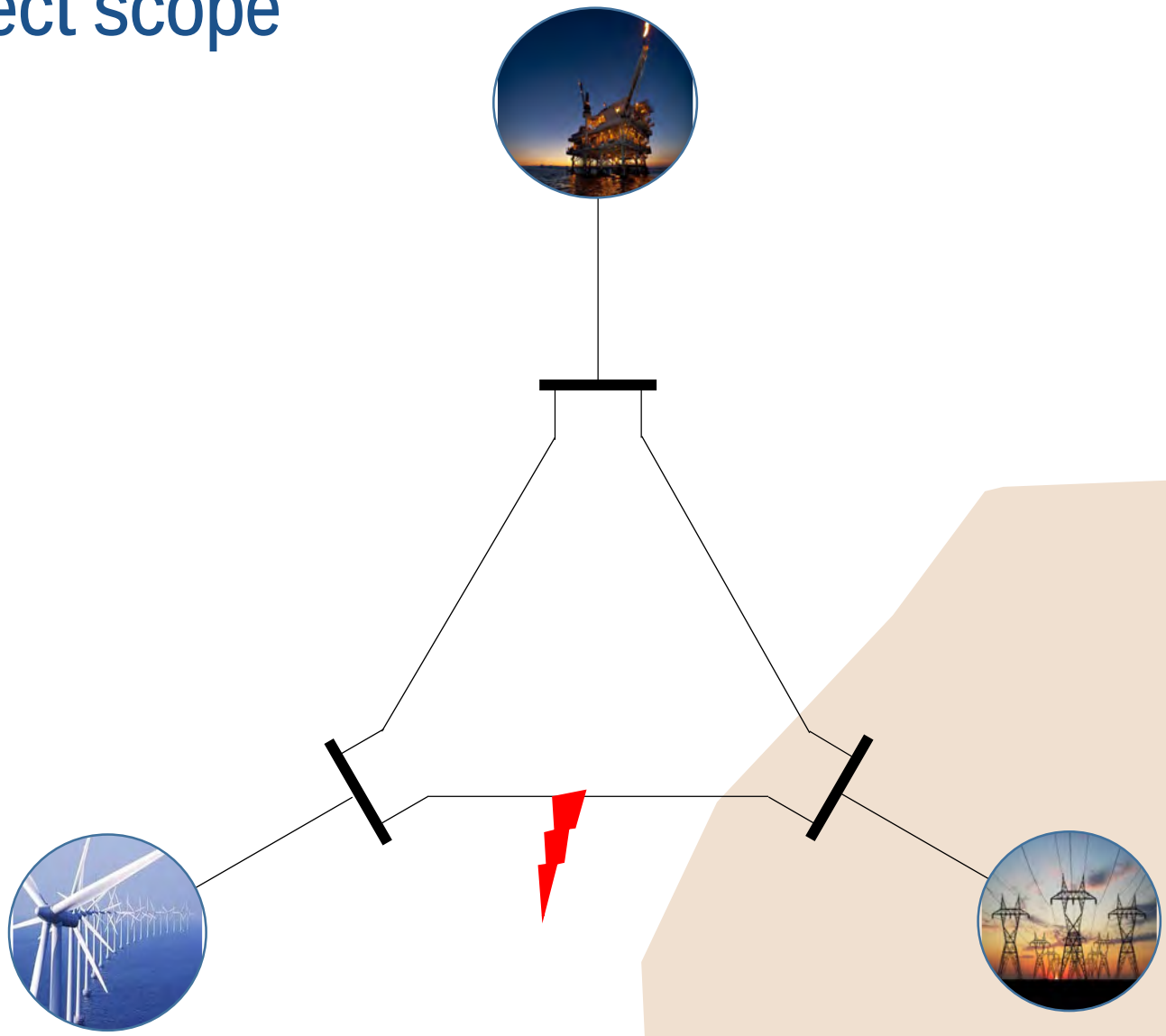
- Project overview
- WP8 situation
- New proposals
- New partner
- Summary

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project overview

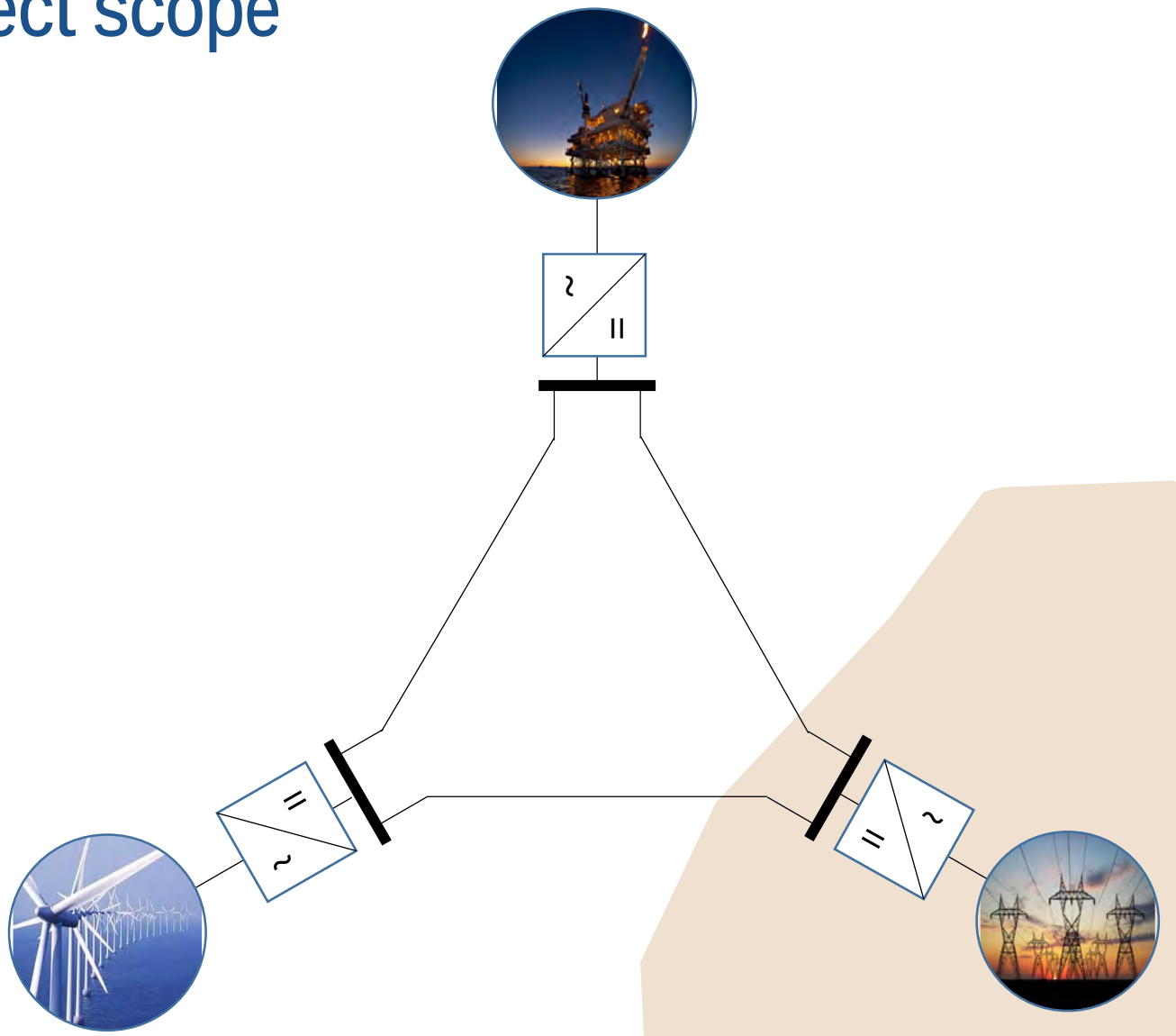
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project scope



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

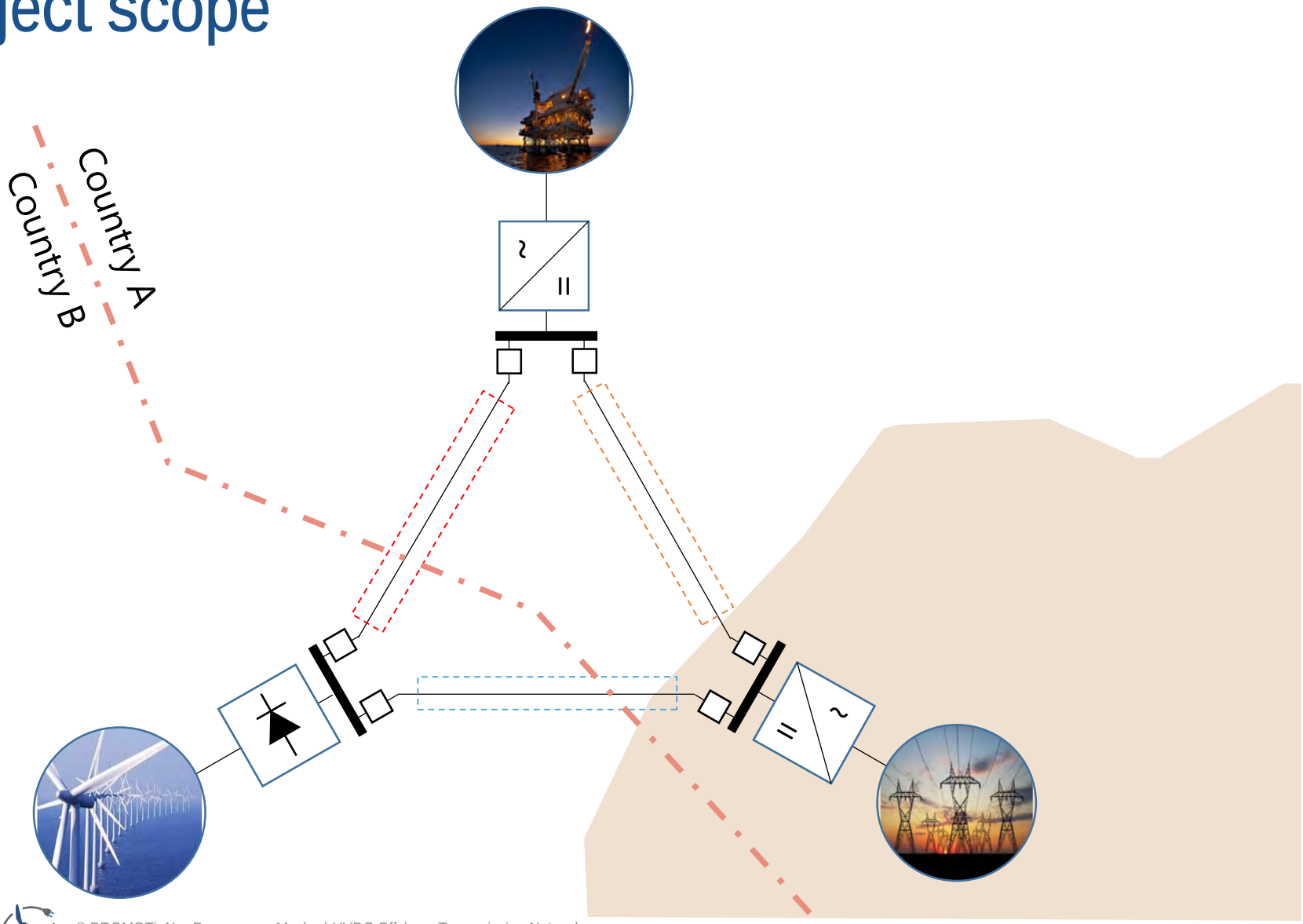
Project scope



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project overview

Project scope



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project objectives

- Identify **technical requirements** and investigate possible **topologies** for **meshed HVDC offshore grids**
- Develop **protection schemes** and **components** for HVDC grids
- Establish components' **interoperability and initiate standardisation**
- **Demonstrate cost-effective** offshore HVDC equipment
- Develop recommendations for a coherent EU and national **regulatory framework** for HVDC offshore grids
- Develop **recommendations for financing mechanisms** for offshore grid infrastructure deployment
- Develop a **deployment plan** for HVDC grid implementation
- **Disseminate results** to relevant stakeholder communities

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

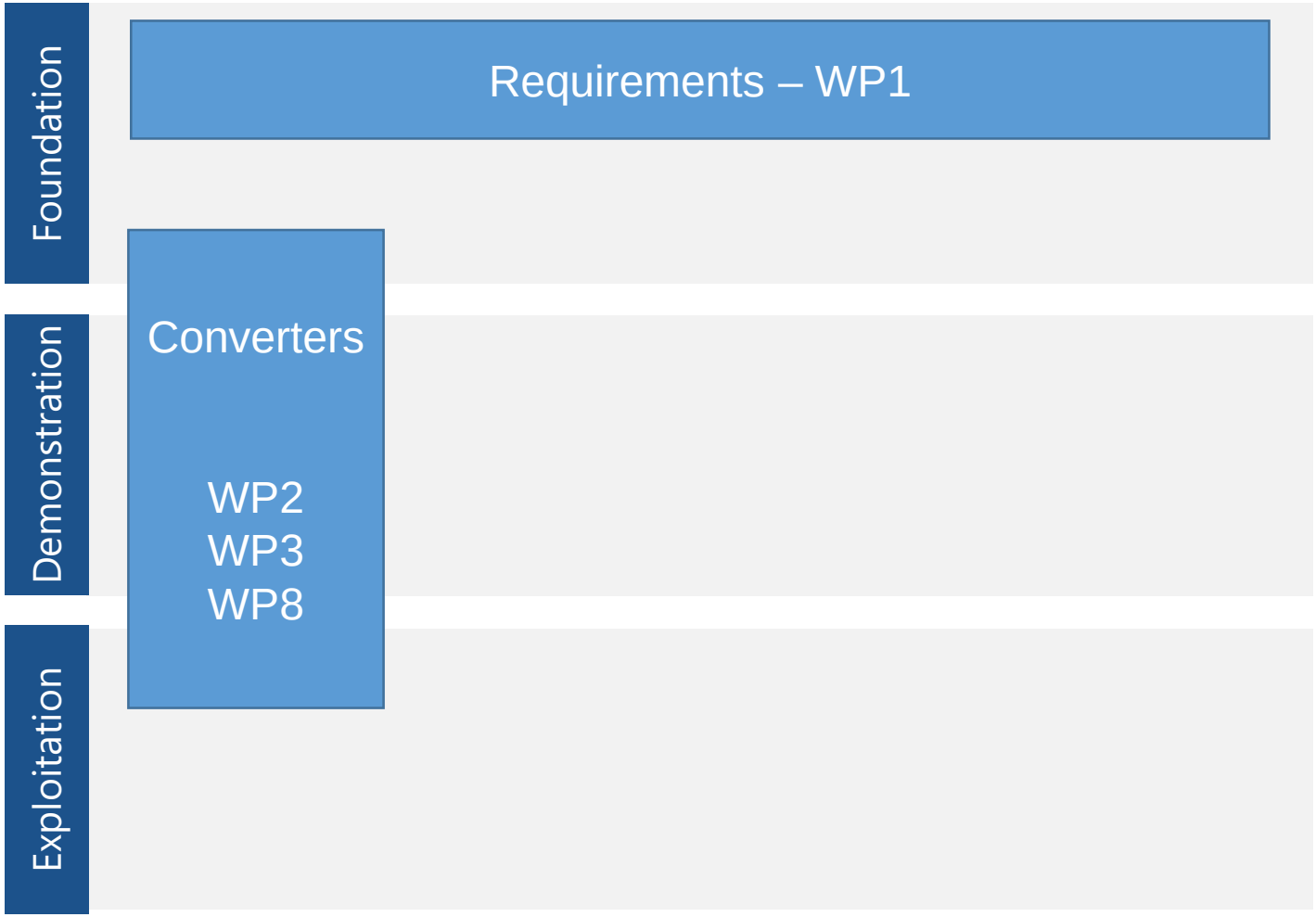
Project Structure

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project Structure - Requirements

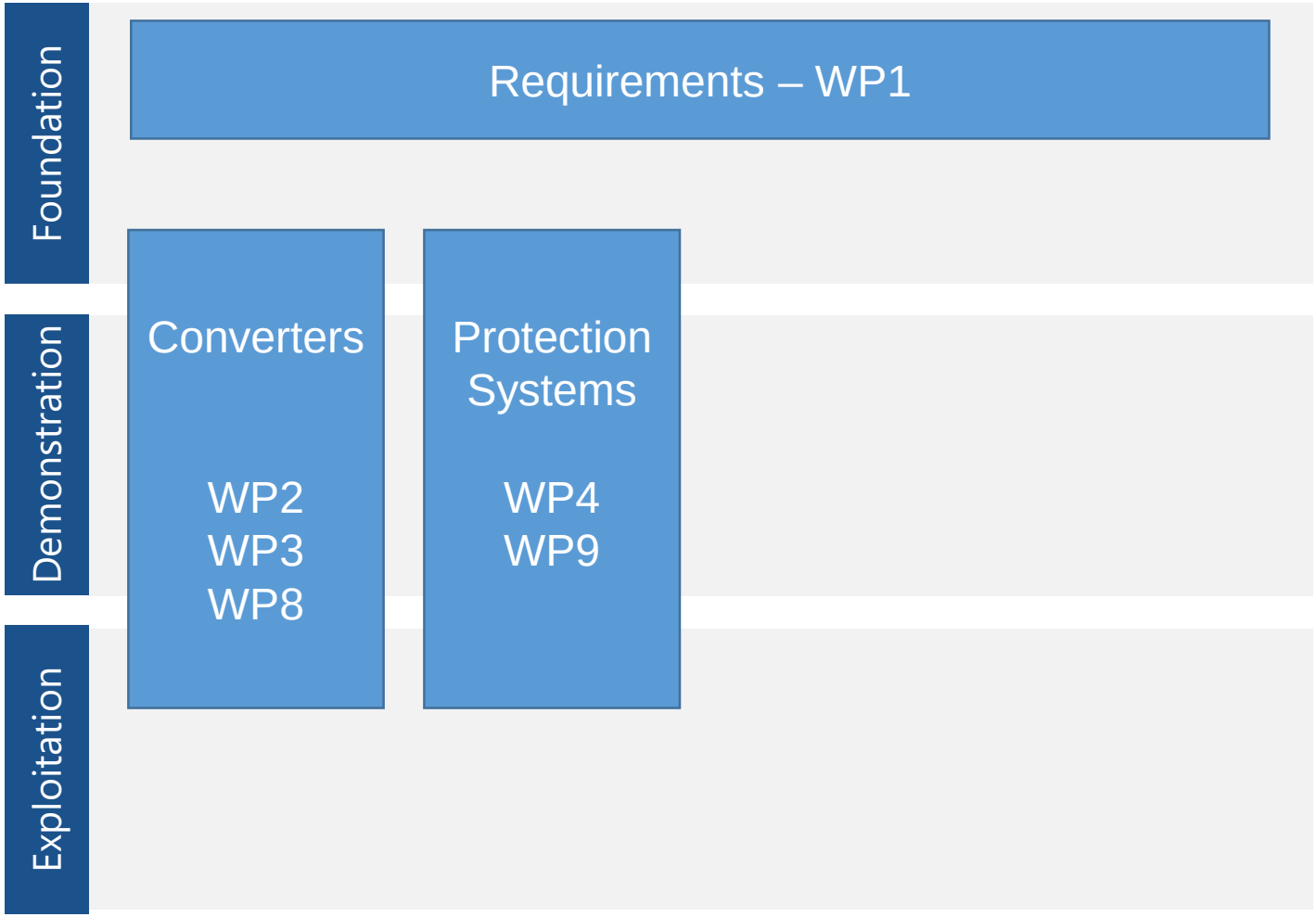
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project Structure - Converters



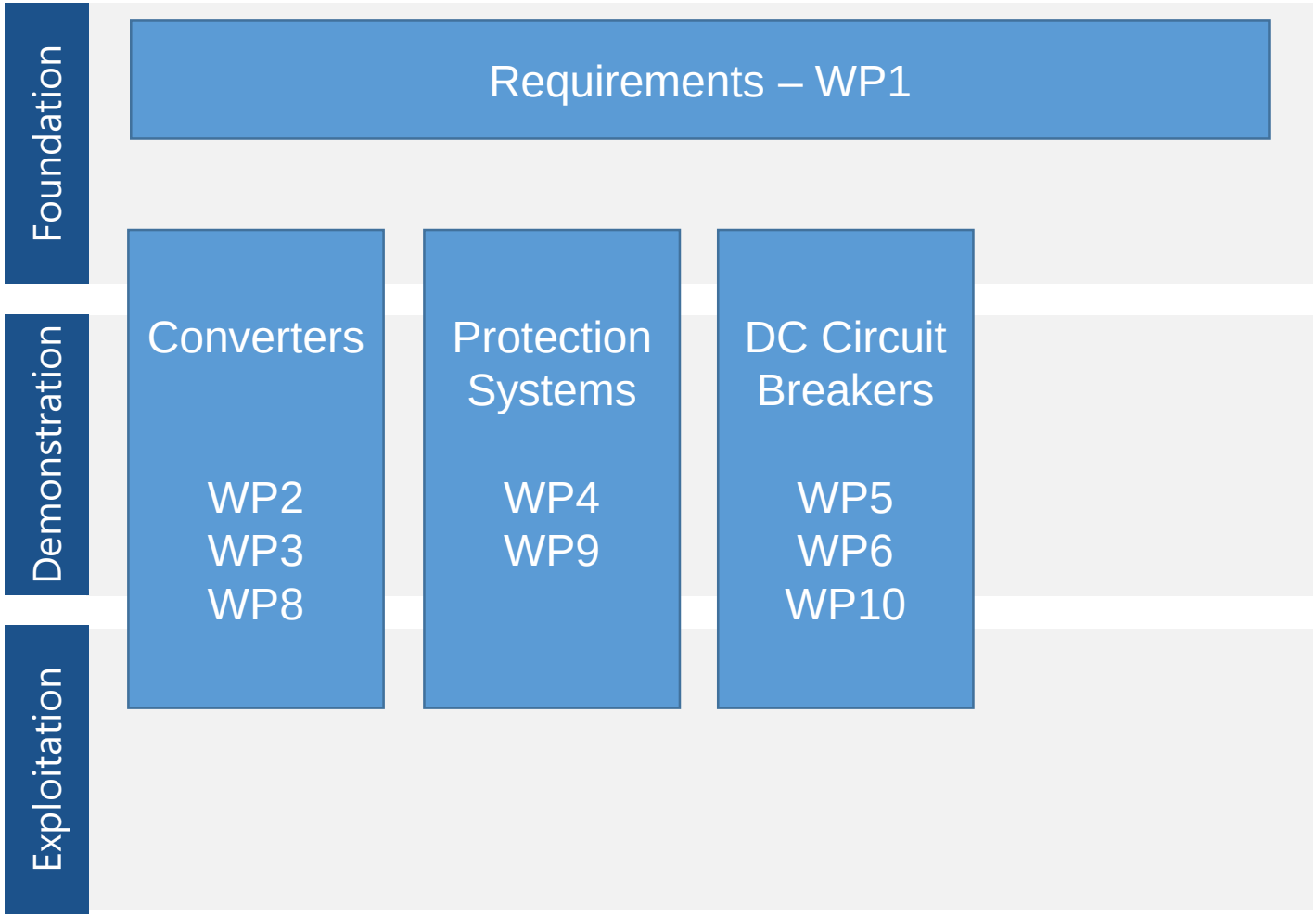
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project Structure – Protection Systems



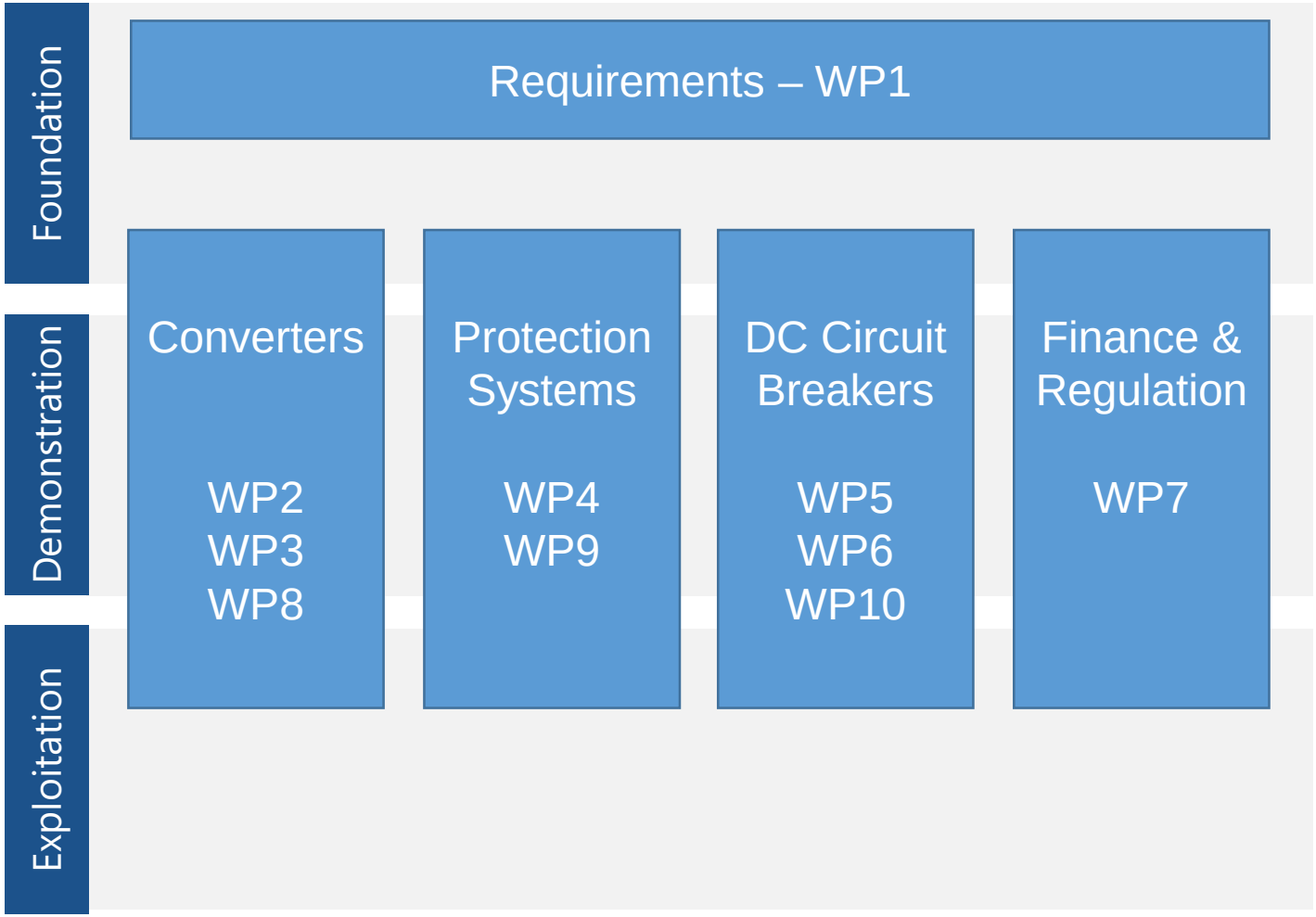
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project Structure – DC Circuit Breakers



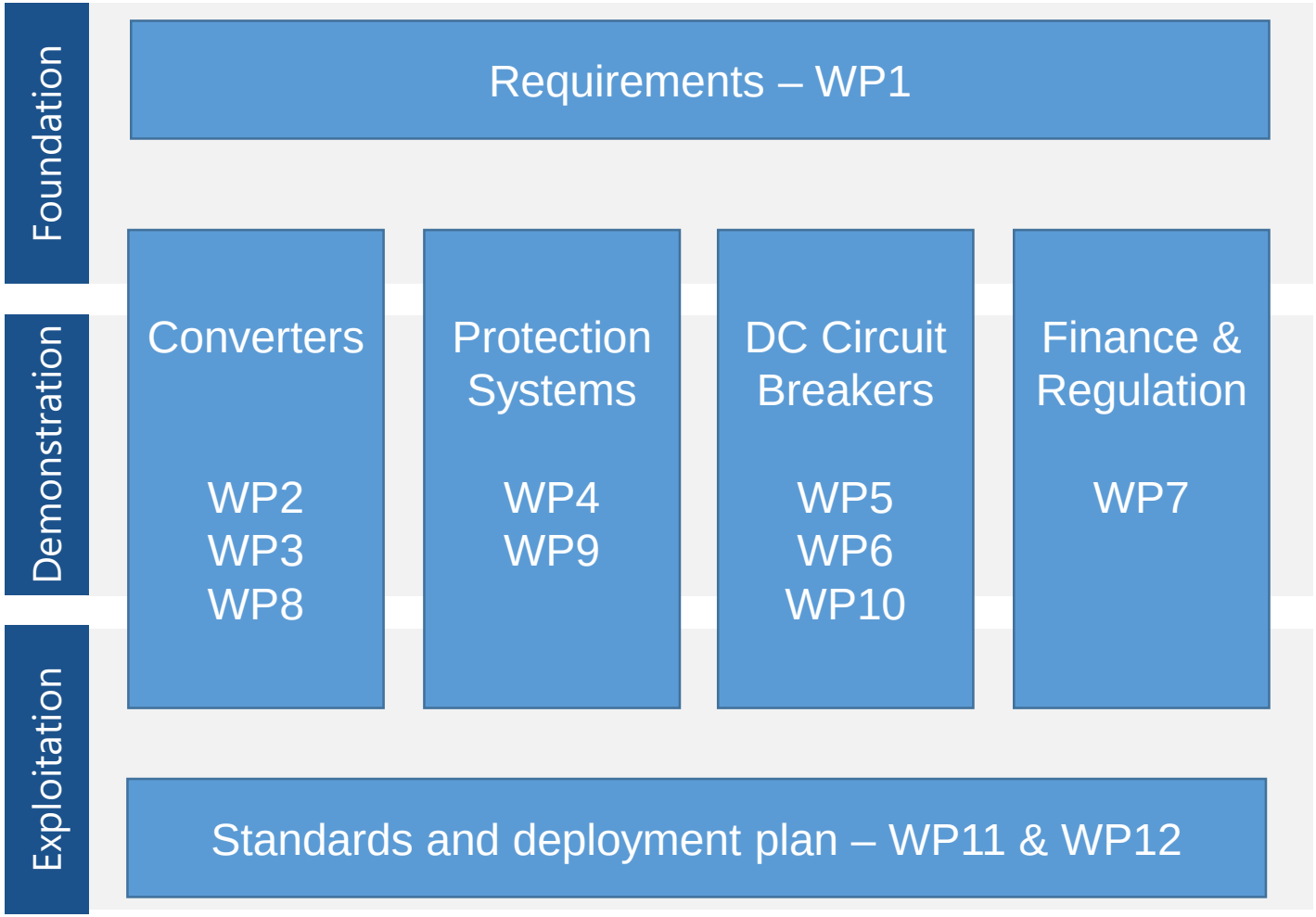
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project Structure – Finance & Regulation



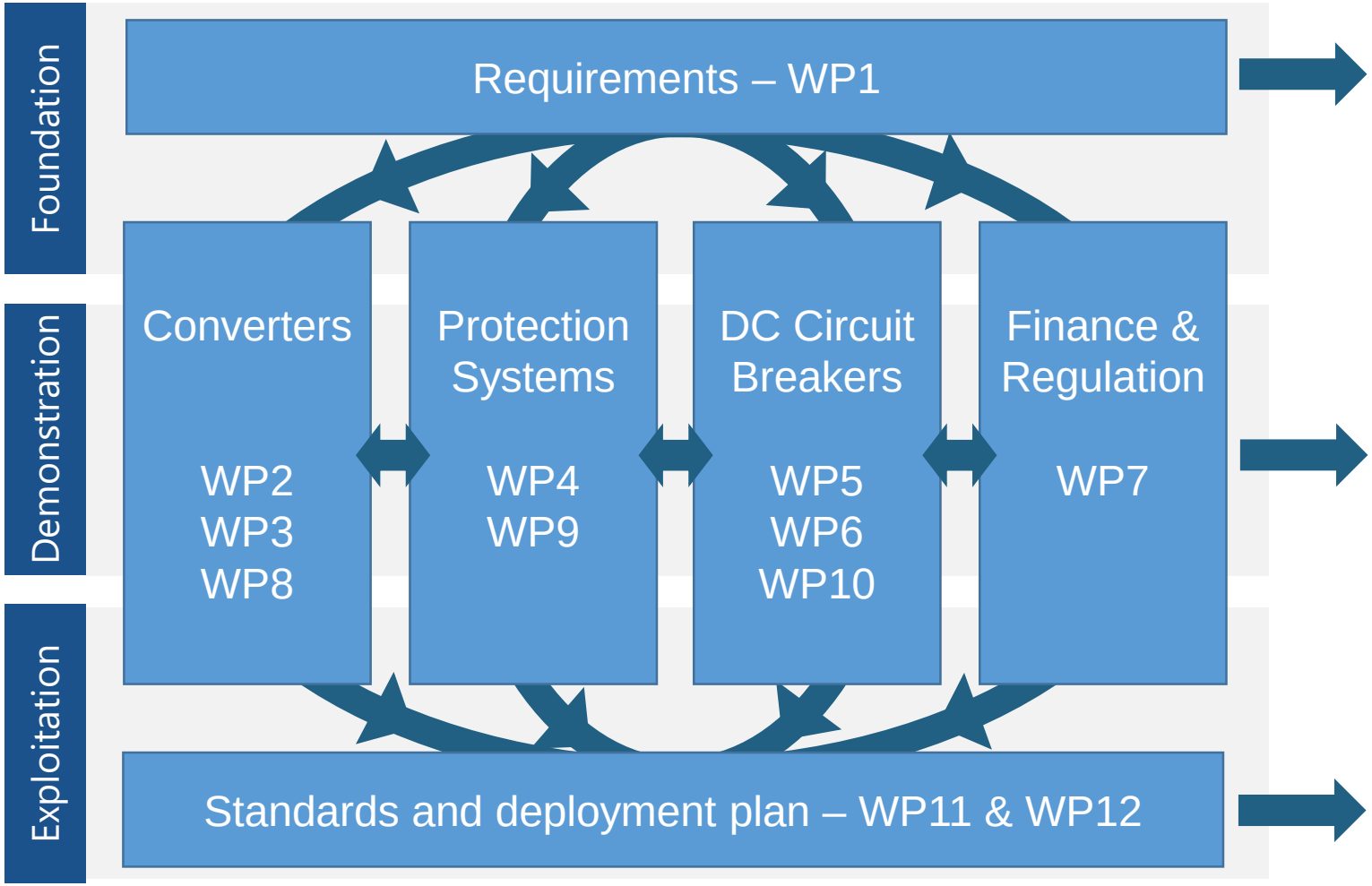
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project Structure – Standards & Deployment plan



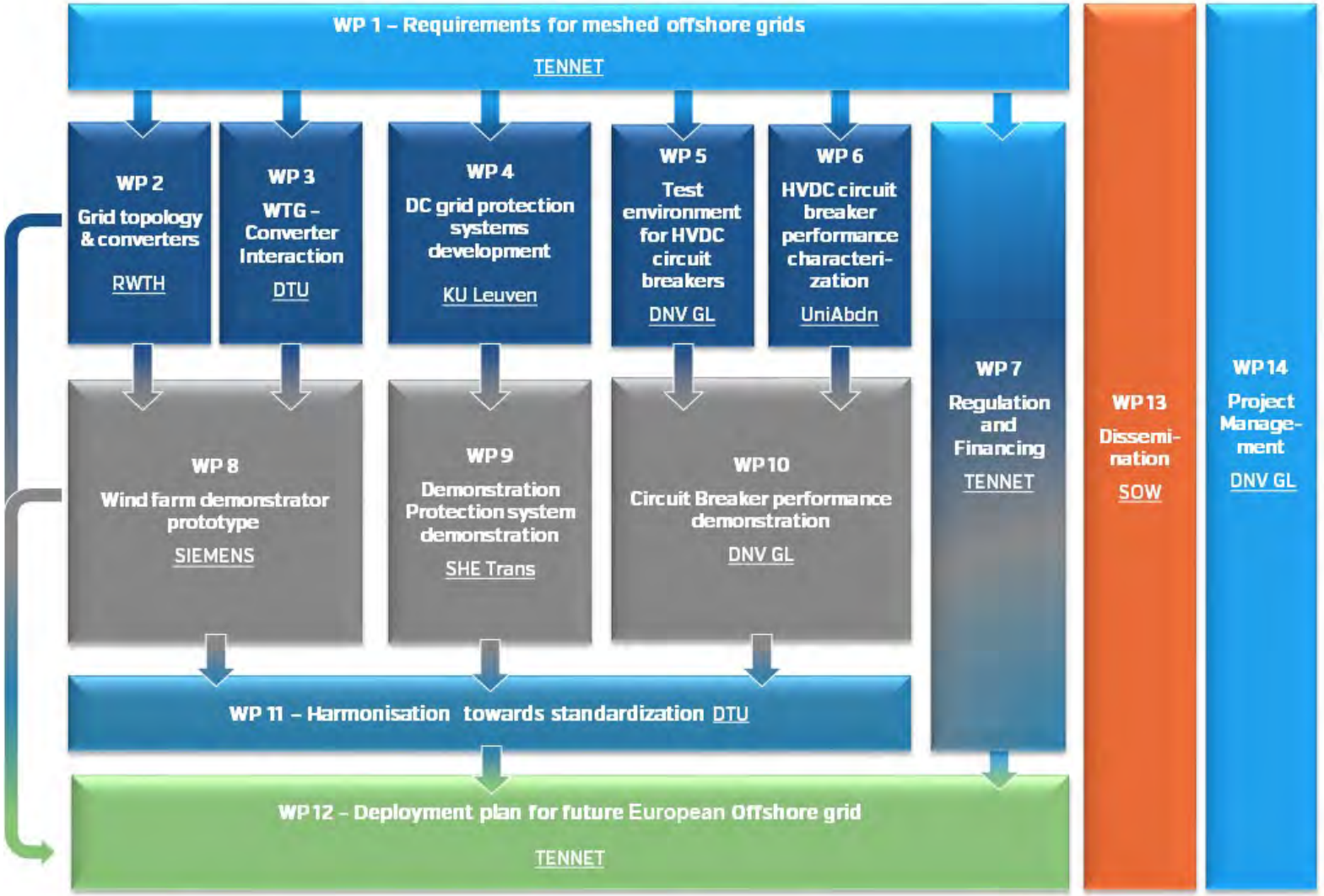
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project Structure – Coordination & dissemination



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project Structure



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

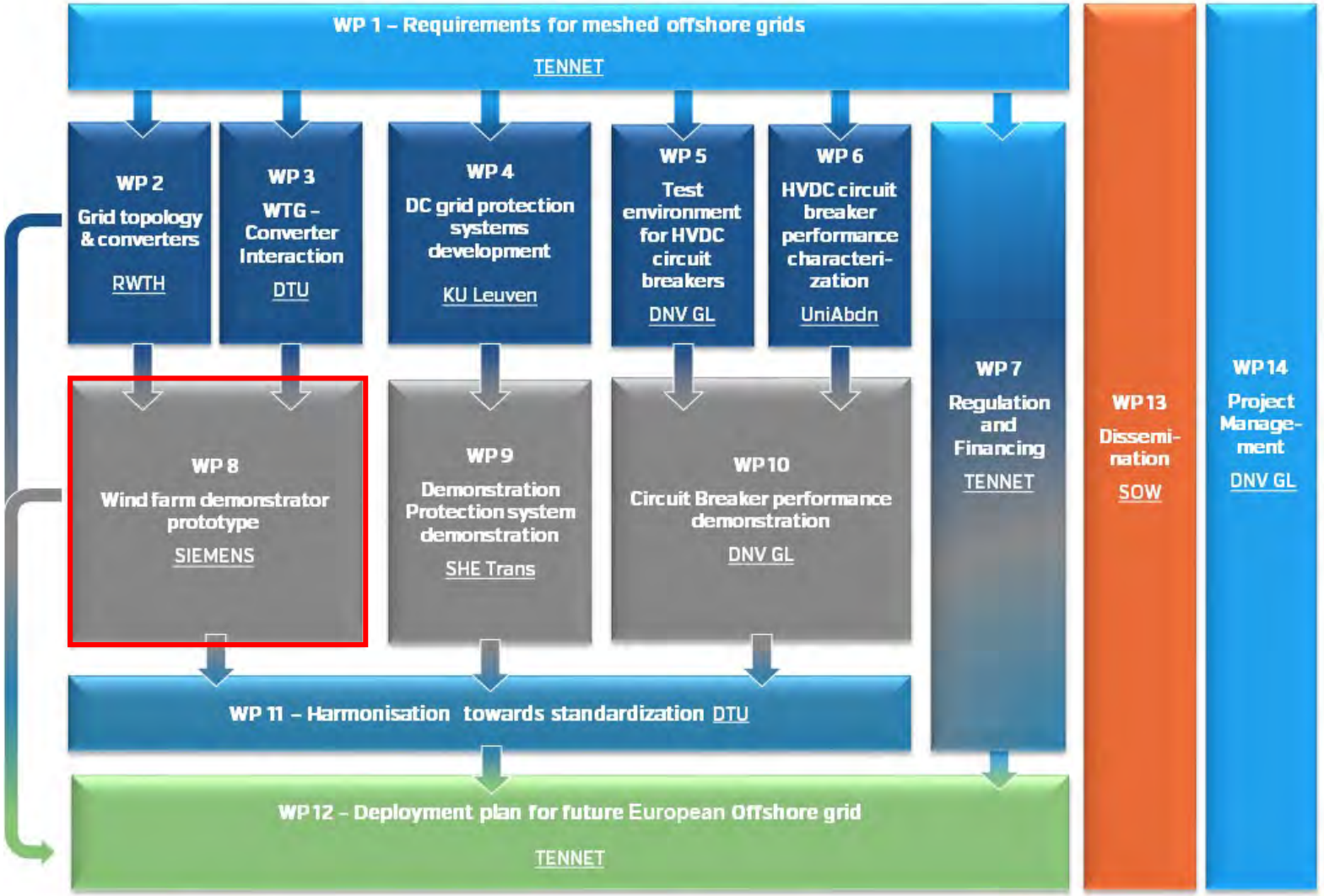
Role of partners

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Proposals

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project Structure



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP8 scope change

01-2016	Demonstrator review deliverable requested in 1st amendment
22-01-2016	Lab-scale demo introduced during 1st meeting
19-04-2016	Need for thorough evaluation of demonstration options discussed during WP8 Kick-off
16-06-2016	Further justification for lab demo provided during Stockholm meeting
	Several meetings between PC, Siemens and EC
01-12-2016	Consortium informed of Siemens NO GO decision in Berlin meeting. Prysmian scope to go ahead
26-01-2017	No DRU demo of any scale in PROMOTioN announced during Schiphol PMG meeting

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Liberated budget

- Prysmian scope will be reduced; no transport or installation
- Siemens WP8 budget returned: EUR 10.928.400,--

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Selection process new proposals

- 09-12-2016 Call for new proposals
- 23-01-2017 Deadline for proposals
- 26-01-2017 1st review in PMG
  - 1st selection
  - suggestions for improvement
- 16-02-2017 2nd review in PMG → selection criteria
  - 4 small proposals as amendment
  - 2 large proposals to be presented to EU as new WP
- 27-02-2017 2 large proposals sent to General Assembly
- 08-03-2017 General Assembly vote in favour of 2 large proposals
- 13-03-2017 Late contributions added to DC GIS & MMC test bench proposals

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Cost Benefit Analysis for North Sea grid development

- Lead: TenneT
- Contact: Daimy Abdoelkariem
- Involved partners: Deutsche Wind Guard
- Budget: EUR 250.000,--

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

CONTENT

- Motivation & objective
- Relation to PROMOTioN‘s objectives
- Expected impact
- Description of work/budget

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.

Motivation

- The current scope of WP7 is to provide a framework for evaluating costs and benefits of European infrastructure investments
- Current ENTSO-E CBA methodology has room for improvement
- North Sea grid development highlights important principles (e.g. accounting for project interaction)

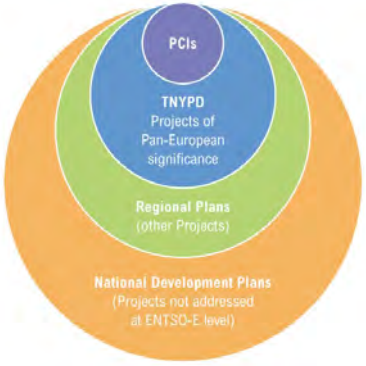
Objective

- Building on existing ENTSO-E methodology
- Drafting a CBA methodology, with a special focus on North Sea grid development
- To provide a common and uniform basis for the assessment of project with regard to their value for European society

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Relation to PROMOTioN's objectives (WP12)

Status of implementation	ENTSO-E 1.0 (approved by the EC in 2015)	ENTSO-E 2.0 (version for ACER opinion)	ENTSO-E Market design - balancing	Significantly more important in the offshore context?
INPUT(1) Project interaction must be taken into account in the project and baseline definition	One baseline (TOOT). Arbitrary clustering rules	One baseline (TOOT), ambiguous update of the clustering rule	Harder applicable but dealt with.	**Almost greenfield development**
INPUT(2) Data consistency and quality should be ensured	TYNDP	TYNDP	TYDNP	
INPUT(3) Costs should be reported in disaggregated form	Not clear	Not clear	Not clear	**Immature technology**
CALCULATION(4) CBA should concentrate on a reduced list of effects	Reduced list	Reduced list	Reduced list	
CALCULATION(5) Distributional concers should not be addressed in the calculation of net benefits	OK		OK	
CALCULATION(6) The model used to monetise the production cost savings and gross consumer surplus needs to be explicitly stated	Explicit model available	Explicit model available	Explicit model available	
CALCULATION(7) A common discount factor should be used for all projects	4 % for all	4 % for all	Uniform; aligned with TYNDP & PCI	
CALCULATION(8) A stochastic approach/scenario analysis should be used to address uncertainty	OK	The need is mentioned, but not specified how to apply the tools	OK	
OUTPUT(9) Benefits should be reported in disaggregated form	Not clear	Not clear	Regional and country effects should be reported	**Various winners/losers**
OUTPUT(10) Ranking should be based on monetisation	Multi-criteria analysis	Multi-criteria analysis, additional monetization of losses	Monetized ranking is suggested	**Various significant externalities**



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement

Expected Impact

- Provide policy makers and system operators with insights to properly value the cost and benefits of European (offshore) investments
- Provide a more concrete basis for the framework for cross border cost allocation (CBCA)

Scope of work work/ budget

- No expertise within the Consortium; subcontractor (tender)
- Detailed projectplan with timeframe & milestones
- Report on CBA methodology Support stakeholder management/presentations ENTSO-E, ACER, EC
- Tender: EUR 250.000 (incl. travelling and other expenses)
- No additional partner MM

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Hybrid HVDC Breaker – logistics and assembling

- Lead: ABB
- Contact: Jenny Josefsson
- Budget: 240 kEUR

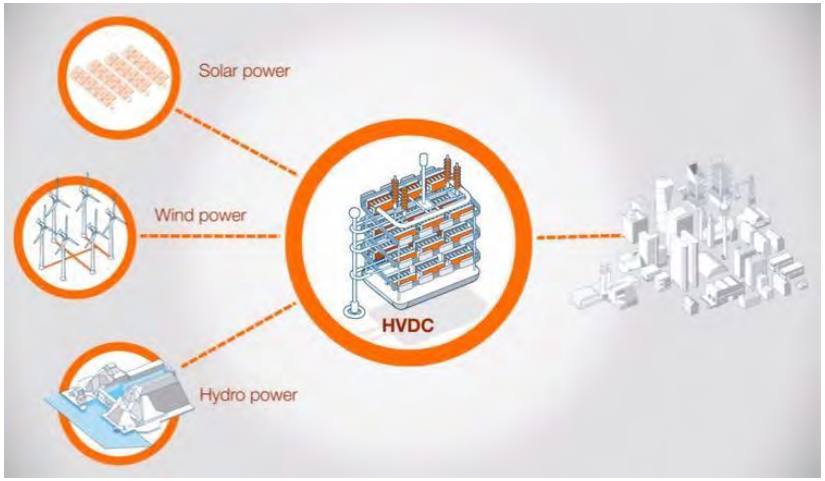
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

CONTENT

- Basic idea
- Motivation
- Impact & Relevance
- Tasks & Deliverables
- Partners & Roles
- Budget

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

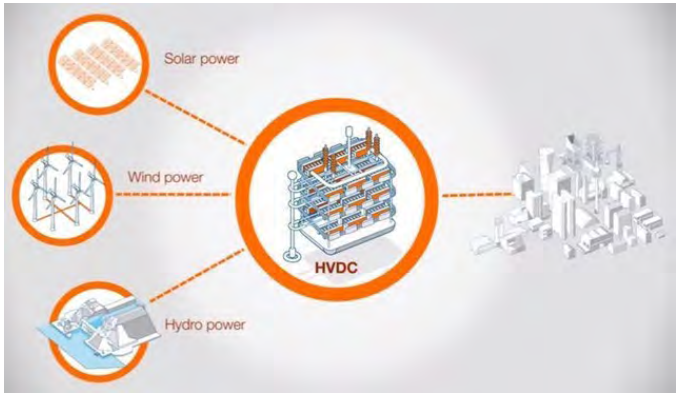
Basic Idea

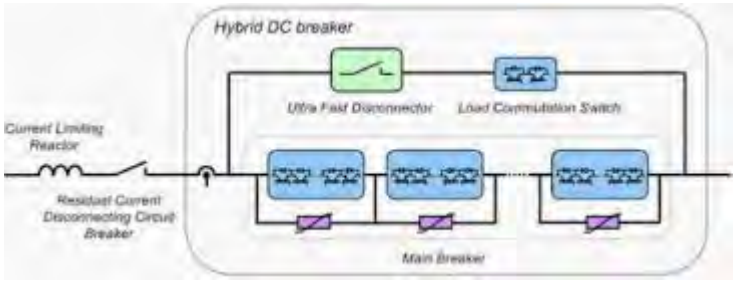


- ABB will test the Hybrid HVDC Breaker at the laboratory of DNV GL.
- ABB was granted 638 kEUR fundings.
- This covers working time and travel for all WP:s.
- ABB is therefore applying for 240 kEUR funding for:
  - Logistics
  - Assembling and disassembling of HHB
  - Installation of HHB control system

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Motivation

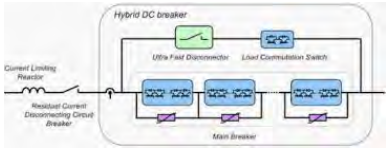




© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Motivation

- The HHB contains several components. For example the UFD will be supplied from CHABB.
- The extra fundings will allow for a flexibility of components to be sent to DNV GL.
- The extra fundings will also allow for support to DNV GL to install the control system in an efficient way.
- Without the extra funding ABB will be more limited in which components to send, for example only the main breaker or prototypes.



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Impact & Relevance

- A limitation of HHB components to be tested will still show the functionality of an HVDC breaker and the test circuit. However, a complete breaker set-up will also show the interoperability between the components.
- Support of installing the control cubicle will shorten the installation time, and limit the interference with other DNV GL testing commitment.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Tasks & Deliverables

- Task 10.6: Testing of HVDC circuit breakers (M37-48)
- Task 10.7: Full demonstration of test circuits and test methods (M40-48).

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Partners & Roles

- ABB, supplier of test object

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Budget

Type of Expense	kEUR
Logistics	10
Assembling and disassembling of HHB (factory and at DNV GL)	80
Installation of HHB control system	150
Total	**240**

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

MMC test bench demonstrator

- Lead: RWTH Aachen
- Contact: Cora Petino
- Involved partners: DTU, DNV GL, KTH
- Budget: EUR 3.973.250,--

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

MMC Test Bench Proposal for PROMOTioN

Proposal for PROMOTioN

Proposal leader: IFHT, RWTH Aachen University

Agenda

MMC Test Bench Proposal for PROMOTioN

- Motivation
- Basic Idea
- Impact and Relevance
- Tasks and Deliverables
- Partners and Roles
- Budget

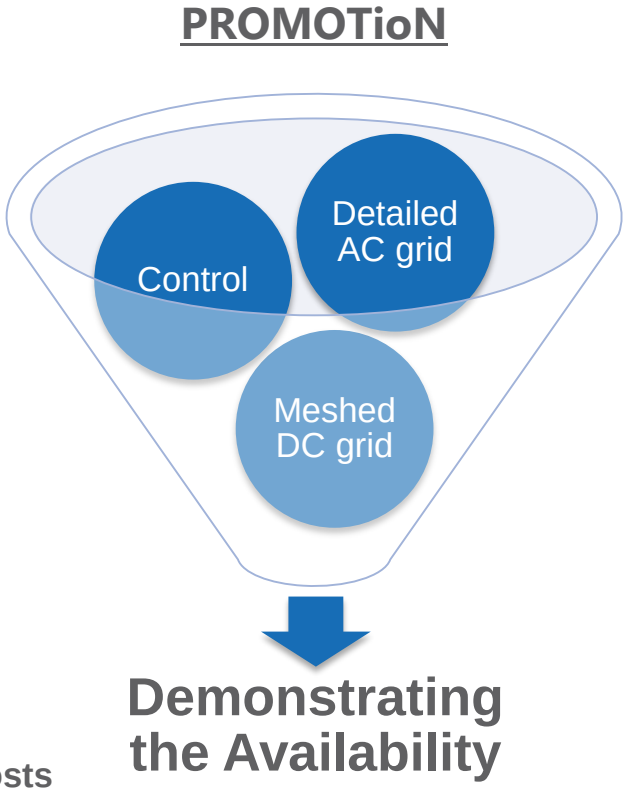
Enhancing PROMOTioN's objectives (1/2)

Motivation

- Overall target in the PROMOTioN context
  - Improve **confidence** in technological and systemic solutions
  - Reduce investment risks by **de-risking** technological decisions
  - Contribute to the **near-future** deployment of meshed offshore HVDC grids
- PROMOTioN present status
  - Termination of full scale DRU demonstrator in WP8
  - Demonstration character of project is at risk

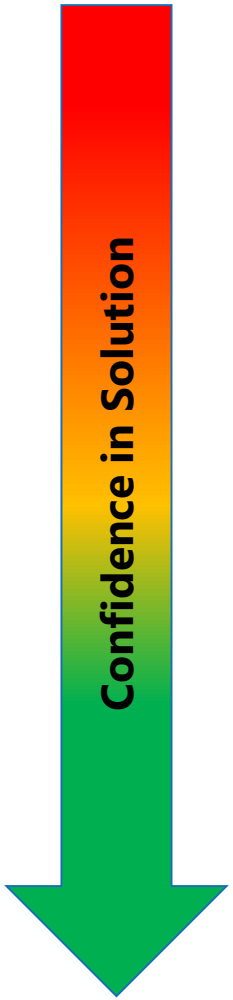
➢ Building of a RTS supported MMC Test Bench

- Allows an **investigation of planed** project results based on a small scale demonstrator
- Additional investigations on interaction of offshore DC grid with meshed AC system becomes interesting option **without additional costs**
  - ➢ Setup of fully operational MMC Test Bench system in 2017 possible
  - ➢ **Demonstration** of developed controls strategies, protection schemes and simulation models from entire PROMOTioN project context

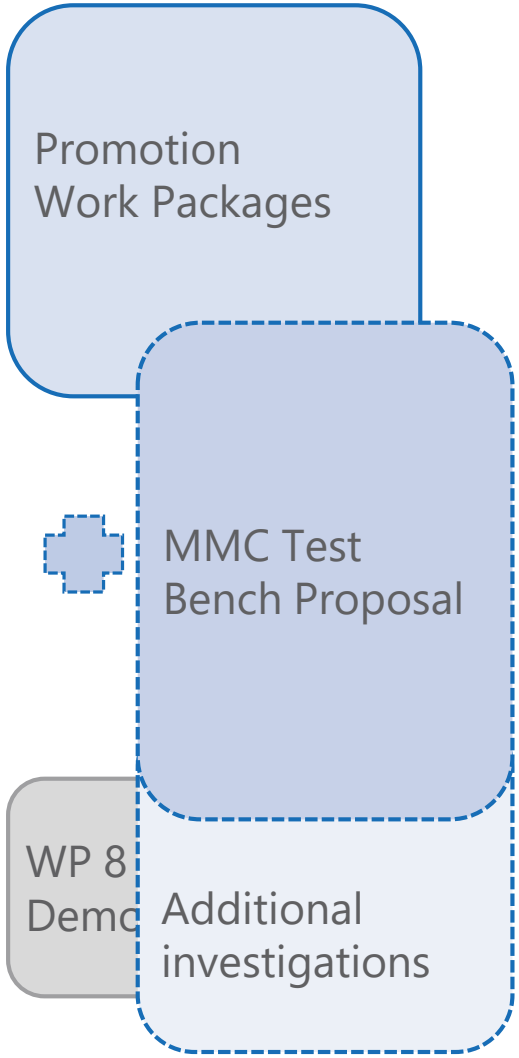


Enhancing PROMOTioN's objectives (2/2)

Specific Benefits



- Simulations as project core
  - Simulative investigation of general principles
  - Investigation of general system behavior
  - Development of basic (control) concepts
- RTS
  - Simulative investigation in real-time context
  - Time critical system responses taken into account
  - First testing of basic (control) concepts
- MMC-Test-Bench + RTS
  - Hardware representation of converter components (no simulation)
  - More exact system and component response
  - Fully realistic testing of control concepts
- Full Scale Demonstration System



Agenda

MMC Test Bench Proposal for PROMOTioN

Institut für Hochspannungstechnik | RWTH AACHEN UNIVERSITY

- Motivation
- Basic Idea
- Impact and Relevance
- Tasks and Deliverables
- Partners and Roles
- Budget

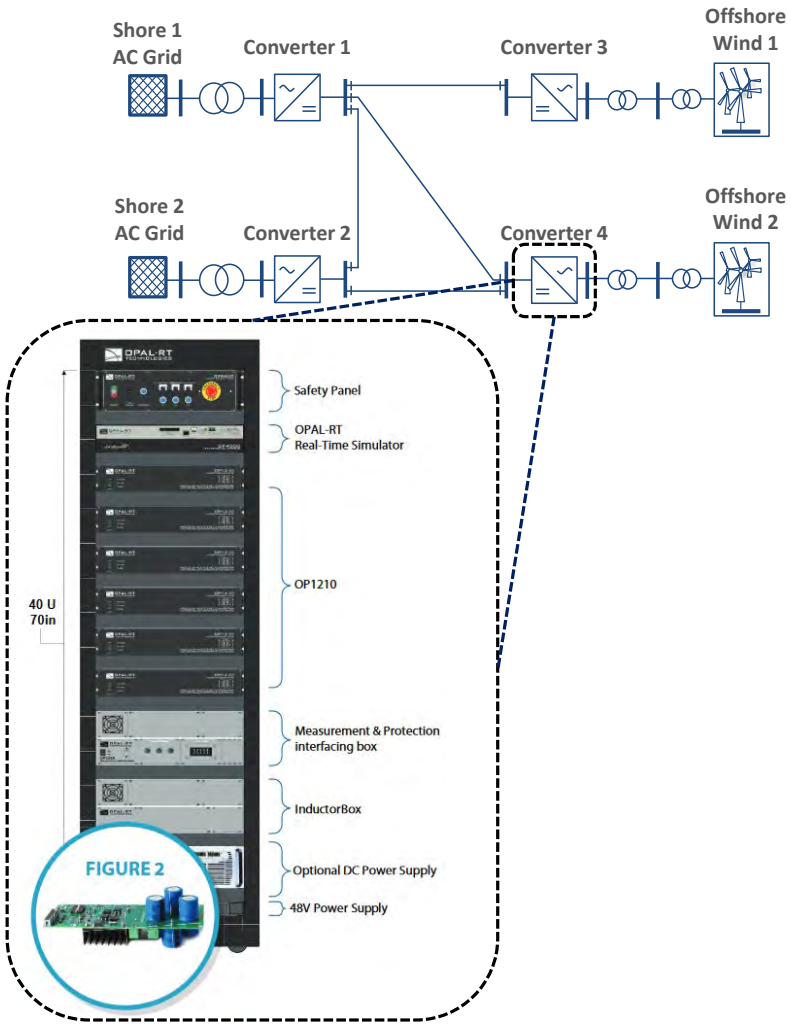
Lab scale Modular Multi-Level Converter

Basic Idea

- 8 MMC units for laboratory investigations
  - Two configurations possible: 4T bipolar and 8T monopole
  - Hardware converter containing control unit, submodules, arm inductors, measurement and protection
  - Configurable submodules (half bridge / full bridge)

Technical Data per MMC	
Rated voltage (DC)	**400 V**
Rated current (DC)	**15 A**
Number of Levels	**11**
Output power	**6 kW**

- Implementation of control schemes
  - Free programmable station and submodule control
  - Software interface: MATLAB/Simulink
  - Analysis of different control concepts under **realistic** constraints possible



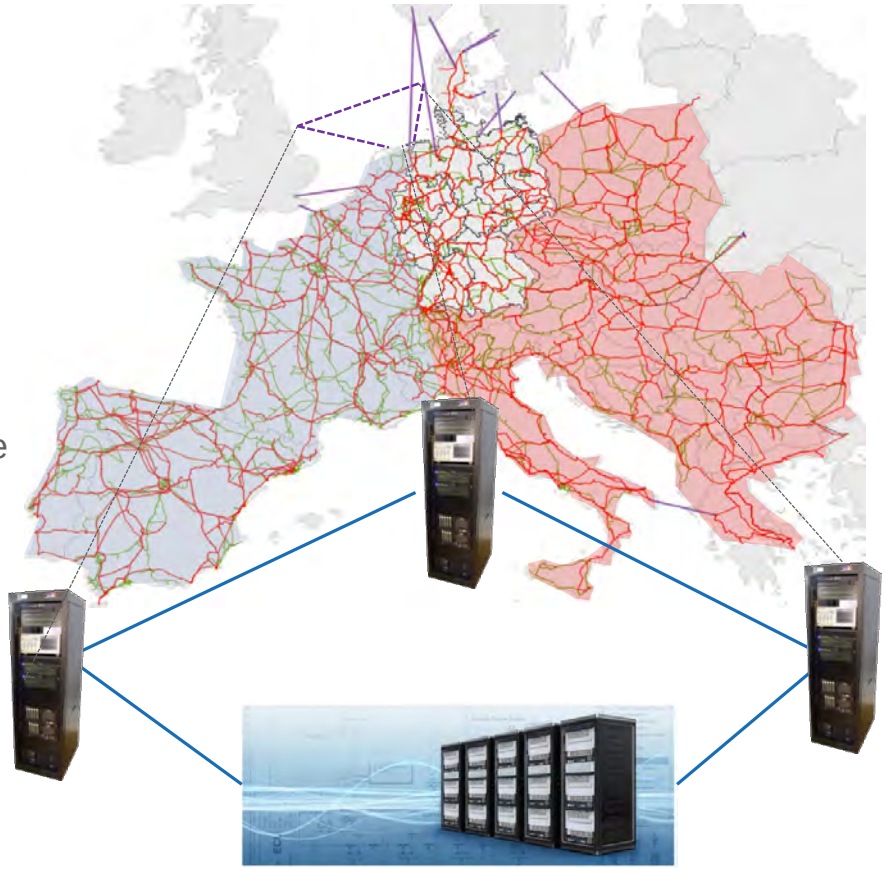
Integrating the DC into the AC grid

Basic Idea

- Modelling (of relevant parts) of the European transmission system with a real time simulator (RTS)
- **Coupling** of the MMC Test Bench and the AC grid simulation by power amplifiers
  - Real physical behavior of converters and control circuits interacts with the real time simulation
  - Investigate impact of offshore DC system on onshore AC grid scenarios
  - Analysis of interactions between AC and DC system
  - Investigation of resonance phenomena

➢ Overall solution includes

1. Lab scale MMC Test Bench with transmission lines
2. RTS simulator for European transmission system
3. Power Amplifiers for coupling both components



Agenda

MMC Test Bench Proposal for PROMOTioN

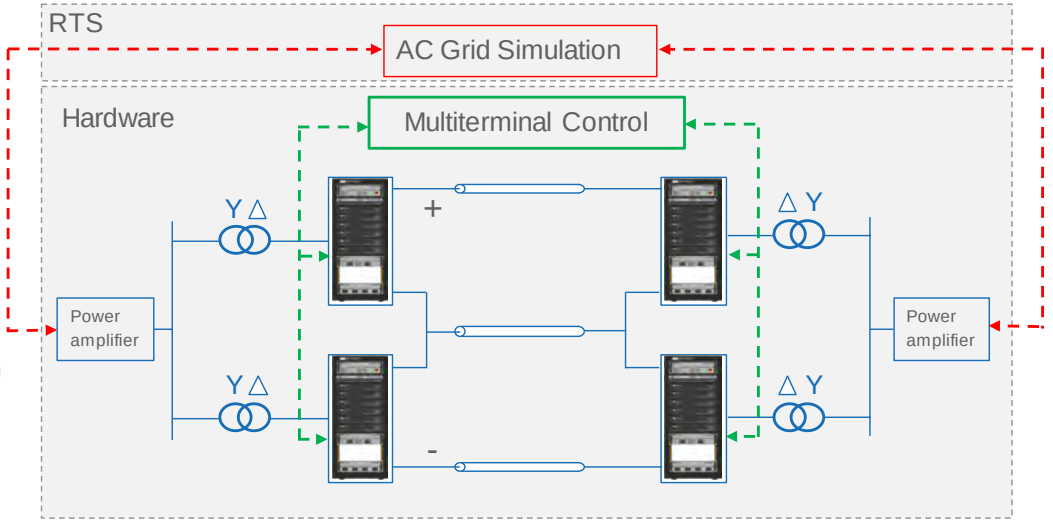
Institut für Hochspannungstechnik | RWTH AACHEN UNIVERSITY

- Motivation
- Basic Idea
- Impact and Relevance
- Tasks and Deliverables
- Partners and Roles
- Budget

Advantages and Flexibility

Impact and Relevance

- Small scale demonstrator compensates major investigations of full scale demonstrator
- **Additionally** an enhanced testing environment is created for
  - System related investigations (e.g. impact of control systems, resonance phenomena)
  - Detailed, real-life analysis of interactions between existing meshed AC grid and off-shore HVDC grid
- MMC Test Bench is available to all members of PROMOTioN consortium on long term
- **Flexibility** of investigations and hardware regarding
  - In grid topology
  - In converter topology
  - In control schemes (e.g. vendor specific)
  - Different fault scenarios applicable (AC faults and DC faults)
  - Different load flow scenarios
  - Different networks (strong / weak AC grids)
  - Different dynamic AC grid responses in real-time

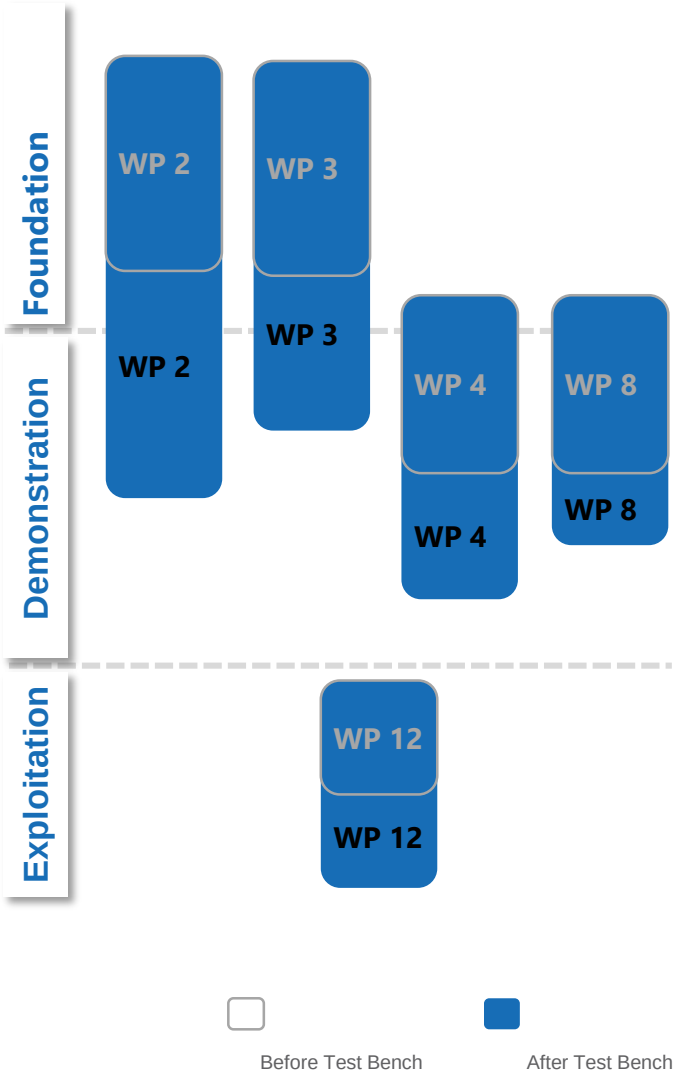


Links to other WPs

Impact and Relevance

- Impact on other PROMOTioN work packages
  - **Demonstration** of interoperability, controllability for different converter configurations (WP2)
  - **Demonstration** of applicability of WT and WPP control (WP3)
  - **Demonstration** of interoperability of protection (WP4)
  - **Demonstration** of interoperability of lab scale MMC, AC grid and DRU (WP8)
  - **Improvement** of certainness for road mapping process and standardization efforts (WP12)
- Pushing the investigations across several PROMOTioN work packages towards demonstration / exploitation
- Promoting compatibility through testing

➢ Significant improvement of WP results possible

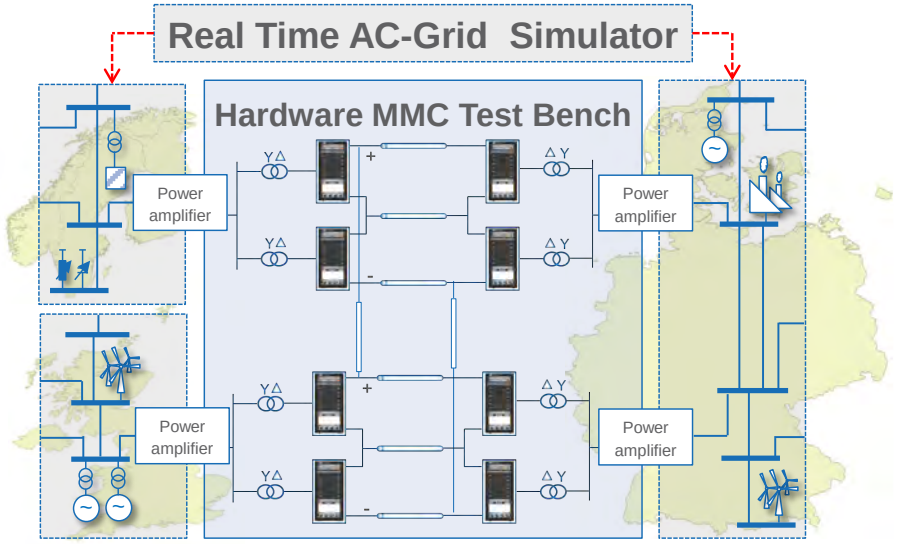


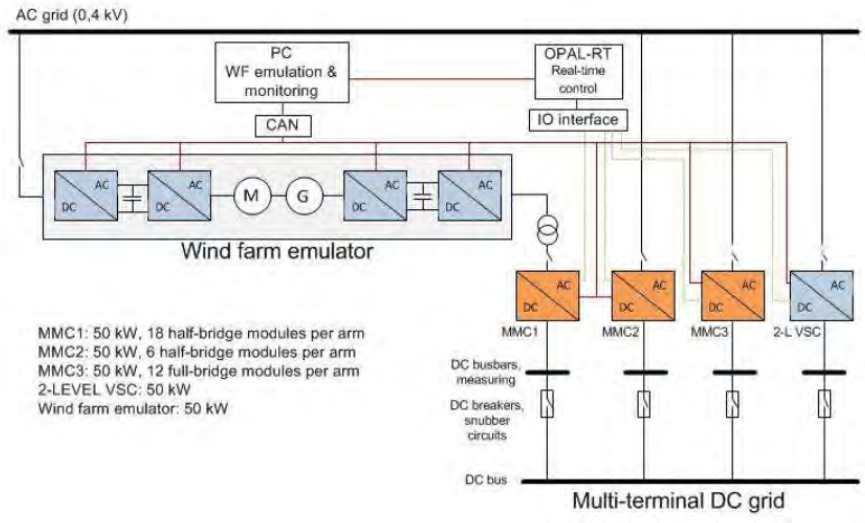
Differences to “Best Paths” Project

Impact and Relevance

- **MMC Test Bench** allows flexible investigation of converter control
- Extensive modelling of large AC grid and meshed DC grid possible
- Investigation of control induced resonance phenomena possible
- Approach close to real-world large scale HVAC and HVDC system

- “**Best Paths**” demonstrator includes single wind farm emulator
- Other Converters directly connected to AC grid
- DC grid is radial-only structure
- Focus of “Best Paths” is on converter operation and interoperability of converters





Source: Best Paths publication, WP2 deliverable 2.1

Agenda

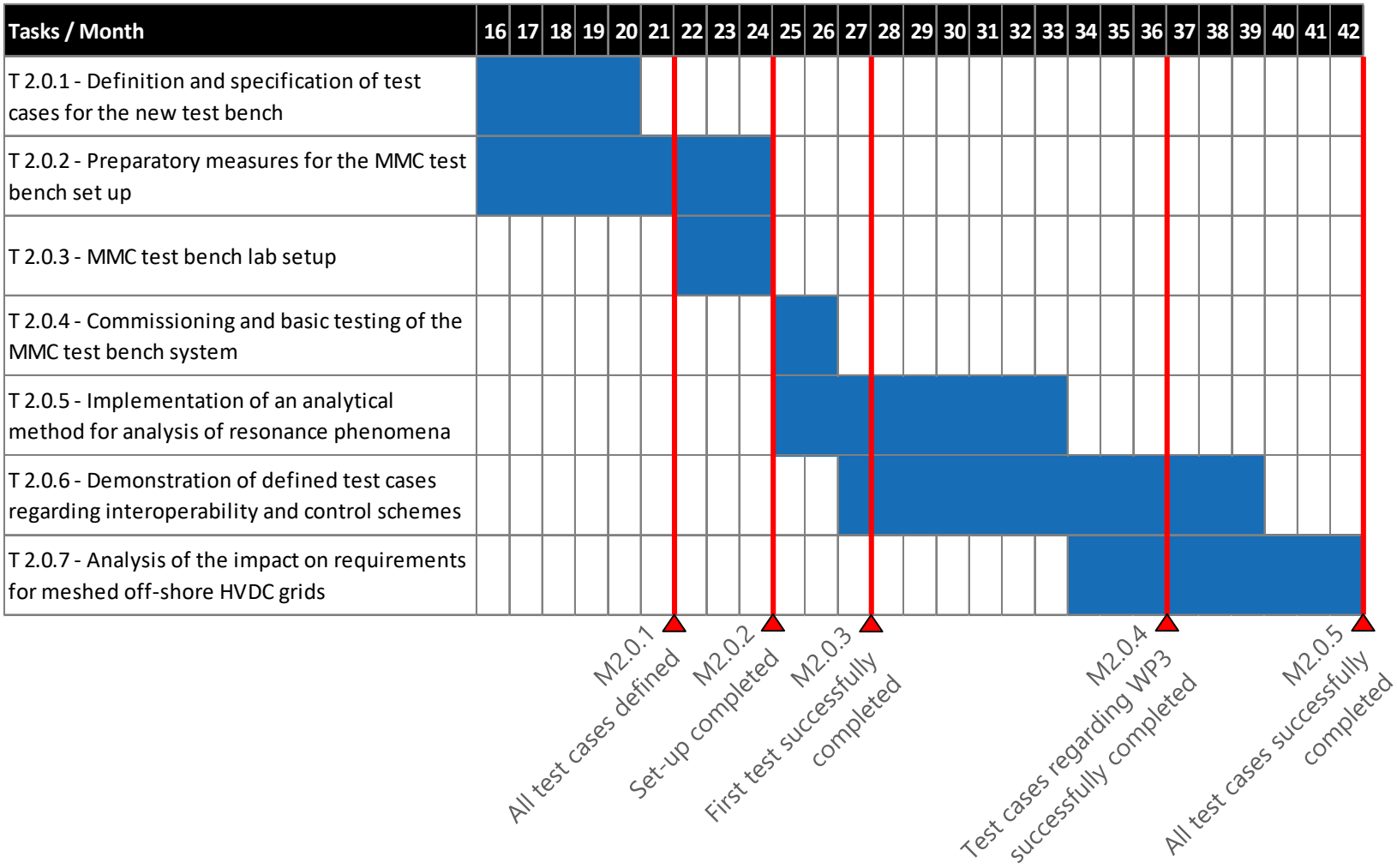
MMC Test Bench Proposal for PROMOTioN

Institut für Hochspannungstechnik | RWTH AACHEN UNIVERSITY

- Motivation
- Basic Idea
- Impact and Relevance
- Tasks and Deliverables
- Partners and Roles
- Budget

Gantt-Chart

Task and Deliverables



Task description (1/2)

Task and Deliverables

- Task 2.0.1 – Definition and specification of test cases for the new test bench
  - Start: M16; End: M20; Participants: RWTH, DTU, DNV GL, KTH
  - Derive test cases from WP 2.2, as well as WP 3, WP 4 and WP 8
  - Definition of additional cases related to grid code development
  - Adaption of scenarios from WP 2.3
- Task 2.0.2 – Preparatory measures for the MMC test bench set up
  - Start: M16; End: M24; Participants: RWTH, DTU, DNV GL, KTH
  - Preparatory measures for test bench setup, including adjustment of existing infrastructure and preexisting testing equipment
  - Preparation of developed control models from WP 2.2 for application in test bench
- Task 2.0.3 – MMC test bench lab setup
  - Start: M22; End: M24; Participants: RWTH, DNV GL, KTH
  - Assembly of components and basic training
- Task 2.0.4 – Commissioning and basic testing of the MMC test bench system
  - Start: M25; End: M26; Participants: RWTH, DNV GL, KTH
  - Conduction of basic tests on real-time components, mirroring the test bench hardware
  - After successful tests, conduction of first test in real test bench hardware

Task description (2/2)

Task and Deliverables

- Task 2.0.5 – Implementation of an analytical method for analysis of resonance phenomena
  - Start: M25; End: M33; Participants: RWTH, DTU, DNV GL, KTH
  - Implementation of an analytical method for resonance phenomena utilizing the test bench system
  - Proposition of a converter harmonic model for AC system stability evaluation
- Task 2.0.6 – Demonstration of defined test cases regarding interoperability, control schemes and protection
  - Start: M27; End: M39; Participants: RWTH, DTU, DNV GL, KTH
  - Conduction of test cases defined in Task 2.0.1
  - Investigation of developed methodology for resonance phenomena analysis
  - Controller replica from wind turbine vendors will be used in CHIL (controller hardware in the loop) verification
  - Investigation and demonstration of interoperability of control schemes and protection
- Task 2.0.7 – Analysis of the impact on requirements for meshed off-shore HVDC grids
  - Start: M34; End: M42; Participants: RWTH, DTU, DNV GL, KTH
  - Parallel evaluation of results from test cases
  - Based on results, recommendations, minimum requirements and general principles are developed for offshore HVDC grids
  - Transition of results into WP 12, extending the grid codes developed in WP 11

Deliverables and Milestone planning

Task and Deliverables

- Deliverables
  - **D2.0.1 – M21 (Public)**
    Overview of all defined test cases to be investigated on the test bench
  - **D2.0.2 – M24 (Confidential)**
    Detailed documentation of the lab set-up, technical specifications and configuration possibilities
  - **D2.0.3 – M36 (Public)**
    Overview of the conducted tests, the results and the associated analyses with respect to the research questions and analyses within WP 3
  - **D2.0.4 – M42 (Public)**
    Overview of the conducted tests, the results and the associated analyses with respect to requirements towards sustainable and interoperable meshed off-shore HVDC grids
  - **D2.0.5 – M33 (Public)**
    Documentation of the investigated/developed analytical methods for analysis of resonance phenomena

- Milestones
  - M2.0.1 – M21: All test cases defined
  - M2.0.2 – M24: Set-up completed
  - M2.0.3 – M27: First test successfully completed
  - M2.0.4 – M36: Test cases regarding WP3 successfully completed
  - M2.0.6 – M42: All test cases successfully completed

Agenda

MMC Test Bench Proposal for PROMOTioN

Institut für Hochspannungstechnik | RWTH AACHEN UNIVERSITY

- Motivation
- Basic Idea
- Impact and Relevance
- Tasks and Deliverables
- Partners and Roles
- Budget

Project partners and roles

Partners and Roles

- Sub-project carried out by:
- IFHT, RWTH Aachen University
  - Call for tenders and acquisition of MMC test bench
  - Creating first test models & Conduction of lab demonstration
  - Building and primarily testing of MMC test bench
  - Project coordination
- DNV GL
  - Work on control replica and testing of wind turbine models
  - Development and validation of resonance phenomena models
- Technical University of Denmark
  - Selection of test cases & Conduction of lab demonstration
  - Preparation of models for demonstration
- KTH Royal Institute of Technology in Stockholm*
  - Testing of protection system of WP4 on MMC test bench
  - Demonstration of interoperability of protection

*The contribution of KTH is an additional amendment to the initial proposal

Agenda

MMC Test Bench Proposal for PROMOTioN

Motivation

Basic Idea

Impact and Relevance

Tasks and Deliverables

Partners and Roles

Budget

Budget and WP effort

Budget

- Budget calculation including possible traveling expenses to / from RWTH testing facilities
- Equipment expenses include
  - Hardware of MMC test bench, real time simulator, power amplifiers and DC line model (RWTH)
  - Upgrade of existing OPAL-RT system to support controller replicas of wind turbines (DNV GL)
- Other goods and services include
  - Professional training from MMC test bench manufacturer (all)
  - Extern service charges for minor room / building adjustments in test bench site (RWTH)
- Calculated WP effort for realization
  - RWTH Aachen: 30 PM
  - DTU: 24 PM
  - DNV GL: 12 PM
  - KTH: 24 PM*
  - **Total: 90 PM**

RWTH Aachen	**Cost**
Travel	- €
Equipment	1,975,000 €
Other goods and services	125,000 €
DTU	
Travel	10,000 €
Equipment	- €
Other goods and services	10,000 €
DNV GL	
Travel	10,000 €
Equipment	400,000 €
Other goods and services	10,000 €
KTH*	
Travel	10,000 €
Equipment	- €
Other goods and services	10,000 €
Total equipment costs	**2,560,000 €**

*The contribution of KTH is an additional amendment to the initial proposal

Summary

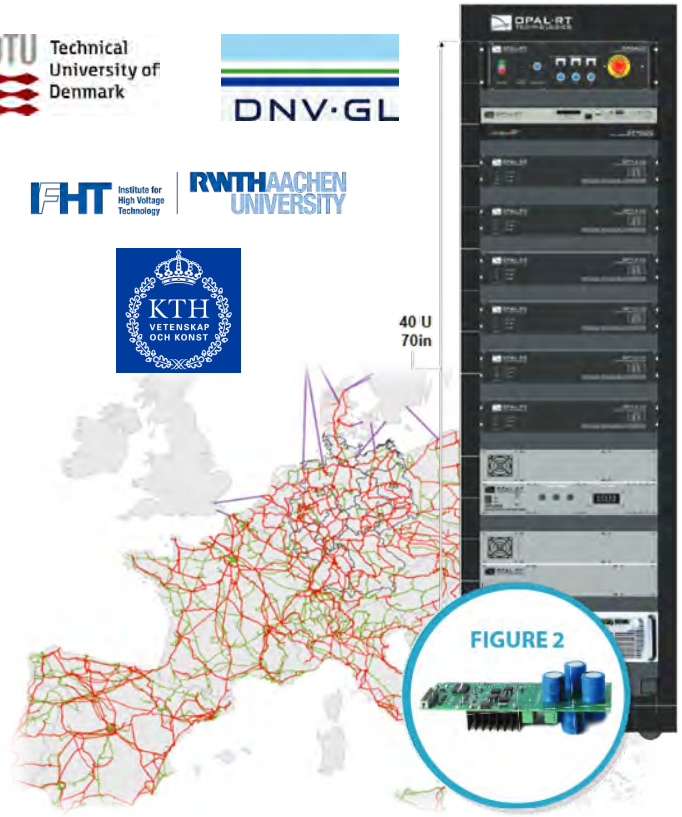
MMC Test Bench Proposal for PROMOTioN - WP2

- Core content of the proposal:
  - Installation of a lab scale MMC test bench
  - Interconnection of the test bench with RTS for large scale AC grid representation using power amplifiers

➢ Enhancing confidence in simulation results

  - Highly flexible demonstrator for different DC grid and converter configurations, control systems and strategies as well as AC grid models
  - **Demonstration** of applicability of developed controls and simulation models of PROMOTioN
  - **Technical and economical de-risking** for the deployment and continuous operation of meshed HVDC-systems
  - **Improvement** of certainness for road mapping process and standardization efforts

- Contributions to WP 2, 3*, 8 and 12 through lab demonstration and experience with real hardware



*The contribution of KTH is an additional amendment to the initial proposal

Thank you for
your attention

DC GIS technology demonstrator

- Lead: ABB
- Contact: Jenny Josefsson
- Involved partners: DNV GL, TU Delft, SHE Transmission, TenneT
- Budget: EUR 4.420.955,--

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

- Basic idea
- Motivation
- Impact & Relevance
- Tasks & Deliverables

- Partners & Roles
- Budget

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Basic Idea

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.
© ABB

DC GIS Technology Demonstrator

- Develop a thorough understanding of technical and operational requirements of gas insulated DC systems in meshed offshore HVDC grids
- Develop and demonstrate monitoring and diagnostic methods
- Develop meaningful standardized test programs based on existing standardization work and increase technology readiness level (TRL) of DC GIS technology
- Demonstrating a full-scale prototype in an independent test lab

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

DC GIS Technology Demonstrator - Idea

- Review of state-of-the-art of DC GIS technology and its state-of-development
- Determine operational stresses on DC GIS through simulation and FMEA
- Develop recommendations for specifying DC GIS installations
- Develop meaningful test program based on Cigré draft and with TSO approval
- Review, compare and develop monitoring techniques based on temperature, gas pressure, gas density and partial discharge measurements
- Review, compare and develop diagnostic methods based on evaluating monitoring outputs
- Analyze and evaluate the performance of a different type of insulating gas*
- Carry out long duration testing on real DC GIS system in high voltage laboratory
- Review and verify monitoring and diagnostic results

* The contribution of SGI is an amendment to the original proposal

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

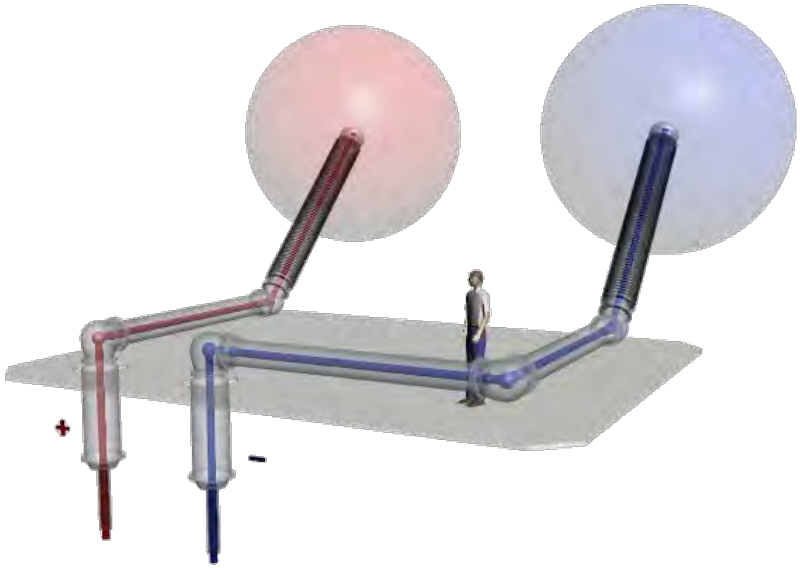
Motivation

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© ABB

Advantages of gas insulated systems

- A DC GIS installation can be built with a much higher degree of compactness and significantly lower sensitivity to ambient factors than with air-insulated switchgear (AIS).
- The most obvious cost-saving potential can be found on off-shore converter platforms where the required air-clearance for AIS leads to much larger and heavier off-shore structures.
- By using DC GIS, the volumetric space of the switchgear installation can be drastically reduced e.g. by 70%- 90%.



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

DC GIS Technology

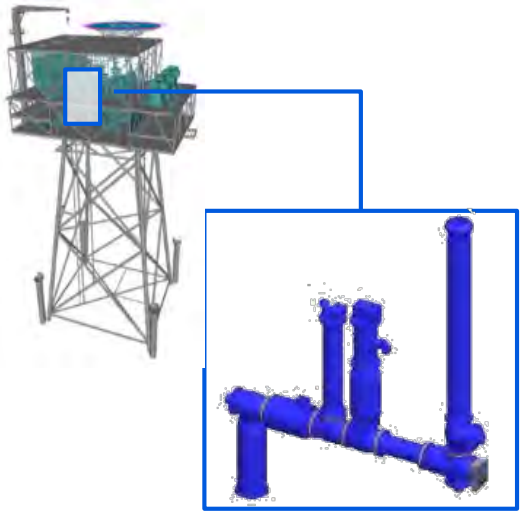
- The HVDC-GIS technology spans a number of switchgear components, e.g.:
  - Bus-ducts and high voltage DC conductors
  - Disconnect- and earthing switches
  - Bushings and cable terminations
  - Current- and voltage measurement sensors
  - Surge arresters

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Application options

DC GIB

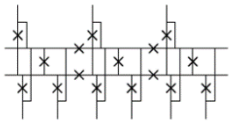
Flexible “3D routing” and connections on platforms

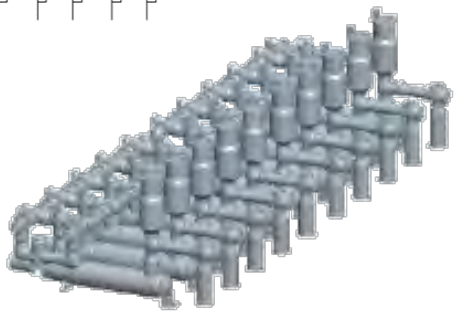


DC Hub

Connections of several DC cables of OHL (MTDC)

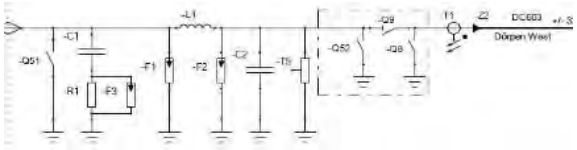
With or without DC circuit breaker





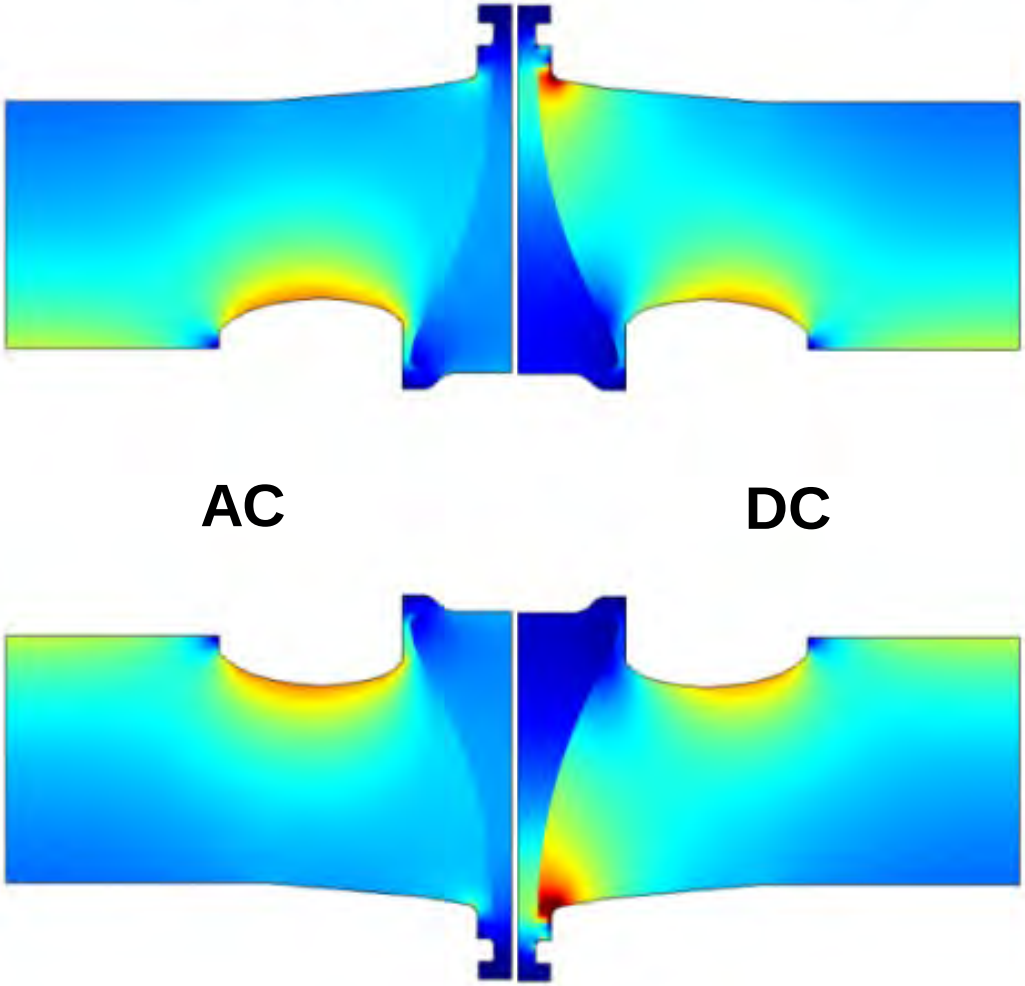
DC Hall

Compact converter station design

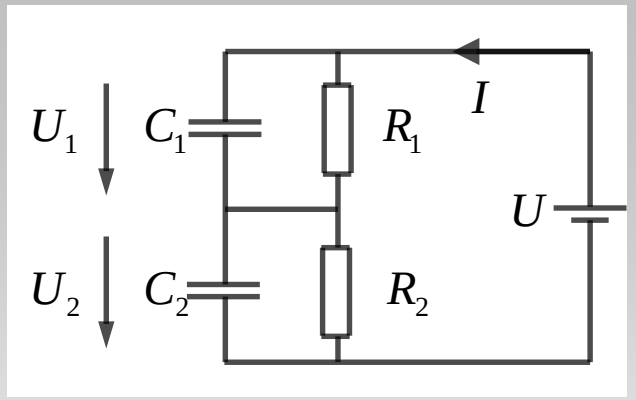


© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.

AC - DC



Circuit Diagramm



$$I = \frac{U}{R} + C\frac{d(U)}{dt}$$

Transition

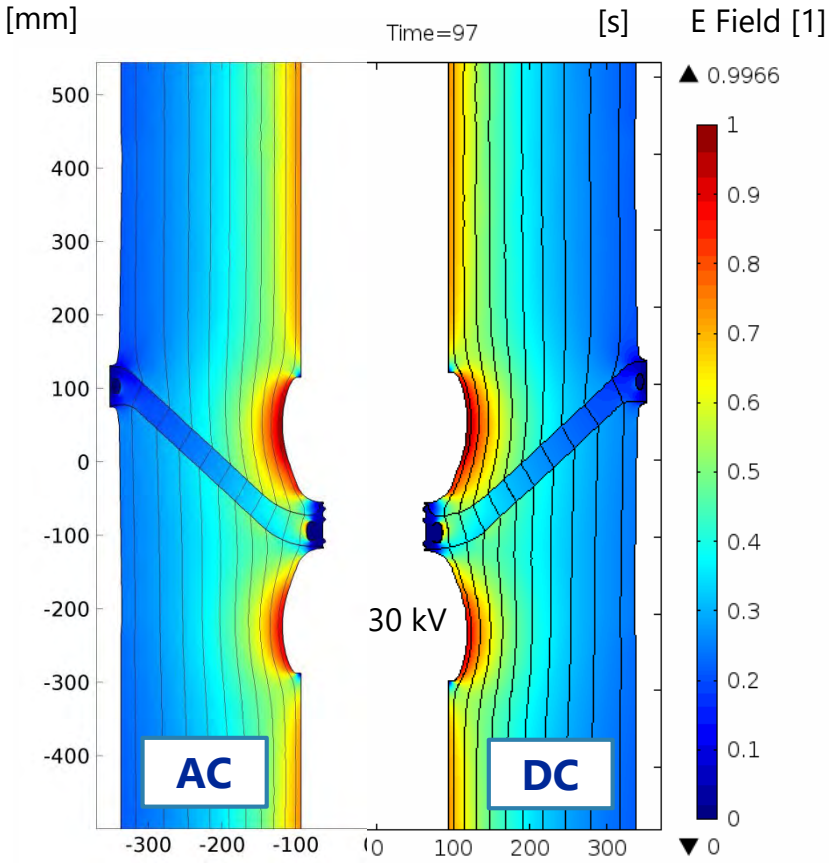
$$\tau = RC = \frac{\varepsilon_0 \varepsilon_r}{\sigma}$$

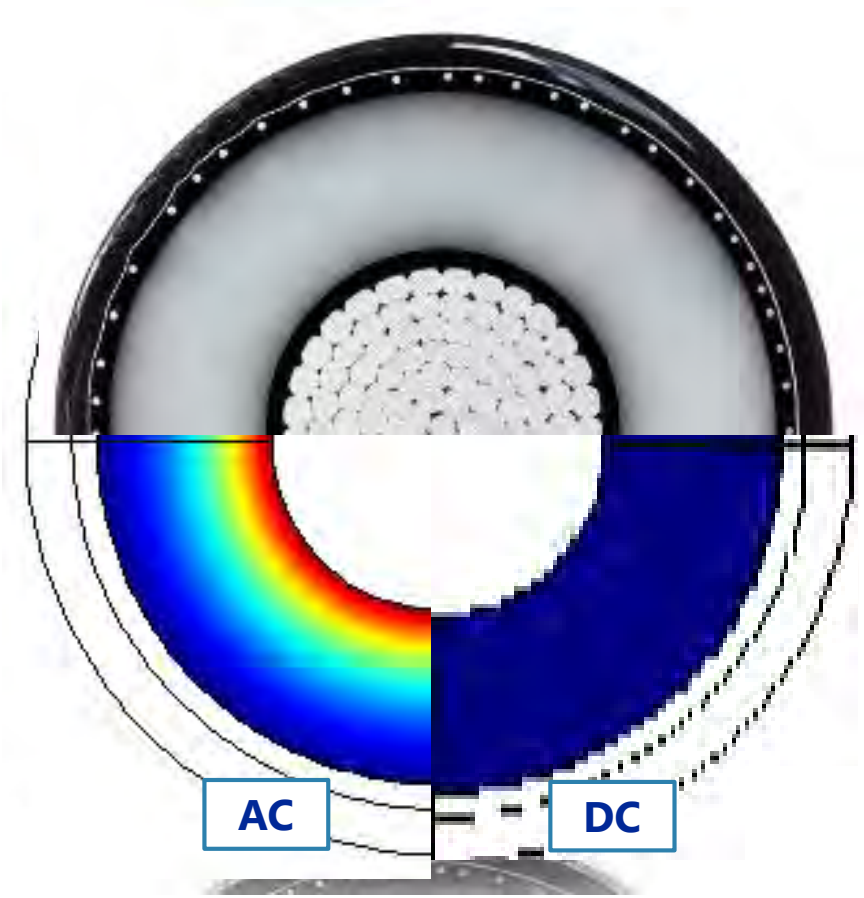
$t = 0$ ("AC") $\qquad$ $t \to \infty$ ("DC")

$$\frac{U_1}{U_2} = \frac{C_2}{C_1} \qquad \frac{U_1}{U_2} = \frac{R_1}{R_2}$$

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

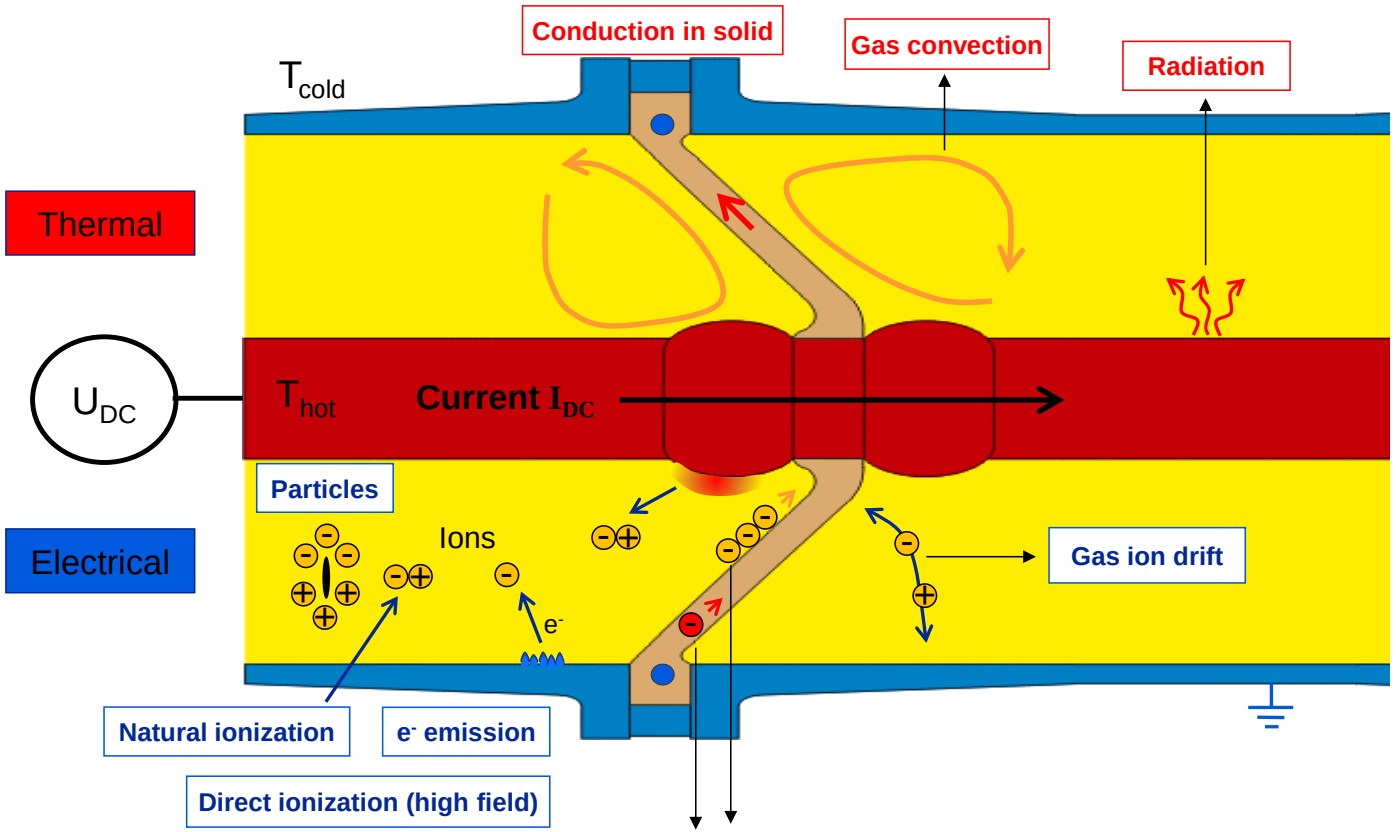
Dimensioning of a HVDC GIS





© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Physical effects in HVDC gas-solid insulation



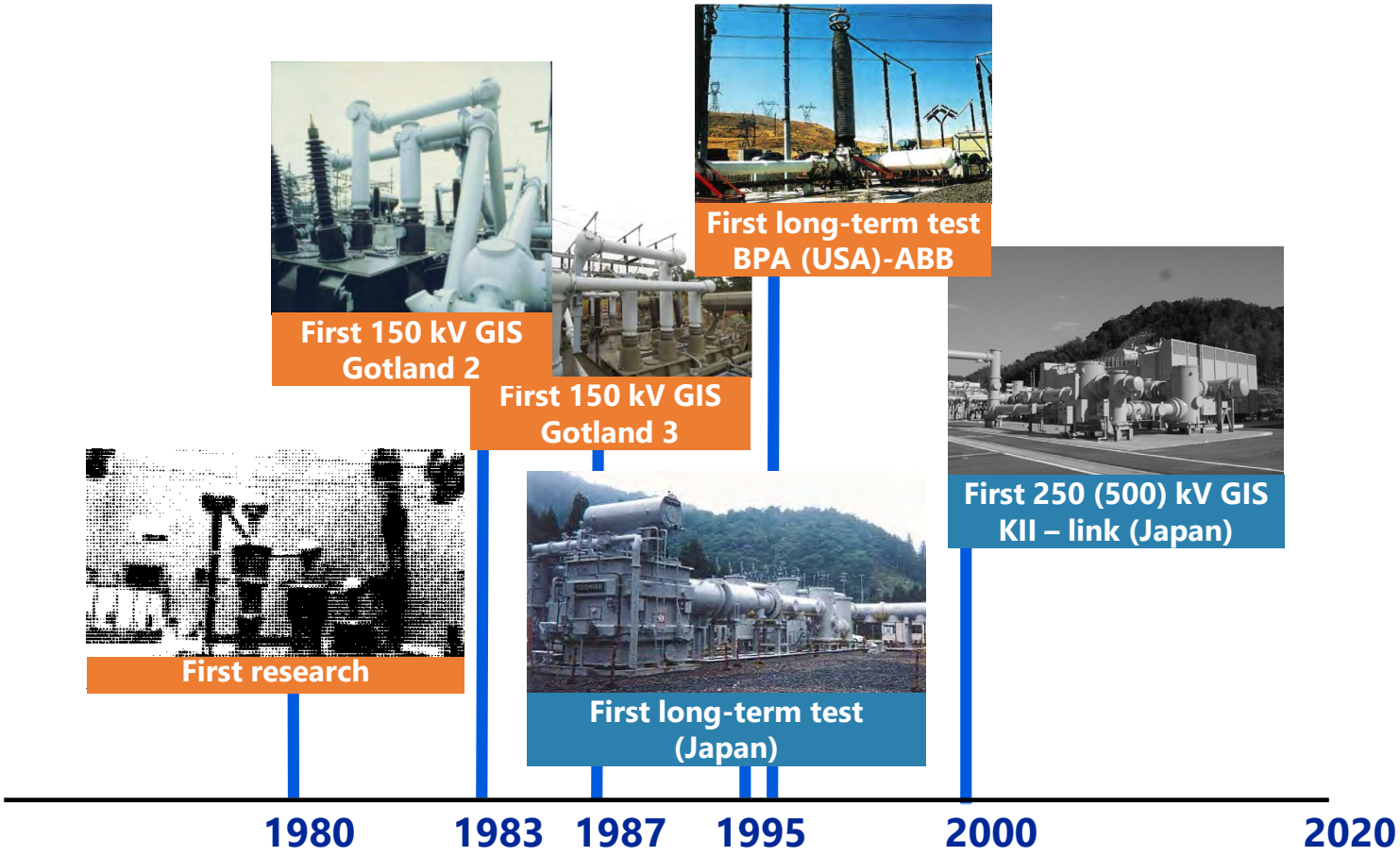
Ion pair: $2\ SF_6 + \mu \rightarrow SF_6^- + SF_5^+ + F$

Ion: $SF_6 + e^- \rightarrow SF_6^-$

The gas-solid interface is key

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

History



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Questions

- Users intending to employ gas-insulated HVDC systems expect the same reliability and long-term performance.
- That leads to the question of the necessity of long-term tests on gas-insulated HVDC systems in general and to the formulation of relevant test procedures if applicable.
  - The most convincing pro-argument for such testing is the lack of experience with this new technology.
  - A long-term test under real service conditions can help to overcome this deficiency. This test should be carried out for collecting more experience with this kind of DC technology and should simulate the real conditions and practical load cycles.
  - Based on project results, a prototype installation test procedure shall be proposed which can prove the long-term capability of this type of new technology and could be used as input for future standardization.
  - In addition, the availability of proven diagnostic methods and monitoring tools are required in order to ensure a safe and reliable operation and maintenance operation of HVDC gas-insulated systems.
  - Moreover, and the use of alternative insulating gases for HVDC systems will be investigated*

* The contribution of SGI is an amendment to the original proposal

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Impact and Relevance

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© ABB

Impact 1/3

- By studying the operational and functional stresses on DC GIS in meshed HVDC offshore grids and providing recommendations for specifying DC GIS systems, the applicability of DC GIS in meshed offshore HVDC grids will be illustrated.
- Guarantee minimum acceptable quality levels at lowest cost by developing effective and well-balanced test program based on existing CIGRE and IEC initiatives. Contributing to interoperability by aiming for industry wide adoption of common test method.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Impact 2/3

- By developing and demonstrating monitoring techniques and diagnostic methods, it will be shown that ageing and degradation mechanisms are well-understood
- and that the condition of DC GIS equipment can be continuously and effectively assessed and preventative action taken, reducing the risk of wide spread damage or outages in case of a defect or damage.
- The work package aims to unlock the cost reduction and reliability increasing potential of the next generation of compact DC GIS by demonstrating its technological maturity and reliability, bringing it a step closer to real-world adoption and reducing required platform footprint.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Impact 3/3

- Ecological aspects
  - Less footprint (smaller platforms)
  - Much higher degree of compactness and significantly lower sensitivity to ambient factors than with air-insulated installations.
  - By using HVDC-GIS, the volumetric space of the switchgear installation itself can be drastically reduced e.g. by 70%- 90% which may result in a size reduction of circa 10% of the total converter platform.
- The performance of an alternative gas to SF6 will be investigated to compare their behavior for different types of defects with SF6 and especially at an equivalent dielectric strength.*

* The contribution of SGI is an amendment to the original proposal

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Tasks and Deliverables

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© ABB

Task 1 - Scope

- ***Defining specifications & long term testing requirements***
- M18-M24
- Leader: SHE Trans

- Participants
  - SHE Trans
  - ABB
  - TenneT
  - TU Delft
  - DNV GL
  - SGI*

* The contribution of SGI is an amendment to the original proposal

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 1 - Details

- Review of DC GIS technology state-of-the-art.
- Analysis of function of DC GIS components in a MTDC network to determine number of operations, and stresses during normal operation and during emergency operation such as faults by modelling the DC GIS system.
- The specific stresses on the various key-components will be identified.
- The analysis will be supported by a review of the environmental impact of the intended offshore application, possible DC substation layouts and operational strategies.
- The identified operational requirements and stresses are translated to test requirements, procedures, methods and test circuits.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 2 - Scope

- ***Develop monitoring and diagnostic methodand applicability of SF6 alternatives***
- M18-M48
- Leader: TU Delft

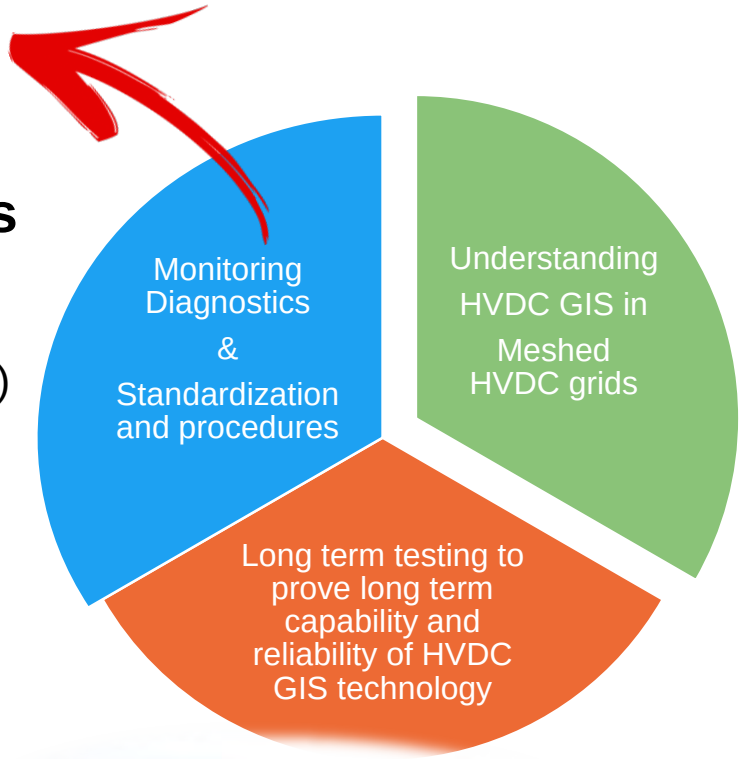
- Participants
  - TU Delft
  - ABB
  - DNV GL
  - SHE Trans
  - SGI*

* The contribution of SGI is an amendment to the original proposal

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 2 – Details Monitoring and Diagnostics

- **Monitoring of critical components**
  - Temperature monitoring (to enable dynamic loading, load management)
- **Monitoring of insulating parameters**
  - Partial discharges (gas/solid insulation degradation)
  - Gas pressure (leakages and partial pressures)
  - Gas quality (gas insulation degradation)
- **Diagnostics of components**
  - Interpretation of results
  - Localization of faulty component
  - Comparison with laboratory tests
  - Risk assessment
  - Maintenance decision



Increase technology readiness level (TRL) of DC GIS technology from 6 to 8

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

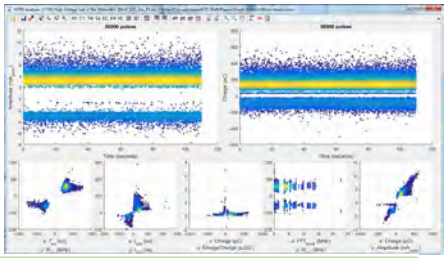
Task 2 – Details Monitoring and Diagnostics

Design sensors and acquisition systems

Monitor

Less hardware requirements

Affordable system



Analyse

Select valid data

Innovative algorithms for data processing by TU DELFT

Interpret

Diagnosis criteria

Standardization

Compare with lab results
Evaluate risks

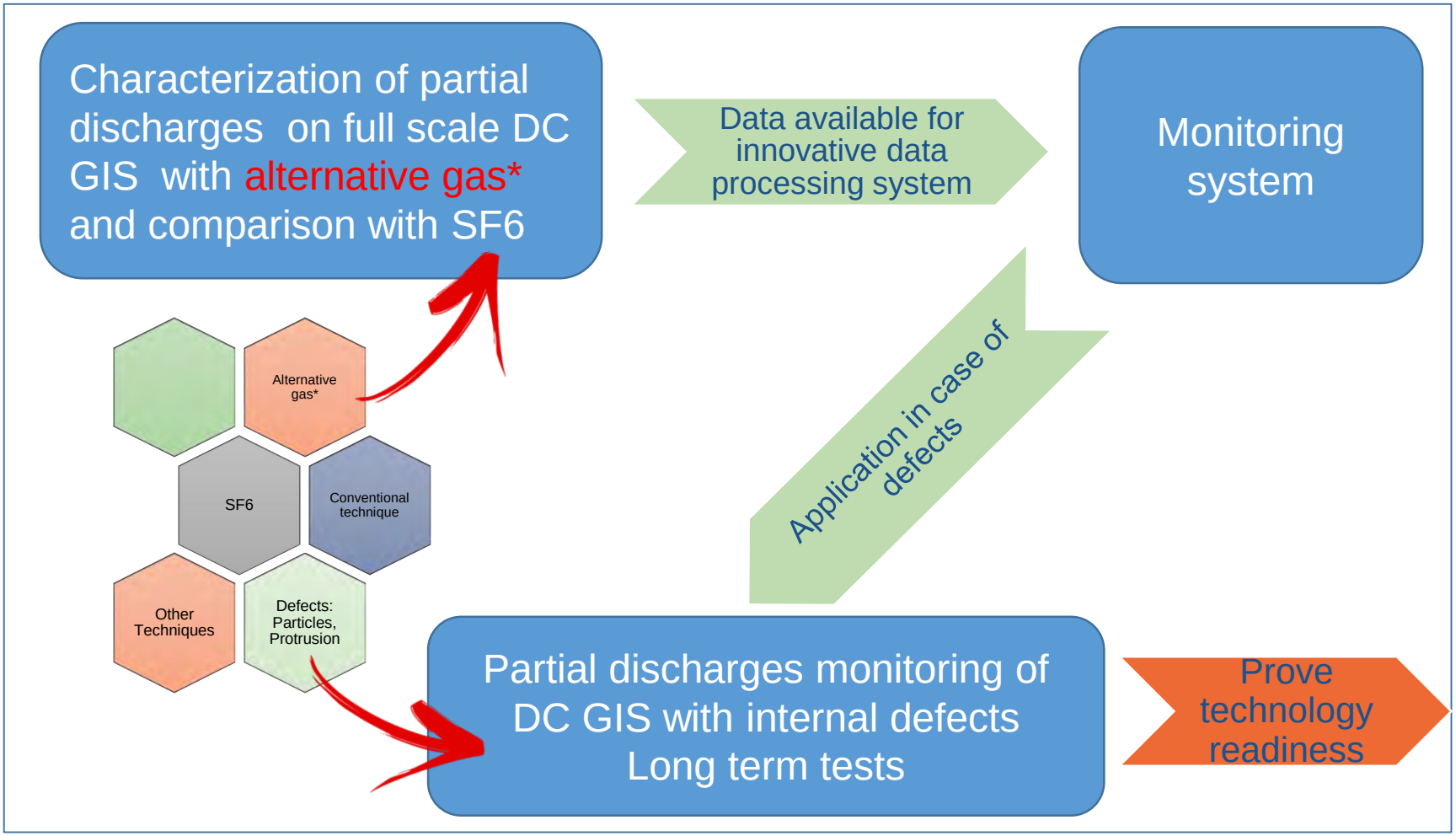
Act

Prevent failures and outages
Schedule maintenance
Improve reliability
Improve performance

Prove technology readiness

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 2 – Details Monitoring and Diagnostics



* The contribution of SGI is an amendment to the original proposal

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 3 - Scope

- ***Long term testing of the DC GIS equipment***
- M24-M48
- Leader: DNV GL

- Participants
  - DNV GL
  - ABB
  - TU Delft

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

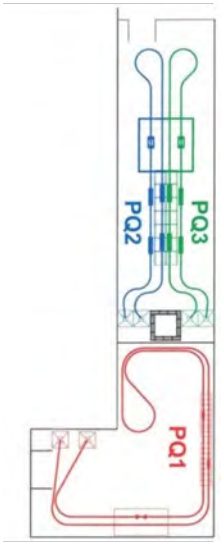
Task 3 - DNV GL – KEMA Laboratories

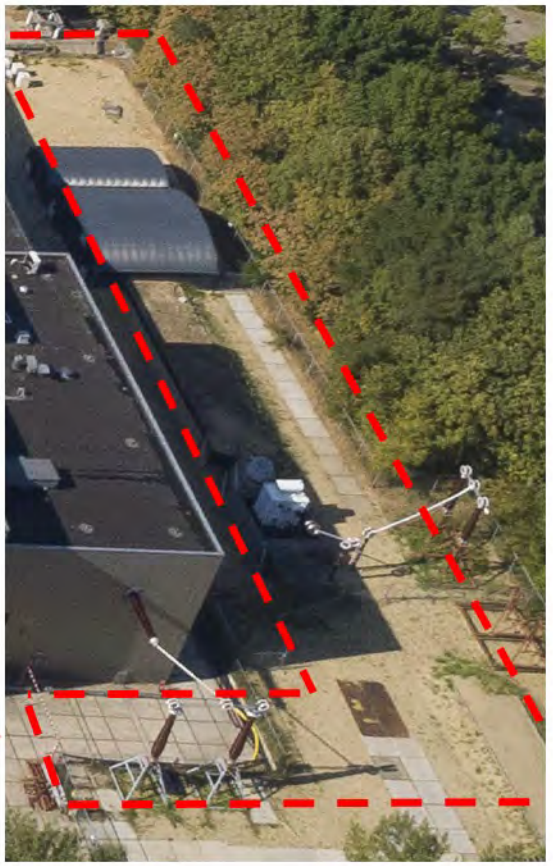
AC GIS testing in KEMA laboratory

- Transfer of online monitoring from research environment to test-laboratory practice
- DC GIS dielectric tests not yet demonstrated in an independent test laboratory
- Experience with testing AC GIS and DC cable system at 320 kV
- Experience with HVAC cable systems long term tests (PQ: prequalification)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 3 - KEMA HV laboratories test facility

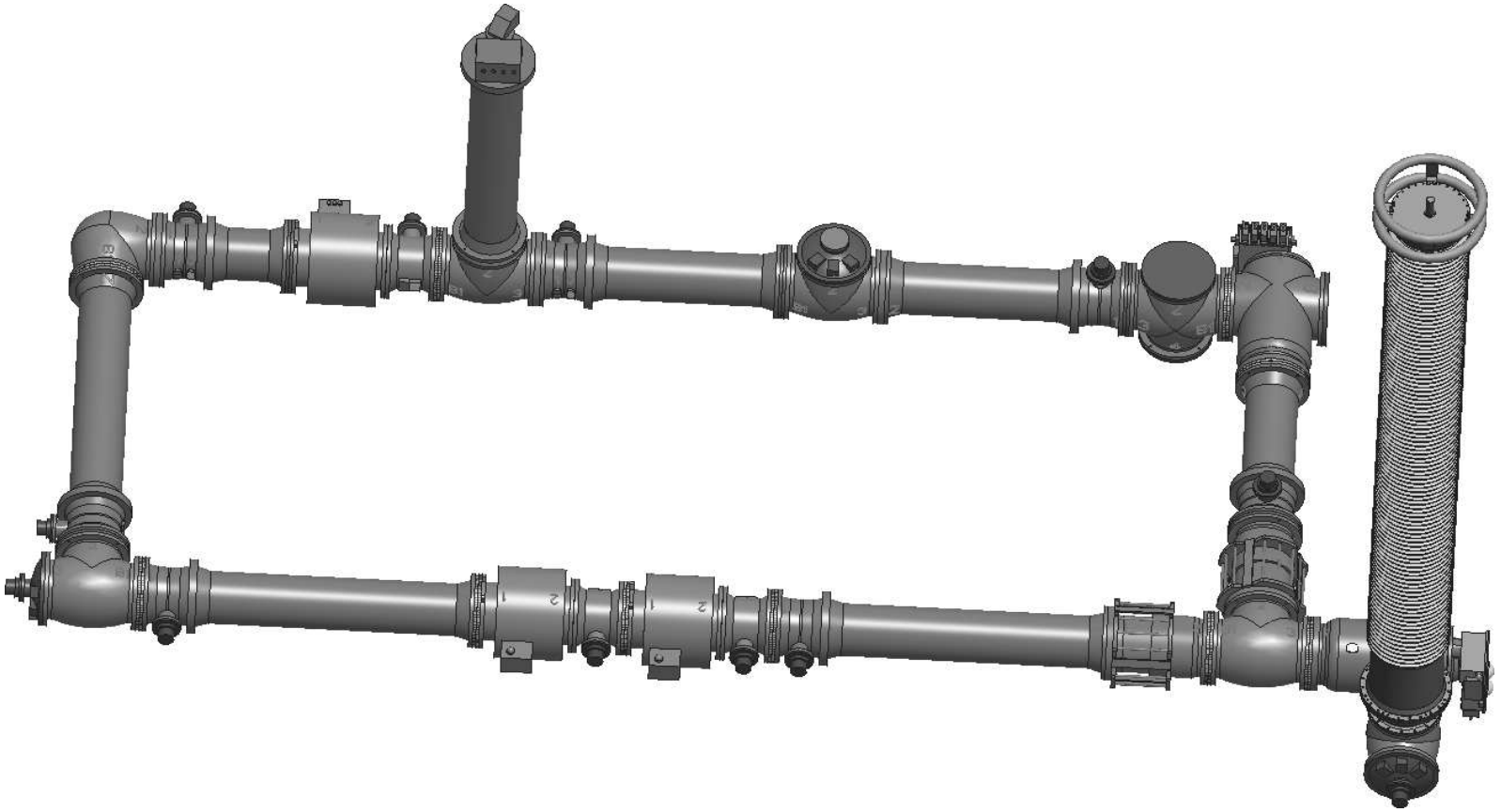




DC cable system type test and AC cable system PQ test in KEMA laboratory

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 3 – Option for test set-up



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 3 – Proposal Ratings

Rating	320 kV	Unit
Nominal DC voltage	± 320	kV_{DC}
Rated DC voltage	± 350	kV_{DC}
Rated LI withstand voltage	±1050	kV
Rated superimposed LI withstand voltage	± 1050 ± 350	kV/kV_{DC}
Rated SI withstand voltage	± 950	kV
Rated superimposed SI withstand voltage	± 950 ± 350	kV/kV_{DC}
Rated DC withstand voltage phase-to-earth	± 610	kV_{DC}

JWG D1/B3.57: Dielectric Testing of gas-insulated HVDC Systems

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 3 - Long term testing of the DC GIS prototypes by DNV GL

- Tests to be done in a dedicated DC testing laboratory
- Includes simulating of thermal stress due to daily DC load cycles as in service
- Monitoring of thermal and electrical stresses to be controlled by an automated system
- Controlling and analysing gas density and pressure to ensure a safe operation
- Remote monitoring test set-up during a long term cycle testing
- After 1 year or 1.5 year long term testing, superimposed switching impulse voltage tests to demonstrate the integrity of the DC GIS equipment as installed
- Full scope measured and recorded data to be evaluated long term effects for a DC GIS system

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 4 - Scope

- ***Initiation of standardization activities for HVDC GIS design, testing and application***
- M43-M48
- Leader: ABB

- Participants
  - ABB
  - TU Delft
  - SHE Trans
  - DNV GL
  - SGI*

* The contribution of SGI is an amendment to the original proposal

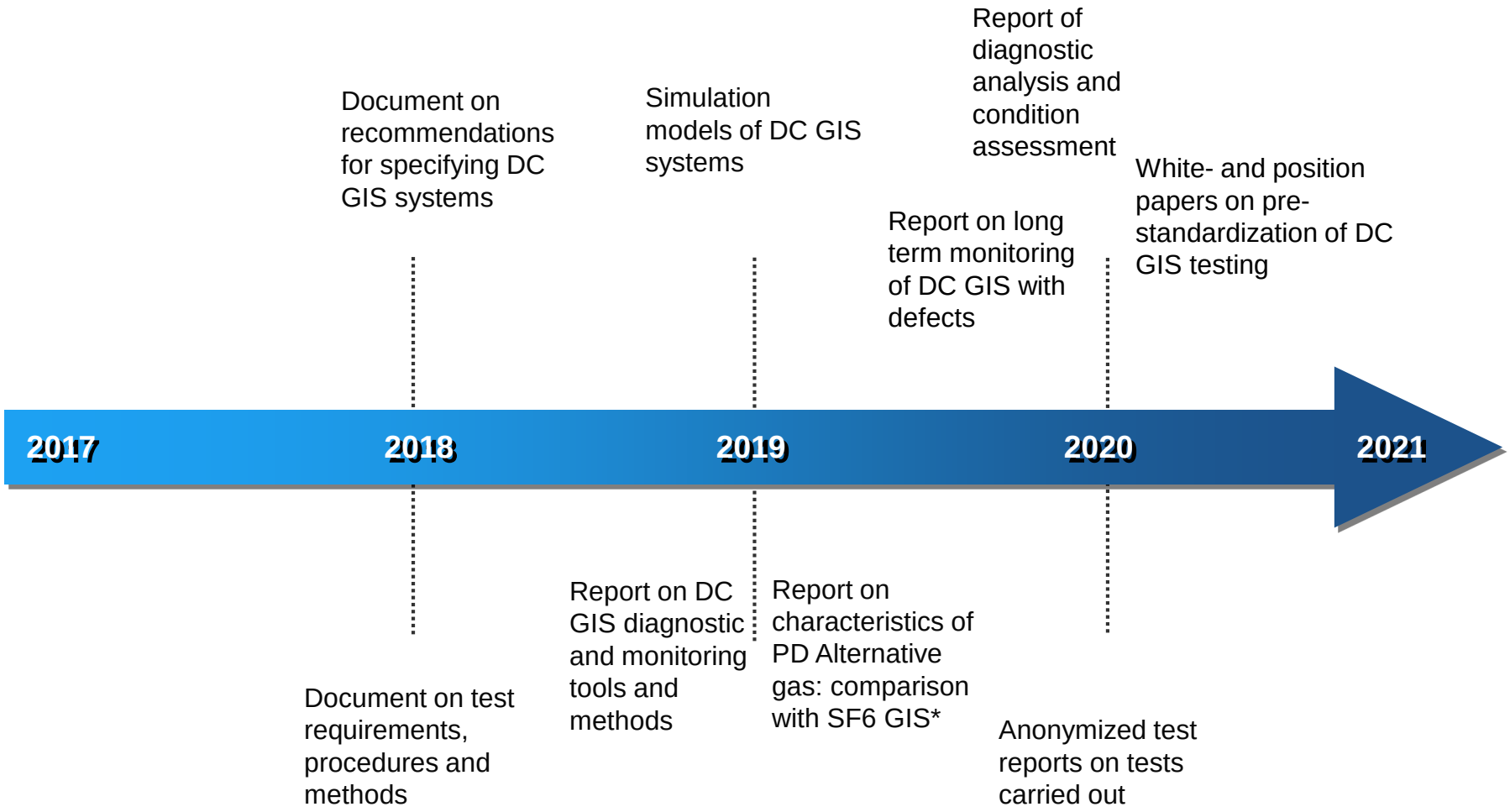
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 4 - Details

- Initiation of standardization activities for HVDC GIS design, testing and application
- Results of test-requirement studies, based on task 1 and verified in task 3 will be documented in a brochure to be delivered to CIGRE and/or IEC as input for future standards.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

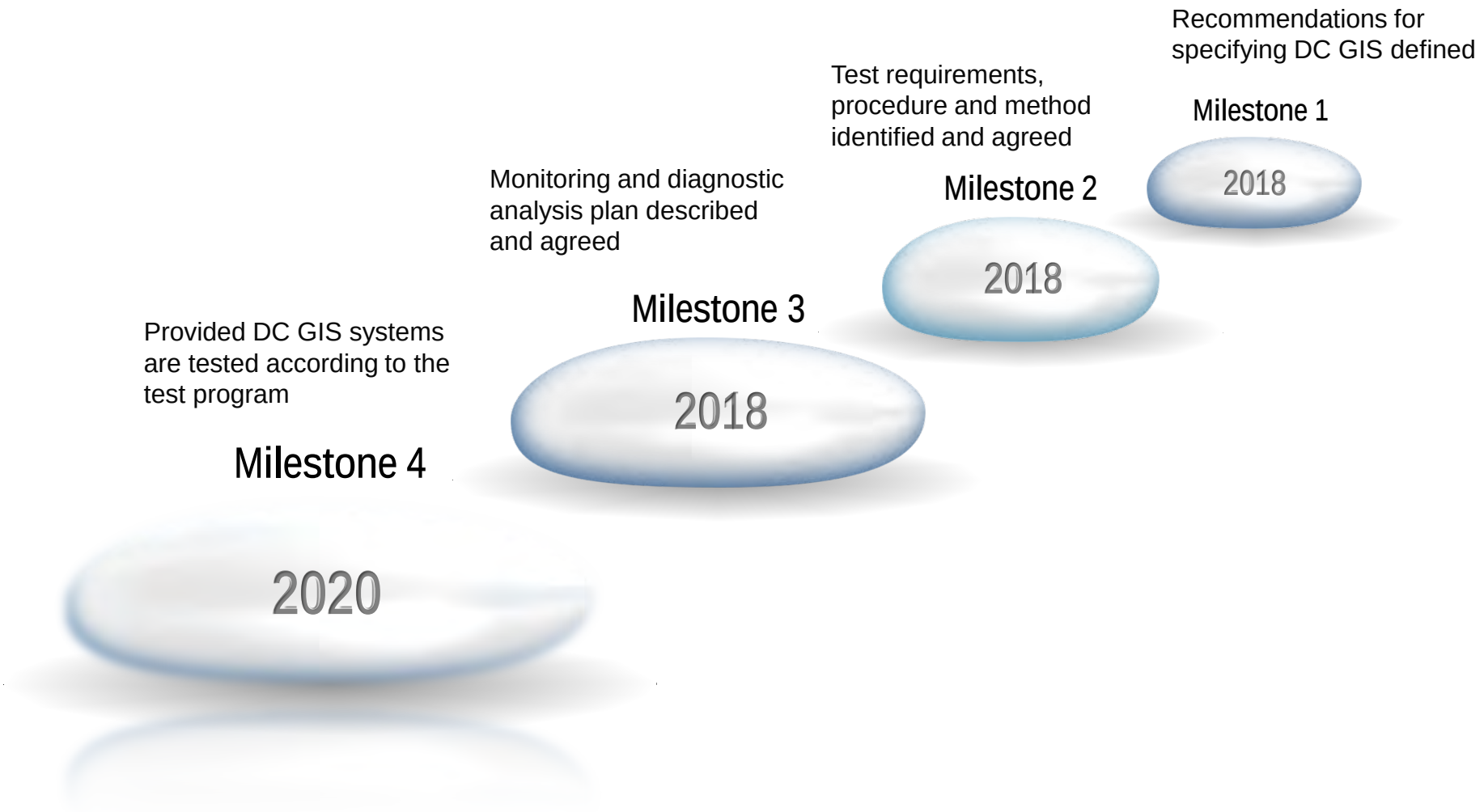
Deliverables



* The contribution of SGI is an amendment to the original proposal

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Milestones



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Partners and Roles

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© ABB

Partners

- SHE Trans
  - Lead task 1
  - Participant task 2, 4
- DNV GL
  - Lead task 3
  - Participant task 1, 2, 4
- ABB
  - Lead WP, task 4
  - Participant task 1, 2, 3
- TU Delft
  - Lead task 2
  - Participant task 1, 3, 4
- TenneT
  - Participant task 1, 4
- SGI*
  - Participant task 1, 2, 4

* The contribution of SGI is an amendment to the original proposal

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Budget

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© ABB

Budget without SGI

	Person-months	Travel	Equipment	Other goods & services	Direct personnel costs	Total + 25% overhead
DNV GL	22.5	20 000 €		190 458 €	220 283 €	595 445 €
ABB	27	38 000 €		1 367 000 €	328 253 €	2 166 566 €
TU Delft	63	30 000 €	125 000 €		360 000 €	643 750 €
TenneT	1	20 000 €			11 676 €	39 595 €
SHE Transmission	7	25 000 €	25 000 €		60 480 €	156 850 €
Total	**120.5**	**133 000 €**	**150 000 €**	**1 557 458 €**	**980 693 €**	**3 583 456 €**

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Summary

The aim of this work package is to

- Define recommendations for specifying DC GIS systems based on technical and operational requirements
- Define long term testing requirements based on the experiences of the manufacturer, utilities, academia and independent testing labs to ensure that the DC GIS equipment is tested for real operation conditions
- Develop understanding of partial discharge behavior of different types of defects in different types of insulating gases*
- Develop monitoring and diagnostic methods to ensure a safe operation, to enable condition assessments, and develop criteria for acceptance
- Carry out long term testing of the DC GIS equipment and the monitoring equipment to prove the concept and increase the Technology Readiness Level (TRL) from 6 to 8 for DC GIS equipment
- Use long-term testing, monitoring, and diagnosis to verify and improve models and develop understanding of degradation mechanisms and failure modes

* The contribution of SGI is an amendment to the original proposal

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Contribution of SGI to original proposal

- TU Delft will develop a monitoring system for DC GIS. However, TU Delft lacks the facilities for handling of alternative gases and therefore will only study defects in SF6.

- SGI will complement TU Delft's work by:
  - Characterising defects in DC GIS with SF6 alternative gas
  - Verifying the defect models through long term testing in DC GIS test pole using alternative gas
  - Verifying the diagnostic and monitoring system developed by TU Delft on gases other than SF6

- Analysis of alternative gases has strong support of TSOs

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Budget without SGI

	Person-months	Travel	Equipment	Other goods & services	Direct personnel costs	Total + 25% overhead
DNV GL	22.5	20 000 €		190 458 €	220 283 €	595 445 €
ABB	27	38 000 €		1 367 000 €	328 253 €	2 166 566 €
SGI*	38.2	15 000 €	160 000 €	255 000 €	240 000 €	837 500 €
TU Delft	63	30 000 €	125 000 €		360 000 €	643 750 €
TenneT	1	20 000 €			11 676 €	39 595 €
SHE Transmission	7	25 000 €	25 000 €		60 480 €	156 850 €
Total w/o SGI	**120.5**	**133 000 €**	**150 000 €**	**1 557 458 €**	**980 693 €**	**3 583 456 €**
Total with SGI	**158.7**	**148 000 €**	**310 000 €**	**1 812 458 €**	**1 220 693 €**	**4 420 955 €**

SGI participation results in increase of EUR 837 499 of required budget

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

New Partner

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

New partner

SCibreak

- 03-2016 Coordinator contacted by SCibreak
- 08-06-2016 DC circuit breaker manufacturers consulted
- 15-06-2016 Introduction during Stockholm meeting
- 01-12-2016 Approval in PMG
- 10-01-2017 Official notification sent to General Assembly
- 24-01-2017 General Assembly vote in favour of accession
- 07-02-2017 Consortium Agreement signed
- 20-03-2017 Presentation to EC

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Presentation SCiBreak AB

Lennart Ängquist

PROMOTioN Review meeting
Brussels 2017-03-20

What SCiBreak does

- ✓ SCiBreak AB is a small Swedish company founded in 2014 by former and current KTH staff
- ✓ The intention is to commercialize new ideas concerning the design of fast breakers for interrupting DC (or AC) current
- ✓ Our concept is suitable for the requirements encountered in HVDC grids i.e. having an interrupting time less than 5 ms
- ✓ SCiBreak thus develops and verifies technology for fast electric breakers

Key persons

Lennart Ängquist, born 1946, MSc 1968, PhD 2002: Worked at ASEA/ABB 1968-2008 at Central Research Dept, Power Electronic Dept and Power Systems with power electronics for industrial and traction drives and reactive power compensation, specifically TCSC. Adjunct professor at KTH 2002-2010.

Staffan Norrga, born 1968, MSc 1993, PhD 2005: Worked at ABB/Adtranz 1994-2011 in various capacities related to power electronics. Associate professor at KTH from 2011. Inventor or co-inventor of 12 granted patents and 13 patents pending, and has authored or co-authored more than 65 scientific papers.

Tomas Modéer was born in Stockholm, Sweden, in 1979. He received the MSc and PhD degrees KTH Royal Institute of Technology in 2004 and 2015 respectively. Worked at Optistring Technologies 2011-2015 managing the technology development.

SCiBreak

Our links and collaborations

- ✓ We have a background in the power electronics group at KTH and some of us have been employed by ABB in the past (more than five years ago)
- ✓ No formal links to manufacturers, like ABB, Siemens or Mitsubishi
- ✓ We are supported by Innoenergy (an incubator-like entity which is part of the EIT)
- ✓ SCiBreak collaborates with SvK and KU Leuven in a development project HIBREAK which runs 2017-2018
- ✓ The company is owned by the founders and Innoenergy has an option for buying 10% of the shares

Key idea in our breaker concept

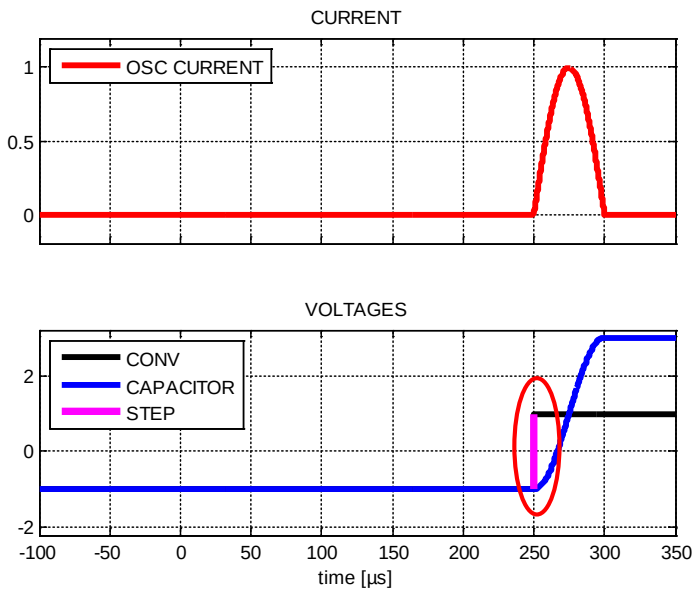
- ✓ proposed (and existing) concepts for DC breakers use a combination of mechanical switches and semiconductors
- ✓ however, the use of semiconductors in proposed DC breakers is inefficent, typically it only performs one switching in each breaking operation
- ✓ power electronics easily can operate at high frequency (10 kHz) and can perform many interventions while its mechanical counterpart separates the mechanical contacts
- ✓ we replace one switching at high voltage (requiring many series-connected semiconductors) by several consecutive switchings at lower voltage, reducing the amount of semiconductors by almost one order of magnitude, thereby improving the utilization of the provided devices

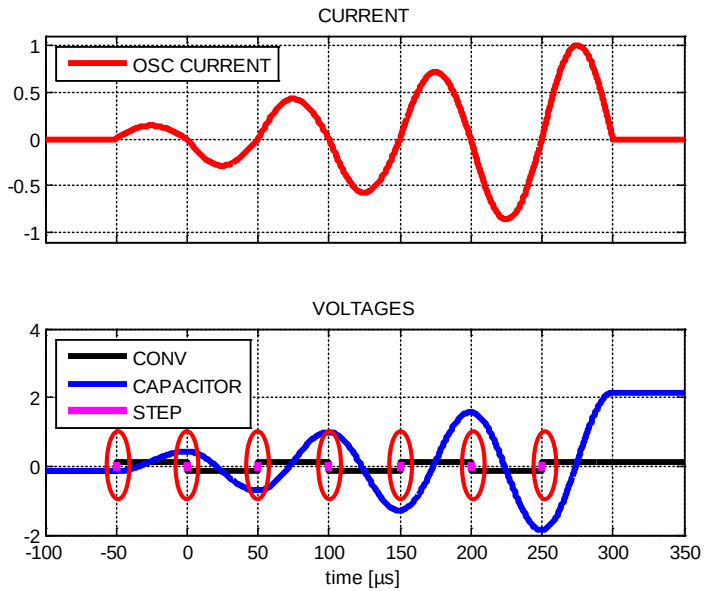
SCiBreak

Excitation of current pulse

many devices switch simultaneously to achieve a large voltage step producing a desired current pulse

few devices consecutively switch a fraction of the high voltage to achieve the same current pulse





SCiBreak

PROMOTio
N

Basic principle for SCiBreak's circuit-breaker

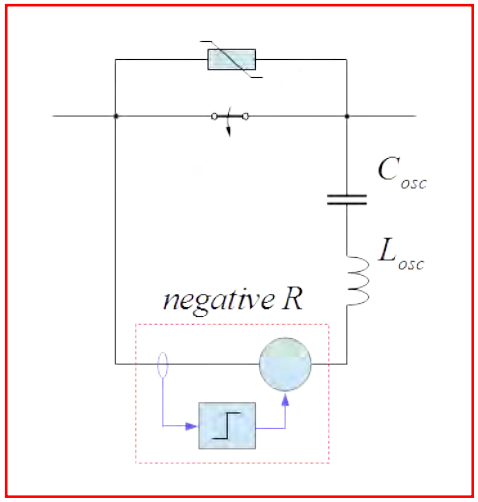
- strong artificial negative resistance can be created by power electronic means using feedback control

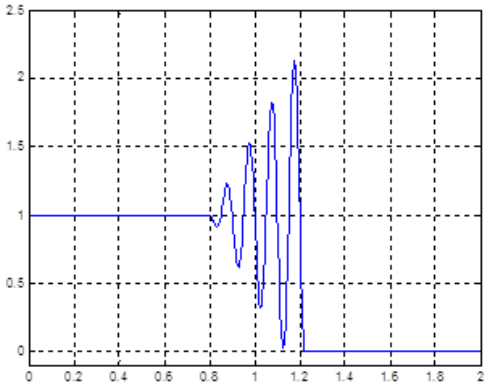
all at once

capacitor precharged to high voltage is discharged through the interrupter

little by little

capacitor voltage evolves by resonance using low-voltage source

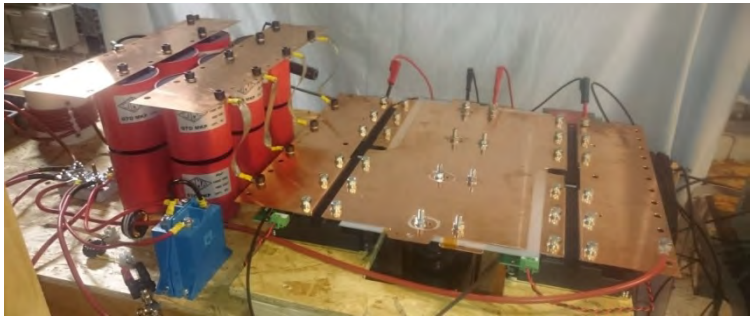




SCiBreak

Experimental work

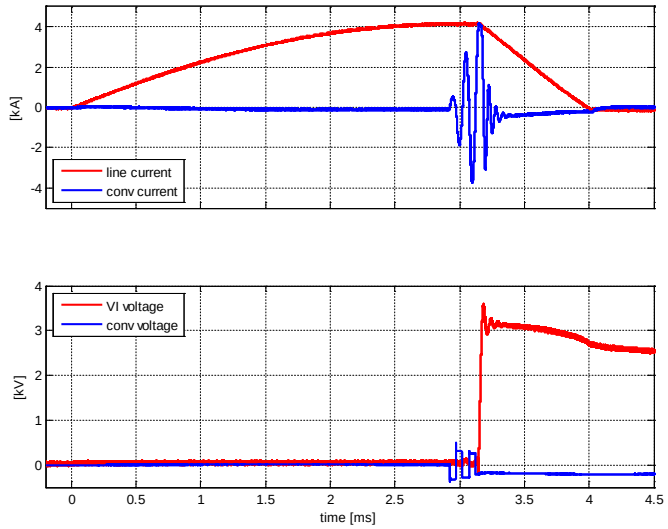
power electronic converter

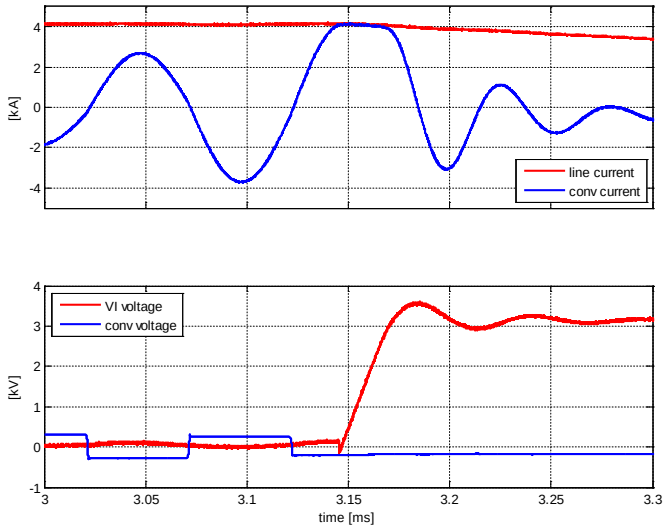


control card using FPGA control

vacuum breaker rated 24 kV, 630 A
conventional mechanical actuator 1.1-1.7 m/s

Experimental results





max experimental results (Dec. 2016):

5 kA peak @ 10 kV peak

SCiBreak

How will SCiBreak contribute to PROMOTioN?

SciBreak's participation directly addresses the core objectives 1 through 3 of the project:

Core objective 1.

"To establish interoperability between different technologies and concepts by providing specific technical and operational requirements, behaviour patterns and standardization methods for different technologies"

SCiBreak's contribution to fulfillment

SCiBreak intends to take part in the work towards standardization in the field of HVDC breakers, together with the other partners. By introducing its breaker technology to the project it will add a furhter perspective to this work. SCiBreak will also provide simulation models of its breaker, at different levels of abstraction, to the project.

How will SCiBreak contribute to PROMOTioN?

SciBreak's participation directly addresses the core objectives 1 through 3 of the project:

Core objective 2.
"To develop interoperable, reliable and cost-effective technology of protection for meshed HVDC offshore grids and the new type of offshore converter for wind power integration"

SCiBreak's contribution to fulfillment
SCiBreak is developing an HVDC breaker making use of advanced converter technology with increased utilization of the provided semiconductors, cutting the needed number of semiconductors by almost one order of magnitude, thereby reducing cost. The concept is suitable for HVDC grids and combines excellent performance with low cost.

By not having any links to the existing manufacturers in the industry SCiBreak will also be committed to interoperability among equipment for HVDC grids.

SCiBreak

How will SCiBreak contribute to PROMOTioN?

SciBreak's participation directly addresses the core objectives 1 through 3 of the project:

Core objective 3.

"To demonstrate different cost-effective key technologies for meshed HVDC offshore grids and to increase their technology readiness level by investigating and overcoming early adopter issues and pitfalls"

SCiBreak's contribution to fulfillment

SCiBreak will provide a breaker module for testing and demonstration at DNV GL'S facilities.

SCiBreak's budget for PROMOTioN activities

WP	No of PM	Our activities	Pers. cost	Travel cost
WP 5	2	Modelling of DCCBs – Attend meetings, PSCAD modelling of DCCB, review deliverable	10 k€ +indir	1 k€ +indir
WP 6	3	Modelling of DCCBs – Attend meetings, PSCAD modelling of DCCB, review deliverable	15 k€ +indir	1,5 k€ +indir
WP 9	2	Support for RTDS modelling of meshed HVDC networks	10 k€ +indir	1 k€ +indir
WP 10	12	Setup and testing of HVDC breaker module, evaluation of results, create input to modelling in WP6. Contribute to standardization.	60 k€ +indir	6,5 k€ +indir
Total	19		95 k€	10 k€
Total + 25%			131,25 k€	

Summary of proposals

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Summary of proposals

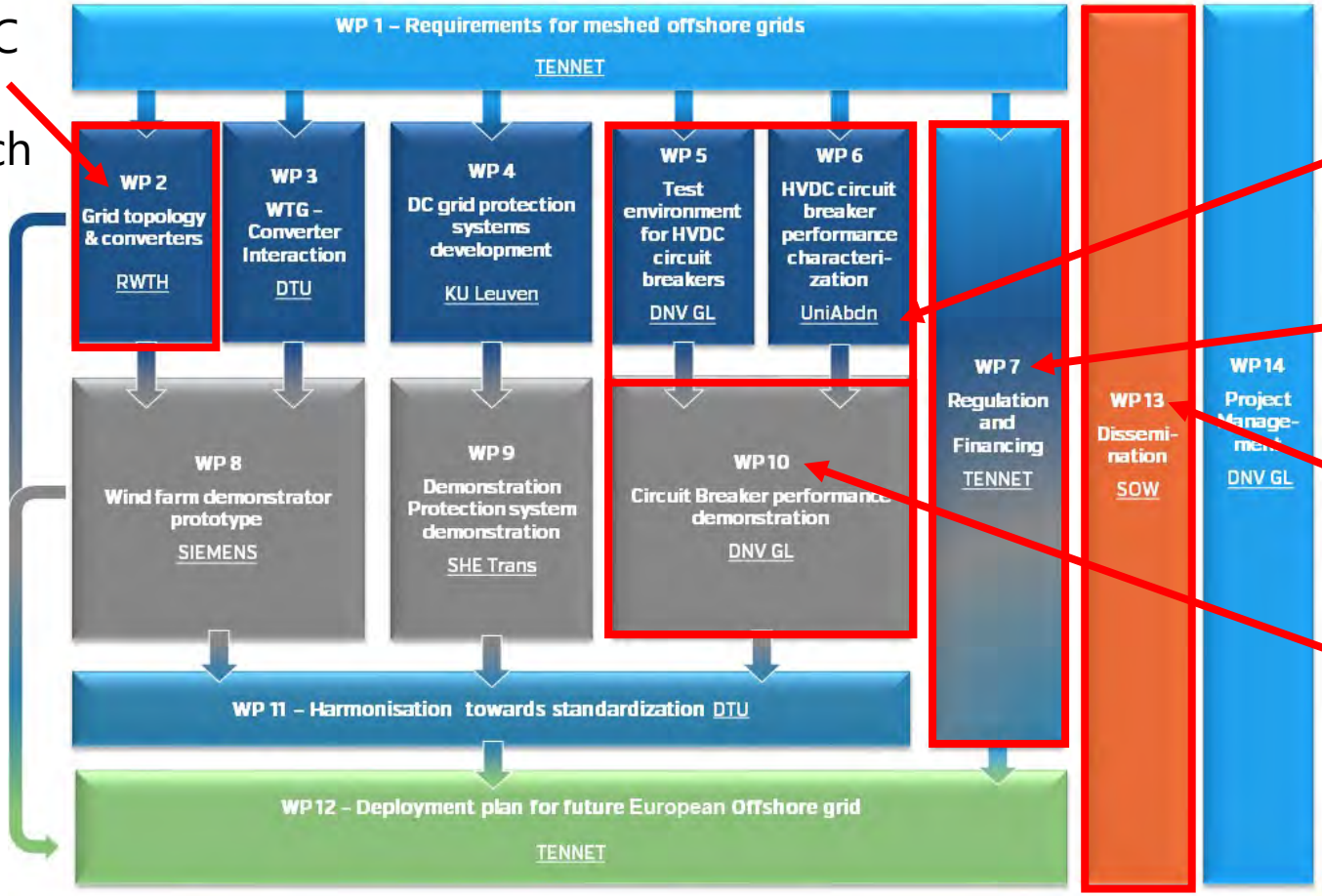
	DC GIS technology demonstrator	MMC Test bench	Extension of WP13	DC Circuit breaker logistics	Cost Beneift Analysis method	Budget for new partner
Identify **technical requirements** and investigate possible **topologies** for **meshed HVDC offshore grids**	X	X				
Develop **protection schemes** and **components** for HVDC grids	(X)			X		X
Establish components' **interoperability and initiate standardisation**	X	X				X
Demonstrate cost-effective offshore HVDC equipment	X			X		X
Develop recommendations for a coherent EU and national **regulatory framework** for HVDC offshore grids					X	
Develop **recommendations for financing mechanisms** for offshore grid infrastructure deployment					X	
Develop a **deployment plan** for HVDC grid implementation						
Disseminate results to relevant stakeholder communities	X		X			

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project Structure

WP15
DC GIS demonstrator
ABB

MMC test bench



Budget for SCibreak

Cost benefit analysis method

Extension of WP13

DC circuit breaker logistics

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Summary of proposals

Proposal	Person-months	Total estimated eligible costs	Max EU contribution
DC GIS demonstrator	168.7	€ 4 420 955.86	€ 3 287 794.10
MMC test bench	127	€ 3 973 250.00	€ 2 850 875.00
Extension of WP13	27	€ 486 161.25	€ 425 191.50
DC circuit breaker logistics	0	€ 300 000.00	€ 210 000.00
Cost Benefit Analysis Method	0	€ 250 000.00	€ 175 000.00
Budget for new partner	19	€ 131 250.00	€ 91 875.00
All proposals	**341.7**	**€ 9 561 617.11**	**€ 7 040 735.60**

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

- Background
- Proposal Wrap-Up
- Introduction for the discussion

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Background

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© ABB

Background

- PROMOTioN has several demonstration aspects across different work package
  - Circuit breaker (WP 5 & 6)
  - Wind farm demonstrator/ diode rectifier unit (WP 8)
  - Protection systems (WP 9)

- WP8 Demonstrator arrived at a “No Go” decision mid to late last year
  - Unfortunate BUT foreseen in the proposal
  - Can the resources be steered towards other activities which also foster a swift diffusion of meshed HVDC offshore grids into practical application by tackling existing barriers?

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.

Background

- PROMOTioN has several demonstration aspects across different work package
  - Circuit breaker (WP 5 & 6)
  - Wind farm demonstrator/ diode rectifier unit (WP 8)
  - Protection systems (WP 9)

- WP8 Demonstrator arrived at a “No Go” decision mid to late last year
  - Unfortunate BUT foreseen in the proposal
  - Can the resources be steered towards other activities which also foster a swift diffusion of meshed HVDC offshore grids into practical application by tackling existing barriers?

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.

Proposal Wrap-up

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© ABB

Proposal generation process

- Process to find alternative opportunities started end of December last year (2016)
  - 3 Months to design, coordinate, write and revise the proposals
  - Budget range several million euros
- Well fleshed out, high quality proposals
  - Well adjusted to the call/ project objectives
  - Well incorporated into the existing project
  - Well aligned to the needs of industrial stakeholders
- Achievement within itself

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Two categories of improvement

- Smaller, focussed adaptions and extensions
  - Increase the effectiveness of PROMOTioN as it is
  - Improve upon existing project branches
  - „Quality of life“ improvements

- Major extensions
  - Expand upon PROMOTioN’s core ideas
  - Add new aspects to the project in line with its key objectives
  - “MMC Test Bench” & “DC GIS Technology Demonstrator”

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.

Major extensions

- Significant new impulses for the project on different technical levels and numerous individual benefits
- Strong connection to the overall project and call objectives
- Closely aligned to the existing ideas and concepts as well as the project structure in place
  - MMC test bench: WP 2, 3, 4, 8 and 12
  - DC GIS demonstrator: WP 5, 6 and 12

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Major extensions - Summary of core benefits

- DC GIS demonstrator
  - Practical demonstration of GIS equipment in the context of HVDC grids
  - Make it ready for deployment developing associated standards
  - Provide confidence regarding technological questions

- MMC Test Bench
  - Creating a demonstrator for HVDC grid behaviour
  - Creating a suitable “tool” for operational analysis and de-risking of operational/ structural decisions of future grids

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.

Introduction for the discussion

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© ABB

PROMOTioN Project

- Accelerating the deployment of meshed HVDC off-shore grids, with particular emphasis on Northern Seas partner countries, before 2020.
- Ensuring that the technology will be ready for deployment in other regions in Europe for all transnational corridors defined in the trans-European energy infrastructure regulation, or be compatible (plug-and-play) with other upcoming technologies (e.g. ocean energy, solar energy, geothermal energy, etc. as soon as these technologies are ready for similar capacities).
- Ensuring plug-and-play compatibility of all relevant equipment of the key suppliers.
- Preparing for corresponding priority infrastructure projects identified under the trans-European energy infrastructure regulation.
- Facilitating the efficient connection of off-shore wind resources to on-shore loads and with other available generation resources for balancing, covering the main Northern Seas partner countries.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

PROMOTioN Project

- **Accelerating the deployment** of meshed HVDC off-shore grids, with particular emphasis on Northern Seas partner countries, before 2020.
- **Ensuring that the technology will be ready** for deployment in other regions in Europe for all transnational corridors defined in the trans-European energy infrastructure regulation, or be **compatible (plug-and-play) with other upcoming technologies** (e.g. ocean energy, solar energy, geothermal energy, etc. as soon as these technologies are ready for similar capacities).
- **Ensuring plug-and-play compatibility of all relevant equipment of the key suppliers**.
- Preparing for corresponding priority infrastructure projects identified under the trans-European energy infrastructure regulation.
- Facilitating the **efficient connection of off-shore wind resources to on-shore loads** and with other available generation resources for balancing, covering the main Northern Seas partner countries.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Practical concerns and barriers

- Preparation
  - What meshed HVDC offshore grid layouts should be targeted?
  - What are viable technological options?
  - How can meshed HVDC grids be suitably connected to the existing grid?
- Implementation
  - Can systems be actually build today?
  - What are civil engineering pitfalls building these systems?
- Operation
  - How can these systems be safely and efficiently operated and maintained?
  - How are grids impacted by new/ changing assets?
  - How are grids impacted by new/ changing topologies?

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

What is gained by the new proposals – MMC

- Preparation
  - What meshed HVDC offshore grid layouts should be targeted?
  - What are viable technological options?
  - How can meshed HVDC grids be suitably connected to the existing grid?
- Implementation
  - Can systems be actually build today?
  - What are civil engineering pitfalls building these systems?
- Operation
  - How can these systems be safely and efficiently operated and maintained?
  - How are grids impacted by new/ changing assets?
  - How are grids impacted by new/ changing topologies?

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

What is gained by the new proposals – GIS

- Preparation
  - What meshed HVDC offshore grid layouts should be targeted?
  - What are viable technological options?
  - How can meshed HVDC grids be suitably connected to the existing grid?
- Implementation
  - Can systems be actually build today?
  - What are civil engineering pitfalls building these systems?
- Operation
  - How can these systems be safely and efficiently operated and maintained?
  - How are grids impacted by new/ changing assets?
  - How are grids impacted by new/ changing topologies?

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Summary

- Different parts of the suggested amendment
  - Smaller adaptions provide significant benefits to existing lines of work
  - Major extension expand the project to address additional aspects

- Major extensions promise substantial additional value in the context of PROMOTioN and the underlying call
  - Additional demonstration of relevant technological options/ solutions
  - Tools for the secure operation and development of future grids
  - Tools for de-risking technological choices

- Strongly interlinked with the exiting tasks, expanding within the project's scope
- The proposed additions are ambitious, but realistic
- Significant steps to make meshed HVDC a viable infrastructure decision

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Thank you for your attention

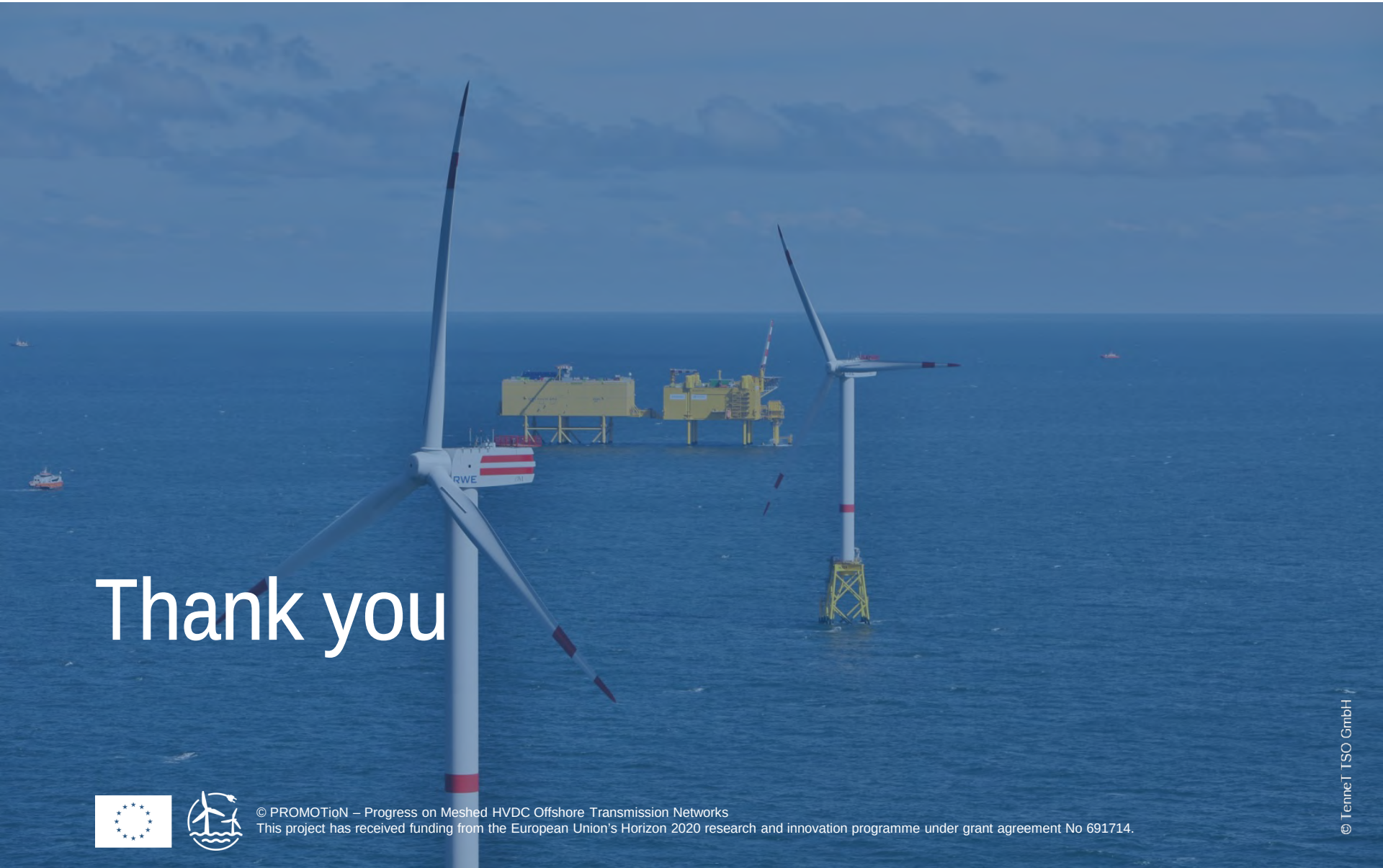
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© ABB

Discussion & Questions

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

PROMOTioN
PROGRESS ON MESHED HVDC
OFFSHORE TRANSMISSION
NETWORKS



Thank you

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© TenneT TSO GmbH

APPENDIX

DISCLAIMER & PARTNERS

COPYRIGHT

PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
MAIL info@promotion-offshore.net WEB www.promotion-offshore.net

The opinions in this presentation are those of the author and do not commit in any way the European Commission

PROJECT COORDINATOR

DNV GL, Kema Nederland BV
Utrechtseweg 310, 6812 AR Arnhem, The Netherlands
Tel +31 26 3 56 9111
Web www.dnvgl.com/energy

CONTACT

PARTNERS

DNV GL (Kema Nederland BV), ABB AB, KU Leuven, KTH Royal Institute of Technology, EirGrid plc, SuperGrid Institute, Deutsche WindGuard GmbH, Mitsubishi Electric Europe B.V., Affärsverket Svenska kraftnät, Alstom Grid UK Ltd (Trading as GE Grid Solutions), University of Aberdeen, Réseau de Transport d'Électricité, Technische Universiteit Delft, Statoil ASA, TenneT TSO B.V., Stiftung OFFSHORE-WINDENERGIE, Siemens AG, Danmarks Tekniske Universitet, Rheinisch-Westfälische Technische Hochschule Aachen, Universitat Politècnica de València, Forschungsgemeinschaft für. Elektrische Anlagen und Stromwirtschaft e.V., Dong Energy Wind Power A/S, The Carbon Trust, Tractebel Engineering S.A., European University Institute, Iberdrola Renovables Energía, S.A., European Association of the Electricity Transmission & Distribution Equipment and Services Industry, University of Strathclyde, ADWEN Offshore, S.L., Prysmian, Rijksuniversiteit Groningen, MHI Vestas Offshore Wind AS, Energinet.dk, Scottish Hydro Electric Transmission plc

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Periodic review meeting

21st of March 2017 / Brussels

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

CONTENT

- Introduction
- Technical review
- Management aspects
- Next period
- Conclusions

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Introduction

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Objectives

- Identify **technical requirements** and investigate possible **topologies** for **meshed HVDC offshore grids**
- Develop **protection schemes** and **components** for HVDC grids
- Establish components' **interoperability and initiate standardisation**
- **Demonstrate cost-effective** offshore HVDC equipment
- Develop recommendations for a coherent EU and national **regulatory framework** for HVDC offshore grids
- Develop **recommendations for financing mechanisms** for offshore grid infrastructure deployment
- Develop a **deployment plan** for HVDC grid implementation

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Offshore wind developments

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP13 – Policy and Market Development Context Offshore Wind in 2016

- Policy Context
- Market Development in Europe
- Outlook 2017 and beyond

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP13 – Policy Context and Market

June 2016 — MoU signed for **North Seas Energy Cooperation,** accompanied by wind industry's cost reduction statements

NL tender results for **Borselle 1+2,** → ***72,7 €/MWh***

July 2016 — **New German RE Act** passed – fundamental shift from FIT to auction regime

Sep. 2016 — **DK Nearshore** tender results → ***60,8 €/MWh***

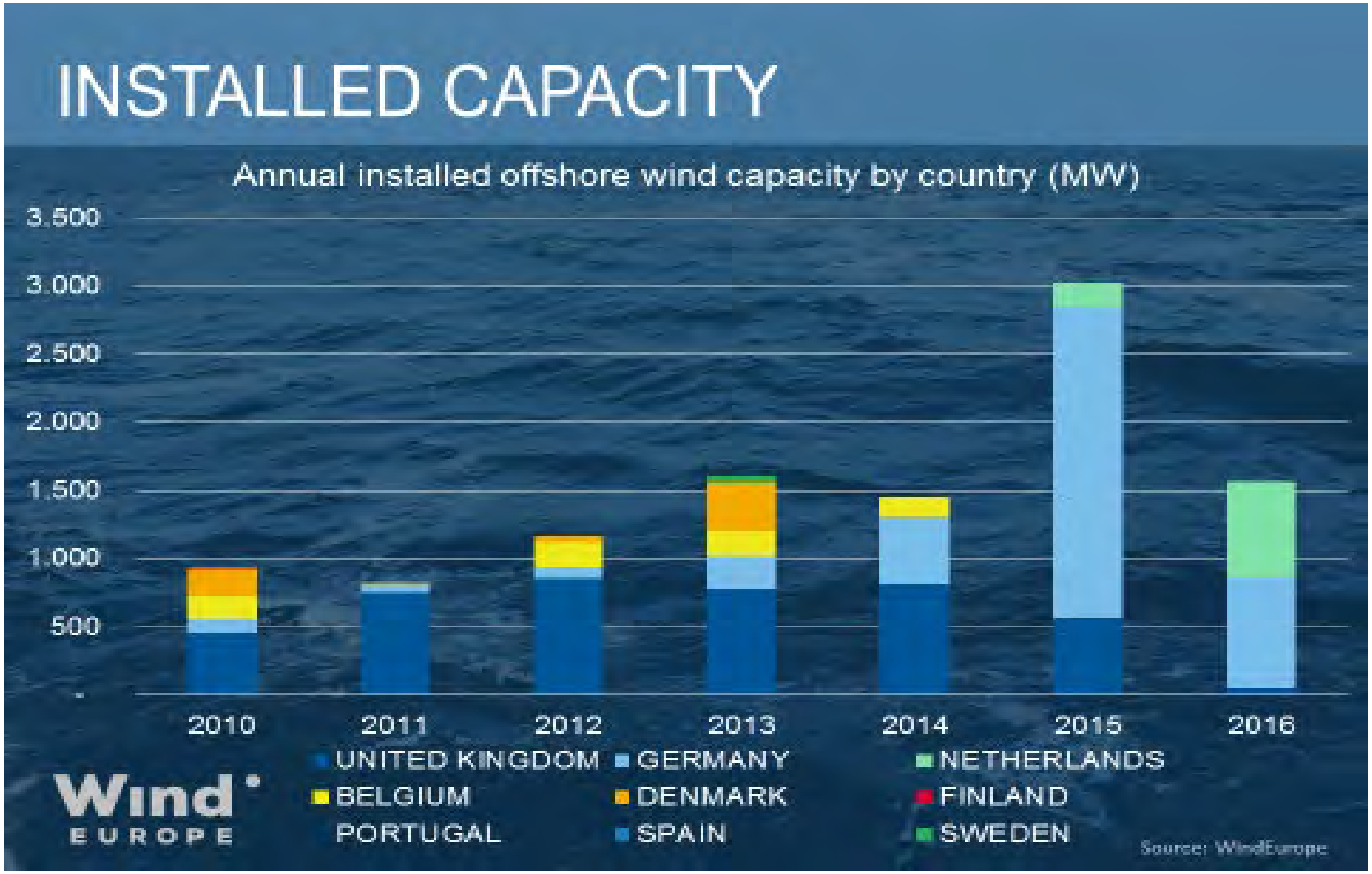
Nov. 2016 — **DK Kriegers Flak** tender result → ***49,9 €/MWh***

NL Borssele 3+4 tender result → ***54,5 €/MWh***

EU Clean Energy Package proposals

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP13 – Offshore Wind Market Development 2010-16



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP13 – Offshore Wind Market Development 2010-16

CONSTRUCTION SUMMARY 2016

Compared against 2015

1,558 MW Installed capacity **-48%**

338 Grid-connected turbines **-55%**

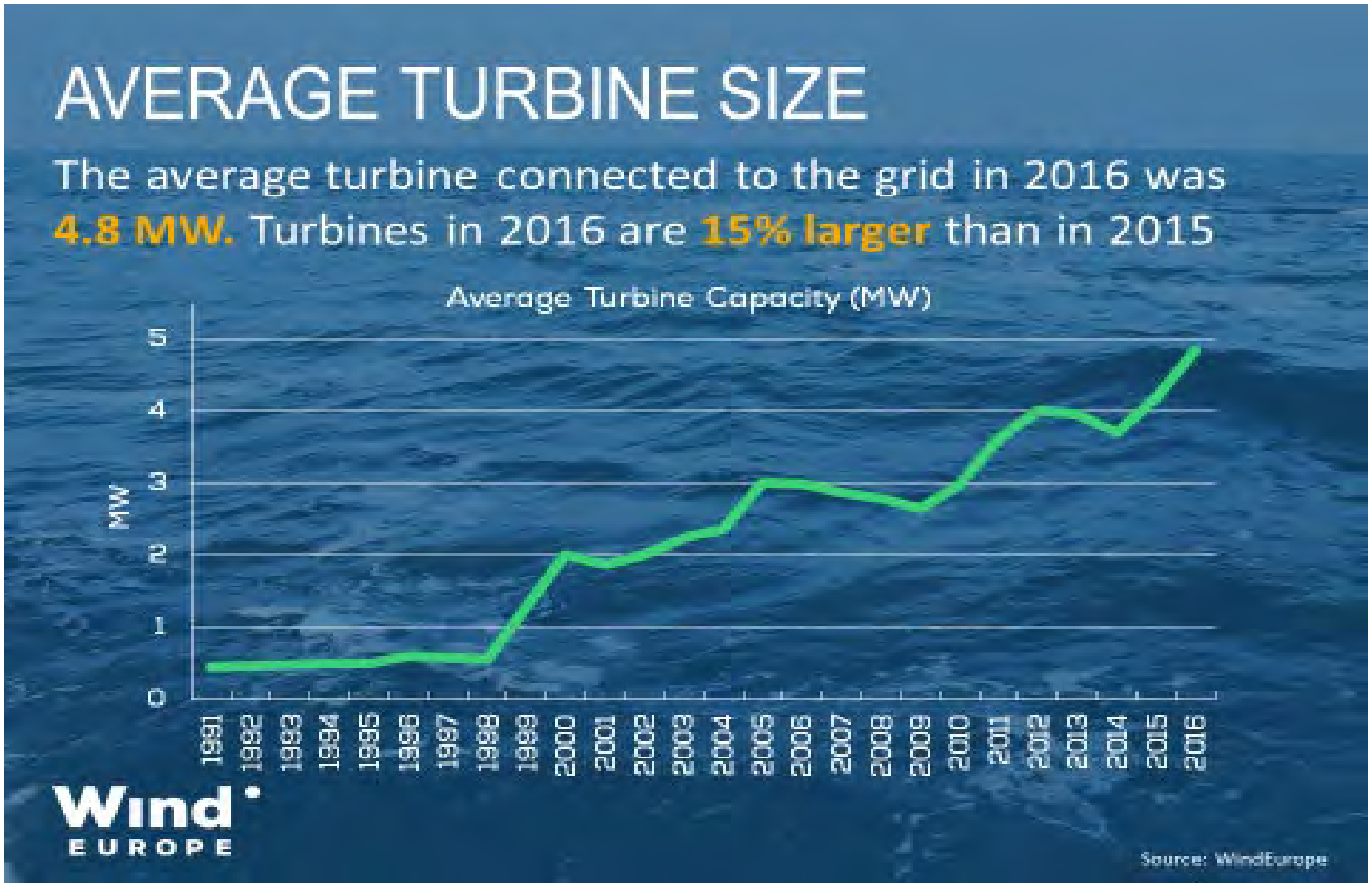
361 Turbines erected **-12%**

568 Foundations installed **+41%**

Wind EUROPE

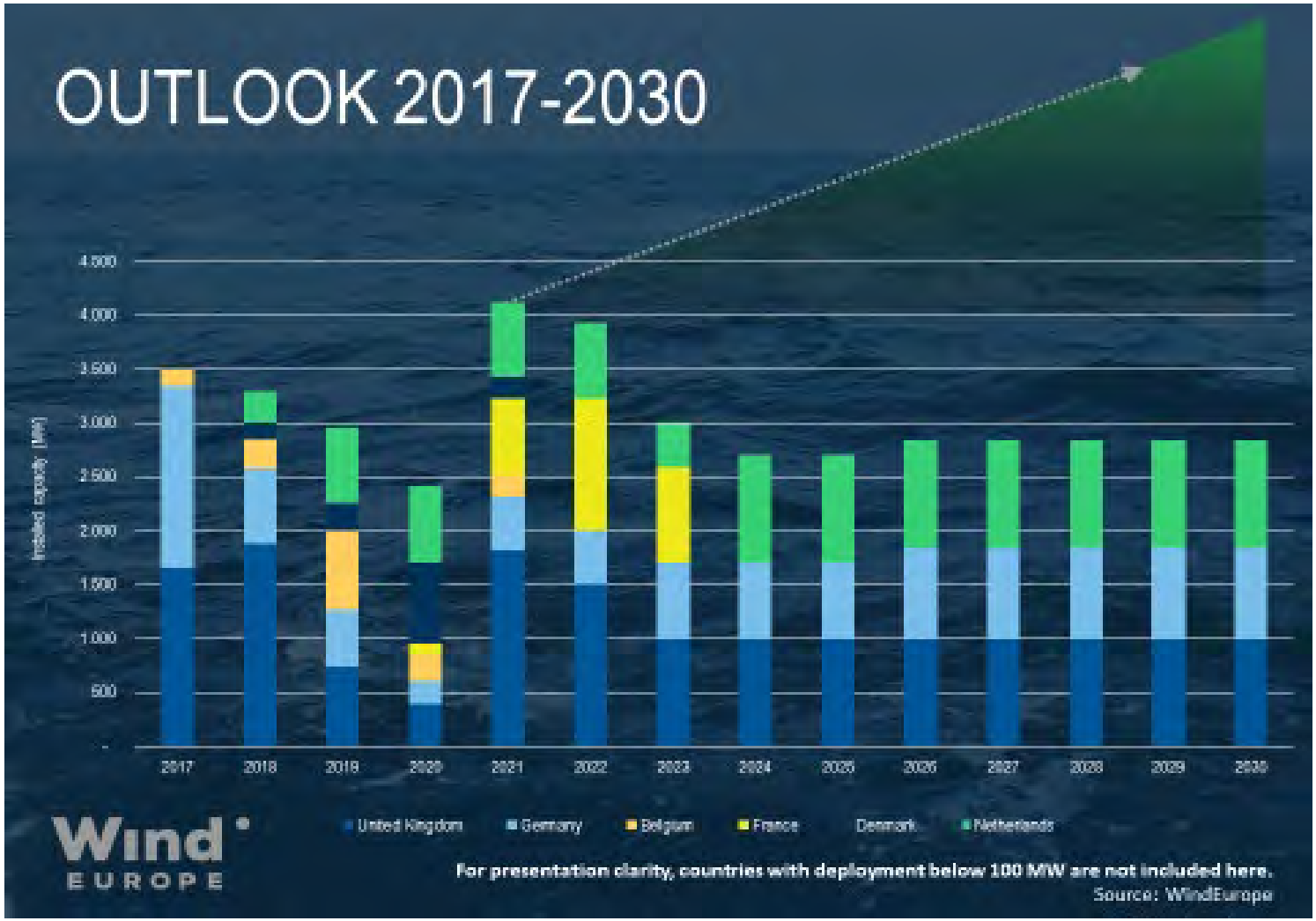
Source: WindEurope

WP13 – Offshore Wind Technology Development 1991-2016



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP13 – Market Outlook



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP13 – Outlook 2017 and beyond

2017 TENDER SCHEDULE for Offshore Wind Farms

- **UK: Next CfD round - Bids open 3 April 2017**
- **NL: Zuid-Holland I +II, Bid open 2017 for 700MW**
- **FR: Third tender at Dunkirk, Selection process in progress**
- **DE: Transitional tenders**
  - **1st tender April 2017 (1.55GW)**
  - **2nd tender April 2018 (1.55GW)**
- **UK: Additional two CfD rounds before 2020**

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

HVDC developments

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP1 – DC Developments

- DC concepts TenneT
- DC within synchronous areas
- Developments in China

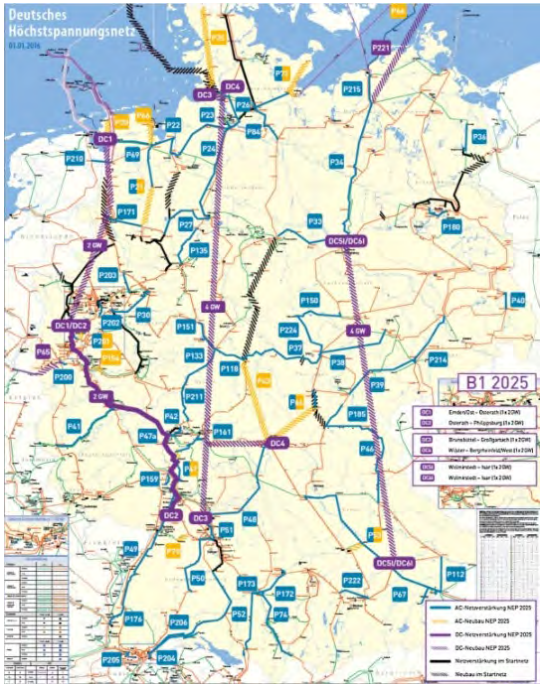
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project context – DC concepts TenneT

- Long term vision: North Sea Wind Power Hub, cooperation TenneT and Energinet.dk, discussion with other potential partners ongoing
- Near term development IJmuiden Ver: all options being considered (up to 6 GW)
  - AC with compensation
  - DC radial
  - DC radial with island
  - DC with windconnector
  - DC with combinations of AC or DC connections offshore
- Interconnectors and windconnection competing for same onshore grid capacity

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project context – DC in synchronous areas



- Connecting load centers to centralized renewable energy production (offshore wind)
- New concepts for operation become available, how to integrate into existing operational and market designs
  - Possibly operation at 100% capacity, where in the AC grid N-1 is standard
  - Reactive power compensation
  - Redirection of flows

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project context – DC in China

Grid boost... UHV lines already online and under construction across China

- Zhoushan 5 terminal project commissioned in 2016 with Circuit Breaker (200kV, 400/300/100/100/100 MW)
- Zhangbei first application of meshed HVDC, 500kV overhead lines, half-bridge VSC converters
- Back to back combinations of LCC and VSC
- ‘Intercontinental’ scale (10.000MW, 800kV)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.

Technical Review

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Work Package 1
Requirements for meshed offshore grids

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

CONTENT

- WP1 objectives & relevance
- Technical review
- Management aspects
- Next period

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Work Package 1

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP1 – Introduction

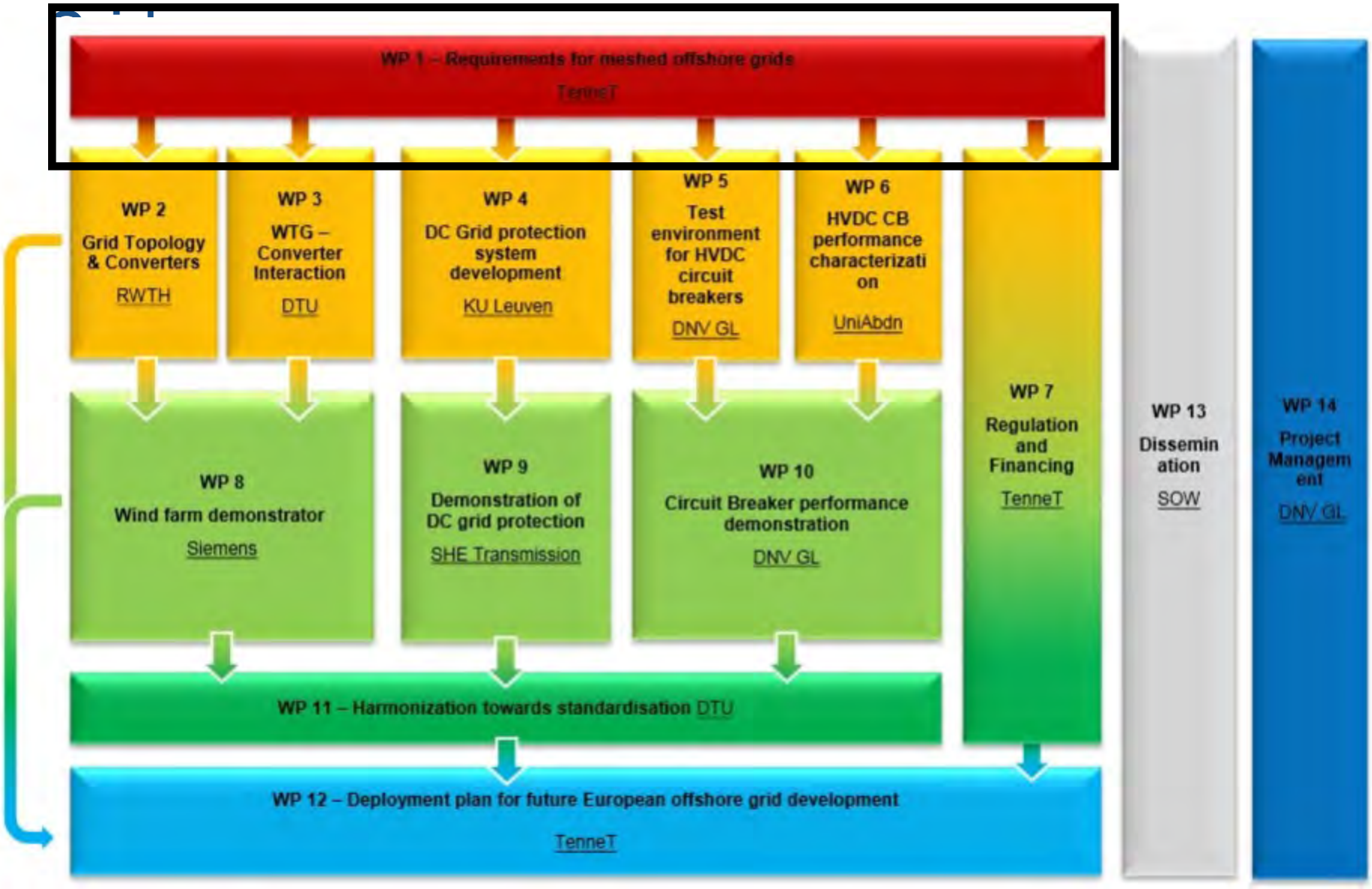
Niek de Groot

- Economic Adviser DC Interconnectors at TenneT TSO
- PROMOTioN Project WP1 Workpackage lead
- Systems Engineering, Policy Analysis & Management, TU Delft

Email: Niek.de.Groot@TenneT.eu

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP1 – Requirements for Meshed Offshore



WP1 – Requirements for Meshed Offshore Grids

- To define reference scenarios and fundamental topologies from a holistic point of view
- To compile and analyze studies and available and emerging technologies for offshore grids
- To assess and evaluate the operational, financial, technical, regulatory, planning, reliability and availability aspects of offshore connections and grids
- To identify under which circumstances a certain fundamental topology is likely to be implemented
- To validate that the requirements that are defined in the beginning of the project, are still valid when the first conclusions are drawn from work done in the project

Create a foundation for the rest of the project; facilitate early interaction between the different workpackages; steer and guide activities towards usable results

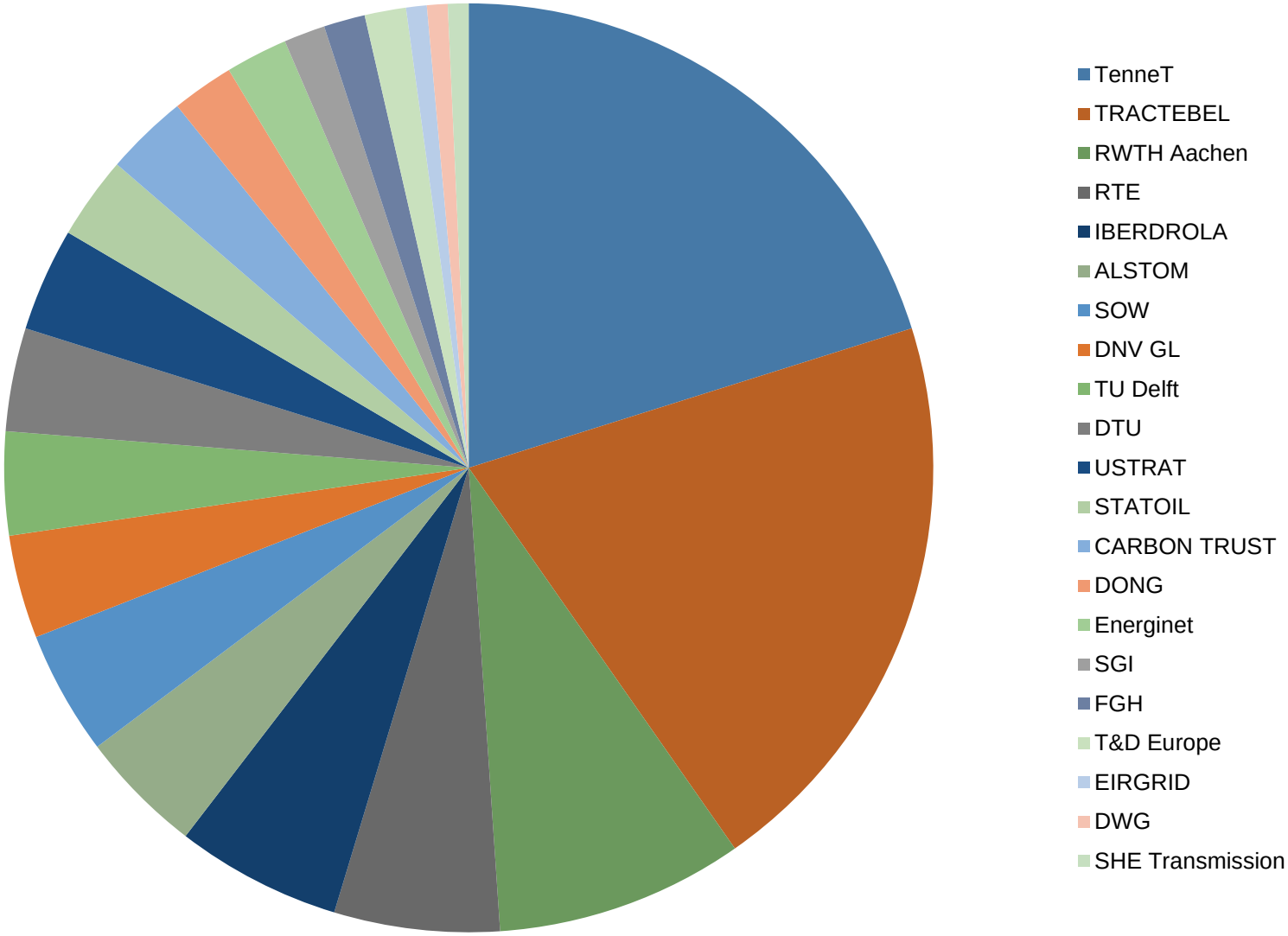
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP1 – Task description

Task 1.1	• Requirements, Reference scenarios and Fundamental topologies
Task 1.2	• Collect knowledge from literature
Task 1.3	• Collect knowledge from projects
Task 1.4	• Design Initial roadmap
Task 1.5	• Review requirements Task 1.

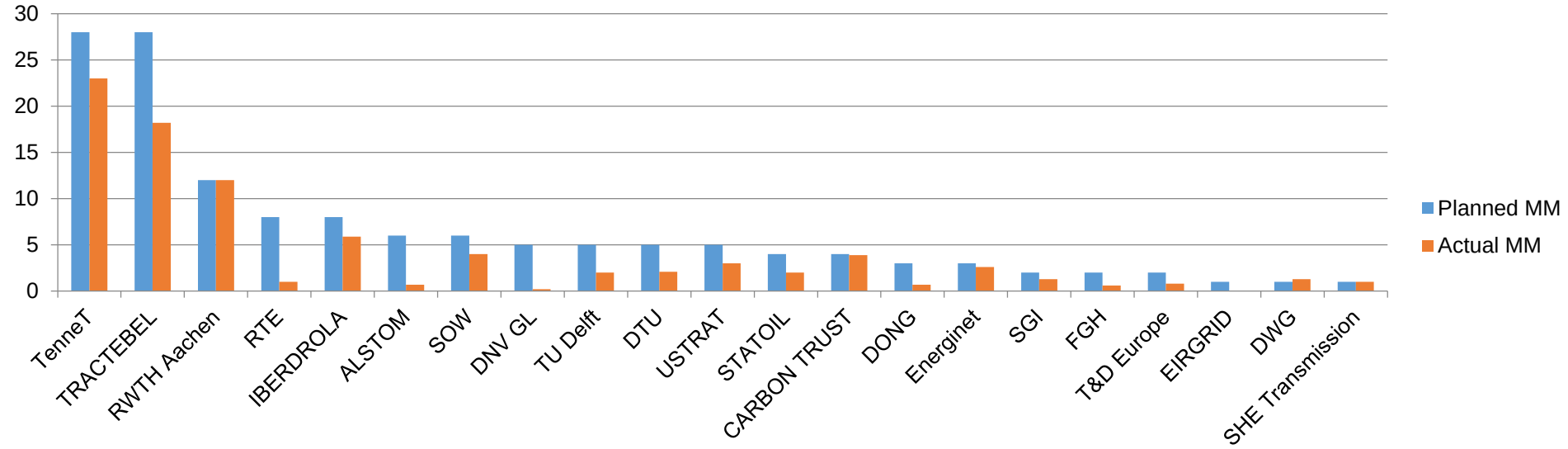
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP1 – Planned partner participation



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP – Partner participation – Planned vs Actual



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP1 – Personal experience

- Pleasantly surprised by the contributions of many of the PROMOTioN project partners
- Great learning experience for young people in the project, great way of sharing experience for more senior people

Positives

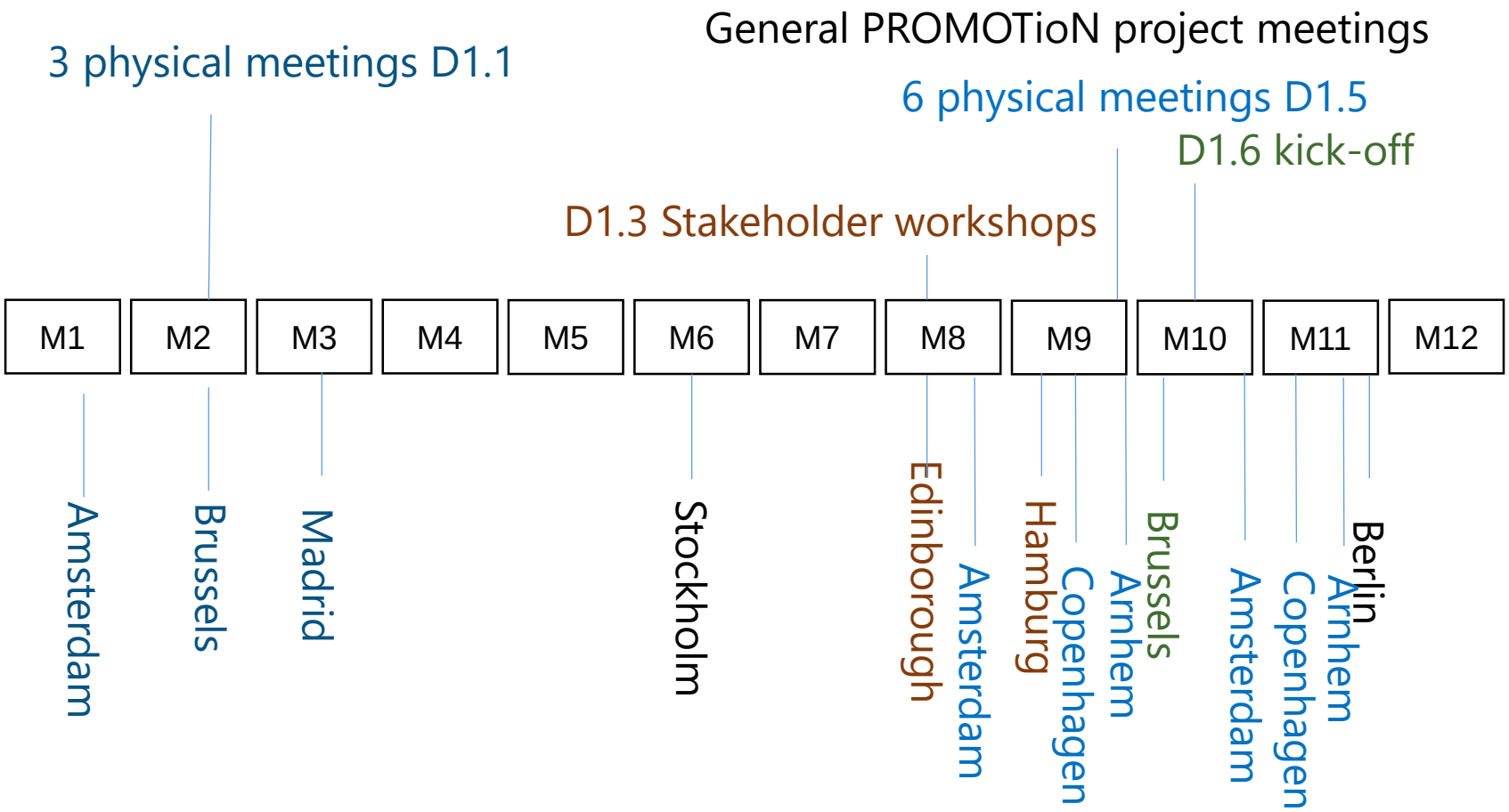
- Wealth of experience and knowledge available within the project consortium
- Wide range of expertise allowing for a holistic approach and end-result
- Strong mix of do-ers, thinkers and experienced reviewers

Challenges

- The scope of the project makes it a challenge to get all the different expertise on the same page
- Sometimes a challenge to reach out to and get input from the many partners in a predefined timeline. Important inputs often arrive late in the production of a deliverable
- Coordination and organization is labour intensive and takes dedication

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Meetings



In addition to numerous Telco's, bilateral meetings, calls etc.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP1 – Requirements for meshed offshore grids

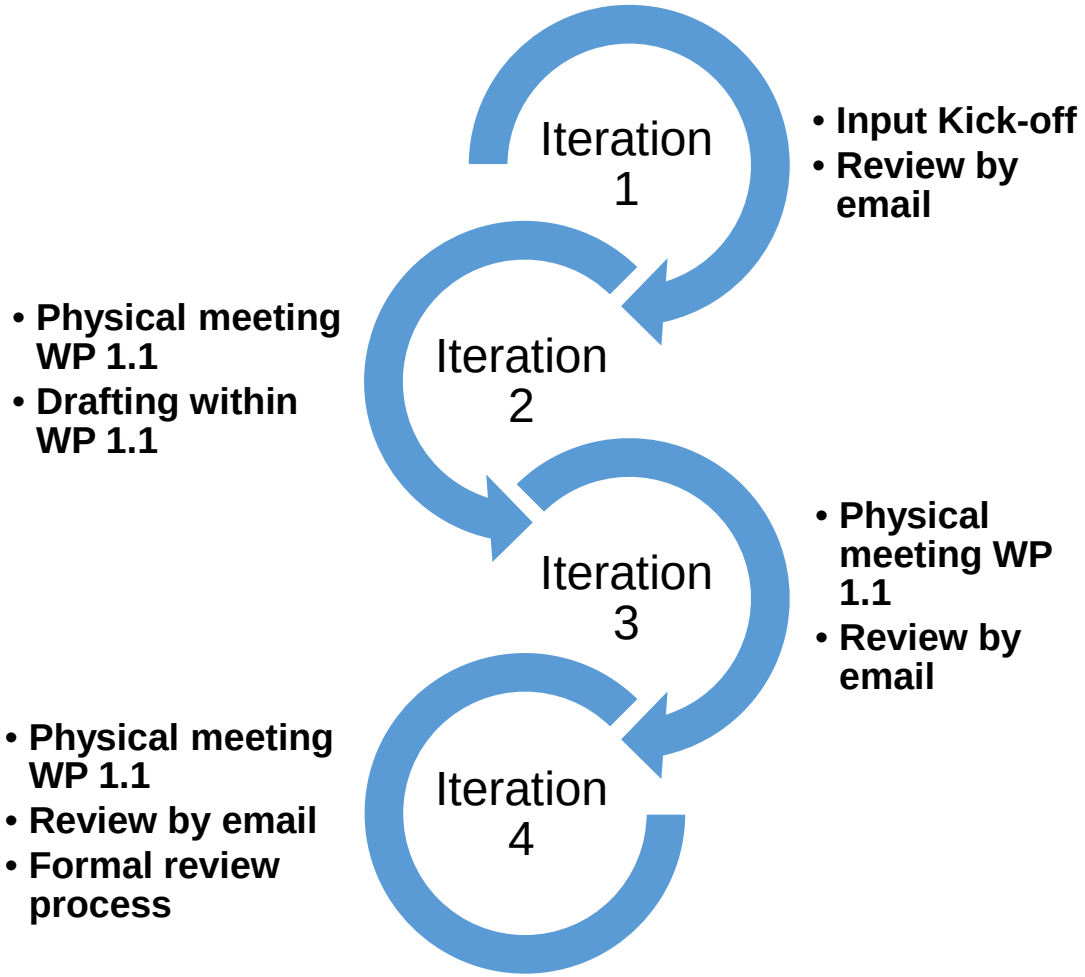
#	Task	2016	2017	2018	2019
1.1	Define requirements, reference scenarios and fundamental topologies				
1.2	Studies, available and emerging technologies for offshore grids				
1.3	Assessment and inputs from existing offshore connections and grids				
1.4	Initial roadmap for the evacuation of offshore renewable generation				
1.5	Re-evaluate requirements based on work of other packages				

● = Deliverable

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 1.1 Deliverable 1.1

Tasklead: TenneT TSO



- Definition of requirements
- First deliverable of the PROMOTioN project after only 3 months
- Large amount of partners involved

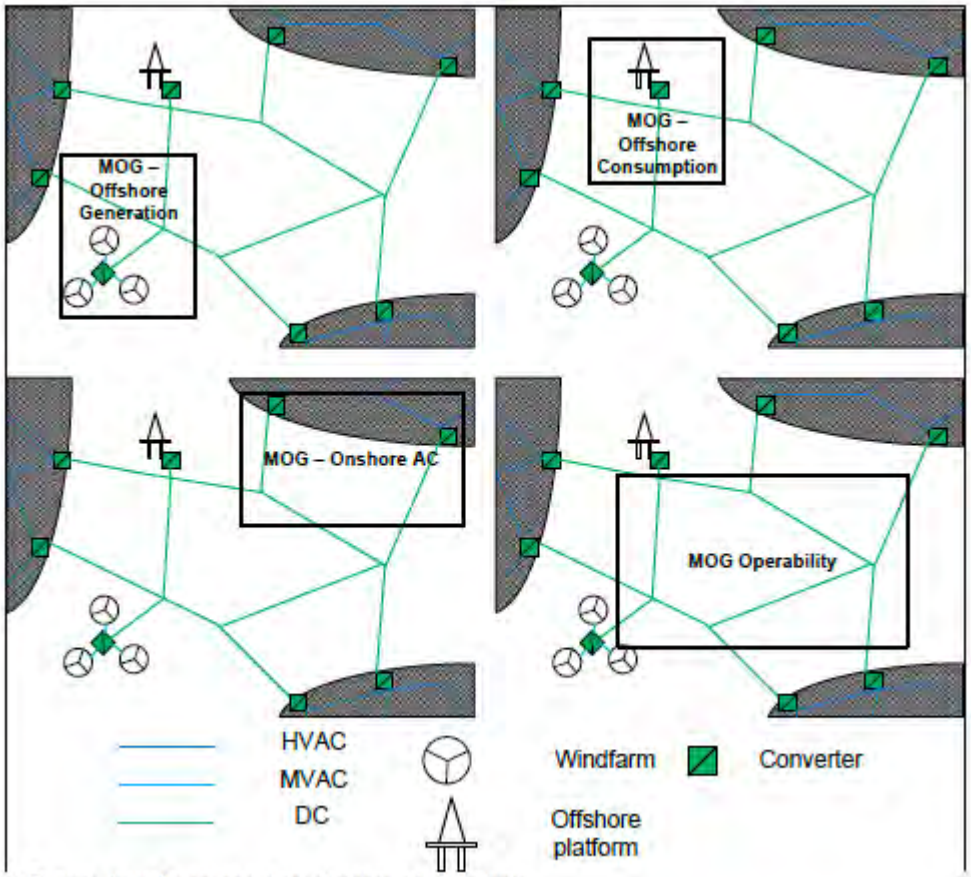
- First defining what requirements are
- Then development of qualitative set of requirements through iterative process

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 1.1 Deliverable 1.1

Tasklead: TenneT TSO

Objective: Definition of requirements



2 Figure: Interfaces used as document structure

- Introduction of possible topologies
- Definition of System Requirements
  - Transmission and capacity requirements
  - Interoperability
  - Reliability
  - Stability and Controllability
- Introduction of interfaces and interface requirements
- Quantified in D1.5

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 1.2 Deliverable 1.3

Tasklead: Tractebel

Objective: Report with a synthesis of the available studies on offshore meshed HVDC grids and related barriers/gaps at the inception of the project

- Tasklead Tractebel delivered an excellent review of available studies with the following chapters:
  - System planning and grid topologies
  - Converters
  - Protection systems
  - Circuit Breakers
  - Finance and Regulation

- The document serves as a very good overview for specialists that want to broaden their view and people new to the subject

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 1.2 Deliverable 1.3 Key conclusions

Tasklead: Tractebel

1. It is unlikely that the final solution consists of a single large interconnected offshore grid: roadmaps usually come up with several offshore grids not connected together by DC branches
2. Complex offshore topologies (i.e. radial multi-terminal and meshed grids) appear to be cost-efficient only for scenarios considering both a high offshore wind generating capacity and numerous offshore hubs to collect this energy (geographical spreading)
3. the economical advantage of complex offshore topologies such as radial multi-terminal and meshed grids can only be demonstrated when the overall grid structure is optimized
4. Adding HVDC components will lead to interactions, especially in weak offshore AC grids. Introduction of DRU will lead to new phenomena of which the impact is still unknown
5. There is no consensus on the best protection system mechanism for MOG, and no basic protection system mechanism fulfills all the requirements for the operation of a MOG. A key barrier is the lack of detailed data on the behavior of DC Circuit Breakers
6. There appears to be no consensus on the way to alleviate regulatory and financial barriers. Several reports propose different and sometimes conflicting recommendations

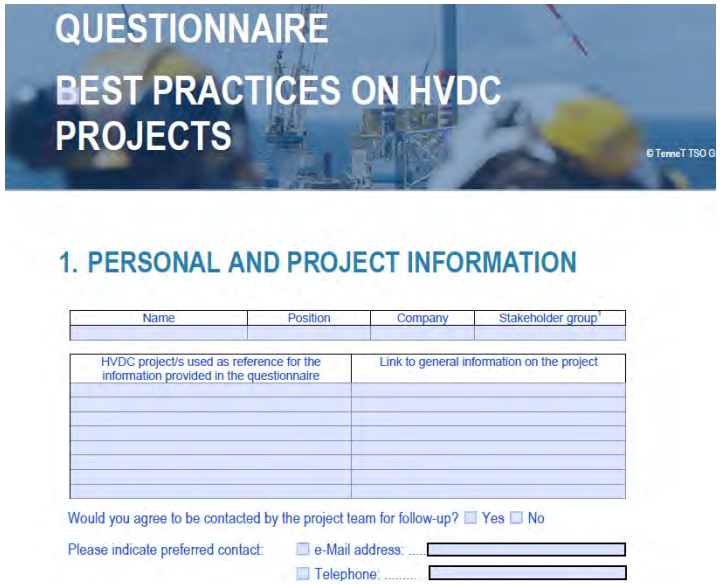
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

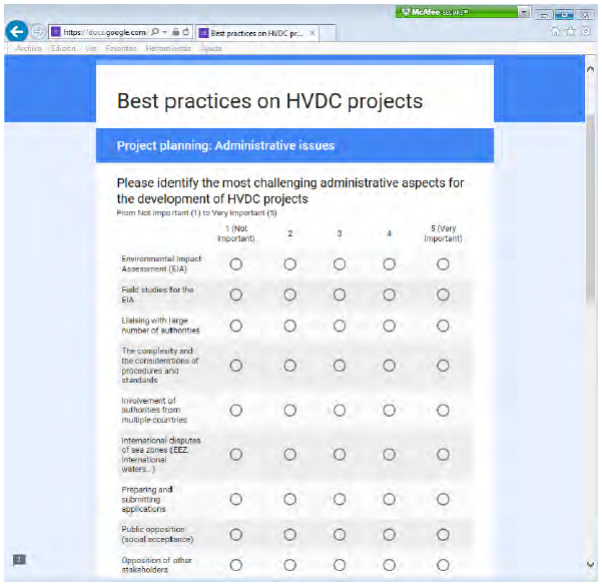
Task 1.3 Deliverable 1.2

Tasklead: Iberdrola

Objective 1: Report document results of the questionnaire on best practices

Objective 2: Stakeholder workshops to enrich the information



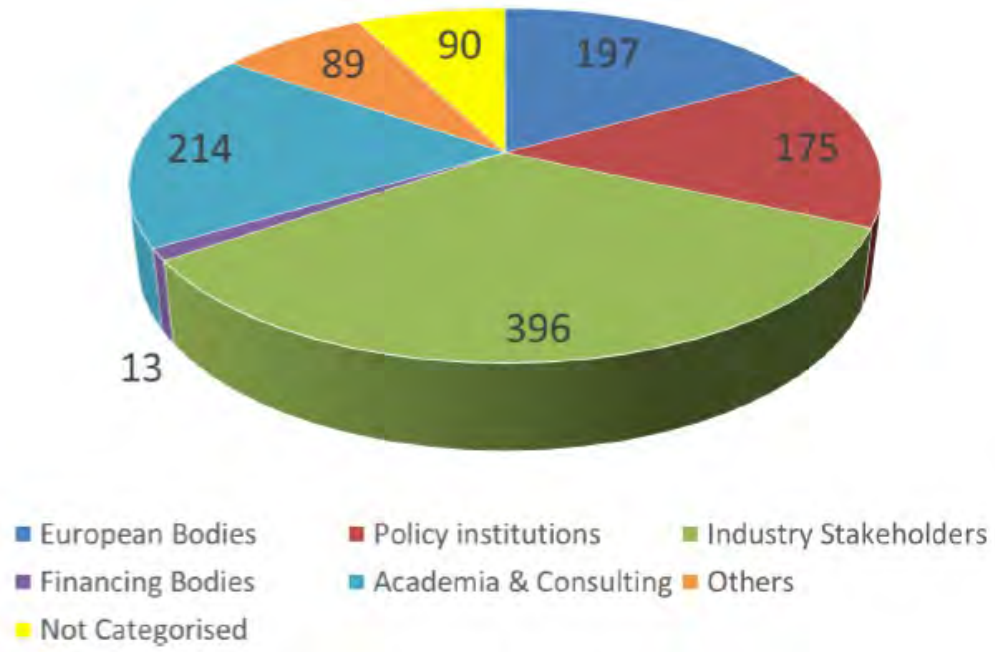


- Questionnaire developed in dual format (word and online)
- Two workshops organized, one in Edinborough and one in Hamburg

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 1.3 Deliverable 1.2

Tasklead: Iberdrola



- A broad range and large quantity of stakeholders was targeted with the questionnaire
- Challenge to get good response to questionnaire even after many mails and mentions in presentations
- The responses we received were generally of good quality and led to interesting insights

- The workshops focused on the UK/Nordics in Glasgow, and continental Europe in Hamburg.
- Both workshops had a good attendance and interesting speakers

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 1.1 Deliverable 1.4

Tasklead: TenneT TSO

Objective: Report with reference scenario and related offshore meshed HVDC grid topology

- Making available and selecting existing scenario's
  - TYNDP
  - E-Highways

- HVDC grid topology;
  - Fundamental topologies already introduced in D1.5 ('building blocks' for a Meshed Offshore Grid)
  - Benchmark topologies were developed by WP2 & 4 in alignment with WP1, ensuring the use of consistend test networks
  - 'Reference Networks' in development in D1.6 and WP12

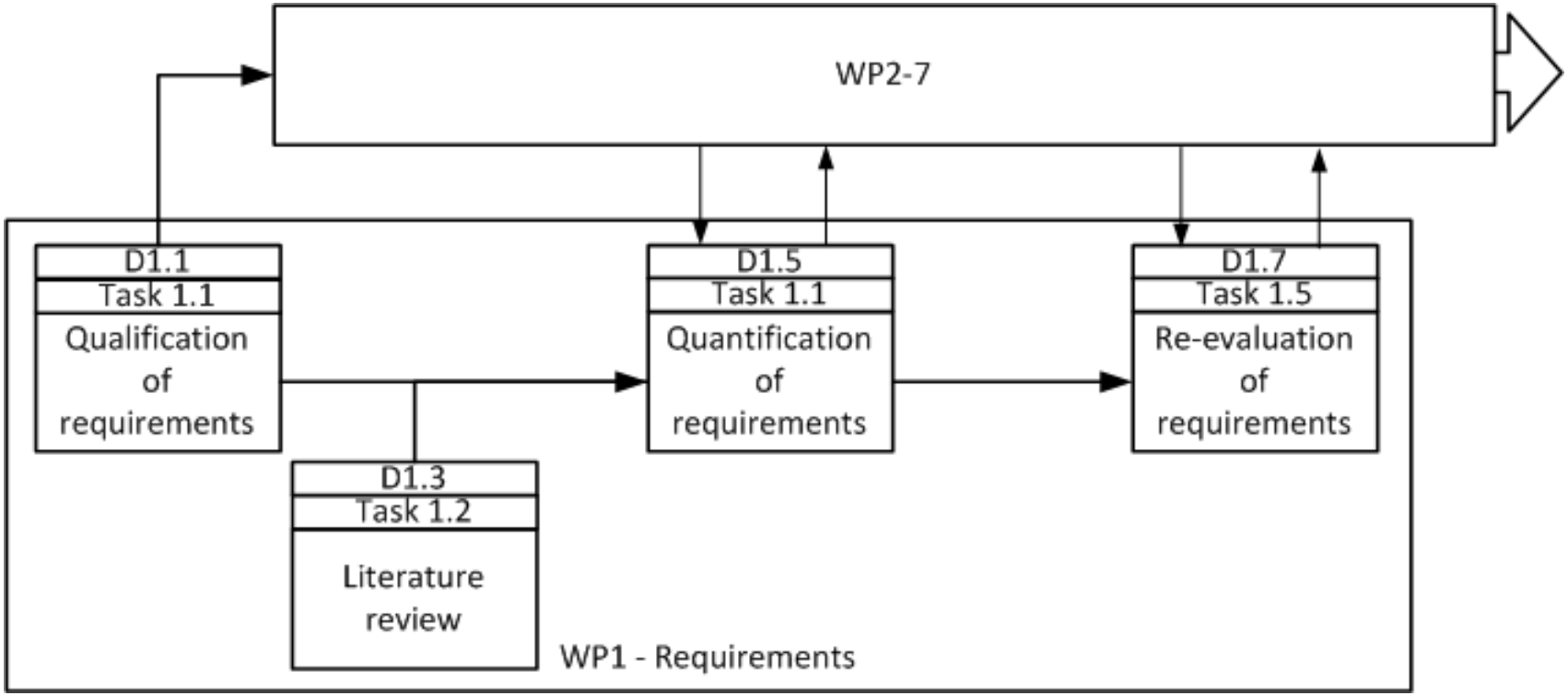
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 1.1 Deliverable 1.5

Tasklead: TenneT TSO

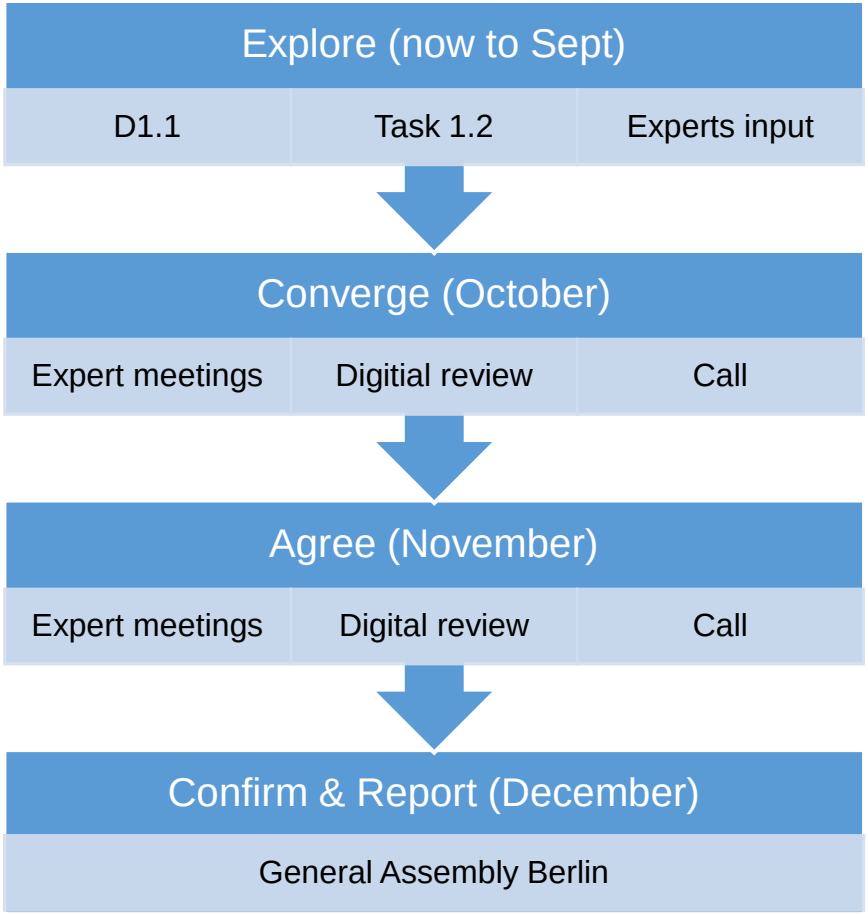
Objective: Quantified set of requirements

- Strong interaction with technical WPs



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 1.1 Deliverable 1.5 approach



2x3 Expert meetings with a scope of chapters out of Deliverable 1.1:

- **Chapter 4**: Onshore AC – DC grid
- **Chapter 5/6**: Meshed Offshore Grid – Offshore Windfarm
- **Chapter 7**: DC grid protection / operation

- Strong interaction with WP 2, 3 and 4.
- Ensuring consistency in assumptions between different studies

Leading to a set of quantified requirements to be reviewed and updated in Task 1.5, D1.7

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Dissemination

- Deliverables
  - Published on website
  - Disseminated via other media by WP13
- Contribution to Reference Group meetings
- Contributions to WP13 efforts (media interviews, promo video's etc.)
- Stakeholder workshops Task 1.3
  - Glasgow
  - Hamburg

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

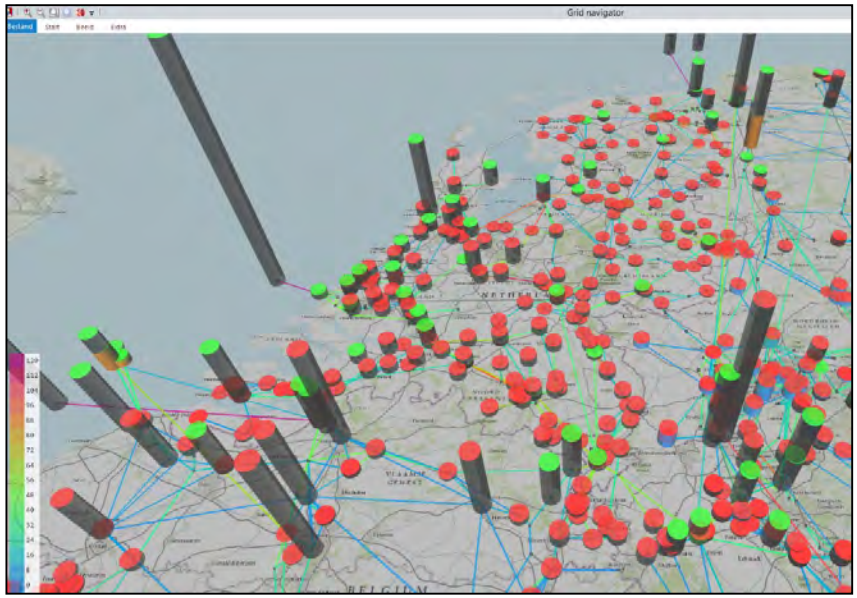
Next period

1.4 Initial roadmap for the evacuation of offshore renewable generation

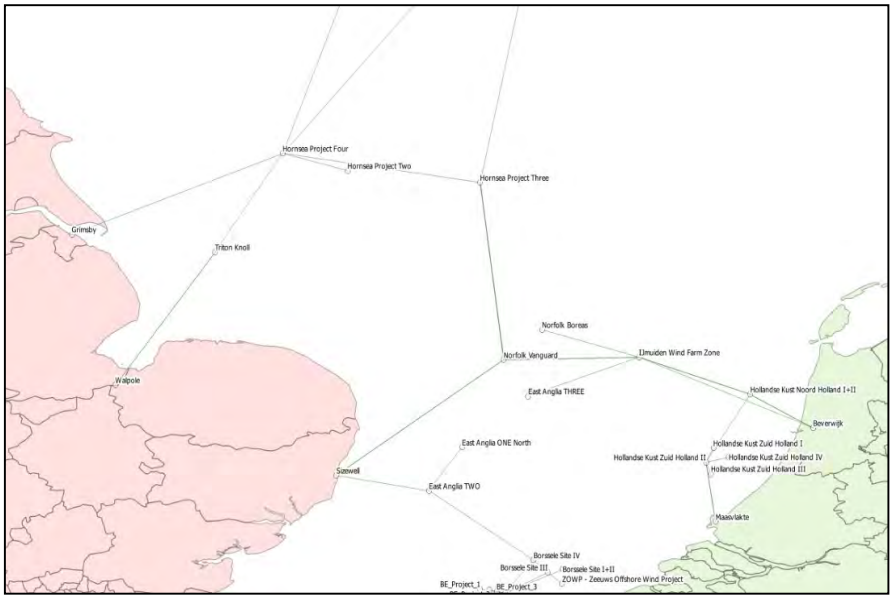
- Simulation of roadmap development
- Reporting and development of reference networks
- Development of visualization tool by Phase to Phase

1.5 Re-evaluate requirements based on work of other packages

- Task starting after the summer of 2017



Draft output Phase to Phase visualisation



Draft output Tractebel simulation draft roadmap development

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Work Package 2
Grid Topology and Converters

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

CONTENT

- Introduction to WP2
- Report on Task 2.1
- Status presentation Task 2.2
- Overview dissemination and timeline

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Introduction – WP 2

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Objectives WP 2

- To compare and perform a trade-off analysis of different topologies
- To develop control and operational concepts for different configurations to ensure interoperability
- To study and demonstrate the interconnection of VSC and DRC HVDC systems in realistic scenarios
- To define recommendations on onshore and offshore power systems for existing grid codes

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

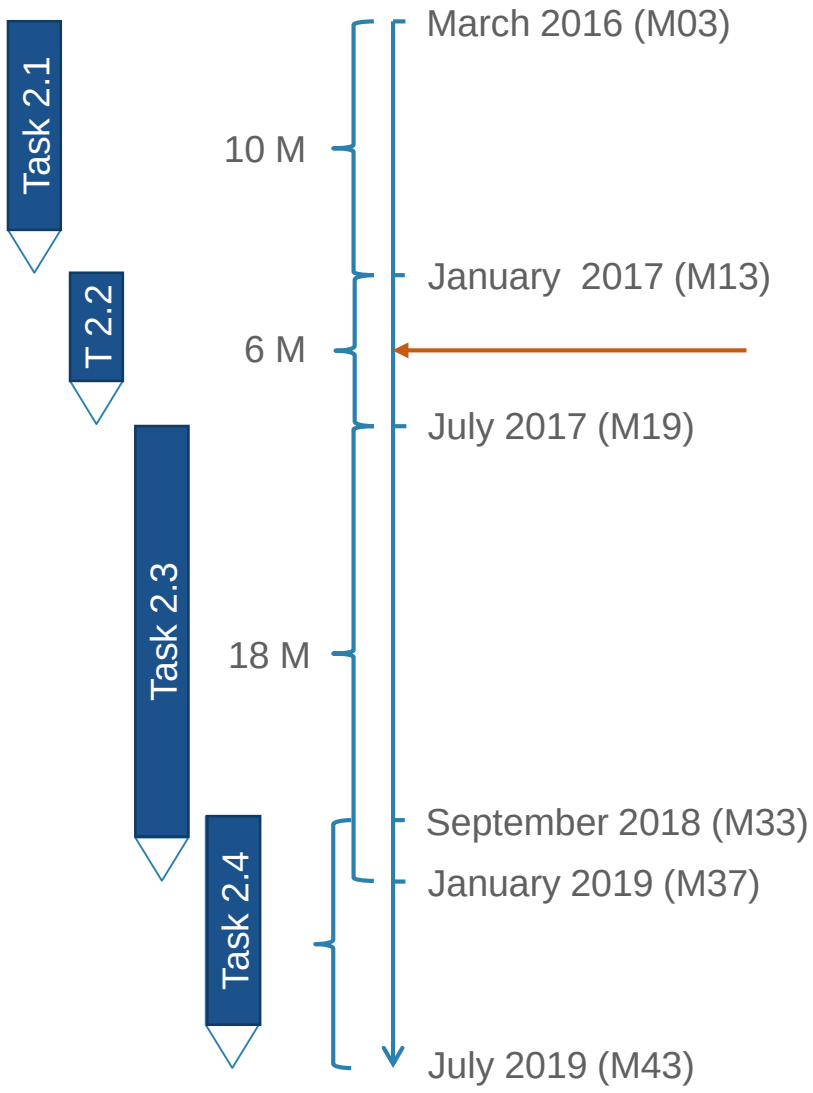
Timeline

2.1 Definition of model parameters, control objectives and operational assumptions for the meshed HVDC offshore topologies
✓ D 2.1: Grid topology and model specification

2.2 Adaption of simulation models for the meshed HVDC offshore topologies
→ D 2.2: Scenario and test case specification

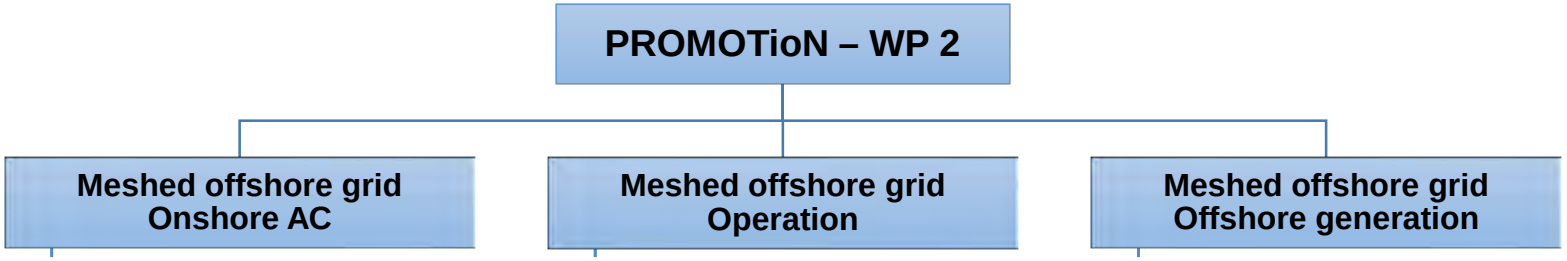
2.3 Simulative investigation and functionality demonstration of the meshed HVDC offshore topology system interoperability
→ D 2.3: Simulation results and benchmark

2.4 Define recommendations for minimum requirements on onshore and offshore power systems
→ D 2.4: Requirements for grid code extension



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Overview of Research Questions Addressed



Steady State Operation

Normal Set point Changes

Fault Or Outtakes

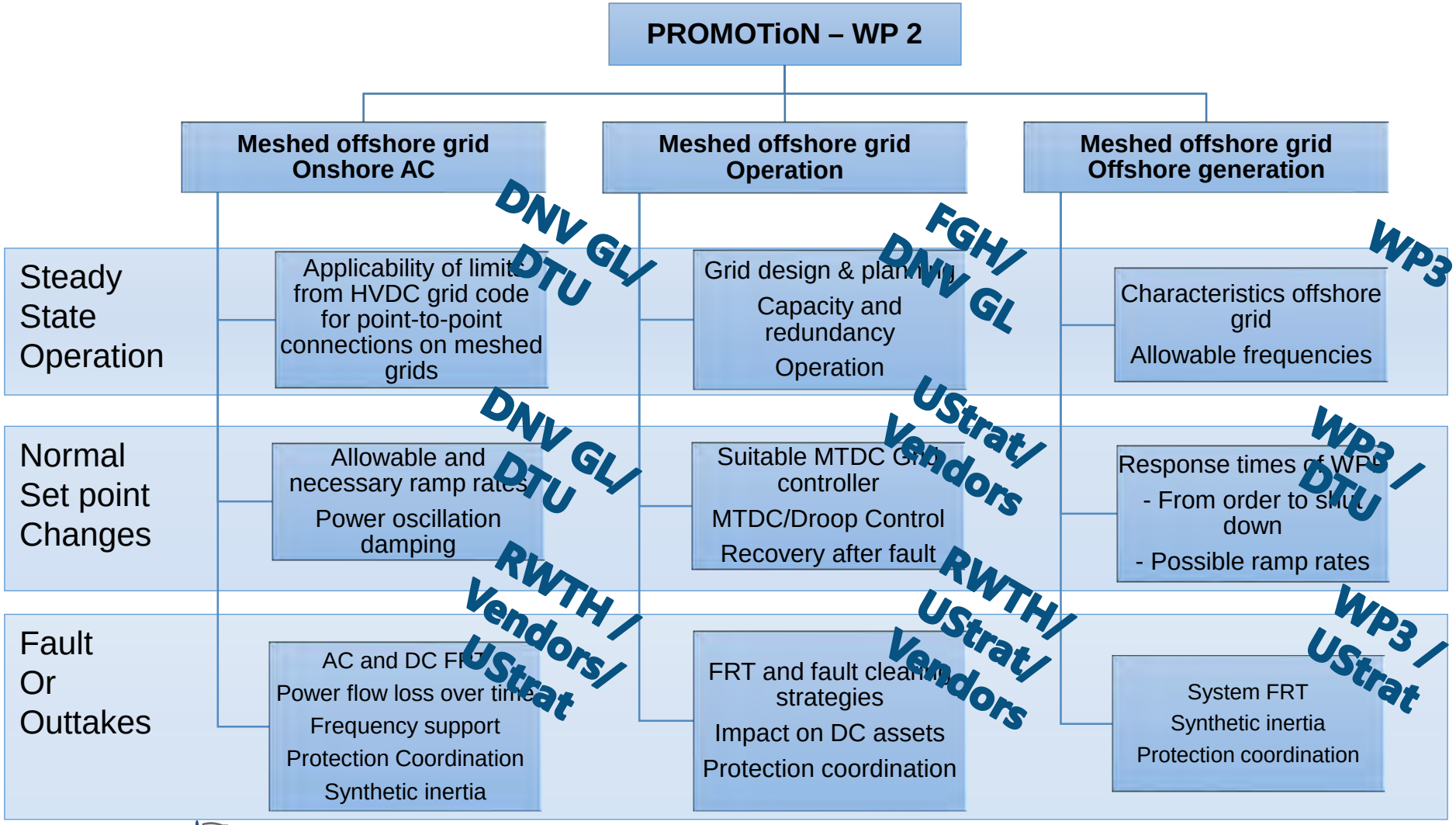
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Involved Partners

- Work Package Leader:
- Participants:

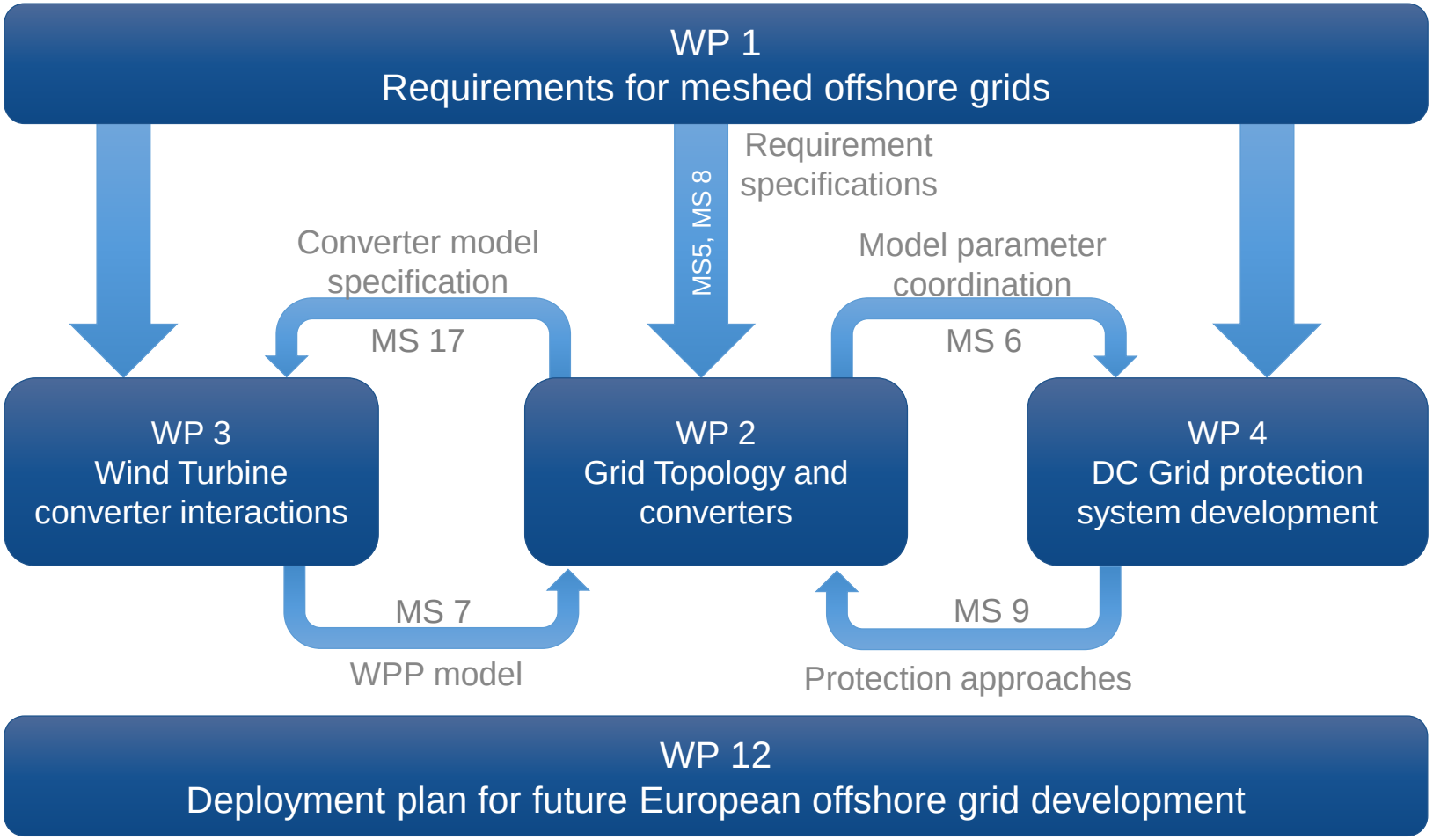
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Beneficiaries contribution and integration



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Integration in the overall project scope



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Report on Task 2.1: Definition of model and control parameters for offshore topologies

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 2.1 – Approach

1. Analysis of existing and planned systems

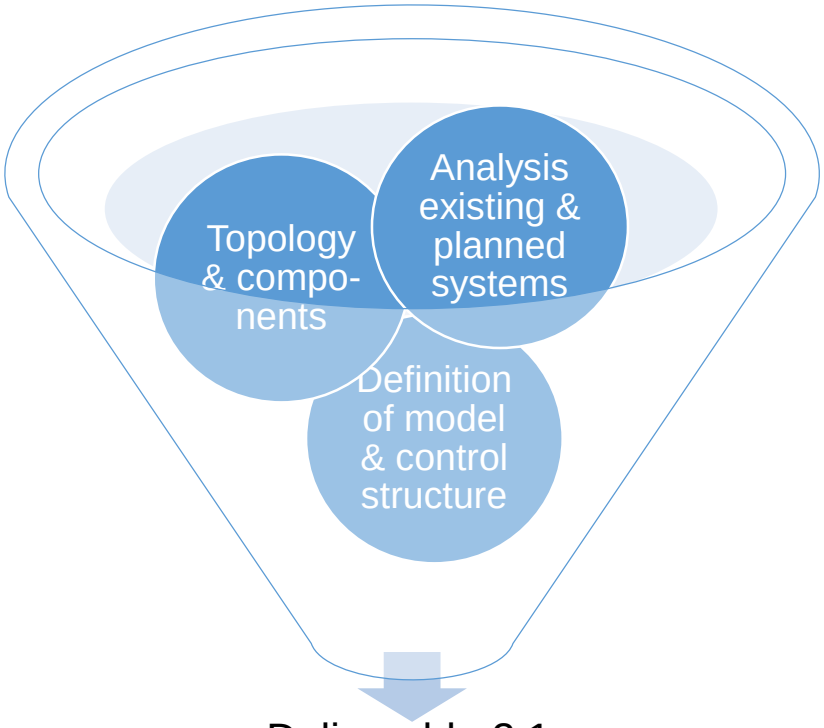
- Input from WP 1 (D1.3)
- Ten Year Network Development Plan (TYNDP)
- Cigré compendium of all HVDC projects

2. Deduction of topology and component specifications

- Comparison of different topologies
- Representation of different technologies

3. Definition of model and control structure

- Based on Cigré definitions
- Different simulation time frames and scopes
- Modelling expertise of beneficiaries



Deliverable 2.1

List of grid topology and model specifications

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 2.1 – Definition of flexible network topology

Aims

- Represent realistic scenarios
- Allow flexibility for different research aims

Considerations

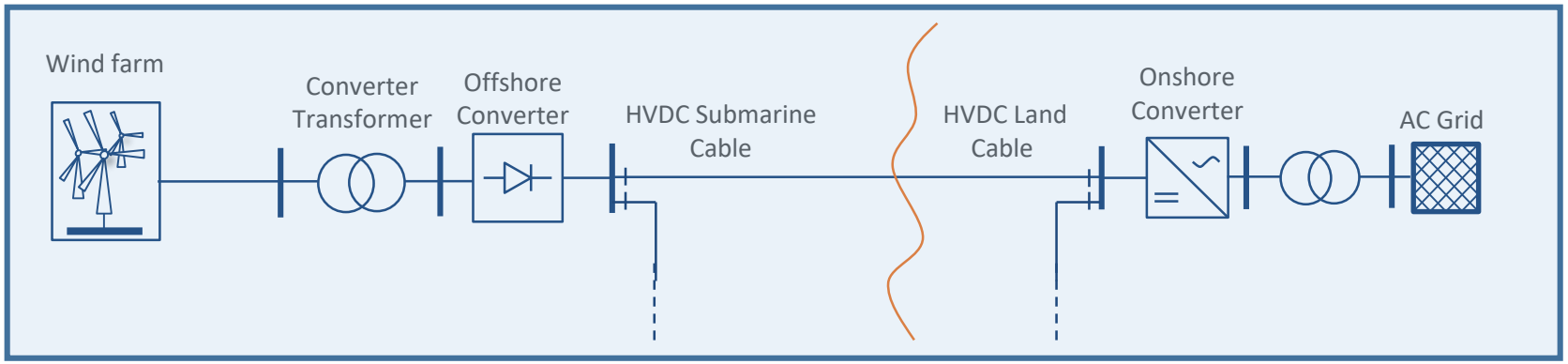
- Current and future technological limits
- Geographical characteristics of the North Sea region

Technical options

- Meshing on the DC side
- Meshing on the AC side
- Different synchronous zones

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 2.1 – Specifications of key component parameters



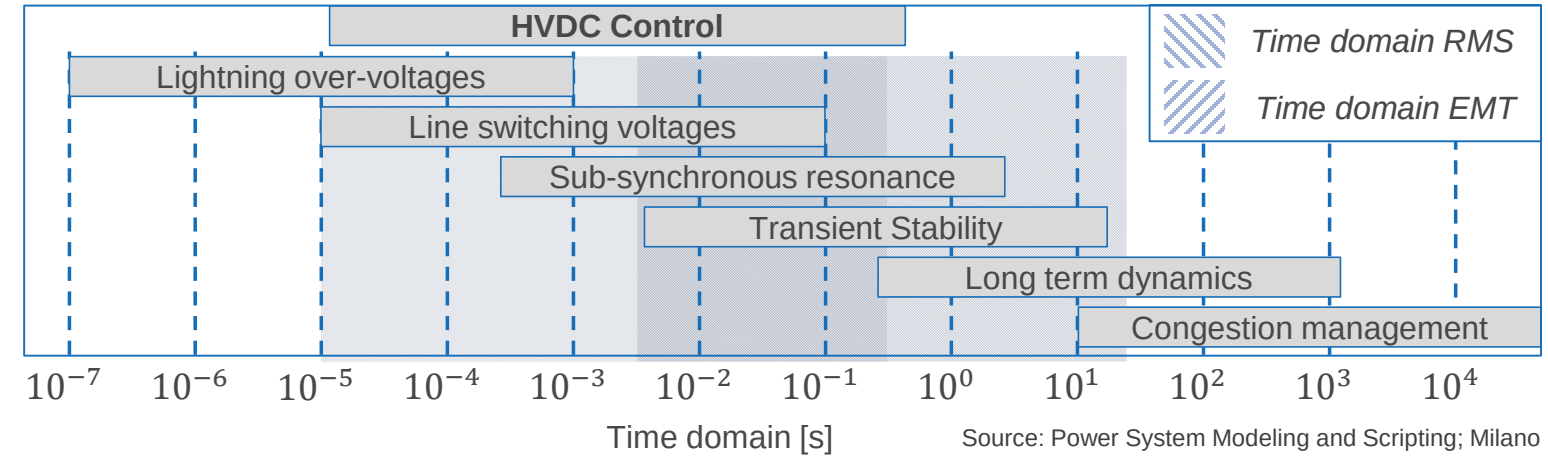
- All offshore components and onshore representations included
- Hardware specification according to existing and planned projects, e.g. German windfarms interconnected by HVDC
- Input from vendors on converter technology and cable specifications

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 2.1 – Model specifications for key components

Consideration of

- Different simulation scopes
- Variety of simulation tools



Source: Power System Modeling and Scripting; Milano

Representation of large grid structures

Level of detail

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Status presentation task 2.2

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 2.2 – Adaption of simulation models

Detailed Model set-up in PSCAD

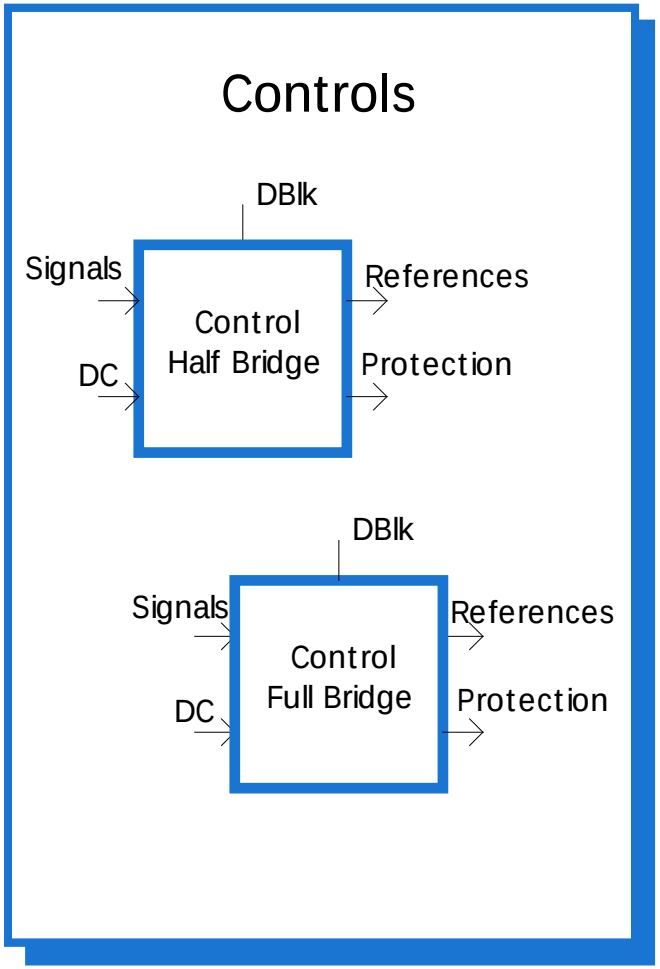
- Based on Cigré working group B4.69
- Adaption to parameter settings from D2.1
- Implementation of network structure

RMS model set-up in various tools

- Based on parameters and control structure of EMT model
- Level of detail according to research scope

Quasi-stationary model set-up in Integral

- Based on data from TYNDP



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

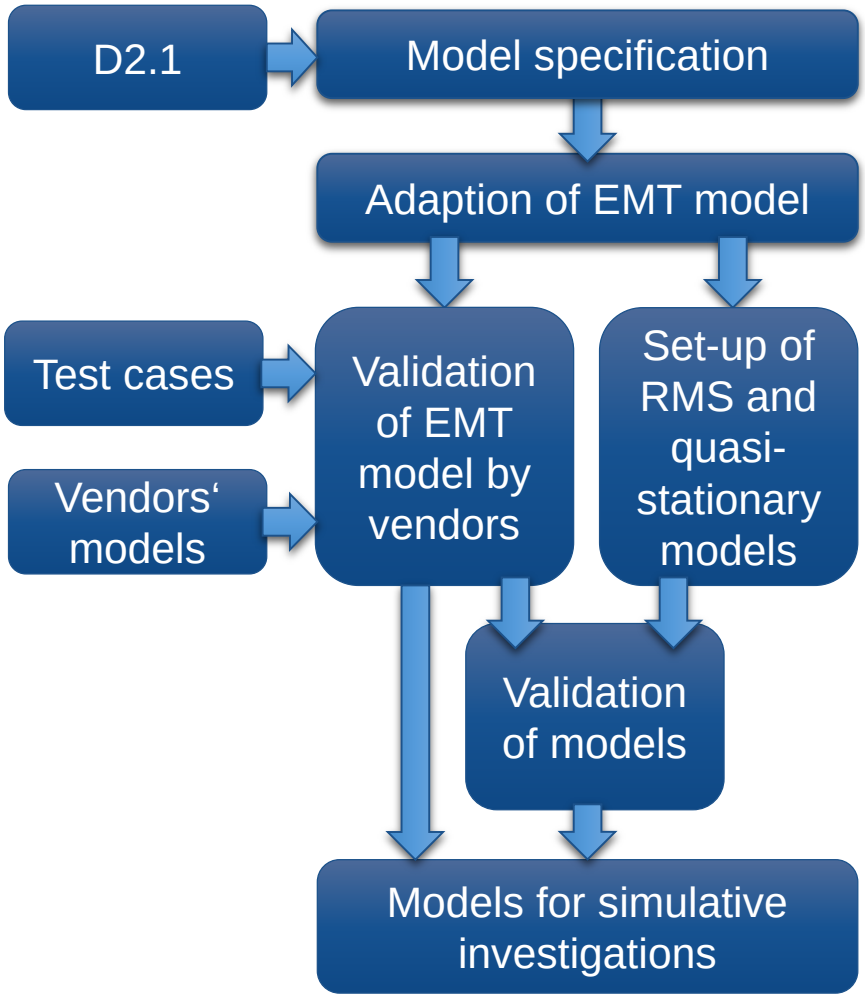
Task 2.2 – Model validation on test cases

Definition of test cases

- Consideration of future investigations
- For steady-state, set point changes and fault situations

Validation of models

- Comparison to vendors‘ models
- Vendors‘ experience
- Feedback from other WPs



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.

Overview dissemination and timeline

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Dissemination

Ongoing:

Interaction with Cigré modelling group on HVDC converters B 4.71, sharing experience in modelling HVDC systems for future system studies

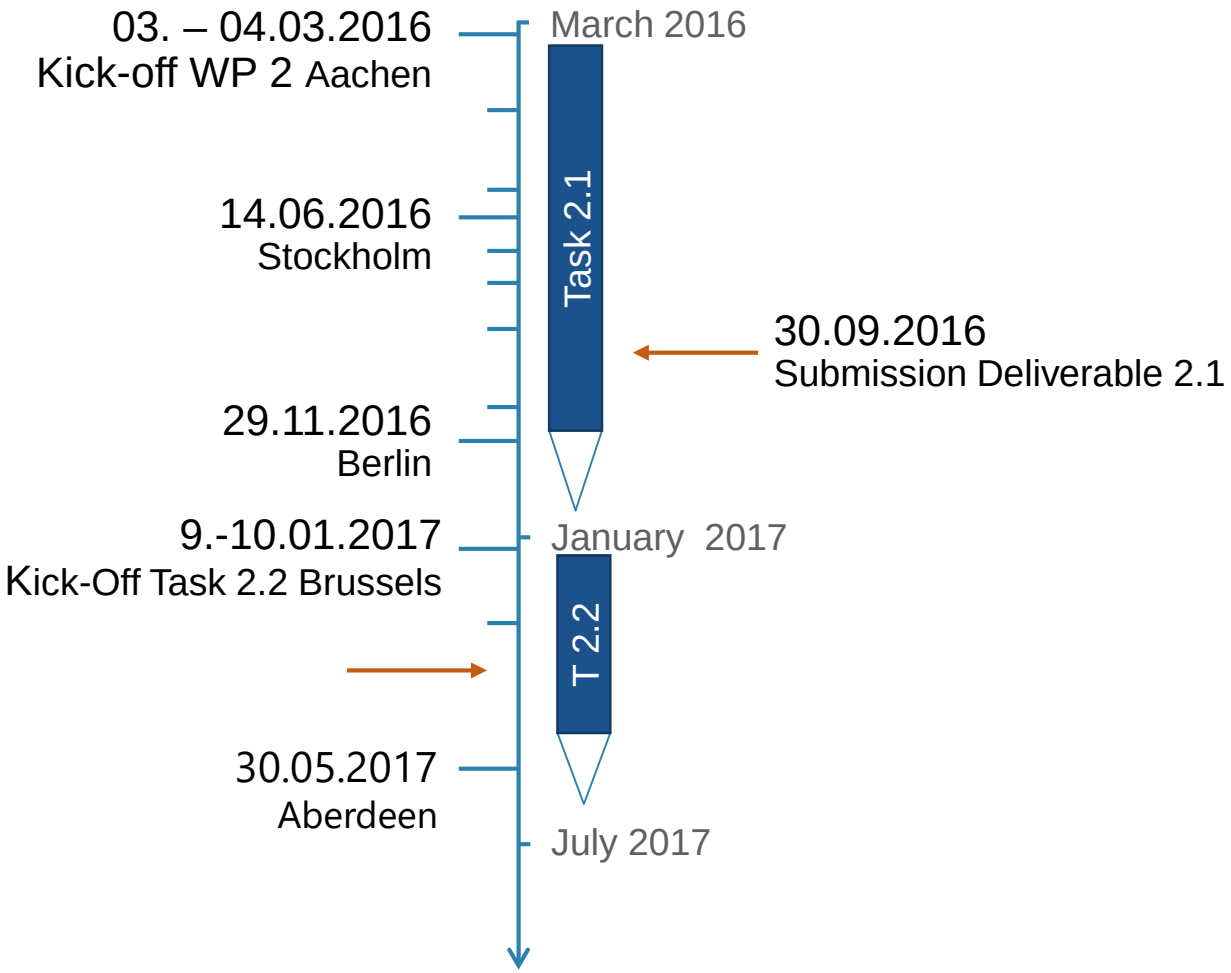
Planned:

Deliverable 2.4: Define recommendations for minimum requirements on onshore and meshed offshore DC power systems in order to adapt and extent existing grid codes

- More holistic approach on HVDC systems
- Consider AC and DC system as one to investigate influence on each other
- Reducing overdimensioning of equipment

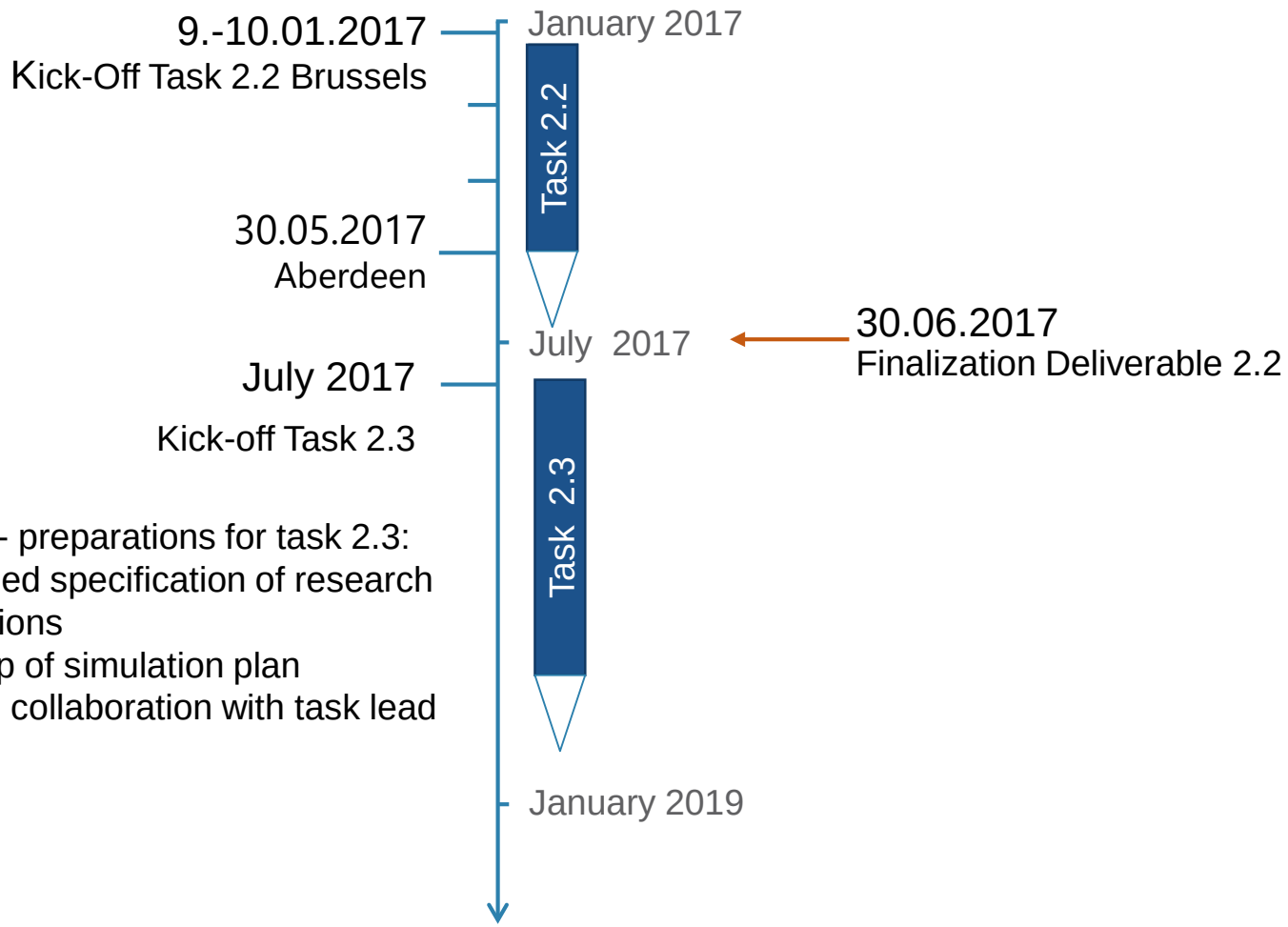
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Meetings



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Next Period



On going- preparations for task 2.3:

- Detailed specification of research questions
- Set-up of simulation plan
- Close collaboration with task lead

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Summary WP 2

- ✓ Specification of models and topologies completed
- ✓ Adaption of simulation models for planned simulative investigations
- ✓ On-going validation of simulation models
- ✓ Identification of open questions to be adressed within the field of WP 2
- ✓ Preparations for task 2.3 for a quick start of simulative investigations

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Thank you for your attention

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Work Package 3
Wind Turbine – Converters Interaction

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP3 Partners

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP3 Core Objectives

To develop reliable and cost-effective technology
for new type of offshore converter for wind power integration

To establish interoperability between different technologies and concepts by providing specific technical and operational requirements, behaviour patterns and standardization methods for different technologies

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP3 Objectives

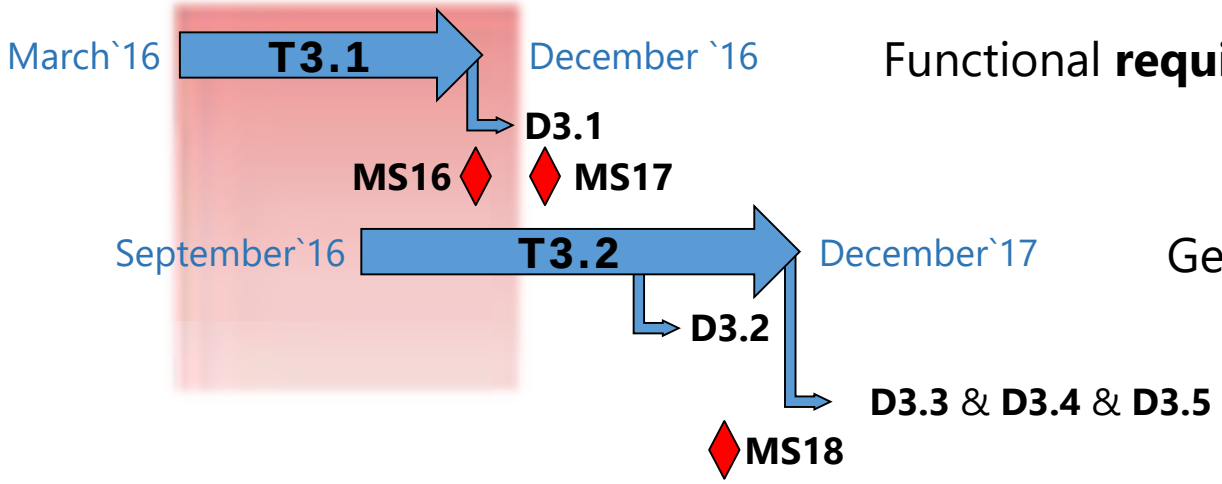
1. define functional **requirements** to OWFs,
   focusing on DR-HVDC case
2. develop general **control** algorithms for OWFs,
   focusing on DR-HVDC case
3. define and apply **compliance** evaluation procedures for OWFs
   by simulations

verify **interoperability** of the WT and OWF controls by simulations

generate **grid code recommendations** for DR-HVDC connection of OWFs

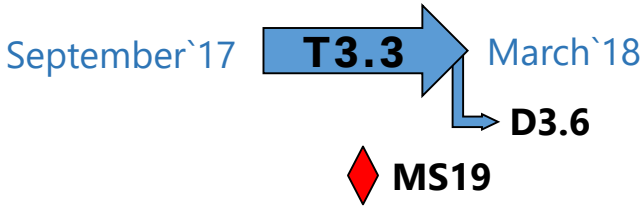
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP3 Plan

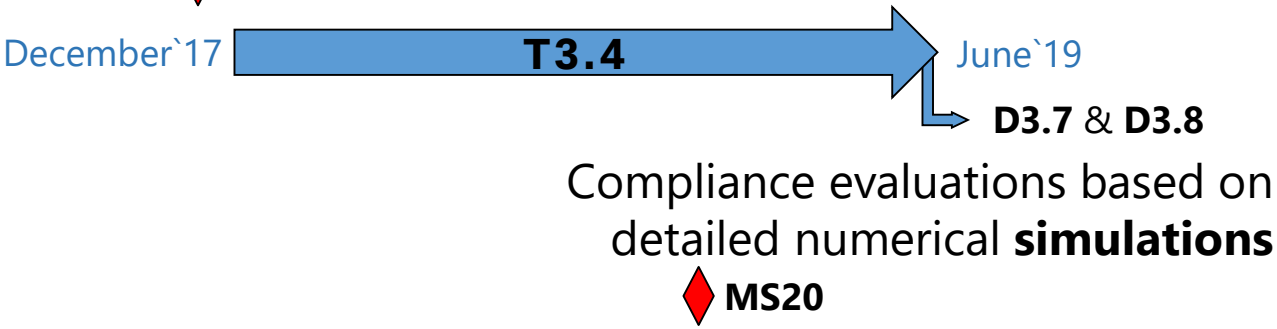


Functional **requirements** to WPPs

General **control** algorithms



Compliance evaluation procedure

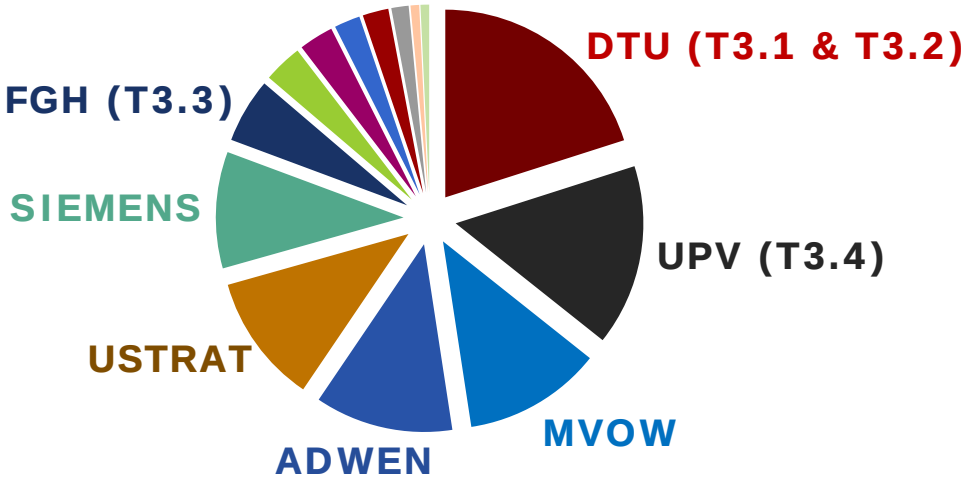


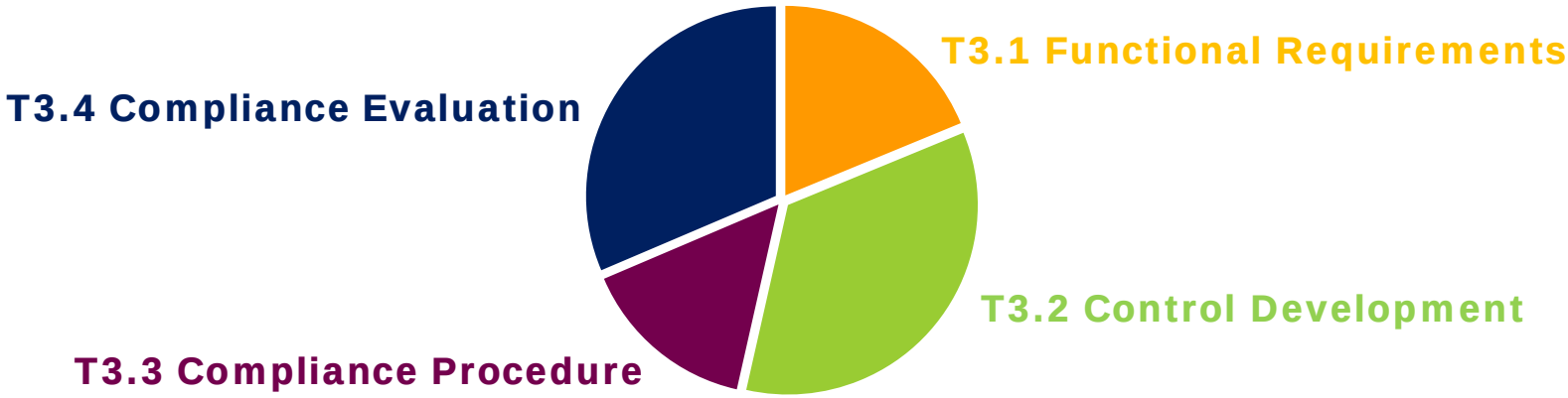
Compliance evaluations based on detailed numerical **simulations**

MS20

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

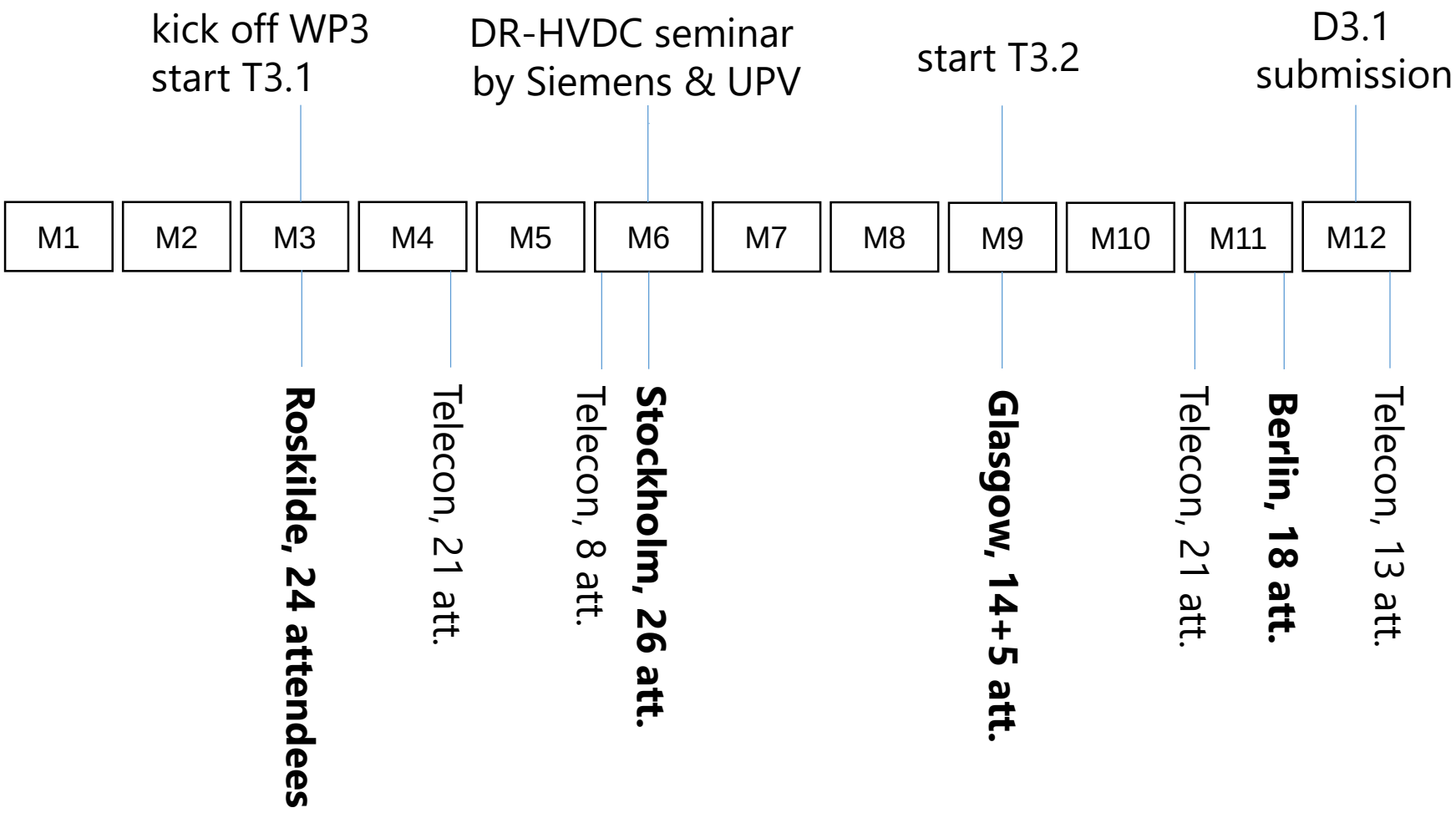
WP3 Resource Plan





© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP3 Meetings



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

D3.1 Detailed functional requirements to OWFs

qualitative D1.1 → elaborate & quantify: D3.1 with focus on DR-HVDC connection

OPERATIONAL REQUIREMENTS

- Operational States
- Start-up
- Voltage Ranges
- Frequency Ranges
- Rate of Change of Frequency Ranges
- Active Power Control
- Islanded Operation
- Harmonics
- Interoperability

SYSTEM STABILITY REQUIREMENTS

- Offshore frequency control/support
- Offshore voltage/reactive power control
- Offshore AC symmetrical/asymmetrical fault
  - Fault Ride-Through
  - Fault Current Injection
  - Post-Fault Recovery
- Onshore AC fault
  - Detection
  - Active Power Limitation
  - Active Power Recovery
- DC fault
  - Permanent DC Fault
  - Securely Cleared DC Fault
- Onshore frequency support/control
  - Fast Frequency Support
  - Synthetic Inertia
- Power Oscillation Damping to onshore AC grid

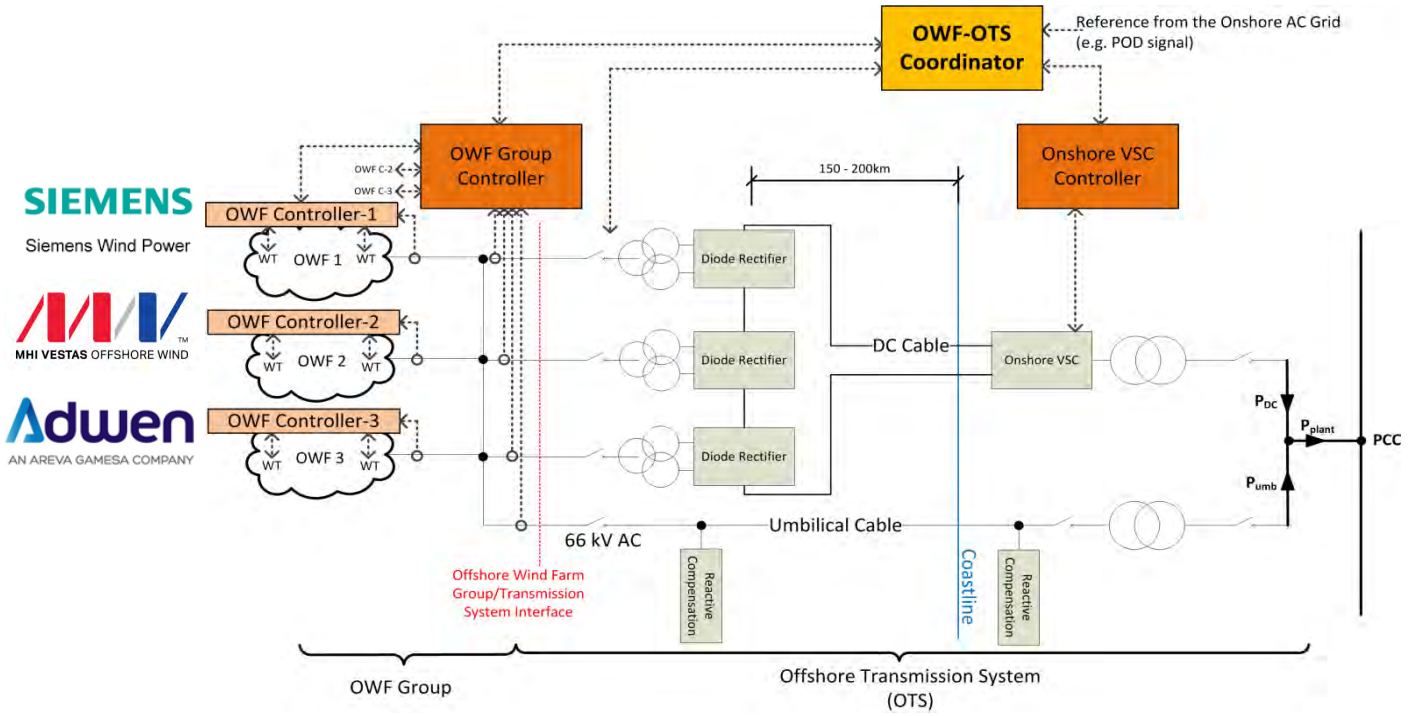
[ENTSO-E RfG and HVDC network codes and national grid codes have been utilized too]

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

D3.1 Detailed functional requirements to OWFs

D1.1 & D2.1 → case studies for DRU-HVDC connection → Task 3.2 Control Specs.

e.g. interoperability (with blackbox models)

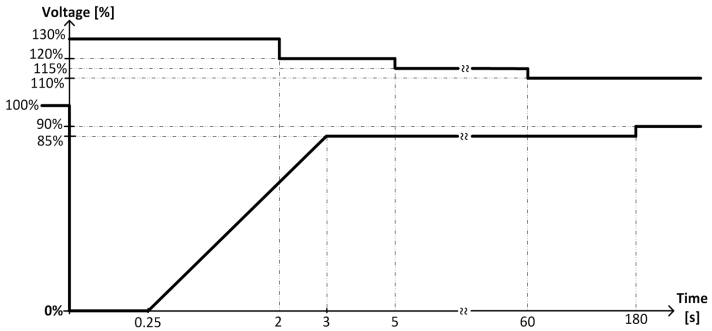


© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

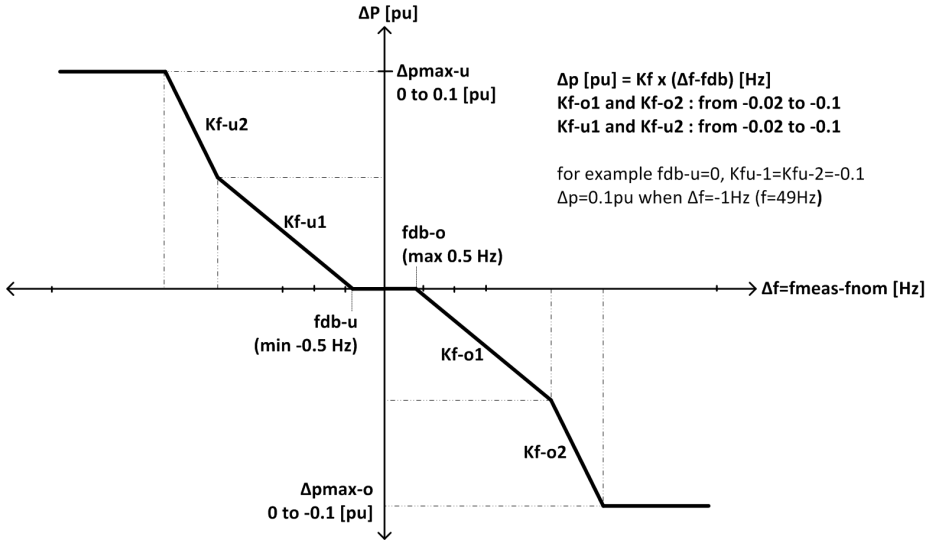
D3.1 Detailed functional requirements to OWFs

D3.1 → Task 3.2 Control Specifications → Modeling and Simulation Results

e.g. offshore fault-ride-through



e.g. frequency support to onshore grid

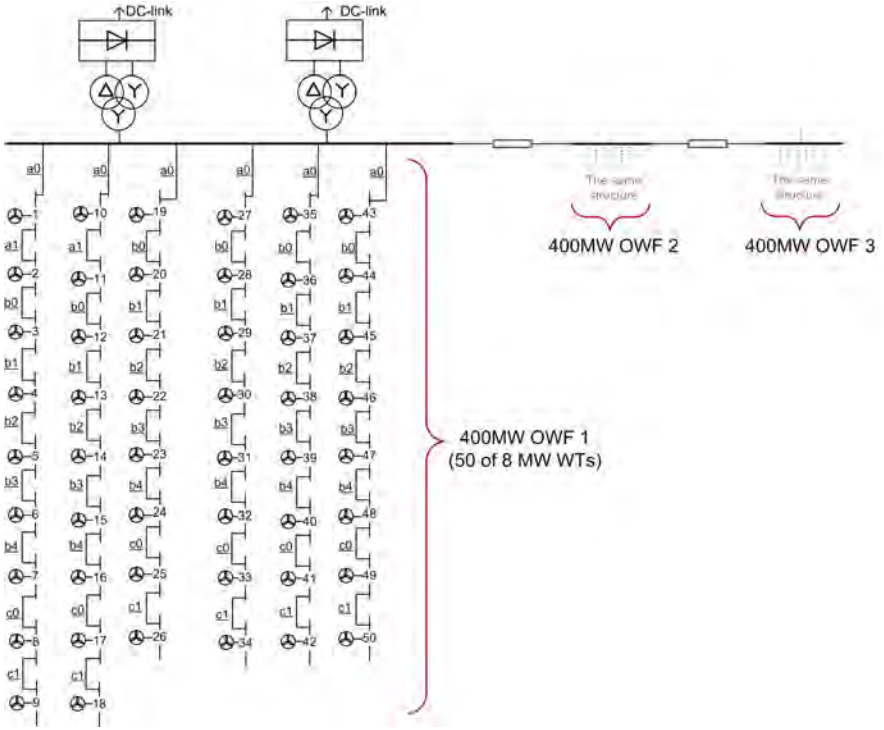


© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

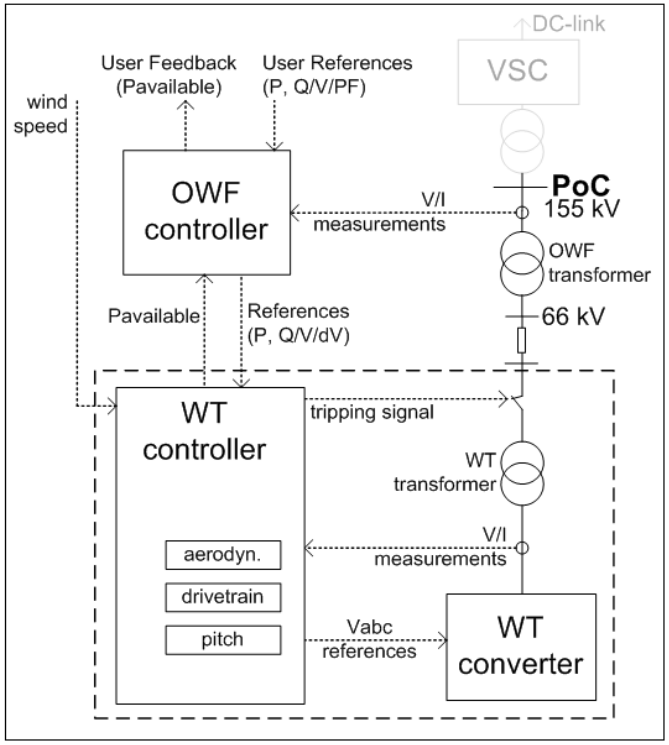
D3.1 Detailed functional requirements to OWFs

D3.1 → OWF Modeling for HVDC connection(s) → T3.2 Detailed Modeling

generic OWF layout



VSC-connected OWF model (to WP2)

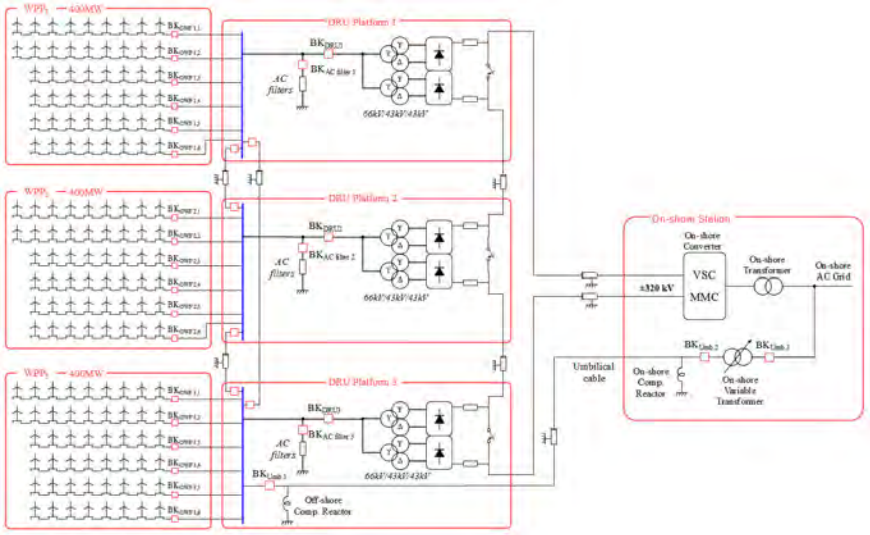


© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

T3.2 General control algorithms for OWFs

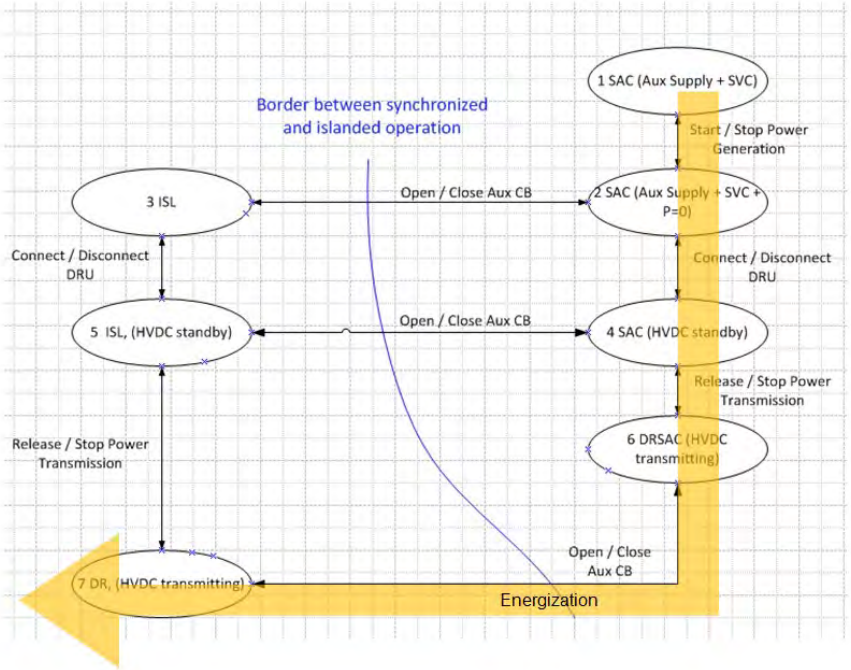
with focus on DRU-HVDC connection

[D3.2] Base line scenario with three DRU platforms



+ 7 levels of aggregation

[D3.2] Energization procedure



P.S.: Deliverable 3.2 is currently being submitted

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP3 Dissemination

Wind Integration Workshop, 15-17 November 2016

- **Connection of OWPPs to HVDC Networks Using VSCs and Diode Rectifiers: an Overview**
- **Modelling of the Diode-Rectifier Based HVDC Transmission Solution for Large Offshore Wind Power Plants Grid Access**
- **Simultaneous Connection of Type-3 and Type-4 Offshore Wind Farms to HVDC Diode Rectifier Units**

Offshore Wind Energy Conference, 6-8 June 2017

- **Generic Electrical Models for HVDC-connected Offshore Wind Power Plants**

Powertech, 18-22 June 2017

- **Asymmetrical Fault Analysis at the Offshore Network of HVDC connected Wind Power Plants**

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP3 Next Period (M13-M24)

T3.2 General control algorithms [M09-M24]

M15
- D3.2 (being submitted)
  Specifications of the control strategies and the simulations test cases

M24
- D3.3
  Models for control of WT/WPP connected to DR- HVDC — open models
- D3.4
  Operation of WPPs connected to DR- HVDC
- D3.5
  Performance of ancillary services provision from WPPs connected to DR-HVDC

— simulation results

T3.3 Compliance evaluation procedure [M21-M27]
(kick off September 2017)

T3.4 Compliance evaluations based on detailed numerical simulations [M24-M42]
(kick off December 2017)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Work Package 4
DC Grid protection system development

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Objectives

This WP aims to develop multivendor DC grid protection system. The goal is:

- to develop a set of functional requirements for various DC grids: from small scale to large overlay grids and for a variety of system configurations and converter topologies
- to analyse a wide range of DC grid protection philosophies on a common set of metrics
- to identify the best performing methods for the systems under study
- to develop detailed protection methodologies for the selected methods
- to develop configurable multi-purpose HVDC protection IEDs to enable testing of the methodologies
- to investigate the key influencing parameters of protection systems on the cost-benefit evaluation

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

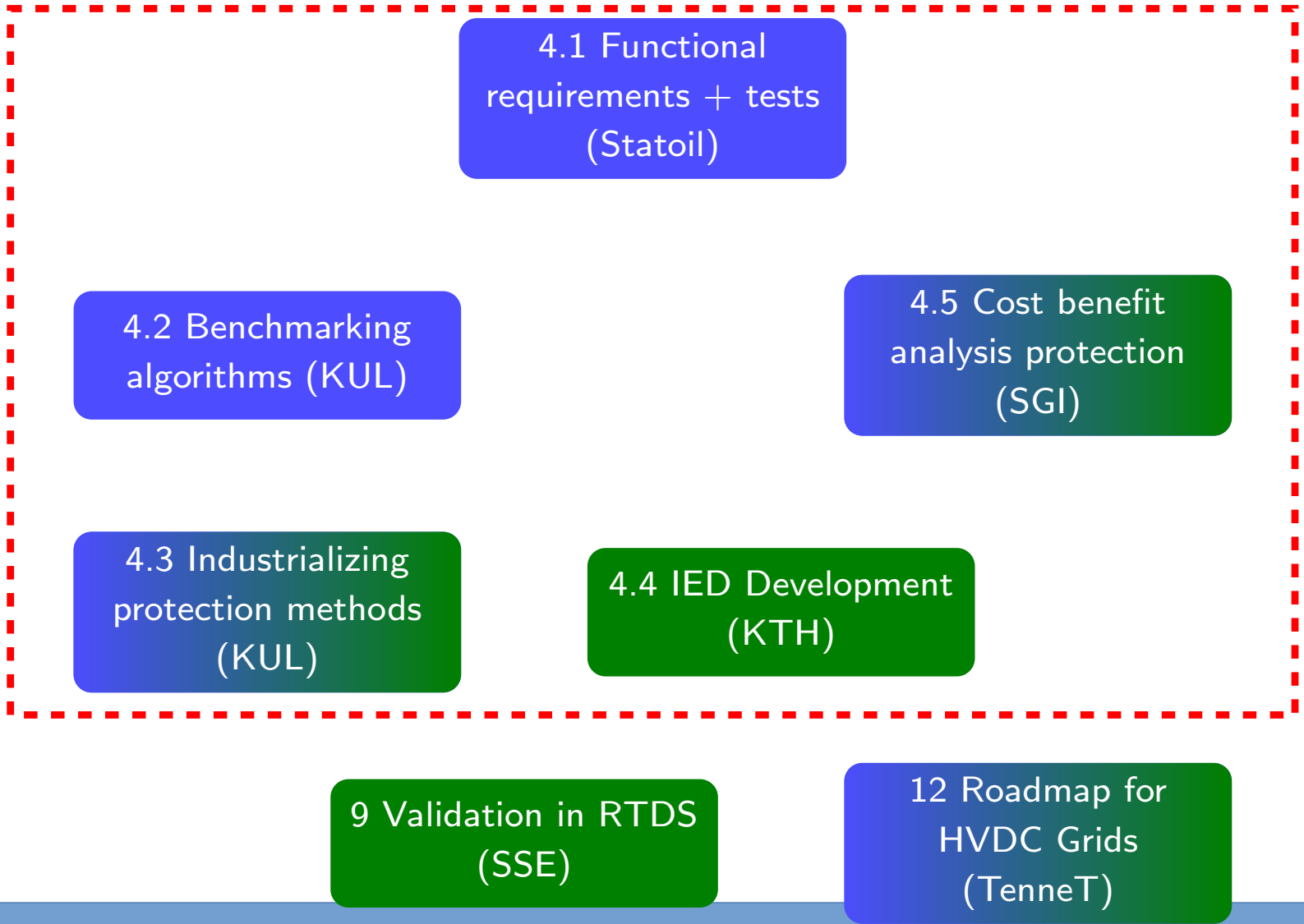
WP4 worktable

Task	LEAD	Description	Start	End
WP4	KUL	DC Grid protection system development	3	42
4.1	Statoil	Investigation and evaluation of fault detection and selectivity methods, towards functional requirements	3	12
4.2	KUL	Screening analysis of various protection methods for different topologies	8	20
4.3	KUL	In depth study of selected protection methods towards practical implementation	18	42
4.4	KTH	Development of configurable HVDC protection IEDs for multi-purpose and multi-vendor grid protection 0)	22	40
4.5	SGI	Preparation of cost/benefit analysis of studied protection solutions	3	42

- Large WP: 362 PM (in 2016 75.6 PM used)
- 18 partners
- Set up a core group to streamline efforts (bi-weekly meetings/telco)

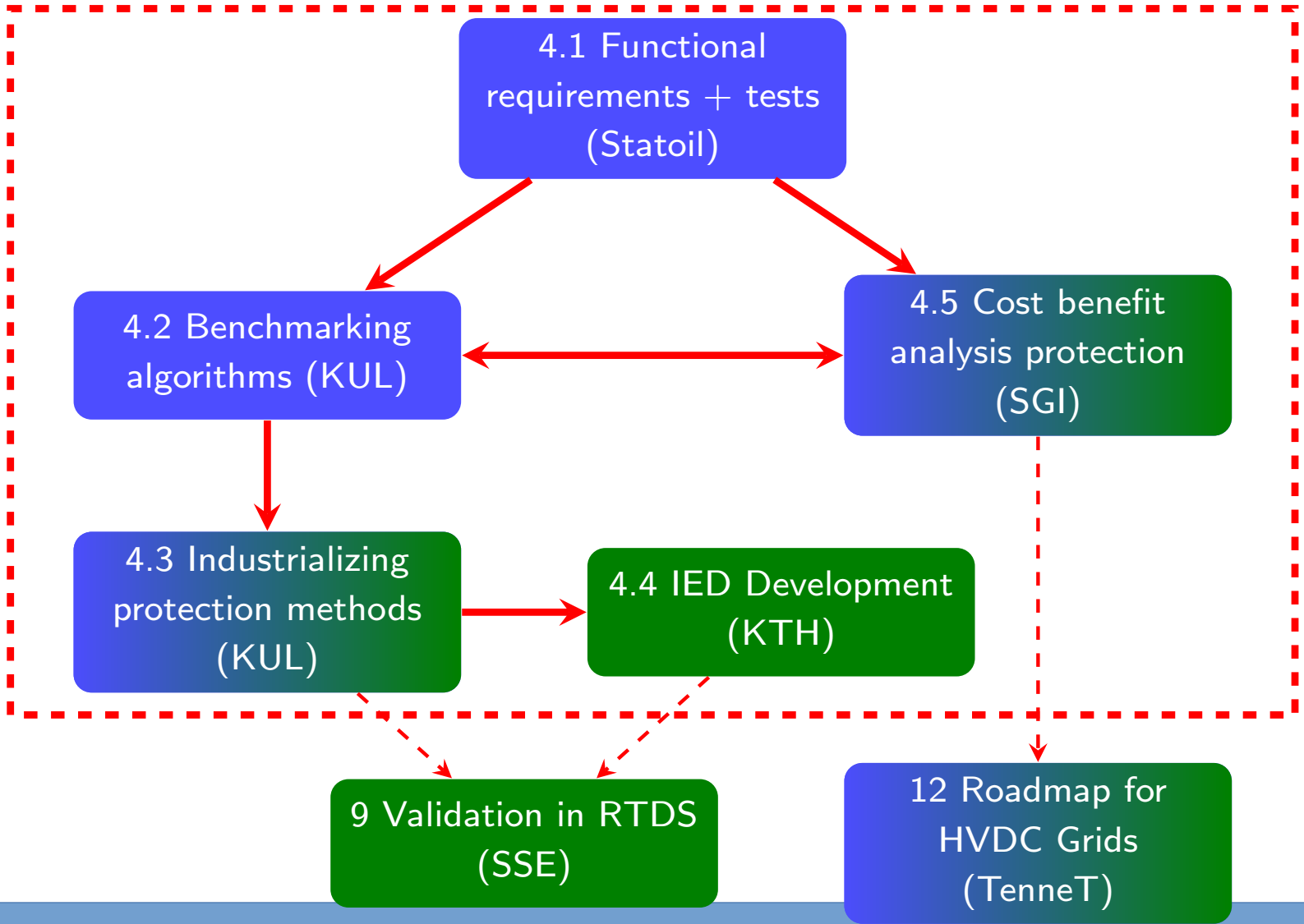
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Basic flows within Promotion related to WP4



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Basic flows within Promotion related to WP4



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Deliverables

- D4.1: Definition of representative test cases for DC grid protection and functional requirements for DC grid protection methodologies (M12)
- D4.2: Report on the broad comparison of protection philosophies for the identified grid topologies (M18)
- D4.3: Report on performance, interoperability and failure modes of selected protection methods (M36)
- D4.4: Preparation of protection methodologies for testing in the MTTE environment (M30)
- D4.5: Requirements for DC switchgear [joint deliverable with WP5] (M42)
- D4.6: Functional HVDC protection IED including documentation (M36)
- D4.7: Preparation of cost-benefit analysis from a protection point of view (M42)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Goal of D4.1

- Definition of representative test cases for DC grid protection and functional requirements for DC grid protection methodologies (M12)
- Objectives:
  - agree on how to design a protection system for DC systems, based on functional requirements
  - understand and agree about the interations in AC/DC grids for protection purposes
  - understand and agree on the main parameters which need to analysed
  - define benchmark networks and test cases to be able to create consistent benchmarks
  - agree on a common vocabulary
  - Very hard task (many opinions/stakeholders)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Delivery of D4.1

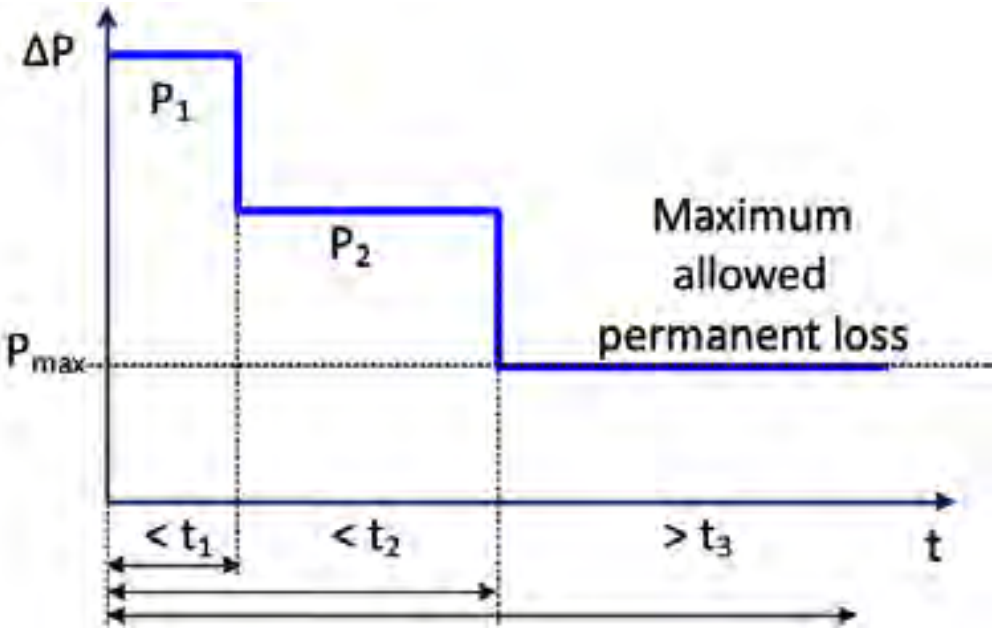
Iterative process to collect data from our partners on functional requirements

- Questionnaire sent out in April
- 10-12 responses received
- Internal discussions over the summer
- First proposal after the summer (London meeting)
- WP4 partner comments on functional requirements (October 1)
- 1st Expert meeting DC grid protection (WP1+WP4) October 4
- Aggregating inputs and sending them out in new version to all partners together with WP1
- Telephone conference to discuss feedback on the inputs (November 1)
- 2nd Expert meeting DC grid protection (WP1+WP4) November 15
- (3rd call for feedback, together with WP1, November 22)
- Near consolidated version 30/11
- Delivery to reviewers early January, submission to EU end of January

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Results from D4.1

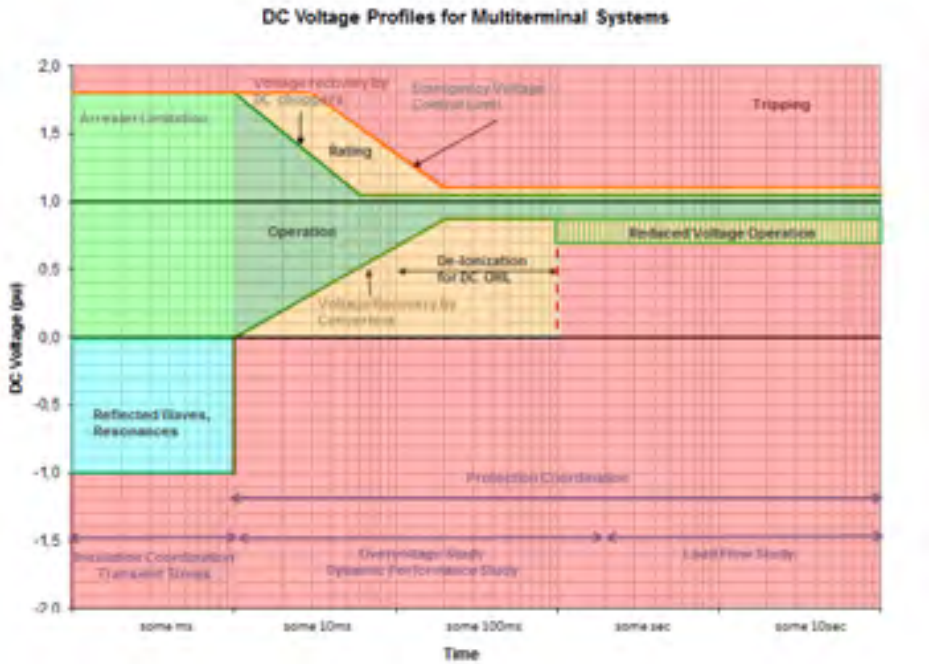
- Maximum loss of infeed is dependent on time
- Time intervals: few ms, hundred of ms, permanent
- Aligned with continuous operation, temporary stop or permanent stop during protection



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Results from 4.1 (II)

- Voltage specifications (at DC side) are necessary
- Specifications depend on a wide number of parameters
- Definition of continuous operation, temporary stop and permanent stop at DC side

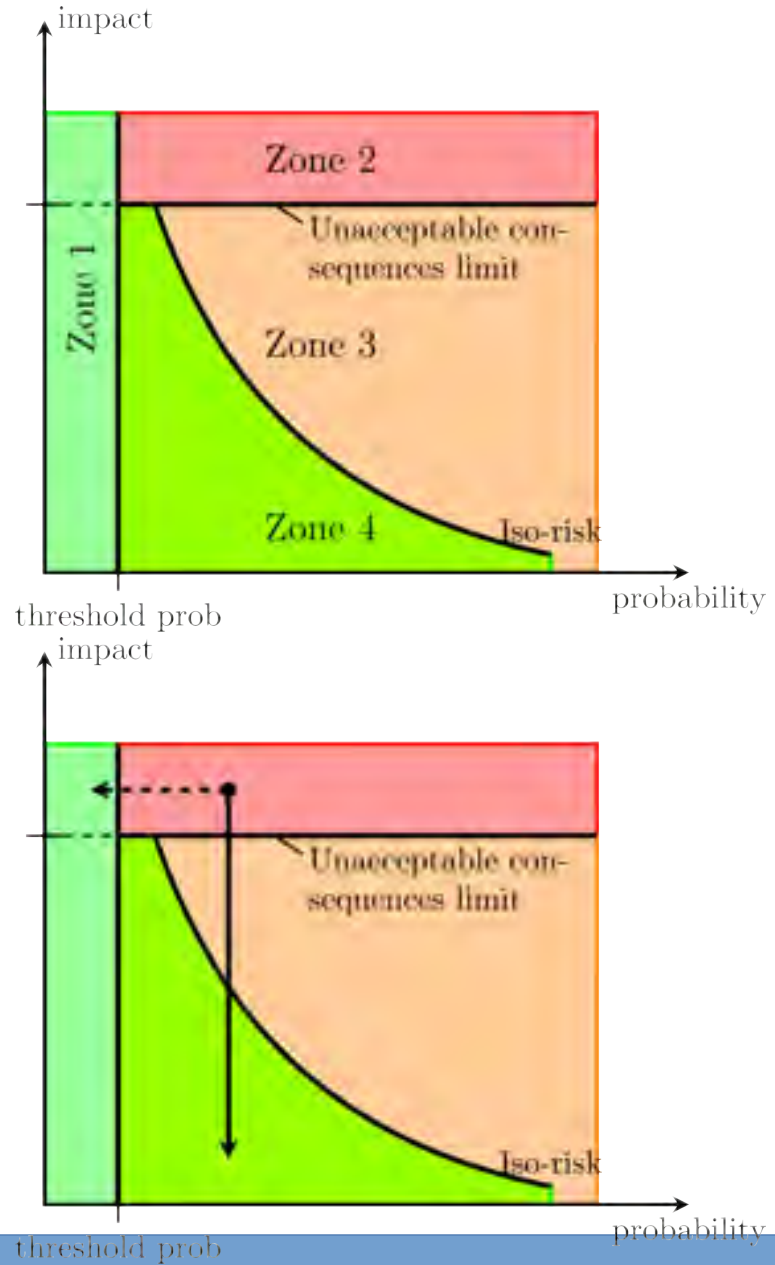


(source: Cigré B4-56)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Results from D4.1 (III)

- Zone 1: out of norm
  - Highly unlikely
  - No particular protection design to address them
- Zone 2: unacceptable consequences
  - High impact, high probability
  - Reduce probability or impact (e.g., by adapting system design or protections)
- Zone 3: unacceptable risk
  - Medium impact, med-high probability
  - Adapting protections needed
- Zone 4: acceptable risk
  - Low impact, med-high probability
  - No actions necessary



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Small, medium, large systems

"Small impact" grid: the loss of the whole HVDC grid will only have limited impact on the AC grids, seen as small voltage and frequency variations which are quickly restored. Loss of the system has an impact comparable to an "N-1" event.

"Medium impact" grid: the loss of the whole HVDC grid will cause significant voltage, rotor angle and frequency transients seen on the AC grid; AC grids are able to recover from the contingency, without black-out, but possible load shedding in part of the system.

"Large impact" grid: The DC grid forms the backbone of the transmission system and loss of this system likely leads to a blackout.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP4.2: Screening analysis for various protection methods for different topologies

- Step 1: a literature study of fault identification methodologies and protection philosophies
- Step 2: qualitative assessment of fault clearing strategies. Linking protection with specific systems (protection matrix concept)
- Step 3: quantitative (high level) assessment of fault clearing strategies
- Develop a benchmarking tool/approach for different protection methods
- Comparative study and analysis of different approaches, with different breaker technologies using protection matrices
- Robustness of schemes
- Backup approach
- Effect of inductors, OHL/Cable, grounding,... Cost elements? $\Rightarrow$ nr breakers needed, max operating speed allowed,... (input from WP4.5)
- Started September 2016, Deliverable 4.2 by M18
- Task Leader: Willem Leterme (KU Leuven)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP4.3: in-depth study of selected protection methods

- Start July 2017
- Select top ranked candidates
  - Do study towards practical implementation
- Including measurements, communication, noise management,. . .
- Multi-vendor application of protection methods
- Restoration after faults
- Standardization of operating ranges (with WP 6)
- Validate functional requirements
- "EMT" based studies
- Task Leader: KU Leuven

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP4.4: development of configurable HVDC protection IED for multi-purpose and multi-vendor DC grid protection

- Start October 2017
- Develop programmable IEDs which allow all protection methods of 4.3 to be implemented
- FPGA based solution
- Make sure it has a degree of "userfriendliness".
- To be used in the RTDS of WP9
- Task Leader: Staffan Norrga (KTH)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP4.5: Preparation of cost-benefit analysis for studied protection methods

- Provide initial indicators to evaluation done in 4.2
- Preparation towards delivery to WP12
- Initial indicators: nr of breakers, EENS, system losses? Volume of breakers offshore,...
- Goal: CBA of protection methods
- Tool developed by SGI, focusing on the reliability/protection aspects of HVDC grid protection strategies
- Methodology is described in an internal report
- In order to have realistic results, realistic data is necessary
- Cost data is very tricky to obtain
- Task Leader: Serge Poullain (SGI)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Dissimination

- Functional requirements were presented to outside stakeholders
  - Reference group meeting in Hamburg
  - Invited presentation at HVDC2016 conference in Shanghai
- General approval of the idea and concepts
  - Written feedback received from two partners
- Two contributions at IET ACDC 2017 (based on work in year 1)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP4: summary

- Kickoff meeting March 9, 2016, further meetings in July, September, November
- Tasks 4.1, 4.2 and 4.5 started
- Task 4.1: Finalized
  - Functional description of protection systems
  - Defining test systems
  - D4.1: delivered M13
- Task 4.2: Started
  - Benchmarking different options for protection
  - Which are the fault clearing strategies (literature review completed and assessment approach determined)
  - How to benchmark?
- Task 4.5: Started
  - Cost-benefit analysis of the protection aspect
  - Description of approach available
  - Providing input to task 4.2
  - Cost data!

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Questions?

Dirk Van Hertem
Dirk.VanHertem@esat.kuleuven.be

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

APPENDIX

DISCLAIMER & PARTNERS

COPYRIGHT

PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
MAIL info@promotion-offshore.net WEB www.promotion-offshore.net

The opinions in this presentation are those of the author and do not commit in any way the European Commission

PROJECT COORDINATOR

DVN GL, Kema Nederland BV
Utrechtseweg 310, 6812 AR Arnhem, The Netherlands
Fon +31 26 3 56 9111
Web www.dnvgl.com/energy

CONTACT

Dirk Van Hertem

KU Leuven/EnergyVille

dirk.vanhertem@esat.kuleuven.be

PARTNERS

Kema Nederland BV, ABB AB, Katholieke Universiteit Leuven, KTH Royal Institute of Technology, EirGrid plc, SuperGrid Institute, Deutsche WindGuard GmbH, Mitsubishi Electric Europe B.V., Affärsverket Svenska kraftnät, Alstom Grid UK Ltd (Trading as GE Grid Solutions), The University Court of the University of Aberdeen, Réseau de Transport d'Électricité, Technische Universiteit Delft, Statoil ASA, TenneT TSO B.V., German OFFSHORE WIND ENERGY Foundation, Siemens AG, Danmarks Tekniske Universitet, Rheinisch-Westfälische Technische Hochschule Aachen, Universitat Politècnica de València, Forschungsgemeinschaft für. Elektrische Anlagen und Stromwirtschaft e.V., Dong Energy Wind Power A/S, The Carbon Trust, Tractebel Engineering S.A., European University Institute, Iberdrola Renovables Energía, S.A., European Association of the Electricity Transmission & Distribution Equipment and Services Industry, University of Strathclyde, ADWEN Offshore, S.L., Prysmian, Rijksuniversiteit Groningen, MHI Vestas Offshore Wind AS, Energinet.dk, Scottish Hydro Electric Transmission plc

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Work Package 5
Test Environment for HVDC Circuit Breakers

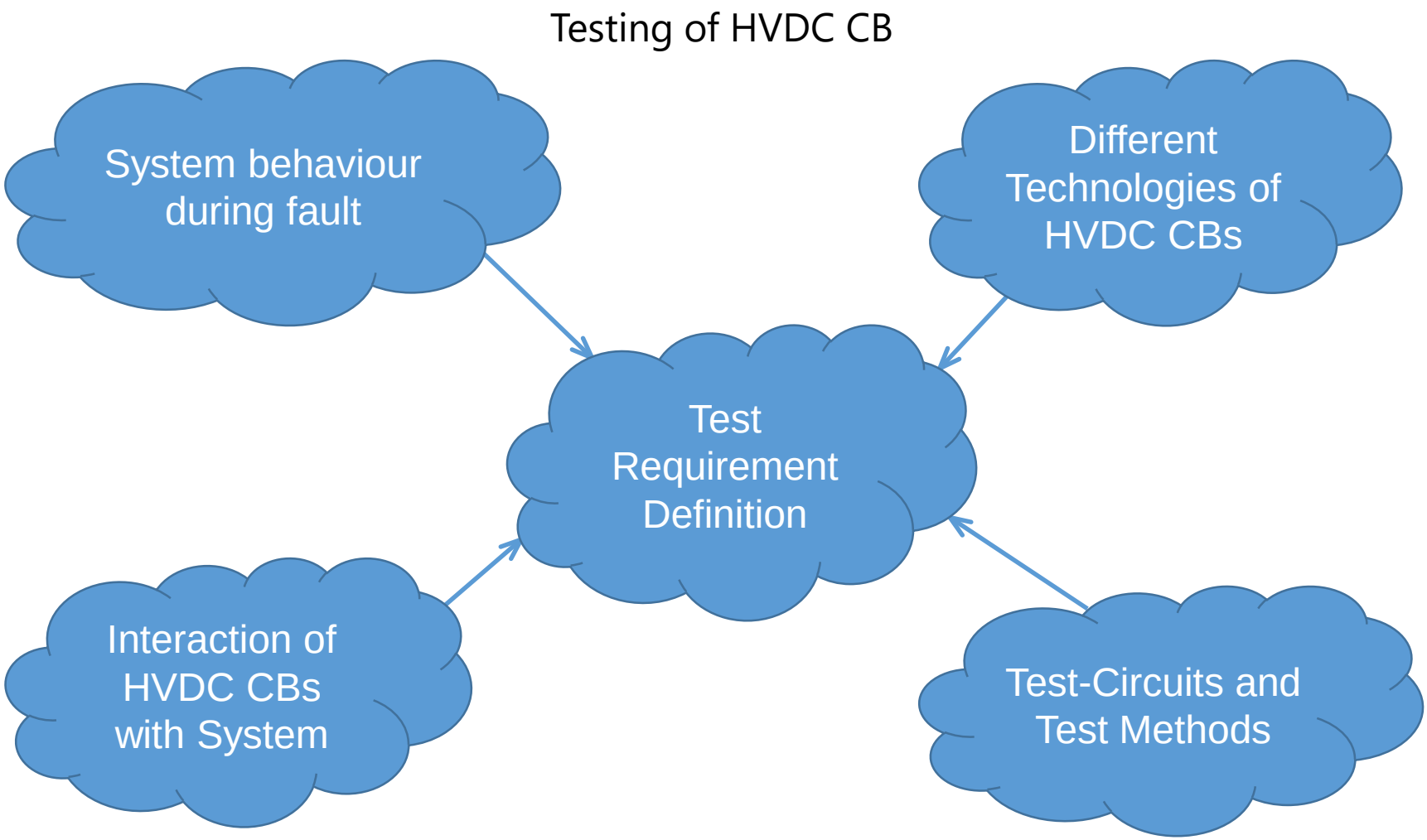
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

CONTENT

- Introduction
- Objective of WP5
- Works completed in 2016
- Works in progress

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP5 – Test environment for HVDC circuit breakers



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP5 – Test environment for HVDC circuit breakers

Partners: DNV GL (WP Leader), ABB, MEU, UniAbdn, TU Delft

Objectives:

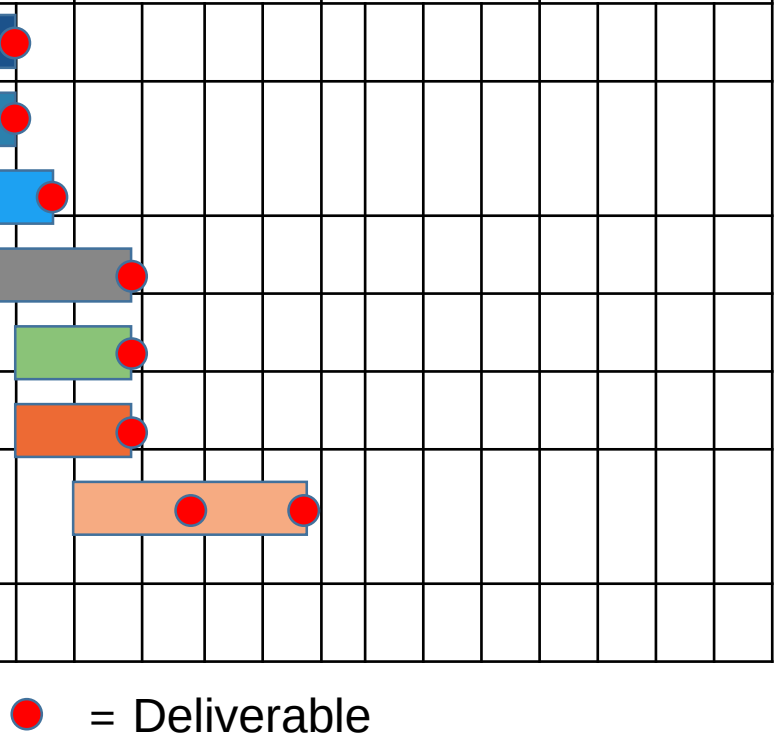
- ✓Identify **worst fault situations** in meshed HVDC grids
- ✓Produce dynamic, **black-box models** of HVDC circuit breakers of various technologies
- ✓Embed these models in a benchmark system to quantify the **electrical stresses** (current, voltage, energy) to which HVDC circuit breakers are subjected during a fault.
- Develop **test requirements and test procedures** for HVDC circuit breakers
- Investigate and compare different HVDC CBs test-circuits and methods
- Realize **high-power test-circuits** including the necessary equipment (components) specifically needed for HVDC testing.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP5 – Test environment for HVDC circuit breakers

Tasks and Deliverables

#	Task	2016	2017	2018	2019
5.1	DC fault analysis				
5.2	HVDC circuit breaker modelling and analysis				
5.3	Fault stress analysis				
5.4	Test requirement specification				
5.5	Definition of test procedures				
5.6	Characterization of candidate test-circuits				
5.7	Realization of test environment				



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 5.1 - HVDC Network Fault Analysis

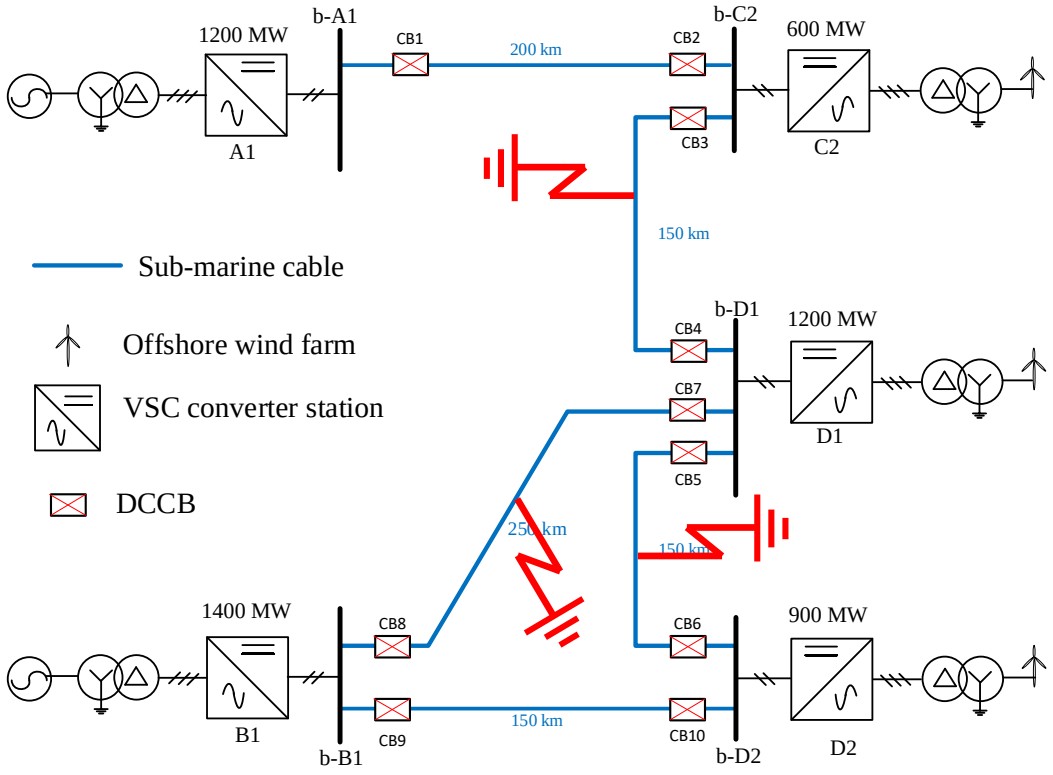
- **HVDC Network Study grid**

✓Five terminal HVDC grid with bipolar converter configuration

✓±320 kV, half bridge MMC converter topology

✓Only cable interconnection is considered

✓A pole-to-ground fault is investigated



- To identify worst case situations of faults from grid simulations

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

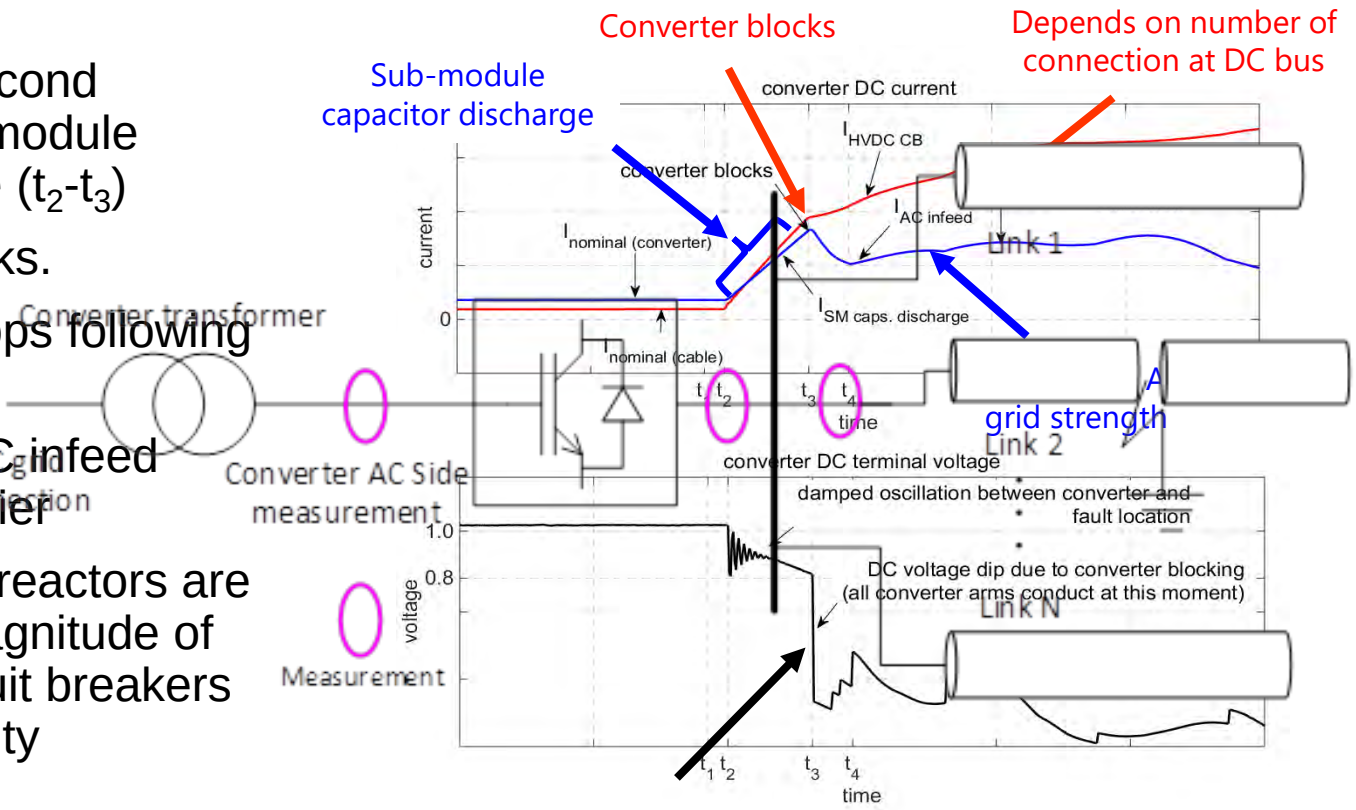
Task 5.1 - HVDC Network Fault Analysis

- Studied the impacts of various system and fault conditions
  - ✓Grid topology
  - ✓Fault location
  - ✓DC current limiting reactor
  - ✓AC network strength
  - ✓Converter blocking

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 5.1 - HVDC Network Fault Analysis

- The first few millisecond dominated by sub-module capacitor discharge (t_2-t_3)
- At t_3 converter blocks.
- The DC voltage drops following converter blocking
- From t_4 onwards AC infeed through diode rectifier
- DC current limiting reactors are used to limit the magnitude of fault current to circuit breakers interruption capability

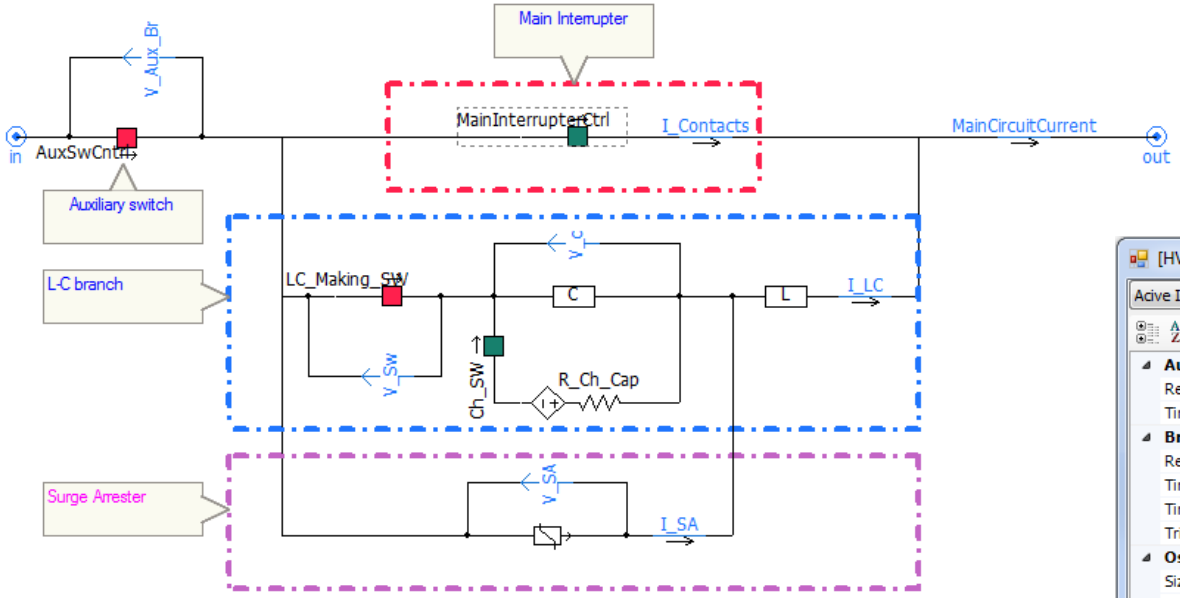


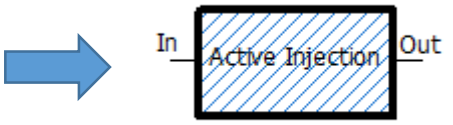
DC bus voltage drops
(all the six arms conduct)

- D5.1 Report describing the fault analysis (M09)

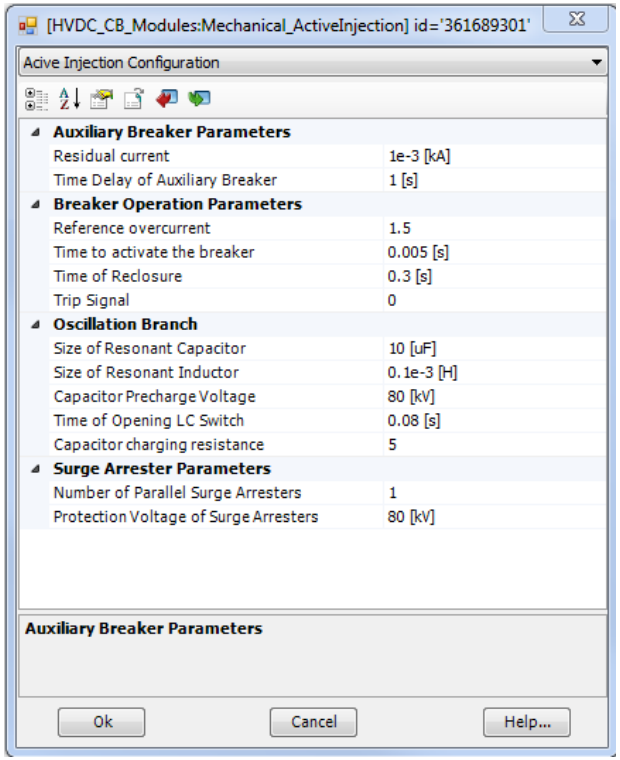
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 5.2 – Dynamic, blackbox models HVDC circuit breakers



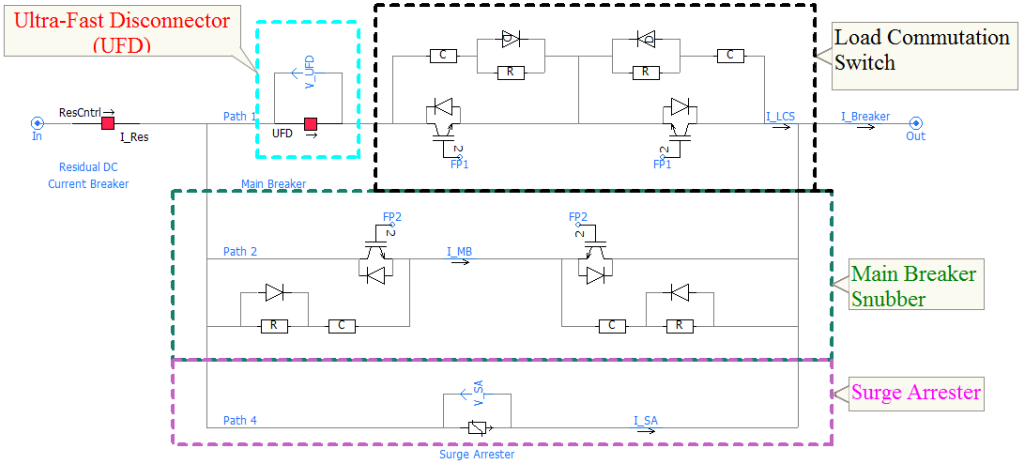


Active current injection HVDC CB

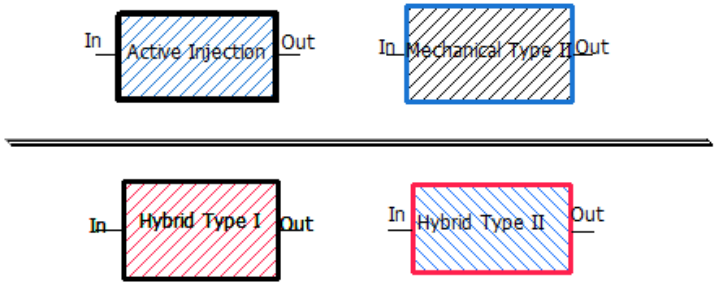


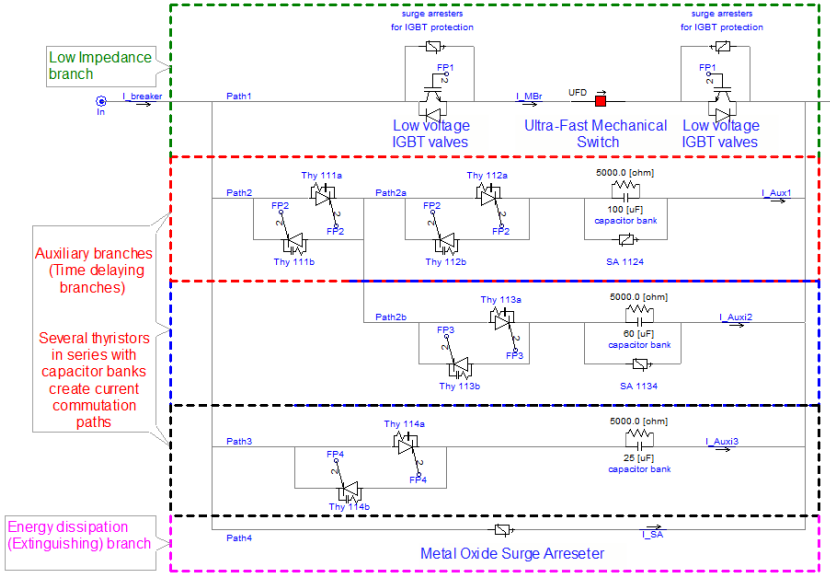
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 5.2 – Dynamic, blackbox models HVDC circuit breakers



Hybrid HVDC CB Type I





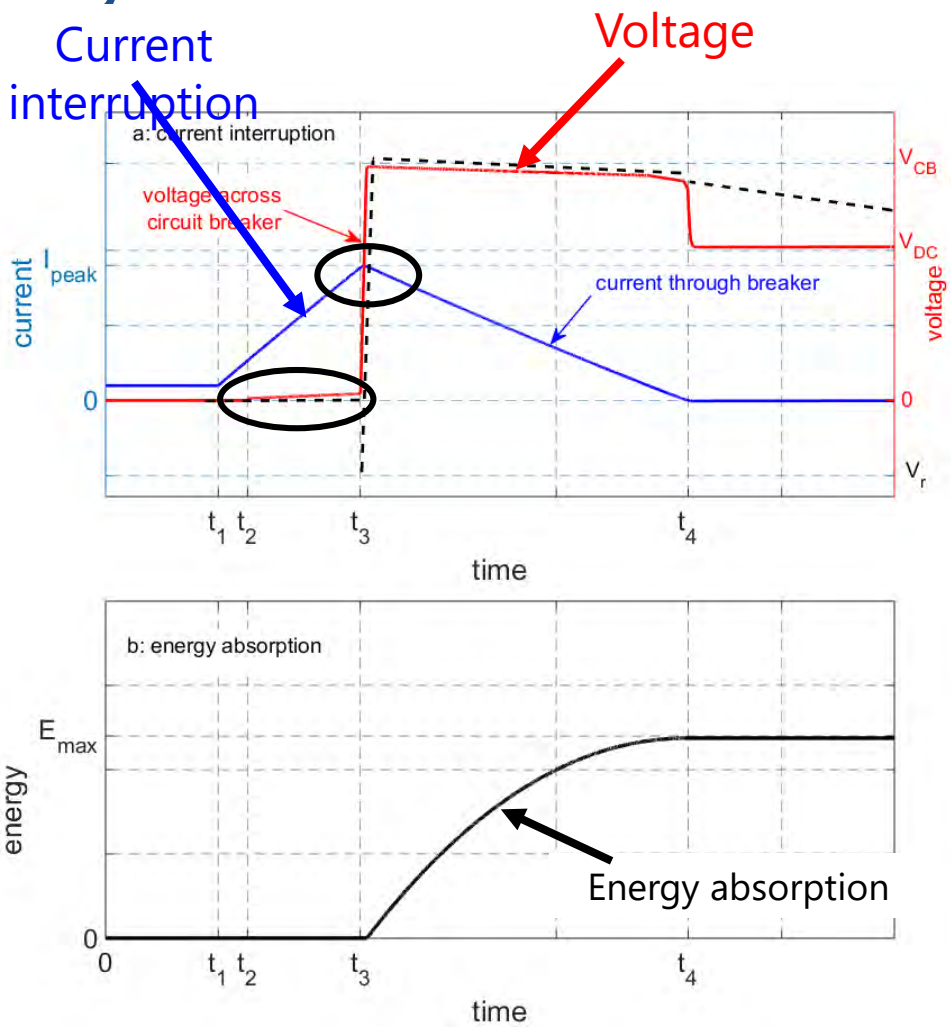
Hybrid HVDC CB Type II

D5.2 PSCAD Software models for the electrical behavior of the HVDC CB (M09)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 5.3 - Fault stress analysis

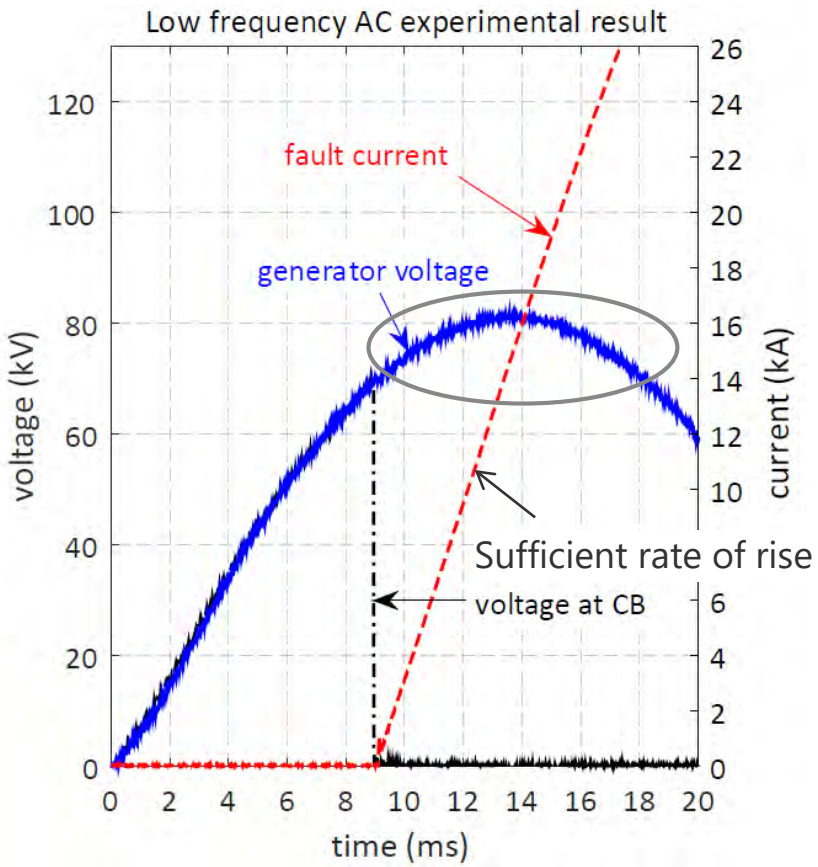
- Current interruption by various technologies of HVDC CBs have been studied
- The main transient stresses on HVDC CB are identified
- Breaker operation
- Maximum current interruption capability
- Energy absorption capability

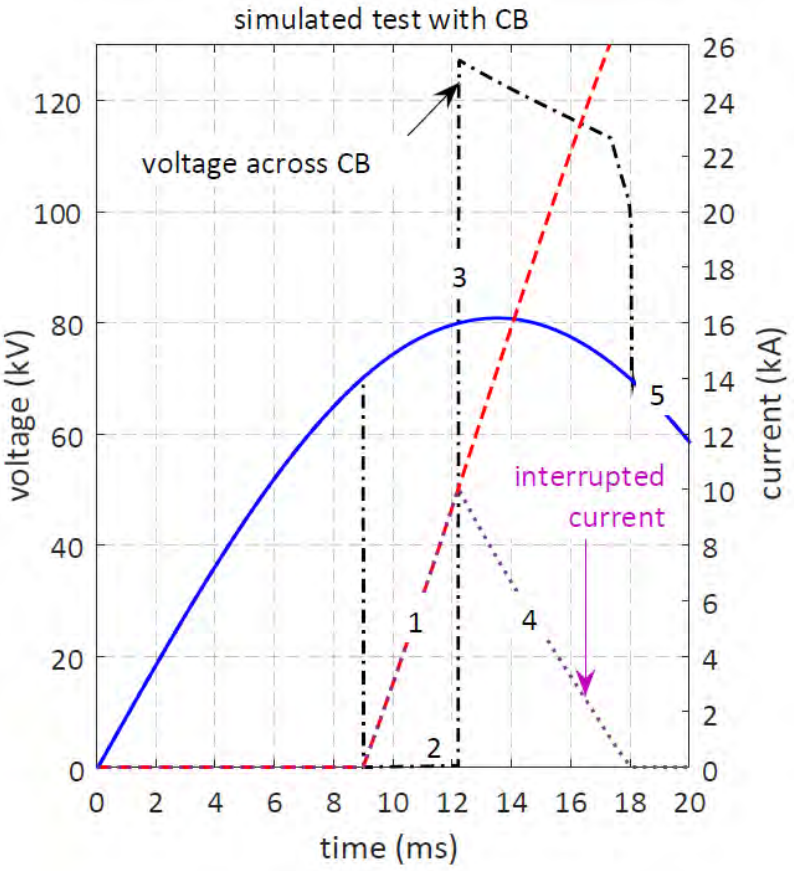


D5.3 Report on fault stress analysis for the various technologies - (M11)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 5.6 - Characterization of candidate test-circuits

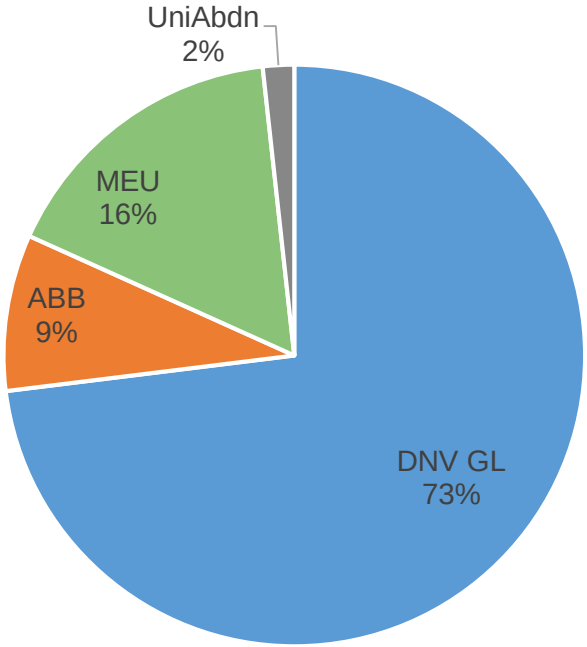




© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

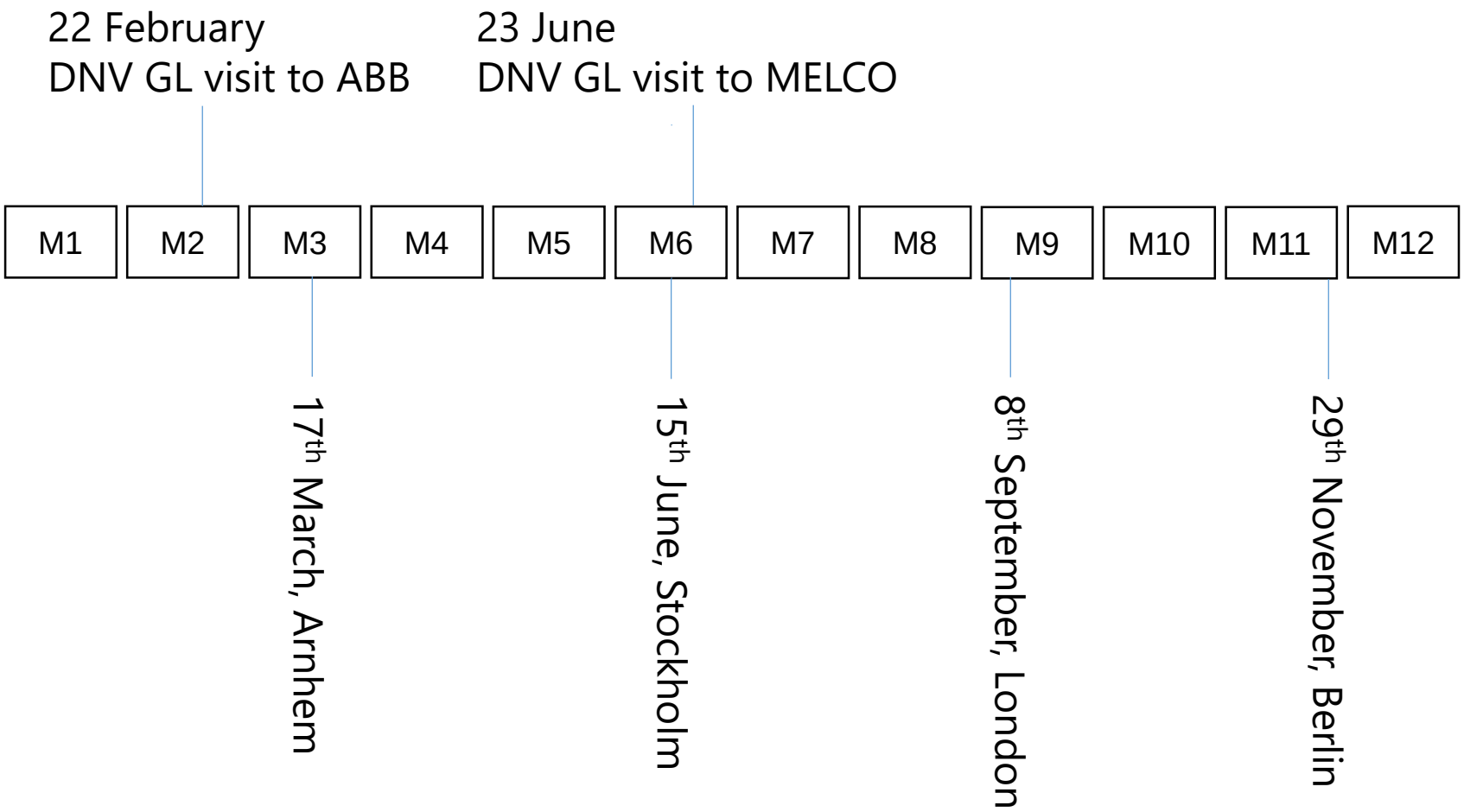
Contributions

- Work package lead
  - Project management
  - Modelling & simulations
  - Reporting D5.1, D5.2 & D5.3
- Contributing partner
  - Modelling & simulations
  - Reporting D5.1 & D5.3
- Reviewing partner
- Reviewing partner
- Reviewing partner



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Meetings



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Dissemination

- Journal paper: '*Test Circuits for HVDC Circuit Breakers*', N. A. Belda and R. P. P. Smeets, IEEE Trans. on Power Delivery, Vol. 32, No. 1, February 2017 285

- Guest lecture '*Testing of HVDC circuit breakers*' – EES-UETP - Universitat Politècnica de Catalunya – 15th December 2016

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Works in progress

- 5.4 Test requirement specification
- 5.4.1 Define different types of test
- 5.4.2 Determine test requirements
- 5.5 Definition of test procedures
- 5.5.1 Determine sequence, type, duty and frequency of tests
- 5.5.2 Determine pass/fail criteria
- 5.5.3 Determine measurements to be made
- 5.6 Characterization of candidate test-circuits
- 5.6.1 Identification of candidate test circuits
- 5.6.2 Comparison of candidate test circuits
- 5.6.3 Qualification of candidate test circuit

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Works in progress

- 5.7 Realization of test environment
- 5.7.1 Design and realisation of test circuit
- 5.7.2 Preliminary experiments
- 5.7.3 Commissioning of test circuit

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Thank you for your attention!

Questions?

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© TenneT TSO GmbH

Work Package 6
HVDC circuit breaker performance characterization

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP6 – HVDC Circuit Breaker Characterisation

Objectives:

- To develop and verify system-level offline model for hybrid and mechanical DC CB,
- To develop and verify detailed component level model for hybrid and mechanical DC CB,
- To develop and verify kW-size hardware prototypes for hybrid and mechanical DC CBs,
- To demonstrate DC CB failure modes on kw-size hardware prototypes,
- To develop roadmap for hybrid DC CB scaling to EHV DC voltage,
- To develop roadmap for mechanical DC CB scaling to EHV DC voltage.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP6 – HVDC Circuit Breaker Characterisation

	Tasks	Lead	partners
6.1	Develop system-level model for hybrid DC CB	UAbdn	ABB, SGI, DNV-GL
6.2	Develop system-level model for mechanical DC CB	DELFT	MEU, DNV-GL
6.3	Develop component-level and real-time model for hybrid DC CB	UAbdn	DELFT, ABB, DNV-GL
6.4	Develop component-level and real-time model for mechanical DC CB	DELFT	MEU, DNV-GL, UAbdn
6.5	Develop kW-size hardware prototypes for hybrid and mechanical DC CBs	UAbdn	ABB, DEFLT, DNV-GL
6.6	Demonstrate DC CB failure modes on kw-size hardware prototypes	UAbdn	DELFT
6.7	Develop roadmap for hybrid DC CB scaling to EHV DC voltage	UAbdn	ABB, DELFT
6.8	Develop roadmap for mechanical DC CB scaling to EHV DC voltage	DELFT	MEU

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP6 – HVDC Circuit Breaker Characterisation

WP6 Deliverables

- D6.1: Offline models for hybrid DC CBs (UniAbdn, M11) ***Delivered December 2016***
- D6.2: Offline models for mechanical DC CBs (TU Delft, M11) ***Delivered December 2016***
- D6.3: Detailed component-level model for hybrid DCCBs (UniAbdn, M24)
- D6.4: Detailed component-level model for mechanical DCCBs (TU Delft, M24)
- D6.5: Hardware prototypes of DC CBs (200V, 400A) at Uni. laboratory (UniAbdn, M30)
- D6.6: Demonstration and report on DC CB failure modes study (UniAbdn, M42)
- D6.7: Techno-economic roadmap for hybrid DC CB scaling to EHV DC voltage (UniAbdn, M42)
- D6.8: Techno-economic roadmap for mechanical DC CB scaling to EHV voltage (TU Delft, M42)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP6 – HVDC Circuit Breaker Characterisation

Meetings:

- Arnhem Netherlands, January 2016. 9 participants in person and 3 over phone.
- Aberdeen, UK, June 2016. 15 Participants.
- Teleconference, November 2016. 8 Participants.
- Berlin, Germany, November 2016. 17 Participants.
- DELFT, Netherlands, February 2017. 15 participants.

Deliverables completed:

- D6.1 Develop system-level model for hybrid DC CB
- D6.2 Develop system-level model for mechanical DC CB

Technical papers:

1. D Jovcic and M.H. Hedayati "DC Chopper based test circuit for high voltage DC circuit breakers" IET ACDC Power transmission, Manchester, February 2017,
2. A. Jamshidifar and D Jovcic "Modelling of Hybrid DC Circuit Breaker Based on Phase-Control Thyristors", IEEE PES GM, Chicago, July 2017.
3. M.H. Hedayati and D Jovcic "Low Voltage Prototype Design and Testing of Ultra-Fast Disconnector (UFD) for Hybrid HV DC CB" CIGRE B4 colloquium, Winnipeg 2017, - in review
4. A. Jamshidifar and D Jovcic Design, Modeling and Control of Hybrid DC Circuit Breaker Based on Fast Thyristors, IEEE Transactions on power Delivery, January 2017 – in review

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP6 – HVDC Circuit Breaker Characterisation

Contributions:

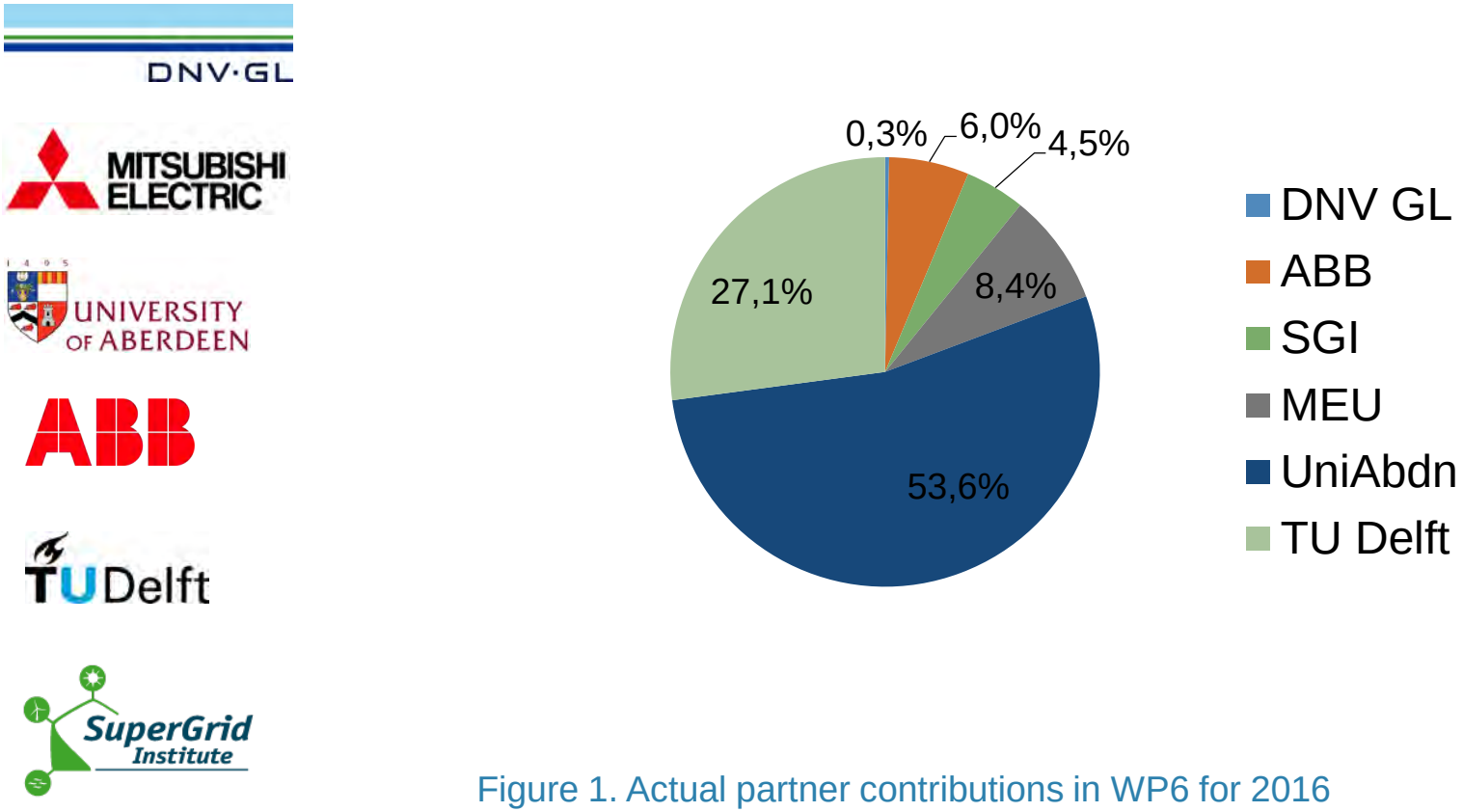


Figure 1. Actual partner contributions in WP6 for 2016

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 6.1 Modelling of Hybrid DC CB

Modelling IGBT Hybrid DC CB:

- Load Branch (Load switch and Ultrafast disconnector),
- Breaker Branch (Commutation switch),
- Energy Absorption Branch (Surge arresters),
- Residual current breaker,
- Series inductor,

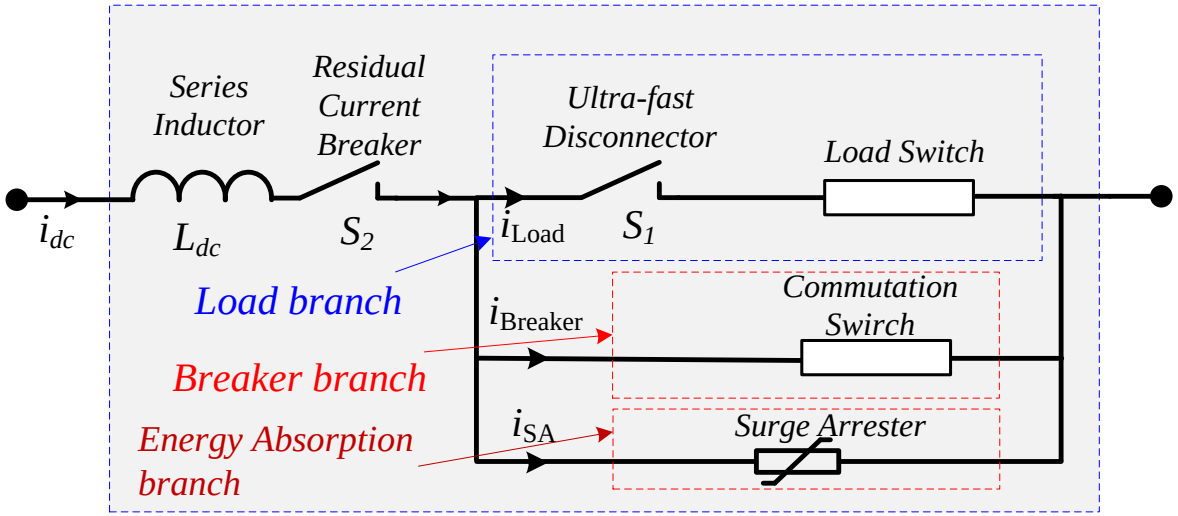


Figure 2. Structure of IGBT based hybrid DCCB

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 6.1 Modelling of Hybrid DC CB

Modelling IGBT Hybrid DC CB:

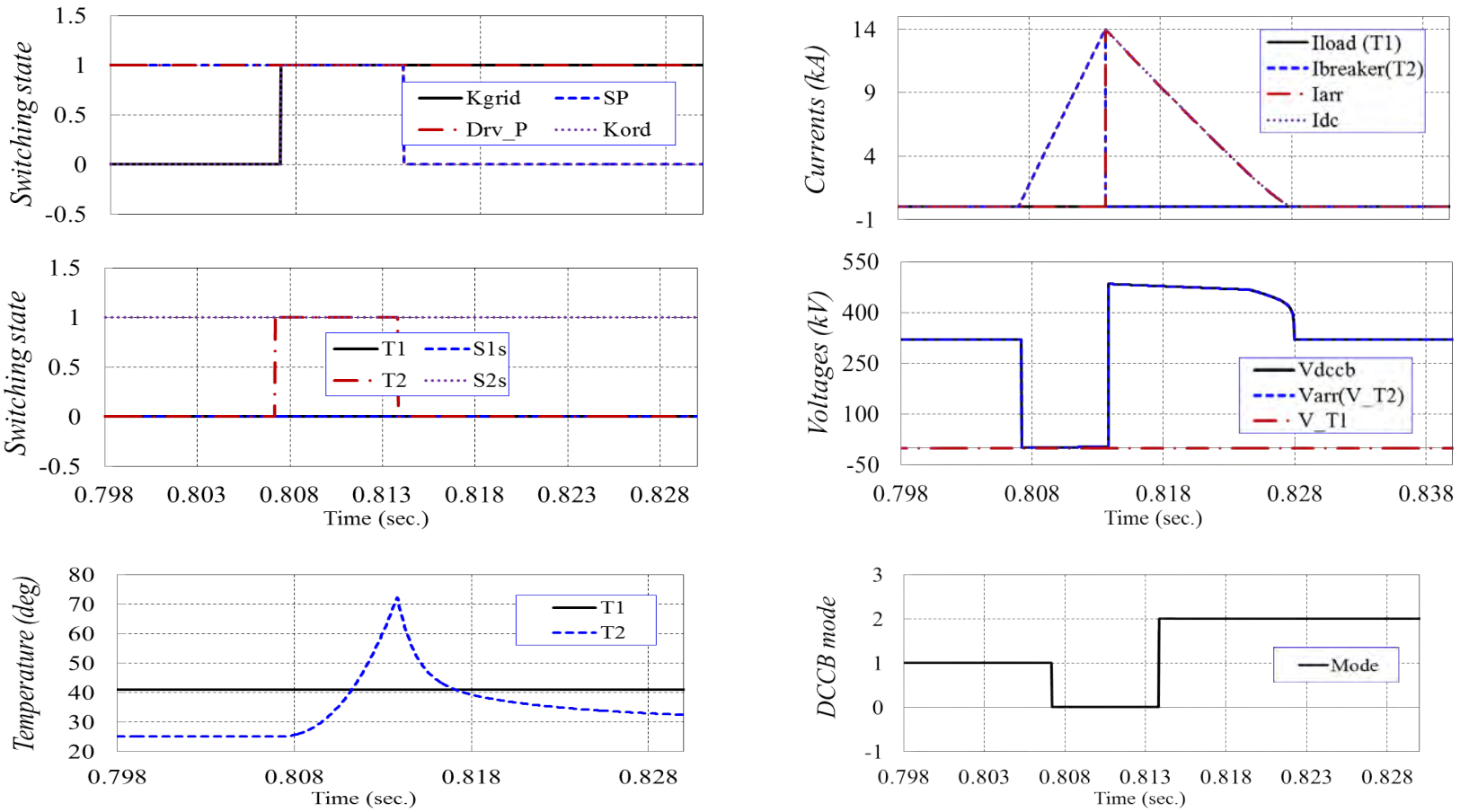


Figure 3. IGBT based Hybrid DC CB Simulation results for reclosing in fault

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 6.1 Modelling of Hybrid DC CB

Modelling thyristor hybrid DC CB:

- Load Branch (Load switch and Ultrafast disconnector),
- Breaker Branch (Time delaying branches with thyristors),
- Energy Absorption Branch (Surge arresters),
- Residual current breaker,
- Series inductor,

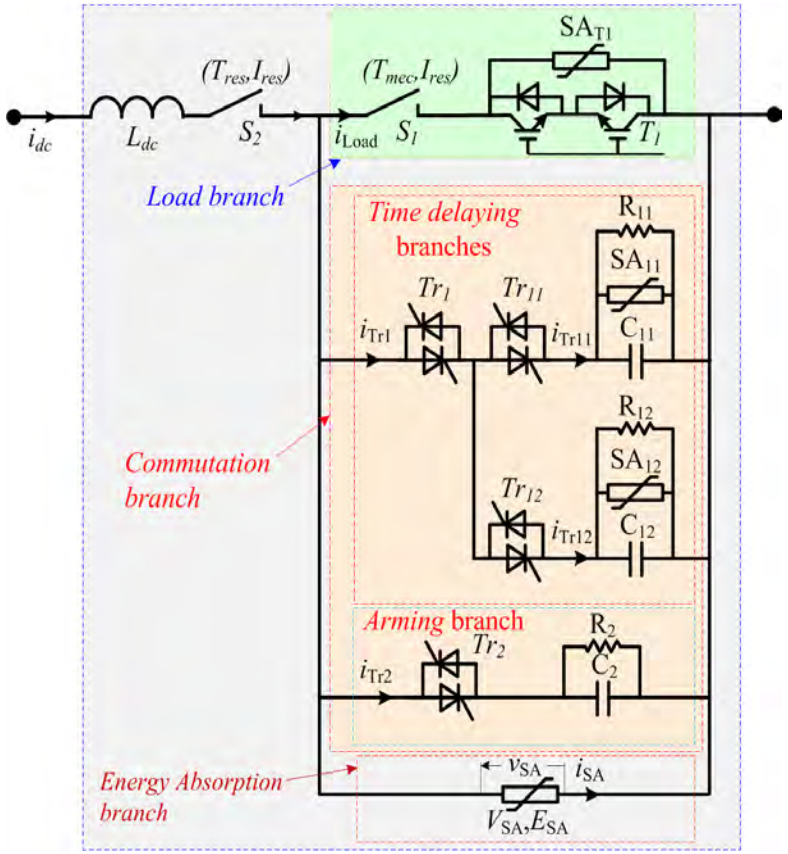


Figure 4. Structure of Thyristor based Hybrid DC CB

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 6.1 Modelling of Hybrid DC CB

Modelling thyristor hybrid DC CB:

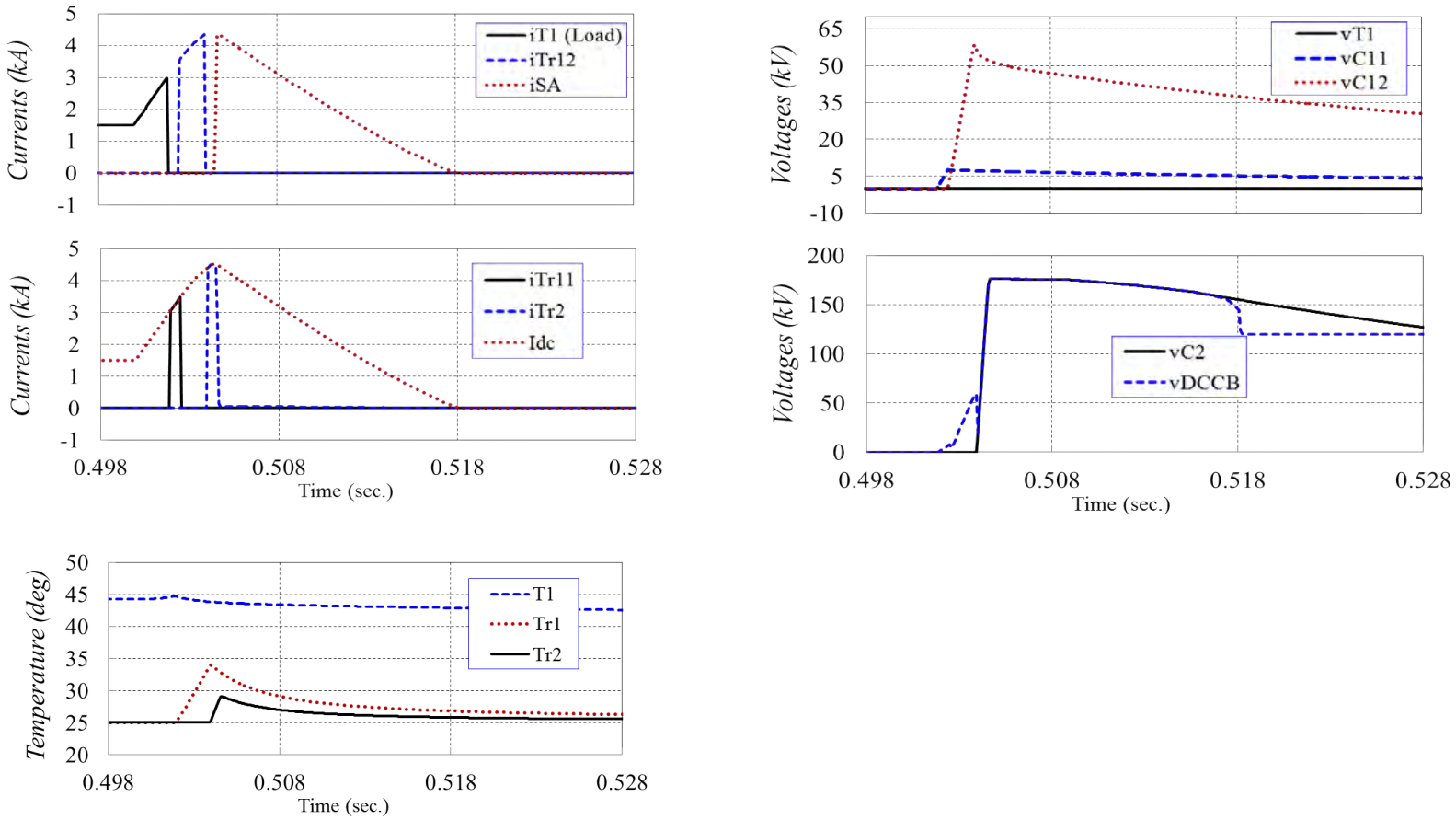


Figure 5. Thyristor based Hybrid DC CB Simulation results for opening

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 6.2 Modelling of Mechanical DC CB

Modelling mechanical DC CB:

- Main branch (main interrupter),
- Current injection branch (high speed making switch, capacitor, inductor),
- Energy Absorption Branch (Surge arresters),
- Residual current interrupter,
- Series inductor,

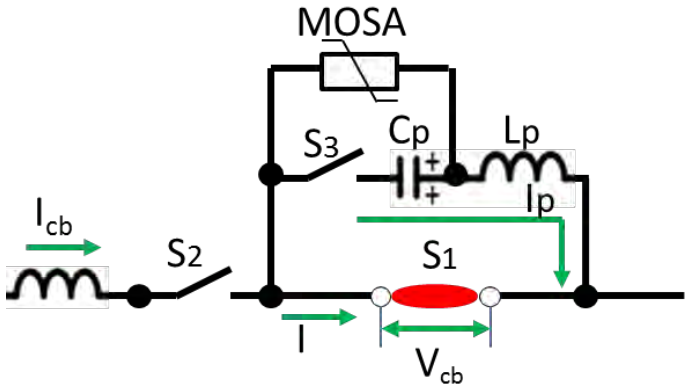
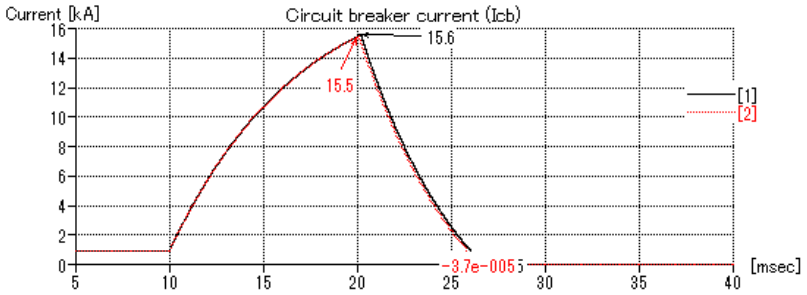


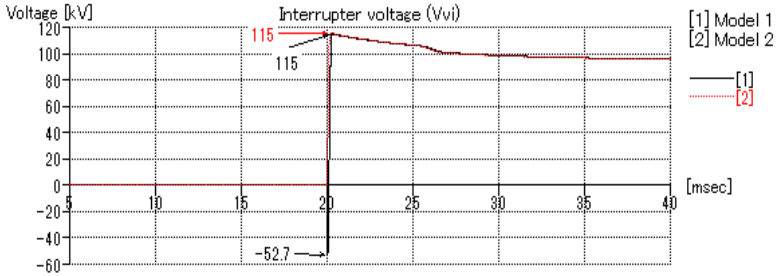
Figure 6. Structure of mechanical DCCB with active resonance.

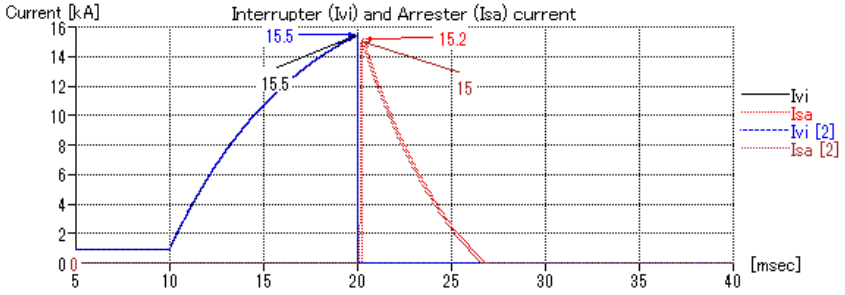
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 6.2 Modelling of Mechanical DC CB

Modelling mechanical DC CB







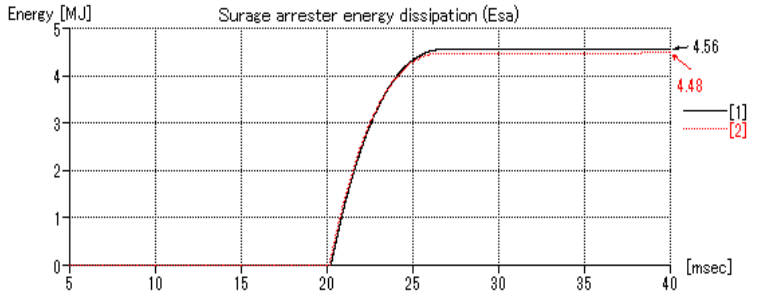


Figure 7. Simulation comparison of model 1 and model 2 for mechanical DC CB.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 6.5 Develop kw-size hardware prototypes for hybrid and mechanical DC CB

Ultrafast disconnector for hybrid DC CB

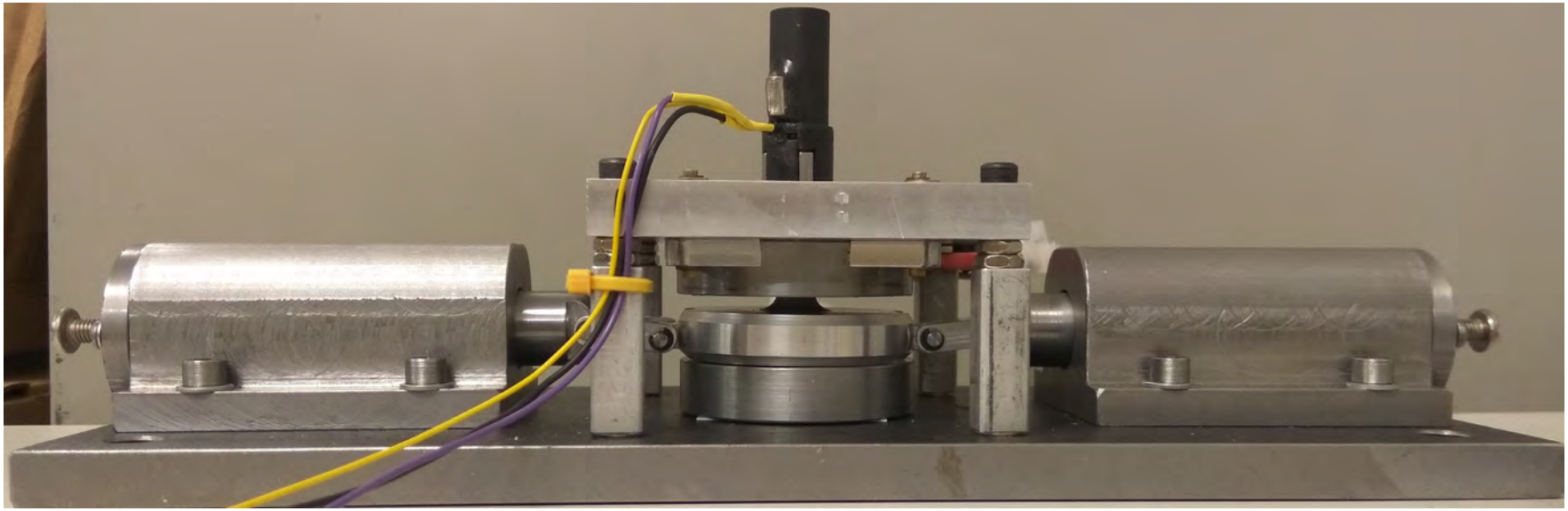


Figure 8. Ultrafast disconnector for hybrid DC CB.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 6.5 Develop kw-size hardware prototypes for hybrid and mechanical DC CB

Ultrafast disconnector for hybrid DC CB

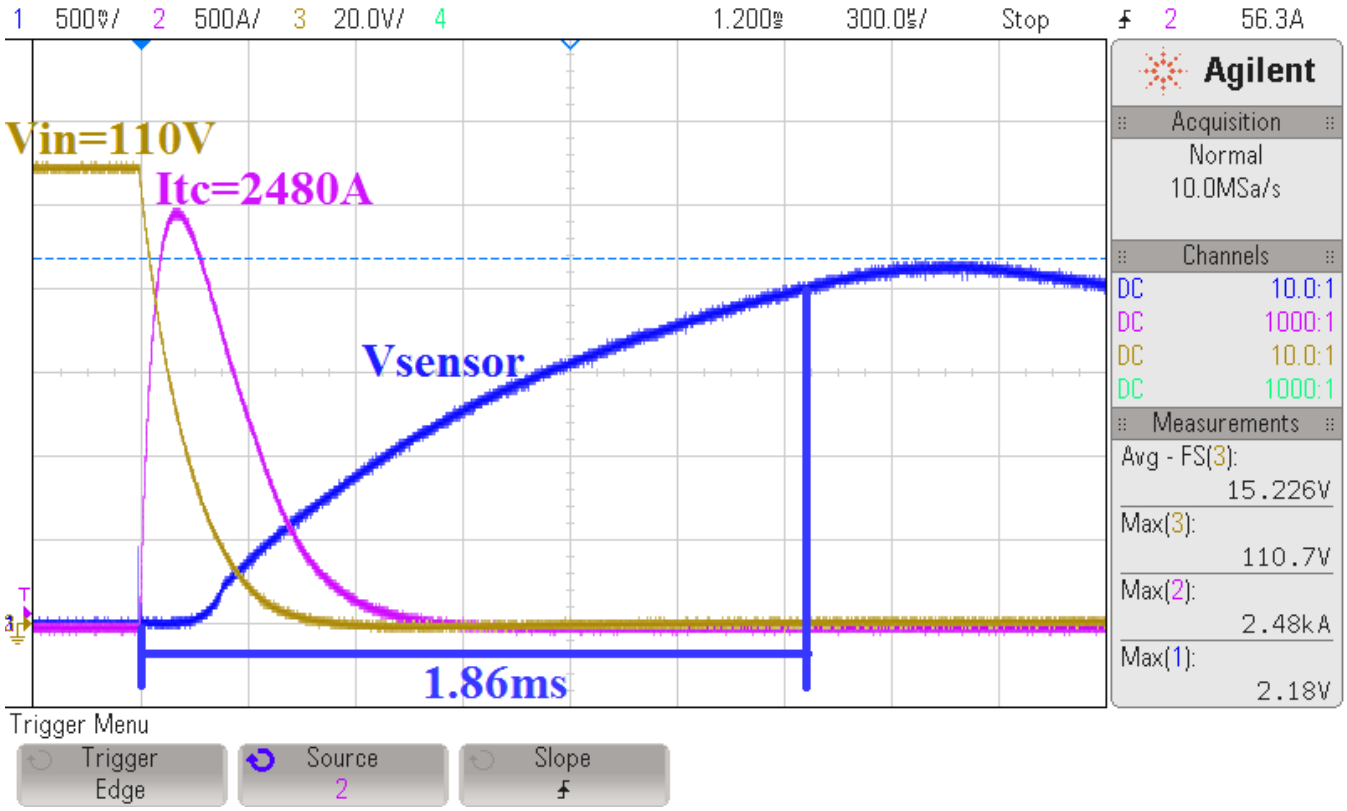


Figure 8. Experimental tests for ultrafast disconnector.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 6.5 Develop kw-size hardware prototypes for hybrid and mechanical DC CB

Test circuit for DC CBs

- Provides 500A peak DC Current, 900V DC voltage, and 2500J,
- Testing load conditions and fault conditions,
- DSP controlled, fast DC voltage control,
- Supports testing fast repeated operations,

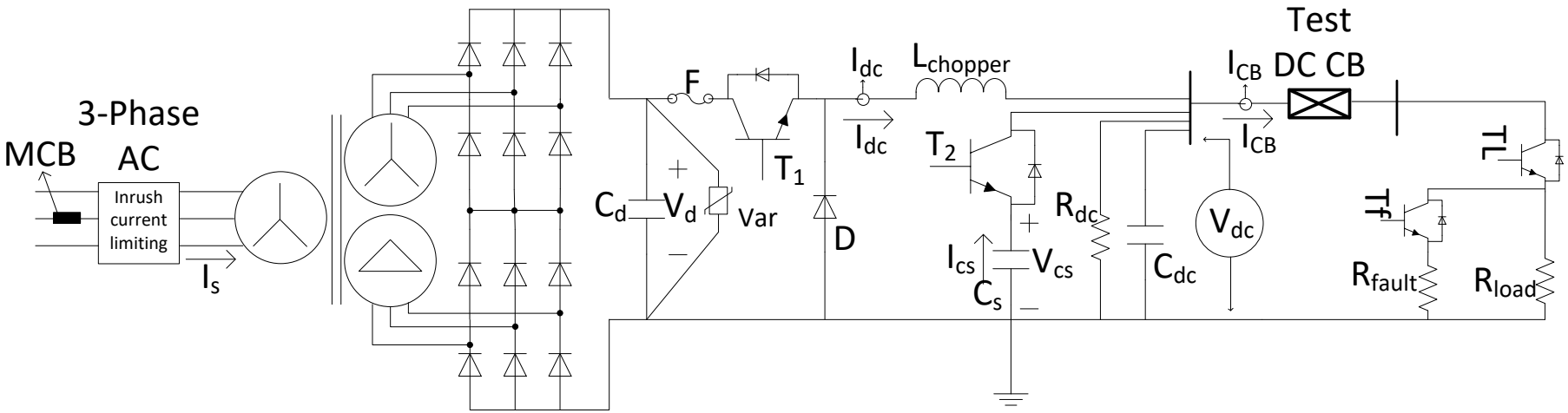


Figure 10. Experimental test circuit for DC CB.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 6.5 Develop kw-size hardware prototypes for hybrid and mechanical DC CB

Test circuit for DC CBs

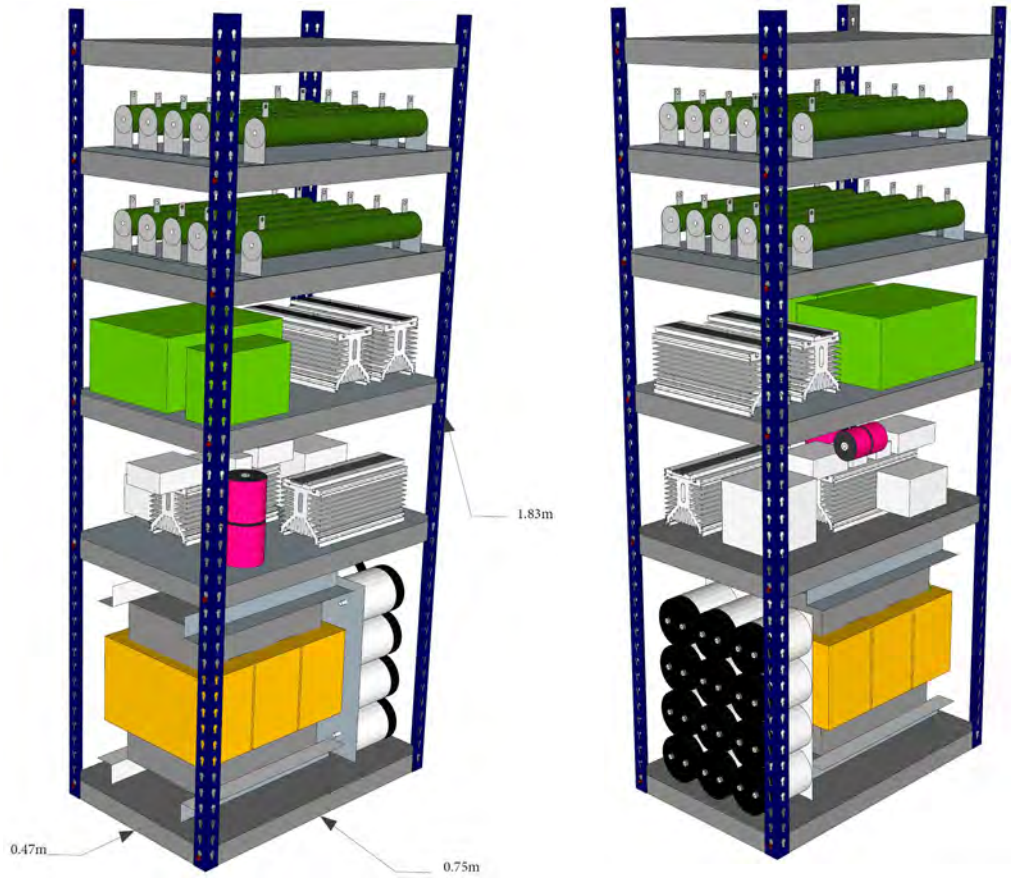


Figure 11. Layout of experimental test circuit for DC CB.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP6 – HVDC Circuit Breaker Characterisation

Future work:

- Task 6.3 Develop component-level and real-time model for hybrid DC CB
- Task 6.4 Develop component-level and real-time model for mechanical DC CB
- Task 6.5 Develop kW-size hardware prototypes for hybrid and mechanical DC CBs
- Inclusion of Scibreak
- Possible Task 6.9. Develop DC CB self-protection, repeated operation and general testing

- Next meeting: Aberdeen 31st May 2017.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Work Package 7
Regulation and Financing

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP7 – Development of a EU target framework

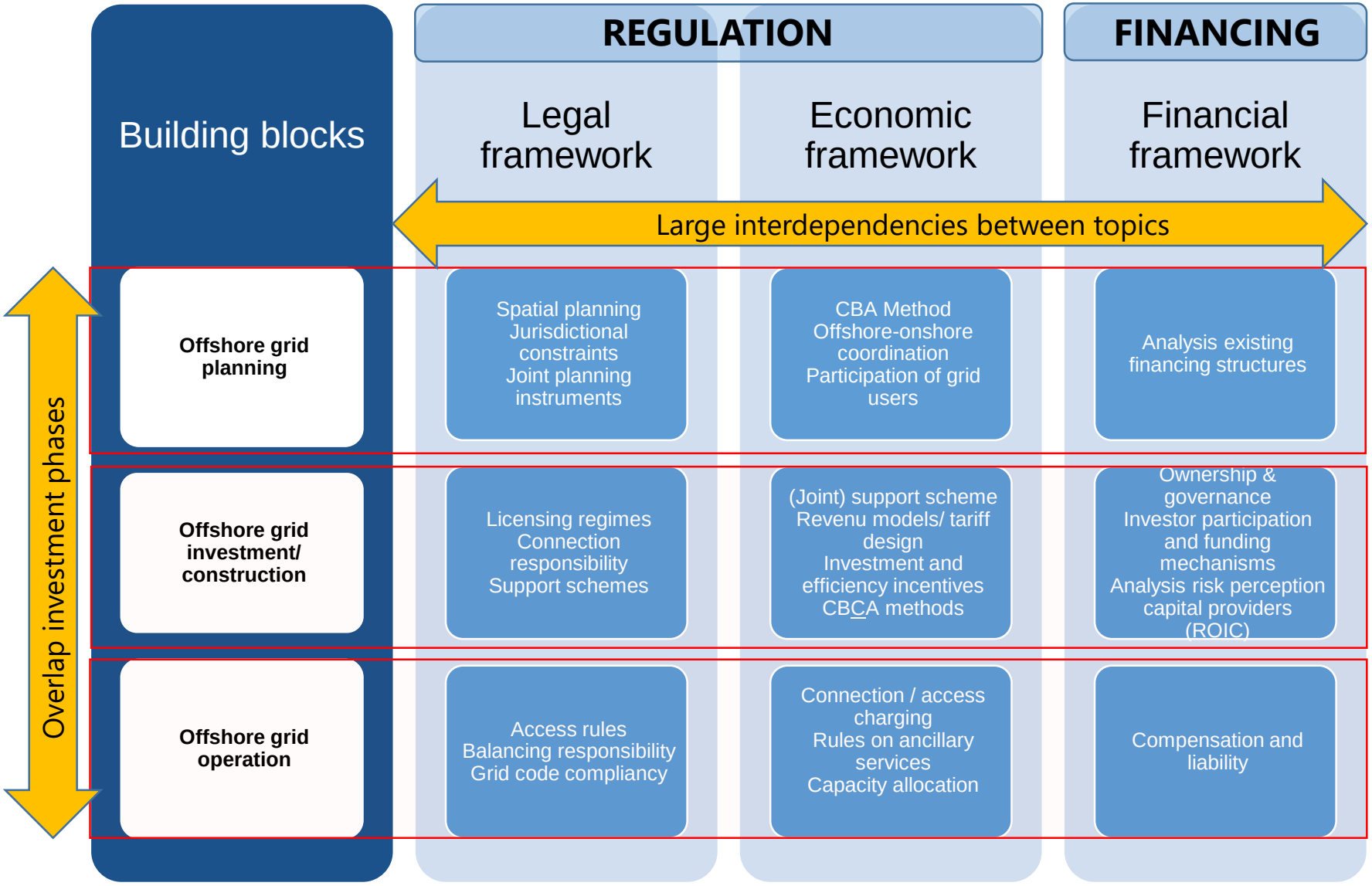
Objective:

- To develop the appropriate European regulatory target framework – in legal, economic & financial properties – for the development of integrated offshore electricity transmission infrastructures with aim:

- to foster efficient investments by creating a level playing field;
- to coordinate the offshore grid development and the connection of wind farms; and
- to ensure its financeability or bankability

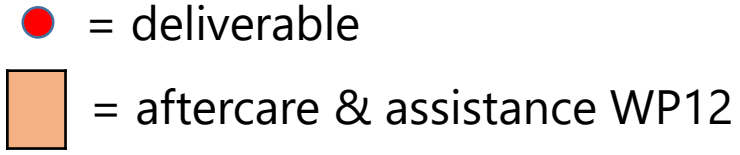
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP7 Setup


Building blocks
REGULATION
FINANCING
Legal framework
Economic framework
Financial framework
Large interdependencies between topics
Overlap investment phases
Offshore grid planning
Spatial planning
Jurisdictional constraints
Joint planning instruments
CBA Method
Offshore-onshore coordination
Participation of grid users
Analysis existing financing structures
Offshore grid investment/ construction
Licensing regimes
Connection responsibility
Support schemes
(Joint) support scheme
Revenu models/ tariff design
Investment and efficiency incentives
CBCA methods
Ownership & governance
Investor participation and funding mechanisms
Analysis risk perception capital providers (ROIC)
Offshore grid operation
Access rules
Balancing responsibility
Grid code compliancy
Connection / access charging
Rules on ancillary services
Capacity allocation
Compensation and liability

WP7

#	Task	2016	2017	2018	2019
7.1	Legal framework				
7.2	Economic framework				
7.3	Financial framework				
7.4	Stakeholder management/reporting				
7.5	Policy recommendations EU target framework				



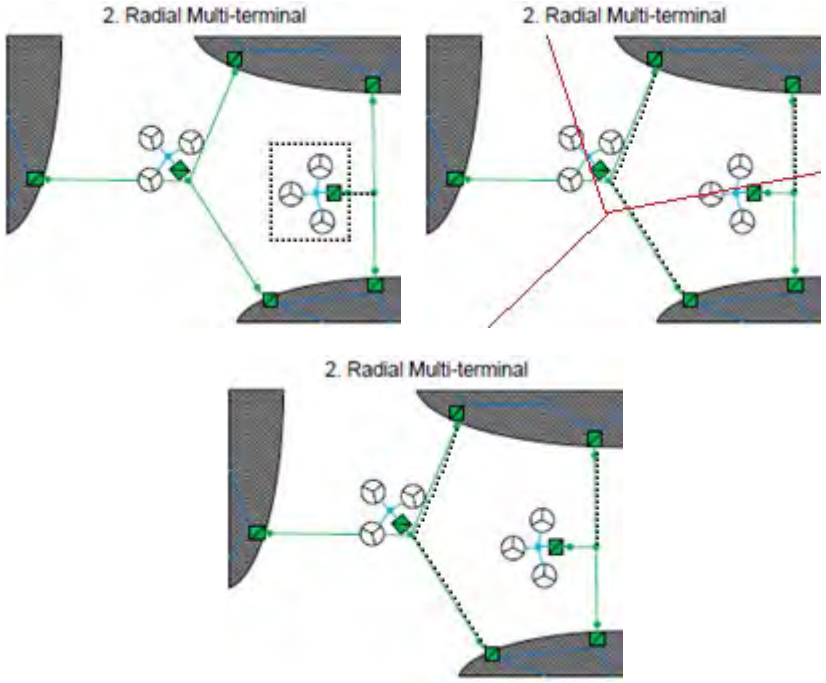
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 7.1 – Legal framework

- Analysis offshore competences

- Analysis EU competences and Relevant legislation applicable to a North Sea grid

- Analysis country specific framework and barriers



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 7.2 – Economic framework

CBA Principles

Status of implementation	ENTSO-E 1.0	ENTSO-E 2.0	ENTSO-E Market design (balancing)	Significantly more important in the offshore context?
INPUT(1) Project interaction must be taken into account in the project and baseline definition	One baseline (TOOT). Arbitrary clustering rules	One baseline (TOOT), ambiguous update of the clustering rule	Harder applicable but dealt with.	x
INPUT(2) Data consistency and quality should be ensured	TYNDP	TYNDP	TYDNP	
INPUT(3) Costs should be reported in disaggregated form	Not clear	Not clear	Not clear	x
CALCULATION(4) CBA should concentrate on a reduced list of effects	Reduced list	Reduced list	Reduced list	
CALCULATION(5) Distributional concerns should not be addressed in the calculation of net benefits	OK	OK	OK	
CALCULATION(6) The model used to monetize the production cost savings, and gross consumer surplus needs to be explicitly stated	Explicit model available	Explicit model available	Explicit model available	
CALCULATION(7) A common discount factor should be used for all projects	4 % for all	4 % for all	Uniform; aligned with TYNDP & PCI	
CALCULATION(8) A stochastic approach/scenario analysis should be used to address uncertainty	OK	The need is mentioned, but not specified how to apply the tools	OK	
OUTPUT(9) Benefits should be reported in disaggregated form	Not clear	Not clear	Regional and country effects should be reported	x
OUTPUT(10) Ranking should be based on monetization	Multi-criteria analysis	Multi-criteria analysis, additional monetization of losses	Monetized ranking is suggested	x

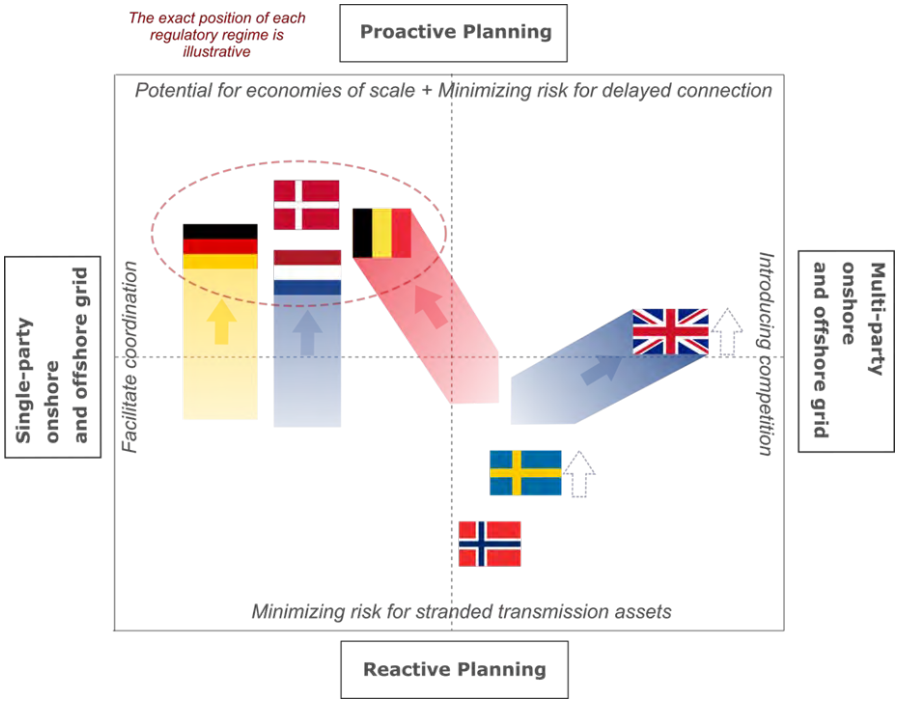
Case studies

	EWIC (IRL-UK)	COBRACABLE (NL-DK)	ISLES (SCO-IRL- N-IRL)	Concern in the ENTSO-E 1.0 and 2.0 methodology
Phase	Commissioned in September 2012	Final investment decision taken, expected to be in operation by 2019	In the study phase	
EU funding	"Project of European Interest," included in (TEN-E) Priority Interconnection Plan. Received significant EEPR funding (110 m€)	On the 2013 and 2015 PCI list. EEPR funding received/allocated for studies and construction (86.5 m€)	On the 2013 and 2015 PCI list. The EU INTERREG IVa Program funded 1.6 m£ for ISLES I and 0.9 m£ for ISLES II	
INPUT (1) Project interaction must be taken into account in the project and baseline definition	No project interaction is taken into account	TOOT approach is applied, and change in congestion rent of other interconnectors is calculated	No interaction with other PCI projects is taken into account. The interaction between ISLES clusters is analyzed partially.	**Critical**
INPUT (2) Data consistency and quality should be ensured	Ok	Ok	No TYNDP by local data is utilized although from respected sources.	**/**
INPUT (3) Costs should be reported in disaggregated form	Ok	Ok	Ok	**Harmonisation needed**
CALCULATION (4) CBA should concentrate on a reduced list of effects	Ok	Ok	Ok for the 2015 analysis. However, not the ENTSO-E CBA 1.0. list is applied.	**/**
CALCULATION (5) Distributional concerns should not be addressed in the calculation of net benefits	Ok	Ok	Ok	**/**
CALCULATION (6) The model used to monetize the production cost savings, and gross consumer surplus needs to be explicitly stated	Explicitly stated but not detailed market and network model used	Ok, explicitly stated and detailed market and network model are used (details are not public)	Ok, explicitly stated and detailed market and network model are used	**/**
CALCULATION (7) A common discount factor should be used for all projects	Ok, there was no common discount factor determined thus the allowed WACC of EirGrid was used	Ok	A very low discount factor is applied in the 2012 analysis (2%) ,and no value is provided in the 2015 analysis	**/**
CALCULATION (8) A stochastic approach/scenario analysis should be used to address uncertainty	Uncertainty is disregarded, no scenario or sensitivity analysis applied	Ok, 2 scenarios are applied plus sensitivity analysis by varying total cost and discount factor	Scenario and sensitivity analysis are applied, although not using the TYNDP scenarios.	**/**
OUTPUT (9) Benefits should be reported in disaggregated form	Only the benefits for Ireland are considered	Ok, benefits are reported disaggregated	Ok, benefits are reported disaggregated	**Ok**
OUTPUT (10) Ranking should be based on monetization	Ok, full monetization is applied	Partial monetization is applied, but a final NPV value of the project is underlined. Additional indicators in non-monetary metrics are mentioned more for informational purposes	Both quantitative as qualitative cost and benefit indicators are reported. No full monetization is conducted.	**Harmonisation needed**

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 7.2 – Economic framework

Coordination onshore-offshore grid planning



Locational siting RES support

Valid for 2017	Germany	Denmark	UK	Sweden
Open-door				x
Zoned			x	
Single-site	x	x		

Onshore access responsibility

Valid for 2017	Germany	Denmark	UK	Sweden
TSO	x	x		
Developer				
Third Party			x	x

Grid connection cost

Valid for 2017	Germany	Denmark	UK	Sweden
Super shallow	x	x		
Shallow			x	
Deep				x

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 7.3 – Financial framework

No.	Key elements
1	Regulatory authority
2	Regulatory period
3	Revenue cap mechanism
4	Allowed revenue: method
5	Allowed revenue: value
6	Allowed return on equity: method
7	Allowed return on equity: value
8	Risk-free rate
9	Market risk premium
10	β_equity
11	Gearing
12	Cost of debt: method
13	Cost of debt: value
14	Depreciation
15	Costs deducted
16	Efficinecy incentives/benchmarking methods
17	Innovation
18	Revenue adjustments
19	Ownership
20	Size of investments
21	Credit rating of TSOs

Regulation has a profound impact on financeability

- Overview historical development ownership & governance
- Analysis existing regulatory models and financing structures

- onshore grid investments
- offshore grid investments
- interconnectors

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Next period

Legal framework
- proposal of solutions to legal barriers / policy choices
- analysis new forms of governance (institutional roles)
- developing the legal form of the legal framework (EU law, Treaty, or combination)
- case study/pilot projects application

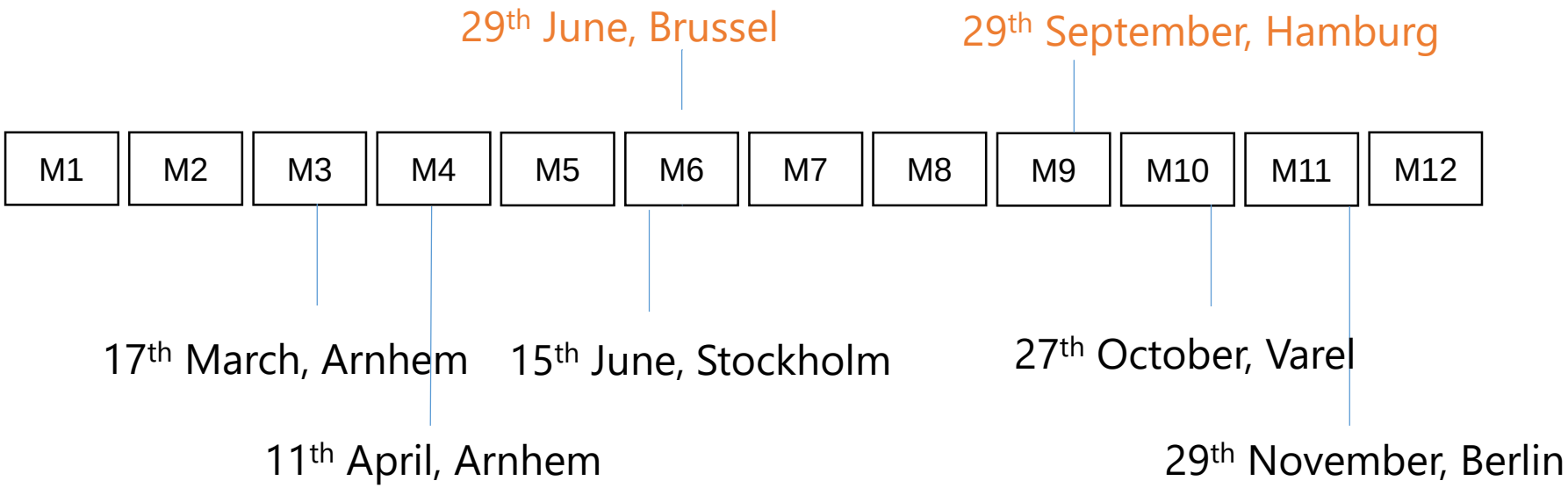
Economic framework
- support schemes
- investment incentives
- cross border cost allocation
- revenu models/tariff design
- governance models regarding ownership, construction and operation
- rules on capacity allocation (interconnection vs generation capacity)
- rules on ancillary services

Financial framework
- financing instruments
- investor participation
- risk analysis for offshore grid planning, construction and operation

Policy recommendations on EU target framework

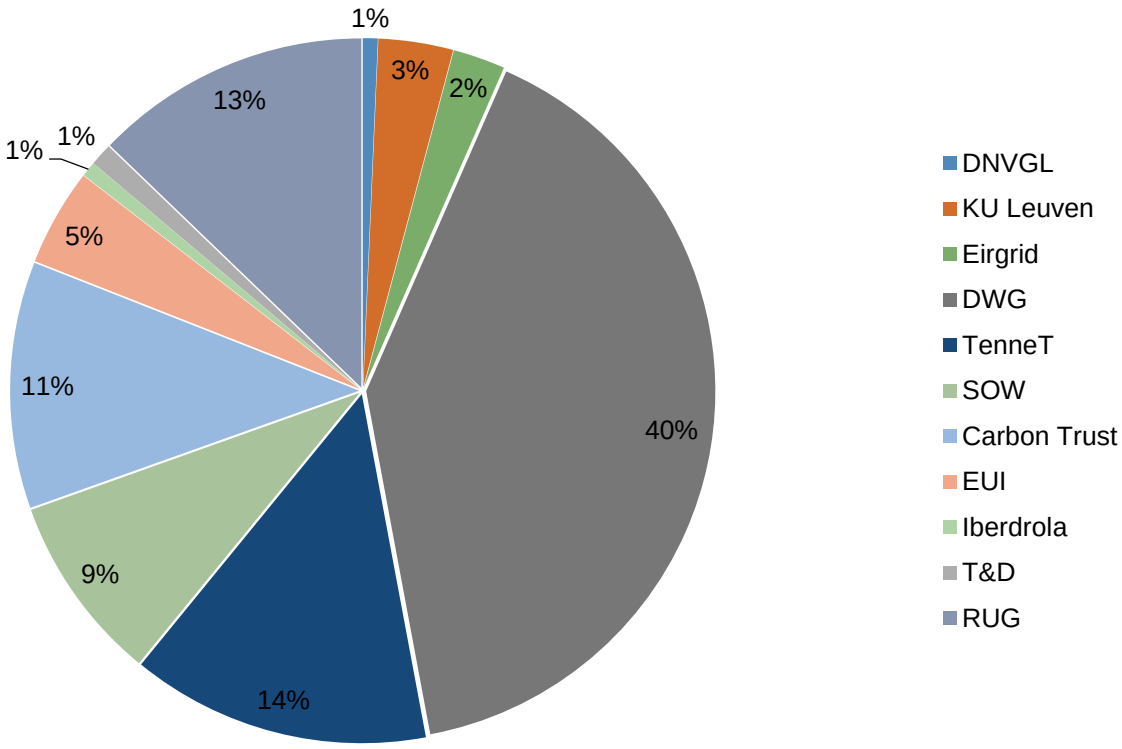
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Meetings and stakeholder workshops



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Contributions



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Work Package 8
Wind Farm Demonstrator Design

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP8 – Windfarm Demonstrator Prototype

Initiate and develop technical solution for a Windfarm Demonstrator Prototype plant at an existing onshore windfarm

- if possible realize and built the plant at site.
- first step: preparing a technical design, applying for necessary consents
- develop a detailed cost breakdown
- Investigation of different realization options will be investigated and evaluated based on a cost/benefit analysis.

A GO/NO GO decision milestone (MS36) is set after twelve months:

- different technical options will be compared and decided if and how the demonstrator prototype plant will be realized.
- This will depend on the elaborated technical solutions and the trade-off between demonstrator prototype cost and benefit.
- The GO/NO GO decision will be made by each WP8 participant for its own scope.

Targets:

- Investigate and compare different technical options on how the prototype can be realized
- Develop a design with dependable cost estimates
- To decide on GO/NO GO for the realization of the plant and if applicable
- To manufacture, assemble and test all equipment including advanced hybrid submarine cable prototype
- To energize and demonstrate functionality through tests especially proper turbine – rectifier interaction

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WP8 – Windfarm Demonstrator Prototype

#	Task	2016	2017	2018	2019
8.1	Work package management				
8.2	Work package scoping				
8.3	System Simulations and Design				
8.4	Cable design and testing				
8.5	Manufacturing and Installation of cable and cable accessories				
8.6	DRU Manufacturing and Testing				
8.7	Other Equipment Manufacturing and Testing				
8.8	Civil Works				
8.9	Installation and Assembly				
8.10	Commissioning				
8.11	Plant operation and Test period				

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 8.2 – Work package scoping

Investigation on three different options for diode rectifier demonstration

- Klim demonstrator (originally proposed)
- Control concept demonstrator
- Oesterild demonstrator

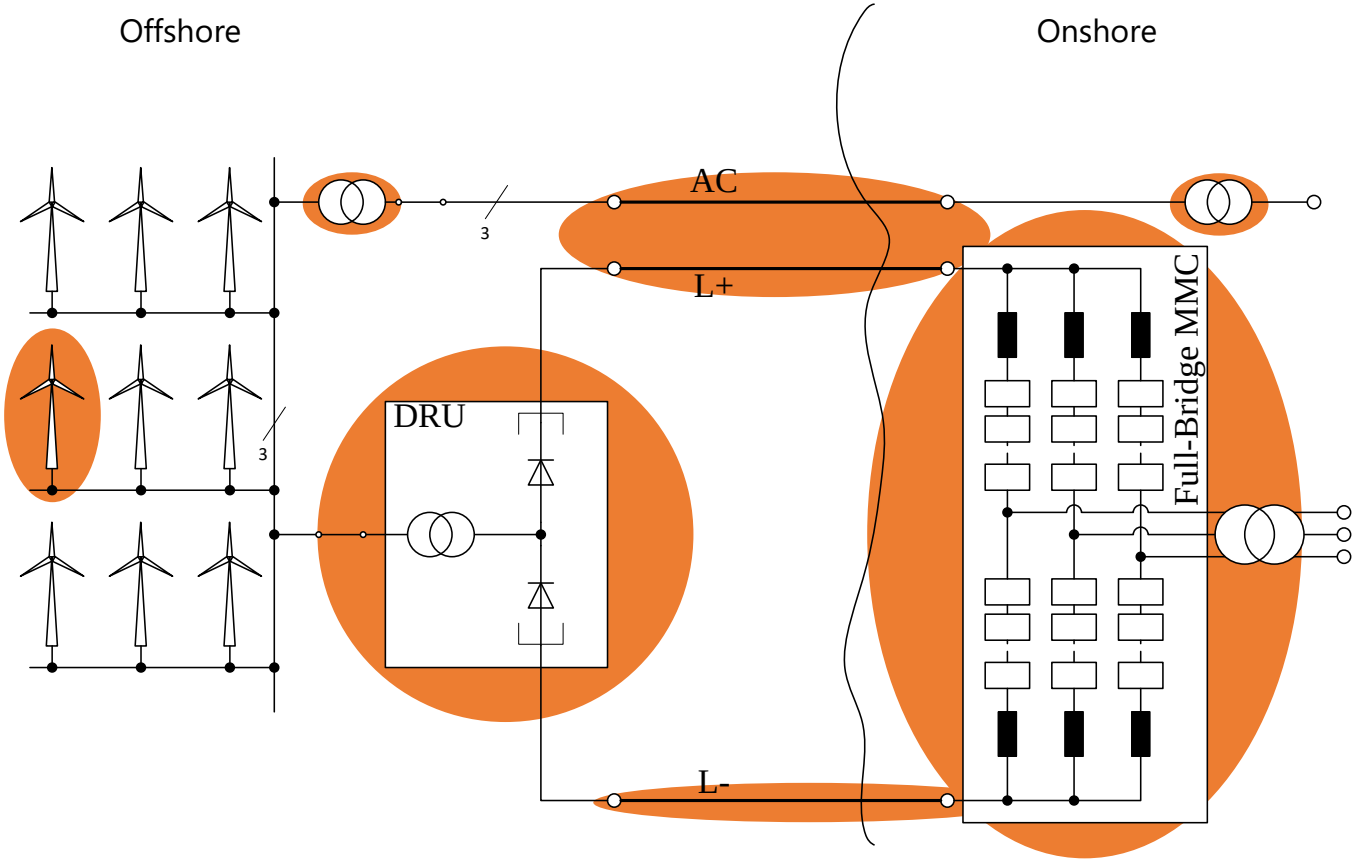
Major goal: cost optimized de-risking of DRU technology

Results documented in

- D8.1 – Project time schedule
- D8.2 – Basic design report
- D8.3 – Plant layout and major equipment specification
- D8.10 – Demonstrator Prototype: Analysis and comparisons of different technical solutions for realization
- Justification for change of scope to European Commission

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 8.2 – Work package scoping



All components of an SGA DRU windfarm (DRU, HVDC Plus, WTG, cable, transformer) are separately type tested and qualified. The challenges for the successful operation of an SGA DRU wind farm are given by the interaction of all components.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 8.2 – Work package scoping

Risk picture of technology

- Simulation Tool Validity
- Operation
  - Energization
  - Normal operation
  - Stability in operational modes
- Faults
  - AC fault onshore/offshore
  - DC fault, intersystem AC/DC

Risk Impact Analysis

- Delay
- Loss of production
- Needed investments
- Occurrence
  - Probability
  - Dependency on stage of commissioning

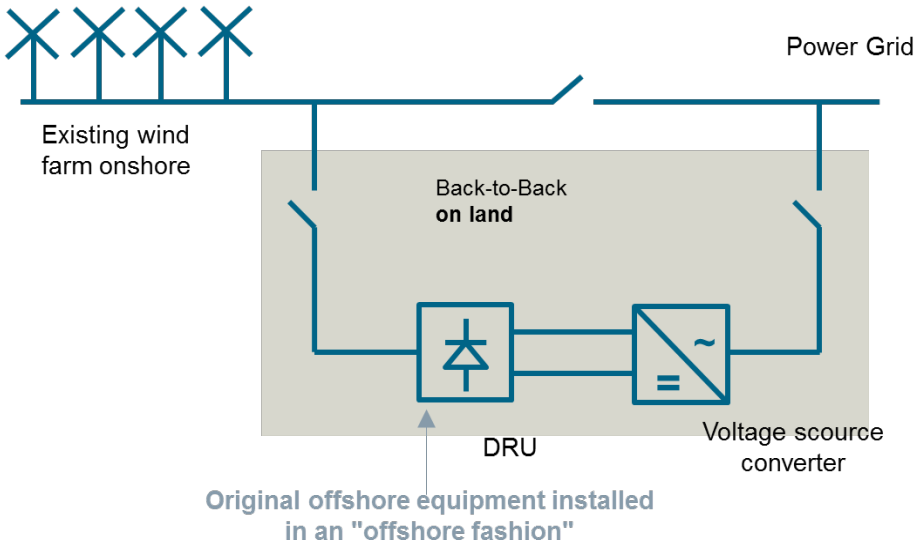
(Results confidential within Siemens)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 8.2 – Work package scoping

Klim – Demonstrator

- 20 MW nom. power of VSC
- 11 turbines (3.2 MW each)
- One DRU operating at max. 10 p.c. of nom. power
- One string



Klim would

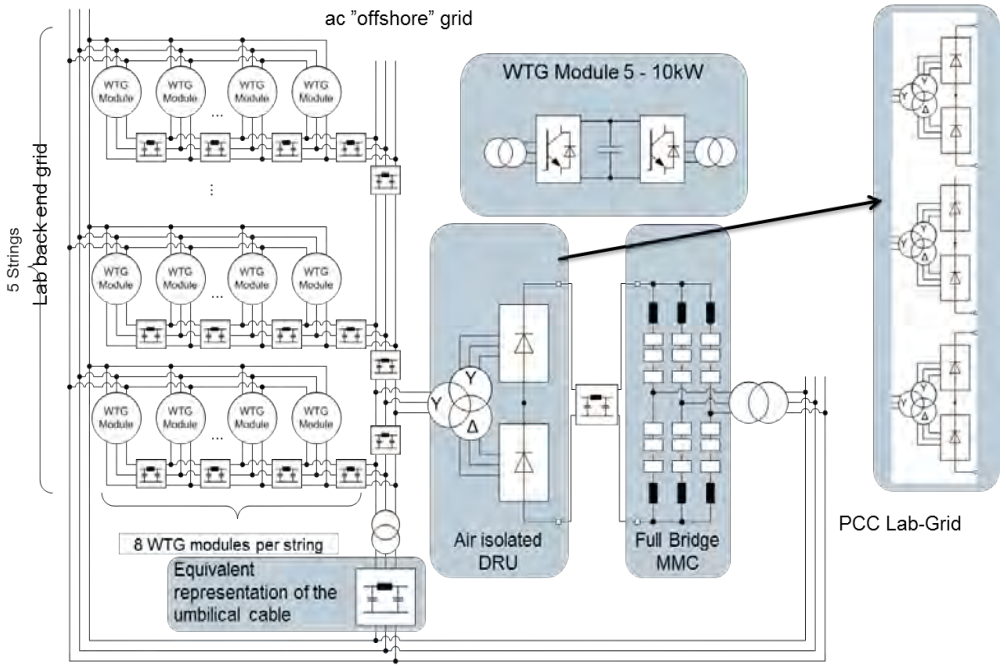
- mainly address the demonstration of handling equipment and sufficient project management.
- also show that the concept in principle is working

but it is highly questionable if the results are transferable in a real offshore wind farm.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 8.2 – Work package scoping

- Nominal Power 250kW operational range
- Low voltage level (nom. 400V AC; ±400V DC)
- Frequency nom. 50 Hz
- 48 back to back rectifier, PN = 5kW
- 3 x 12 pulse DRU
- Full bridge MMC
- DC voltage WTG: 640V
- AC voltage der WTG (sec): 400V
- AC voltage Offshore: 400V
- AC voltage DRU-Transformer (sec): 105V
- DC voltage cable: 800V (2 x 400V, symmetrical grounding)



Scaling of impedances

$$Z_{\mathrm{Lab}} = Z_{\mathrm{OWP}} \cdot \lambda \,, with\, \lambda = \left(\frac{U_{\mathrm{Lab}}}{U_{\mathrm{OWP}}}\right)^2 \cdot \frac{P_{\mathrm{OWP}}}{P_{\mathrm{Lab}}}$$

To achieve correct dynamic behavior of converters:
Scaling according to the using the correcting variable reserve as well as the time constants due to the fact that these values have a high influence on the dynamic behaviour of the system.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 8.2 – Work package scoping

	Simulation	Klim Demonstrator (I)	High power Lab Demonstrator (II)	Control Concept Demonstrator (III)
Behavior of 100+ WTG converters on a very weak AC grid	+ Possible to the extend of the quality of the simulation models	– Not possible / Partial verification of WTG model possible	– Not possible / Partial verification of WTG model possible	/ Partially possible with 50 WTGs / Partial verification of WTG model possible
Operating a large cable grid on a weak umbilical cable	+ Possible to the extend of the quality of the simulation models	– Not possible	– Not possible	/ Partially possible to the extend of the quality of the cable models
Defined load situations	+ Full load range and critical situations possible	– Depending on wind, load situation during test period is unpredictable	+ Full load range and critical situations possible	+ Full load range and critical situations possible
WTG harmonic injection	+ Freely adjustable	/ Partially possible, load situation during test period is unpredictable	+ Freely adjustable	+ Freely adjustable
Verification of converter control / Operation MMC-DRU	+ Possible to the extend of the quality of the simulation models	/ Partially possible, depending on the extend of the MMC setup	/ Partially possible, depending on the extend of the MMC setup	/ Partially possible, depending on the extend of the MMC setup
Risk/Costs	+ +	– –	+ /	+ +

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 8.2 – Work package scoping

Dynamic voltage distribution of the series connected DRUs

Due to the series connection of the DRUs, in cases of changing the DC link voltage, different cable length of the DC cable lead to asymmetrical voltage drops, which has to be considered in the systems design.

In cases of faults, in the series connection (DC to ground) the dynamic behavior has such high transients that the isolations of cables may collapse.

Resonances related to active tower damping (ATD) and drive train damping DTD

The PP are equipped with control strategies to damp the drive system (DTD) active as well as the tower itself (ATD).

The typical eigen frequencies are around 2 Hz (DTD) and 0.2 Hz (ATD).

The activation of these features may lead to power oscillations in the system, even in cases where the system is in islanded operation. Every WPP stores energy in the mechanic system and may become a low frequency source to start resonances with in the electrical system.

Resonances in high frequency ranges due to converter interaction

Unintended interactions between converters in frequency range of IGBT switching signals

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 8.2 – Work package scoping

The basic aspects to investigate are

- interactions of several WTG within one string
- interactions of strings connected in parallel
- supply of OWP via a long AC cable with aux. power
- interaction of OWP with uncontrolled DRU
- interaction OWP with DRU and DRU-filter
- interaction of 3 DRU on different locations via ringbus cable
- connection of DRU via a long DC cable

The control concept demonstrator is not intended

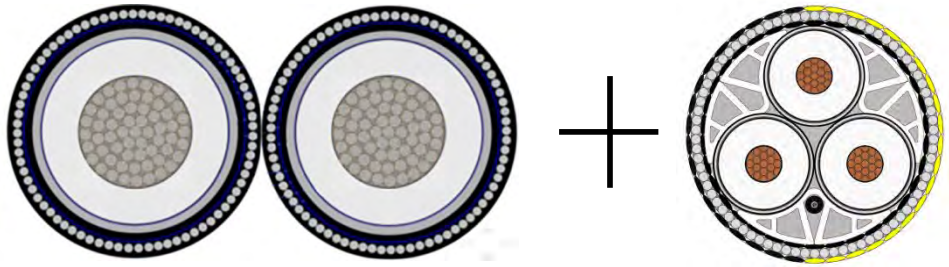
- To investigate/demonstrate interface protocols, (ISO/OSI Model)
- To test real world devices like C&P equipment,
- To investigate HVDC onshore operation
- For verification of the later on real word system behaviour (by definition impossible)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

TRADITIONAL vs. INNOVATIVE options

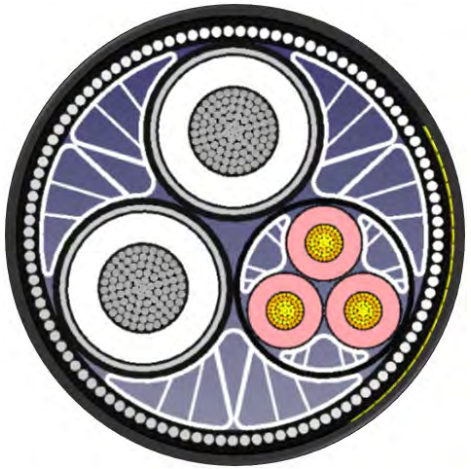
Two HVDC bundled cables + One HVAC threecore cable

- ✓ HVDC cable technology
- ✓ HVAC cable technology
- X Three cables
- X Two installation processes
- X Two routes



One Hybrid three-core cable

- ✓ One cable
- ✓ One installation process
- ✓ One route
- ✓ HVDC cores technology
- ✓ HVAC cores technology



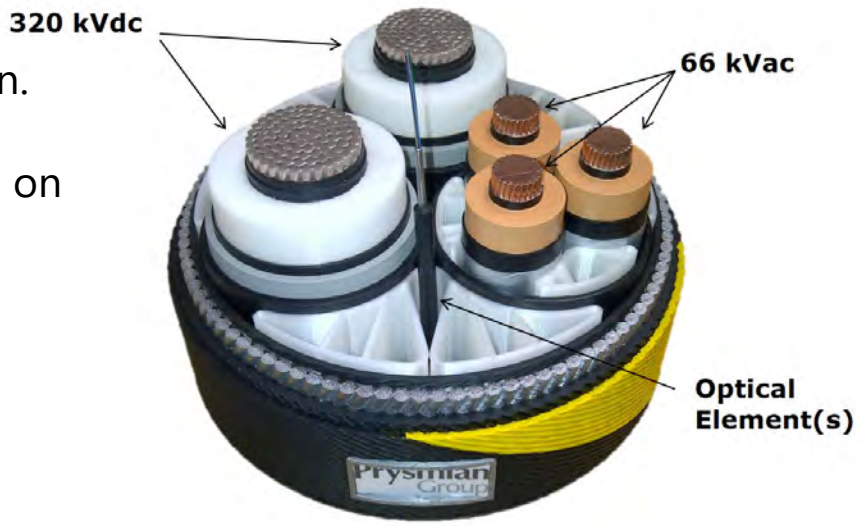
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

PRYSMIAN GROUP CONTRIBUTION – WP8

Task 8.4 Cable design and testing

"The work package covers all design, build and operation tasks for testing a real size cable loop that could be used in the future with diode rectifier converter technology . It shall proof the functionality and feasibility of the new cable concept"

- Electrical analysis based on the IEC standards and proprietary computation programs.
- Thermal analysis based on the IEC standards and Proprietary computation programs.
- Construction details and bill of material definition.
- Selection of manufacturing plants to be involved on prototype construction.
- Mechanical analysis of cable behaviour.
- Definition of tests procedure.



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Contributions

SIEMENS

- Work package lead
  - Scoping phase
  - Modelling & simulations
  - Reporting D8.1, D8.2, D8.3 & D8.10

Prysmian Group

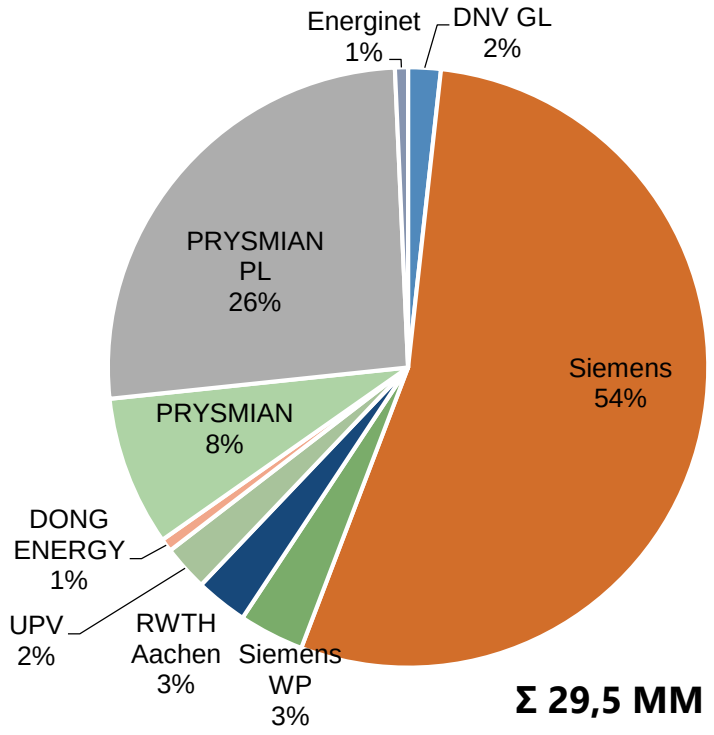
- Hybrid cable development

DNV·GL

- Reviewing partner

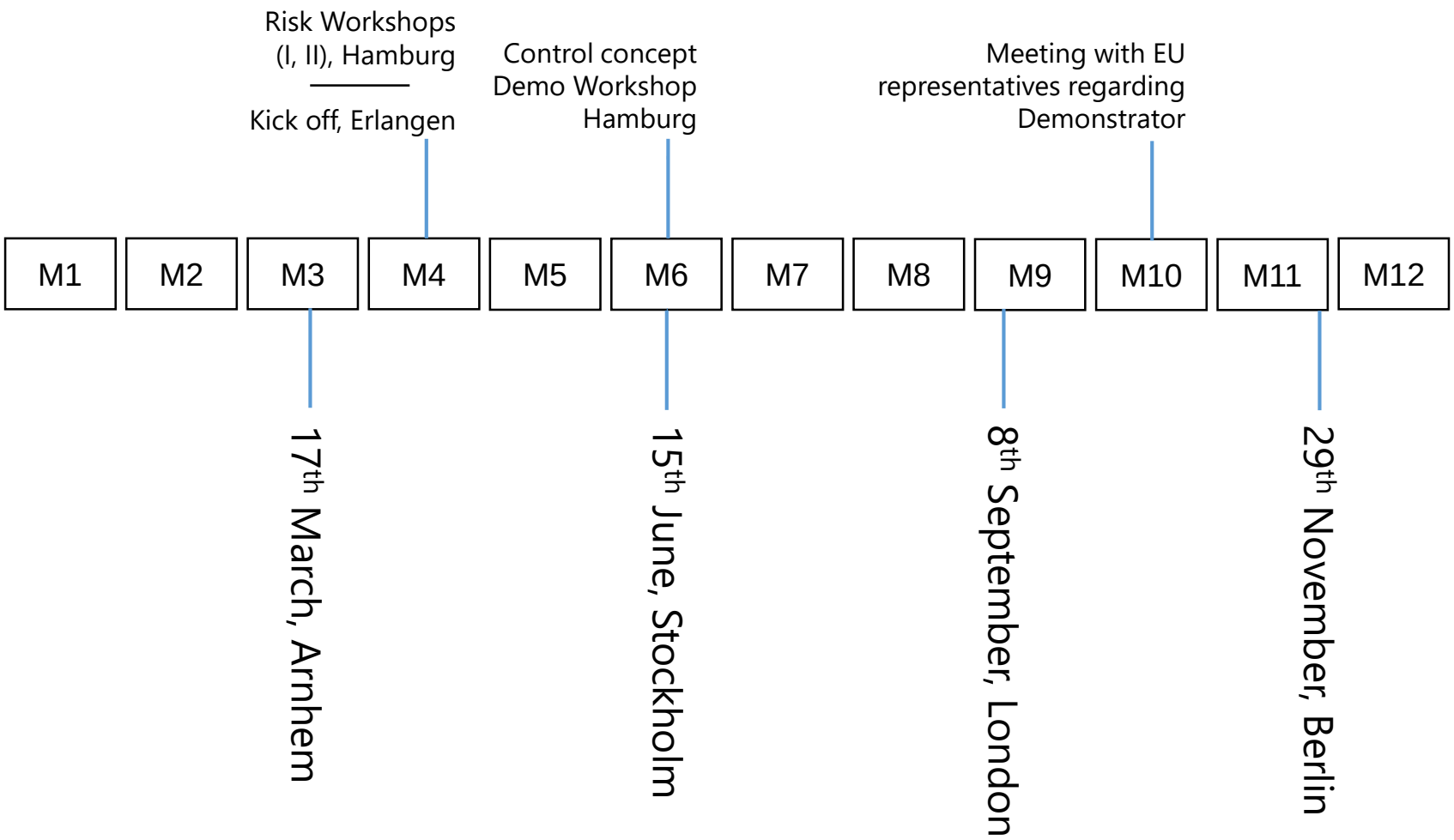
RWTH AACHEN UNIVERSITY

- Reviewing partner



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Meetings



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Dissemination

No disseminations

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Next period

After Siemens' NO GO Descision:

- Update of the scope of work/objectives of WP8.
- (WP8 consists only of PRYSMIAN work.)

Remaining tasks:

Task 8.4 Cable design and testing (M06-M20)

Task 8.5 Manufacturing and Installation of cable and cable accessories (M12-M28)

Deliverables:

D8.7 Cable design and modelling parameters Report (M20)

D8.8 Feasibility Report on prototype cable (M24)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Dissemination

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Overview Status Deliverables WP13

Deliverable Number	Deliverable Title	Submitted
13.1	Development of Project Identity	Jun. 16
13.2	Newsletter – bi-annual	Jun. 16
13.3	Establishment of internal/external Project information system	Jul. 16
13.4	Mailing list - regularly updated	Jun. 16
13.5	Executive summary of project interim report	Mar. 17
13.6	Publications (x number of papers, articles, reports, conf. presentations …)	Dec. 16
13.7	Stakeholder interaction	Nov. 16
13.8	External Communication via marketing material and media work	Jul. 16

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Overview Status Milestones WP13

Milestone Number	Milestone Title	Due Date
MS59	Beta version of website is launched	May 2016
MS60	Website launched	Jul. 2016
MS 61	First convention of Reference Group	Sep. 2016
MS62	Intermediate Conference	Jun. 2018
MS63	Final Conference	Dec. 2019

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 13.1 - Development of project identity

- ***Deliverable 13.1*** **- submitted June 2016**

- **Corporate design:**
  - Logo
  - Templates
  - Website
  - Fonts
- **Templates:**
  - Letters
  - Reports
  - Press releases
  - Invitation
  - PowerPoint

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Newsletter production

Task 13.2 Development and production of a newsletter

- ***Deliverable 13.2*** **- submitted June 2016**

Newsletter #1 / JUNE 2016

No Images? Click here

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Dear readers,

This first newsletter presents you with the latest news about and recent events of the PROMOTioN project. PROMOTioN is about diode rectifier offshore converters, interoperability, multi-vendor HVDC grid protection systems, full power testing of HVDC circuit breakers and more. I must say that when I heard these wordings for the first time last year, I didn't understand it promptly, and I am probably not alone in saying so among folks from the energy community.

- Published bi-annually
- 264 subscribers

Structure:

- Editorial
- Policy News
- PROMOTioN
- Upcoming events

Newsletter #1 – Content (30th June 2016)

- Intro –> DNV GL (Paul Raats)
- Editorial ("About PROMOTioN")
- Introduction WP 1
- Introduction WP 7
- Report/Summary Deliverable 1.1
- Announcement Kick-off stakeholder workshop (WP7)
- North Sea Political Declaration of 6 June
- Upcoming events

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Newsletter #2 – Content (20th December 2016)

Editorial: Paul Raats (DNV GL)

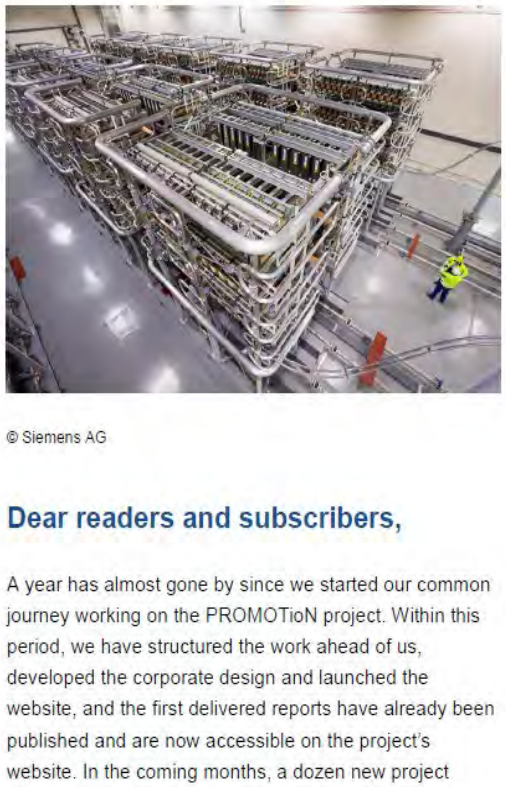
POLICY:

- EU Winter Package
- New electricity interconnection targets expert group
- Ground-breaking ceremony NordLink HVDC power grid interconnection
- Fichtner study (Germany): Acceleration and cost reduction potentials for Offshore HVDC Grids (June 2016)

PROMOTioN:

- Review of Stakeholder Interaction 2016
- Deliverable 1.3: Synthesis of available studies on offshore meshed HVDC grids
- Deliverable 5.1: HVDC Network Fault Analysis
- Deliverables 6.1 and 6.2: System-level models for three DC circuit breakers

UPCOMING EVENTS



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Online activities

Task 13.3
Content management for website and intranet

- Deliverable 13.3 Project information system - **launched July 2016**
- Internal area for stakeholder interaction e.g. Reference Group
- **www.promotion-offshore.net**

Mailing list

Task 13.4
Development of a targeted mailing list

- ***Deliverable 13.4*** **- submitted June 2016**

- For stakeholder interaction
- More than 1000 recipients
- Regularly updated
- Input from project partners

STAKEHOLDER CATEGORIES

1. European bodies
2. Policy institutions
3. Industry Stakeholders
4. Financing bodies
5. Academia & Consulting
6. Others

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Dissemination

Task 13.6
Production of public reports, papers/articles, presentations

- ***Deliverable 13.6***

- submitted December 2016

- 13 presentations in 2016
- 3 conference papers in 2016

- *Total amount of 25 journal articles and 50 conference papers is pursued*
  (acc. to GA Annex 1B Communications Activities)

Simultaneous connection of Type-3 and Type-4 Off-shore wind farms to HVDC Diode Rectifier Units

R. Vidal-Albalate†, R. Pena‡, E. Belenguer†, S. Añó-Villalba*, S. Bernal-Perez*, R. Blasco-Gimenez*
*Universitat Politècnica de València, Spain (r.blasco@ieee.org)
†Universitat Jaume I de Castelló, Spain
‡Universidad de Concepción, Chile

Abstract—This paper introduces a control strategy which can be used for the connection of both type-3 and type-4 wind turbines to HVDC-Diode Rectifier (HVDC-DR) stations. In this way, wind turbines from different technologies could effectively connected to the same HVDC Diode Rectifier station. The proposed strategy is verified by means of PSCAD simulations including start-up operation, optimal power tracking with changing wind conditions and off-shore ac-grid frequency reference changes. Moreover, reactive power sharing between the wind turbines is proven for the aforementioned scenarios.

I. Introduction

A continuous drive to reduce offshore wind levelized cost of energy (LCoE) is paramount in order to reduce subsidies to offshore wind energy, driving it closer to market prices.

Diode rectifier stations for the connection of large offshore wind power plants (OWPPs) allow for increased efficiency and robustness and can lead to substantial CAPEX and OPEX reduction [1], [2]. The use of diode rectifier stations for the HVDC connection of OWPPs has been proposed for type-4 OWPPs [3], [4], [5], [6], [7]. The authors have also proposed a general solution for the connection of type-3 wind turbines to diode rectifier based HVDC links [8].

It is envisaged that more than one OWPP might be connected to one (or several series connected) diode rectifier units. Therefore, it is important to show that different types of OWPPs can cooperate in the control of the off-shore ac-grid.

This paper extends the results of the control framework already presented in [8] for type-3 wind turbines to obtain a compatible control strategy also applicable to type-4 OWPPs.

The paper covers the detailed description and analysis of the proposed control strategy, as well as simulation studies based on detailed PSCAD models which show the technical feasibility of joint type-3 and type-4 OWPP operation when connected to the same diode rectifier station.

The approach used in this paper consists on using the strategy in [9], [8], which allows the DFIG to behave as an ac voltage source of programmable amplitude and phase.

The off-shore ac-grid is controlled by standard P/f, Q/V droops, which can easily be implemented in the grid side converter of type-4 wind turbines.

The proposed control approach is verified by means of detailed PSCAD simulations. Considered scenarios include start-up operation, optimal power tracking to changing wind conditions and the response of the off-shore ac-grid to changing frequency references.

In all these cases, good reactive power sharing amongst the wind turbines has been verified.

A small signal stability analysis has also been included as a guideline for choosing the droop parameters.

Therefore, this paper will show the technical feasibility of the joint connection of type-3 and type-4 wind turbines to HVDC diode rectifier stations using the same voltage referenced control strategy in both types of wind turbines.

II. Wind turbine control strategy

Figure 1 shows the system under consideration. The 405 MW wind farm consists of 135 wind turbines of 3 MW each, connected to a 66 kV collector bus. The collector bus is connected to a ±300 kV HVDC link by means of a 12-pulse HVDC diode rectifier station. A HVDC-VSC inverter is used for onshore grid connection and for HVDC link voltage control.

The simulated wind farm consists of 5 clusters of 27 wind turbines (81 MW each). The first three clusters consist of DFIG-based wind turbines, whereas cluster 4 and cluster 5 correspond to PMSG-based wind turbines.

A. DFIG-based Wind Turbine Control

The wind turbine dc-link voltage (E_{Dlink}) control is carried out by the wind turbine front-end converter, using standard vector control [9].

The back-end converter is used to control the DFIG using Indirect Stator Flux Orientation (ISFO) [9].

Considering the DFIG dynamic equations in the synchronous rotating $d-q$ frame, we have:

$$\lambda_{ds} = L_s i_{ds} + L_0 i_{dr} \quad (1)$$

$$\lambda_{qs} = L_s i_{qs} + L_0 i_{qr} \quad (2)$$

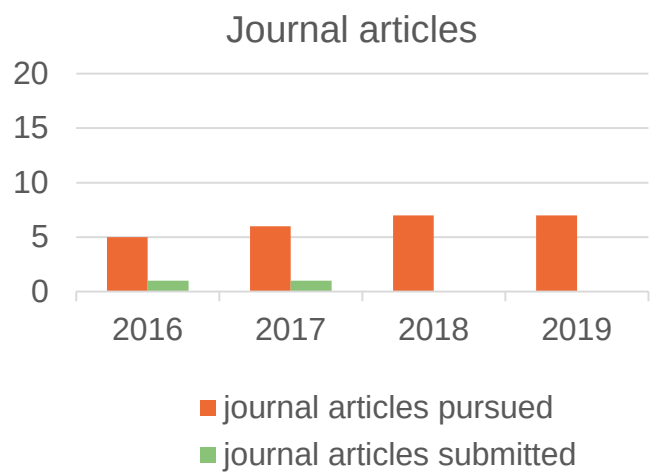
$$\lambda_{dr} = L_0 i_{ds} + L_r i_{dr} \quad (3)$$

$$\lambda_{qr} = L_0 i_{qs} + L_r i_{qr} \quad (4)$$

$$v_{ds} = R_s i_{ds} + \frac{d\lambda_{ds}}{dt} - \omega_s \lambda_{qs} \quad (5)$$

$$v_{qs} = R_s i_{qs} + \frac{d\lambda_{qs}}{dt} + \omega_s \lambda_{ds} \quad (6)$$

$$v_{dr} = R_r i_{dr} + \frac{d\lambda_{dr}}{dt} - (\omega_s - \omega_r)\lambda_{qr} \quad (7)$$



Task 13.6 Presentations

No.	Date	Event	Presenter
1	11 May 2016	***WindEurope Working Group: Offshore Wind***	Andreas Wagner - SOW
2	24 May 2016	***Belgian Electrical Engineers Society***	Karim KAROUI - Tractebel
3	27-28 Jun. 2016	***InnoGrid 2020+***	Alexander Yanushkevich - DNV GL
4	28 Jun. 2016	*Internal meeting with partners in Carbon Trust's* ***Offshore Wind Accelerator (OWA) programme***	Carbon Trust
5	14-16 Sep. 2016	***6th HVDC Doctoral Colloquium, Porto,***	Oscar Saborio-Romano, DTU
6			Ali Bidadfar, DTU
7	16 Sep. 2016	***RTDS European User Conference, Gaslgow, UK***	SHE Trans
8	29 Sep. 2016	***WindEnergy Hamburg***	Cornelis Pleet - DNV GL
9	25 Oct. 2016	***CIGRE 2nd International Conference on HVDC***	Dirk Van Hertem - KU Leuven
10	15-17 Nov. 2016	***Wind Integration Workshop***	R. Vidal-Albanate, R. Pena, E. Belenguer, S. Añó-Villalba, S. Bernal-Perez, R. Blasco-Gimenez
11			Oscar Saborío-Romano, Ali Bidadfar, Ömer Göksu, Müfit Altin, Nicolaos A. Cutululis, Poul E. Sørensen Department of Wind Energy Technical University of Denmark
12			Slavomir Seman, Ngoc Tuan Trinh, Rainer Zurowski, Sarina Kreplin; Energy Management Division SIEMENS AG
13	25 Nov. 2016	***Conference Baltic InteGrid project: Offshore Wind in the Baltic Sea:*** *Legal and Policy Perspectives on a Regional Meshed Grid*	Ceciel Nieuwenhout (Groningen Centre of Energy Law)

Task 13.7
Interaction with stakeholders and other initiatives

- ***Deliverable 13.7*** **- submitted November 2016**
- Task 13.7.1: Industry Reference Group and Advisory Board (M09-48)
- Task 13.7.2: Regional/External Events (M06-48)
- Task 13.7.3: Intermediate and Final Conference (M30, M48)

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Stakeholder Interaction

13.7.1 Reference Group Meeting

29 September 2016 **Kick-off meeting Reference Group**

in Hamburg alongside WindEnergy Exhibition & conference

- participants: 20
- to provide additional feedback and input from outside the project consortium

WindEnergy Hamburg
The global on- & offshore expo
27 – 30 September 2016
windenergyhamburg.com

Wind EUROPE SUMMIT 2016
27-29 SEPTEMBER
HAMBURG

PROMOTioN Reference Group Meeting - 29 September 2016

CCH – Congress Centre Hamburg

Level: Floor 1

Room name: C4.1

THURSDAY 29 SEPTEMBER 2016

09:00–09:15	Registration and Coffee
09:15–09:30	PROMOTioN – Project Background and Purpose of the Reference Group Paul Raats – DNV GL
09:30–10:15	Introduction and Expectations of the Members of the Reference Group Moderation: Andreas Wagner, Stiftung OFFSHORE-WINDENERGIE
10:15–10:45	Socio-economic perspective on benefits of a meshed HVDC grid Edwin Haesen – Ecofys
10:45-11:00	Technical perspective on benefits of a meshed HVDC grid Prof. Tim Green – Imperial College London
11:00–11:30	Coffee Break
11:30–12:15	Functional requirements from AC and DC grids for DC grid protection development Dirk van Hertem – KU Leuven
12:15–13:00	Drafting a roadmap for the evacuation of offshore renewable generation in the context of the PROMOTioN project Pierre Henneaux – Tractebel
13:00-14:00	Joint Lunch
14:00–14:45	Cost Benefit Analysis (CBA) for trans-European Offshore Infrastructure Investments (WP7) Tim Schittekatte – EUI
14:45–15:00	Final statements Reference Group Moderation: Andreas Wagner, Stiftung OFFSHORE-WINDENERGIE

Please note: **Chatham House rule** applies for the meeting!

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Stakeholder Interaction

Kick-off Stakeholder workshop (WP7),
29 June 2016, Brussels (participants: 60)

10:00–10:30	Registration and Coffee
10:30–10:45	Opening and Welcome – PROMOTioN – Meshed Offshore HVDC Grids as a Pathway to a Sustainable European Electricity System Paul Raats – DNV GL
10:45–11:00	Offshore-Windenergy – Present status and prospects Tbd. – WindEurope
11:00–11:30	The Vision of meshed HVDC Offshore Grids – What it means for Europe Marie Donnelly – European Commission
11:30–12:00	Regulatory and Financial Aspects of meshed HVDC Offshore Grids Alan Croes – TenneT
12:00–13:15	Panel and Stakeholder Discussion: Energy Policy Aspects of meshed HVDC Offshore Grids Claude Turmes – EUFORES President, MEP Jan Hensmanns – NSCOGI Jean-Baptiste Paquel – ENTSO-E Lineke den Ouden – The presidency of the Council of the EU (requested) Moderation: Andreas Wagner – Stiftung OFFSHORE-Windenergie
13:15–14:30	Joint Lunch
14:30–16:00	Panel and Stakeholder Discussion: Suitable Technologies for meshed HVDC Offshore Grids Jenny Josefsson – ABB Dr. Frank Schettler – Siemens Samer Oukalli – Mitsubishi Electric Europe Alessandro Conte – Prysmian Tbd. – GE Grid Solutions Moderation: Dr. Gregor Nikolic – RWTH Aachen
16:00–16:30	Final statements and Wrap-Up Paul Raats – DNV GL
16:30	End of the Workshop

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Dissemination

Task 13.8
External communication via marketing material and media work

Deliverable 13.8 **- submitted July 2016**

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

PROMOTioN
OBJECTIVES AND PARTNERS

A meshed European offshore HVDC transmission grid connecting offshore wind farms to shore could provide significant financial, technical and environmental benefits to the European electricity market.

BROAD RANGE OF CHALLENGES ADDRESSED:
- Identification of requirements and investigation of suitable topologies for meshed HVAC/DC offshore grids
- Development of protection components and schemes for offshore grids
- Ensuring interoperability of components and initiation of standardization
- Recommendations for a coherent EU and national regulatory framework including financing mechanisms for meshed offshore grid infrastructure deployment
- Demonstration of cost-effective offshore HVDC equipment
- Deployment plans for HVDC grid implementation

WIDE CONSORTIUM – DIFFERENT EXPERTISE – ONE GOAL!

WHAT HAMPERS THE DEPLOYMENT OF A MESHED HVDC OFFSHORE GRID?
- high cost of converter technology
- lack of experience with protection systems and fault clearance components
- Legal/ Regulatory/ Economical barriers

Marketing materials

- Roll up banners
- Leaflets
- Business cards
- Standard project presentation (PPT)

POLITICAL CONTEXT

CONTACT

PROMOTioN

DEVELOPING MESHED HVDC OFFSHORE GRIDS FOR COST-EFFECTIVE AND RELIABLE ELECTRICITY SUPPLY

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Press Releases

- **14 March 2016**: PROMOTioN - New EU project to boost the development of meshed HVDC offshore grids in Europe
  - Announcement of the start of the PROMOTioN project, including official statements by the European Commission, Project Coordinator as well as valuable information on the content of the project.

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

PRESS RELEASE

PROMOTioN – NEW EU PROJECT TO BOOST THE DEVELOPMENT OF MESHED HVDC OFFSHORE GRIDS IN EUROPE

Berlin, 14 March 2016. A meshed offshore transmission grid connecting offshore wind farms to land could provide significant financial, technical and environmental benefits to the European electricity market. Launched this January, the project 'PROgress on Meshed HVDC Offshore Transmission Networks' (PROMOTioN) aims to investigate these benefits during the next four years. Currently it is the biggest energy project in the EU's Horizon 2020 Research Program.

The goal is to develop and demonstrate three key technologies: diode rectifier offshore converters, multi-vendor HVDC (high-voltage direct current) grid protection system, and the full power testing of HVDC circuit breakers. Furthermore, a regulatory and financial framework will be developed for the coordinated planning, construction and operation of integrated offshore infrastructures, including an offshore grid deployment plan (roadmap) for the future offshore grid system in Europe.

Currently, the high cost of converter technology, a lack of experience with protection systems and fault clearance components hamper the deployment of meshed HVDC offshore grids. In addition the deployment is hindered by limitations inherent to existing European regulations for the purpose of developing cross border offshore infrastructures, national legal and regulatory barriers and financing issues.

Marie Donelly, Director Renewables, Research and Innovation, Energy Efficiency – DG ENER, said: "There is great potential in the Northern Seas to deliver significant quantities of clean energy, helping us both to decarbonise our economy and to increase the security of our energy supply. The Northern Seas offer unique opportunities for cooperation and to deliver cost-reduction to the offshore energy systems. We think that an offshore grid in the North Sea could become a flagship project for regional cooperation as foreseen by the Energy Union."

- **23 June 2016**: EU project PROMOTioN launches new website
  - Announcement of official launch of the website of the PROMOTioN project, as well as newsletter and first stakeholder event on 29 June in Brussels

- sent to around 1.500 media contacts

- 27 media reports

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Press Coverage

EU Examining Benefits of Meshed Offshore Grid

A 4-year project investigating the benefits of a meshed offshore transmission grid has been launched recently under the EU's Horizon 2020 Research Program, and is currently the biggest energy project within the program.

A meshed offshore grid connecting offshore wind farms to land could provide significant financial, technical and environmental benefits to the European electricity market, DNV GL said.

The goal of the PROgress on Meshed HVDC Offshore Transmission Networks PROMOTioN) project is to develop and demonstrate three key technologies:

Offshorewind.biz 22/03/2016

EU spotlight on offshore links

14/03/2016 RENEWS

The EU has launched a four-year project to boost the development of meshed HVDC offshore grids.

EU to weigh benefits of 'meshed' offshore grid in North Sea

16/03/2016 Recharge

EU project to boost meshed HVDC offshore grids

Horizon 2020 | A meshed offshore transmission grid connecting offshore wind farms to land could provide significant financial, technical and environmental benefits to the European electricity market. Launched earlier this year, the project PROgress on Meshed HVDC

ence with protection systems and fault clearance components are hampering deployment of meshed HVDC offshore grids. In addition, the deployment is being hindered by limitations inherent in existing European regulations for the purpose of developing cross-border offs-

large-scale renewables into the grid and to ensure a future-proof grid that is affordable, reliable and sustainable. By bringing in our 90 years of expertise in power systems, renewable technologies and experience in leading many joint industry projects. I am confident (the

02/05/2016 Ship & Offshore

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Press Briefing

- Alongside Berlin GA meeting – 1st Dec. 2016
- Targeted at German **trade press**
- Explain the project more detailed at an informal setting
- Media: BizzEnergy, Energie und Management, Zeitschrift für Energiewirtschaft, Energate
- Project participants: DNV GL (C. Plet); TenneT (N. de Groot; D. Abdoelkariem); RWTH (S. Winter); SOW (S. Boie; A. Wagner)
- Highlighted project **objectives** and **benefits**, presented first **deliverables** and described the **political context** of the project
- Press Coverage: 2 articles
  - 2nd December 2016 Energie und Management
  - January 2017 Magazin für Energiewirtschaft

Energie & Management powernews vom 02.12.2016

E&M POWERNEWS

Informationen für bessere Entscheidungen

STROMNETZ: Zukunftsprojekt Offshore-Grid

In einem europäischen Forschungsprojekt mit dem Titel "Promotion" sollen Grundlagen für den Aufbau eines integrierten europäischen Offshore-Stromnetzes entwickelt werden.

Trends + Analysen

Forschungsprojekt Promotion

34 Partner erarbeiten Grundlagen für ein Offshore-Stromnetz

An Land ist das Stromnetz in Europa bereits weitgehend ausgebaut, auf See gibt es bisher erst Einzelverbindungen. Mit der Zunahme der Offshore-Windparks wird auch hier der Bedarf für den Stromtransport steigen. Ein europäisches Forschungsprojekt mit dem Namen Promotion – Progress on Meshed HVDC Offshore Transmission Networks beschäftigt sich seit Anfang des Jahres 2016 mit einem Stromnetz für die Nord- und Ostsee.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Task 13.8
External communication activities

Testimonials - Video Clips

- Project partners **highlight** relevant **aspects/aims** of PROMOTioN
- Clips with **Jenny Josefsson** (ABB), **Cornelis Plet** (DNV GL), **Niek de Groot** (TenneT), **Ceciel Nieuwenhout** (RUG), **Alexander Broy** (Siemens), **Andreas Wagner** (SOW)
- 6 video clips, each roughly 1 minute
- Embedded on **project website and YouTube** channel
- https://www.promotion-offshore.net/insight/detail/promotion-testimonials/
- https://www.youtube.com/channel/UCnJOa4oeTyRIuI60Ufecpmw
- Support from subcontractor Edelmann.ergo

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project Management

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project coordination

- Management Procedures & Actions
  - Collaboration & Interaction
  - Contract Management
  - Quality Control
  - Reporting
  - Liaison
- Financial Aspects

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Management procedures and methods

- Project plans for WPs: WBS, planning, budget allocation
- ProjectPlace: Online project collaboration tool
- Weekly project coordination meetings
- Monthly PMG telcons & physical meetings
- 6 monthly project conferences
  - Day 1 – WP meetings
  - Day 2 – WP reporting to consortium
  - Day 3 – General Assembly and PMG
- Liaising with EU and interested parties: BRIDGE, China State Grid, Hyosung, SCibreak
- 1 amendment carried out & 1 prepared
- Proposal selection process initiated after WP8 ‘NO GO’

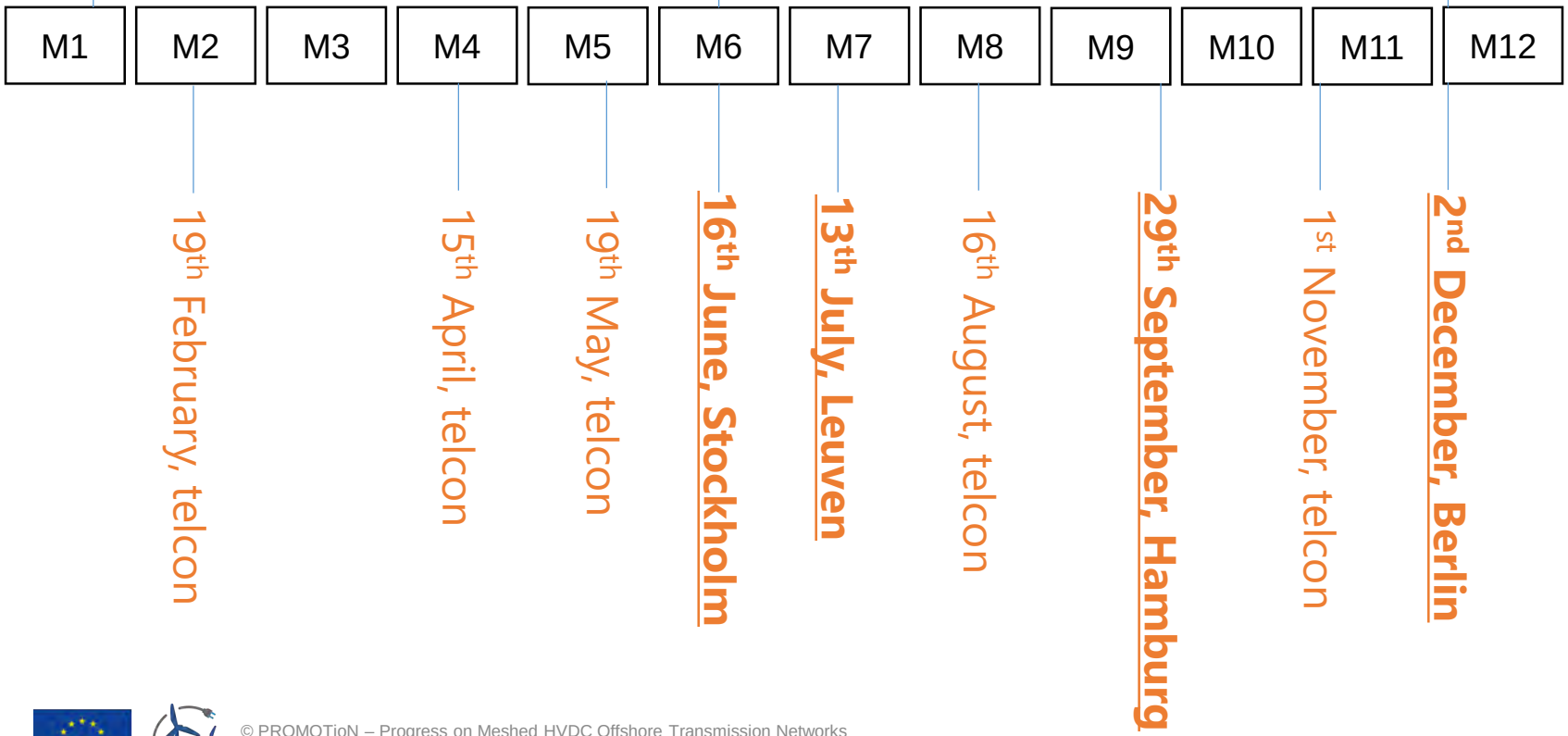
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.

Project conferences and PMG meetings

21-22 January 2016
Kick-off
Arnhem, Netherlands

14-16 June 2016
6 Month meeting
Stockholm, Sweden

1-2 December 2016
12 Month meeting
Berlin, Germany



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Quality control

- Publication review procedure - SOW
  - Inform Project Coordinator & WP13
  - PMG approval
  - Fast & normal procedures
  - Procedure for press release

- Deliverable review procedure – R&D Coordinator
  - Two reviewers from PMG
  - Two review rounds
    - 8 weeks prior - Structure and basic idea
    - 3 weeks prior - Content and quality
  - Review sheet

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project internal reporting

- Per partner
  - Technical reporting
    - Work performed during the period
    - Explanatory note on major cost items
    - Explanation of the impact of major deviations from the budget
  - Financial reporting (excel)
    - Man-hours per person and costs
    - Travel cost linked to Meetings or other purposes
    - Equipment costs
    - Cost of other goods and services
    - Subcontracting cost
  - Each half year
  - If applicable combined with Periodic report to EU
  - First half year – 88% received, missing info partly accepted as participation in first half year was limited
  - Second half year / periodic report – 100% received

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Project internal reporting

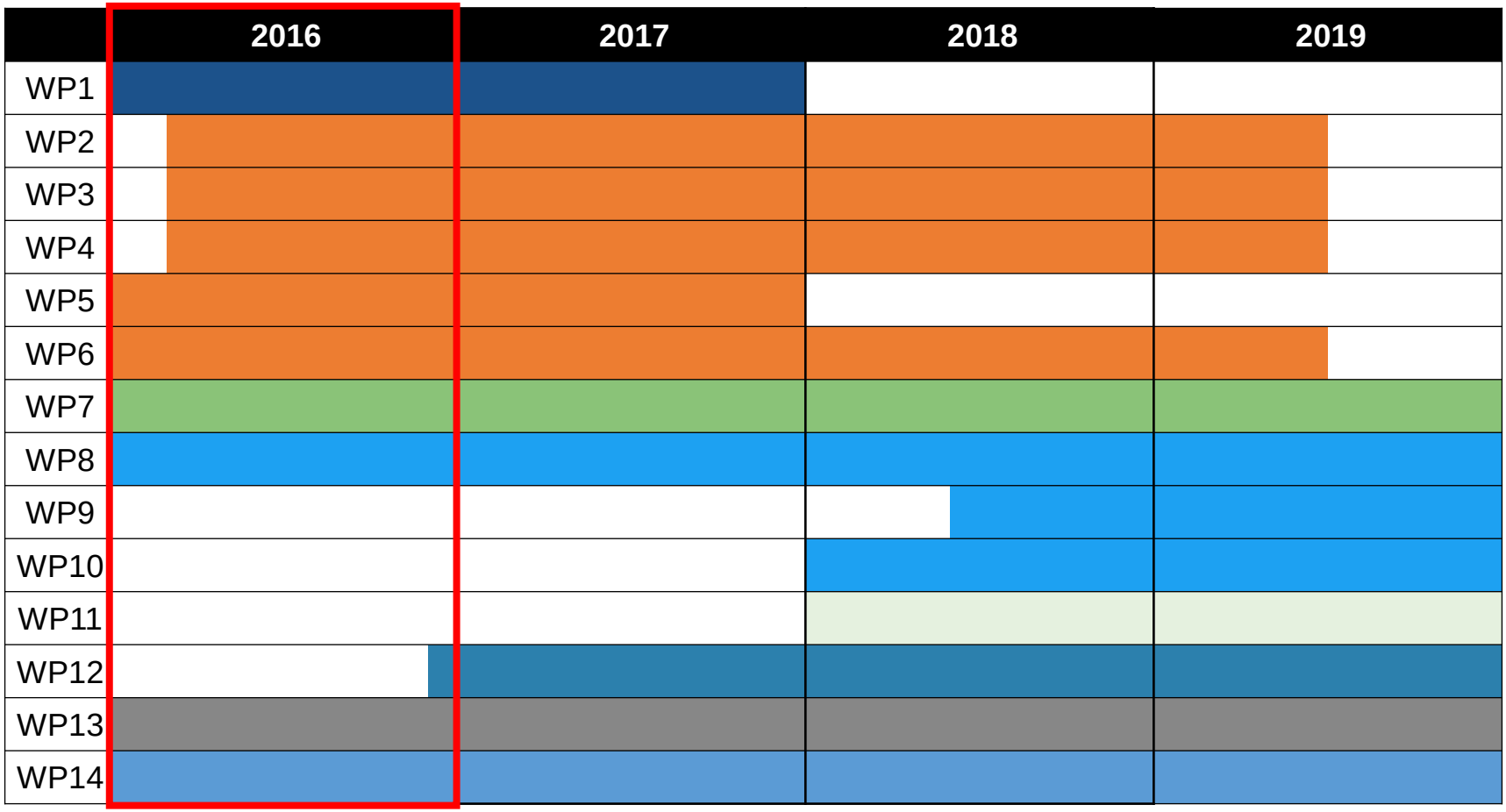
- Per Work package by WP leader
  - PowerPoint presentation
    - Objectives (per quarter)
    - Progress
    - Deviations
    - Bottlenecks and remedy
  - Quarterly and presented and discussed in PMG
  - If combined with Periodic report to EU, a more detailed description in Word

  - We started with a quarterly reporting in Word, but that didn't work. PowerPoint is a good solution as it also discussed right away in the PMG.

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

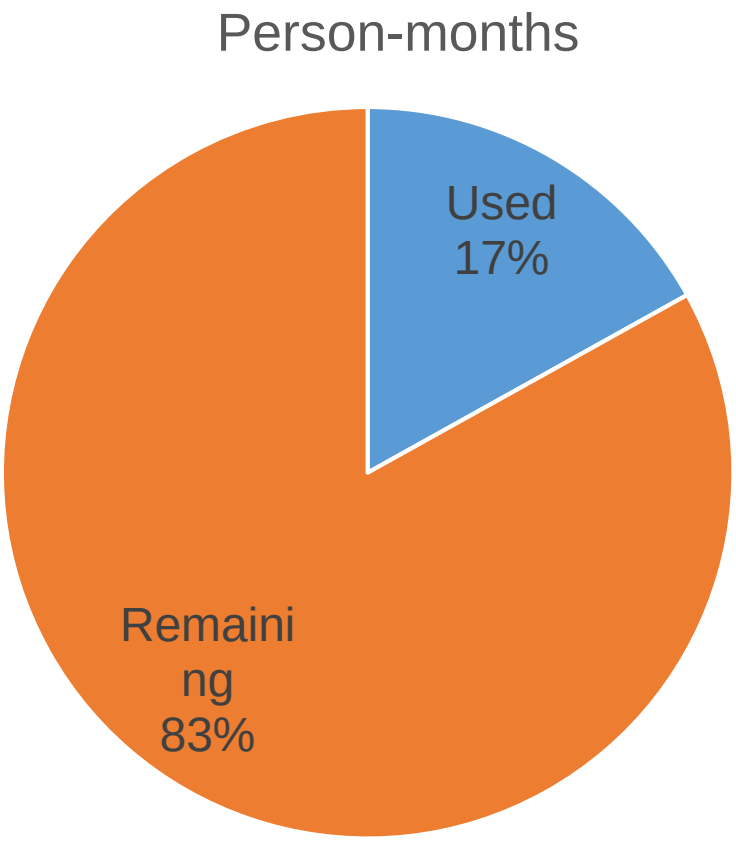
Planning

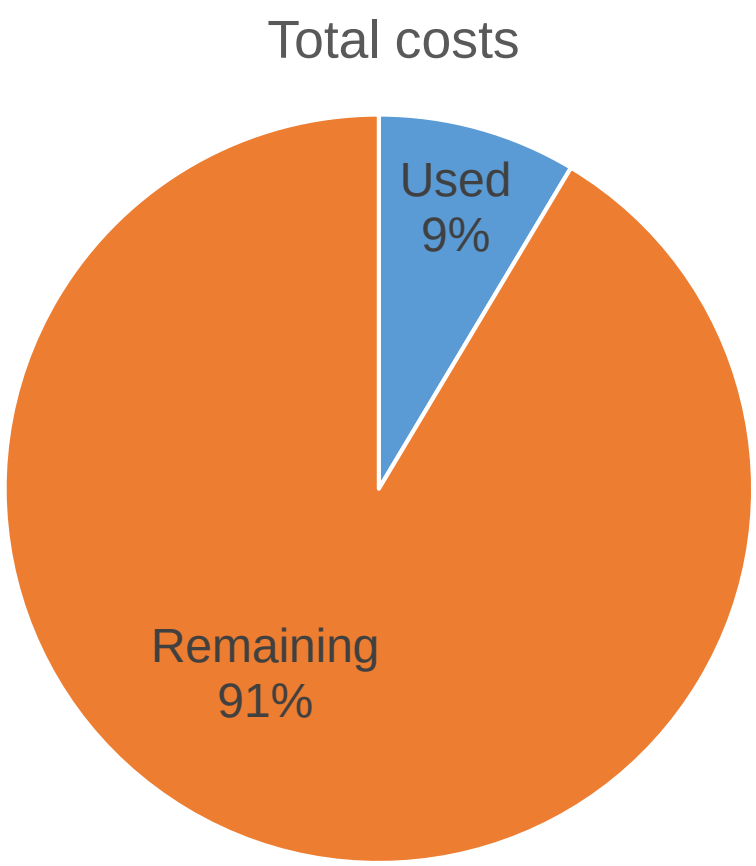
Period 1



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

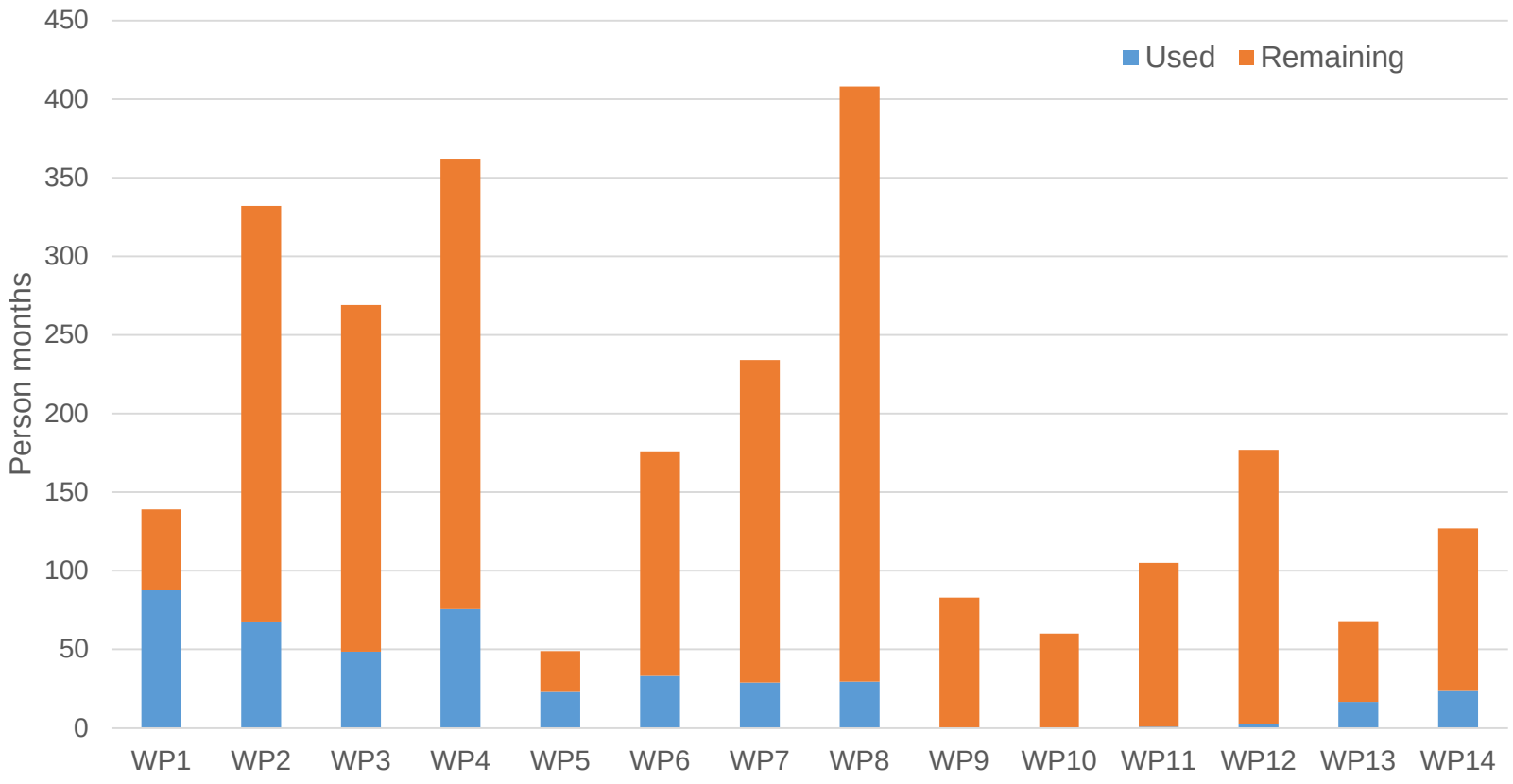
Financial Aspects





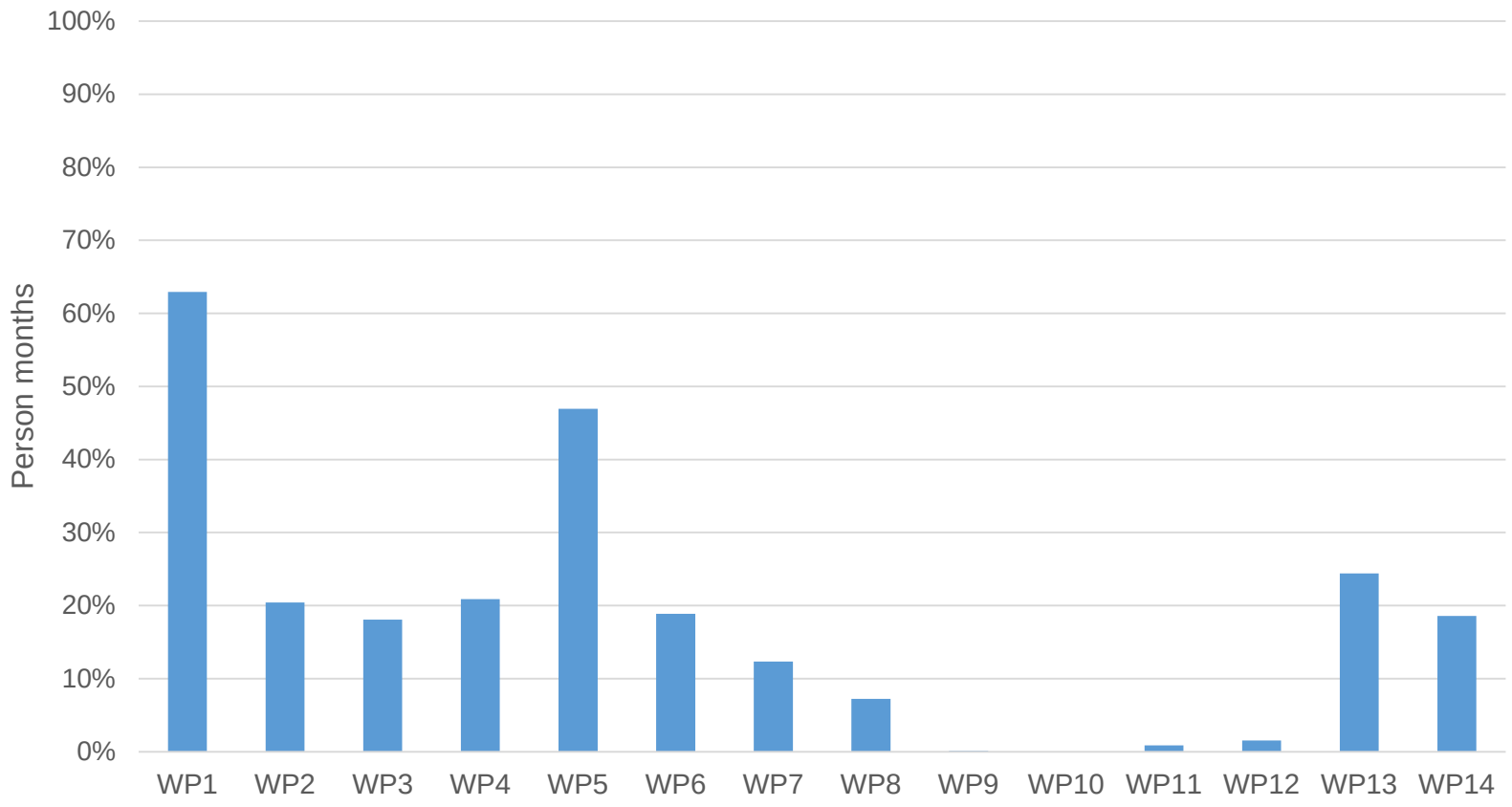
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Person-months budget – WP level



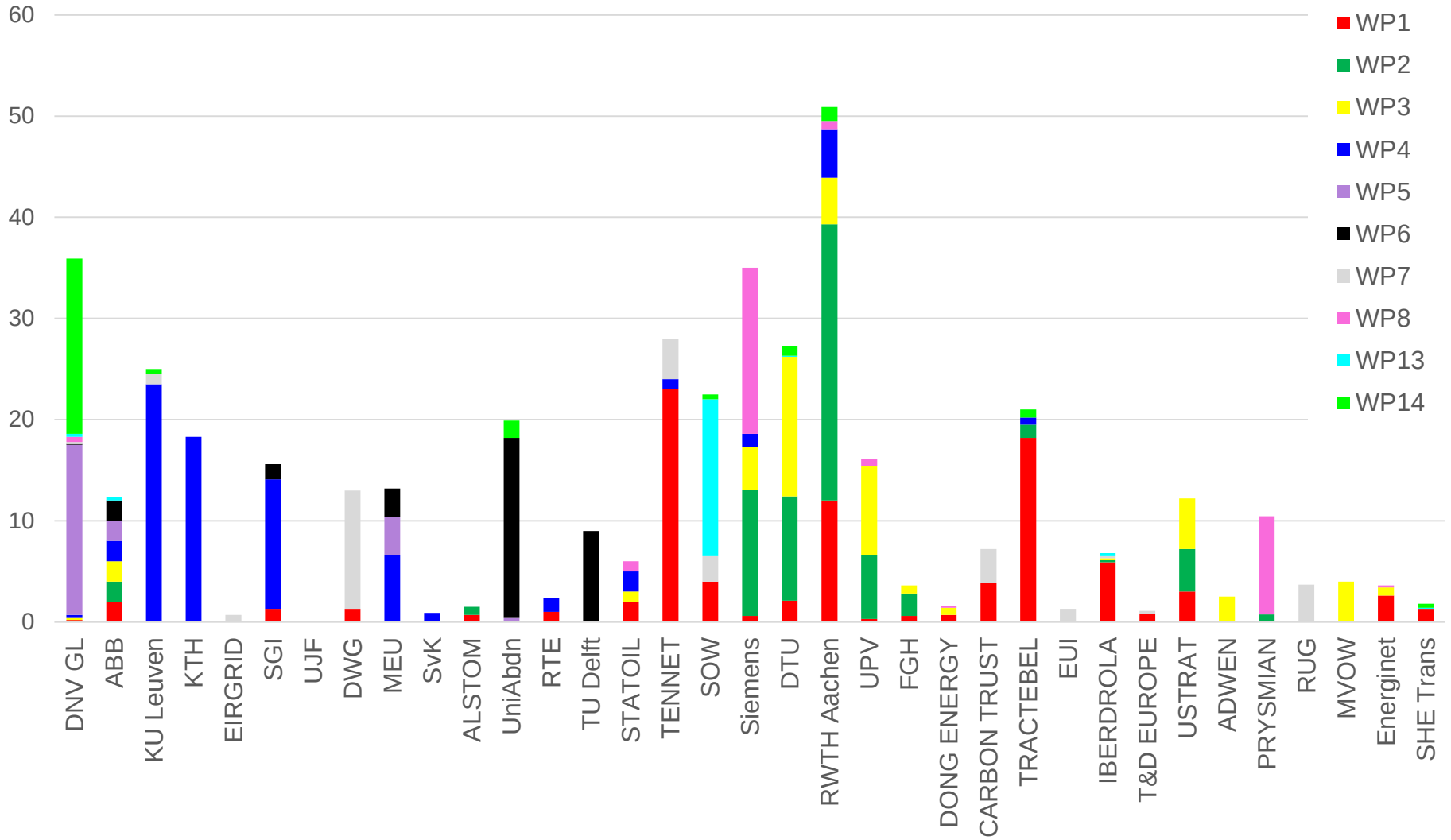
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Person-months % completion – WP level



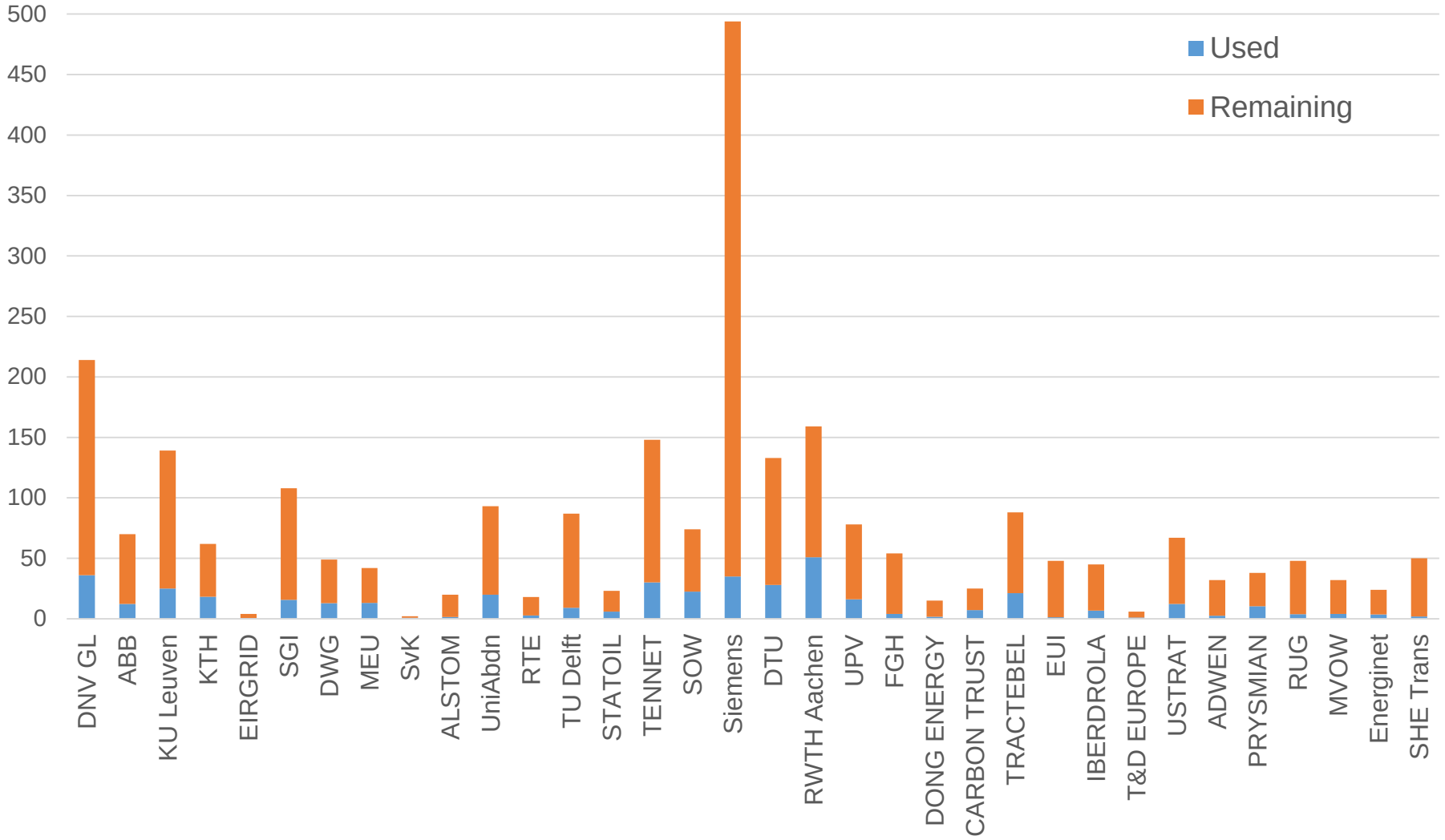
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Work package participation – Partner level



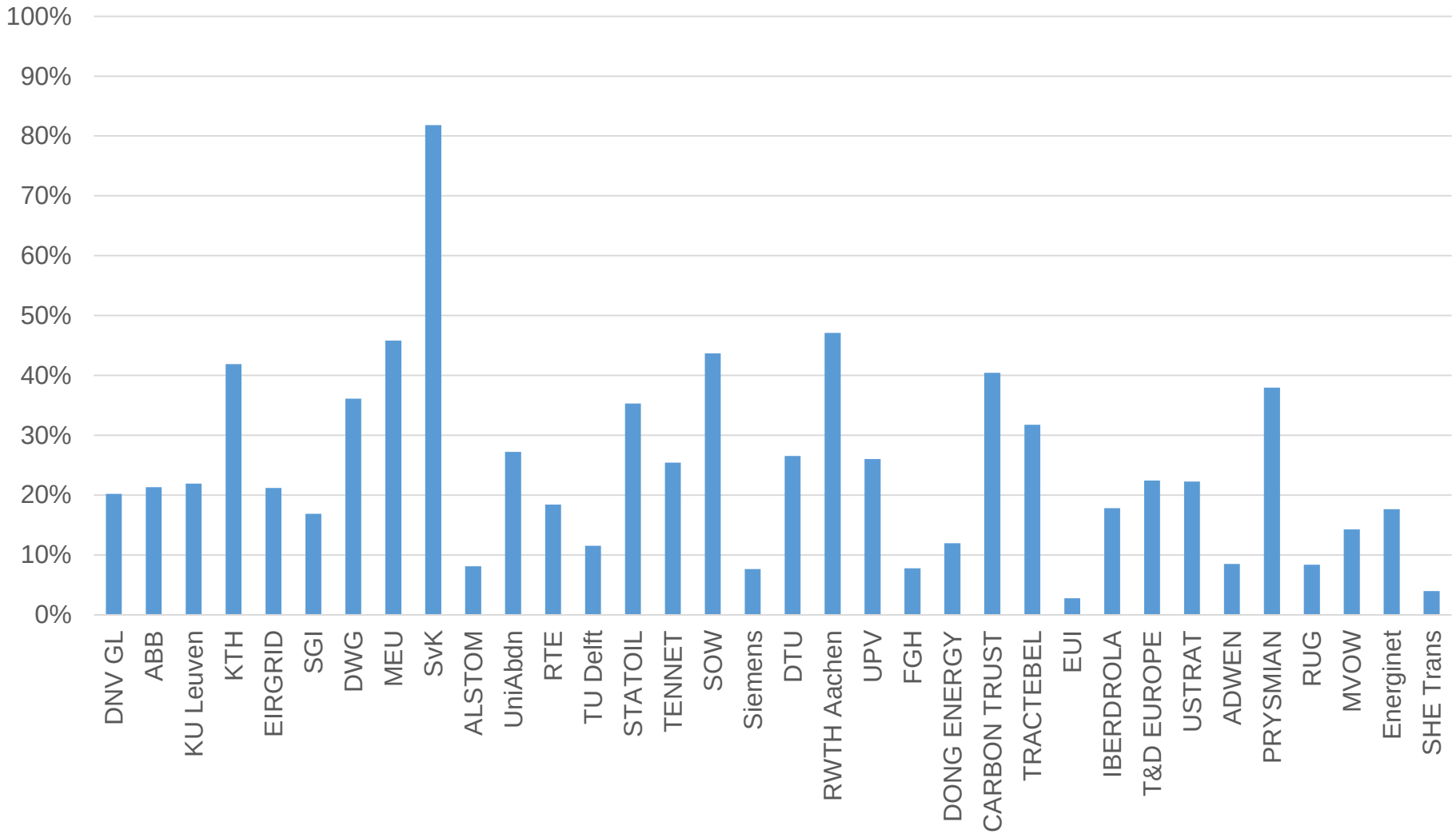
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Person-months budget – partner level



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Person-months budget – Partner level



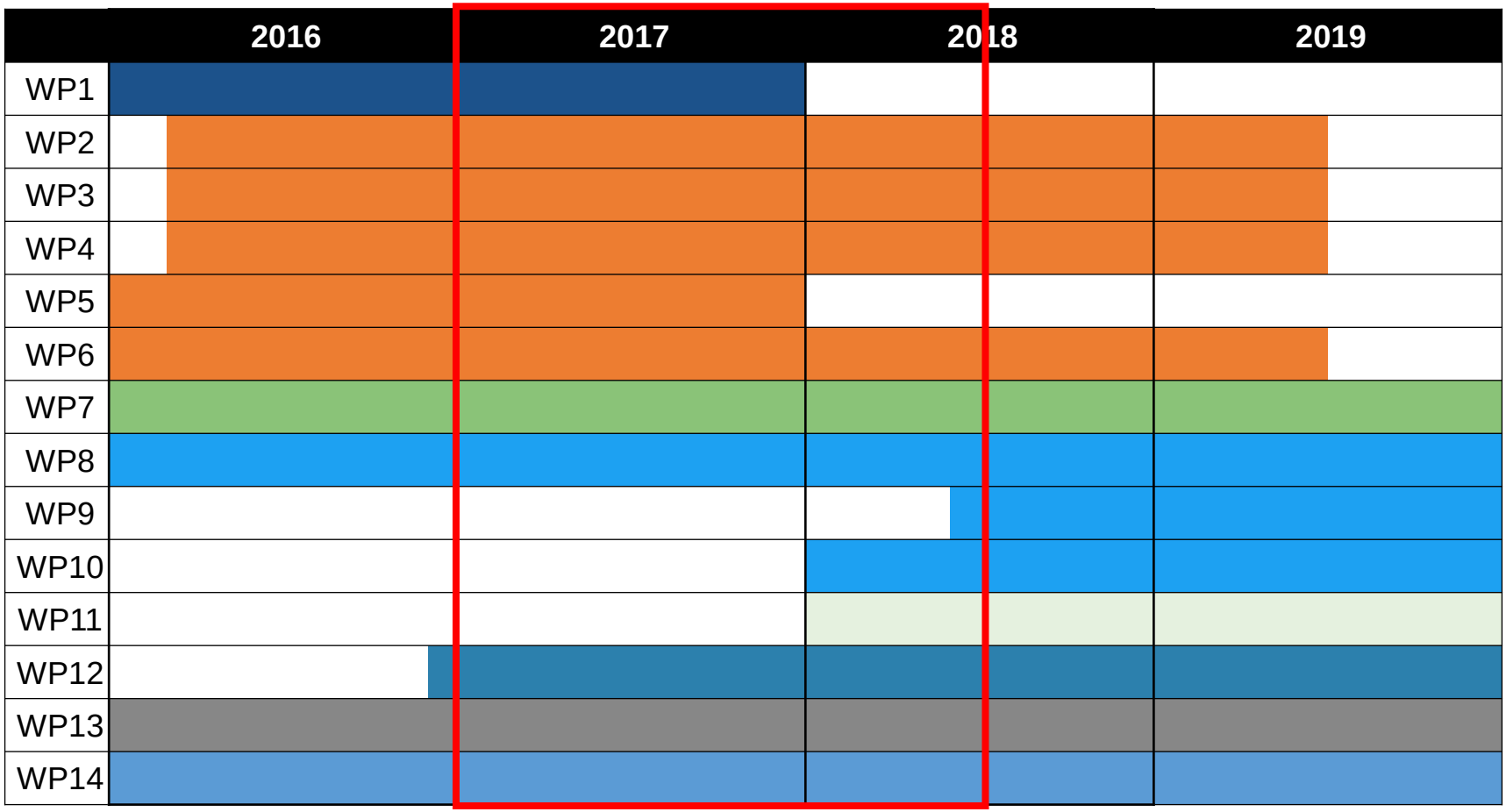
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Next Period

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Next period

Period 2



© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Next Period

- Project conference in Aberdeen: 31st May – 2nd June
- Second stakeholder & reference group meetings
- Two amendments
  - New partner
  - New proposals
- End of work packages
  - work package 1 – Requirements for meshed offshore grids
  - work package 5 – Test environment for HVDC circuit breakers
- Start of demonstrators
  - Work package 9 – Demonstration of DC grid protection
  - Work package 10 – Circuit breaker performance demonstration
- Start of harmonisation & standardisation
- Start of deployment plan

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Summary of proposals

	DC GIS technology demonstrator	MMC Test bench	Extension of WP13	DC Circuit breaker logistics	Cost Beneift Analysis method	Budget for new partner
Identify **technical requirements** and investigate possible **topologies** for **meshed HVDC offshore grids**	X	X				
Develop **protection schemes** and **components** for HVDC grids	(X)			X		X
Establish components' **interoperability and initiate standardisation**	X	X				X
Demonstrate cost-effective offshore HVDC equipment	X	X		X		X
Develop recommendations for a coherent EU and national **regulatory framework** for HVDC offshore grids					X	
Develop **recommendations for financing mechanisms** for offshore grid infrastructure deployment					X	
Develop a **deployment plan** for HVDC grid implementation	X	X	X	X	X	X
Disseminate results to relevant stakeholder communities	X		X			

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Summary

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Main achievements so far – 1st Year Wrap-Up

21th of March 2017 / Brussels

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© TenneT TSO GmbH

- Introduction
- Laying foundations
- Deliverables & quality management
- Project management
- Impact

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Introduction

- PROMOTioN started 01.January 2016
- Running for about a year
- Ambitious work program, biggest H2020 energy project so far
- General challenges
  - Number of diverse topics
  - Number of deliverables
  - Number of partners
  - Structural changes

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Introduction

- PROMOTioN started 01.January 2016
- Running for about a year

A smooth sea never made good sailors…

- Number of deliverables
- Number of partners
- Structural changes

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Starting up PROMOTioN

- Common challenges at the start of big projects
  - Communication needs to be organized and take up speed
  - Same description of work, different perspectives on its meaning
  - Open questions from the proposal stage
  - Need to further define various interfaces between work packages/ different project branches
  - …
- PROMOTioN is no exception to the rule

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Laying foundations

- Organizational achievements
  - Management & communication structures set up
  - Same description of work, same understanding
  - Swift start of “actual work”

- First key project results
  - Setting up scenario frameworks and defining requirements (e.g. WP 1)
  - Unifying perspectives, methodologies and tools (e.g. WP 2)
  - Foundations for demonstration activities (e.g. WP 6)
  - … (and many more)

- Building the road for future activities, deliverables and the deployment plan

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.

Overview

- Number of deliverables in PROMOTioN: 101
- Number of deliverables due to this date: 27 (> 2/ month)
- Majority of deliverables were delivered in time
- Exceptions
  - General staffing issues
  - Sum of minor subtask delays
  - “Rather a few weeks late, than having open endings/ being unclear”

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.

Quality assurance (1)

- Deliverable quality assurance process set up
  - Internal reviews for all deliverables
  - Two reviewers from the PMG per deliverable
  - Ensures critical “external” feedback

- “*We had meetings and meetings and meetings…*”
  - Extensive coordination between partners
  - Many direct exchanges facilitating in depth discussions
  - Getting to know each other always makes coordination easier

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.

Quality assurance (2)

- Making knowledge available where it is needed
  - Flexible handling of participation across WP
  - Good cooperation between work packages
  - Good cooperation across different work packages

- Build in quality assurance - predefined review loop
  - Requirements defined early in the project
  - Possibly: changing external framework, new internal insights
  - Re-evaluation of requirements in work package 1 mid project

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Addressing challenges

- WP 8 “No Go” decision
  - Significant implications for project structure and associated topics
  - Need to manage the “No Go process”
  - → Robust project management structures

- Setting up a new proposal process
  - 3 months time
  - Several million euros “budget”
  - → Effective project management structures

- Making adjustments where needed
  - Focussing on results pushing the TRL of relevant concepts and technologies
  - Revision of procedures and structures
  - → Flexible project management structures

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.

External exchanges and acknowledgements

- Reminder: We just finished year one!
- Good start of the stakeholder interaction
  - Participation at PROMOTioN events
  - Solid interest of press (although directed towards final results)
  - Very positive feedback from external organizations
  - First publications on their way
- International attention
  - Lots of feedback from European stakeholders
  - Interest of international stakeholders to exchange with PROMOTioN

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Summary

- Foundations for the upcoming phases of the project are set
- Maintaining a strong focus on questions of high practical significance and pushing TRL of meshed HVDC offshore solutions
- Management structures working
- Successful start of project activities

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Summary

- Foundations for the upcoming core phase of the project set
- Maintaining a strong focus on questions of high practical
- Management structures working
- Successful start of project activities

…, but the project has proven to be able to stay on course despite rough waters

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Thank you for your attention

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© ABB

Thank you

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

© TenneT TSO GmbH

APPENDIX

DISCLAIMER & PARTNERS

COPYRIGHT

PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
MAIL info@promotion-offshore.net WEB www.promotion-offshore.net

The opinions in this presentation are those of the author and do not commit in any way the European Commission

PROJECT COORDINATOR

DNV GL, Kema Nederland BV
Utrechtseweg 310, 6812 AR Arnhem, The Netherlands
Tel +31 26 3 56 9111
Web www.dnvgl.com/energy

CONTACT

PARTNERS

DNV GL (Kema Nederland BV), ABB AB, KU Leuven, KTH Royal Institute of Technology, EirGrid plc, SuperGrid Institute, Deutsche WindGuard GmbH, Mitsubishi Electric Europe B.V., Affärsverket Svenska kraftnät, Alstom Grid UK Ltd (Trading as GE Grid Solutions), University of Aberdeen, Réseau de Transport d'Électricité, Technische Universiteit Delft, Statoil ASA, TenneT TSO B.V., Stiftung OFFSHORE-WINDENERGIE, Siemens AG, Danmarks Tekniske Universitet, Rheinisch-Westfälische Technische Hochschule Aachen, Universitat Politècnica de València, Forschungsgemeinschaft für. Elektrische Anlagen und Stromwirtschaft e.V., Dong Energy Wind Power A/S, The Carbon Trust, Tractebel Engineering S.A., European University Institute, Iberdrola Renovables Energía, S.A., European Association of the Electricity Transmission & Distribution Equipment and Services Industry, University of Strathclyde, ADWEN Offshore, S.L., Prysmian, Rijksuniversiteit Groningen, MHI Vestas Offshore Wind AS, Energinet.dk, Scottish Hydro Electric Transmission plc

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

APPENDIX

COLOR SUMMARY

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.