PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Progress on Meshed HVDC Offshore Transmission Networks

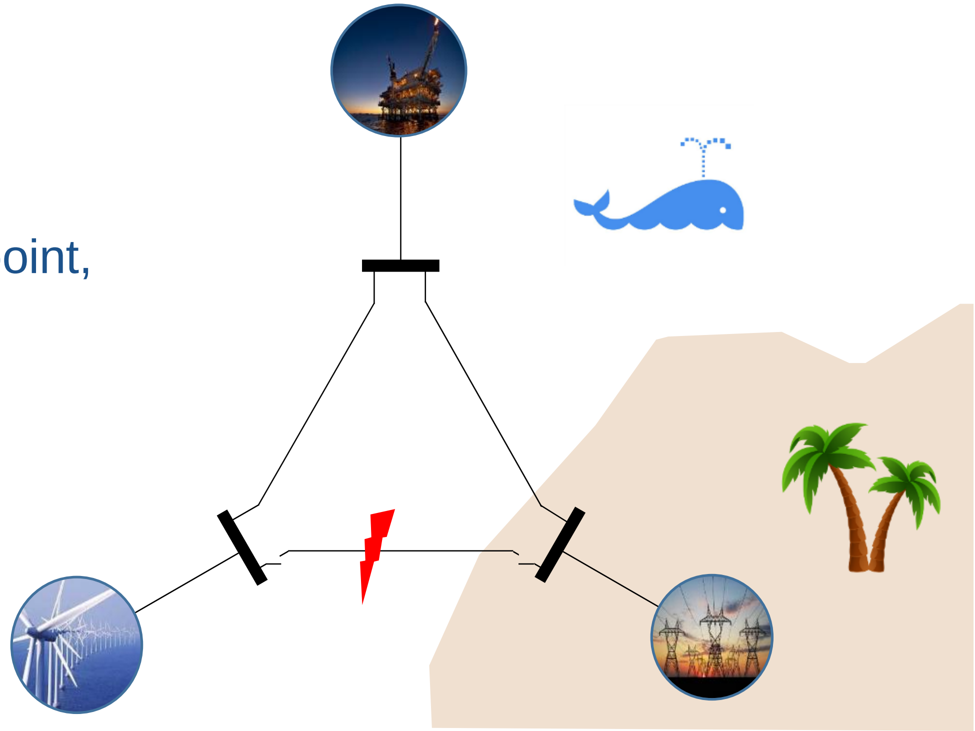
Berlin, 27-02-2019, Ivan Savitsky (CarbonTrust)

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

PROMOTioN Context

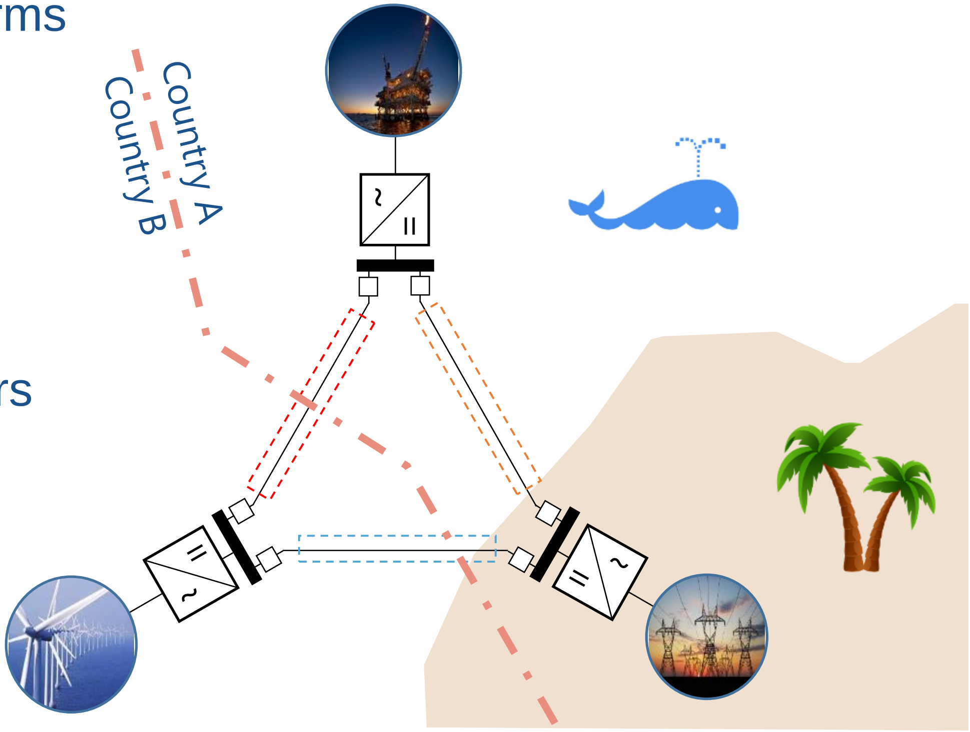
Why a meshed grid?

- Different types of offshore users
  - Consumers
  - Producers
  - Interconnectors
- Traditionally connected point-to-point, dedicated connection
  - Lower utilisation
  - Reliability offshore
- Mesh offers benefit



Challenges

- Offshore requires cables & platforms
- Long cables require HVDC
- HVDC requires converters
- HVDC network requires HVDC control & protection system
- HVDC protection system requires HVDC switchgear / circuit breakers
- Transnational network
  - Regulatory differences
  - Business models
  - Governance
  - Financing



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Objectives

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

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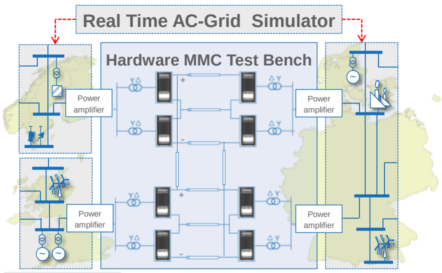
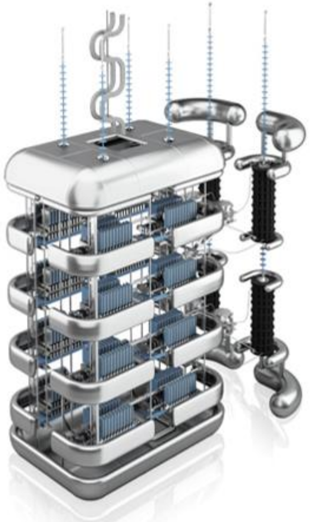
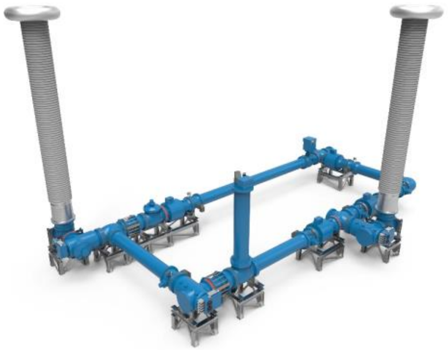
Demonstrators







HVDC network control

MMC test bench
RWTH Aachen
Aachen, Germany

HVDC network protection

Multi-terminal test centre
SHE Transmission
Glasgow, UK

HVDC circuit breakers

KEMA High Power Lab
DNV GL
Arnhem, Netherlands

HVDC gas insulated systems

KEMA High Voltage Lab
DNV GL
Arnhem, Netherlands

Statistics

33 partners

11 countries

4 years

42 million EUR

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Partners

TenneT Taking power further

sse

ENERGINET DK

Rte

SVENSKA KRAFTNÄT

EIRGRID

ABB

MITSUBISHI ELECTRIC

SIEMENS

Prysmian Group

SCiBreak Enabling the Supergrid

MHI VESTAS OFFSHORE WIND

DNV·GL

TRACTEBEL Engineering GDF SUEZ

DEUTSCHE WINDGUARD

CARBON TRUST

Ørsted

equinor

RWTH AACHEN UNIVERSITY

UNIVERSITY OF ABERDEEN

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

KTH VETENSKAP OCH KONST

DTU

KU LEUVEN

TU Delft

rijksuniversiteit groningen

European University Institute

University of Strathclyde

STIFTUNG OFFSHORE WINDENERGIE

T&D europe

FGH

SuperGrid Institute

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Carbon Trust Involvement in PROMOTioN

- Carbon Trust have supported PROMOTioN in three work packages

WP1 - Requirements	WP7 – Regulation & Financing	WP12 – Deployment Plan
Requirements for offshore grids	The Legal, Economic and Financial Framework for a meshed offshore grid	CBA Analysis of different topologies Development of a roadmap for meshed offshore Grid

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Legal Framework

Legal Instruments

Asset Classification	Governance Model	Support Schemes for OWF	Planning and Permitting	Decommissioning
Requirement for hybrid asset classification	Provides a structure for economic and financial framework to develop	How would national support schemes operate in a meshed grid	Recommendations for streamlining	Recommendations for alignment across countries

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Financial Framework

Investment Need

Investor Income

How could investors be remunerated?

Financial Strategies

What changes need to be made to attract sufficient finance?

Ownership Models

Who owns the assets and what responsibilities do they have?

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Economic Framework

Planning	Investment	Operation
How should new investments be assessed and progressed?	How should costs and revenues be allocated to generators and investors?	Balancing Mechanism

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Next Steps

1. Recommendations from Work Package 7 will be shared with stakeholders over next few months
2. Final recommendations will be published in the summer
3. The findings from Work Package 7 will feed into the Deployment Plan being developed by Work Package 12.
4. The deployment plan is due to be published towards the end of 2019

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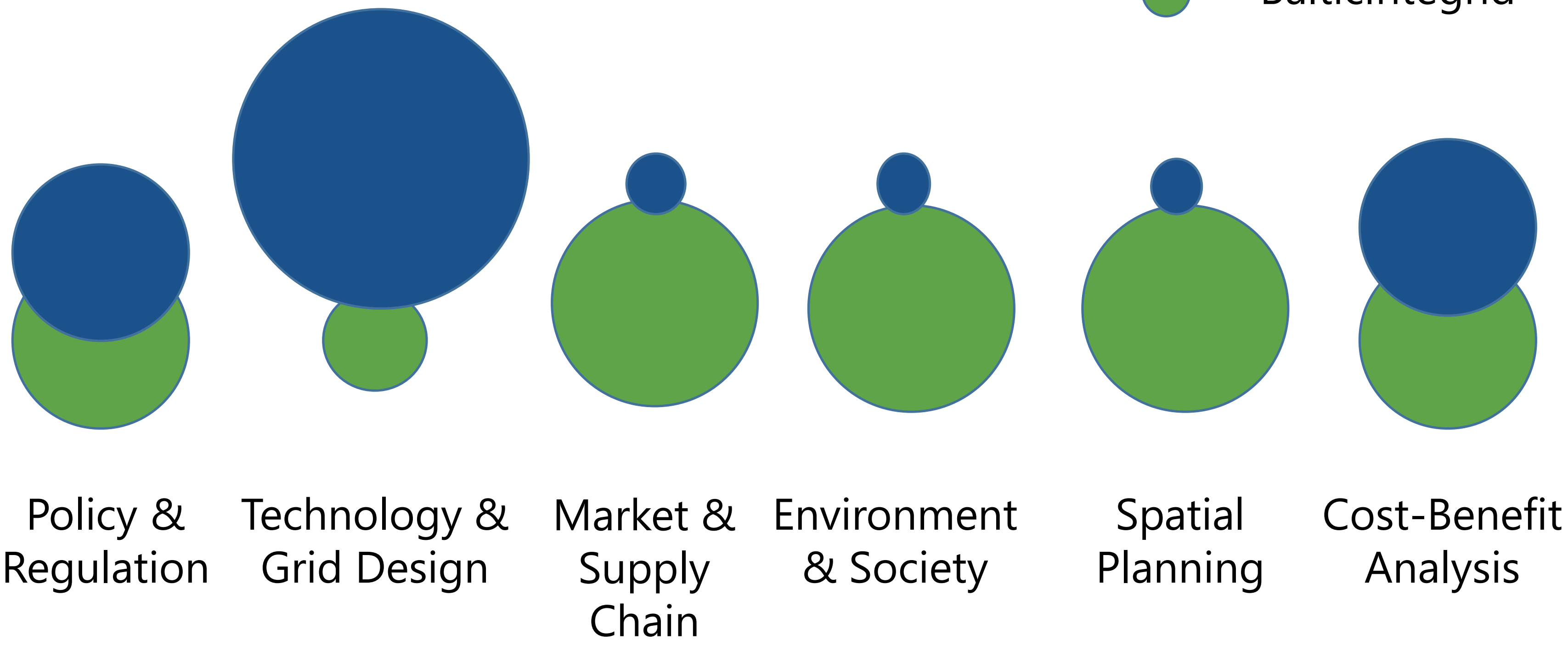
Complementarities with Baltic Integrid



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PROMOTioN workshop in Berlin – 28th February

- Technical Challenges and Recommendation for the Future European Power Grid
- Workshop this Thursday in Berlin looking at:
  - The changes in system inertia;
  - The control and operation of no or low inertia grids;
  - Power quality issues; and
  - Regulation and grid codes.

- 28th February 2019 – Maritim Hotel Stauffenbergstraße 26 10785 Berlin
- 10:00 – 17:00

https://www.promotion-offshore.net/news_events/calendar/detail/technical-challenges-and-recommendation-for-the-future-european-power-grid/ - **REGISTER HERE**

PROMOTioN Newsletter

Sign up for the newsletter

www.promotion-offshore.net/newsletter

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APPENDIX

DISCLAIMER & PARTNERS

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PROJECT COORDINATOR

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

CONTACT

Cornelis Plet
cornelis.plet@dnvgl.com
+31 26 356 2370

PARTNERS

DNV GL Netherlands B.V., 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, Equinor, TenneT TSO B.V., Stiftung OFFSHORE-WINDENERGIE, Siemens AG, Danmarks Tekniske Universitet, Rheinisch-Westfälische Technische Hochschule Aachen, Universitat Politècnica de València, SCiBreak AB, Forschungsgemeinschaft für. Elektrische Anlagen und Stromwirtschaft e.V., Ørsted Wind Power A/S, The Carbon Trust, Tractebel Engineering S.A., European University Institute, European Association of the Electricity Transmission & Distribution Equipment and Services Industry, University of Strathclyde, Prysmian, Rijksuniversiteit Groningen, MHI Vestas Offshore Wind AS, Energinet.dk, Scottish Hydro Electric Transmission plc, SCiBreak AB

European Commission Energy Strategy 2030

40%
Cut in greenhouse gas emissions compared to 1990 levels

32%
Share of renewable energy consumption

27%
Energy savings compared with the business-as-usual scenario

15%
Electricity interconnection target

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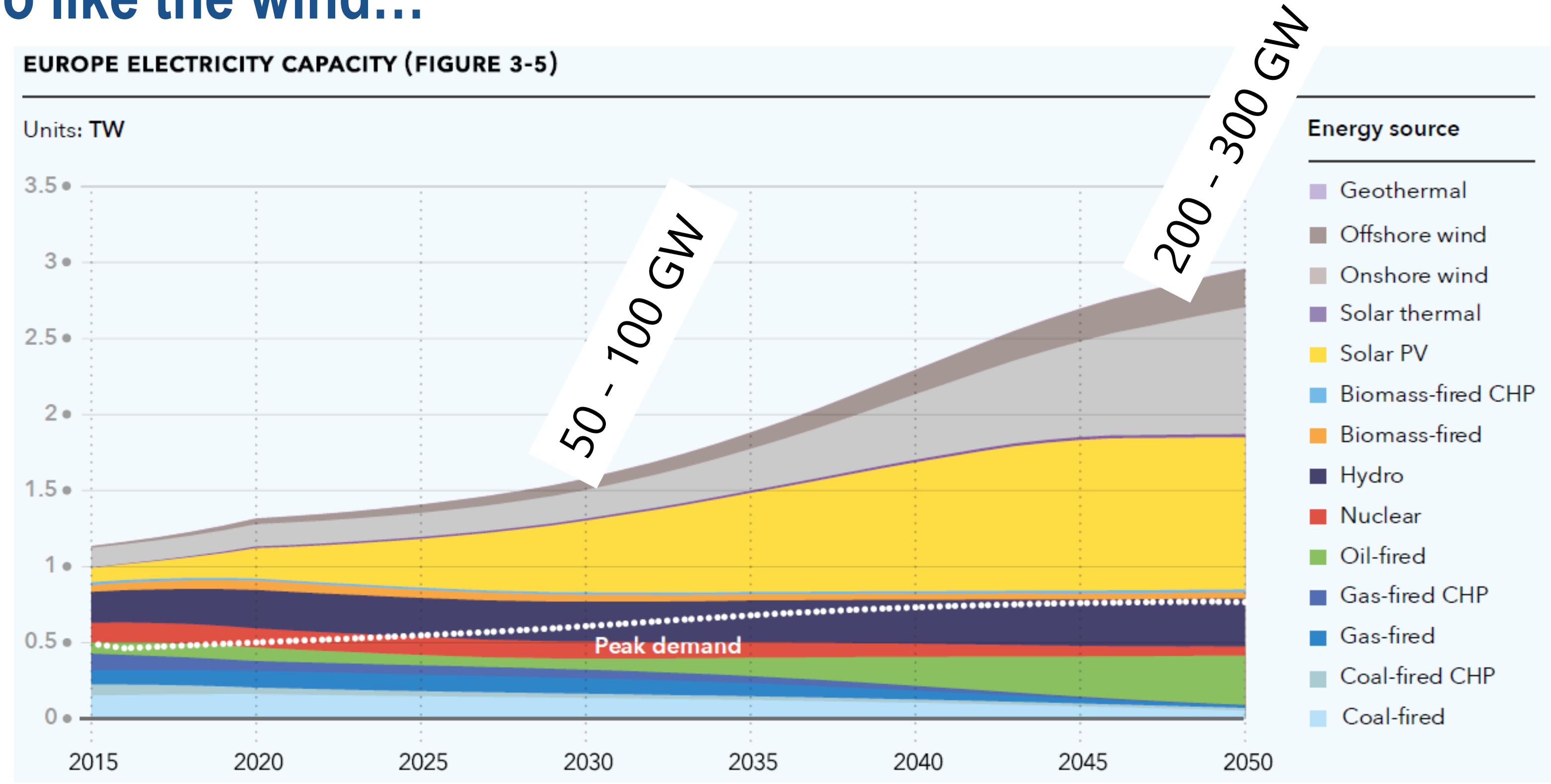
PROMOTioN Context

Go like the wind…



Source: DNV GL - Energy Transition Outlook

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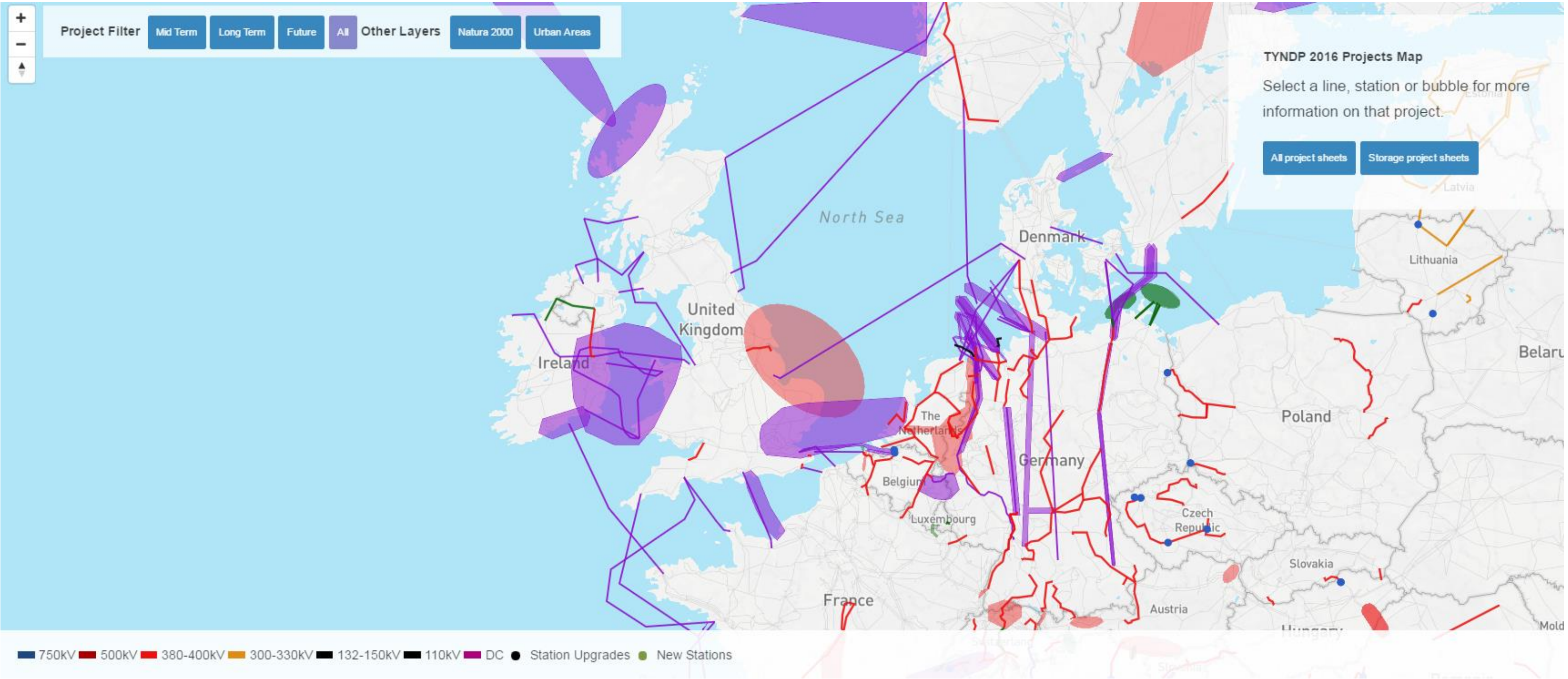
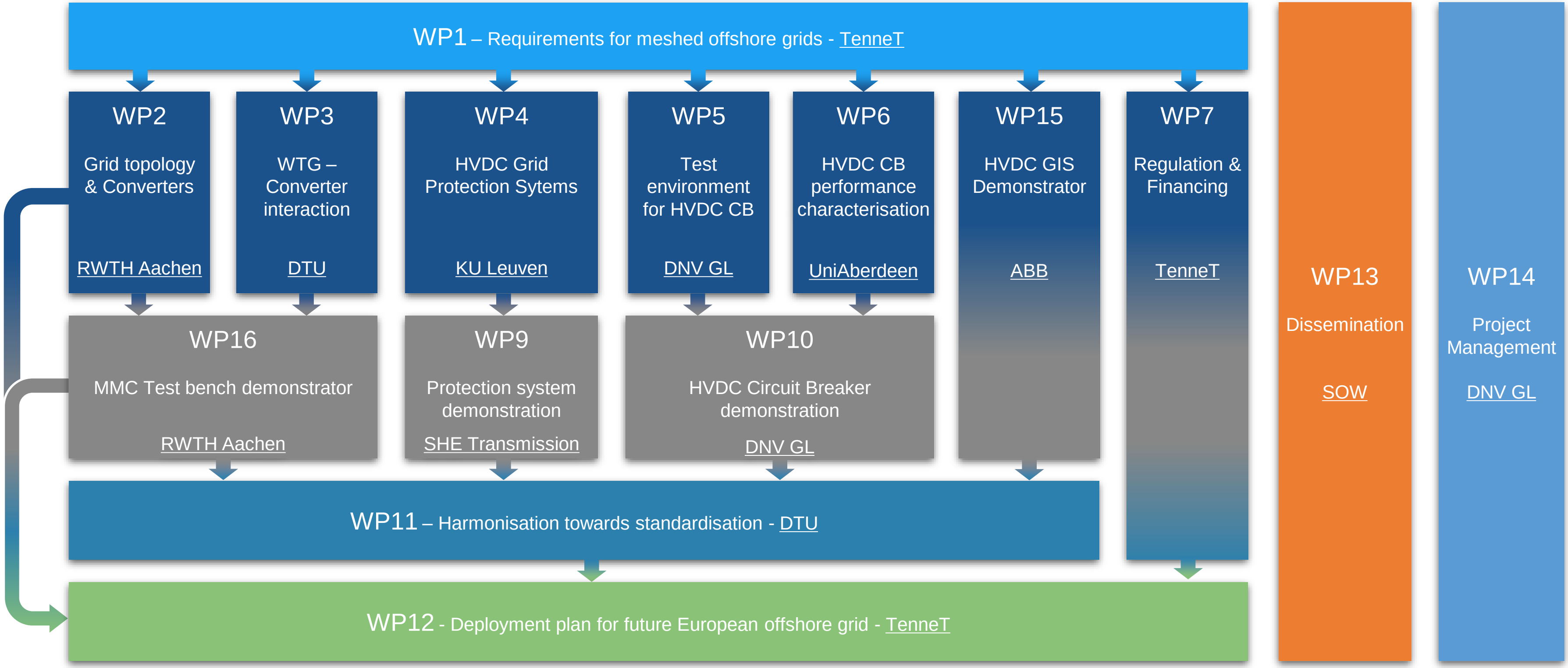
New Transmission Infrastructure



PROMOTioN Project organisation

Work packages



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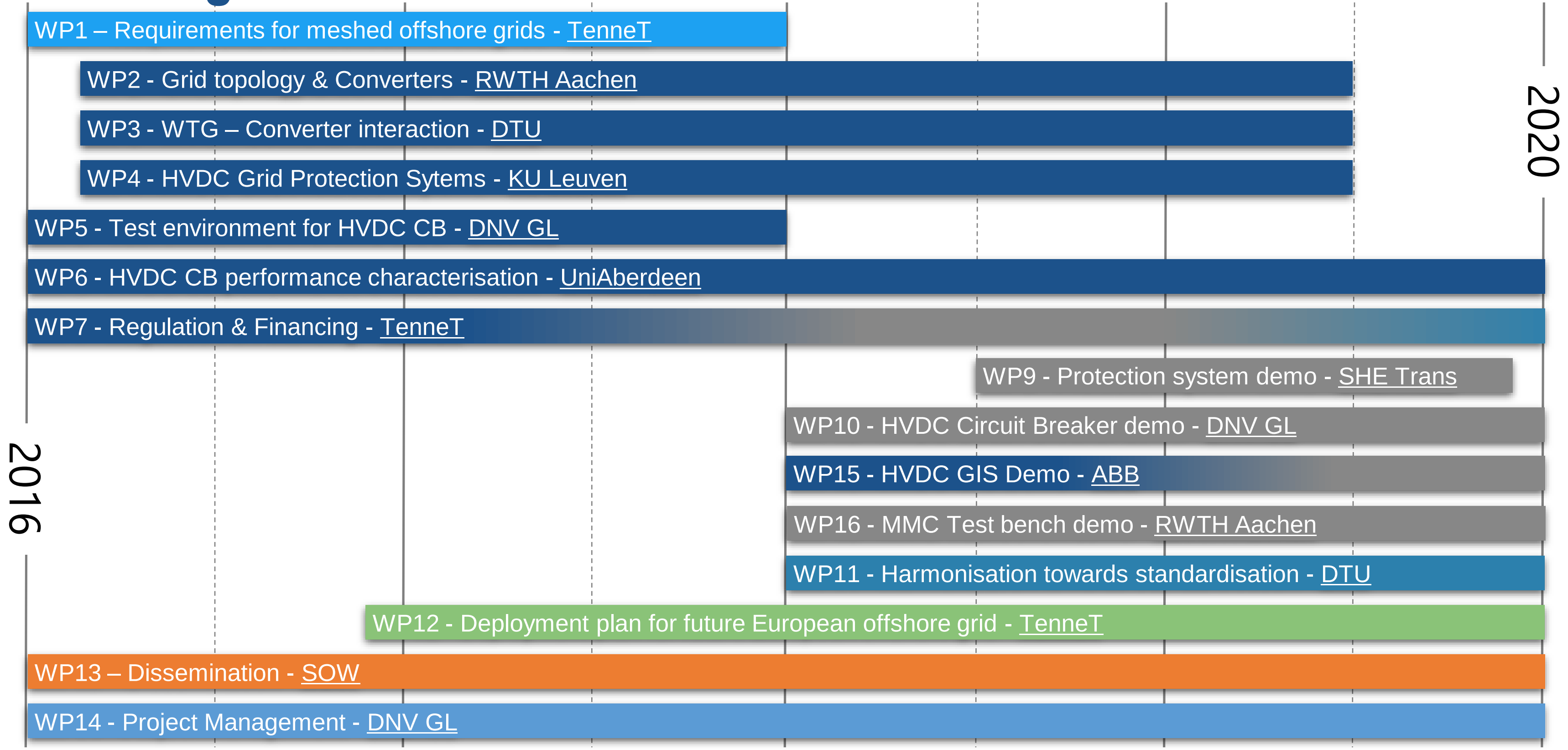
Planning



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WP2 - Grid Topology and Converters

Status

✓ Identification of relevant topologies and study cases

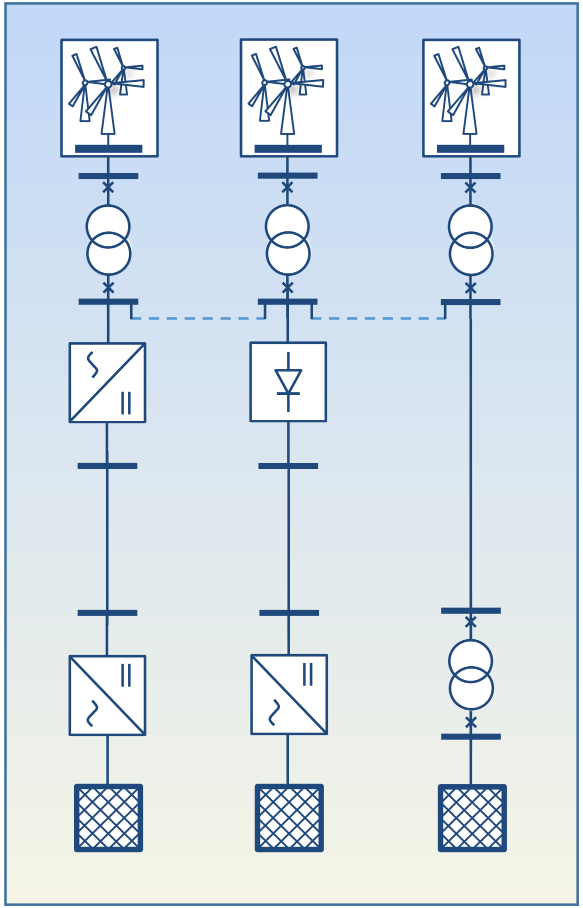
✓ Set-up of flexible simulation models for a wide range of components and simulation time frames

~ Simulation studies based on the overall system from the offshore windfarm to the onshore grid

- Derivation of requirements for future HVDC grids

Exemplary achievements and findings

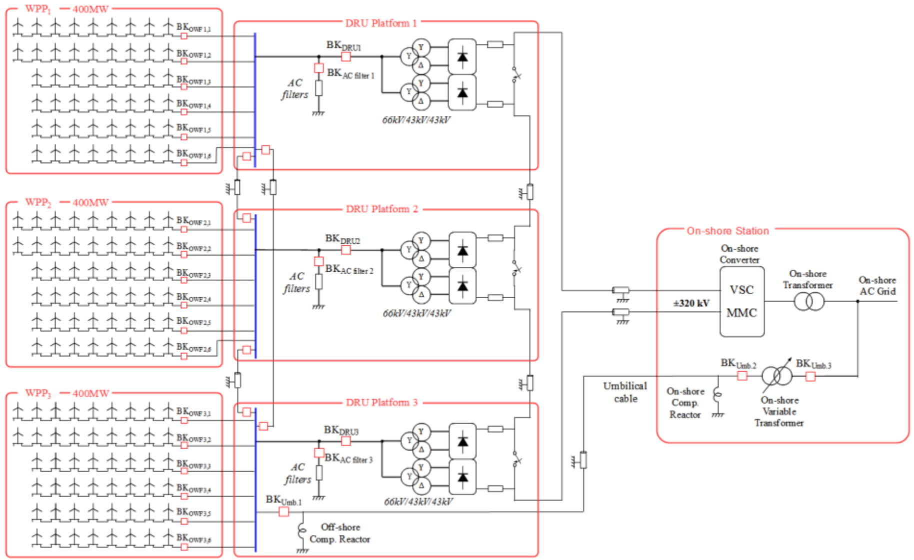
- Enhancement of converter and wind farm controls
- Operation of DRUs in different grid layouts is possible
- Different DC fault clearing strategies lead to different requirements for the wind farms



WP3 - Wind Turbine – Converter Interaction

Developments

- ✓ Functional requirements for Diode-Rectifier (DRU) connection of Wind Power Plants
- ✓ Control algorithms and simulation test cases & results
- ✓ Grid forming wind turbine controls
- ✓ Confidential grid forming WPP simulation models
  - ✓ Academic (white-box) & Industrial (black-box)
- ✓ Generic VSC-connected WPP models



Ongoing

~ Compliance test procedures for DRU connection

~ Self-energization of offshore WPP and black start

~ Grid code recommendations for grid forming WPP

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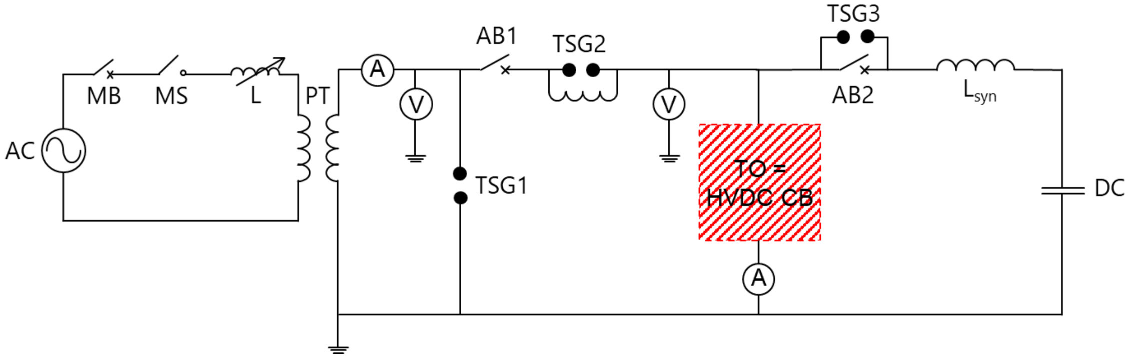
WP5 - Test environment for HVDC circuit breakers

- Stresses on HVDC circuit breaker technologies were identified
- Test requirements and procedures were documented
- A test circuit has been designed, implemented and tested at KEMA Laboratories
- A Mitsubishi mechanical DC circuit breaker with active current injection was tested



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WP6 - Characterisation of DC Circuit Breakers

- Deliverables completed:
  - 6.1 Develop system-level model for hybrid DC CB
  - 6.2 Develop system-level model for mechanical DC CB
  - 6.9 Develop standard DC CB verification plan and RTDS models

- Major outputs:
  - Agreed test circuit for DC CB model verification,
  - Agreed DC CB model verification plan,
  - 2 journal and 6 conference articles,
  - Panel at an IEEE conference,
  - 900V, 500A DC CB test hardware,
  - 900V, 500A hybrid and mechanical DC CB demonstrators,
  - PSCAD models for hybrid and mechanical DC CB,
  - RTDS models for hybrid and mechanical DC CBs,

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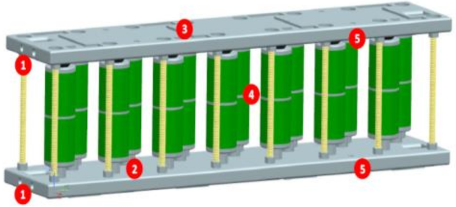
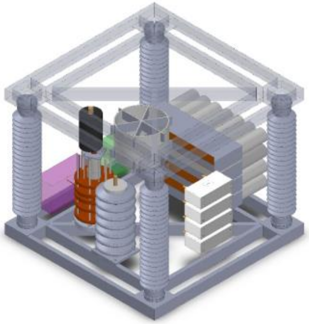
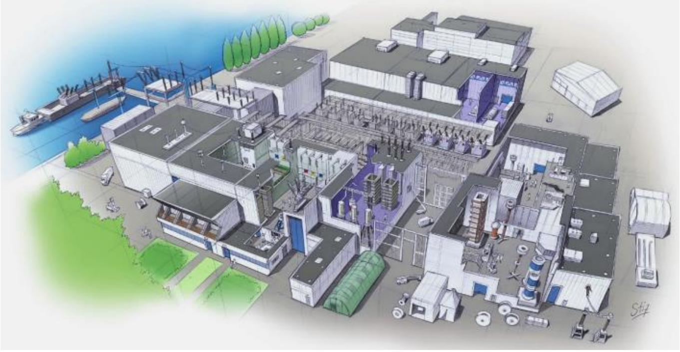
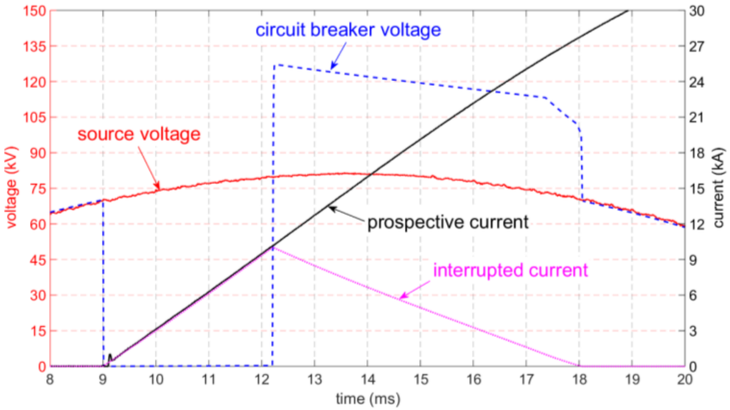
WP10 - Demonstration of Performance of HVDC Circuit Breaker Technologies

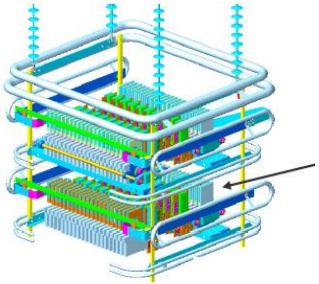
- Analyse the actual stresses on breaker sub-components
- Provide input data for models of HVDC circuit breakers
- Demonstrate testing HVDC circuit breakers of various technologies
- Testing of multi-module HVDC CBs
- Initiate standardization activities











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WP11 - Harmonisation towards standardisation

- Kickoff meeting April 2018
- Detailed work plan: Common workflow across work package tasks

Harmonization catalogue
- Map relevant harmonization activities
- Analyse potential PROMOTioN contributions

Initial workshops
- Discuss possible new harmonization initiatives with external harmonization groups

Writing
- Proposals for new harmonization work
- Deliverables
- Papers

Final workshop
- Communicate PROMOTioN contributions
- Discuss future needs

- Started mapping relevant activities in Harmonization catalogue
- Updated workshop scopes and partner responsibilities

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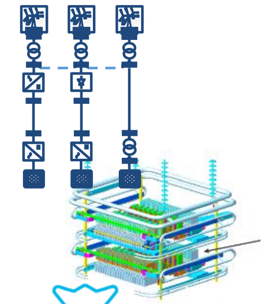
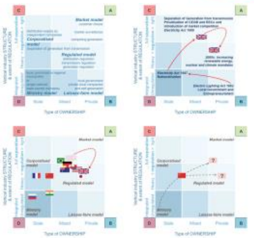
WP12 – Deployment Plan for future European offshore grid

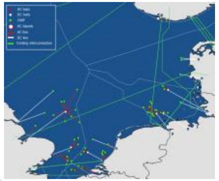


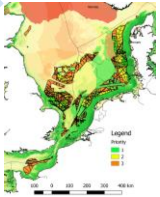


1. Collation and analysis of conclusions drawn from other work packages and projects, barriers and solutions:

- Key technical (WP1, 2, 4, 11)
- Financial, economic (WP7)
- Governmental, regulatory (WP7) and
- Market

Delivered December 2017

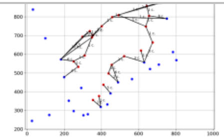


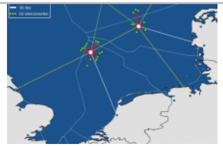


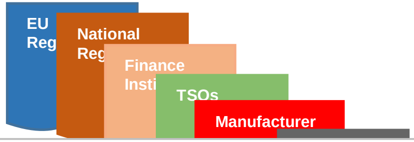
2. Develop optimal scenarios for the development of an offshore grid

- Cost Benefit analysis

December 2018







3. Deployment plan for future offshore grid development

- Stakeholder recommendations

March-June 2019

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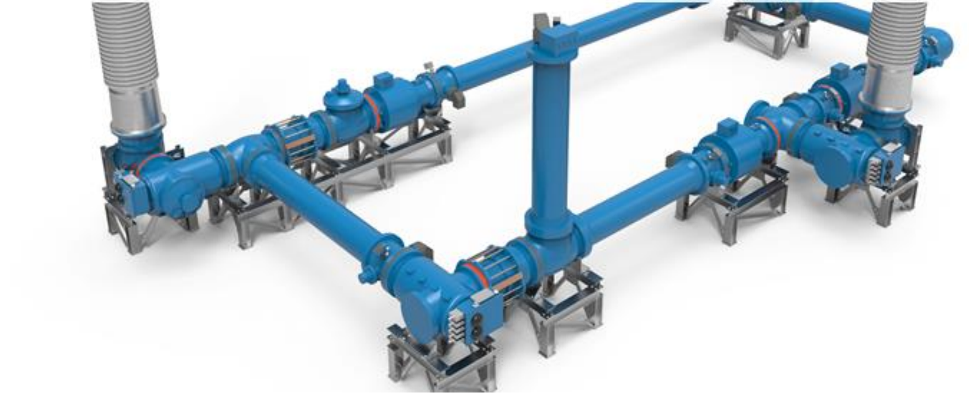
WP15 - DC GIS technology demonstrator

- Test specification and test procedures for HVDC gas-insulated systems were proposed and documented
- Test set-up for the technology demonstrator were defined and assembly was started
- Work plan for investigations regarding partial discharge diagnostic and use of alternative gases is defined



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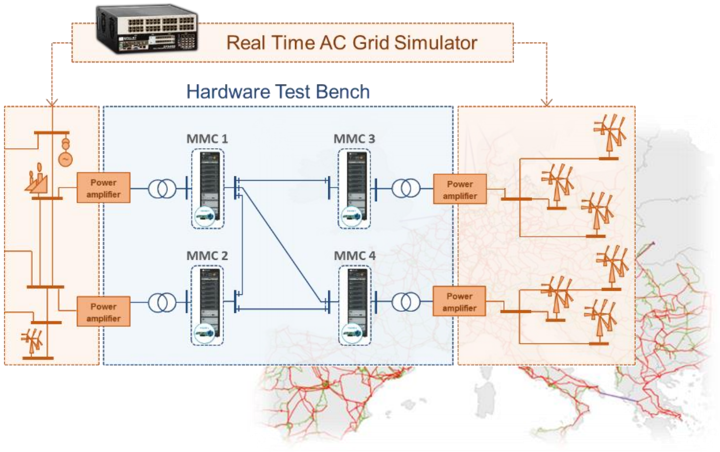
WP16 - MMC Test Bench Demonstrator

Motivation:

- MTDC systems cause novel challenges for TSOs, grid planners and manufacturers
- Experience missing concerning
  - Multi-terminal operation
  - Interaction with the large AC transmission systems
  - Interaction with offshore WPPs



Scope:

Investigation regarding the operation and control of meshed HVDC system using

- ➢ Power Hardware in the Loop (PHiL)
- ➢ Control Hardware in the Loop (CHiL)
- ➢ Real-Time Simulation of large AC grids (RTS)

Achievements:

- ✓ **System design** of the MMC Test Bench
- ✓ **Definition of test cases and** for future investigations

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