PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

HALF YEARLY MEETING SUPERGRID INSTITUTE, LYON, FRANCE

10-12 December 2018

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

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HALF-YEARLY MEETING LYON

Place: **Bibliothèque Marie Curie**
Institut National des Sciences Appliquées (INSA) Lyon
20 avenue Albert Einstein, Villeurbanne.
Across from the "INSA Einstein" Tramway stop.

Date: **10 – 12 December 2018**
13 December 2018 – PMG Meeting

Monday 10 December

Plenary Meeting

12:00 – 13:00	Lunch
13:00 – 13:20	Welcome by SGI
13:20 – 13:40	WP2
13:40 – 14:00	WP3
14:00 – 14:20	WP4
14:20 – 14:40	Break
14:40 – 15:00	WP6
15:00 – 15:20	WP7
15:20 – 15:40	WP9
15:40 – 16:00	Break
16:00 – 16:20	WP10
16:20 – 16:40	WP11
16:40 – 17:00	WP12
17:00 – 17:20	Break
17:20 – 17:40	WP13
17:40 – 18:00	WP15
18:00 – 18:20	WP16
19:30 - Late	Dinner at "L'Avenue 45". Address: 45 Avenue Albert Einstein, 69100 Villeurbanne

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PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Tuesday 11 December

Work Package meetings

Work Package	**Time**	**Room** (will follow)
WP2	09:00 – 12:30	
WP3	09:00 – 12:30	
WP4	09:00 – 12:30	
WP6	09:00 – 12:30	
WP7	11:00 – 12:30	
	13:30 – 16:00	
WP9	13:30 – 16:00	
WP10	13:30 – 16:00	
WP11	13:30 – 16:00	
WP12	09:00 – 12:30	
WP15	09:00 – 12:30	
	13:30 – 16:00	
WP16	13:30 – 16:00	
Lunch	12:30 – 13:30	
Visit to SGI	**16:15 departure of bus**	
Break	Determined per WP	

Wednesday 12 December

General Assembly (see sheets https://service.projectplace.com/pp/pp.cgi/r1825831004)

09:00 – 09:20	Amendment 7 update
09:20 – 12:30	Explanation of Vote 2-7
12:00 – 12:30	Vote 2-7
12:30 – 13:30	Lunch
13:30 – 14:30	Explanation of Vote 1 (excluding OEM vendors)
14:30 – 15:00	Vote 1 (excluding OEM vendors)
15:00 – 15:30	Break
15:00 – 17:00	PMG Meeting (WP leaders only)

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WP2

Grid Topology & Converters

RWTH Aachen University ● Christina Brantl

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- Timeline and Amendment
- Task 2.3
- Next steps

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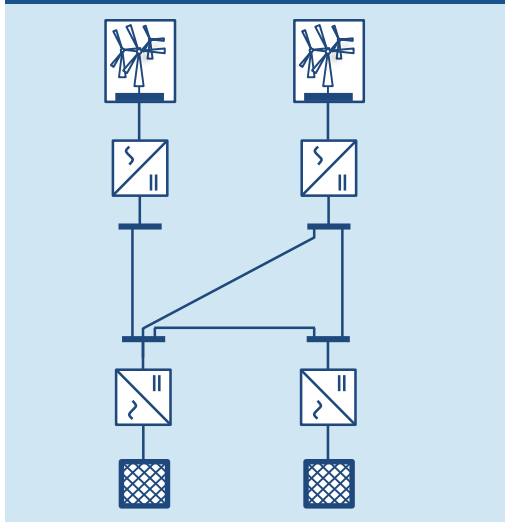
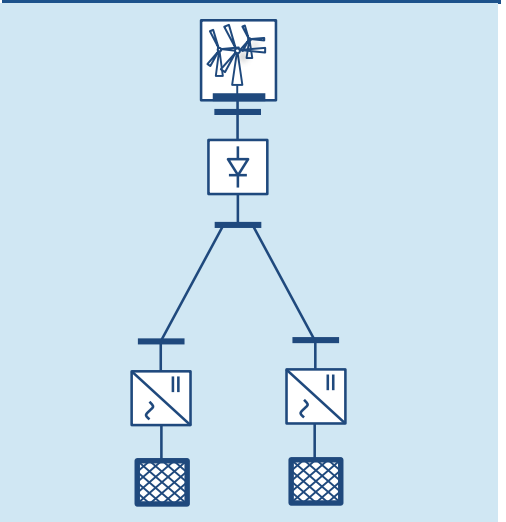
Objectives

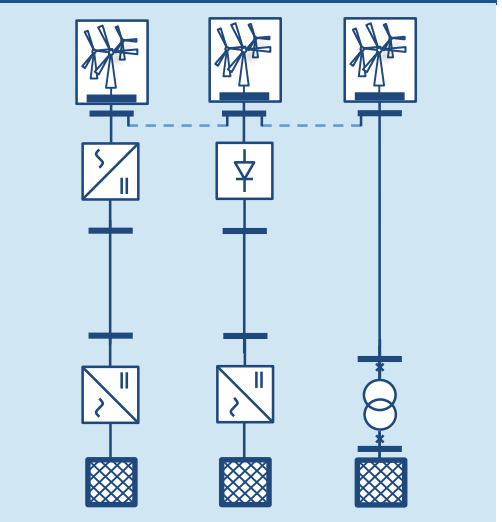
Trade-off analysis of different topologies



Interconnection of VSC and DRC systems



Control concepts to ensure interoperability



To define recommendations on onshore and offshore power systems for existing grid codes

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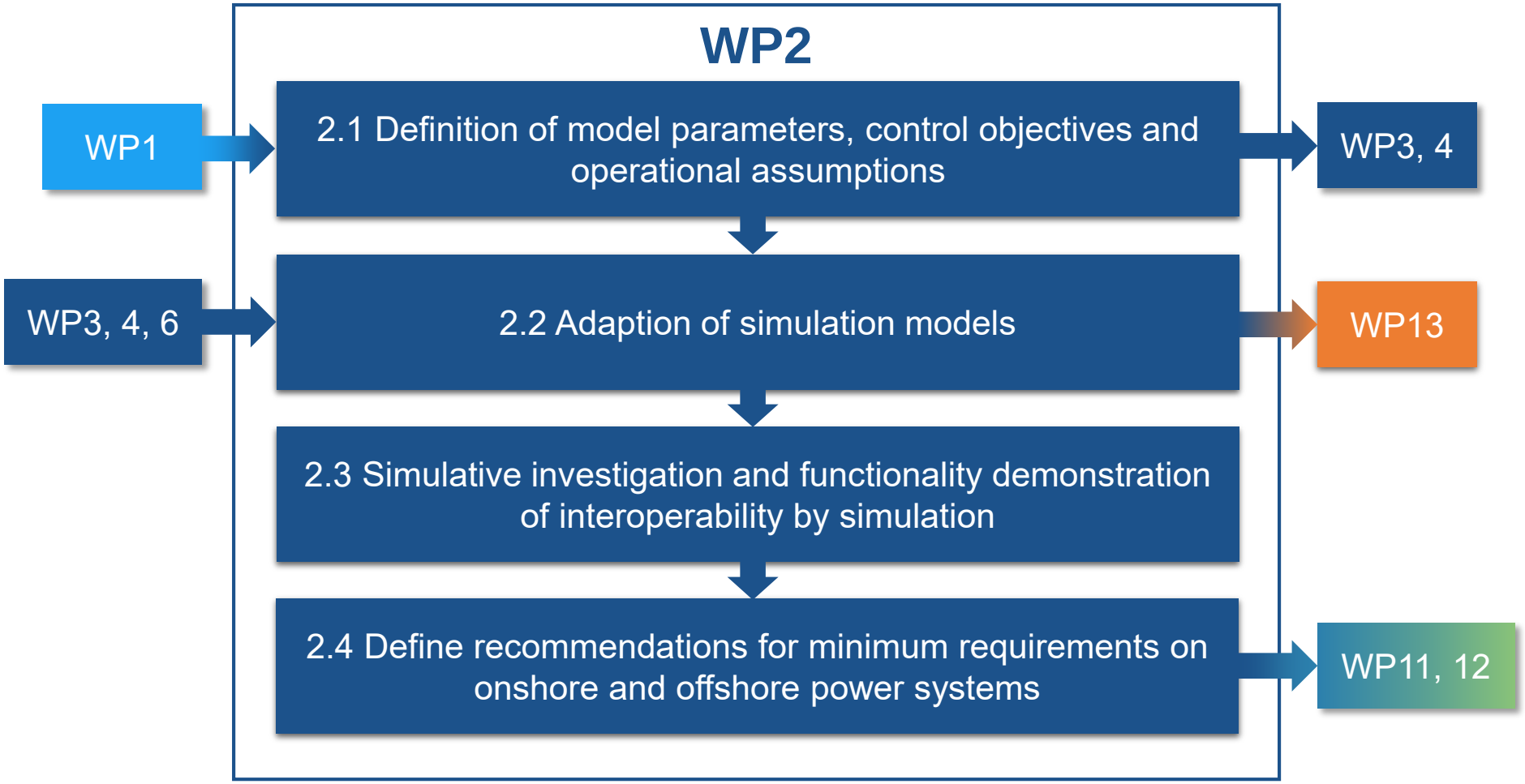
Task Structure



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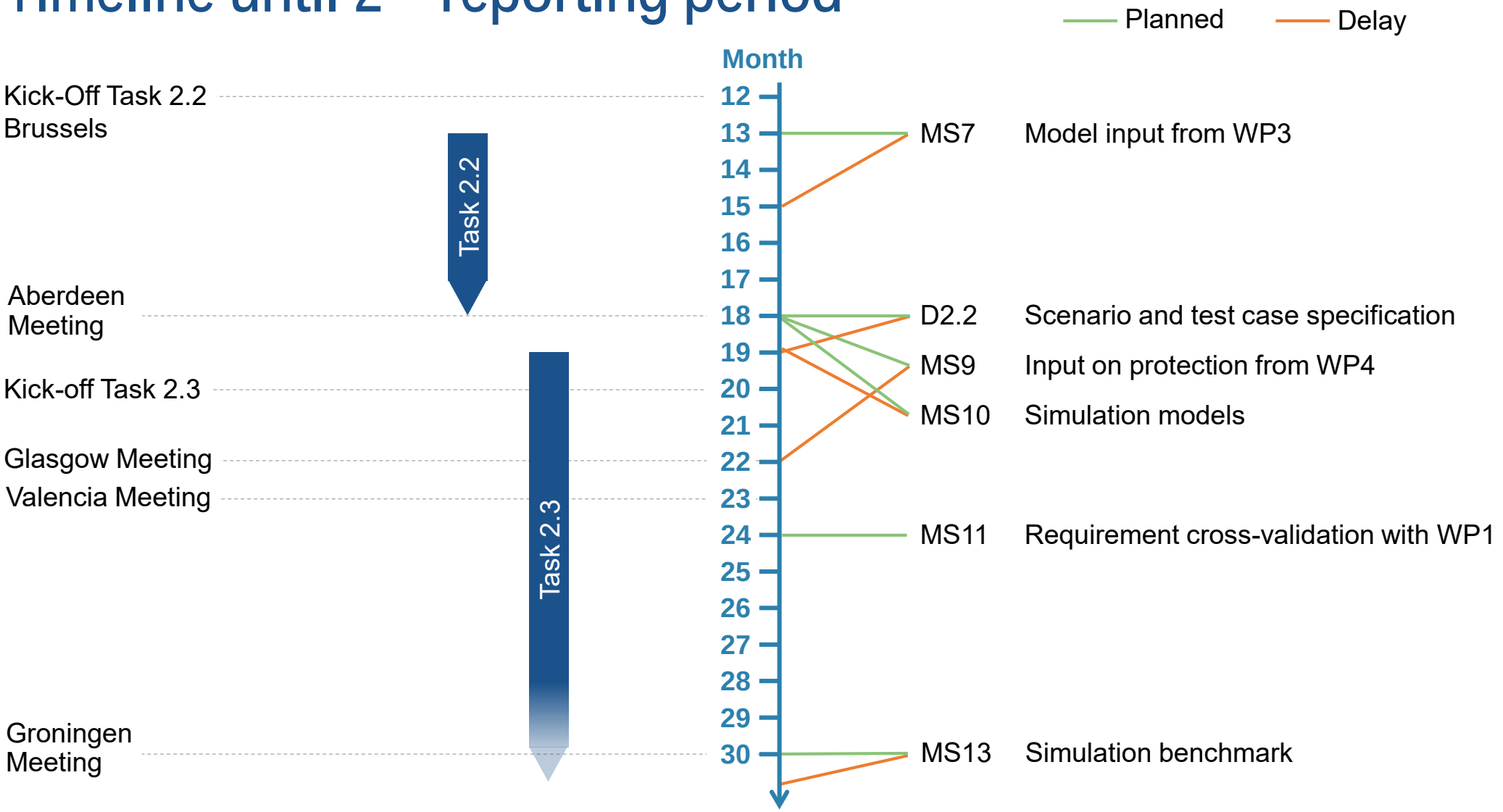
Timeline until 2nd reporting period



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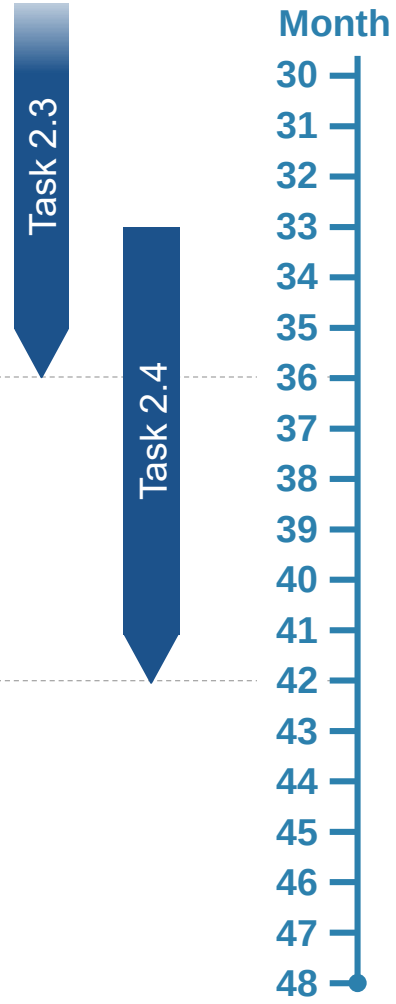
Timeline according to Amendment No.6

Simulative investigation and functionality demonstration of the meshed HVDC offshore topology system interoperability

Lyon Meeting

Define recommendations for minimum requirements on onshore and offshore power systems

Aachen Meeting



MS13	Simulation benchmark
MS14	Coordination with WP4
MS15	Recommendations on grid code extension
D2.3	Report on simulation results and benchmark
D2.4	Requirements for grid code extension

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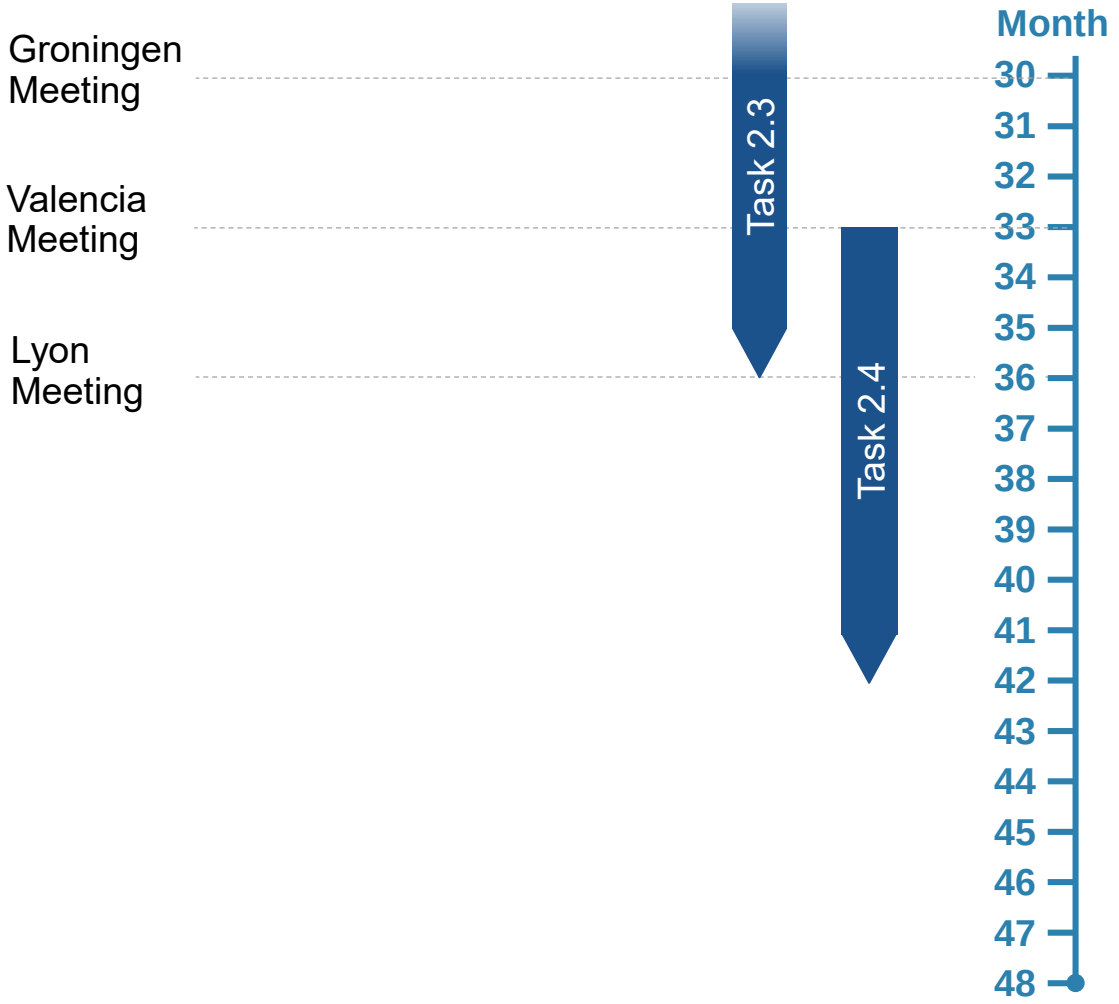
Status Update Progress



Task 2.3

- Change of task lead from Siemens to UPV
- Delay of work of several months
- Discussion on benchmark
- Agreement on Structure of D2.3
- Set-up of format from cross-validation with WP4
- Start of writing of D2.3

Task 2.4

- Kick-off: 11 September 2018
- Agreement on aligned way forward with all tasks and work packages related to grid codes
- Participation in WP11 workshop on Control and Protection

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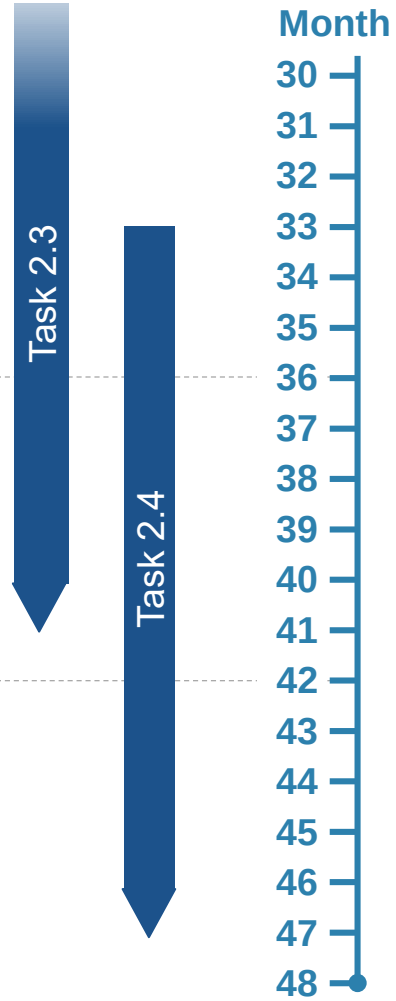
Proposed timeline in Amendment No.7

Simulative investigation and functionality demonstration of the meshed HVDC offshore topology system interoperability

Lyon Meeting

Define recommendations for minimum requirements on onshore and offshore power systems

Aachen Meeting



MS13 Simulation benchmark

MS14 Coordination with WP4

D2.3 Simulation results and benchmark

MS15 Recommendations on grid code extension

D2.4 Requirements for grid code extension

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Status Task 2.3

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Overview D2.3

- Operational Strategies for Multi-terminal HVDC systems
- Operation of DRU in HVDC Systems
  - Radial DRU connection
  - DRU with AC meshing – parallel connection to AC and VSC links
  - DRU in meshed HVDC systems
- Investigations on AC Side Faults and Contigencies
  - AC FRT for meshed DC systems
  - Frequency Support
  - Impact of MMCs on the AC protection
- DC side faults and contingencies
  - Impact on the DC cables
  - DC FRT of the wind power plants
  - Impact on the AC system
- Benchmark

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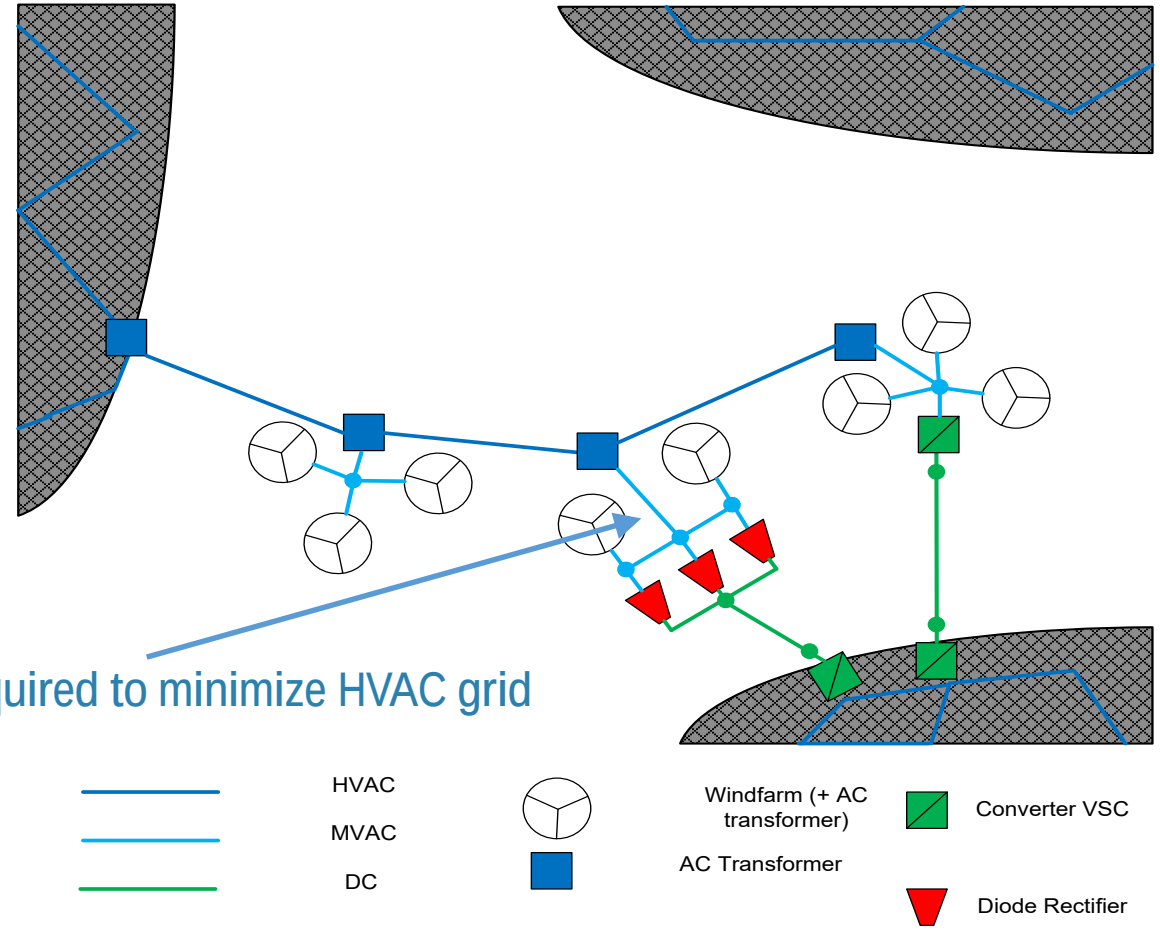
HVAC || HVDC || DRU :

1. AC interconnections



Tap changer required to minimize HVAC grid losses

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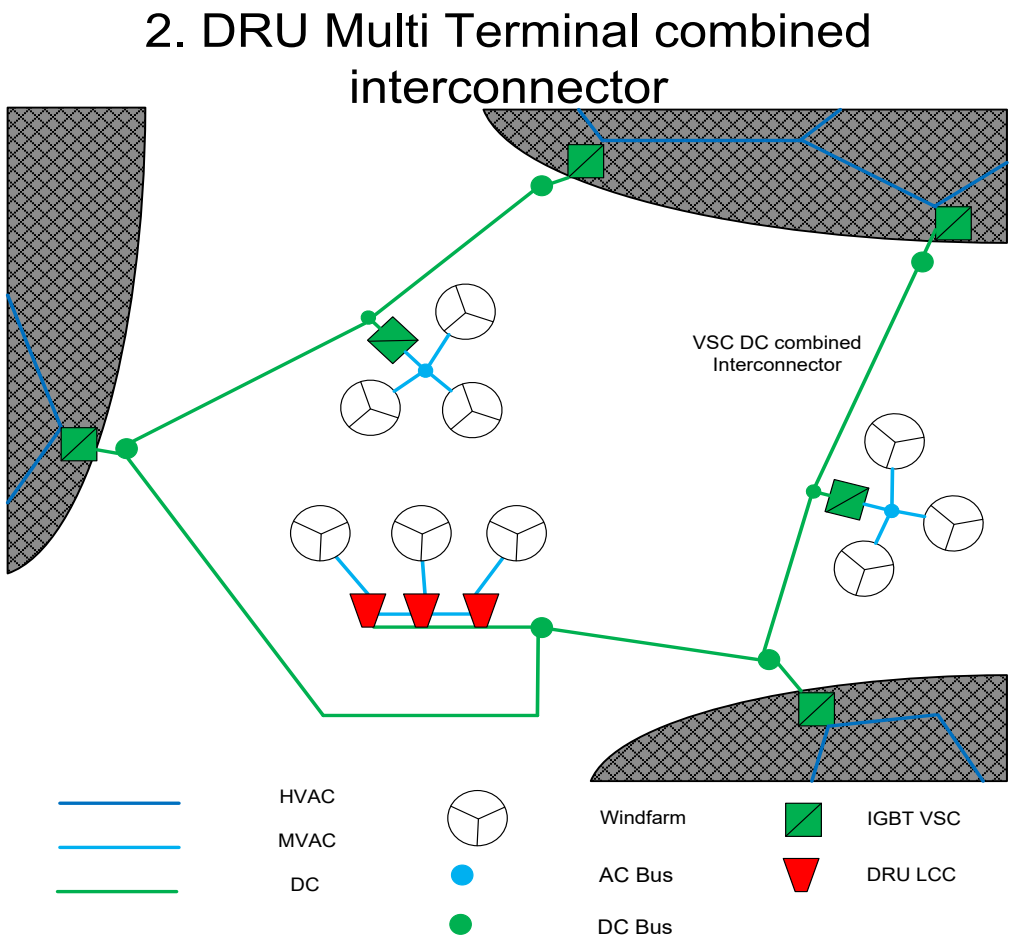
HVDC - DRU Multiterminal



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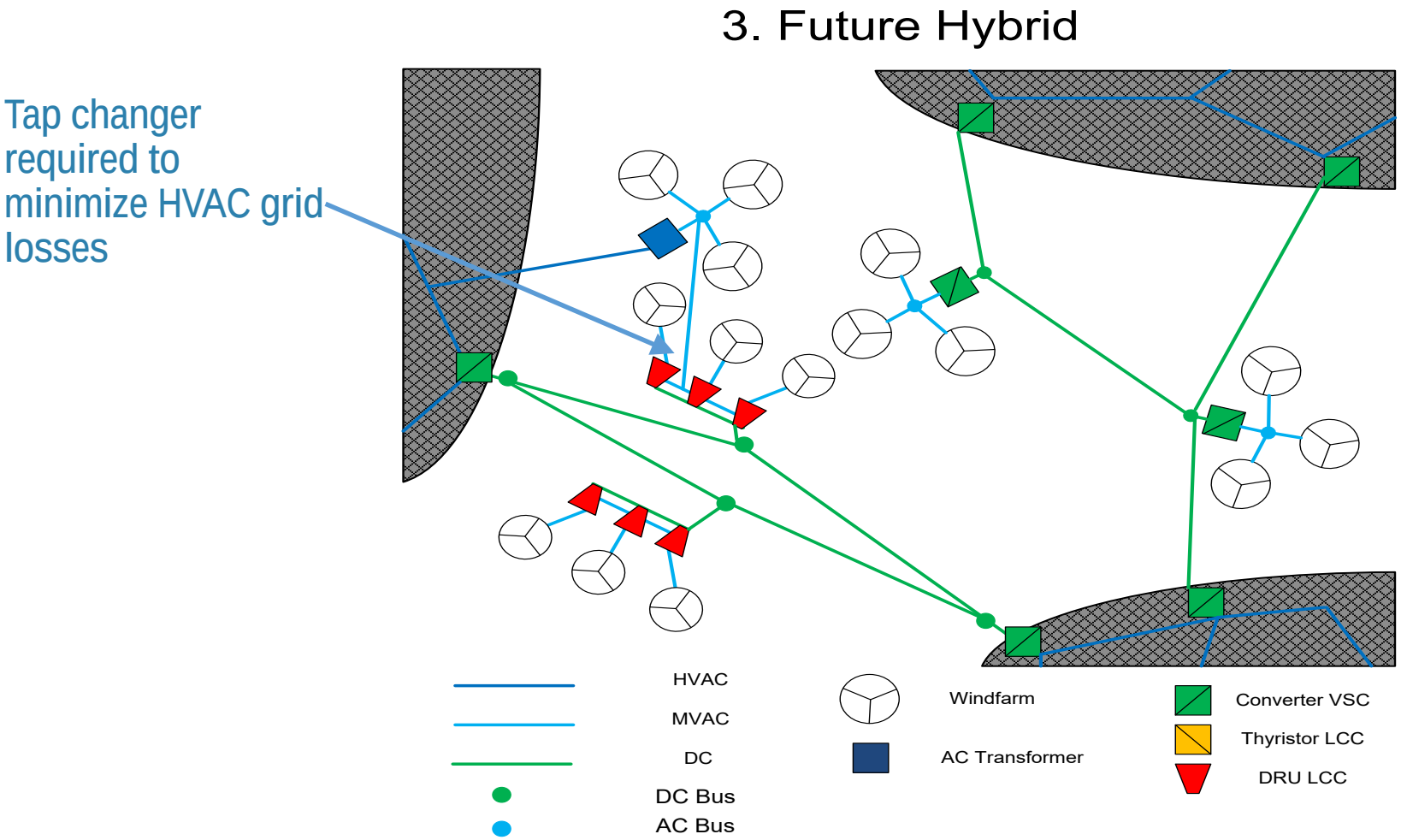
HVDC - DRU Meshed:

all HVDC stations (included DRUs) must be coordinated to control HVDC power flow.



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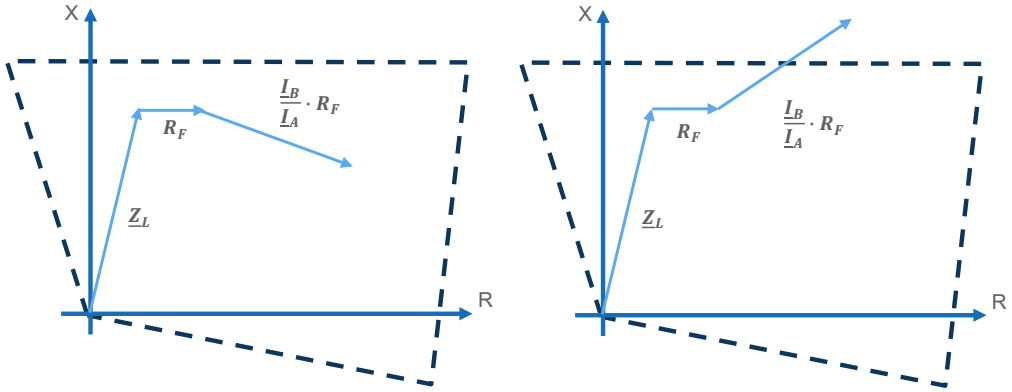
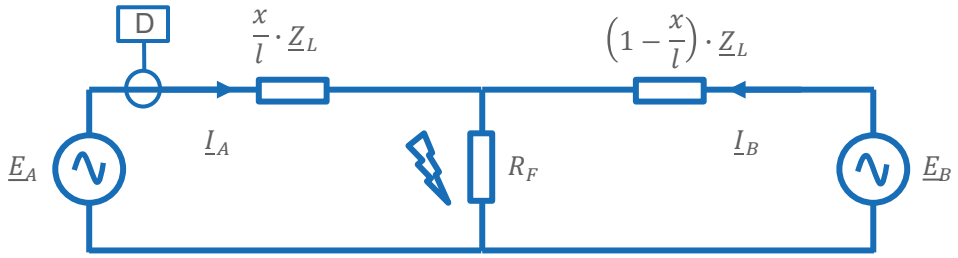
Impact of MMCs on the AC protection

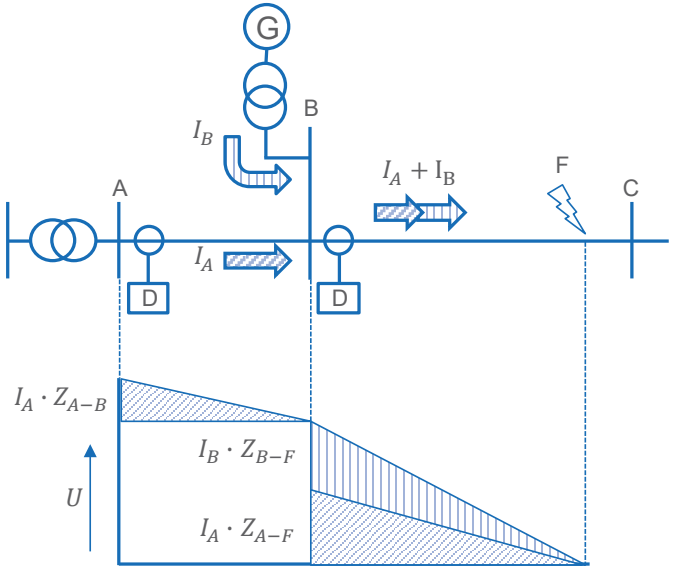
- Analysis focused on the distance protection
- Impact devided into two categories:
  - Topological Impact
  - Control Impact



Impact of load-flow on impedance measurement



Double-sided infeed



Intermediate infeed

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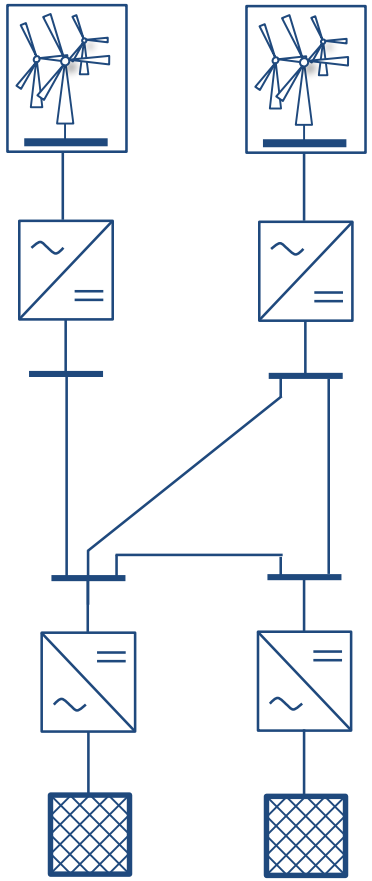
Fault Studies in VSC systems
Complimentary to WP4

<u>FRT of Offshore Windfarms for DC faults</u>

- DC breaker based fault clearing
  - Without blocking
  - With blocking
- Back-up fault clearing using AC breakers
- Full-bridge based fault clearing

<u>Aim:</u>

- Ensure FRT of WPP without violating constraints of the WPP
- Ensure fast resume of power transfer after DC fault clearing



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Next Steps

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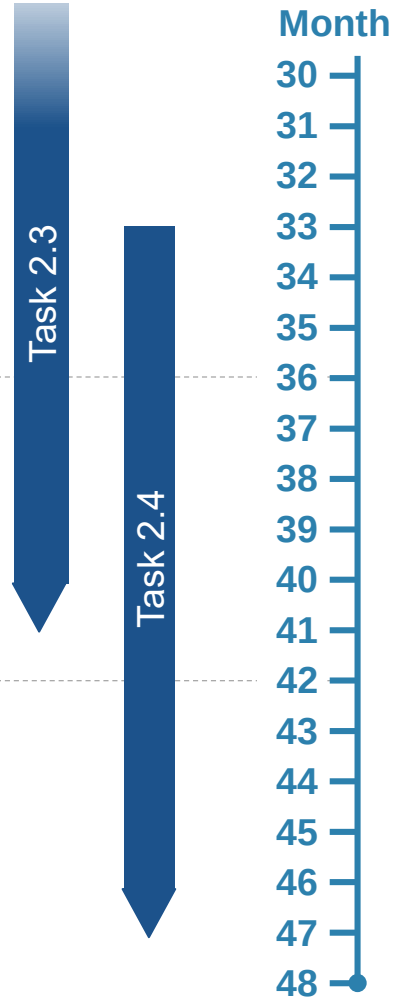
Next steps

Simulative investigation and functionality demonstration of the meshed HVDC offshore topology system interoperability

Lyon Meeting

Define recommendations for minimum requirements on onshore and offshore power systems

Aachen Meeting



Finalisation Task 2.3

- Complete Benchmark (MS13)
- Call with WP4 on cross-validation (MS20)
- Consolidate results
- Summarise results and findings in D2.3

Task 2.4

- Objective: Define recommendations for minimum requirements on onshore and offshore power systems
- Summary of results for harmonization catalogue in WP11

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Thank you for your attention!

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WP3

Wind Turbine Generator – Converter Interaction

DTU ● Ömer Göksu

10 December 2018, Lyon, France

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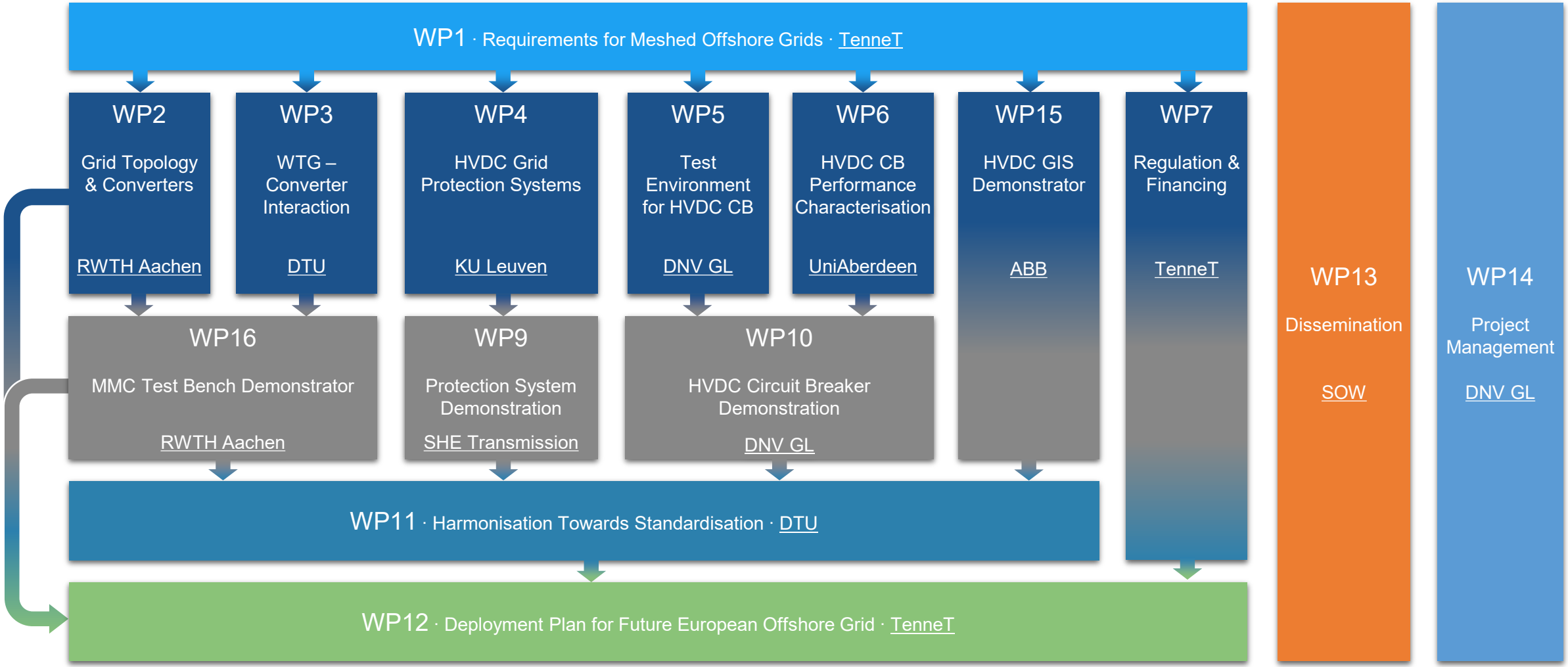
Work Packages



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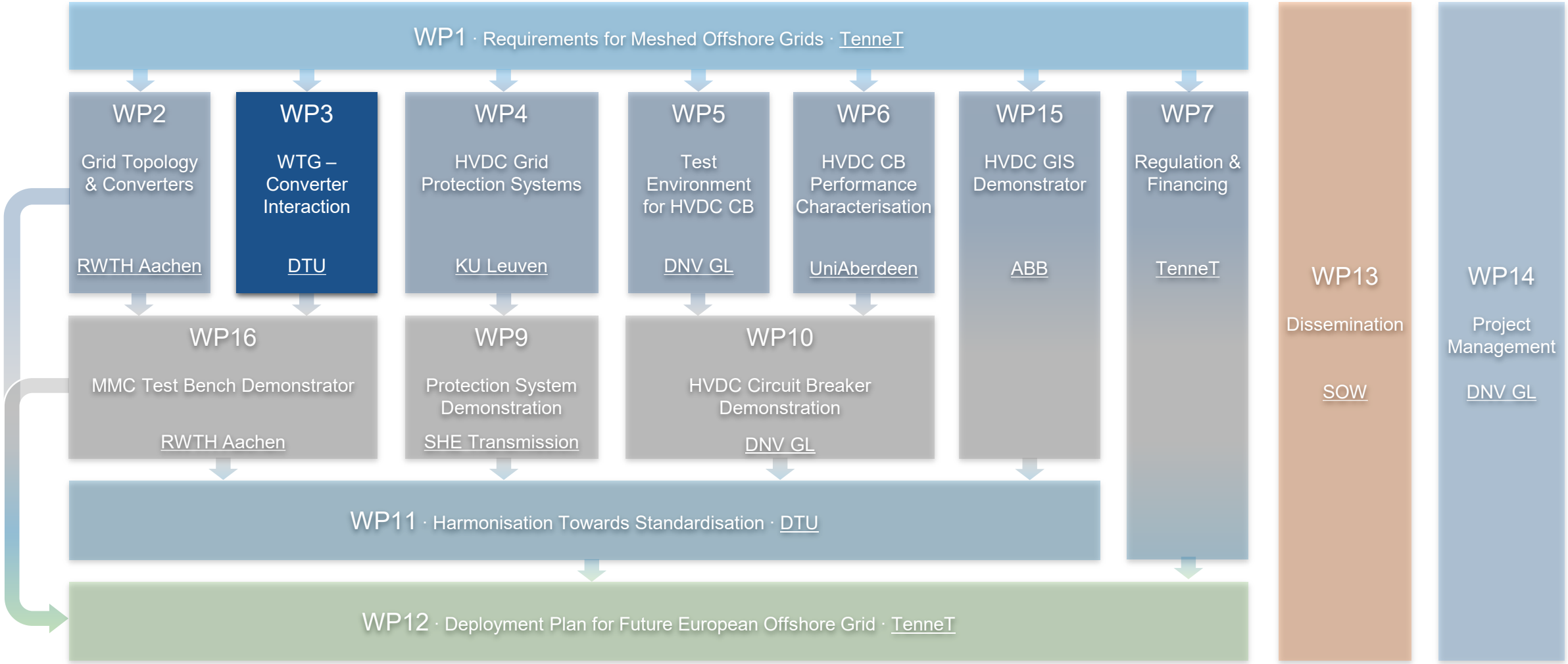
Work Packages



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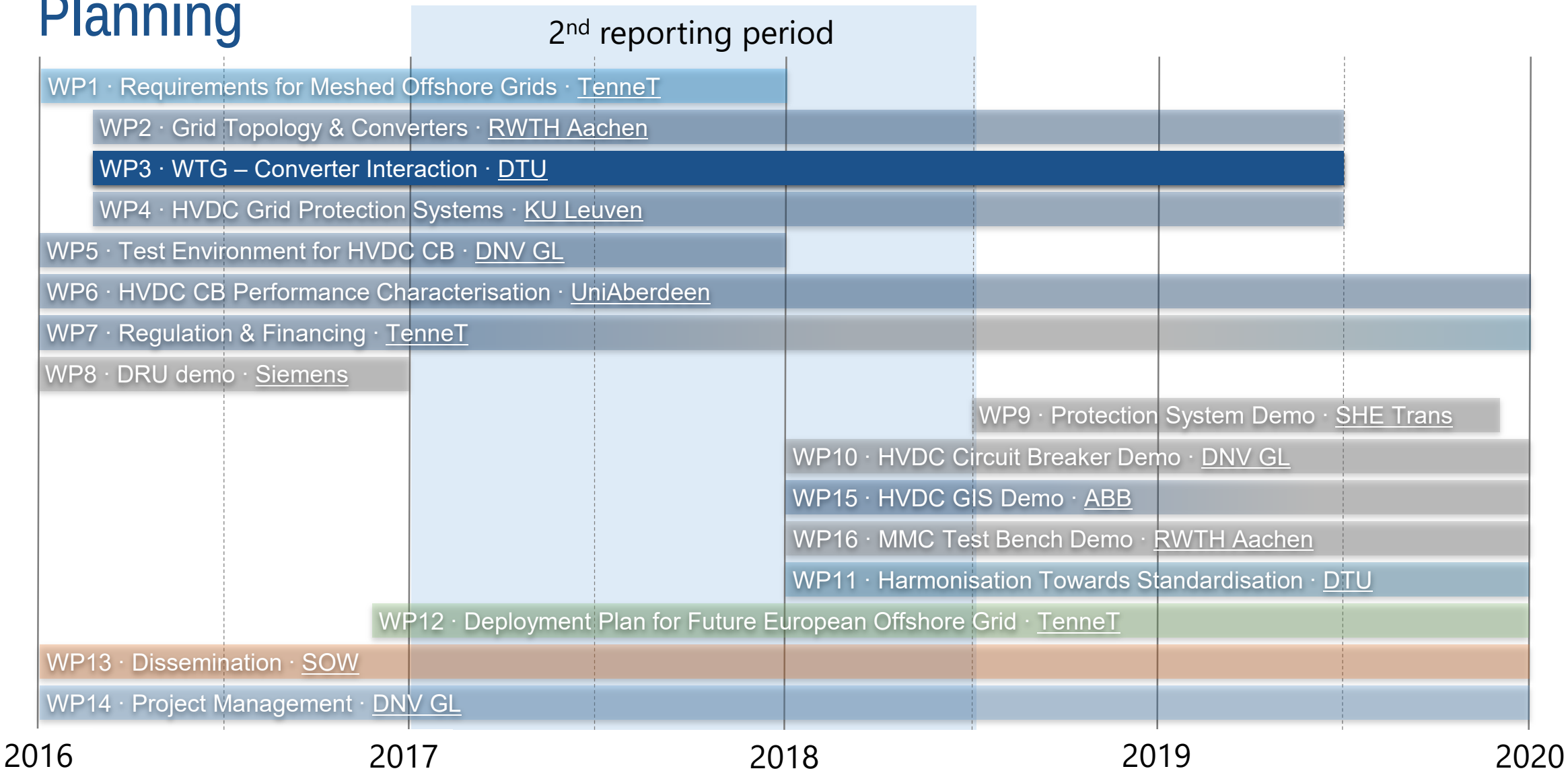
Planning



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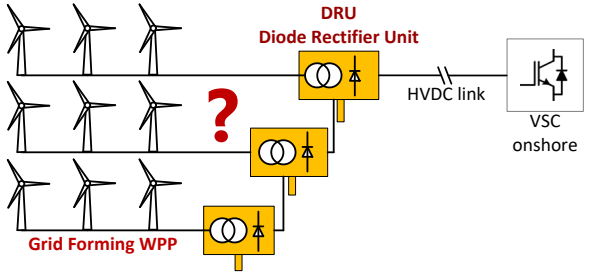
Objectives

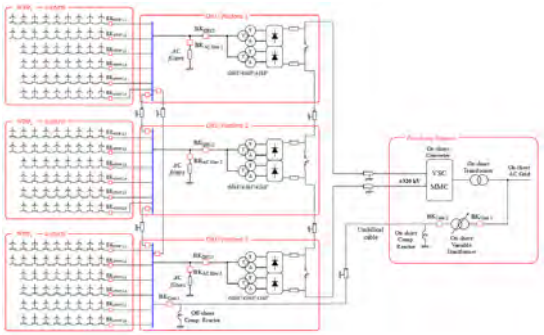
Objective 1
Define functional requirements to OWFs

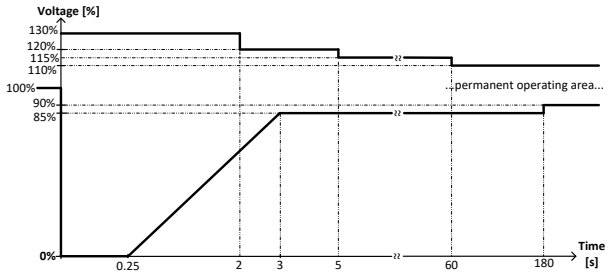
Objective 2
Develop test cases & control algorithms

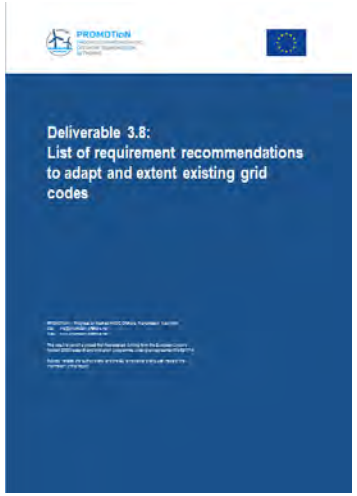
Objective 3
Define & apply compliance evaluation

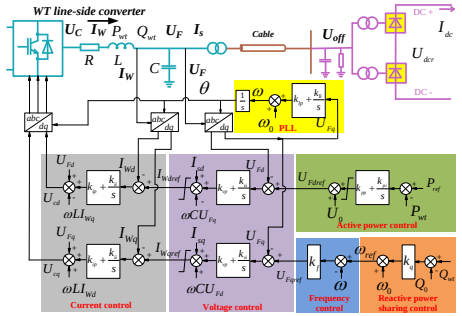
Objective 4
Recommend grid code requirements

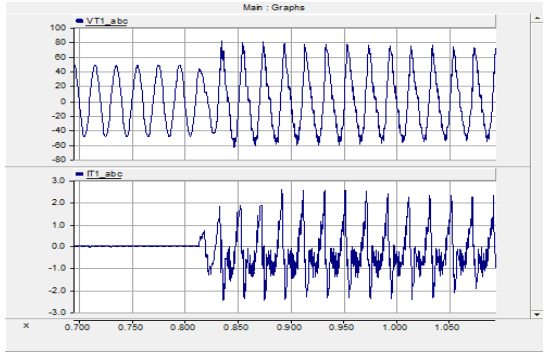












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WP3 Partners

DTU
Technical University of Denmark

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

MHI VESTAS OFFSHORE WIND

University of Strathclyde

RWTH AACHEN UNIVERSITY

FGH

DNV·GL

ENERGINET

Ørsted

ABB

SIEMENS

equinor

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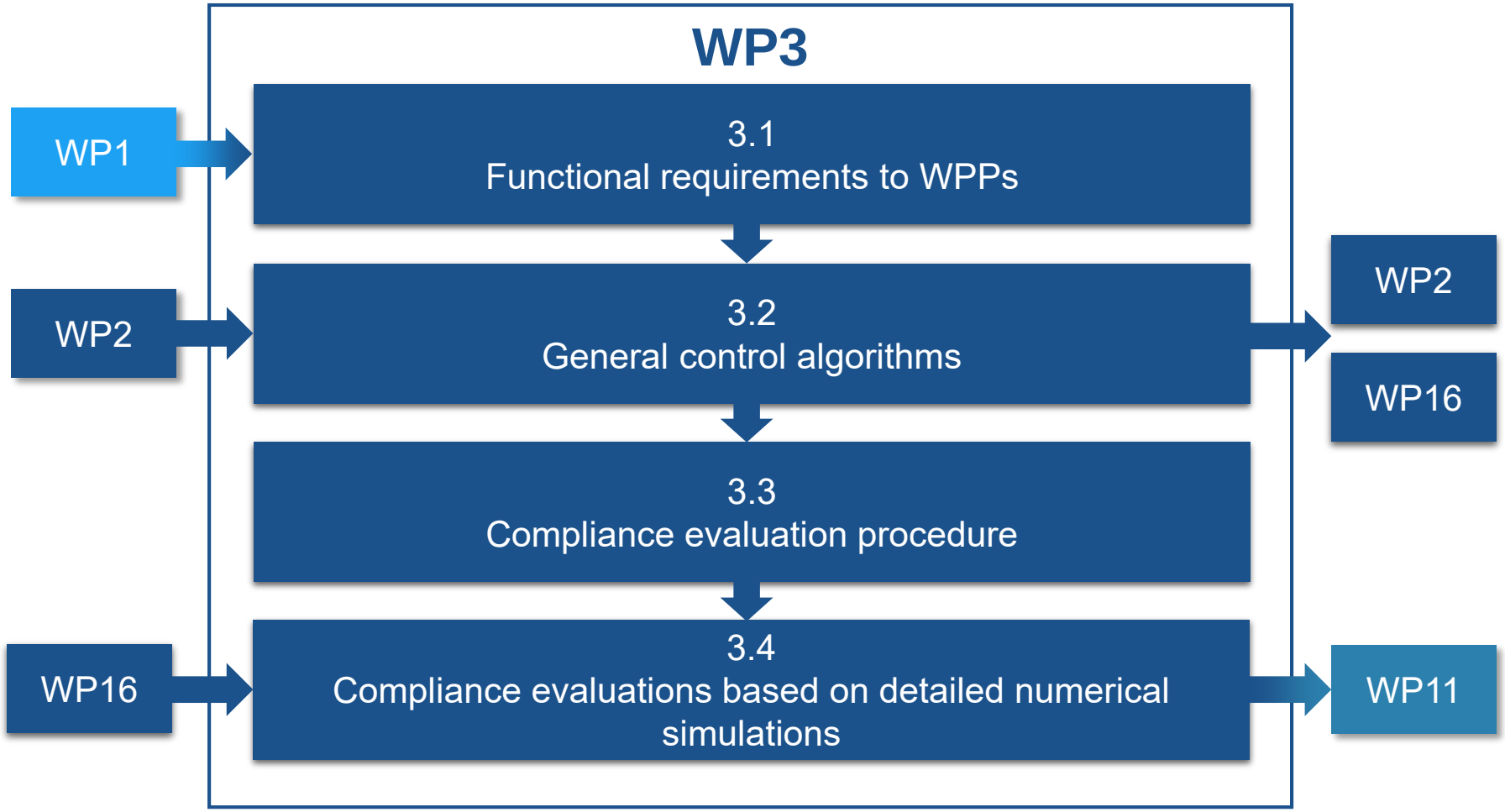
Task Structure



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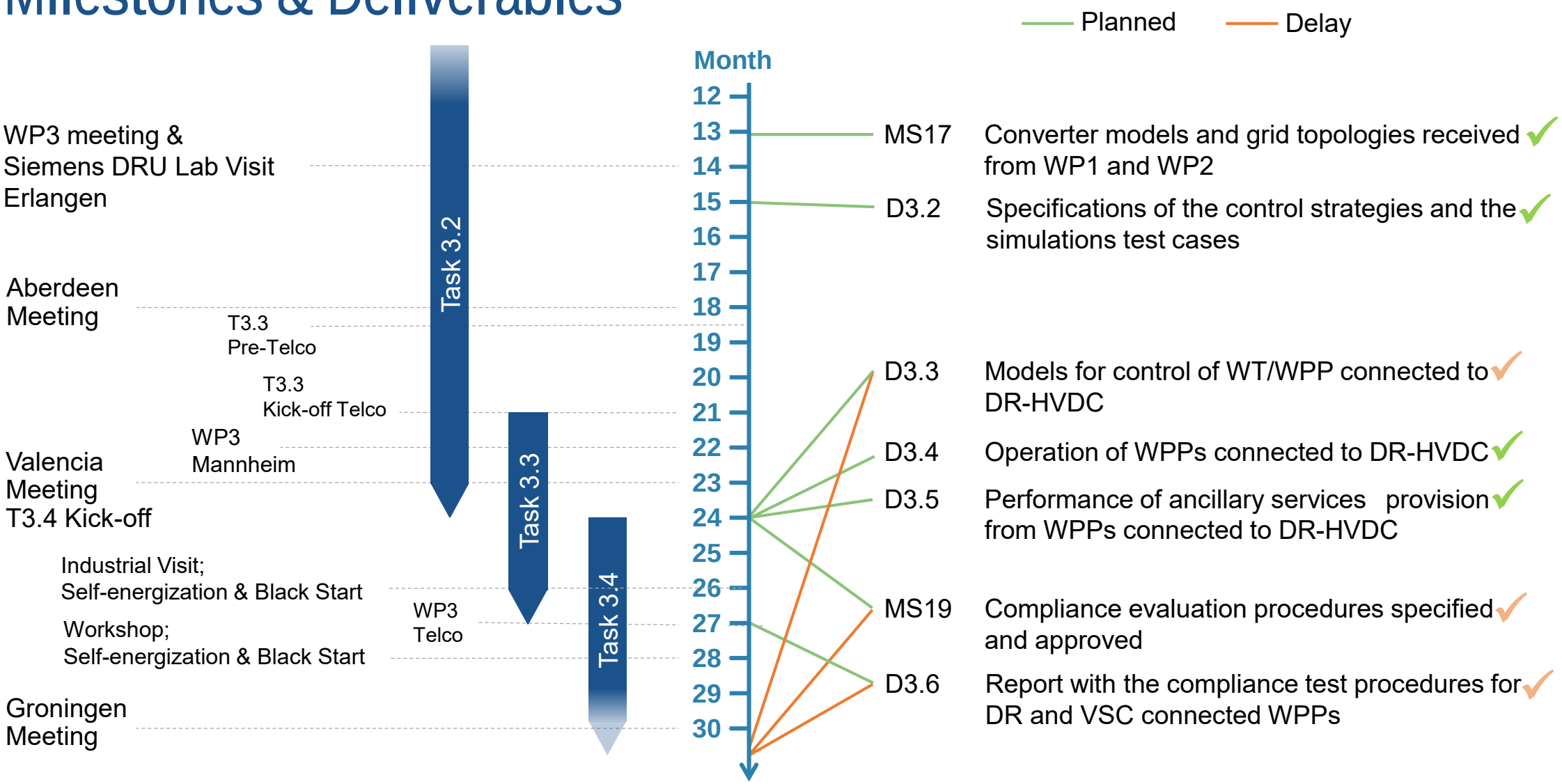
Milestones & Deliverables



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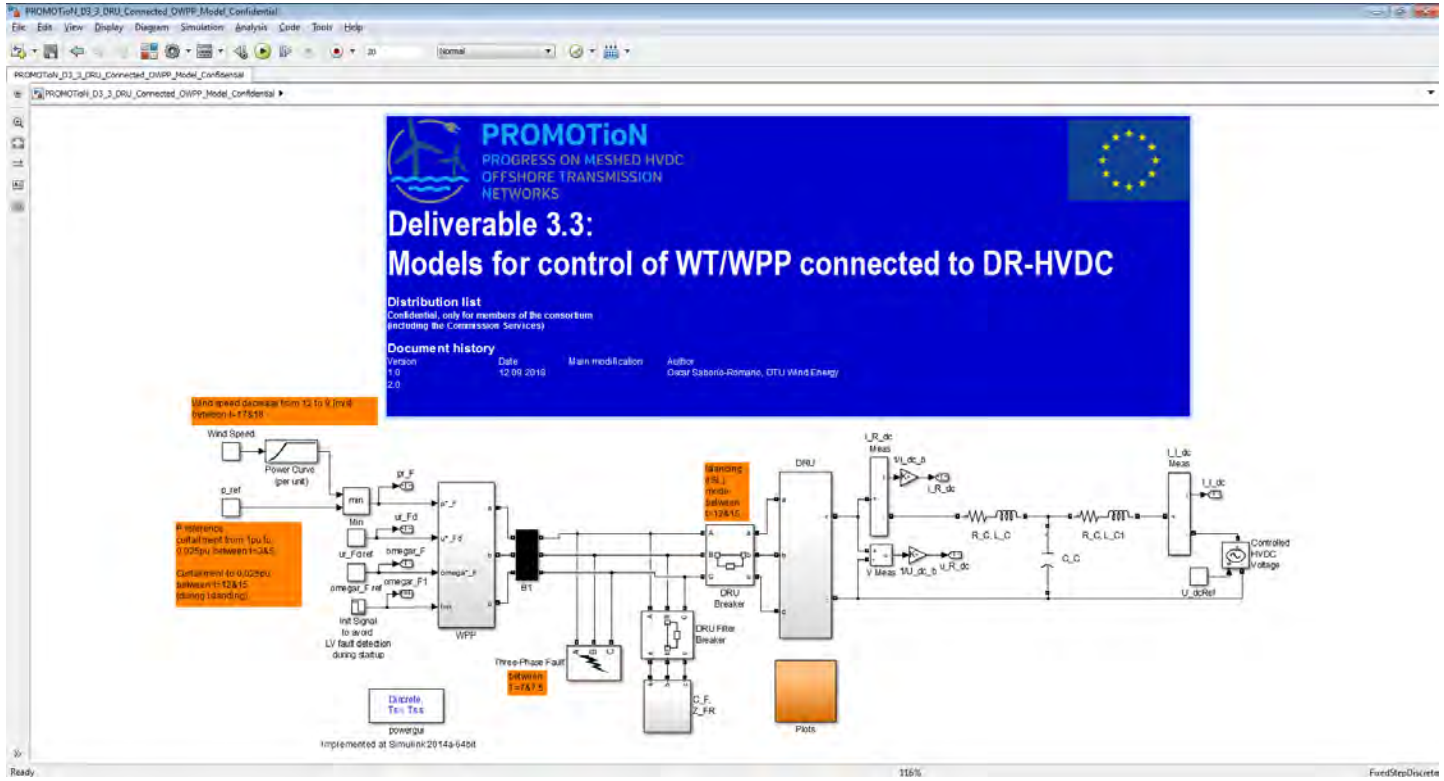
D3.3 Models for Control of WT/WPP Connected to DR- HVDC

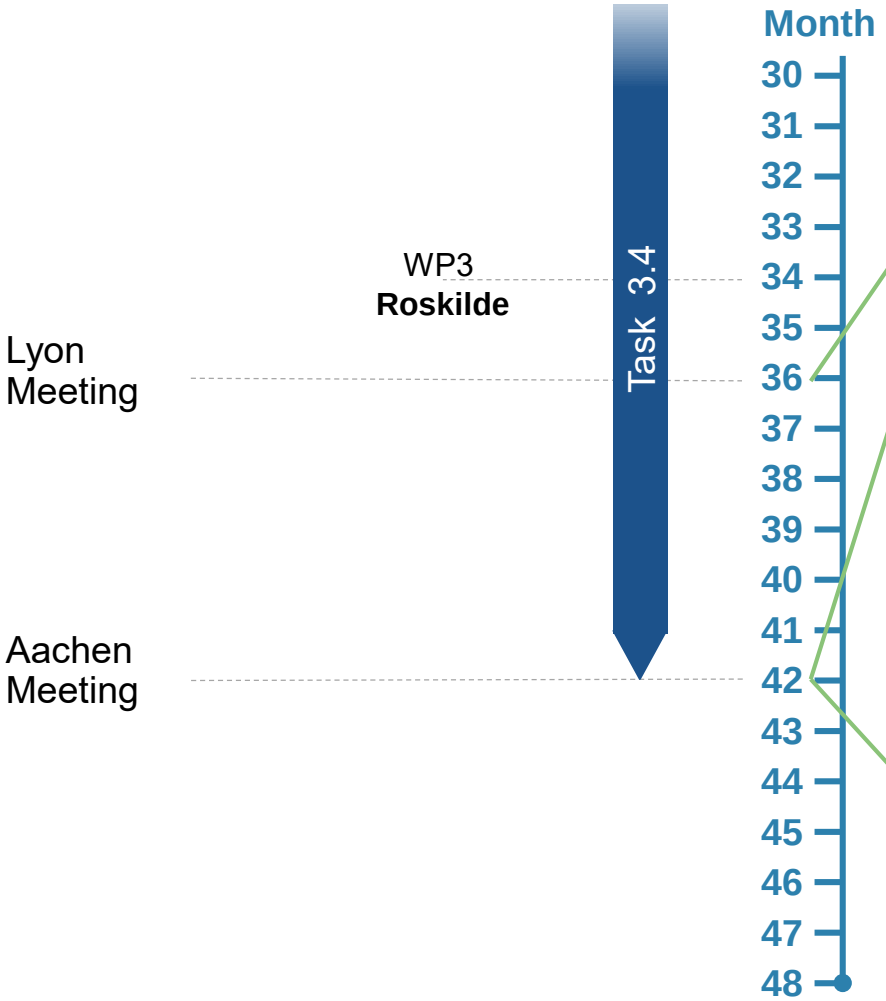
Confidential - only for members of the consortium

- ➢ Aggregated single WT
- ➢ Ideal onshore DC voltage
- ➢ Ideal WT DC voltage

- ✓ Offshore AC start-up
- ✓ Voltage & frequency control
- ✓ Active power setpoint control
- ✓ Offshore AC fault ride-through
- ✓ Intentional islanded operation



Ongoing Work



MS20 Recommendations on requirements to existing grid codes provided to WP11

- An internal deliverable with the recommendations

D3.7 Report with the compliance evaluation results using simulations

- Compliance test procedures for DRU connection
- Self-Energization & Black Start
  - Requirements and Test Scenarios – HVAC and HVDC connected OWPP
  - Simulations results, academic and industrial
  - Black start capability assessment

D3.8 List of requirement recommendations to adapt and extent existing grid codes

- Paradigm shift from grid following wind turbines to grid forming
- 100% converter-based AC grid
- Assessment of Grid Code recommendations based on WP16 results

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Progress Towards Demonstration

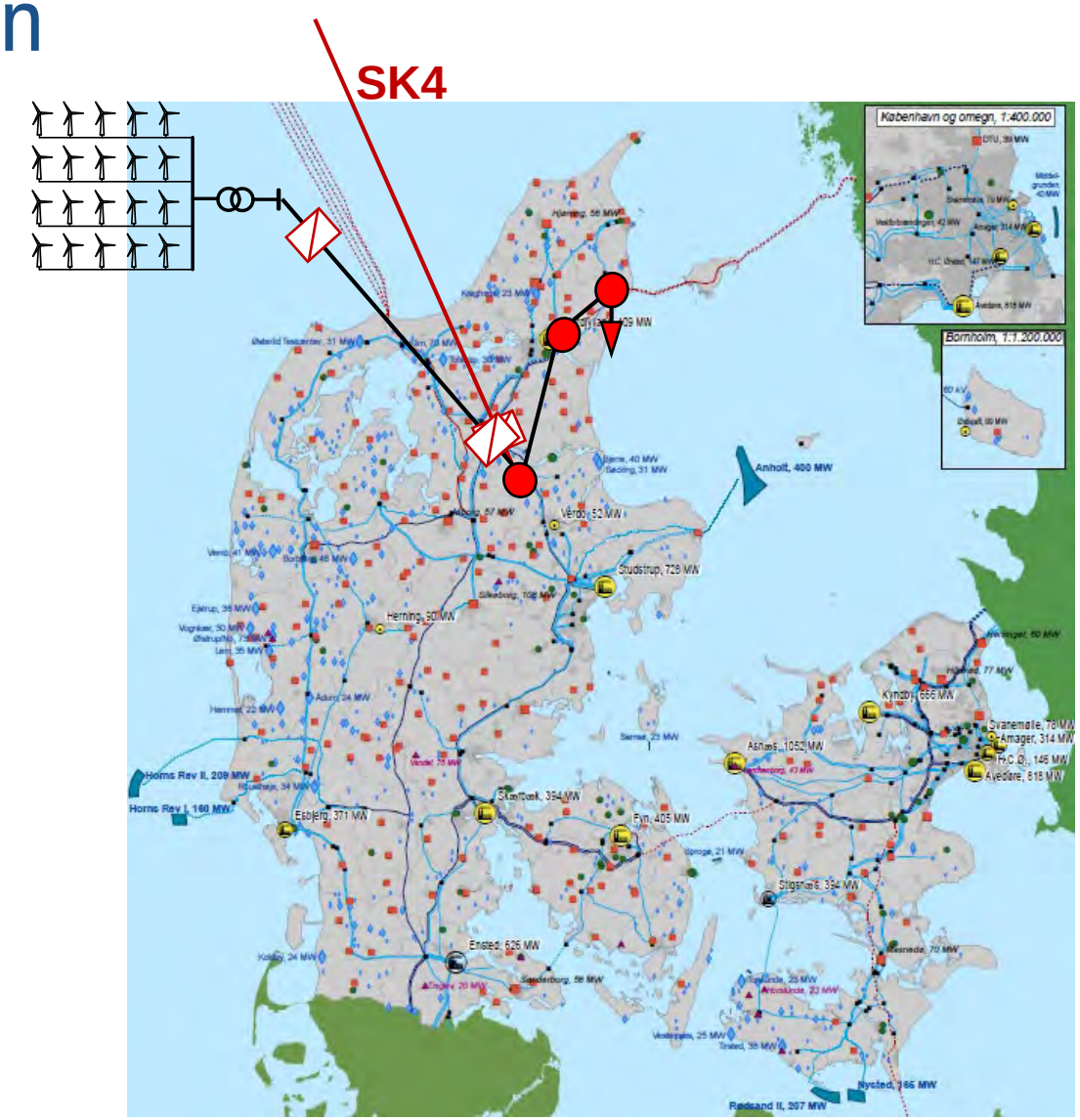
Outside PROMOTioN
Energinet performs Black Start field test with Skagerrak 4 (SK4) HVDC interconnector

WP3 Performs Black Start Simulation Test with Offshore WPP

To energize:

- 3 buses
- Overheadline & underground cable
- Shunt reactor & transformer
- Step MW++ load
  - Load changes
  - Frequency & voltage setpoint changes
  - Load disconnection

Results to be compared against HVDC field tests by Energinet



[https://ens.dk/sites/ens.dk/files/Statistik/el_produktion_og_transmission_2017_300dpi.pdf]

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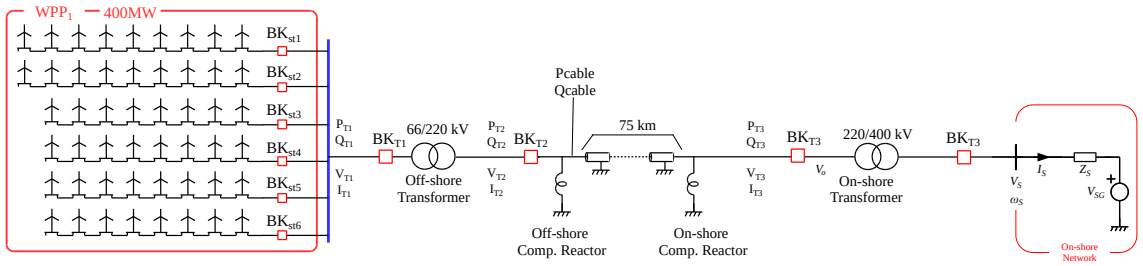
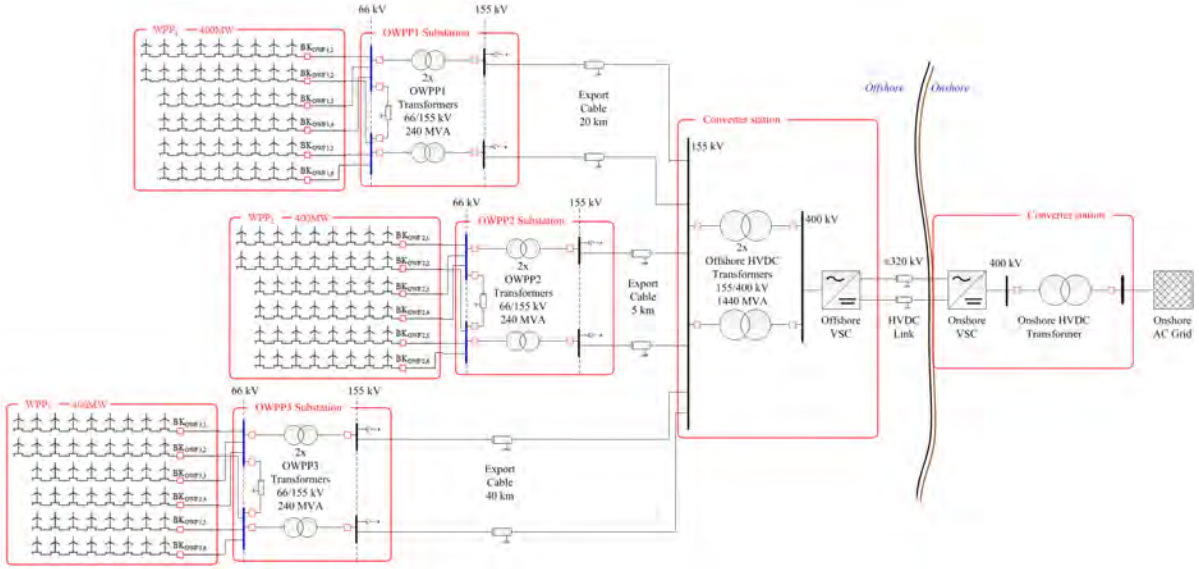
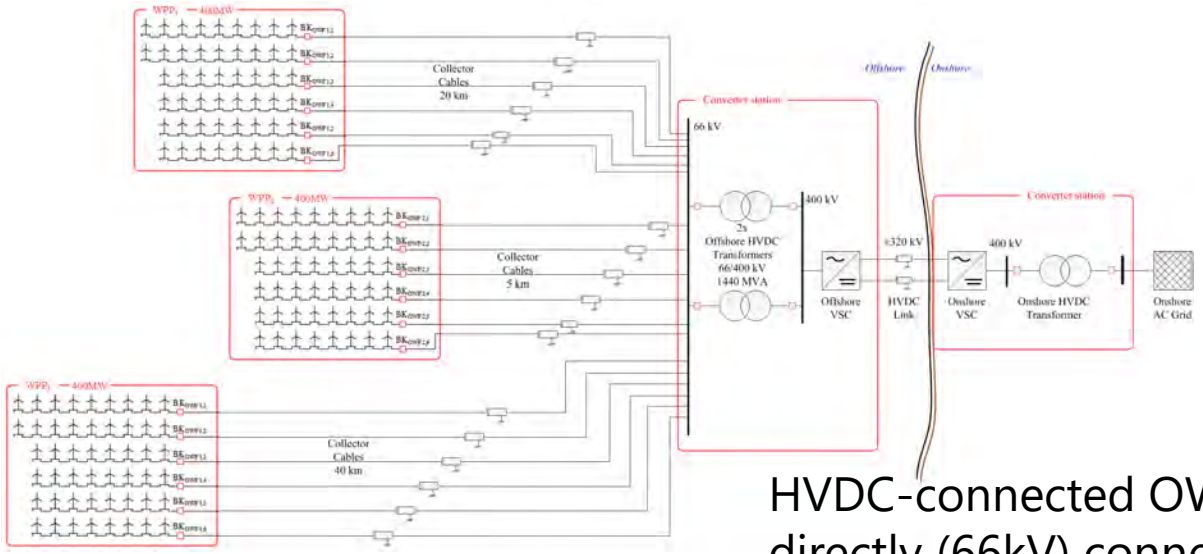
Scenarios – Self-Energization & Black Start



HVAC-connected OWPP



HVDC-connected OWPP(s)
with AC collector substation(s)



HVDC-connected OWPP(s)
directly (66kV) connected to the HVDC

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Preliminary Findings – Self-Energization & Black Start

- Self-energization of the WTs – feasible & achievable
  - Availability of wind still investigated

- Hard-switching of large transformers and long export cables
  - might be a challenge for the WT converters

- Soft-start (voltage ramp-up) by the WTs
  - Feasible for the HVDC offshore AC network
    (HVDC onshore handles the onshore AC network switchings)
  - Fast energization of onshore AC network regions
    e.g. energizing the network and allowing conventionals to take over

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Preliminary list - Recommendations for Requirements

- Grid forming WTs
  - Capabilities
  - Operational ranges (V, f, df/dt)
  - Control gains (e.g. droop, reserve)

- Fault response in 100% converter-based grids

- Black Start contribution by OWPPs
  - Soft (voltage ramp-up) but very fast start

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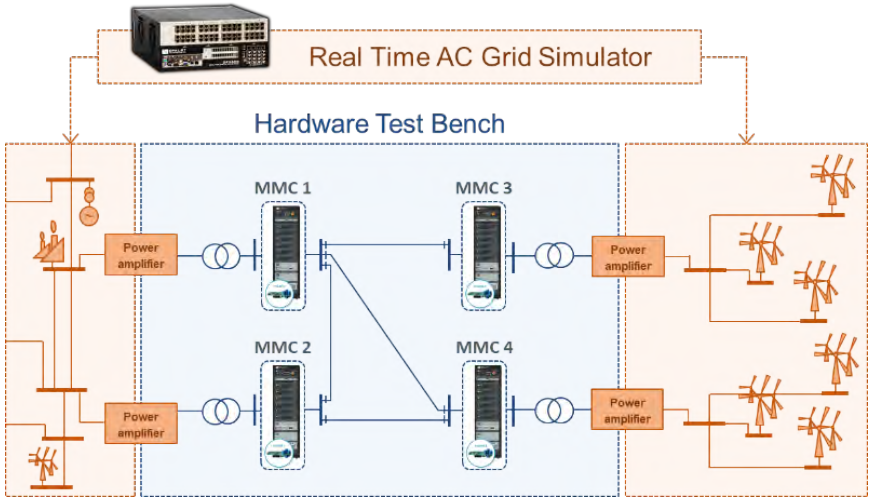
Progress Towards Demonstration in WP16



WP3 controls → WP16 setups

- Offshore AC and DC faults
- Grid forming OWPP cluster
- Fault Handling with Grid-Forming WTGs
- Black start capability of HVAC and DRU-connected offshore wind farms
- Frequency Support and Power Oscillation Damping by OWPP Cluster
- Cluster Control of Two/Three OWPPs Connected to the Same HVDC Converter

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Risk Management

Risks	Effects	Measures	P(Risk)
• **Compliance evaluation procedures are not confirmed by the simulations**	• Delay or impossibility in defining and testing compliance evaluation procedures	• P: defined as milestone and will be monitored • C: compliance procedures redefined based on the initial simulation results	**Medium**

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Any Questions?

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Budget Use

Person-month usage of most partners on track

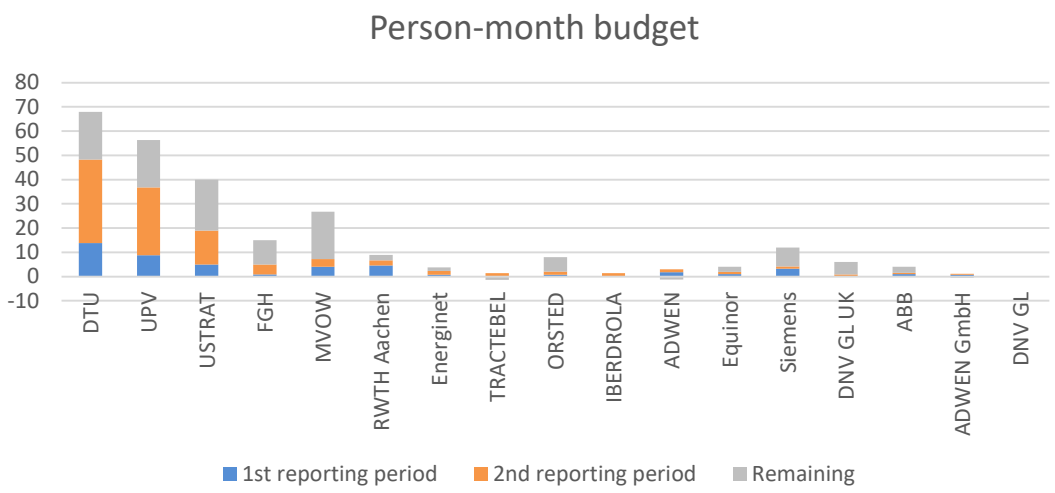
- Especially the major partners with large budgets

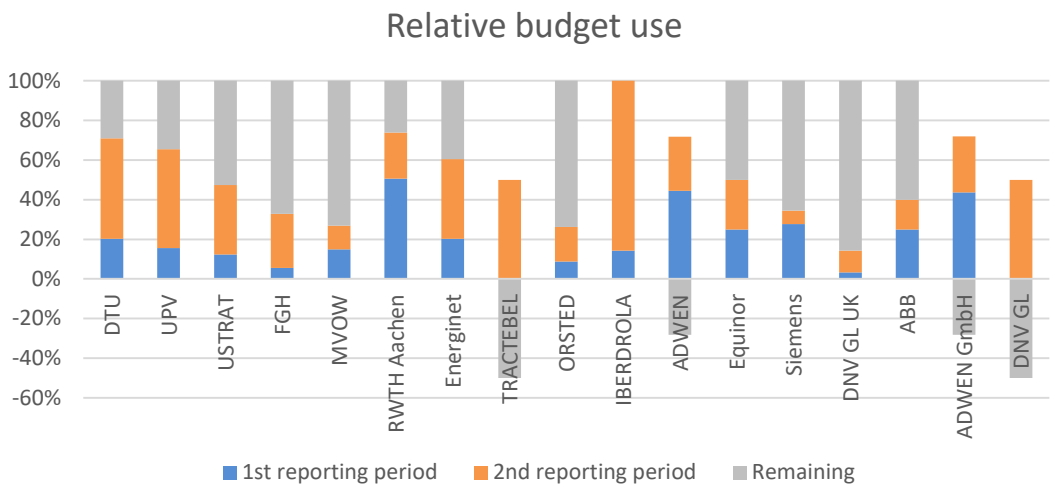
FGH had substantial commitment in 2018 Q3

- This will be observed in the next period

Most of the industrial partners' commitment has been increasing due to increased focus on Self-Energization & Black Start by 2018 Q2

- This will be observed in the next period





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PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Task4.3
Main results from D4.3

WP4

Alberto BERTINATO

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

Structure of the document

Title: D4.3 – Performance, interoperability and failure modes of selected protection strategies

Due Date: M36

D4.3

Part 1

Methodologies for protection strategy development

Part 2

In depth development of selected protection strategies

WP9
Real Time Simulations

T4.2
Screening analysis of fault clearing strategies

WP6
DCCB models

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Part 1
Methodologies for protection strategy development

- Failure mode analysis
- Key Performance Indicators
- Interoperability
- AC system impact
- Overvoltage management

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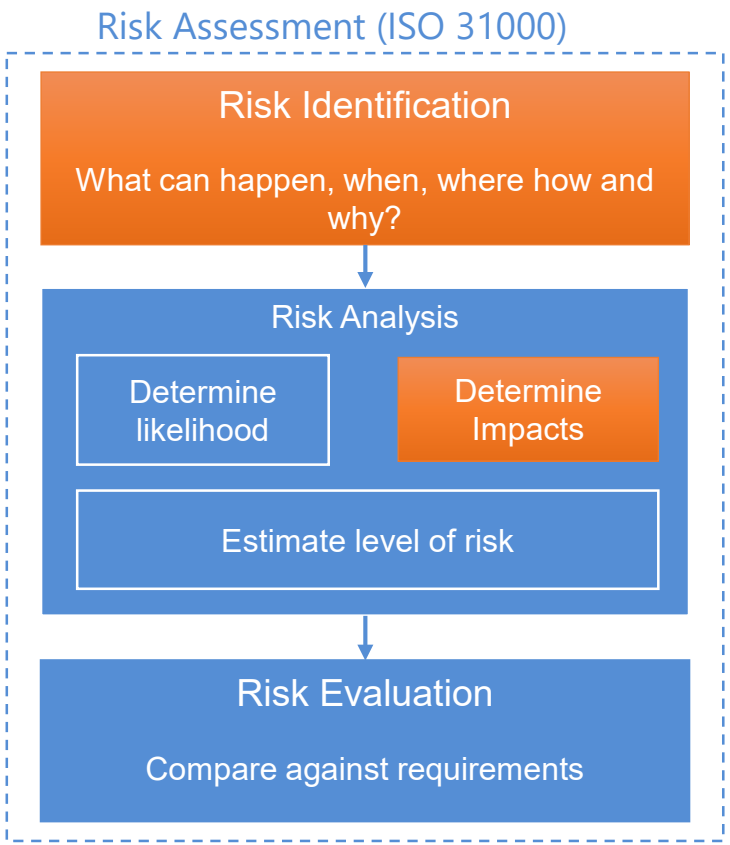
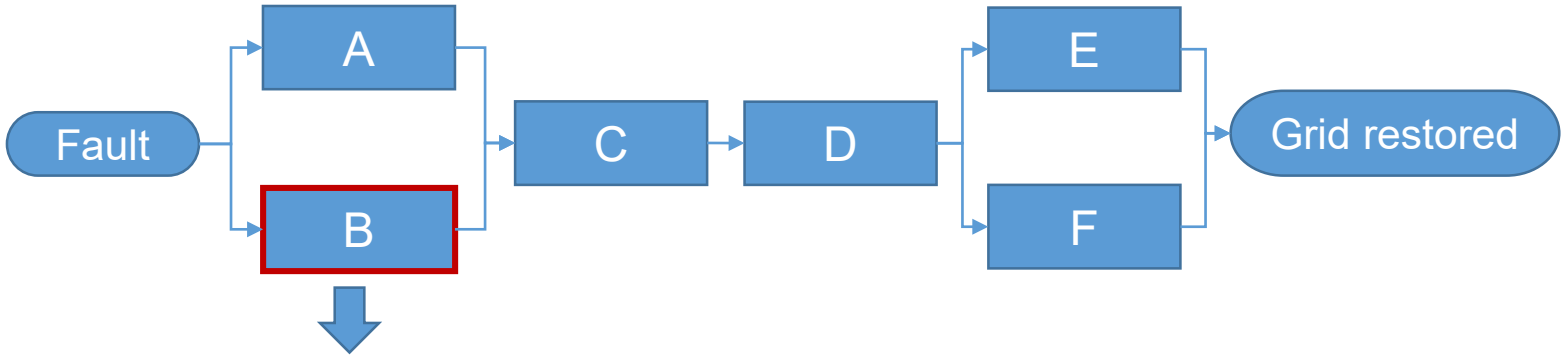
Methodologies for protection strategy

- <u>Failure mode analysis</u> of protection strategy



For each step in the protection strategy the following questions are asked:

Protection strategy description



- Which of the defined failure modes can happen during a step?
  - DCCB failure
  - Dependability failure…
- Which are the impacts of this failure mode?
- Development of consistent backups

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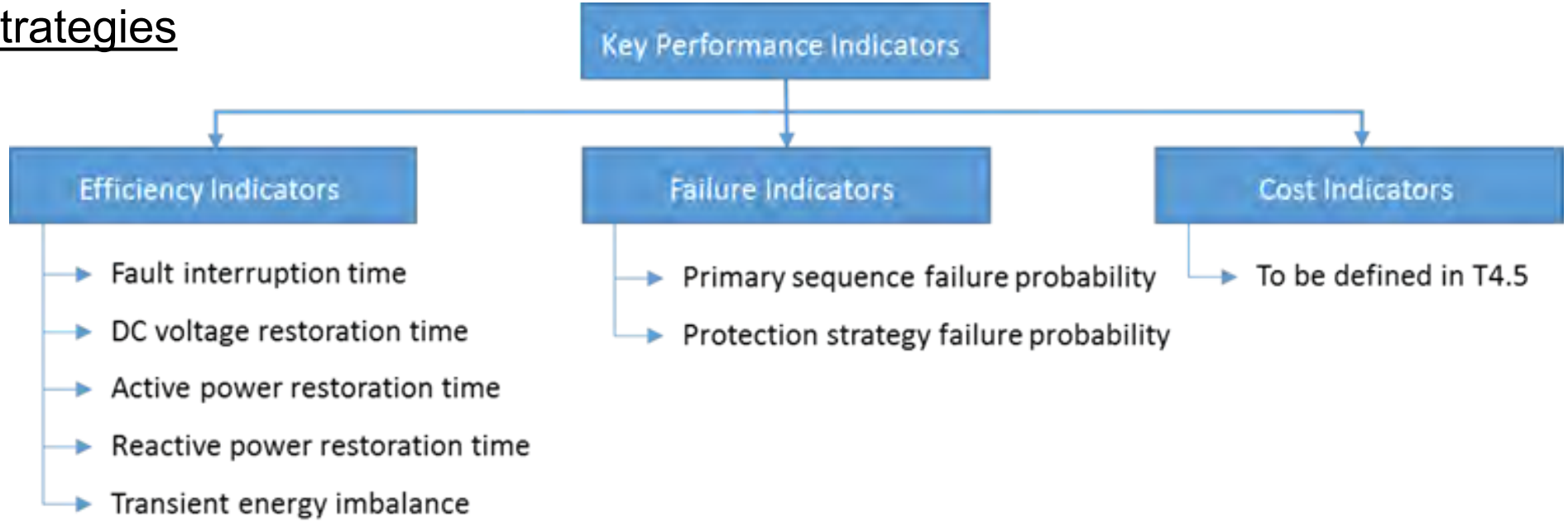
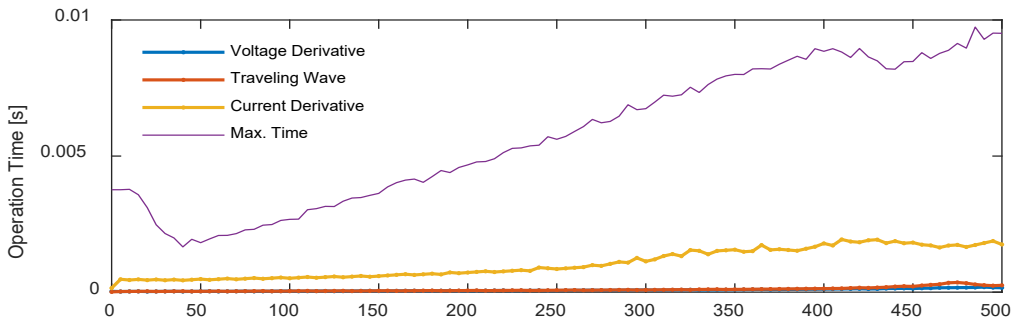
Methodologies for protection strategy

- <u>KPI for protection strategies</u>



- <u>KPI for protection algorithms</u>
  - Speed
  - Protection margin (for non-unit algorithm)
  - Dependability



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Methodologies for protection strategy

- <u>Interoperability approach :</u>

Interoperability among key elements

Interoperability among protection strategies

Functional interoperability
(define functional requirements at component or system level)

Syntactic and Semantic interoperability
(ability to exchange data and to use the exchanged data)

Electrical interface interoperability
(related to voltage and current withstand capability)

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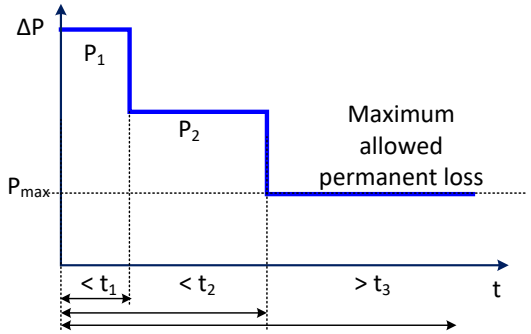
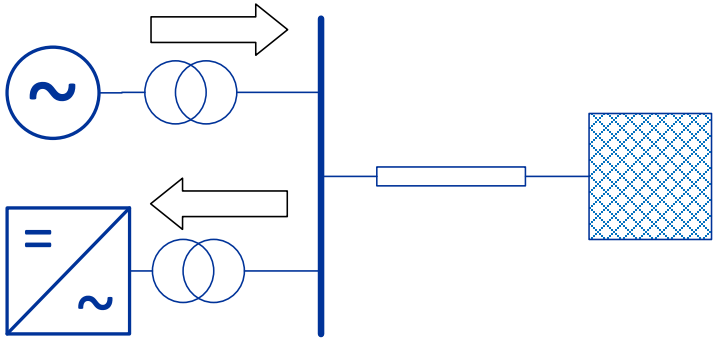
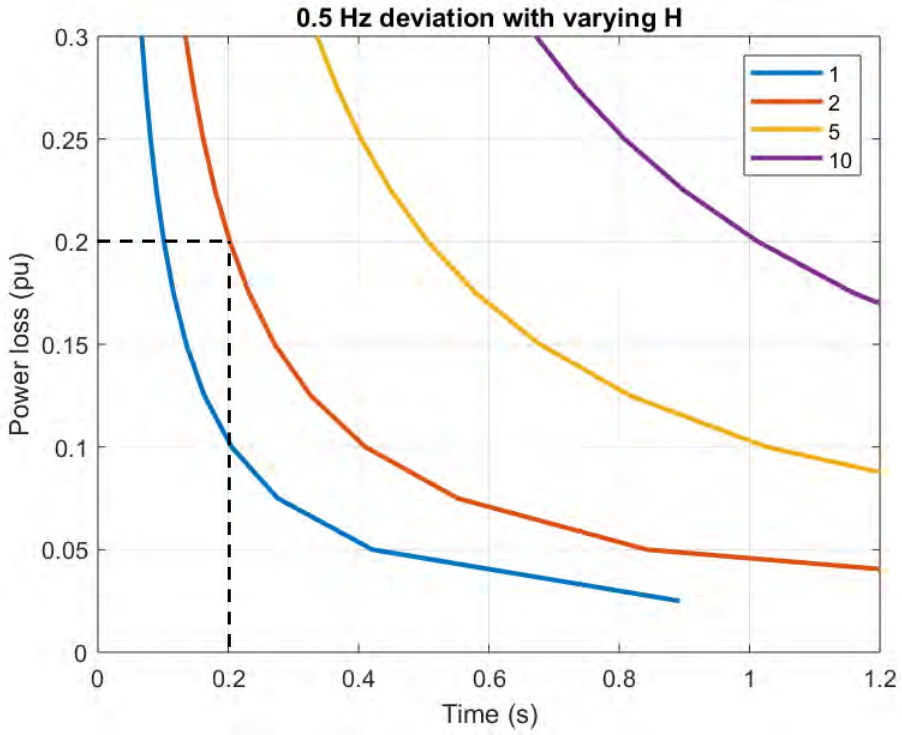
Methodologies for protection strategy

- <u>AC system impact</u> : depending on its magnitude and duration, temporary loss of DC grid could effect
  - Frequency stability
  - Rotor angle stability
  - AC Voltage stability







Power loss in per-unit relative to the AC system power

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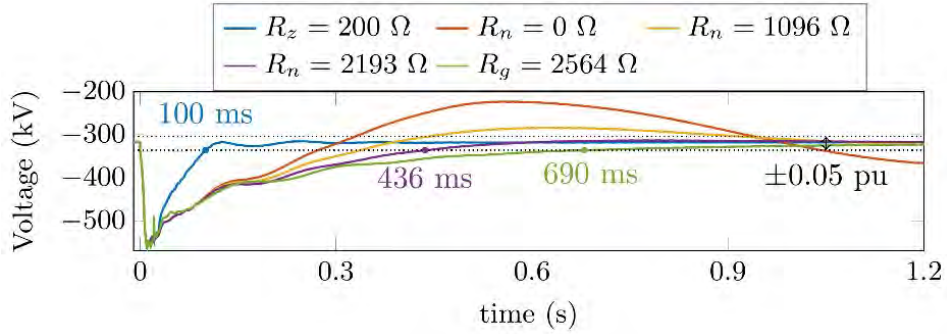
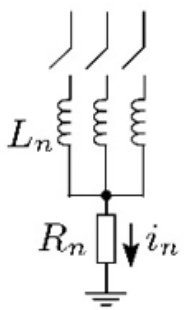
Methodologies for protection strategy

- Overvoltage management during pole-to-ground fault in a symmetric monopolar system

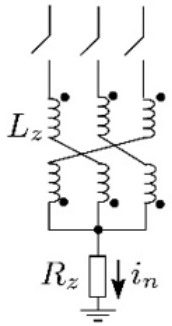
Investigated solutions

- Pole Rebalancing Reactor (AC side)
- Zig Zag transformer (AC side)
- Neutral grounded transformer (AC side)
- Dynamic Braking System DBS (DC side)

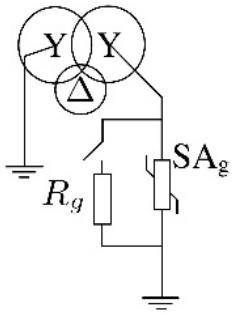




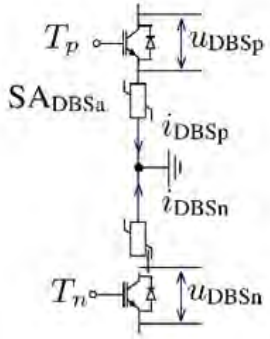
PRR



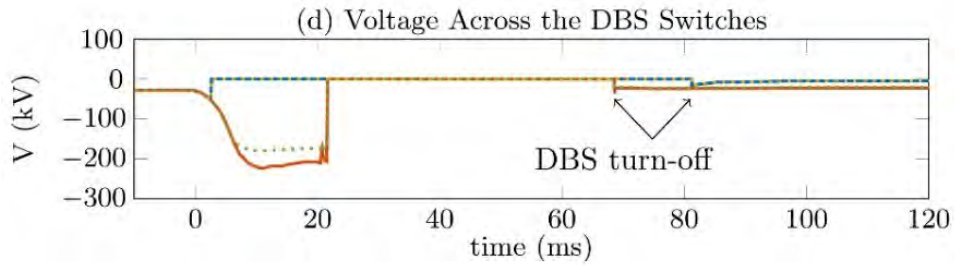
ZigZag Transformer



Neutral Grounded Transformer



DBS



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Part 2
Protection Strategy Development

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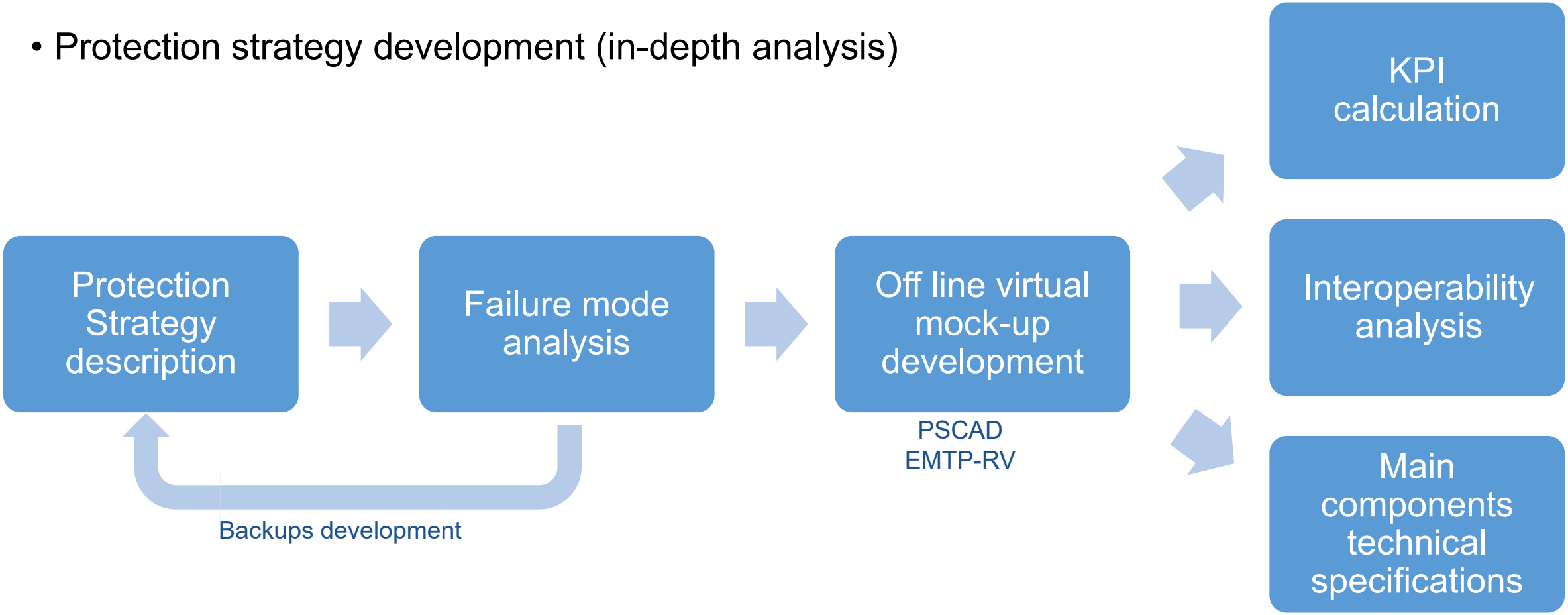
Protection Strategy Development

- Protection strategy development (in-depth analysis)



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Protection Strategy Development

- Selected protection strategies

Full-selective fault clearing strategies

- Full selective with Mechanical-DCCB
- Full selective with Hybrid-DCCB

Non-selective fault clearing strategies

- Full Bridge MMC based strategy
- Converter breaker strategy

Investigated architecture and type of fault

- Symmetric Monopolar
  - Pole-to-ground fault
  - Pole-to-pole fault
- Bipolar
  - Pole-to-ground fault

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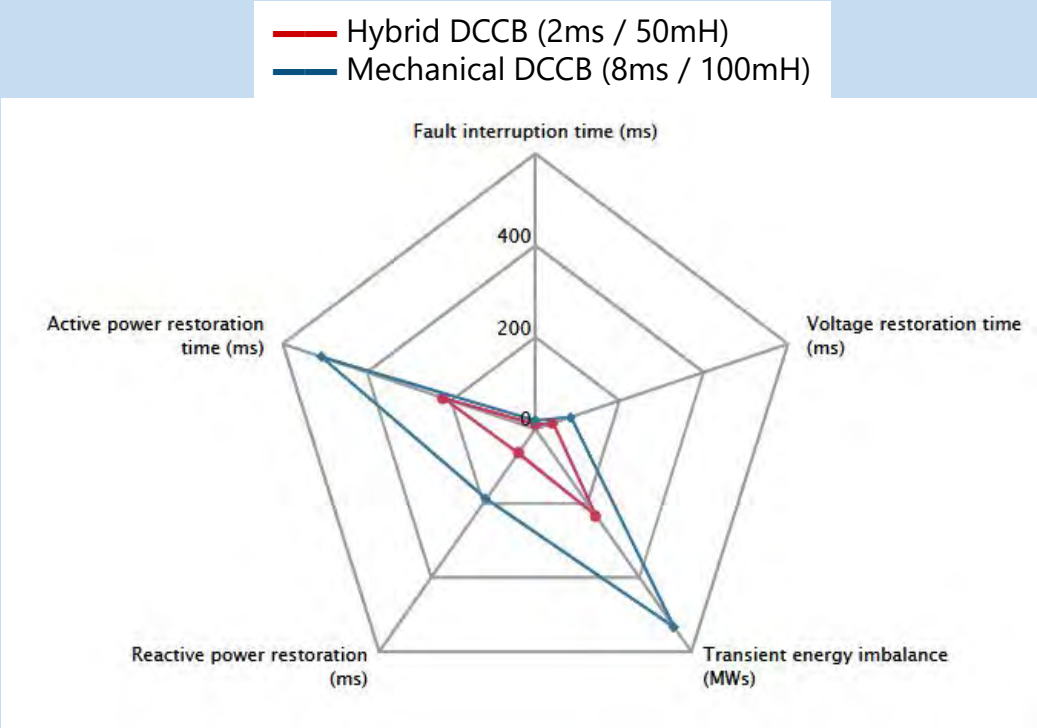
Protection Strategy Development

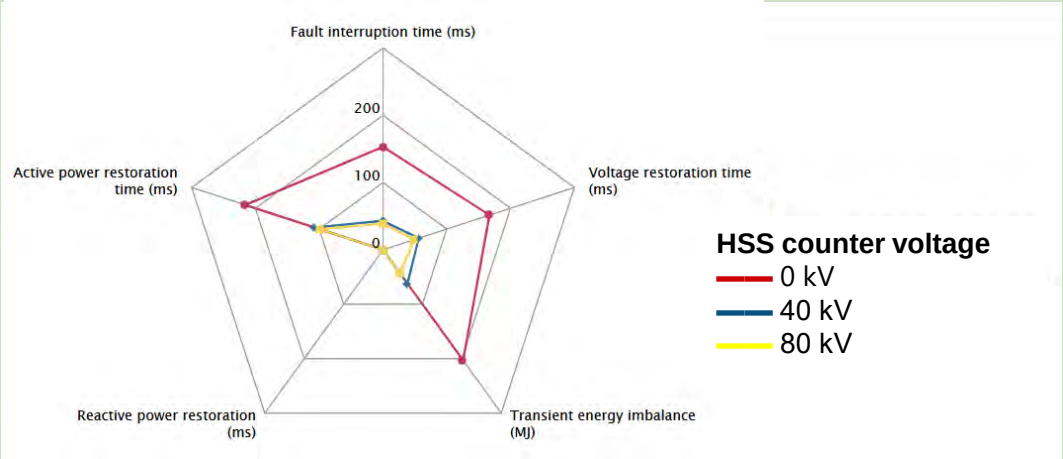
- Main results for pole-to-pole fault in a symmetric monopolar system

Full-selective fault clearing strategies

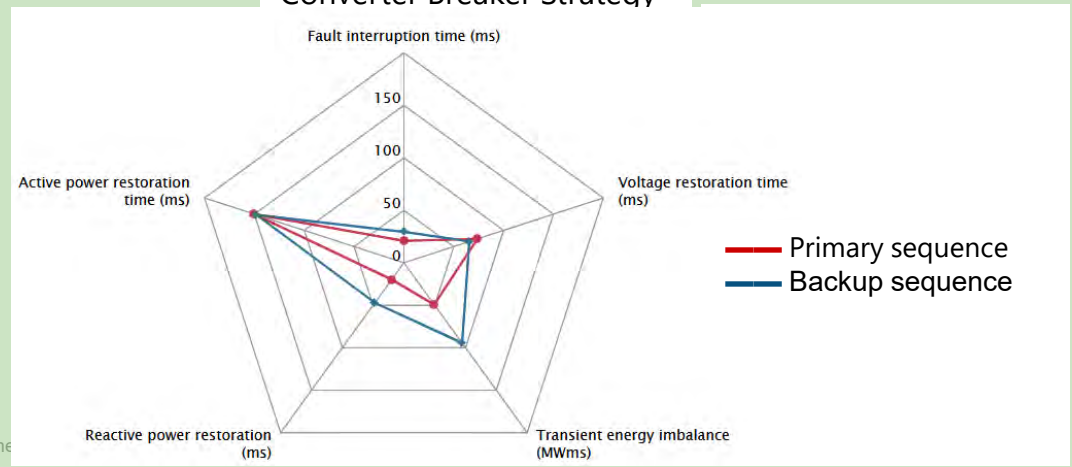


Non-selective fault clearing strategies

FB MMC based strategy



Converter Breaker Strategy



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PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Task4.5

WP4

Serge POULLAIN

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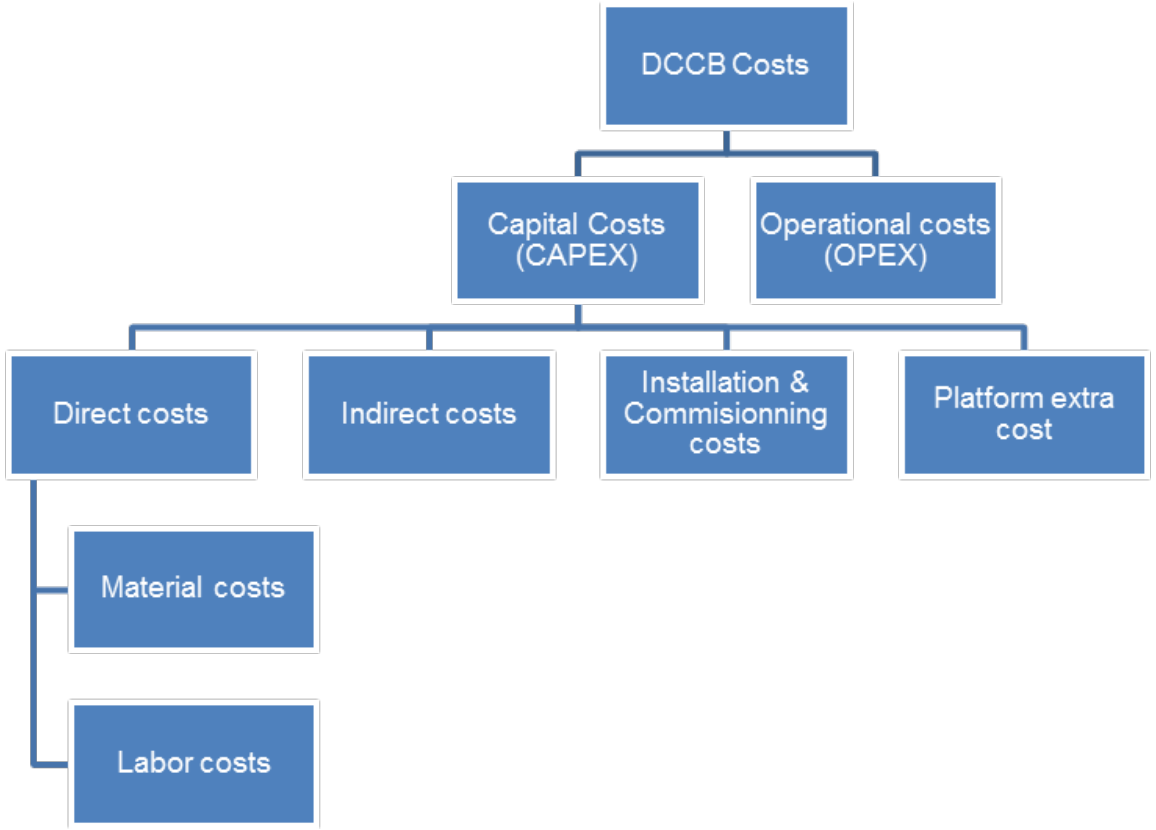
WP 4.5: DC CB cost model development: Methodology / Main parameters



Nominal pole to ground DC voltage	U
Transient Interruption Voltage (TIV) peak value (Maximum voltage between the two terminals during the breaking process)	U_{brM}
Maximum DC breaking current	I_{brM}
Maximum DC permanent / operating current	I_n
Breaker opening time at maximum DC breaking current (Time from breaker trip signal to current diversion to energy dissipators)	T_o
Maximum Energy Dissipation (Maximum electromagnetic energy that can be dissipated during one cycle of the breaking process)	E
Current limiting DC reactor	Ldc
Uni-directional vs Bi-directional	
Opening/closing cycle (O vs OCO)	
Onshore vs Offshore	

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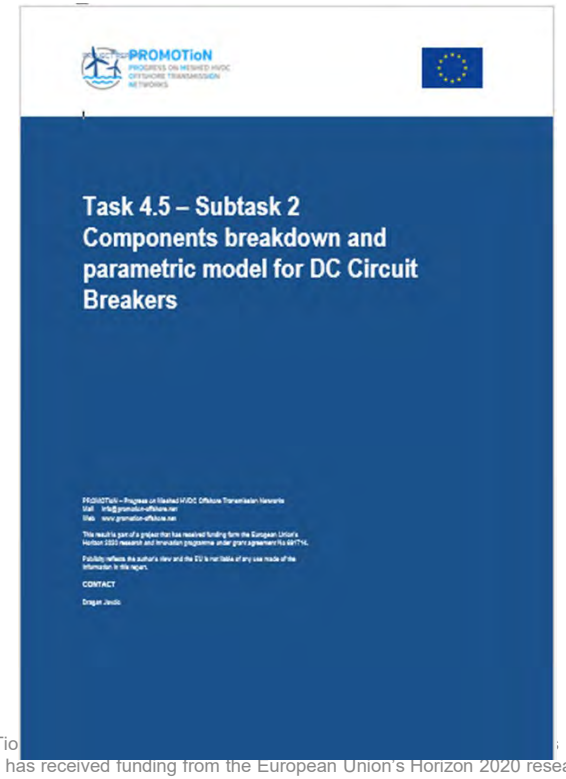
WP 4.5: DC CB cost model development: Organization & Contributions

Sept. 2017	Feb. 2018		Nov. 2018	Jan. 2019
DC CB main specifications	DC CB's component breakdown parametric models	Estimation of material direct cost models	Shallow estimation of other costs (Labor, indirect, SIC)	Review and validation process
SuperGrid Institute (from D 4.2 report)	**Univ Aberdeen** Review SGI	**SuperGrid Institute** Review DNV-GL	**SuperGrid Institute** Review DNV-GL	DNV-GL WP 12 Project Partners



WP 4.5: DC CB cost model development: Further steps and uses

Make the Component breakdown report available to project partners

Make the DC CB cost model report available for Project Partner feedback/validation (step 5 of proposed process)

Is a contribution to Cost Data Collection report from WP 12

Will be used for cost-benefit analysis in both WP 4.5 and WP 12

What about confidentiality?

Diffusion outside PROMOTioN Consortium ? Write a publication ?

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WP 4.5: Support to WP 12

Meeting with WP 4.5, WP 7 and WP 12 about CBA activities within PROMOTioN on 02 October 2018 in Lyon

CBA studies within PROMOTioN:

WP 12 is in charge of grid CBA studies. These studies will be mainly performed by FHG and Carbon Trust

WP 4.5 is in charge of Protection system CBA.

AC grids models and data from WP 12 to support WP 4.5 CBA studies

Tractebel could provide some AC Grid Data to perform a simplified DC Power Flow on AC side.

AC Grids models and data could also be provided by FGH, from TYNDP data.

Organization and roadmap of support from WP 4.5 to WP 12

Lot of HVDC grid case studies (several concepts, wind scenario and system configurations, busbar configurations)

Four protection strategies to be considered (from WP 4.3)

Need to define a suitable methodology with 3 phases

Would require a WP 4.5 extension from M42 to M48

Phase	Main contributors	Due time
Methodology set-up and validation through application to a first case study (8 GW DC Hub)	SGI KUL	March 2019
Definition of other HVDC grid option (other grid case studies)	WP 12	March 2019
Application of the methodology to all grid case studies	SGI KUL	Oct.. 2019
Main outcomes synthesis for WP 12 deployment plan	SGI, KUL WP 12	Dec. 2019

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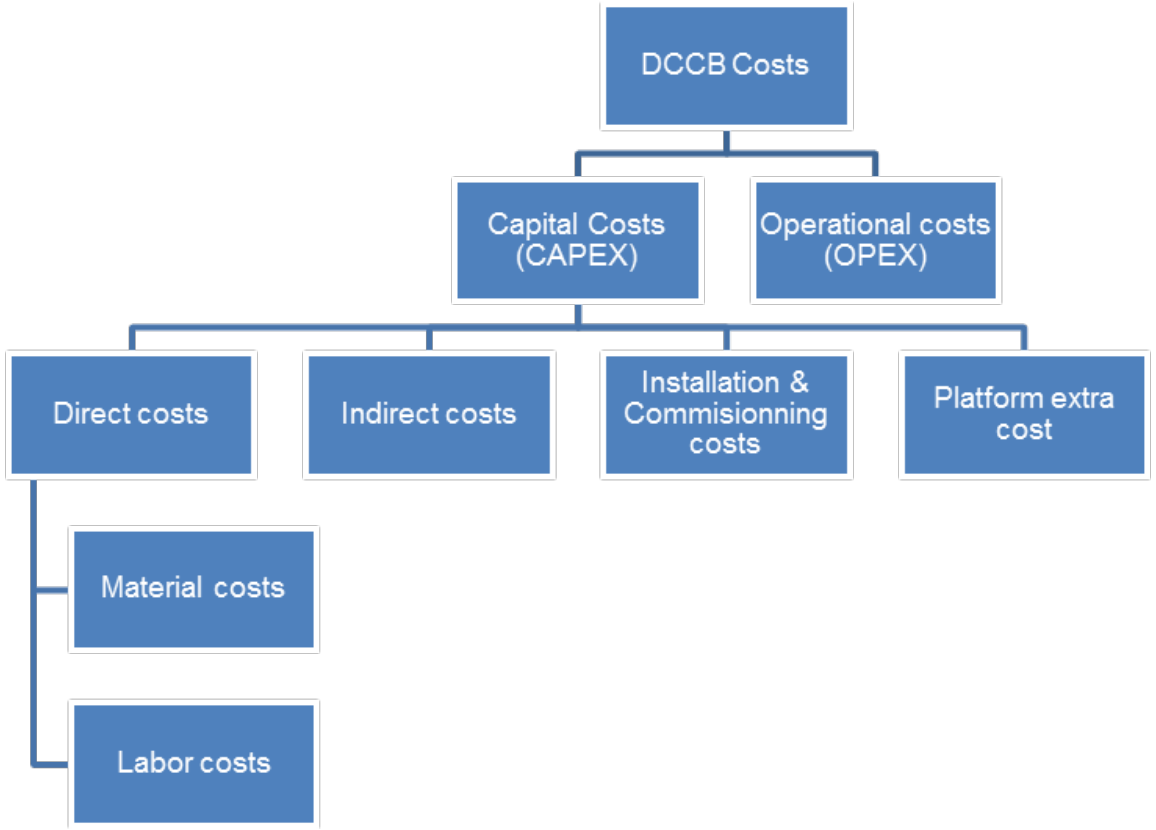

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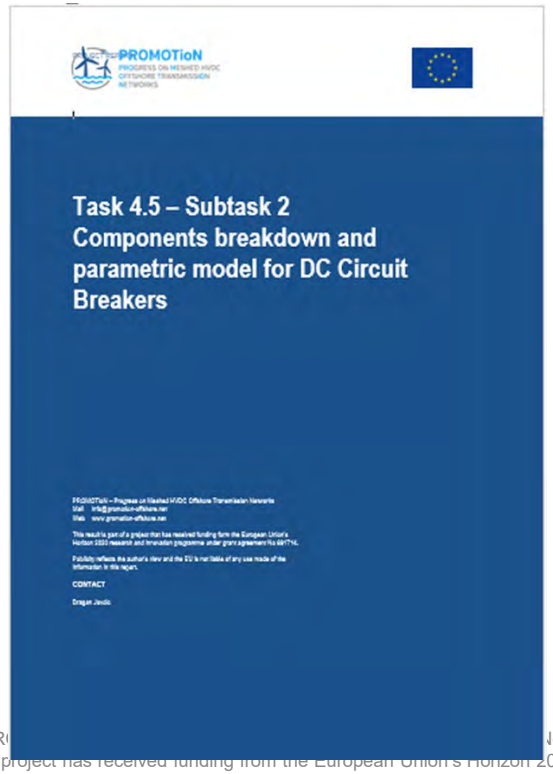

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PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Characterisation of DC Circuit Breakers

December 2018

Dragan Jovcic, University of Aberdeen

PROgress on Meshed HVDC Offshore Transmission Networks

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CONTENT

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- ↗WP6 overview,
- ↗Tasks 6.5 and 6.6, DC CB Demonstrator and failure modes,
- ↗Task 6.7, Hybrid DC CB grid integration and scaling,
- ↗Task 6.8, VARC DC CB grid integration and scaling,
- ↗Task 6.10, Mechanical DC CB grid integration and scaling,

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1) Characterisation of DC CBs, WP6 overview

	Tasks	Lead	partners	timeframe
6.1	Develop system-level model for hybrid DC CB	UAbdn	ABB, SGI, DNV-GL	M1-M11
6.2	Develop system-level model for mechanical DC CB	DELFT	MEU, DNV-GL	M1-M11
6.3	Develop component-level and real-time model for hybrid DC CB	UAbdn	DELFT, ABB, DNV-GL	M18-M30
6.4	Develop component-level and real-time model for mechanical DC CB	DELFT	MEU, DNV-GL, UAbdn	M18-M30
6.5	*Develop kW-size hardware prototypes for hybrid and mechanical DC CBs*	*UAbdn*	*ABB, DEFLT, DNV-GL*	*M1-M36*
6.6	Demonstrate DC CB failure modes on kw-size hardware prototypes	UAbdn	DELFT	M31-M48
6.7	Analyse hybrid DC CB integration into EHV DC grid	UAbdn	DELFT, TenneT	M31-M48
6.8	Develop roadmap for VARC DC CB scaling to EHV DC voltage	DELFT	SciBreak, TenneT	M31-M48
6.9	Develop standard DC CB verification plan and RTDS models	UAbdn	ABB, DELFT, MEU, DNV-GL, SGI, SciBreak	M12-M24
6.10	Develop roadmap for mechanical DC CB scaling to EHV DC voltage	MEU	DNV-GL, TenneT, UAbdn	M31-M48

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

1) Characterisation of DC CBs, WP6 overview

conferences published:

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, DOI: 10.1049/cp.2017.0030*
2. *A. Jamshidifar and D Jovcic "Modelling of Hybrid DC Circuit Breaker Based on Phase-Control Thyristors", IEEE PES GM, Chicago, July 2017.*
3. *F. P. Page at all. "Mechanical Circuit Breaker Modelling for System-level, Real-time Protection System Simulations" CIGRE B4 colloquium, Winnipeg 2017,*
4. *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,*
5. *A. Jamshidifar, D Jovcic and A. Hassanpoor "Control methods for fault current limiting using hybrid HV DC Circuit Breakers", CIGRE Paris 2018.*
6. *A. Jamshidifar, D Jovcic. M Popov and S. Liu " Modelling and Comparison of Common Functionalities of HVDC Circuit Breakers" IEEE PES GM 2018.*
7. *M.H. Hedayati and D Jovcic "500A, 900V, Mechanical DC CB Demonstrator for HVDC applications", ISGT, Sarajevo, October 2018*

journals published:

1. *A. Jamshidifar and D Jovcic "Design, Modeling and Control of Hybrid DC Circuit Breaker Based on Fast Thyristors", IEEE Transactions on power Delivery, October 2017, DOI: 10.1109/TPWRD.2017.2761022*
2. *M. Hedayati and D Jovcic "Reducing Peak Current and energy in HVDC CB using disconnector voltage control", IEEE Transactions on power Delivery, February 2018, DOI: 10.1109/TPWRD.2018.2812713 ,*
3. *L. Lian, S. Liu, M. Popov: Optimized Algorithm of Active Injection Circuit to Calibrate DC Circuit Breaker, submitted to International Journal of Electric Power And Energy Systems*
4. *S. Liu, M. Popov: Development of HVDC System-level Mechanical Circuit Breaker Model, submitted to International Journal of Electric Power And Energy Systems*

panels:

1. *Characterisation and testing of DC CBs for future DC grids, IEEE PES GM, Portland, August 2018,*
2. *DC Grid protection, IEEE ISGT, Sarajevo, October 2018,*

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Overview of work:

1. 320kV UFD
    a. Detailed modelling: Dynamics, Thomson coils,
    b. Cassie – Meyer arc model (SF6 medium),

2. Hybrid DC CB failure mode study

3. 900V UFD
    a. DC arc modelling in air,
    b. Reducing opening time

4. 900V mechanical DC CB
    a. Series connection of interrupters,
    b. Failure analysis

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1. 320kV UFD: Detailed modelling: Dynamics, Thomson coils,

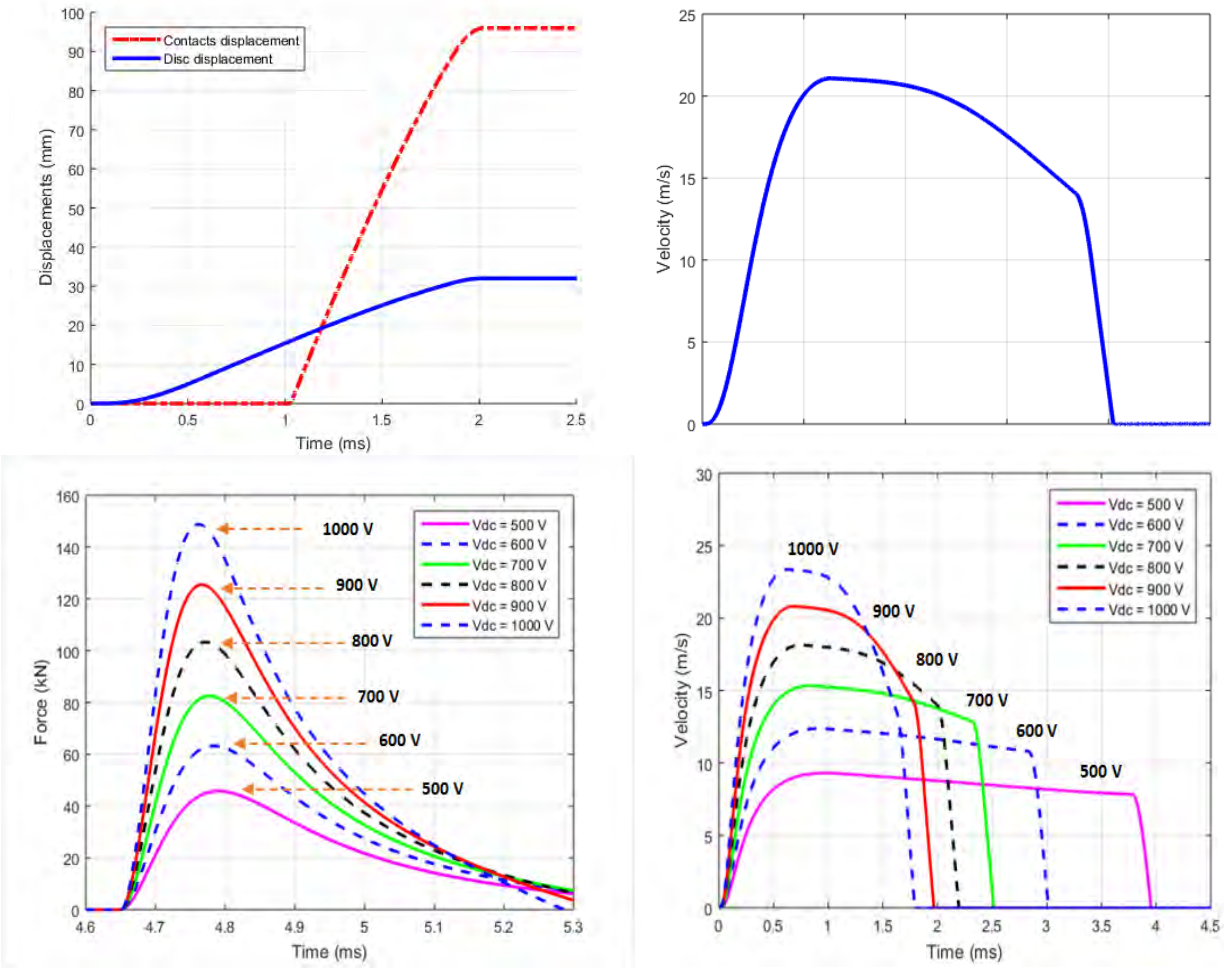

Figure 1. Simulation results on PSCAD model of 320kV UFD.

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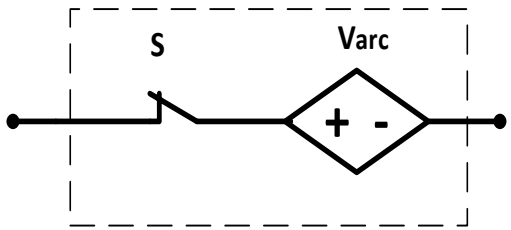
1. 320kV UFD: failure modelling

- Open signal is received while UFD conducts large current.
- Cassie arc model for SF6 medium.
- Entry and exit from arcing mode. Positive and negative current.



$$\frac{dg_c}{dt} = \left(\frac{g_c}{\theta_c}\right)\left[\left(\frac{U_a}{U_0}\right)^2 - 1\right] \quad (5)$$

Figure 2. 320kV UFD model structure.

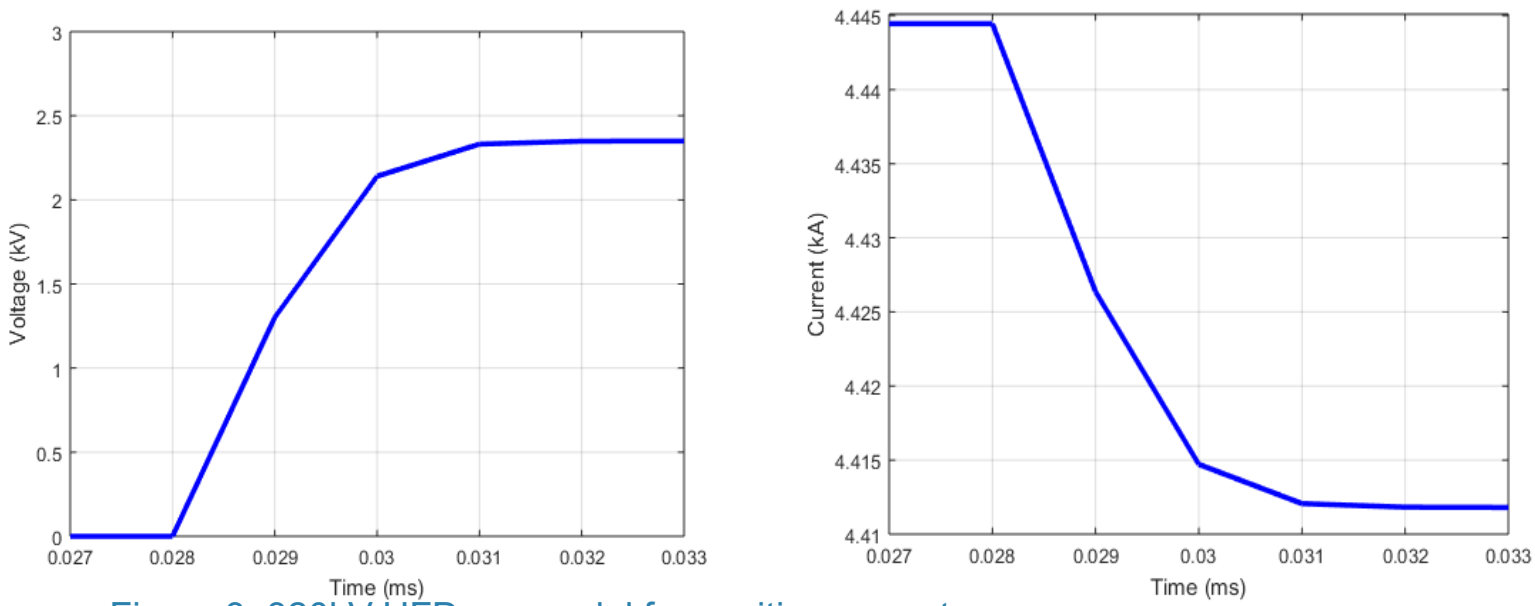
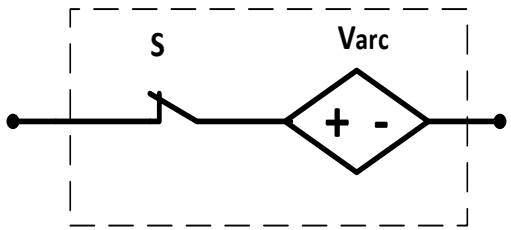


Figure 3. 320kV UFD arc model for positive current.

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

2. 320kV UFD: failure modelling

- Open signal is received while UFD conducts large current.
- Cassie-Mayr arc model for SF6 medium.
- Entry and exit from arcing mode. Positive and negative current.



$$\frac{dg_c}{dt} = \left(\frac{g_c}{\theta_c}\right)\left[\left(\frac{U_a}{U_0}\right)^2 - 1\right] \quad (5)$$

Figure 2. 320kV UFD model structure.

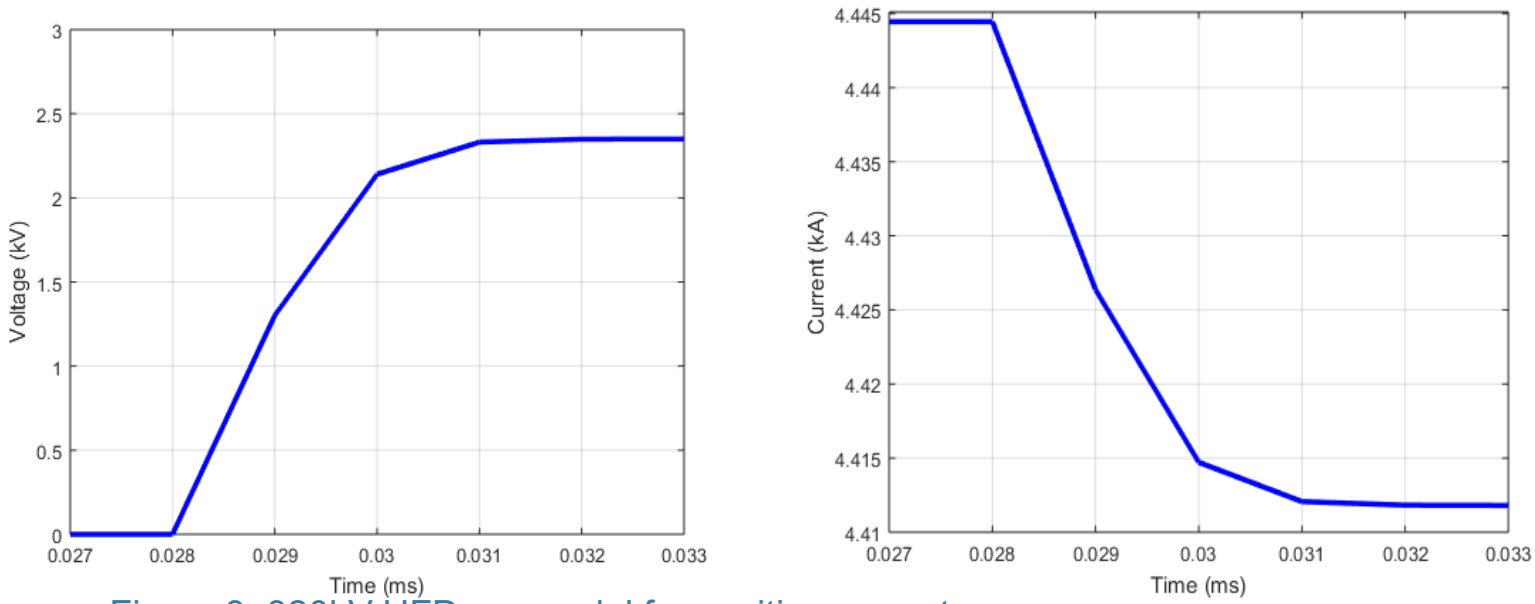


Figure 3. 320kV UFD arc model for positive current.

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

2. 320kV DC CB failure mode study

- Failure in closed state.
- Failure in open state.
- Failure while opening.
- Impact of failure of each of 5 components are studied:
  - LCS
  - UFD
  - Main breaker
  - Residual Breaker
  - Energy absorber
- Failure tree diagram,
- assumptions:
  - primary protection operates within 10ms,
  - back up protection operates within 200ms

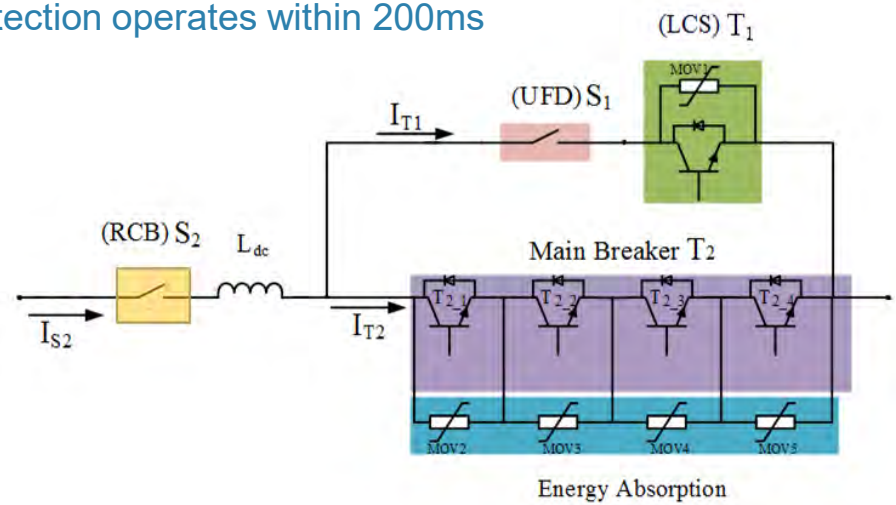


Figure 4. 320kV hybrid DC CB.

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

2. 320kV DC CB failure mode study

In closed state DC CB fails if

a) RCB fails or,

b) Any other two switches fail

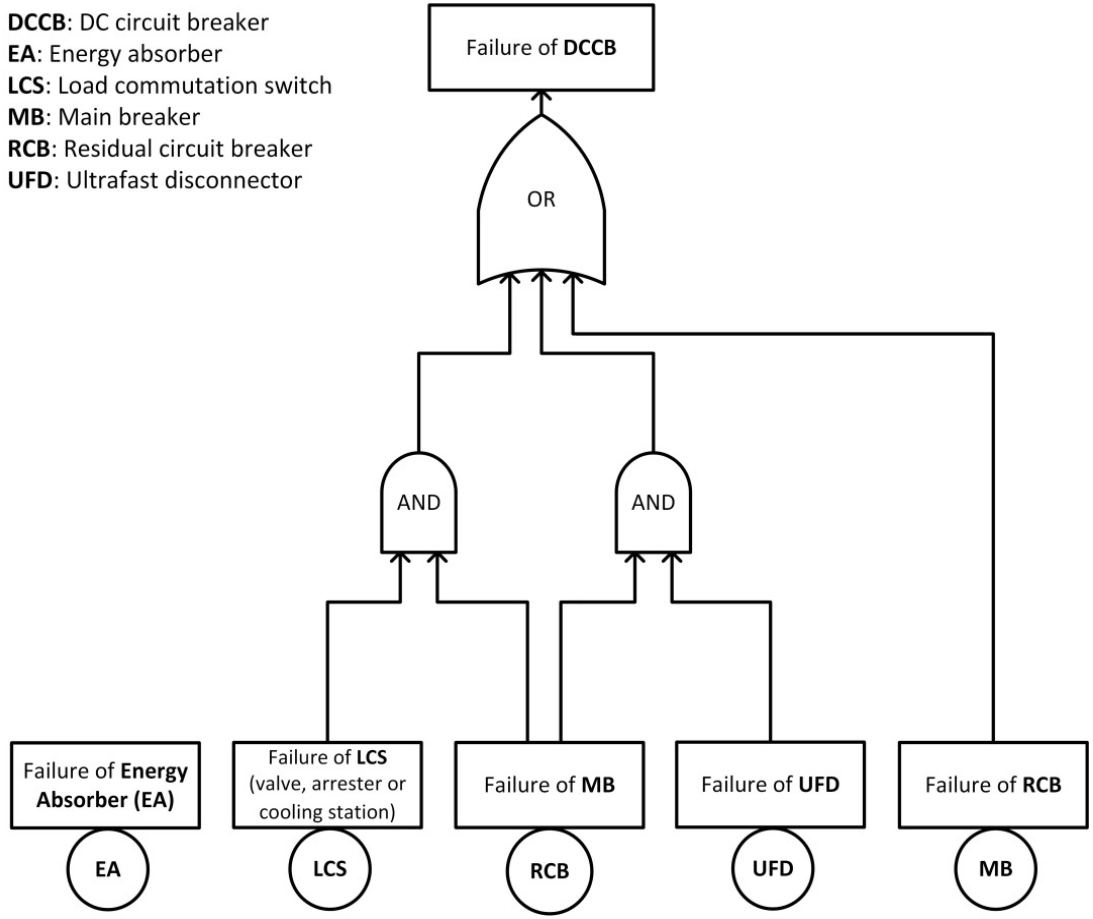


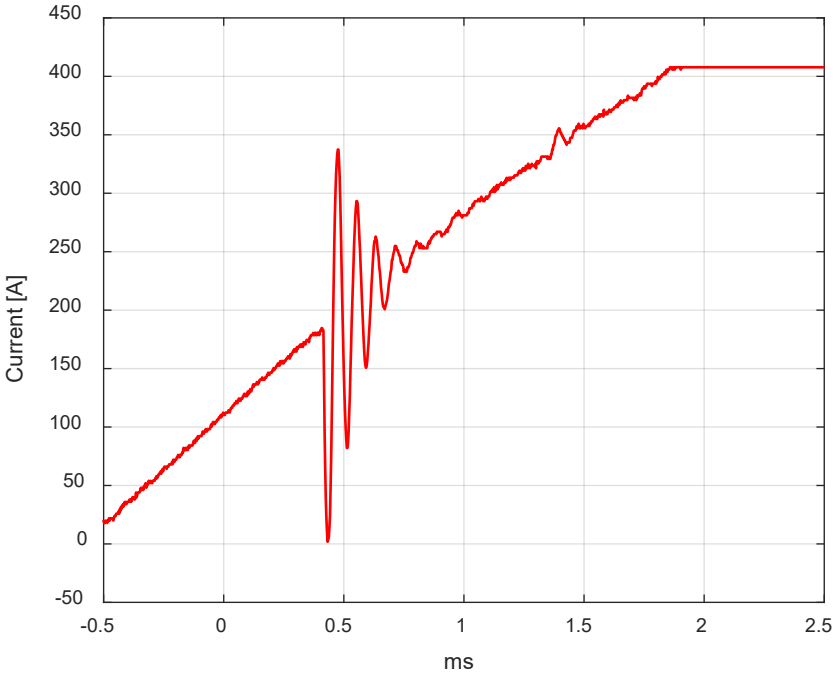
Figure 5. Failure tree diagram for closed state.

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

3. 900V UFD improvements and failure mode

a) Opening time reduced to 1ms,

b) DC arc model in air



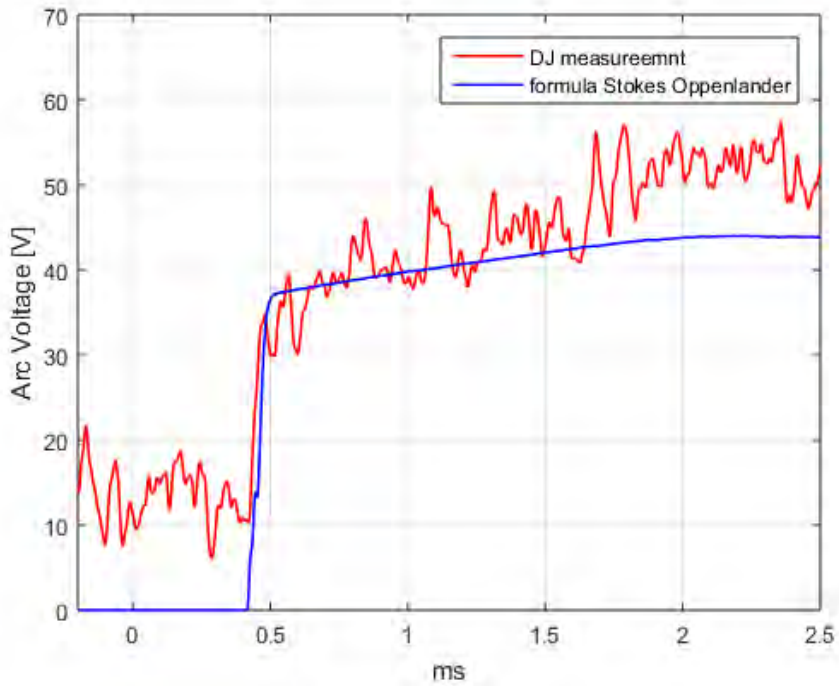


Figure 6. 900V UFD (Air) arc model verification.

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

3) Task 6.7 Hybrid DC CB Grid intergation and scaling to high voltage

1. DC grid integration of hybrid DCCB
    a) DC grid model from WP4,
    b) Tennet is working on finalising parameters,
    c) Same DC grid will be used in T6.7, T6.8 and T6.10,
2. Pre-standardisation of DC CB inputs and outputs
    a) Connection with IED (coordination with WP4)

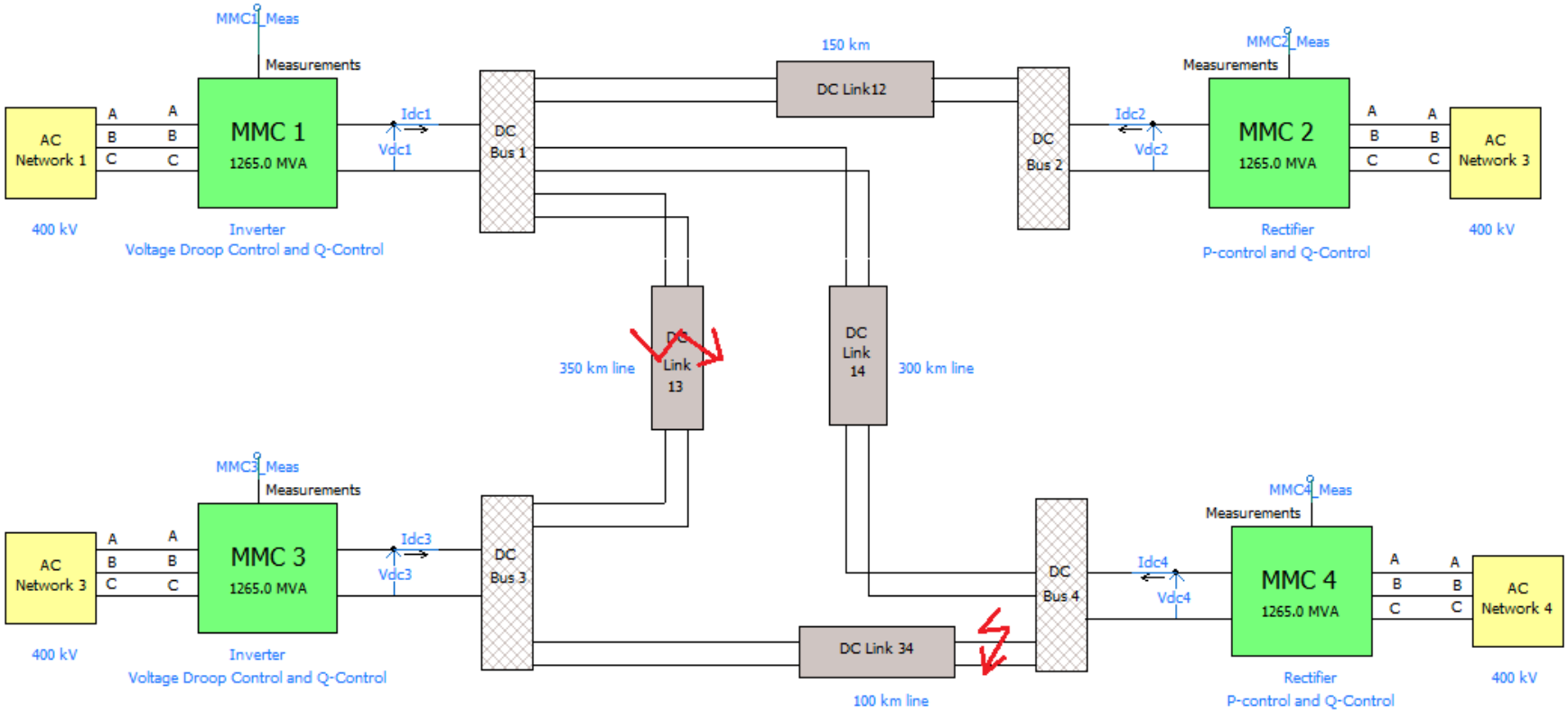


Figure 7. DC grid test system.

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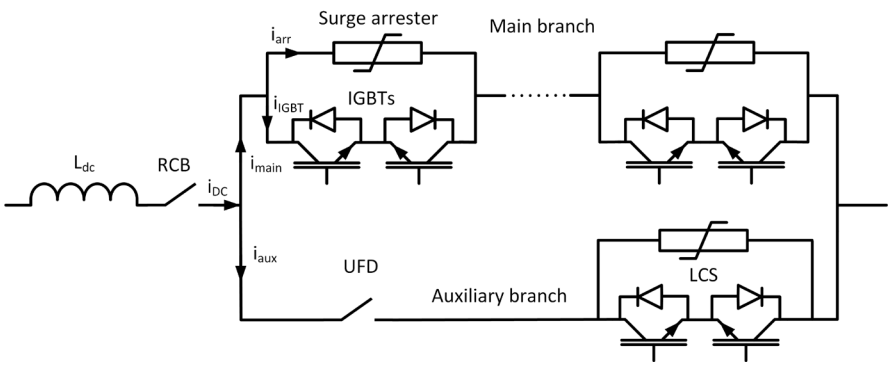
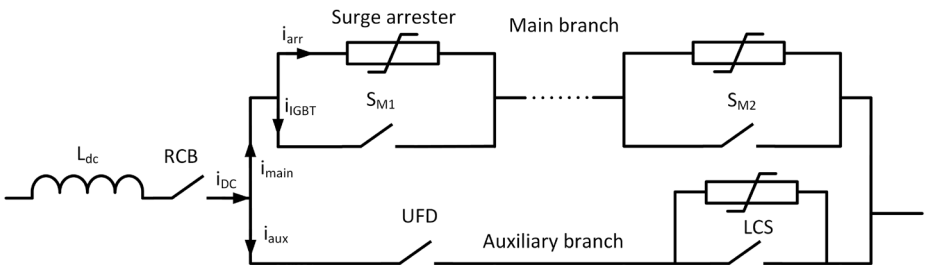
3) Task 6.7 Hybrid DC CB Grid intergation and scaling to high voltage

1. DC grid integration of hybrid DCCB

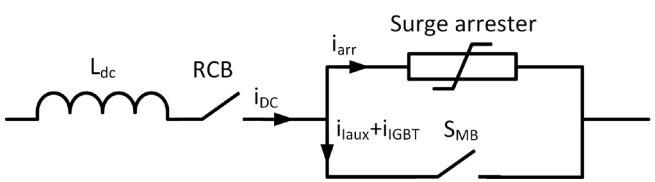
a) DC CB model influence ,



a). Detailed hybrid DC CB model.



b). Switched hybrid DC CB model.



c). Generic hybrid DC CB model.

Figure 8. Hybrid DCCB models .

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

3) Task 6.7 Hybrid DC CB Grid intergation and scaling to high voltage

1. DC grid integration of hybrid DCCB
   a) At system level response of three DCCB models is very similar,

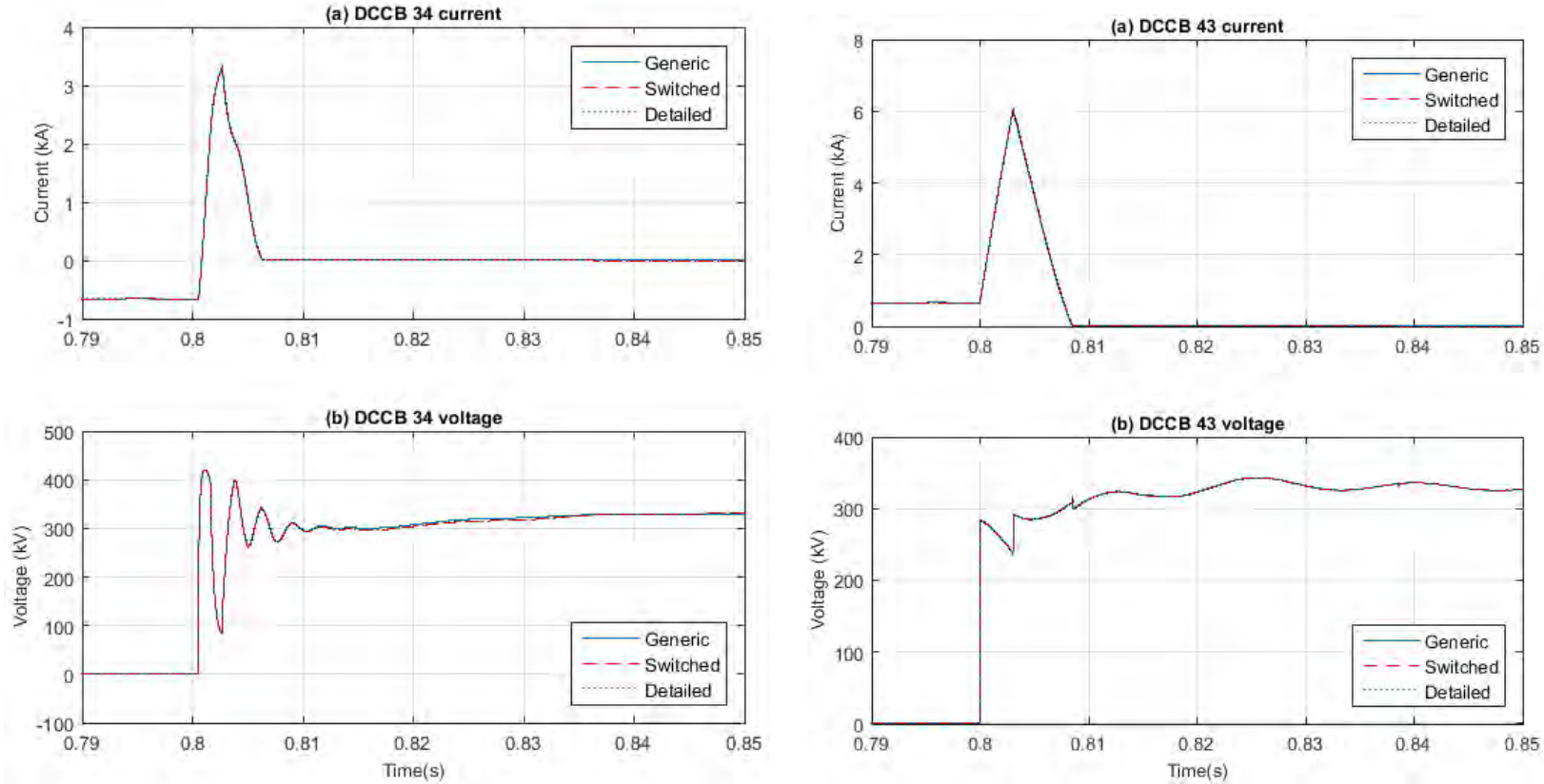


Figure 9. Comparison of hybrid DCCB models .

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3) Task 6.7 Hybrid DC CB Grid intergation and scaling to high voltage

1. DC grid integration of hybrid DCCB

Table 1. Properties of Hybrid DCCB models .

	Detailed	Switched	Generic
Current breaking	Yes	Yes	Yes
Fault current limiting	Yes	Yes	No
Individual branch currents	All	All	Some
Power loss estimation	Yes	Yes	No
Switch temperature estimation	Yes	Yes	No
Arrester energy estimation	All arresters	All arresters*	Main branch only, no FCL
LCS voltage estimation	Yes	Yes*	No
Self-protection	Full	Full	Limited
Failure modes	All	Most	Few

1s real time, 10 us time step:

- Generic DCCB: 2.5 min
- Switched HDCCB: 25 min
- Detailed HDCCB: 690 min ~ 11.5 h

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1. DC grid integration of hybrid DCCB

a) study of different fault location on line 13.

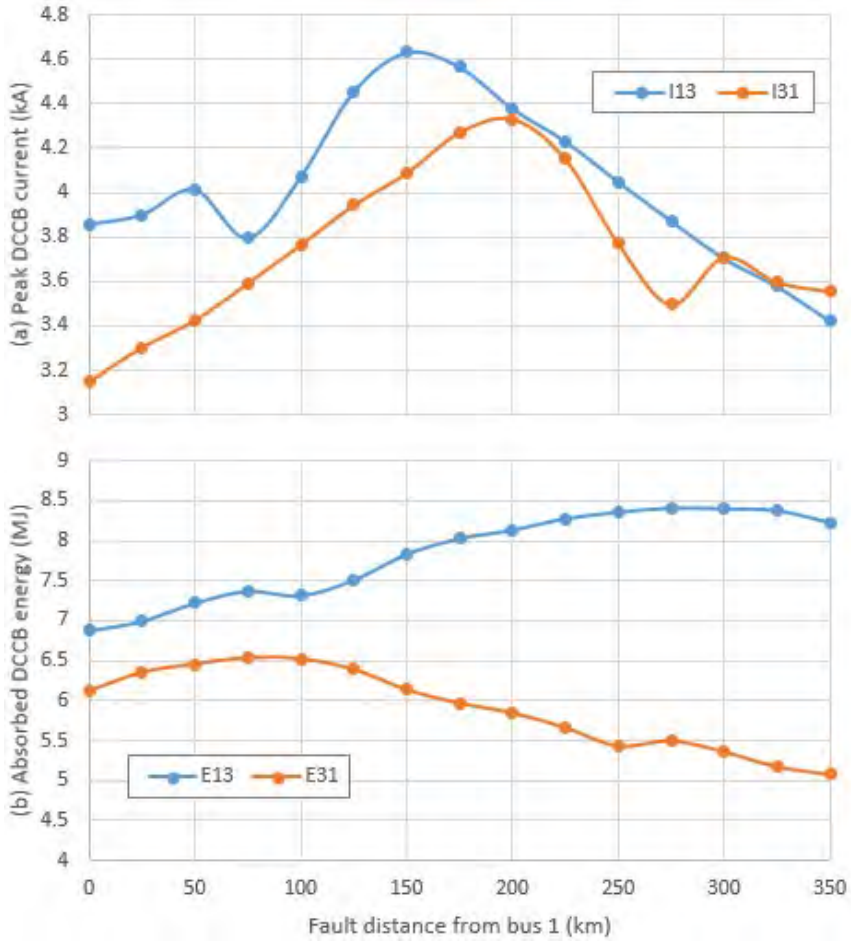

Figure 10. Peak DC CB current and energy dissipation for different fault location.

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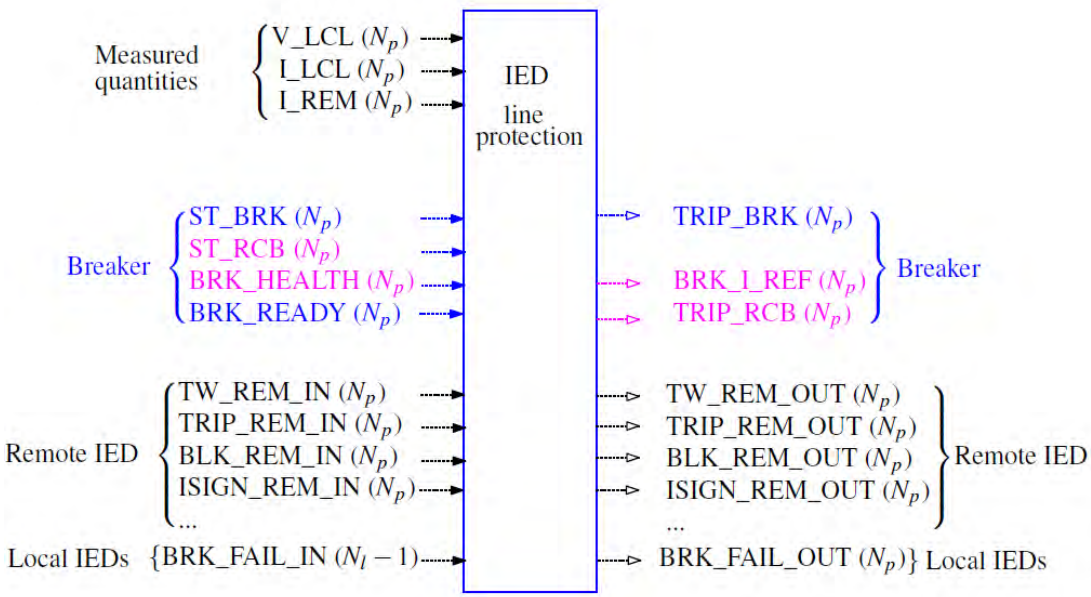
2. Pre-standardisation of interfaces between hybrid DCCB and protection

a) 3 DC CB inputs.

b) 4 DCCB outputs



- Mechanical CB:
  - TRIP_BRK: 1/0→open/close order
  - BRK_I_REF: not used
  - TRIP_RCB:not used
  - Breaker monitoring:
    - ST_BRK: include VI and RCB
    - BRK_READY: ready to operate, including all components in the mechanical DCCB

Figure 11. Input and output connection between IED and DC CB.

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

4) Task 6.8 VARC DC CB Grid intergation and scaling to high voltage

1. Detailed Simulation of VARC DC CB including RTDS modelling
2. Stress study for HV scaling
3. Series connection of units
4. Energy absorber thermal modelling and model verification (with WP10)

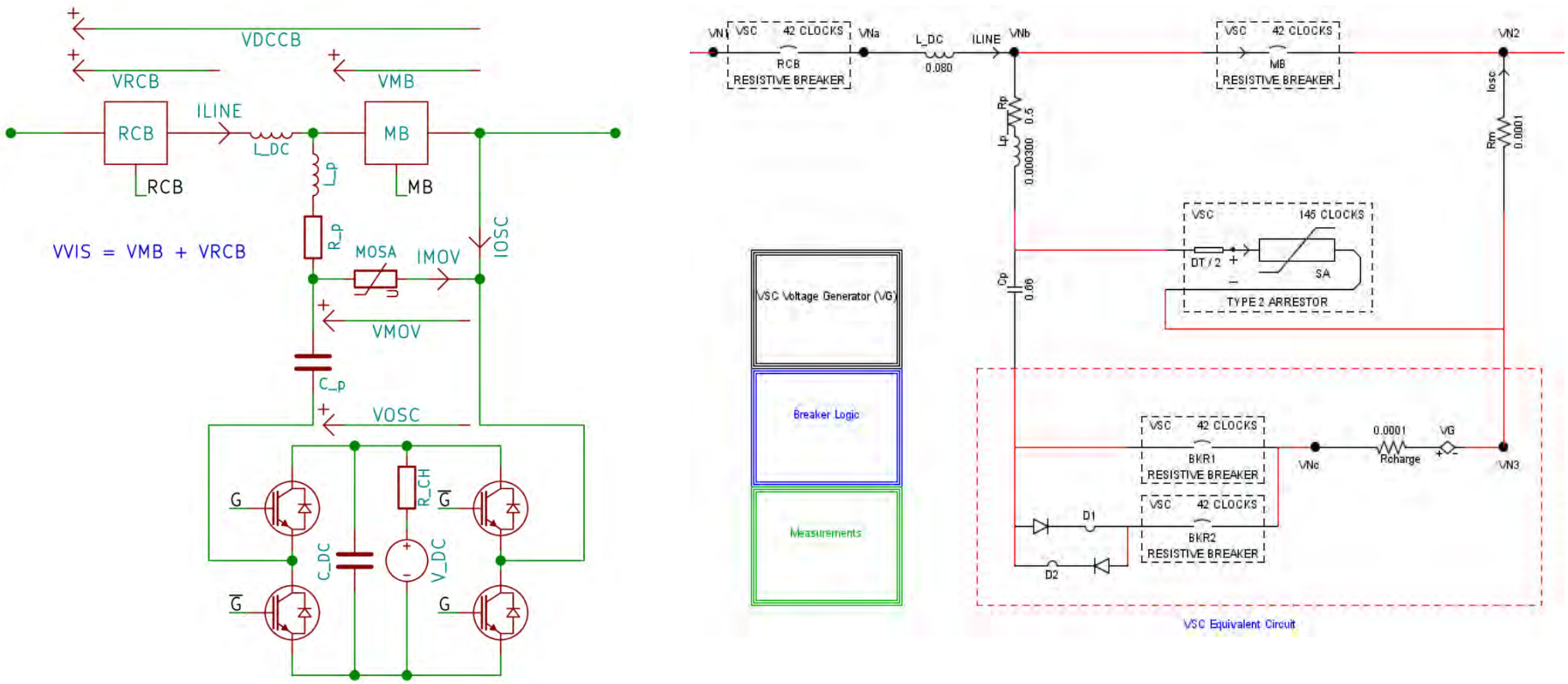


Figure 12. VARC DC CB schematic and RTDS model.

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4) Task 6.8 VARC DC CB Grid intergation and scaling to high voltage

1. Detailed Simulation of VARC DC CB including RTDS modelling

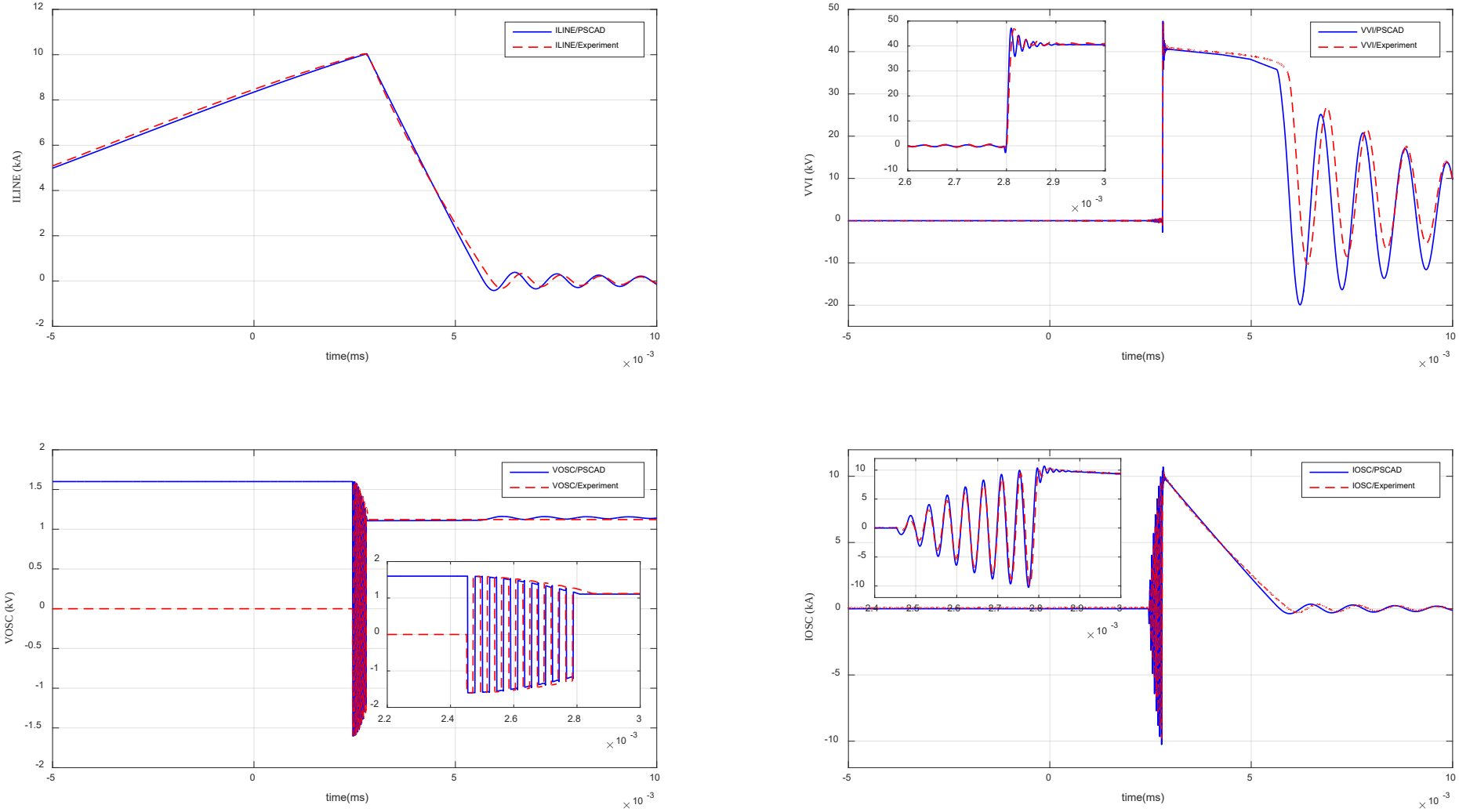

Figure 13. Verification of PSCAD model using experimental results.

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

4) Task 6.8 VARC DC CB Grid intergation and scaling to high voltage

1. Detailed Simulation of VARC DC CB including RTDS modelling

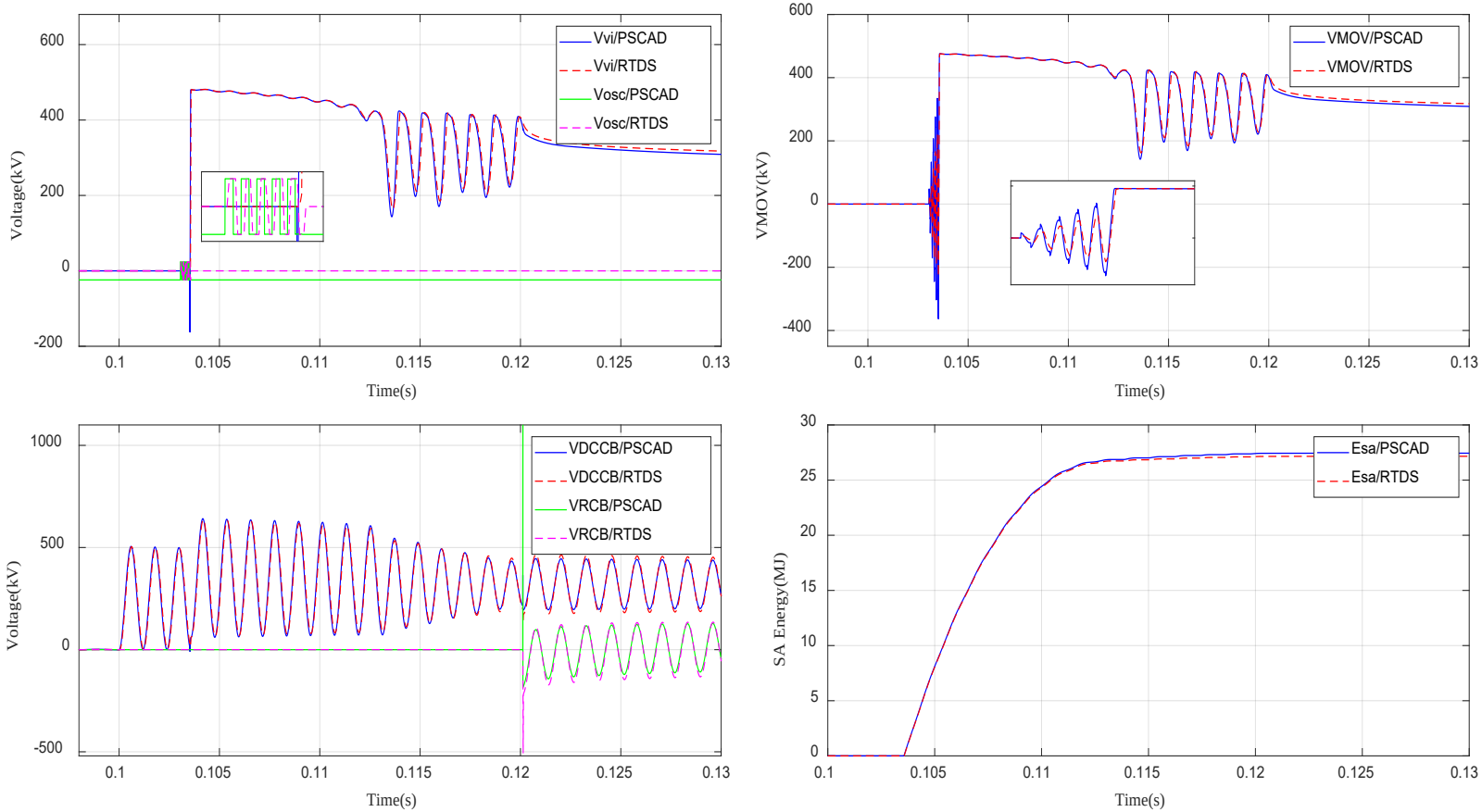

Figure 14. Verification of RTDS model.

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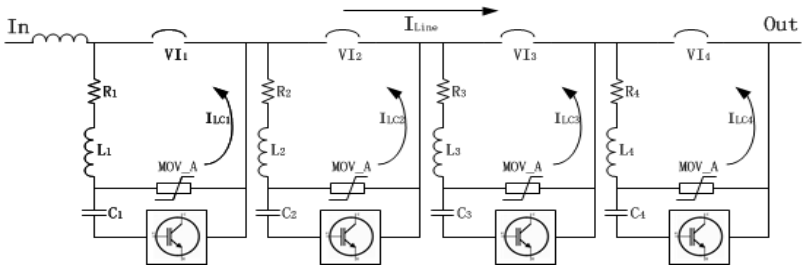
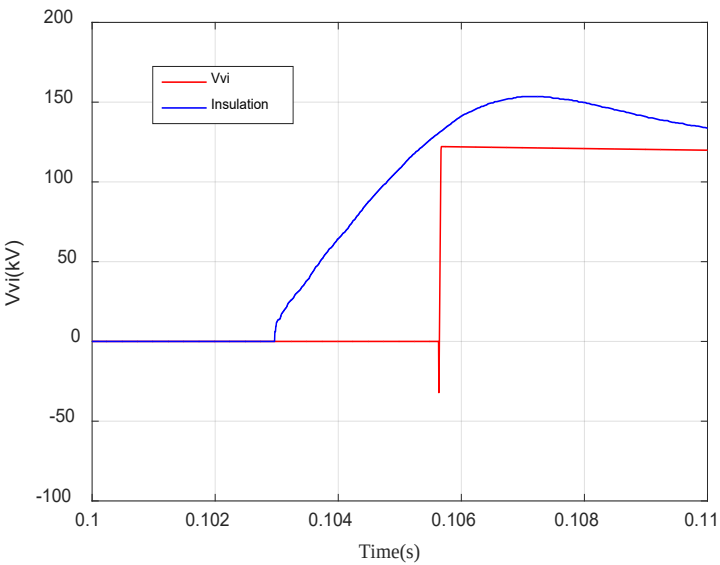
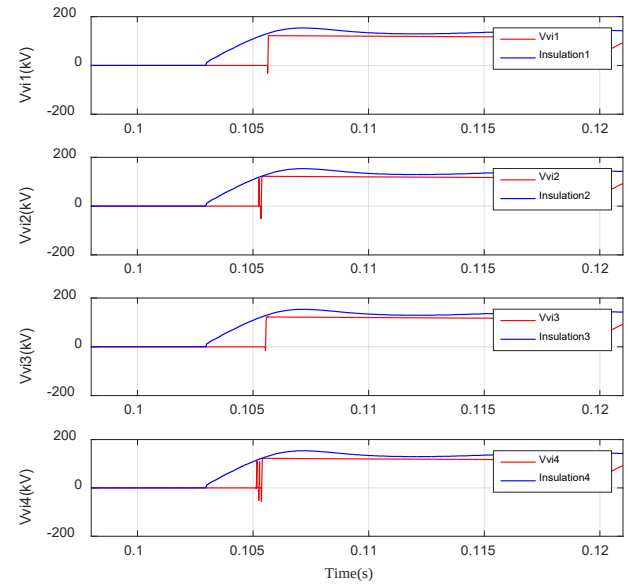
4) Task 6.8 VARC DC CB Grid intergation and scaling to high voltage

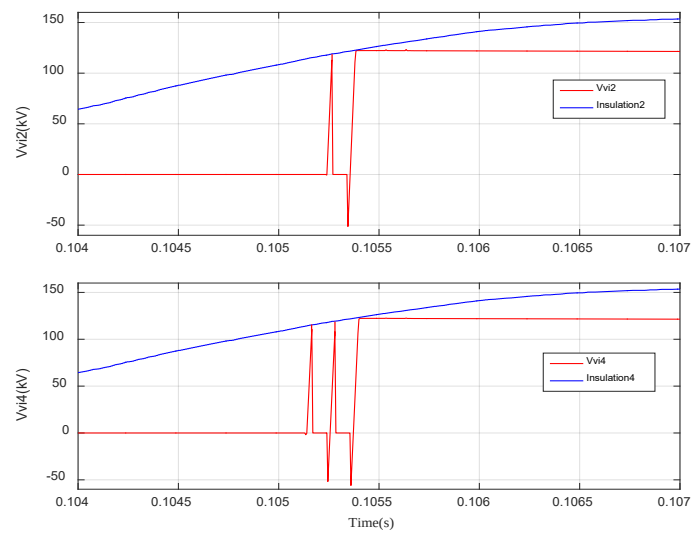
Stress study for HV scaling





a) Successful interruption





b) Failed interruption because of early injection

Figure 15. VARC DC CB insulation strength modelling.

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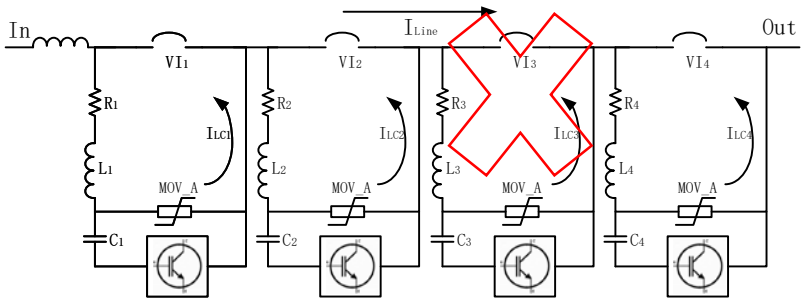
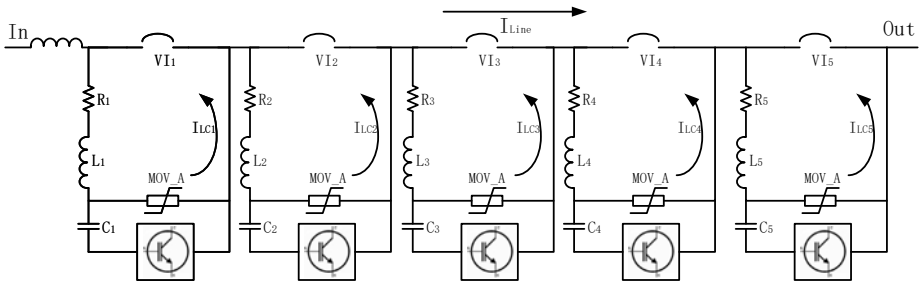
4) Task 6.8 VARC DC CB Grid intergation and scaling to high voltage

Series connection of units

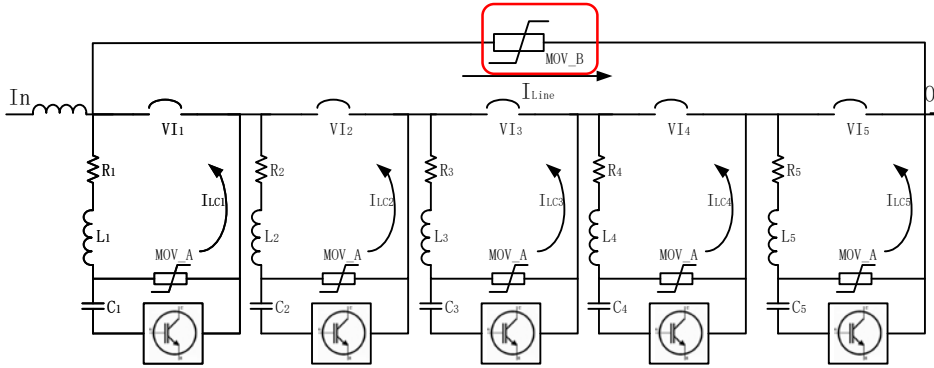
4 modules in series



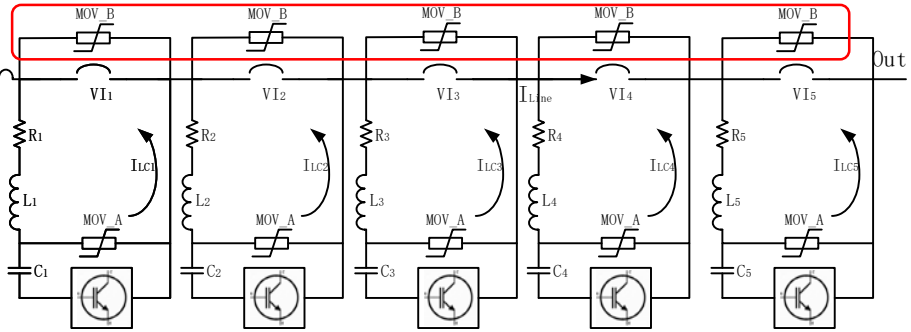
5 modules (with 1 redundant module) in series



An extra surge arrester connected in parallel with 5 modules



Extra surge arresters connected in parallel with each modules



Additional SAs

Figure 16. VARC scaling to HV using series connection of modules.

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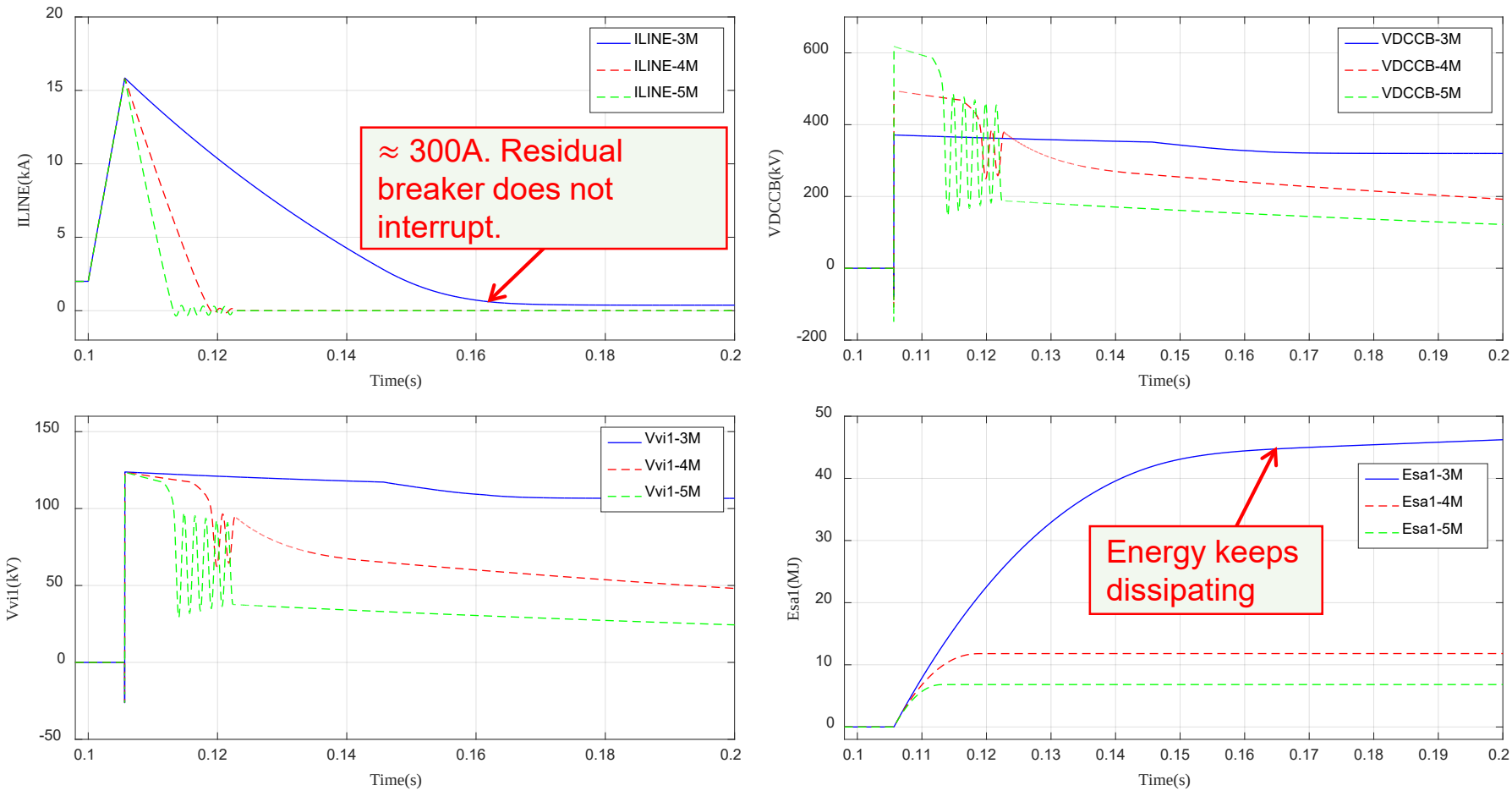
4) Task 6.8 VARC DC CB Grid intergation and scaling to high voltage

Series connection of units



CB cannot interrupt the fault with 3 modules

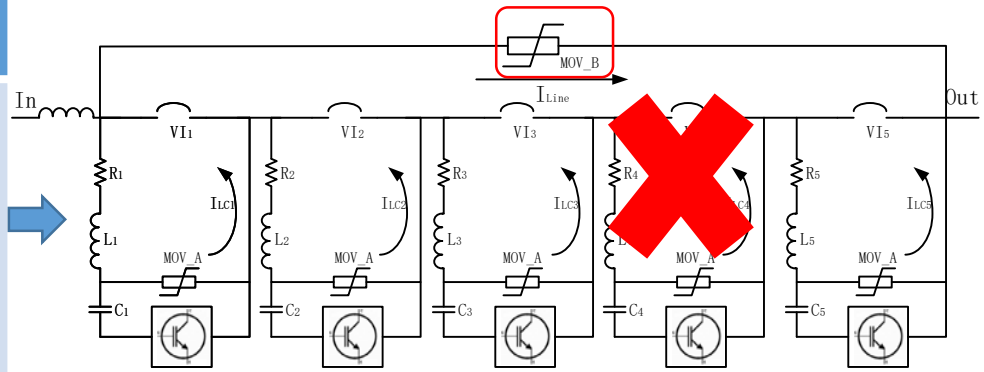
Figure 17. Comparison of VARC DC CB with 3,4, and 5 modules.

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

4) Task 6.8 VARC DC CB Grid intergation and scaling to high voltage

Series connection of units

Advantage	Disadvantage
• If all modules work well, the external SA will dissipate all energy. In this case, the design of SAs inside the module is not affected by the energy. • If one module fails to operate, the external SA will dissipate the energy with the SAs inside the module.	Additional SAs;
• Possible issues from the SA capacitance inside the breaker module can be mitigated. • If one SA fails to operate, the other SAs can still dissipate the energy.	Additional SAs; If one module fails to operate, the corresponding parallel SA may fail as well, the other four external SAs need to withstand more voltage than expected



The equivalent clamping voltage across the DC CB is set to $1.5 \cdot 320$ kV

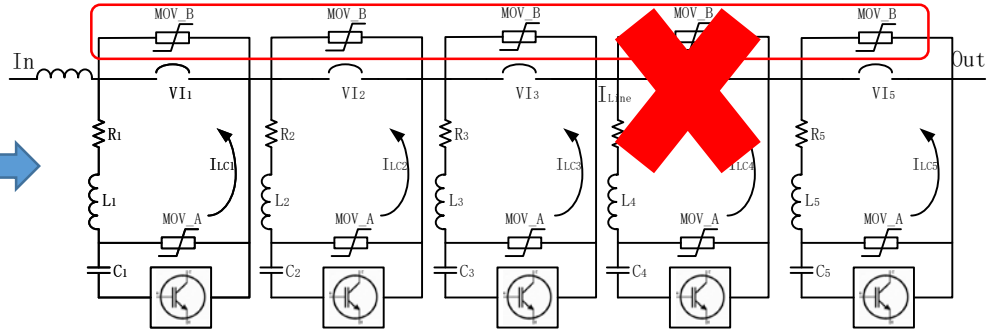


Figure 18. Comparison of options for location of additional arresters.

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5) Task 6.10 Mechanical DC CB Grid intergation and scaling to high voltage

1) Study of scaling DC CB to EHV (ongoing)
2) Analysis of DC grid integration of mechanical DC CB, (just started)
3) Verification of system level model, (not started)

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

1) Study of scaling DC CB to EHV

Topology 1

- This configuration uses a common current injection circuit.
- A number of series-connected interrupter units are used to withstand the required voltage imposed by the MOSA.
- Voltage grading networks are required to ensure distribution of voltage stress across the interrupters during static and transient conditions.

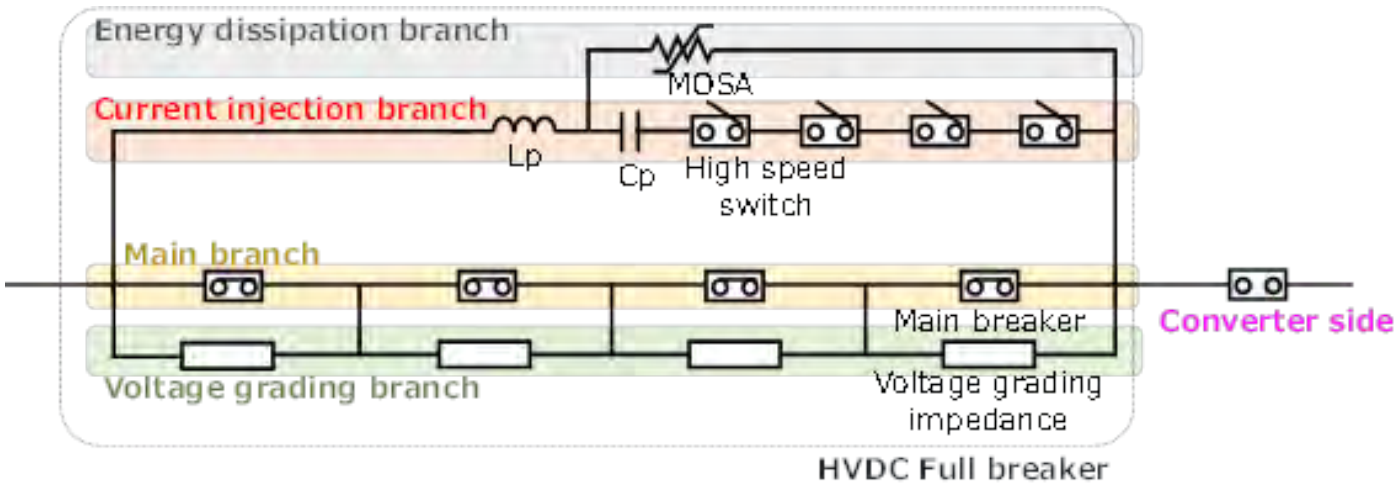

Figure 19. Mechanical DC CB for 320kV. Topology 1.

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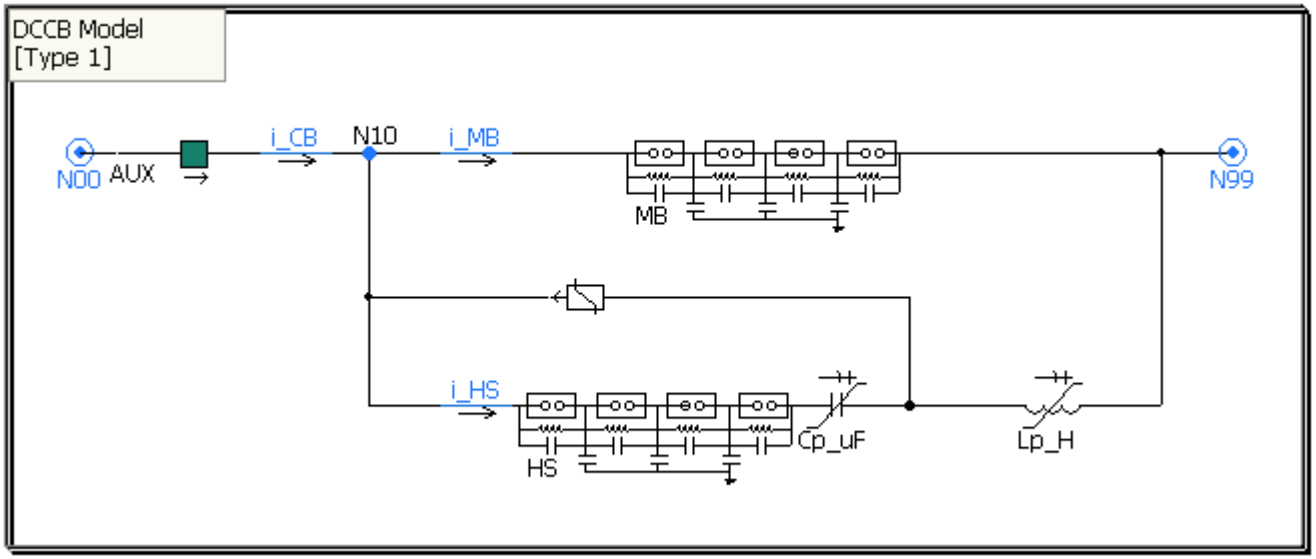
1) Study of scaling DC CB to EHV
Topology 1



Individual control over interrupter operation time is possible

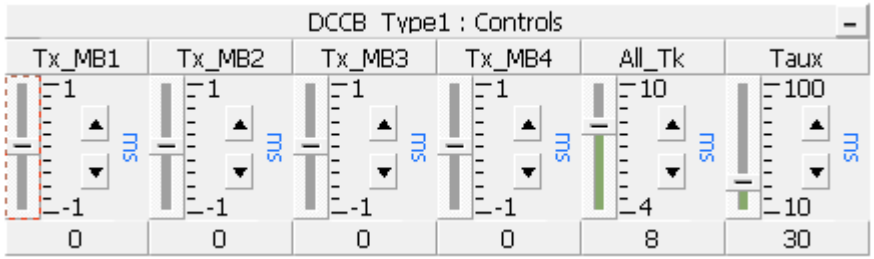


Figure 20. Model of mechanical DC CB for 320kV. Topology 1.

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

1) Study of scaling DC CB to EHV
Topology 2

- This configuration circuit series connected modules
- Each module contains the key elements of an individual DC breaker: current injection circuit and MOSA;
- Modules are connected in series to generate the required counter-voltage to interrupt fault current

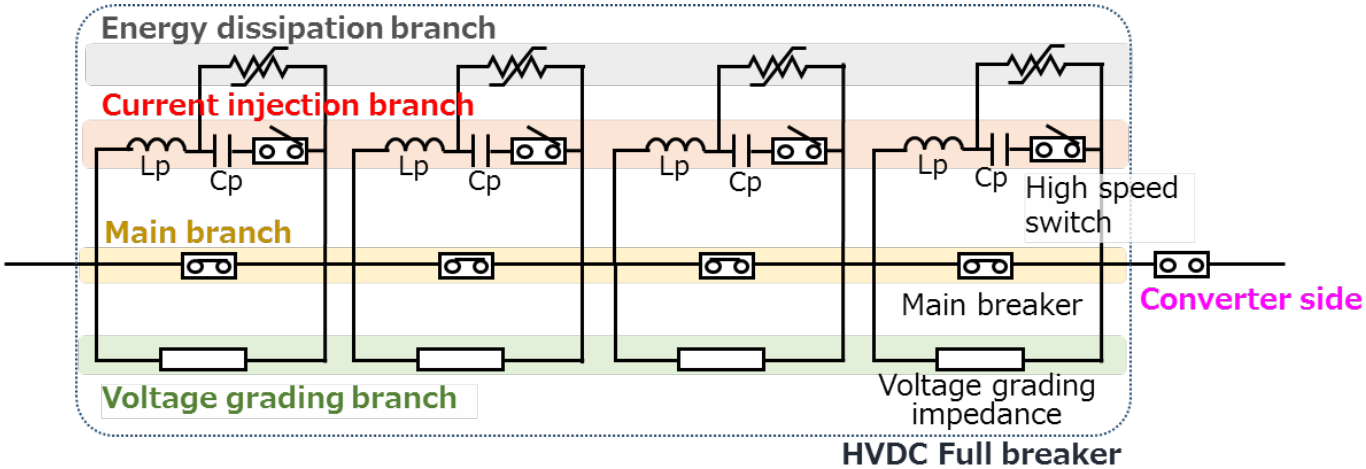


Figure 21. Mechanical DC CB for 320kV. Topology 2.

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1) Study of scaling DC CB to EHV
Topology 2

The multi-break DCCB PSCAD component contains all electrical elements and control blocks

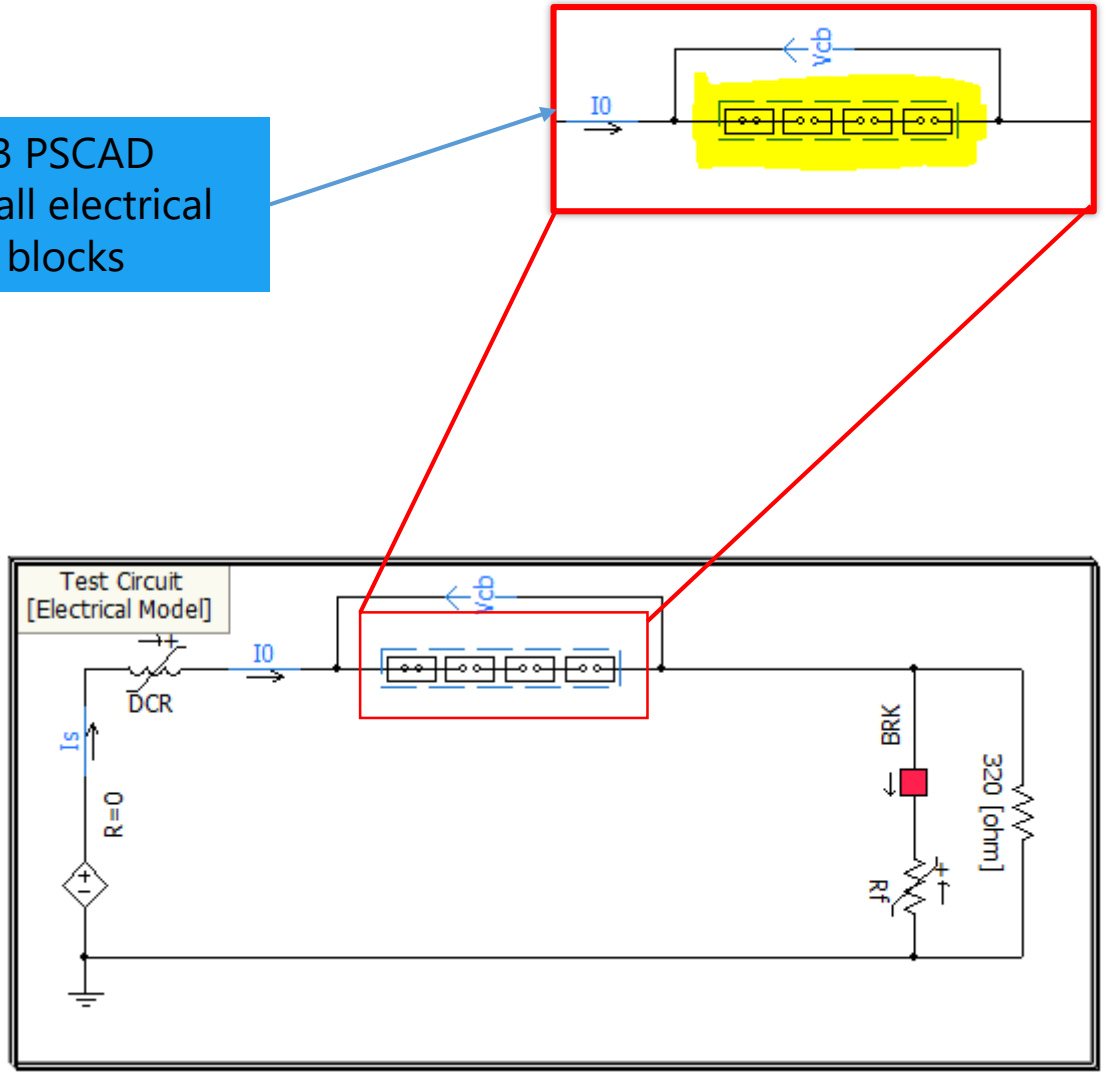

Figure 22. Model of mechanical DC CB for 320kV. Topology 2.

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

1) Study of scaling DC CB to EHV

Item	Topology #1: Common Current Injection Circuit	Topology #2: Module Topology
Impact of mechanical switch operation variation	Small	Large
Grading unit for high speed switch	Necessary	Unnecessary
Design flexibility for higher voltage levels	Less flexible	More flexible
Capacitor charging sequence	Simple	Complicated

Items regarding electric circuit phenomena
➔ Reflected in the models

Items regarding operation

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

Conclusions

1. T6.5, T6.6 900V Demonstrator DC CB development and failure mode study
   a. 320kV UFD
   b. Hybrid DC CB failure mode study
   c. 900V UFD
   d. 900V mechanical DC CB ,
2. T6.7 Hybrid DC CB grid integration and scaling
   a. DC grid integration of hybrid DCCB
   b. Pre-standardisation of DC CB inputs and outputs (with WP4)
3. T6.8 VARC DC CB grid integration and scaling
   a. Detailed Simulation of VARC DC CB including RTDS modelling
   b.Stress study for HV scaling
   c.Series connection of units
   d.Energy absorber thermal modelling and model verification (with WP10)
4. T6.10 Mechanical DC CB grid integration and scaling
   a. Study of scaling DC CB to EHV

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

WP7
Regulation and Financing of a meshed offshore grid in the North Sea

Plenary Meeting | 10 December 2018 | Lyon

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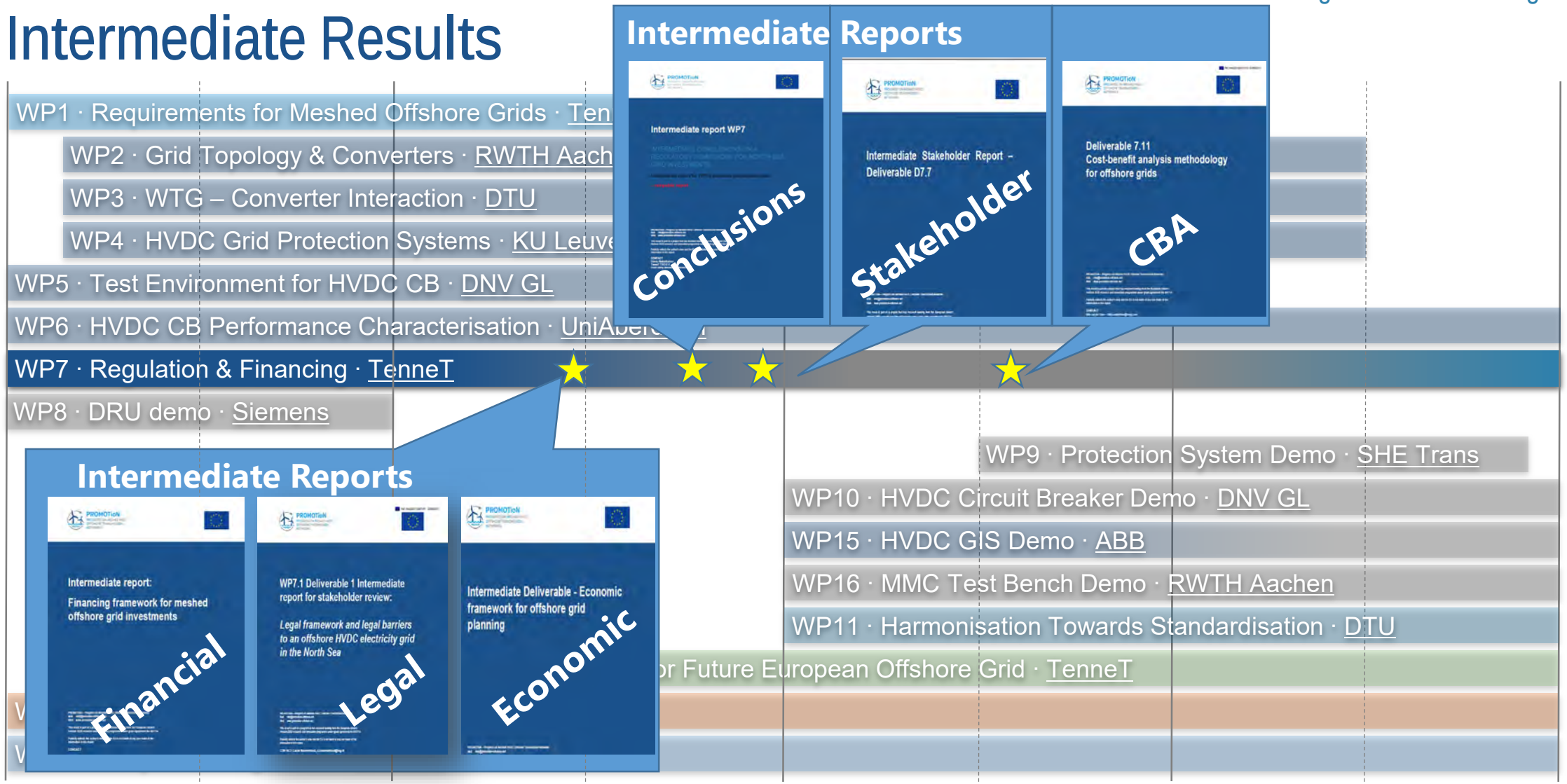
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Intermediate Results



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

Outlook

today

Remaining project timeline

WP1 · Requirements for
WP2 · Grid Topolo
WP3 · WTG – Con
WP4 · HVDC Grid
WP5 · Test Environmen
WP6 · HVDC CB Perfor
WP7 · Regulation & Fina
WP8 · DRU demo · Siemens
WP9 · Protection System Dem ns
WP10 · H
WP15 · H
WP16 · M
WP11 · Ha
WP12 · Deployment Plan for Futu uropean Of
WP13 · Dissemination · SOW
WP14 · Project Management · DNV GL

2016 2017 2018

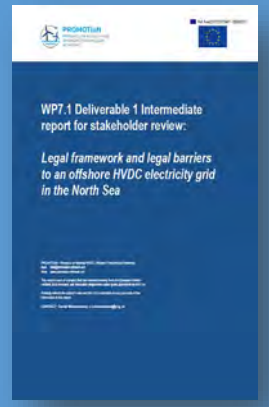
April 2019

Development of legal framework

Development of economic framework

Development of financial framework

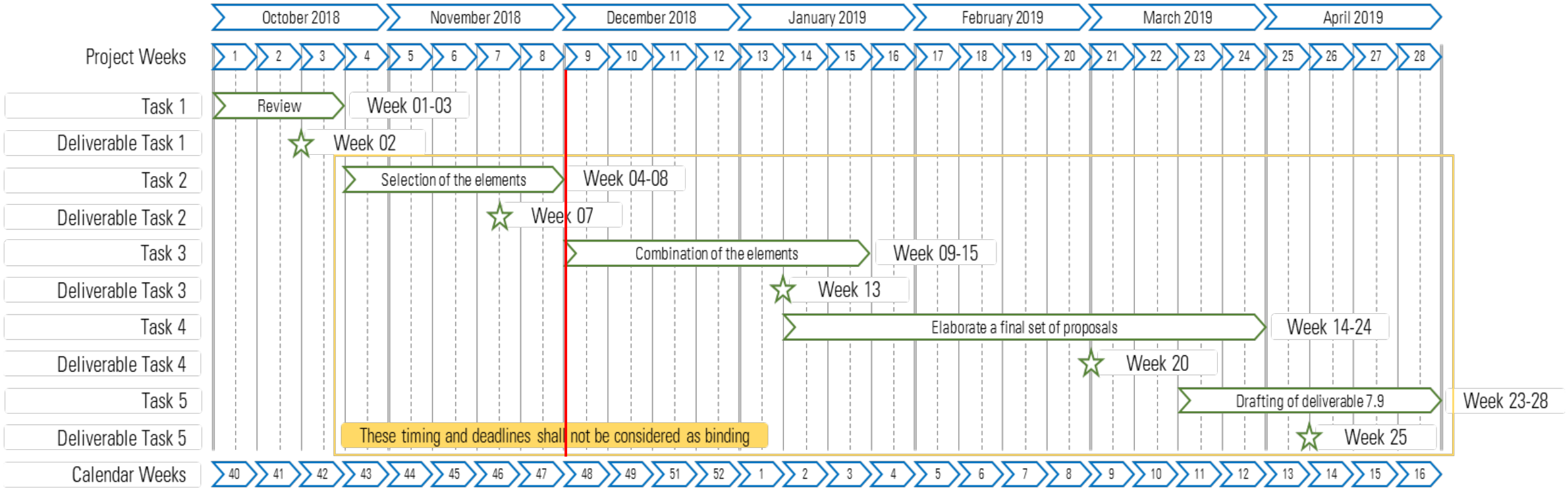
June 2019



Policy recommendations

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

Work Package planning until April 2019



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Set of aspects, covering parts of the financial and regulatory framework

- ✓ Cross-border offshore grid ownership
- ✓ Cross-border offshore grid operation
- ✓ Remuneration of hybrid assets
- ✓ Grid connection costs (treatment of generation v load)
- ✓ Grid connection costs (super-shallow, shallow, deep)
- ✓ Priority dispatch
- ✓ Cross-border cost allocation method
- ✓ Locational planning of offshore wind farms
- ✓ Renewable energy supplies (RES) support schemes cooperation

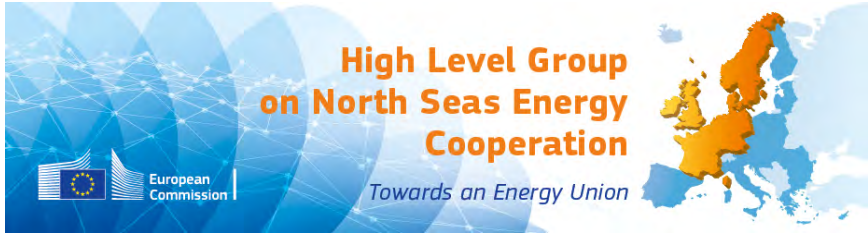
Important elements have to be brought in the picture of WP7

- ❖ The adherence to the ENTSO-E technical regulation (network codes) about market access across all time frameworks (as indicated at least in FCA NC, CACM NC and EB NC)
- ❖ The regulatory governance: who should be the overarching regulatory
- ❖ Risk analysis and development of financial framework
- ❖ Offshore grid operations / balancing
- ❖ Legal classification of hybrid assets and support schemes for OWF
- ❖ Licensing & permitting and decommissioning
- ❖ Bidding zone design

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

Stakeholder Involvement

26 November 2018, Brussels



Presentation of and discussion with the North Seas Energy Cooperation Support Group 2

- *General introduction on work package 7: regulatory issues*
- *Balancing mechanisms*
- *Possible ownership and system operation governance models*
- *Barriers identified by Roland Berger*

27 November 2018, Brussels

Working session on regulatory aspects with ministries, NRAs, developers, TSOs, wind associations

- *Who should regulate a MOG? The regulatory governance structure*
- *Who should own and operate a MOG?*
- *The role and design of support schemes in a MOG*

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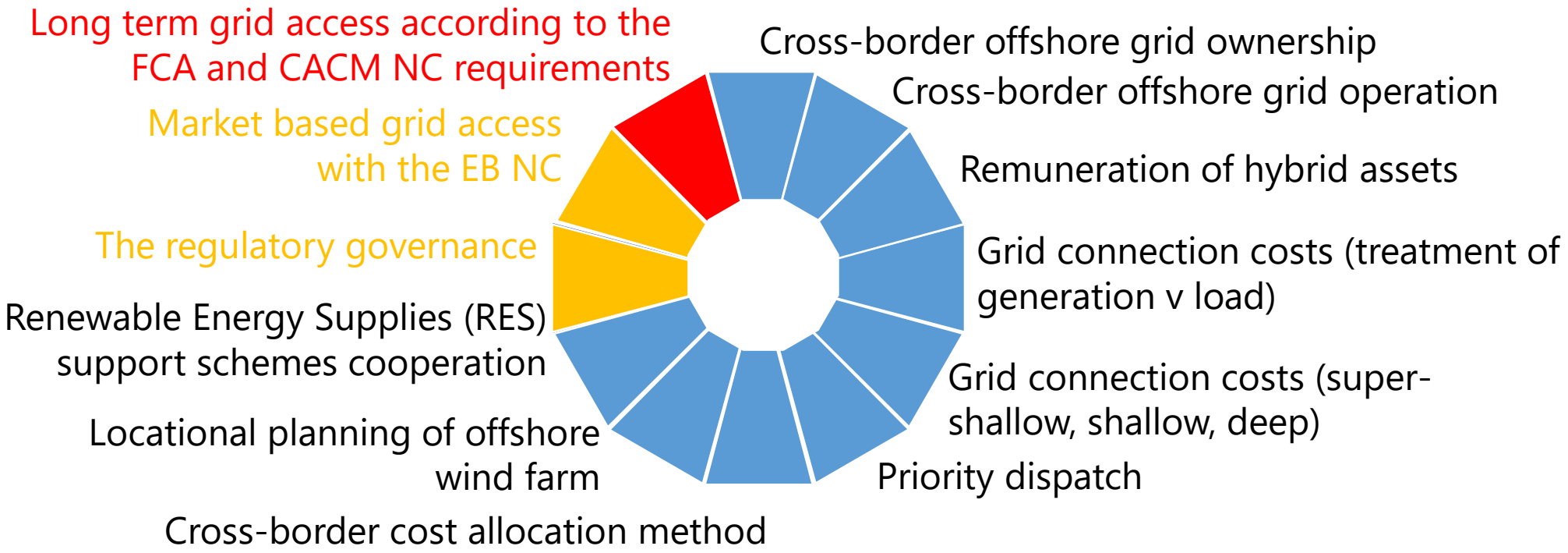
Our way towards a comprehensive framework



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Next step: compile all options derived from the different tasks

- Examples:
  - Parameter: Cross-border offshore grid ownership
    - Options:
      - Model A: North Seas grid (NSG) transmission system operator (TSO)
      - Model B: Cooperation of national TSOs (from continental Europe) and offshore transmission owners (OFTOs) (in the UK)
      - Model C: Third parties (tendered before construction)
      - Model D: NSG TSO builds, then tenders ownership to third parties
      - Model E: National TSOs build, then tender ownership to third parties work)
  - Parameter: Remuneration of hybrid assets
    - Options:
      - Only regulated income
      - Regulated income plus congestion rents
      - Congestion rents only
- Need to consider the full list for legal, economic, and financial frameworks – and in particular identify options from different parameters which need to be selected in combination

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

Next step: identify the criteria to review the different options

- Our criteria should include all characteristics of the legal, economic, and financial frameworks for a MOG that are important to the Commission (**collectively exhaustive**). These could include:
  - Least cost for a given outcome (e.g. energy delivered via offshore wind in Europe by 2050).
  - Simplest/fastest/least disruptive to implement.
  - Lowest risk/most stable/predictable regime to minimise uncertainty and the cost of capital.
  - Most socially and politically acceptable, to maximise North Seas countries' buy in.
  - Most likely to facilitate provision of private capital, given investment needs.
  - Technically feasible/easy to implement.

- Ideally **mutually exclusive** so we're not counting the same thing twice in different criteria e.g. there is a conceptual overlap between 'least risky' and 'most likely to facilitate provision of private capital'.
- Has to **show differences** between options – i.e. criterion is not useful if all options score the same.
- Ideally **the same criteria** should be applicable across all relevant design parameters whether they are legal, economic, or financial.
- We want the **minimum number of criteria** consistent with the above.

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Criteria used so far to draft the tasks reports

1. Economic benefits: The objective is to deliver solutions at least cost and maximum benefit for society.

2. Speed of implementation: How quickly can the MOG be built under the proposed regime? Both the time needed to design and legislate for the regulatory regime/s for each governance model and the consequent impact on the time needed for construction after the regime is in place.

3. Socio-political acceptance: Acceptance by policy-makers at national (countries around the North Sea) and EU-level (European or supranational institutions).

4. Provision of private capital: Facilitation of private capital provision to maximize the chances of raising 100 billion+ € to pay for the MOG

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Final step: compile recommendations to provide a consistent regulatory and financial framework

What should these recommendations look like:

- We agreed to design a final deliverable without hard boundaries, but providing two-three scenarios, whenever possible ranking them in terms of likelihood of possible implementation.
- We must support the definition of options and criteria which account for the existence of solutions with no sharp edges for the regulatory and financing policies: the fast-changing scenario in Europe could determine sudden changes in the macro-economic scenario, crashing any hard-coded plan into pieces

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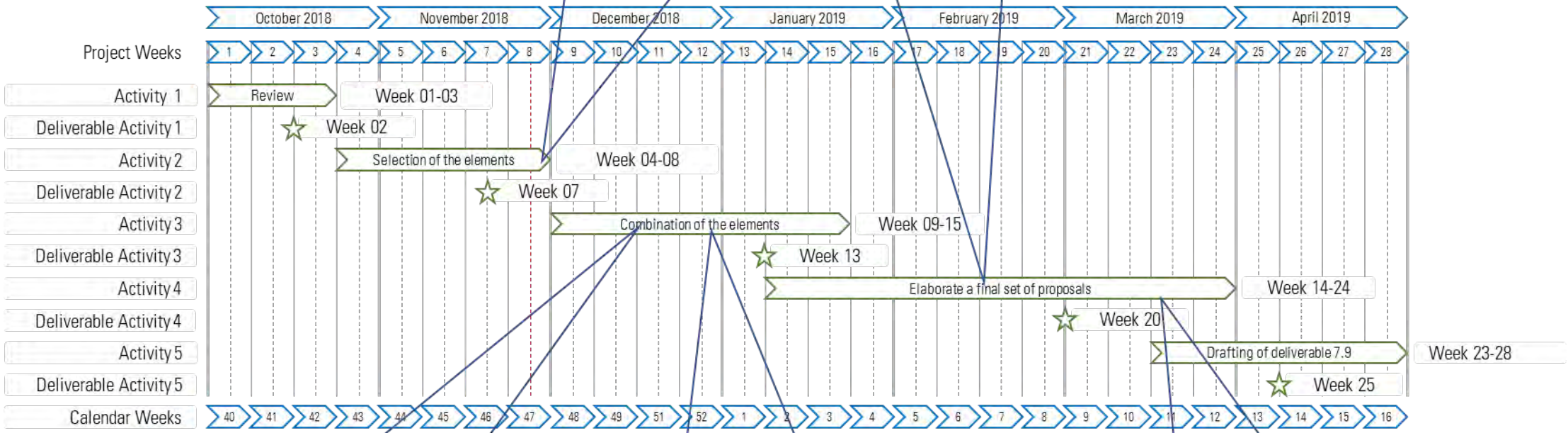
How to get there?

1 Reach a definitive conclusion about the business parameters to be tackled and how to cover them

4 Evaluate all possible inconsistencies and unrealistic combinations of combinations and prepare the scoring



2 Work in the frist part of this activity 3 to assess options for all business parameters and scoring criteria

3 Evaluate the opportunity to extend the task until end of January so to have enough time to iterate the proposal for options and scoring criteria

5 Score the remaining scenarios and prepare the final summary for the drafting of the recommendations

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APPENDIX

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Any Questions?

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PROMOTioN
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WP10

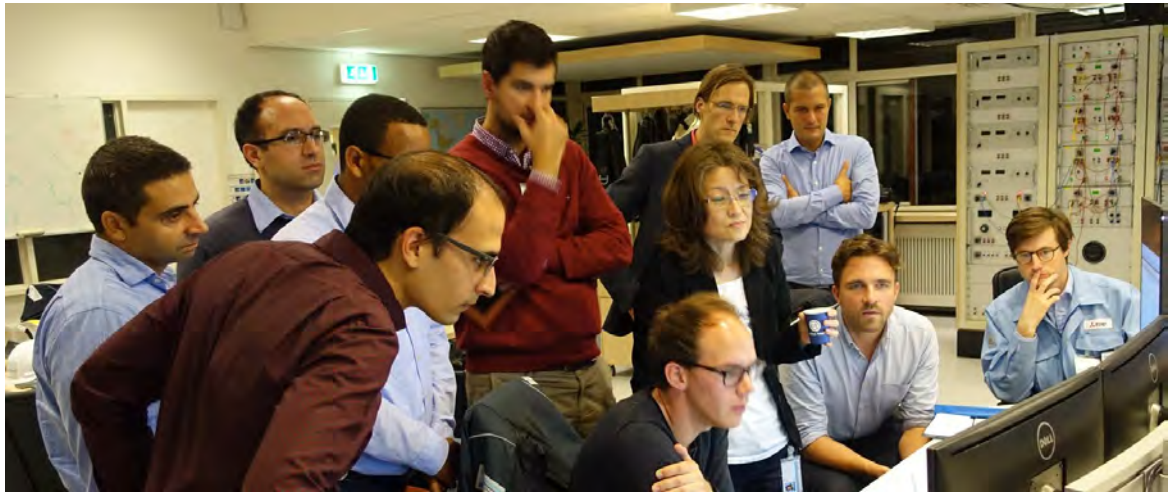
HVDC Circuit Breaker Demonstration

René Smeets / Nadew Belda
DNV GL KEMA Laboratories

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

WP 10

- Demonstration of full-power testing of HV DC circuit breakers
- Started January 2018
- Deliverables under review (M36)
  D10.1: “Testing of prototypes of HVDC circuit-breakers”
  D10.2: ‘’Evaluation of the interaction of CB sub-components with the circuit”
- Three demonstrators scheduled for 2019



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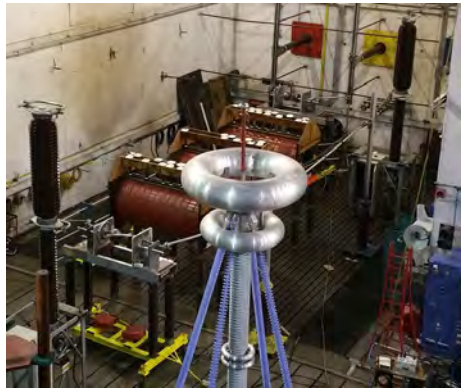
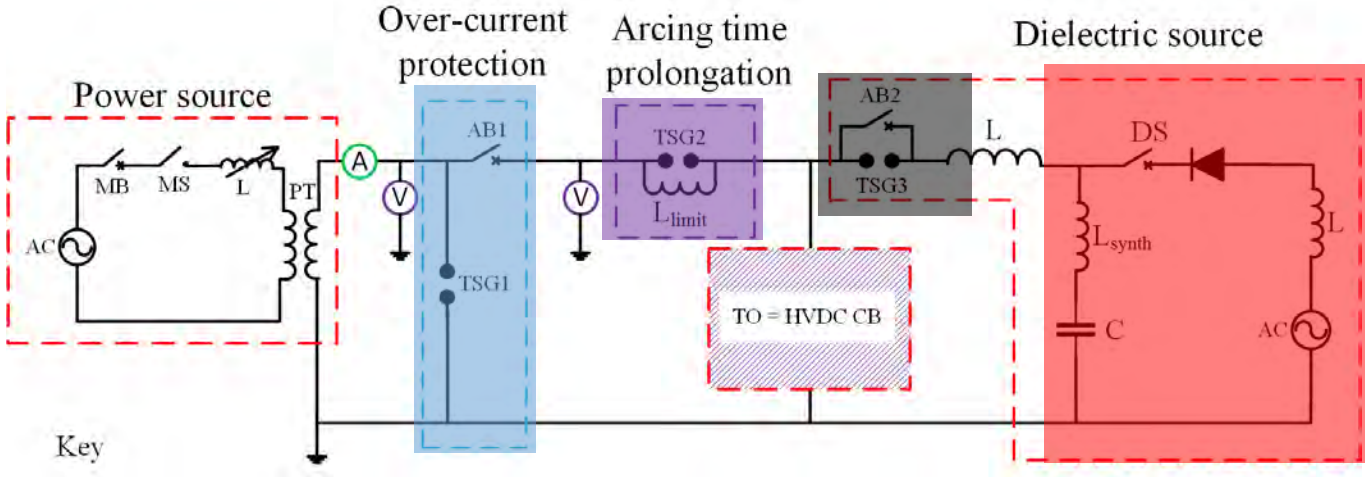
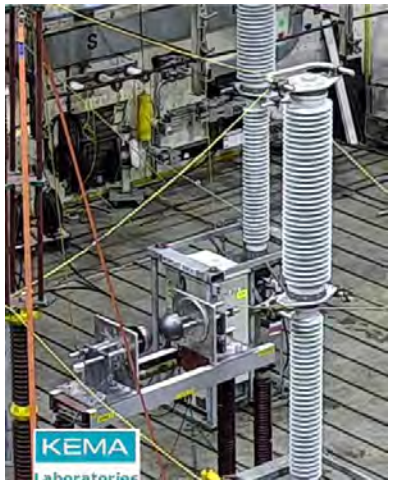
Activities

- WP5: Full-power testing feasible for technologies of project partners
- Over-current protection and application of DC voltage stress requires real-time current monitoring with very fast switching technology (triggered spark gaps)
- Design of an experimental HVDC breaker (current injection type) to evaluate stresses
- Single, double and three-break vacuum gaps
- Design of instrumentation







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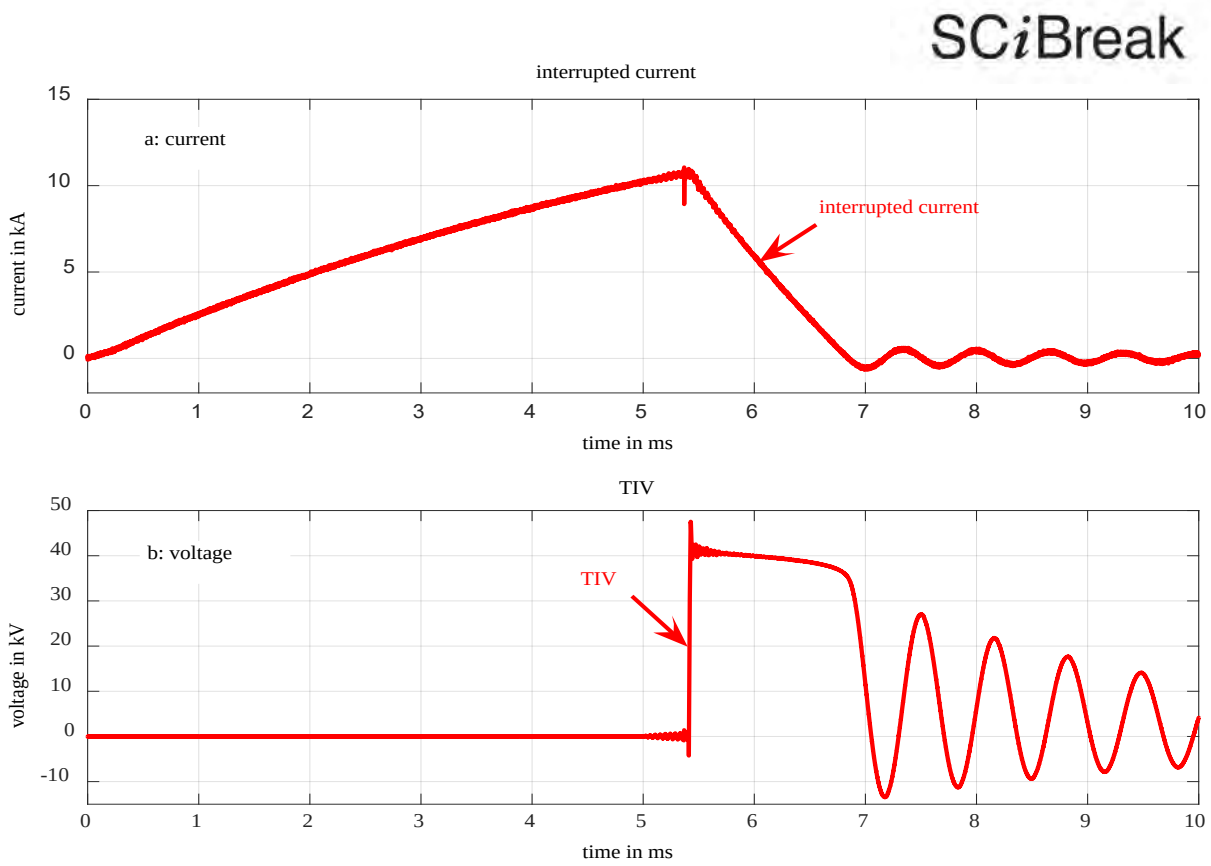
VSC assisted technology

- Demonstration of single module testing of VSC assisted resonant breaker
- In cooperation with SciBreak
- Positive results, 10 kA, 40 kV TIV, 3 ms



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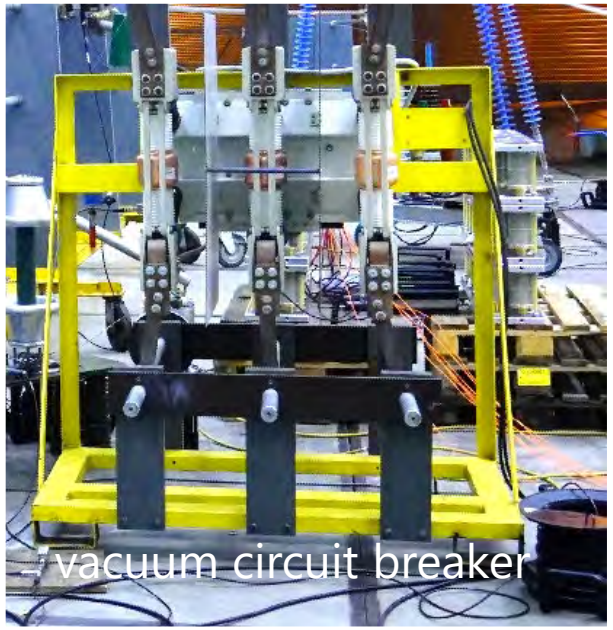
Testing of experimental HVDC breaker



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

Evaluation of HVDC breaker stresses

- Mechanical interrupter, vacuum interrupter
  - High-frequency (> 5 MHz) performance measurements
- Surge arrester for energy absorption
  - multi-channel, high-voltage isolated data acquisition system
  - transient thermal, IR
  - transient electrical

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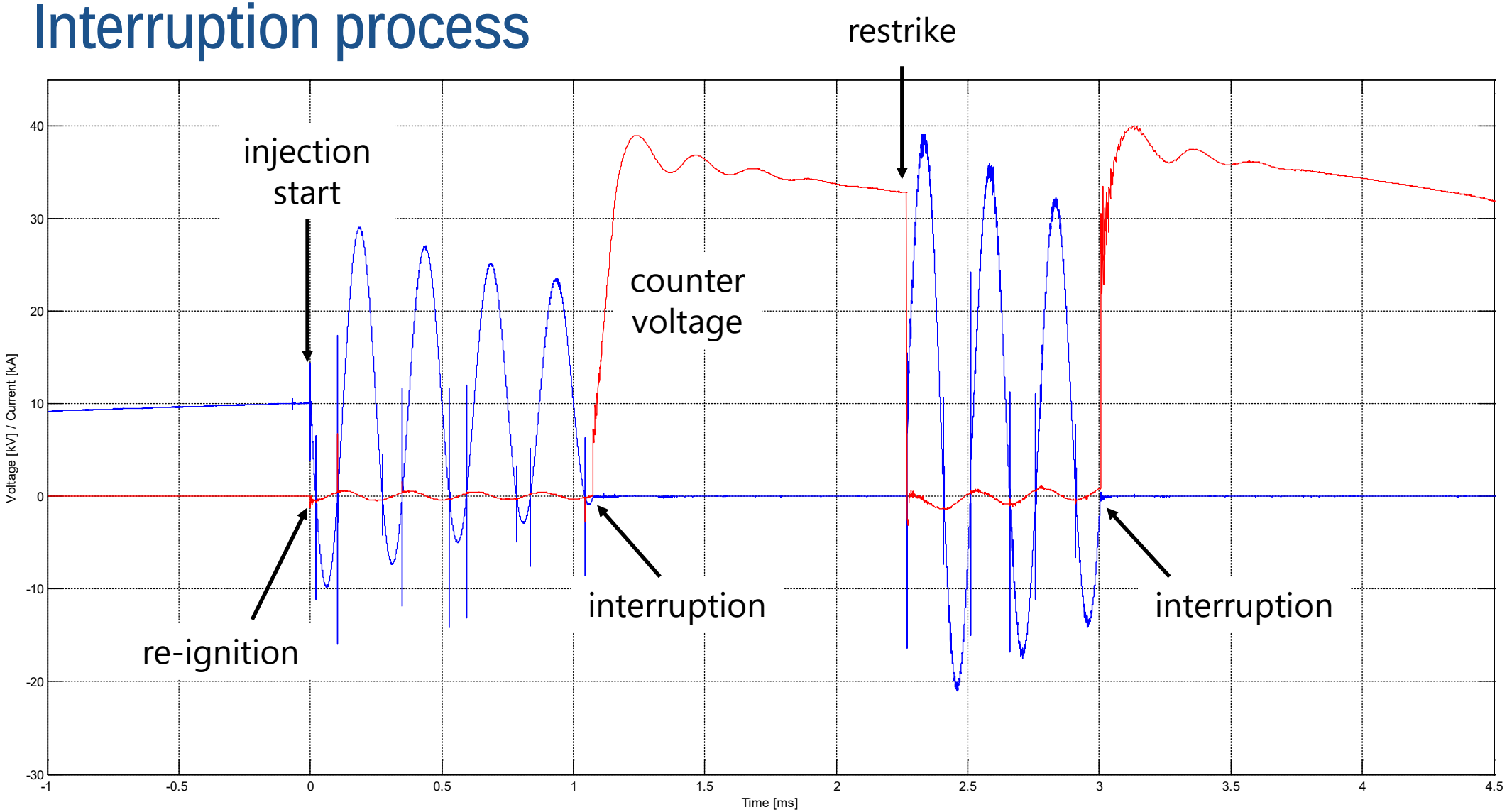
Interruption process



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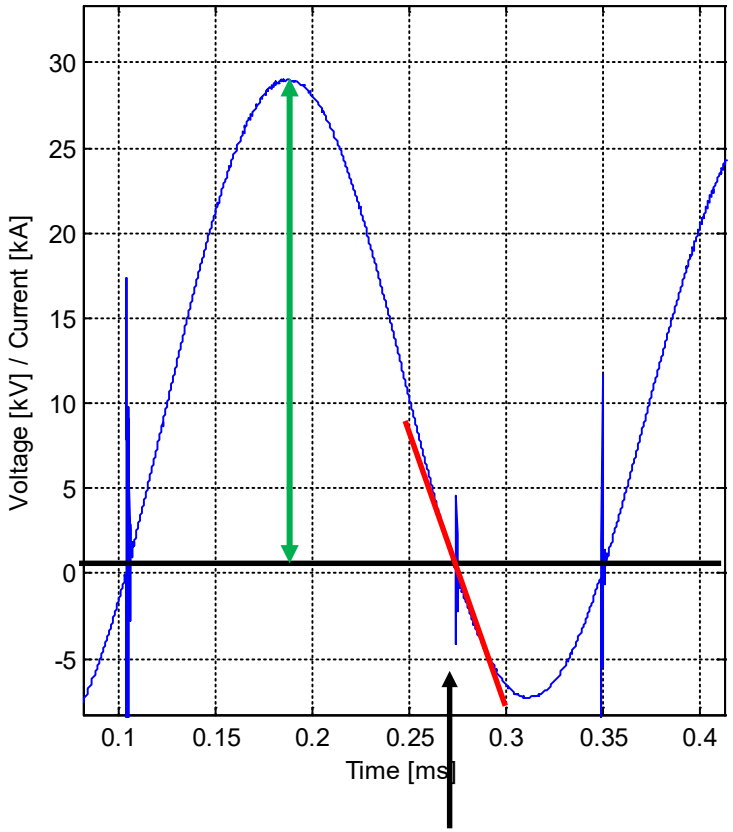
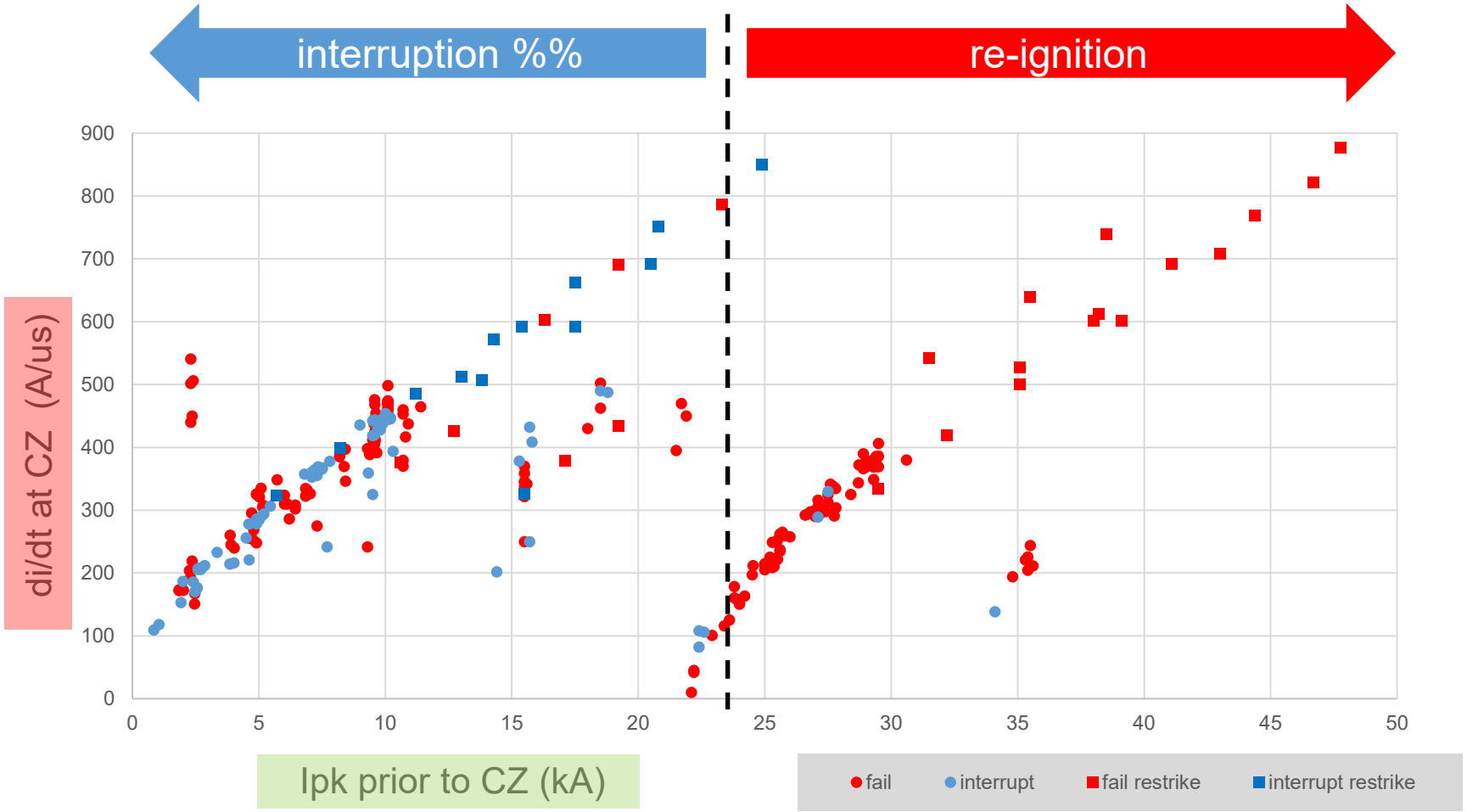
Identifying critical parameters and their relevance



re-ignition



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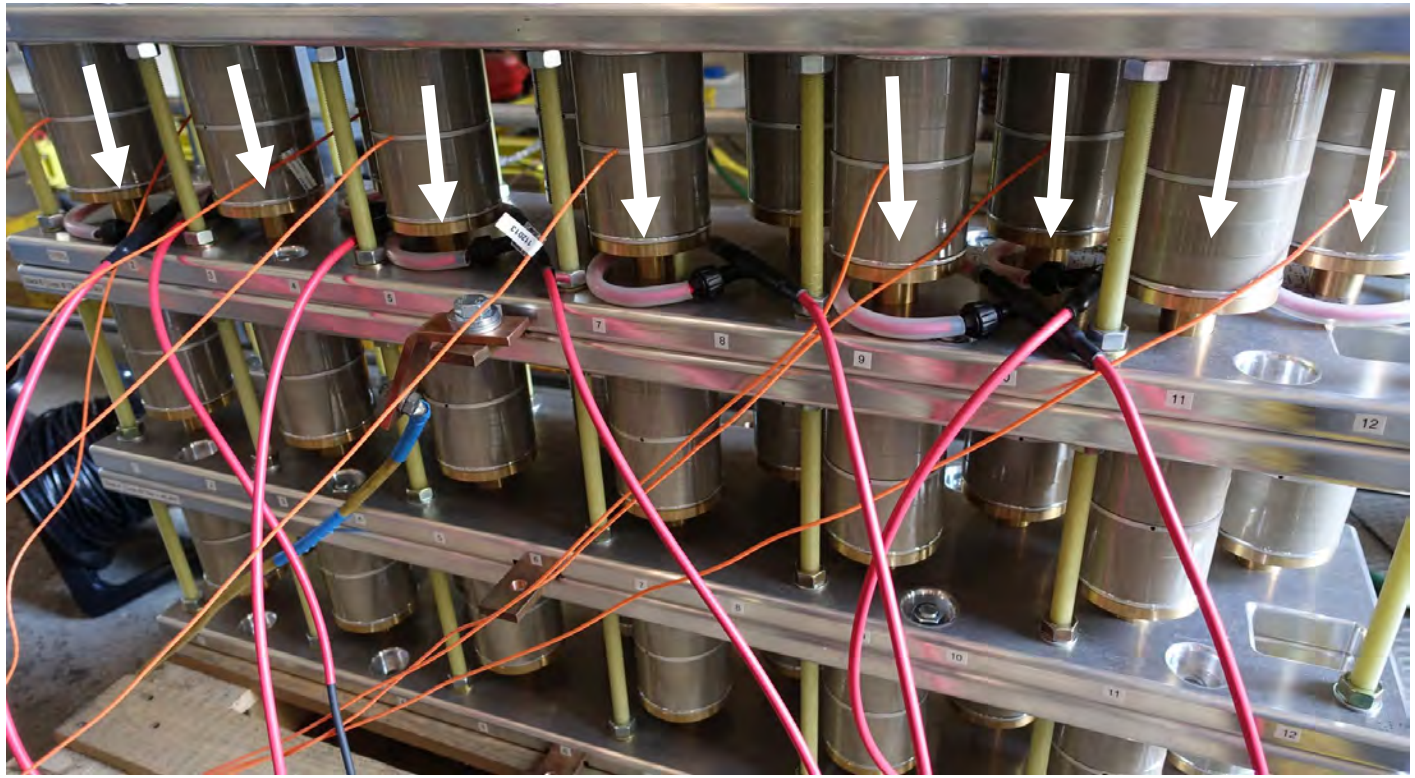
Thermal stresses

- Surge arrester is another critical component
- Current is shared between a number of columns
- Non-linear character of the ZnO needs careful design and application
- Current and temperature is monitored to evaluate stresses during full power testing
- Analysis in progress



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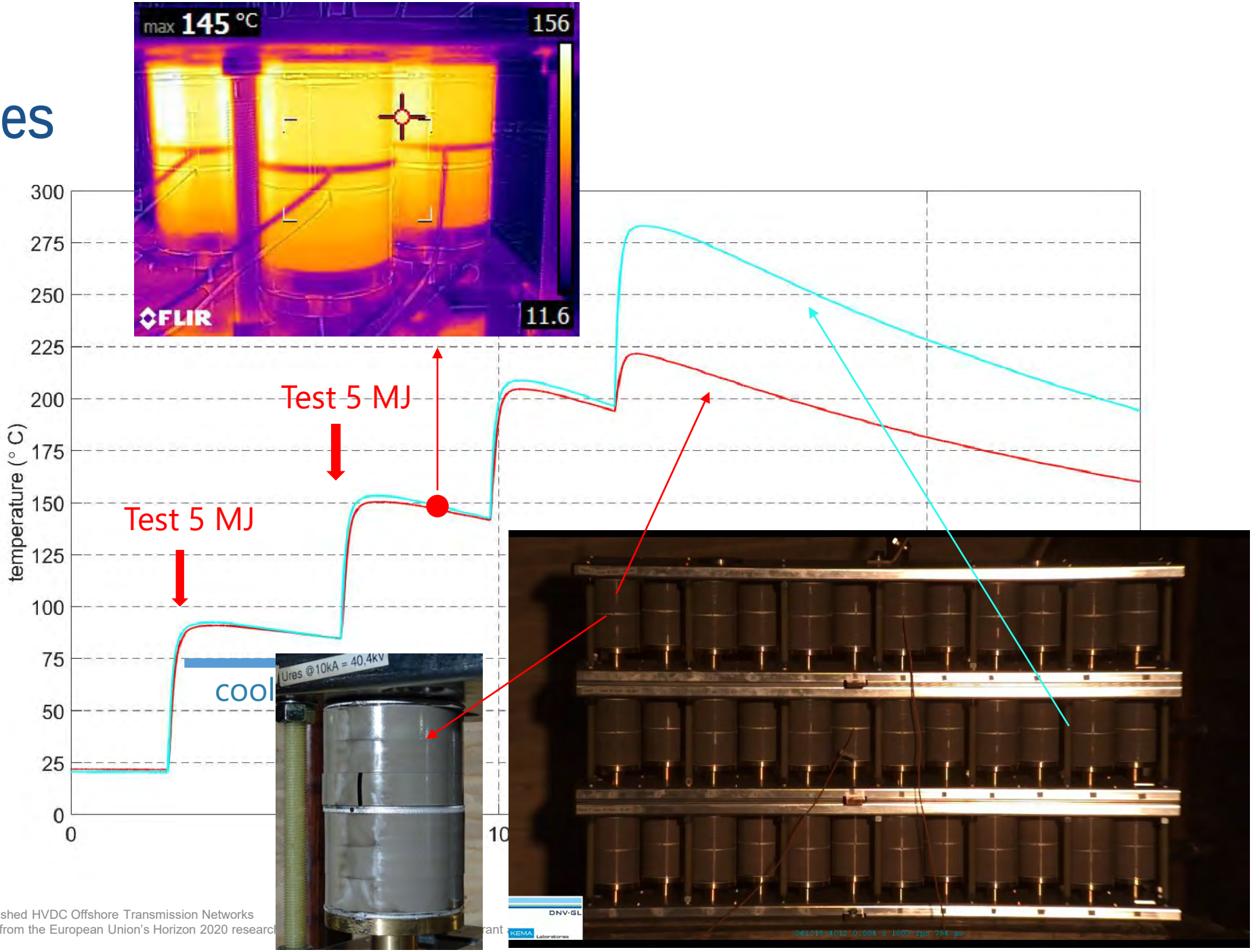
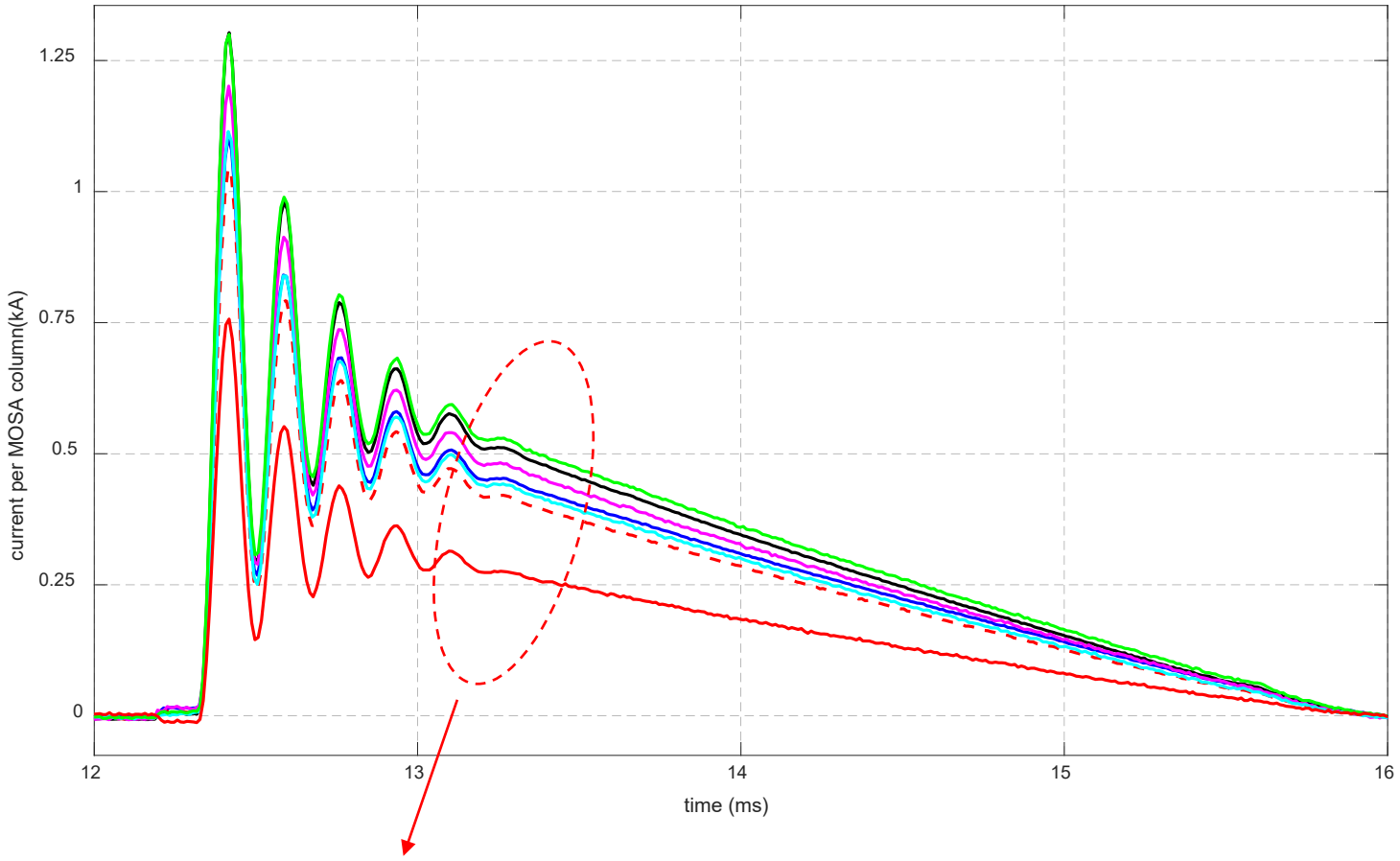
Thermal stresses

- 8 channel measurements with an optical system
- To be used by WP6 to verify thermal model of the energy absorption
- Accumulation of stored energy at repeated operation



Current sharing

- 8 channel measurements with electrically isolated Rogowski coils
- To be used by WP6 to develop thermal model of the energy absorption
- Analysis is ongoing
- D10.3



Current (thermal load) not always shared equally

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Dissemination

- 3rd paper under review IEEE TPD
- CIGRE Paris workshop HVDC breakers 8 presenters,140 participants
- Follow-up CIGRE-IEC Japan WP 5,10,15 tutorials
- PhD thesis in preparation

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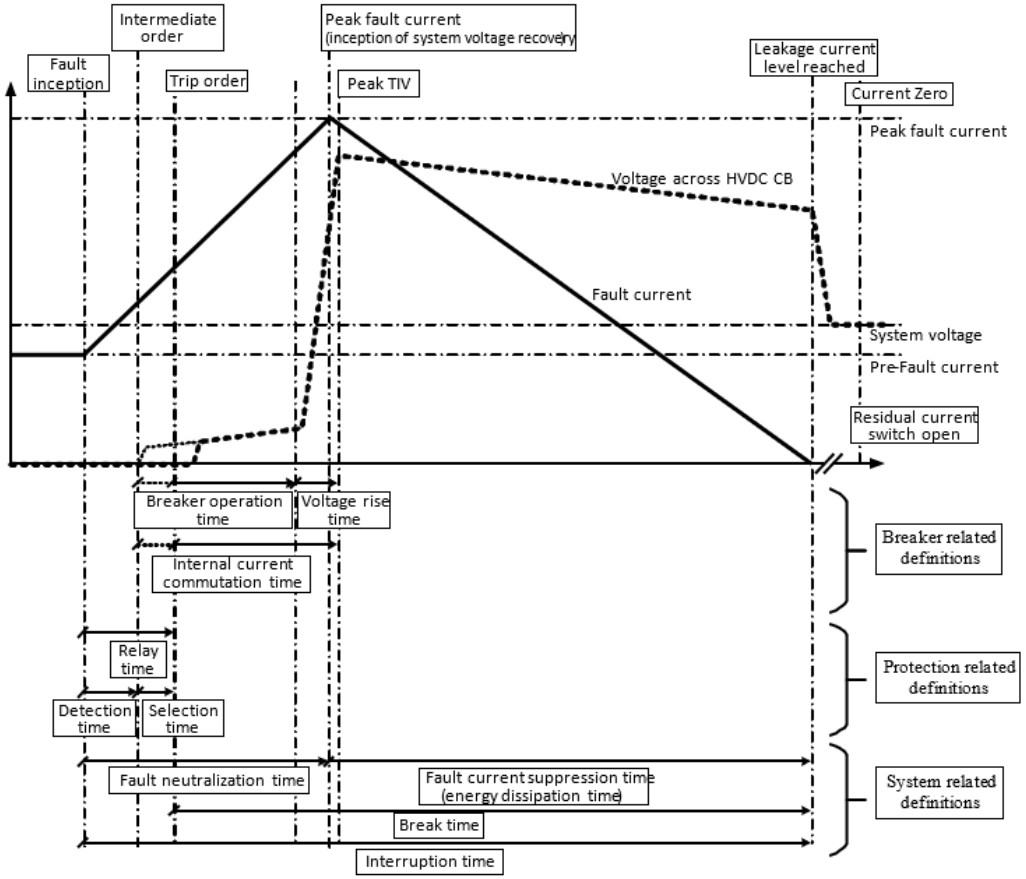
Standardization

- Inventory on the need of standards made in IEC AHG 04, 60
- It summarizes Chinese National Standard NB/T 42107, 2017 on HVDC breakers
- Combines recommendation of CIGRE JWG A3/B4.34 with PROMOTioN experiences Definitions proposed
- Report submitted to IEC TC 17A, Nov. 2018
- IEC TC17A decides to establish 5 working groups on HVDC switchgear:
  - Switchgear (4), incl. circuit breakers
  - Switchgear assemblies (1)
- Reported to ctrl & prot workshop WP11 20181206



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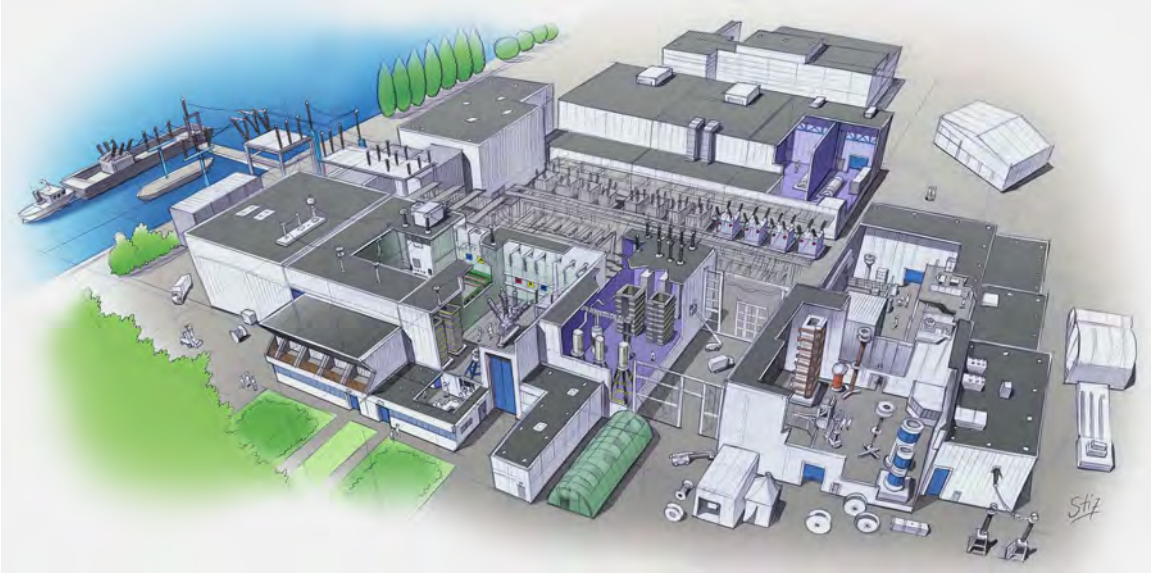
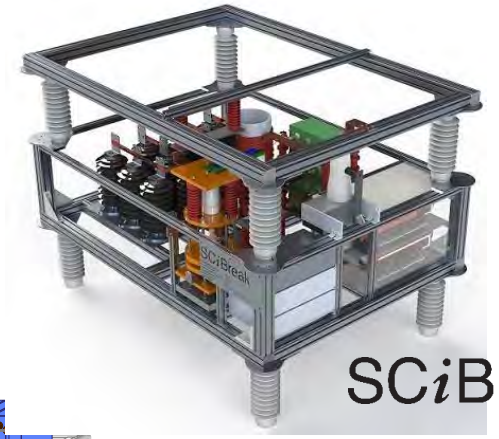
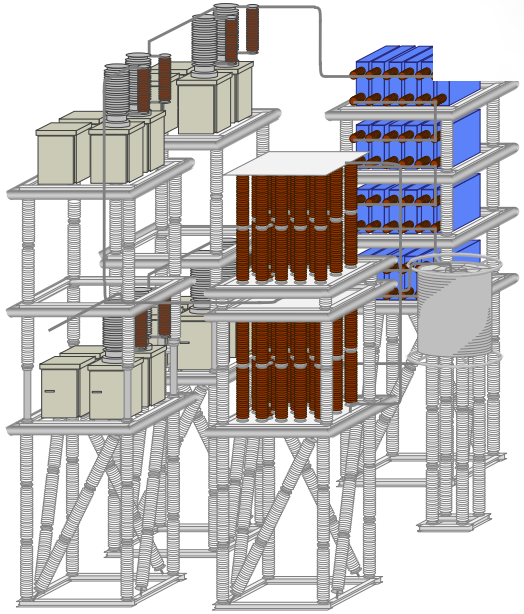
Demonstrators 2019

- Demonstration of testing in 2019:
  - multiple-unit breaker of active current injection type
  - multiple-unit breaker of VSC assisted resonant current type
  - full hybrid type of HVDC circuit breaker
- TRL level 7







MITSUBISHI ELECTRIC
Changes for the Better

ABB

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Any Questions?

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PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

WP11 – Progress report to plenary meeting

06-12-2018, Poul Sørensen, Technical University of Denmark

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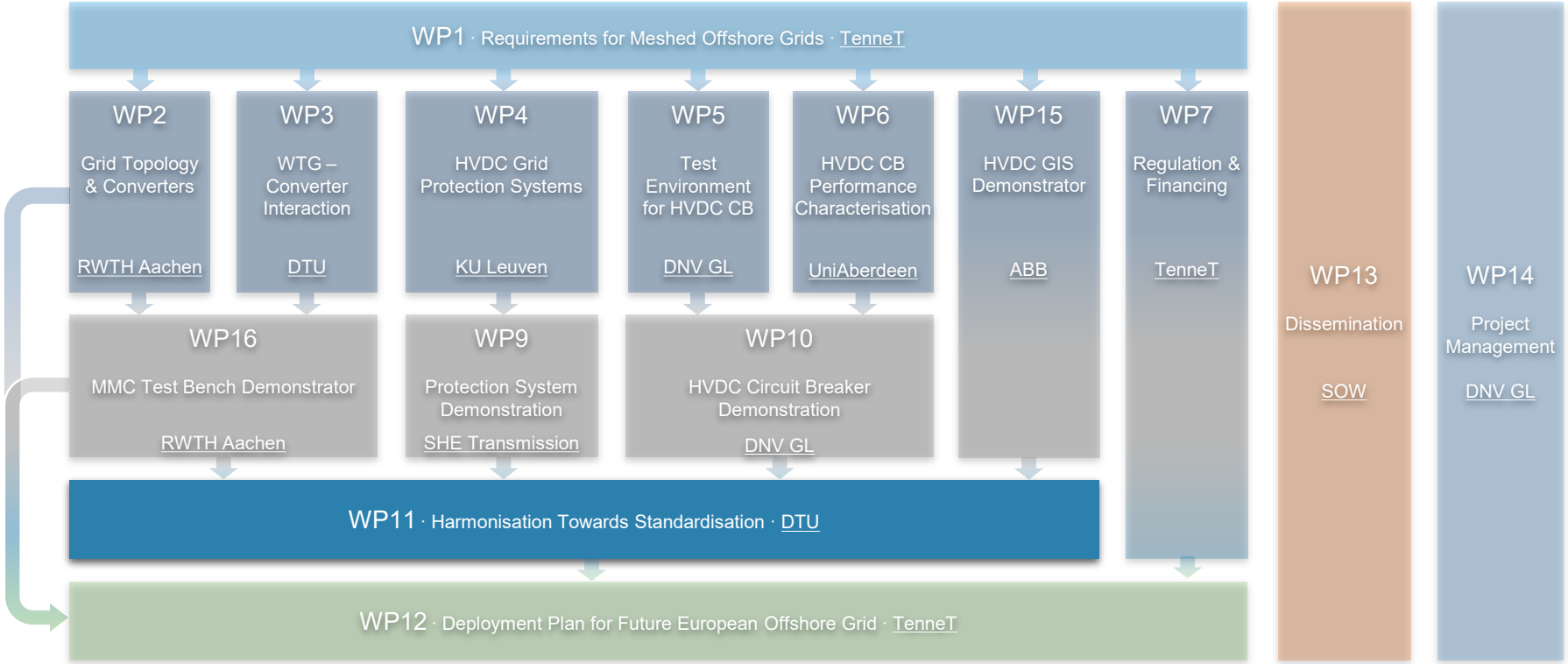
Work Packages



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Objectives

Overall Objectives

- To support harmonization of the industry's best practices, standards and requirements.
- To ensure that the PROMOTioN experience is utilised in harmonization work.
- To harmonise the work between existing and future working groups.
- To ensure that different manufacturer concepts are considered.

Outputs are formulation and justification of:

- Functional specifications / requirements.
- Test and measurement procedures.
- Simulation models.
- Procedures for compliance validation.

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WP11 Tasks

Original contract

- Task 11.1 Coordination and harmonisation across working groups (DTU).
- Task 11.2 Contributions to CENELEC TC8X WG06 on system aspects of HVDC grids (RWTH)
- Task 11.3 Contribution to relevant working groups in CIGRE (KUL).
- Task 11.4 Contribution to Standards for Wind Power Plants (DTU)
- Task 11.5 Recommendations to grid codes (FGH)
- Task 11.6 Recommendations for best-practices in compliance evaluation (FGH)

Amendment 7

- Task 11.1 Coordination of harmonisation activities and initiatives (DTU M25-54).
- Task 11.2 Contributions to harmonization of control and protection of HVDC systems (KUL M25-52).
- Task 11.3 Contribution to Standards for Wind Power Plants (DTU M25-51)
- Task 11.4 Recommendations to grid codes and compliance evaluation (FGH M31-51)

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WP11 Deliverables

Original contract

- D11.1. Report with harmonised functional specifications of HVDC systems and connected WPPs (RWTH M46)
- D11.2. White paper on test procedures for WPPs connected to HVDC systems (DTU M36)
- D11.3. Report with justified recommendations to grid codes (FGH M42)
- D11.4. Report with recommendations to best practice for compliance evaluation (FGH M42)
- D11.5. Report with recommendations on harmonized requirements for tests and models of WPPs connected to HVDC systems (DTU M45)
- D11.6. White paper on harmonisation of models for WPPs connected to HVDC systems (DTU M46)

Amendment 7

- D11.1 Harmonization catalogue (DTU M38)
- D11.2 Report on harmonization of HVDC systems (RWTH M52)
- D11.3 Report on harmonization of WPPs connected to HVDC systems (DTU M51)
- D11.4 Report on justified recommendations to grid codes (FGH M51)
- D11.5 Report with recommendations to best practice for compliance evaluation (FGH M42)
- D11.6 Report with summary of findings from PROMOTioN final harmonization workshop (DTU M54)

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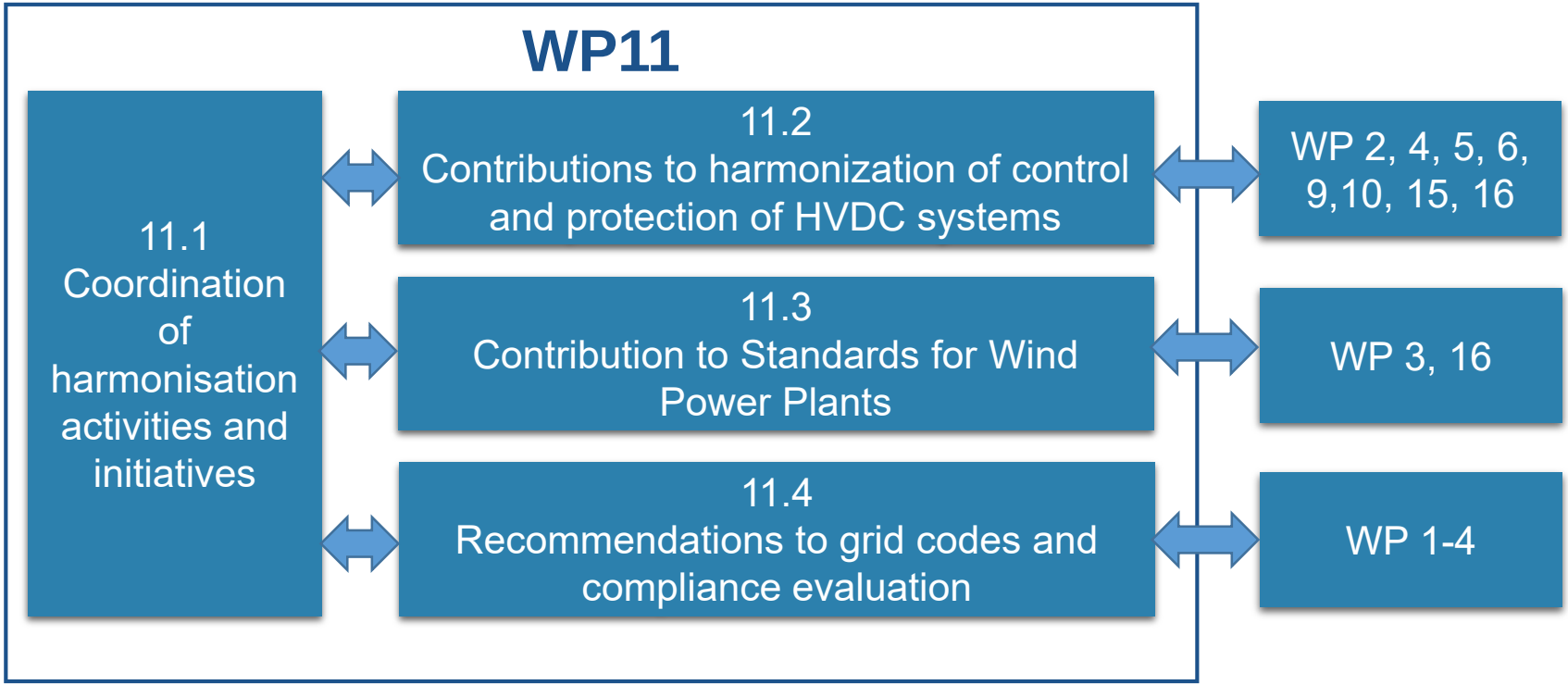
Links to other work packages



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WP11 Main Workflow

Harmonization Catalogue

- To provide common overview of relevant harmonization activities and potential PROMOTioN contributions

Initial Workshops

- To discuss possible new harmonization initiatives with external harmonization groups

Writing Contributions

- Contributions to existing WGs
- New work proposals
- Deliverables
- Other

Final Workshop

- Disseminate PROMOTioN contributions
- Discuss future work

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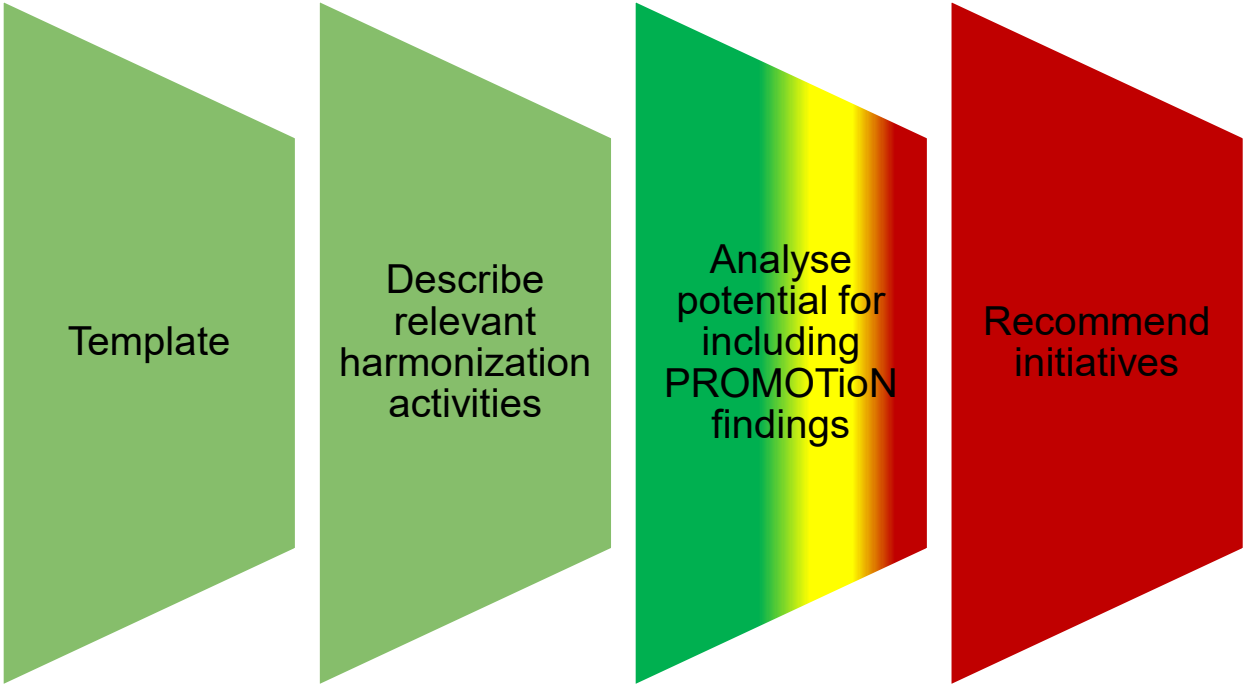
Harmonization catalogue



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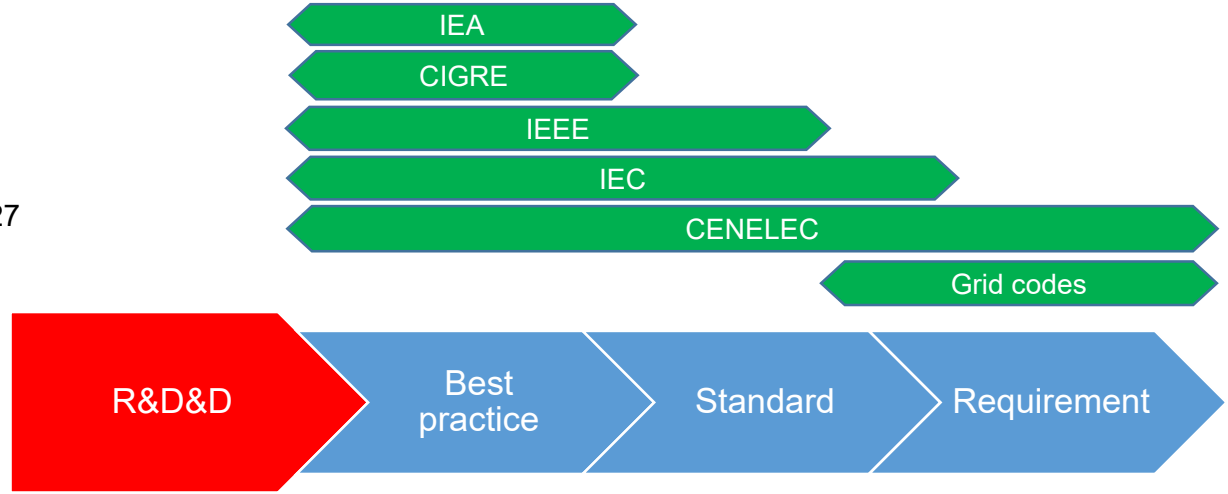
Relevant Harmonization Activities

- CIGRE
  - SC B4
  - SC D1
  - SC C2
  - SC C4
- IEC
  - TC88 MT21 / WG27
  - TC8A
  - TC115
  - TC17
- China GB/T
- CENELEC
- IEEE-SA
- Grid codes
  - ENTSO-E HVDC
  - ENTSO-E Requirements for generators
  - ENTSO-E Demand connection Code
  - inter-TSO coordination in CNC implementation



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PROMOTioN WP11 workshops on harmonization towards standardization

- Workshops are organised with regards to
  - HVDC GIS (done 2018-09-20 – WP15)
  - Control and Protection of HVDC systems (2018-12-06)
  - HVDC connected wind power – IEC TC88 focus (2019-01-15)
  - Grid codes (2020-01?)
  - Final harmonisation workshop (2020-05?)
- Each workshop will contain sessions on:
  - Overview of ongoing standardisation activities
  - Presentation of current status of standardisation in different working groups
  - Gathered knowledge in PROMOTioN
  - Discussion and potential alignment of the current standardisation work
  - Identification of future standardisation activities

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Workshop on HVDC Control and Protection of HVDC systems

6 December 2018 in Brussels

- Premesis:
  - CENELEC office
- 17 participants
- Representatives from:
  - CENELEC
  - CIGRE
  - IEC

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Workshop on HVDC Control and Protection of HVDC systems

6 December 2018 in Brussels

Time	Topic	Responsible party
09:30 – 10:00	Welcome and Coffee	Geraint Chaffey, Christina Brantl
10:00 – 10:35	Introduction & Presentation of PROMOTioN	Poul Sørensen, Christina Brantl, Dirk van Hertem
10:35 – 10:50	Overview of existing and ongoing standardisation work in the field of HVDC control and protection	Christina Brantl
10:50 – 11:10	Coffee break	
11:10 – 11:30	CENELEC work on HVDC control and protection	Marcus Zeller
11:30 – 11:50	CIGRÉ work on HVDC control and protection	Willem Leterme
11:50 – 12:10	Standardisation with regard to HVDC switchgear	René Smeets
12:10 – 12:30	Presentation of afternoon break-out sessions	Christina Brantl
12:30 – 13:30	Lunch break	

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Workshop on Control and Protection of HVDC systems

Afternoon breakout sessions – prepared discussion topics

Protection systems

- Design of protections system
- Performance evaluation of protections system
- Fault separation concepts
- Insulation coordination
- Communication protocols
- Communication interfaces
- Testing of protection devices

Control

- Integration of DRU
- DC FRT
- AC FRT
- Interoperability
- Control in large grid structures
- Harmonics / models

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Workshop on HVDC connected wind power plants

15 January 2018 in Roskilde, Denmark

- Back to back with relevant WG meetings in IEC TC88 Wind Energy Generation Systems
  - WG21: Measurement and assessment of electrical characteristics
  - WG27: Electrical simulation models

- Migrate also invited

- Identified discussion topics:
  - Control
    - Gird forming
    - FRT (AC and DC)
    - Ancillary services
  - Harmonic
    - Test
    - Modelling
    - Validation
  - EMT
    - Modelling
    - Validation

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APPENDIX

DISCLAIMER & PARTNERS

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PROJECT COORDINATOR

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Formatvorlagen des Textmasters bearbeiten

Zweite Ebene

Dritte Ebene

Vierte Ebene

Fünfte Ebene

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

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PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Deployment Plan for an Offshore Grid Plenary Session –Lyon

Brussels 26th November 2018

John Moore TenneT

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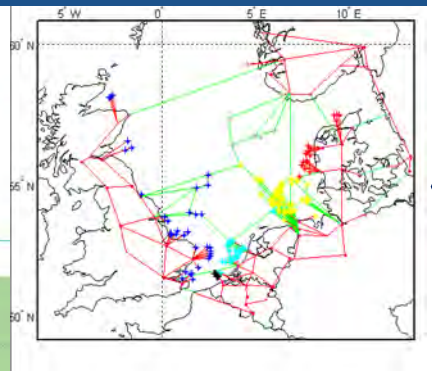
Objectives of Work Package 12

To produce a Deployment Plan for European future offshore grid development

Technical

Governmental

Financial



Economic

Market

Legal & Regulatory

Stakeholder actions & guidance

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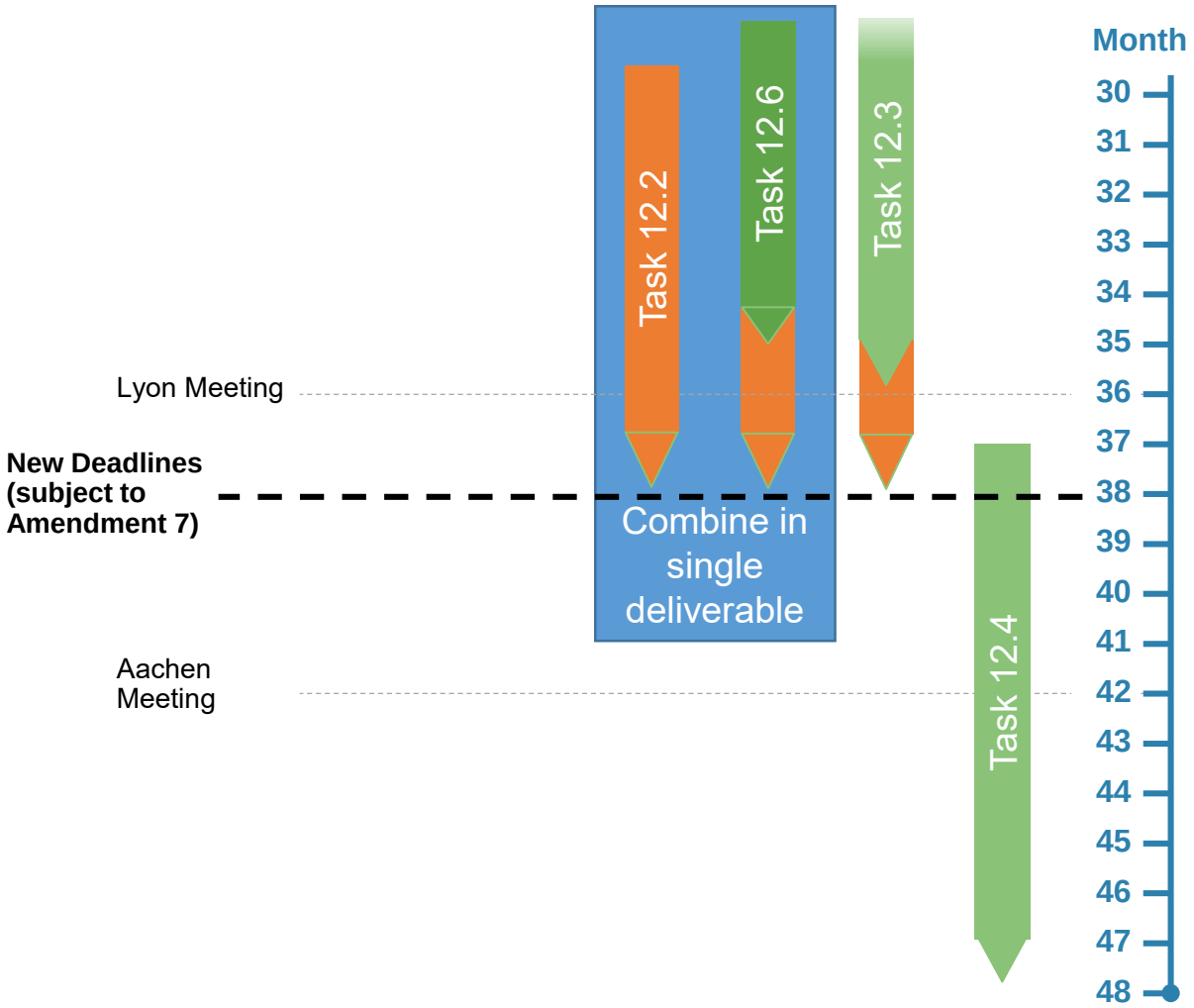
Project Planning



Extended & Changes to Scope

- New task T12.6 added in March 2018: “Overview economic evaluation of operational strategies” led by FGH. It will be rolled into D12.2
- Scope and description modified to match requirements of CBA November 2018
- Contents changes: D12.2 (include detail of CBA, include overview of Outputs other WPs) and D12.3 (Including stakeholder specific recommendations)

	Old Due Date	New Due Date
D12.1v2	No official due date. Reviewed ,but will be finalised after bottlenecks in 12.2 solved	
T/D12.2	36	38
T12.6	*36*	*38*
T/D12.3	36	38

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The deliverables of WP12 will be structured as follows:

D12.2 An Optimal Scenario for an Offshore Grid

- Wind Scenarios
- Detailed description of concepts
  Grid topologies
- Cost Benefit Analysis
- Social Benefits (ex-D12.6)
- Markets Analysis

D12.4 Deployment Plan

- Recommendations per Stakeholder
  - Technical Trajectory
  - Governmental
  - Finance
  - Economic
  - Legal & Regulatory
  - Markets
- Short Term Actions/Projects
- Summary of Barriers
- Summary of Outcomes Other work Packages

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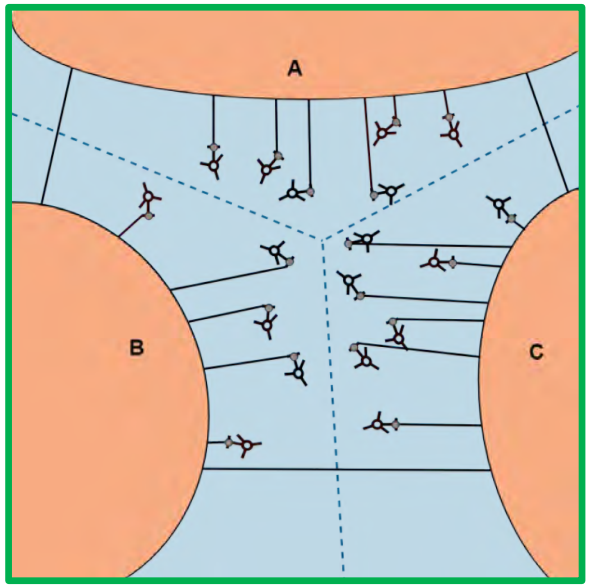
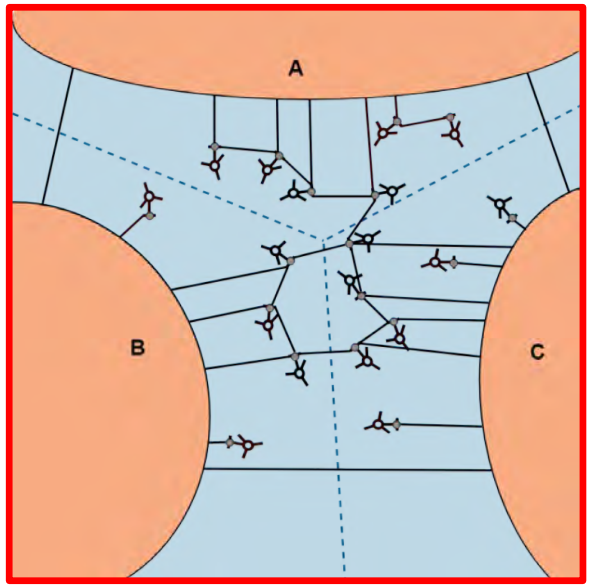
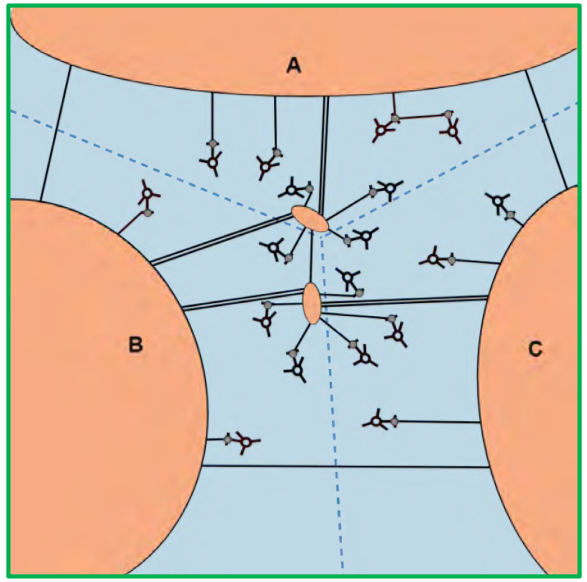
Progress on D12.2 Optimal Scenario delayed due to difficulties with locating wind and building topologies



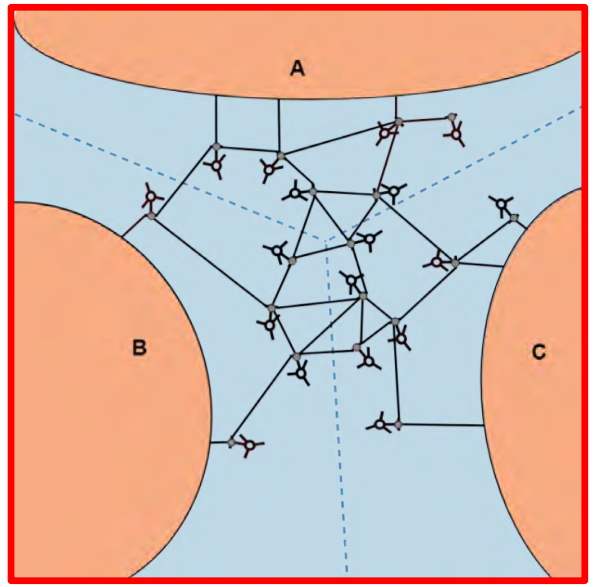
Business as Usual



National Distributed



European Centralised



European Distributed

PROMOTioN GA asked WP12 to evaluate different grid concepts to assess the relative costs & benefits of potential grid solutions

Wind problem solved with stricter adherence to TYNDP prognosis, which although is realistic may not maximise Benefit

Topology problem is more fundamental as this is related to the ability to build a large scale Meshed Offshore Grid

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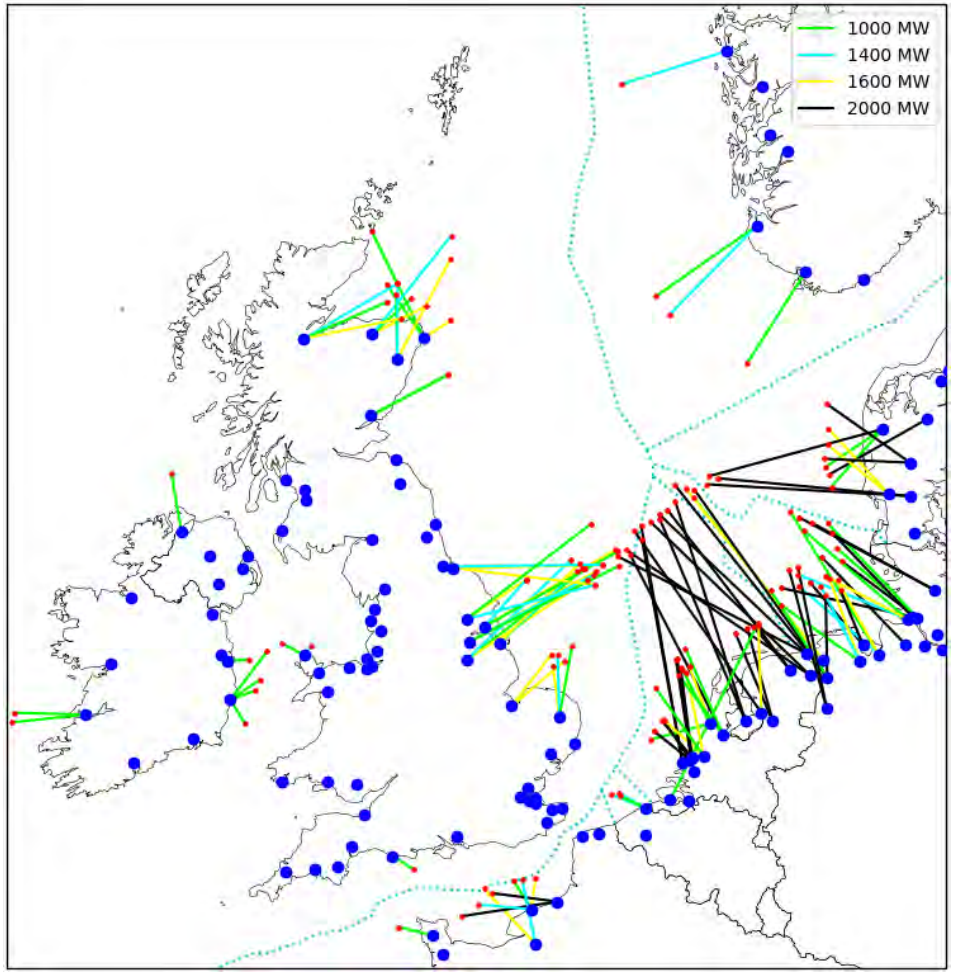
Business as Usual prognosis 2050 indicates the scale of our project



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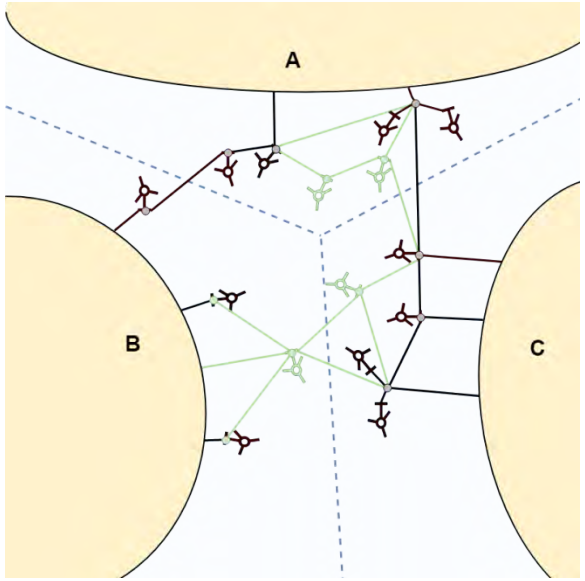
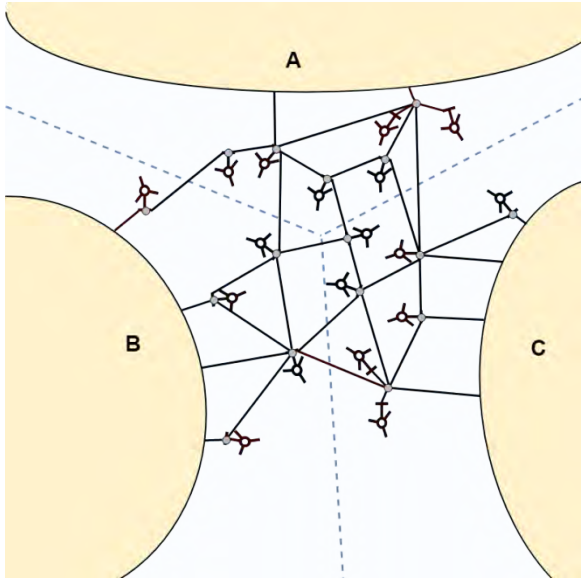
Consensus and Vision versus outcomes Work Packages

- The gap appears to be the difference between “a few simple projects” and a fully meshed grid. This seems inside PROMOTioN as well as in other programs.
- The challenge is to go from a few small initiatives today, compared to the 40-100 projects required to build a full 205GW grid.



PROMOTioN promises a fully meshed grid



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WP12 is seeking guidance on the scale up of the grid – needed to be able to progress the topology and perform a CBA

- A bottleneck was identified during the Topology optimisation:
  - When ambition in terms of generation capacity was communicated back questions raised on the scope and complexity of the grid
  - WP2 and WP4 both concerned about higher complexity and indicated that the simulation and testing within these WPs was far less complex.
  - We understand that for WP4 a scale up if not straightforward, is possible to evaluate.
  - For WP2 and 5, the control aspects are far more complex and would require significant longer term research.

- We are working with WP2 and experts in other WPs to solve this, but it potentially has material impact on the PROMOTioN outcomes:

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Large portions of WP12 are delayed until the topology is finalised.

- Goal needs to be realistic: we can expect that it could be built.
- If some weaknesses in the design, we realise that not all of items are available and on the market today. However the step to solve these are known and are anticipated to be solved during or soon after PROMOTioN.
- However, we need to make assumptions for the benefit of progress.

- We require approval by the Consortium of the issues described in order to progress.
  - Be aware of this when voting on Wednesday!

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Short Term Projects Update – the Dirk Sneaky Proposal

- Evaluation of existing projects.
  - 5 projects from Roland Berger study – 3 include relevant HVDC components – if not complex
  - 2/5 relate to a single TenneT project. Today this is at critical phase of negotiations. We are unable today to discuss these 2 projects
  - 1/5 is Cobra cable that has already been laid.
    - Designed to include a branch to a wind park.
    - No suitable wind park planned and German government has serious problems if an OWF is subsidised and not connected directly to Germany.
    - Cable is now almost completed. Mixed meaning about the ease of pulling the cable to connect a wind farm.
  - 2 Projects identified in Sweden. May be possible modification to meshed HVDC. To be discussed.
  - TSO Consortium partners within WP12 asked to make an inventory of potential projects

  - TenneT island concept will be open to using HVDC also
    - Longer term
    - Limited HVDC
    - But space and ambition to include some HVDC meshing.

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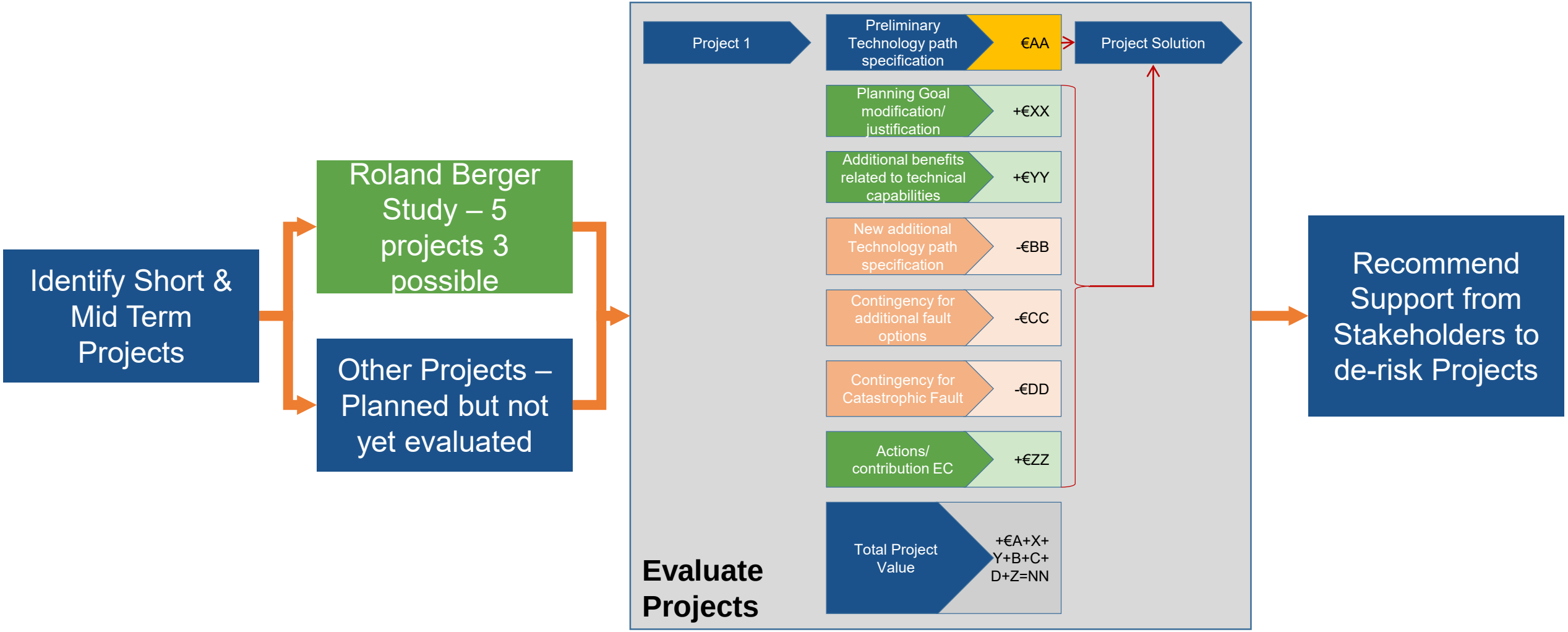
Short term initiatives are being evaluated



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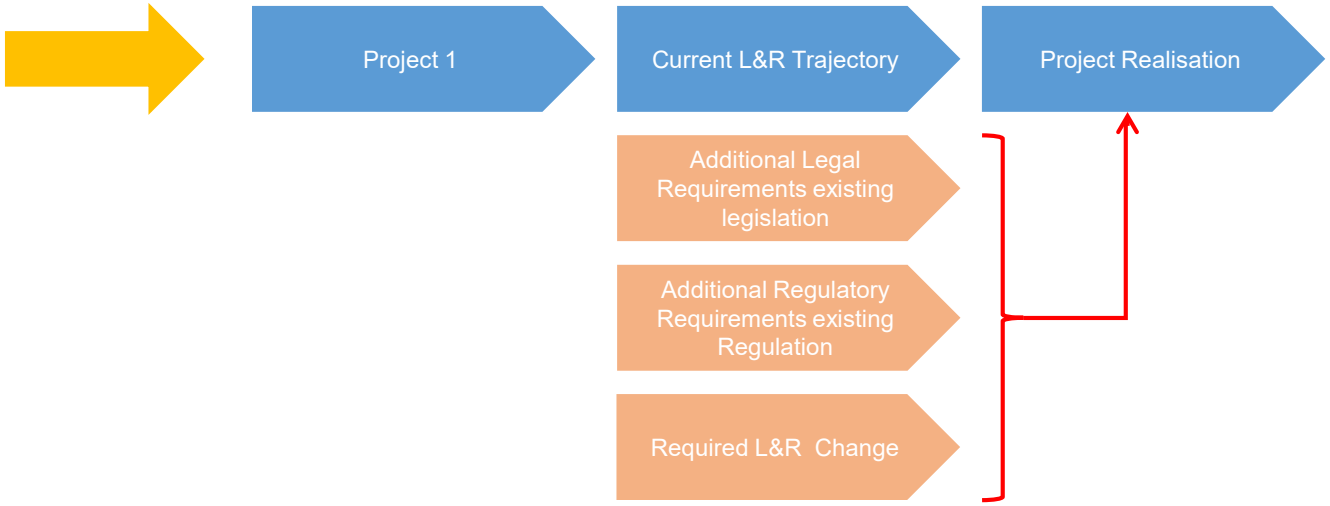
Short term projects issues arising to date:

1. Barriers to modification of projects are also related to non-financial factors which also need evaluation
2. Confidential issues around multi-party projects, makes it difficult to break in.
   - solution to create a “shadow” project analysis being investigated.
   - Difficult to influence confidential negotiations and discussions.
3. Mind set as in previous slides: people not yet looking at the long term.
4. But, realisation that if we are to develop HVDC meshing, a first step is needed, and we cannot continue pushing this into the future.



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Any questions?

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PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

WP13
Dissemination

Stiftung OFFSHORE-WINDENERGIE ● Andreas Wagner

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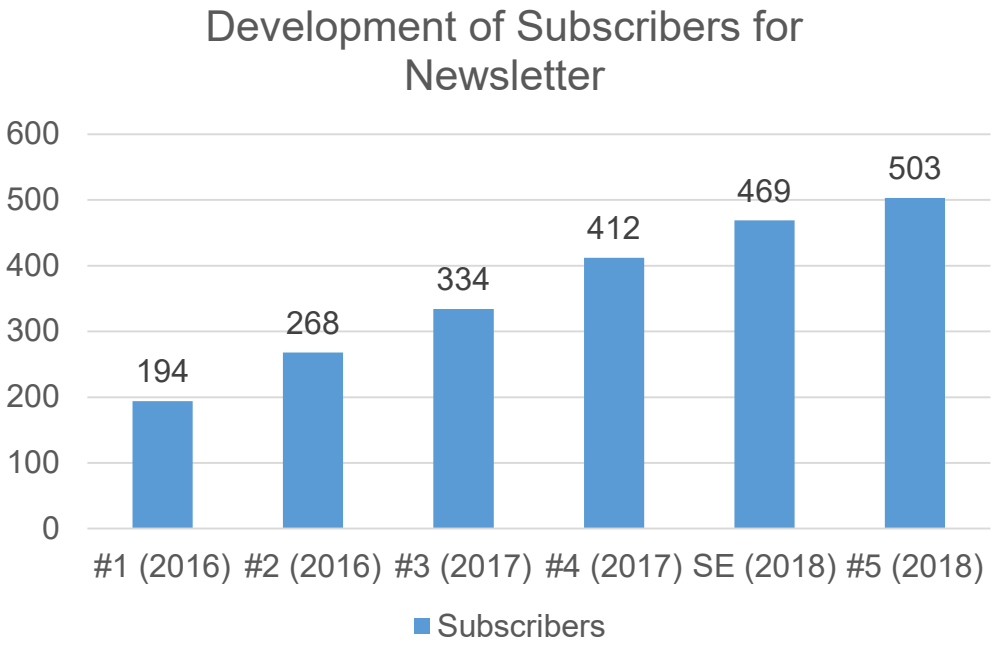
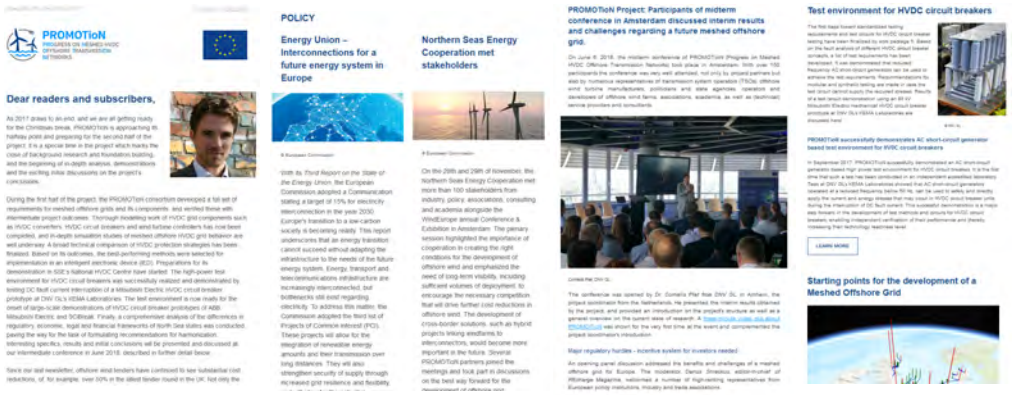
Progress Task 13.2 – Development and production of a newsletter

- **Steady increase in subscribers** for newsletter since project start
- Regular cooperation & exchange with PMG
- **Newsletter #5 for Q4/2018, topics amongst others**
  - Successful Factory Acceptance Test MMC Test Bench (WP16)
  - Successful Completion of HVDC gas insulated switchgear (GIS) test prototype installation (WP15)
  - CBA Methodology (WP7)
  - Optimal scenarios for the future European offshore grid (WP12)
  - Two low-power demonstrator DC circuit breakers developed and tested at University of Aberdeen laboratory (WP6)





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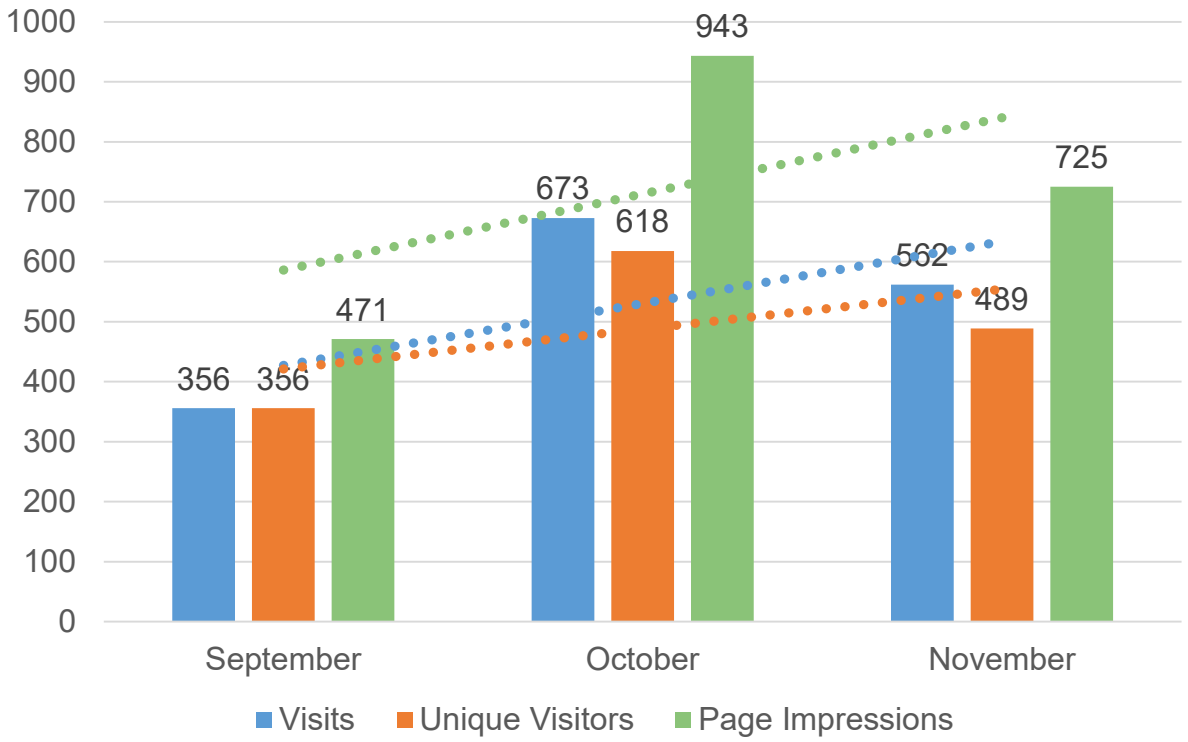
Progress Task 13.3 - Content management for website and intranet

- Main Objective: maintenance and constant improvement of the PROMOTioN website
- Regular updates of news, calendar and download-sections
- Satisfactory numbers of visitors and page impressions – increasing tendency
- People stay between **2:51 min** (September) and **1:48 min** (November) on our website
- Visitors look at ~ 2 different pages per visit (average **bounce rate ~ 50%)**
- Highest "consumption" of pages per session in France, Germany, the UK & the Netherlands (between 4 and 2)
- Lowest in the US, Russia and Czech Republic



Visits: Number of overall visits
Unique Visitors: Distinct individuals
Page Impressions: Number of different pages

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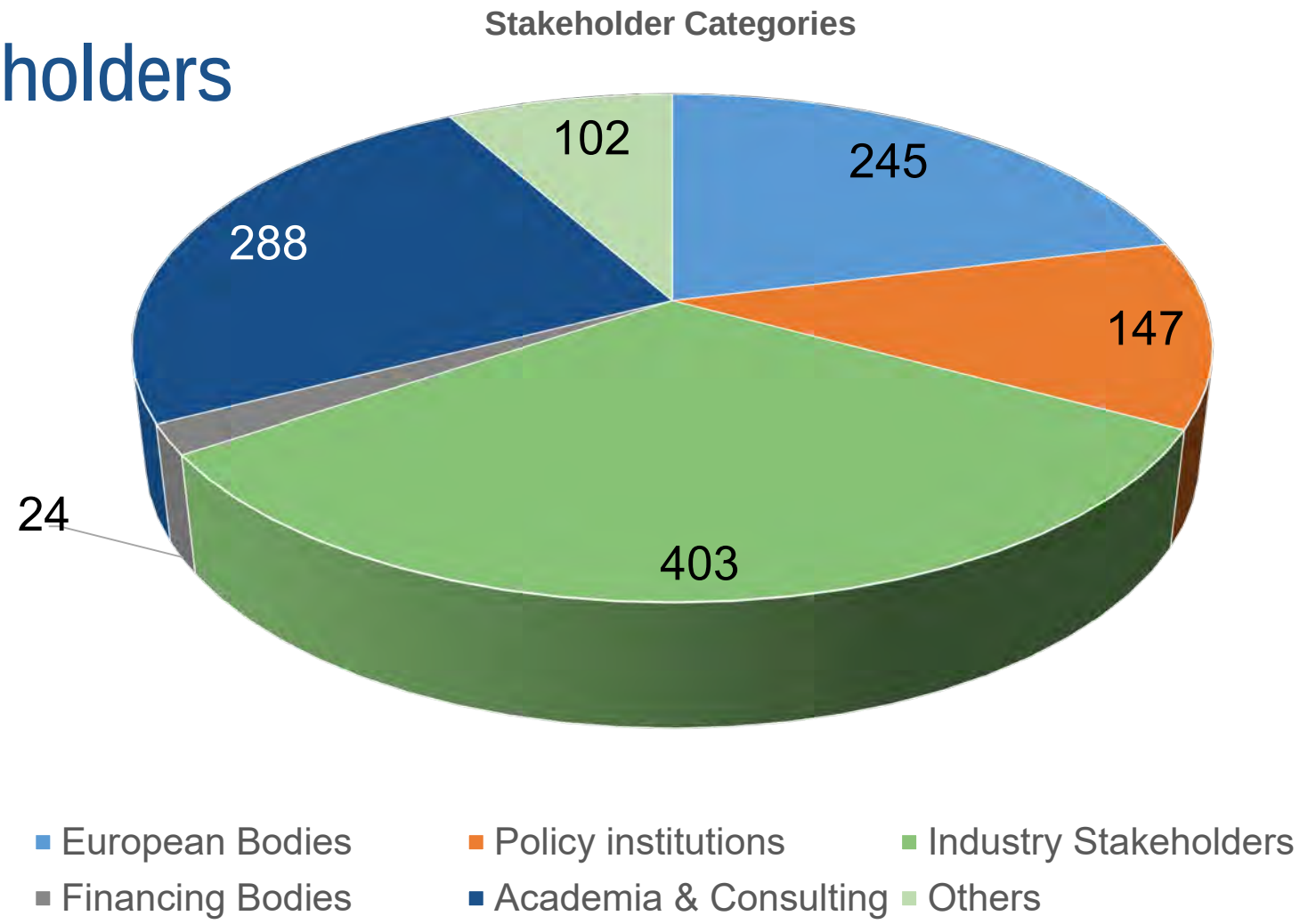
Progress Task 13.4 - Development of a targeted mailing list

1,209 Stakeholders



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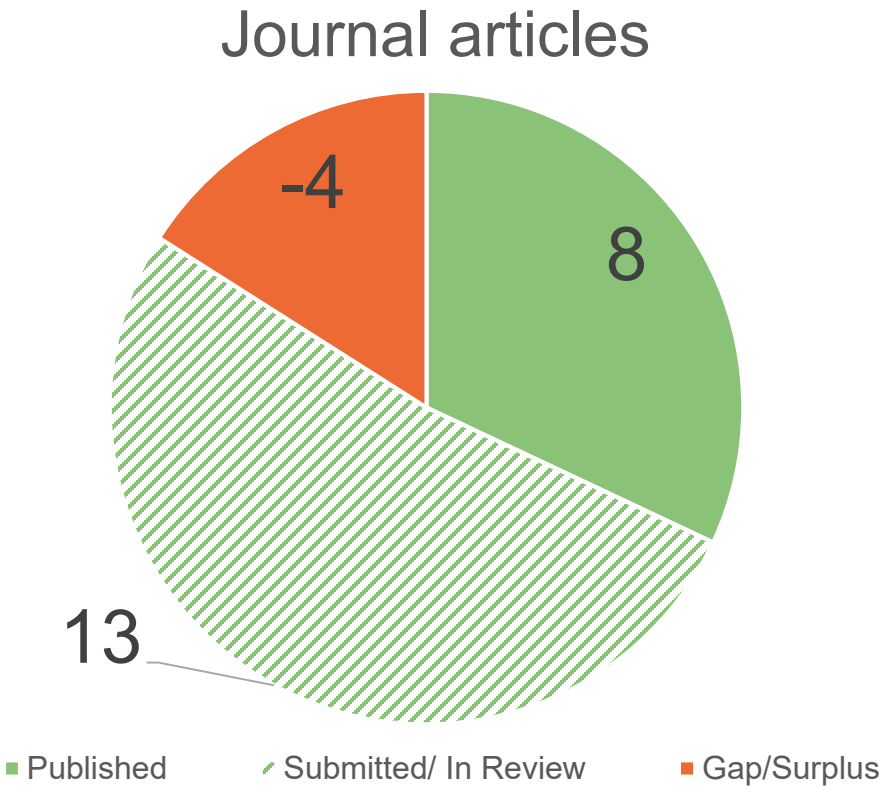
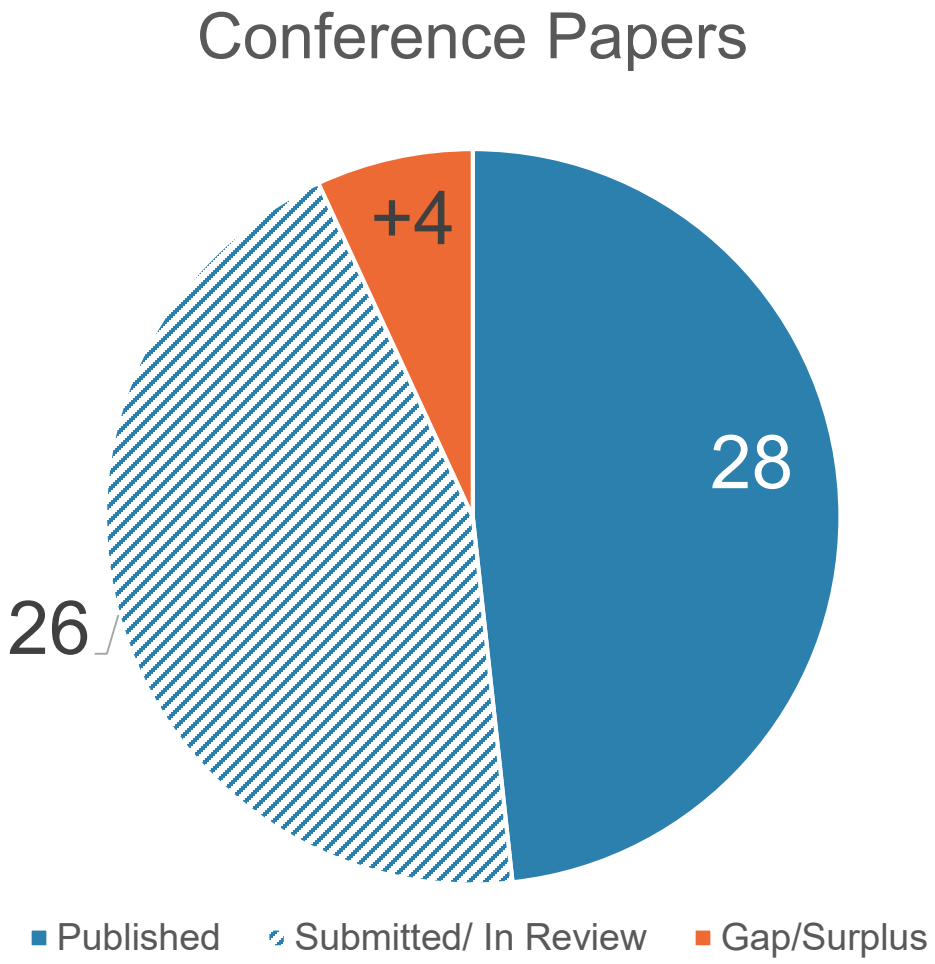
Progress Task 13.6 - Production of public reports, papers/articles, presentations

Good news! We are right on track!





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Progress Task 13.7. – Stakeholder Interaction Upcoming Events [I]

ACDC 2019 - The 15th IET international conference on AC and DC Power Transmission (papers submitted by e.g. WP2 & WP4)

5 – 7 February 2019 in Coventry, UK

NorthSEE & Baltic LINes MSP Conference (PROMOTioN WP7 contribution)

13 - 14 February in Hamburg, Germany

The Baltic InteGrid: Roadmap for a meshed offshore grid in the Baltic Sea region (PROMOTioN presentation by Cornelis Plet)

26 - 27 February 2019 in Berlin, Germany

Joint MIGRATE and PROMOTioN Workshop → Details next slide

28 February 2019 in Berlin, Germany

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Joint MIGRATE & PROMOTioN Event [I]

„PROMOTioN & MIGRATE –

Technical challenges and recommendations for the future European power grid“

Background and schedule

- Mariana asked for a closer collaboration between MIGRATE and PROMOTioN
- Workshop on highlighting the technical complementarity of the two projects
- 13 December 2018: **Save The Date**
- 17 January 2019: **Official Invitation**
- 28 February 2019: **Workshop** in Berlin, Germany
- Expected number of **participants** lies between **50** and **100**

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Joint MIGRATE & PROMOTioN Event [II]

PROMOTioN contributions on:

- **the changes in system inertia** (**WP 2 & 4**)

What impact does changing inertia have on offshore HVDC power system?

- **the control and operation of no or low inertia grids** (**WP 3**)

Offshore windfarm voltage control & black start capability

- **power quality questions** (**WP 16**)

Modelling and validation of inverter harmonics

- **regulation & grid codes** (**WP 2 & 11**)

Recommendations for offshore HVDC grid inverter interfaces

Time	Session
09:30 – 10:00	**Walk In & Registration**
10:00 – 10:30	**Future of power systems** • Overview MIGRATE *(15 min)* • Overview PROMOTioN *(15 min)*
10:30 – 11:45	**Change in system inertia** • Introduction & Expectations of the audience *(10 min)* • MIGRATE: How does inertia change and what is impact on existing power system *(20 min)* • PROMOTioN WP 2 & 4: What impact does changing inertia have on offshore HVDC power system *(20 min)* • Wrap Up & Discussion
11:45 – 12:00	**Coffee Break**
12:00 – 13:15	**Control and operation of no or low inertia grids** • Introduction & Expectations of the audience *(10 min)* • PROMOTioN WP 3: Offshore windfarm voltage control & black start capability *(20 min)* • MIGRATE: Operating a system with 100 % power electronics *(20 min)* • Wrap Up & Discussion
13:15 – 14:00	**Lunch Break**
14:00 – 15:15	**Power Quality** • Introduction & Expectations of the audience *(10 min)* • PROMOTioN WP 16: Modelling and validation of inverter harmonics *(20 min)* • MIGRATE: Impact of harmonics on future converter dominated power system *(20 min)* • Wrap Up & Discussion
15:15 – 15:30	**Coffee Break**
15:30 – 16:45	**Regulation & grid codes** • Introduction & Expectations of the audience *(10 min)* • MIGRATE: Impact of the project results and recommendations for the future power system*(20 min)* • PROMOTioN WP 2 & 11: recommendations for offshore HVDC grid inverter interfaces *(20 min)* • Wrap Up & Discussion
16:45 – 17:00	**Closing Remarks**
17:00	**End of Event**

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Progress Task 13.7. – Stakeholder Interaction Upcoming Events [II]

WindEurope Conference & Exhibition 2019

2 - 4 April 2019 in Bilbao, Spain

CIRED 2019 (papers submitted by PROMOTioN partners)

3 - 6 June 2019 in Madrid, Spain

CIGRÉ International Symposium (papers submitted by e.g. WP2, WP3, WP4, WP6)

04 - 07 June 2019 in Aalborg, Denmark

EU Sustainable Energy Week → Details next slide

17 – 21 June 2019 in Brussels, Belgium

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EUSEW 2019 – 17 - 21 June 2019, Brussels

- PROMOTioN will apply to host a policy conference session during the EUSEW 2019
- Application deadline: **28 January 2019**
- General Structure
  - Session will take place between 18 - 20 June 2019
  - 90 minutes per session
- Suggested topics for the conference:

"The next step towards meshed offshore grids – recommendations how to regulate and finance the future European power grid" (WP7)

"Deployment plan for a European meshed offshore grid – A roadmap until 2050" (WP12)

- SOW will prepare the application in close cooperation with DNV GL and the relevant partners

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Further upcoming events (yet unclear PROMOTioN contribution)

- Hamburg Offshore Wind Conference (organised by EEHH & DNV GL)

2./3. April 2019 in Hamburg, Germany

- Support Group 2 Meeting
- 3rd North Seas Energy Forum
- Roland Berger Presentation of results from cluster study

All likely in Q1 2019

- IEEE PES Powertech 2019, Milano, Italy

23rd – 27th June 2019

- ENTSO-E conference (*Q3 2019)*

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Global Wind Summit 2018 – Review of PROMOTioN activities

- PROMOTioN booth
- Press background talks
- DTU presentation on “black start capabilities”
- Workshop on WP7 content with 40 participants

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Progress Task 13.7.2 - Reference Group meetings

- The ‘Reference Group’ (RG) consists of around 50 stakeholders from different branches
- Chatham house rule applies to the meetings → confidentiality agreement
- Objective: feedback on preliminary project findings
- Last facilitation: 6 December 2017, Brussels
- Future planning:
- RG ‘Technical’ → suggested date: **27 February 2019**
- RG ‘Regulatory’ → suggested date: **alongside NSEF in Q1 2019**

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Progress Task 13.8 – External Communication activities

- Includes press and media work (e.g. press briefings, social media)
- Press briefings & background talks (e.g. during Global Wind Summit 2018)
- Communication of news-items on Twitter channel (**152 Followers**) & LinkedIn
- High visibility on social media if “tweeted correctly”:
- **Own content is key!**

→ **Recommendations for making the most out of social media on the next slides**

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Examples of social media activity

Du hast retweetet

Diederik Peereboom @DiederikP · 27. Nov.

Case study on #meshed #offshore #HVDC #grids by Andrea
@PROMOTioN_HVDC #EUGrids2018

Tweet übersetzen

4 8

PROMOTioN Project @PROMOTioN_HVDC · 8. Okt.

Congratulation to @DNVGL_Energy and @ABBgroupnews on successful completion of HVDC gas insulated switchgear (GIS) test prototype install within the scope of @PROMOTioN_HVDC . Another milestone reached o way towards meshed #hvdc offshore grids!
promotion-offshore.net/news_events/ne...

Tweet übersetzen

7 8

Andreas Wagner • 1.
Managing Director at Stiftung Offshore Windenergie
3 Wochen

Great achievement!

Übersetzung anzeigen

ABB Power Grids
39.655 Follower
3 Wochen

ABB enables world's first HVDC grid in China - Delivery of wind energy will ensure more stable and reliable electricity to meet higher demand during Beijing 2022 Winter Olympic Games. #HVDC #energy #Beijing #China ... mehr anzeigen

Übersetzung anzeigen

ABB enables world's first HVDC grid in China
new.abb.com

1 Gefällt mir

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How can we use Twitter/ LinkedIn to our mutual advantage

Twitter

In order to function properly, project partners (companies) should

- **Forward contacts of Social-Media representatives** of your company to SOW
- **Follow the PROMOTioN Twitter Channel**

  Retweet & Like the Tweets by PROMOTioN (“on demand” – no constant effort needed!)

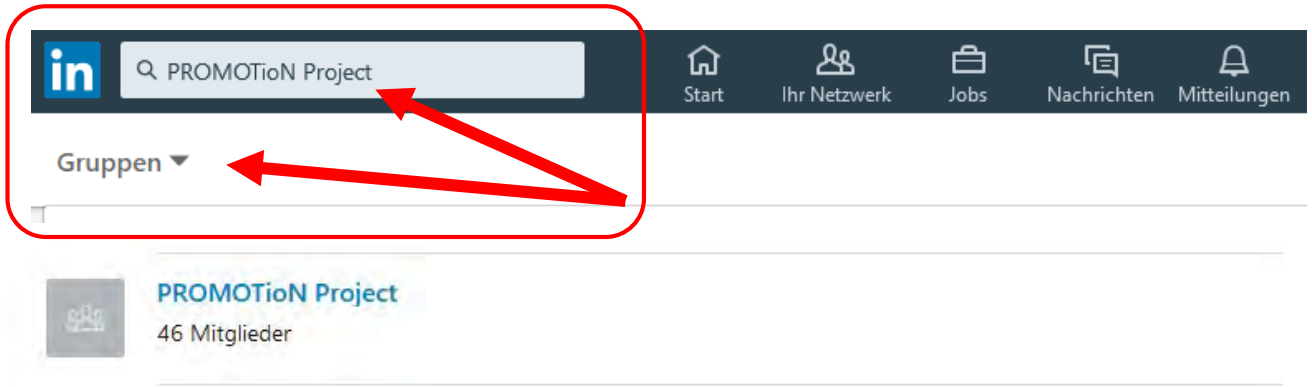
Twitter Advantage and Example

- Project News following K.I.S.S.- principle (events, demonstration etc.)
- One tweet by PROMOTioN reaches 152 followers – but: if retweeted by the **WP leads affiliation only**, we can reach more than

113,000 followers

LinkedIn Group

- Same principle as Twitter, however, range depends on individual size of networks
- Nevertheless: Join the LinkedIn project group and **forward the news on your profile**



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Any Questions?

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WP15

HVDC Gas Insulated Systems Demonstrator

ABB • Uwe Riechert

Half-yearly meeting Lyon, Monday, 10th December

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

Task Structure

WP15 – HVDC GIS technology demonstrator

WP1

WP4

Task 15.1: SHE Transmission
Defining specifications and long term testing requirements

Task 15.2: TU Delft
Develop monitoring and diagnostic method and applicability of SF_6 alternatives

Task 15.3: DNV-GL
Long term testing of the DC GIS equipment

Task 15.4: ABB
Initiation of standardization activities for HVDC GIS design, testing and application

WP11

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Milestones & Deliverables

Planned — Delay

Month: 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

Aberdeen Meeting

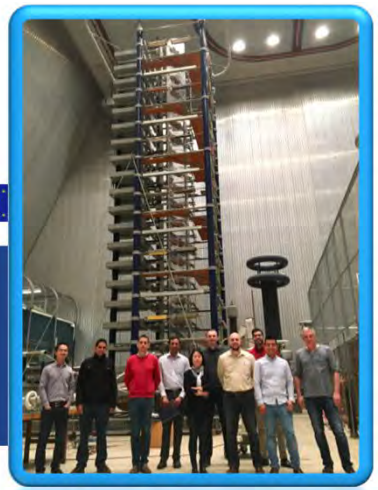
Valencia Meeting

Groningen Meeting

Task 15.1

Task 15.2

Task 15.3



D15.1	Document on recommendations for specifying DC GIS systems
D15.2	Document on test requirements, procedures and methods
MS68	Recommendations for specifying DC GIS defined
MS69	Test requirements, procedure and method identified and agreed

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

Task Structure

WP15 – HVDC GIS technology demonstrator

WP1

WP4

Task 15.1: SHE Transmission
Defining specifications and long term testing requirements

Task 15.2: TU Delft
Develop monitoring and diagnostic method and applicability of SF_6 alternatives

Task 15.3: DNV-GL
Long term testing of the DC GIS equipment

Task 15.4: ABB
Initiation of standardization activities for HVDC GIS design, testing and application

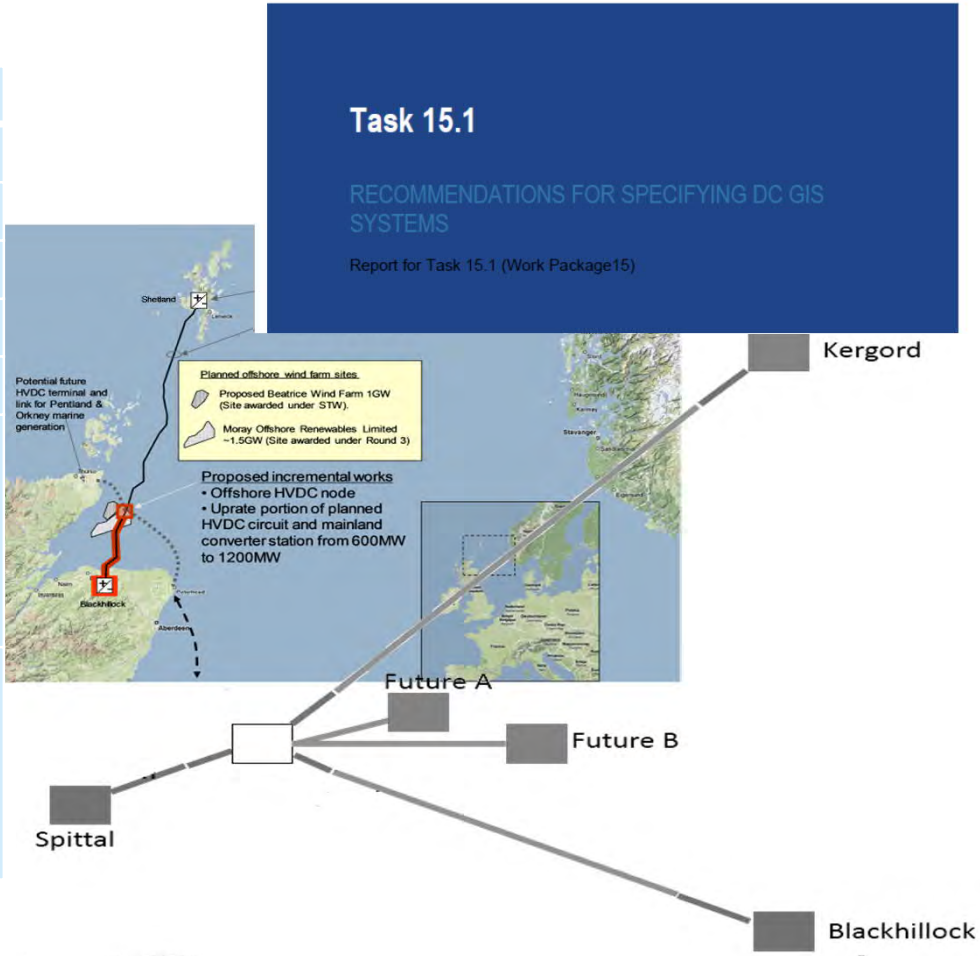
WP11

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

Achievements: specifications

- HVDC GIS prototype installation test values

U_n Nominal Voltage	±320 kV
U_r Rated dc operation voltage	±350 kV
U_p Rated lightning impulse withstand voltage	±1050 kV
U_s Rated switching impulse withstand voltage	±950 kV
I_r Rated normal current	4000A
I_{sc} Rated short-time withstand current, 1 second	50kA
Rated superimposed lightning impulse withstand voltage	
Lightning impulse voltage	±1050 kV
DC voltage	350 kV
Rated superimposed switching impulse withstand voltage	
Switching impulse voltage	±950 kV
DC voltage	350 kV



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Task Structure

WP15 – HVDC GIS technology demonstrator

WP1

WP4

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WP11

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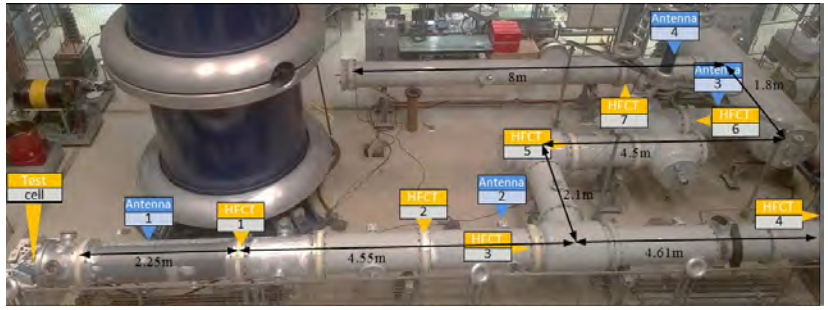
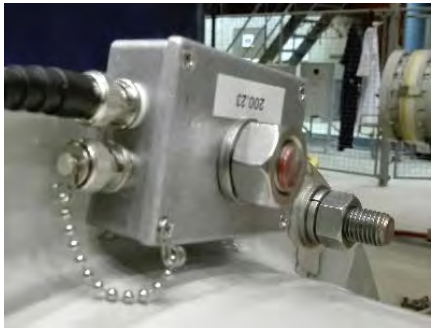
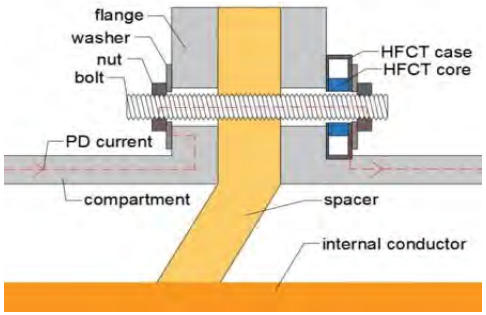
Main Achievements

1- Detection of PD currents in the GIS compartments – HFCT



HFCT is installed at one bolt of the GIS compartments, not in the ground path as conventionally has been used.





The approach has proven feasibility in Laboratory experiments.

Advantages

- Simplicity
- lower hardware specs
- Higher spatial sensitivity
- Estimation of PD parameters plausible

Disadvantages

- Noise and disturbance
- Demand modifications to be implemented in spacers of new design
- Demand extra post-processing

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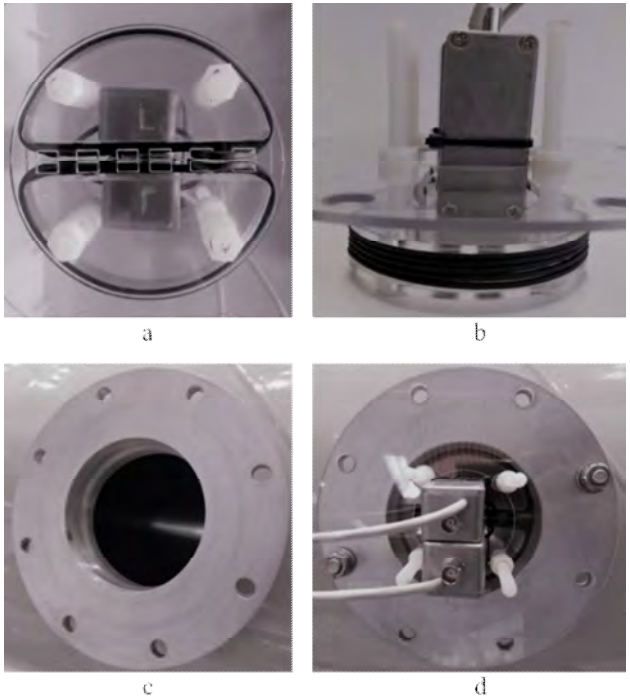
Main Achievements

1- Detection of PD currents in the GIS compartments - Magnetic antenna



The proof of concept of a pick up coil installed in the opening of the compartments showed to be feasible for PD detection

Advantages

- Use already existing openings so its implementation if feasible
- lower hardware specs
- Higher spatial sensitivity

Disadvantages

- Absolute sensitivity needs to be improve
- Only meant for PD detection, quantification of PD parameters is not possible.

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PROMOTioN – Task 15.2. To develop monitoring and diagnostic methods for HVDC GIS equipment.

Working Plan – Follow-up

WP 15. HVDC GIS Technology Demonstrator																								
Task 15.1	Define specifications and test requirements																							
Task 15.2 TU Delft	Hardware specification for partial discharge measurements						Definition and testing of parameters for monitoring and diagnostics						Development of advanced techniques (data post processing and software development)											
month	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48

- Experimentation with DC voltage
- Validation of the HFCT system on ABB HVDC GIS (long term testing)
- Research on algorithms for PD parameter estimation for monitoring and diagnostics
- Post processing techniques for disturbances and noise cancelation
- Research on automatic clustering techniques

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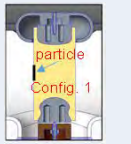
Subtask WP15.2.4

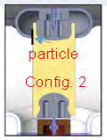
- Short term PD behavior for SF6 and SF6 alternative gases with defects
  - Two kinds of defect: protrusion on HV busbar and metallic particle on spacer surface
  - 4 measuring systems are used: conventional method, UHF method, light emission and High Frequency Current Transformer (HCFT) – in collaboration with TU Delft

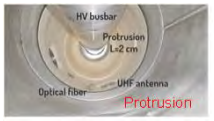
Investigated gases for SGI Task

Gas	Pressure (bar abs)			Equivalent pressure to SF6 (bar abs)
SF6	5			
	6			
	6.8			
Air Plus	**Novec 5110**	**Technic Air**	**Mixture**	
	0.5	7	7.5	5
	0.5	8.9	9.4	6
	0.5	10.5	11	6.8
FN-CO_2 mixture	**Novec 4710**	**CO_2**	**Mixture**	
Mixture 4%	0.32	7.68	8	5
Mixture 10%	0.65	5.85	6.5	5

Defect	Gas	Experiment	Data analysis	Deliverable D15.7
Protrusion	All gases	✓	✓	
Metallic particle on spacer surface	Config. 1 – all gases	✓	✓	
	Config. 2: AirPlus	✓	✓	
	Config. 2: FN-CO2 mixture	✓		
	Config. 2: SF6			







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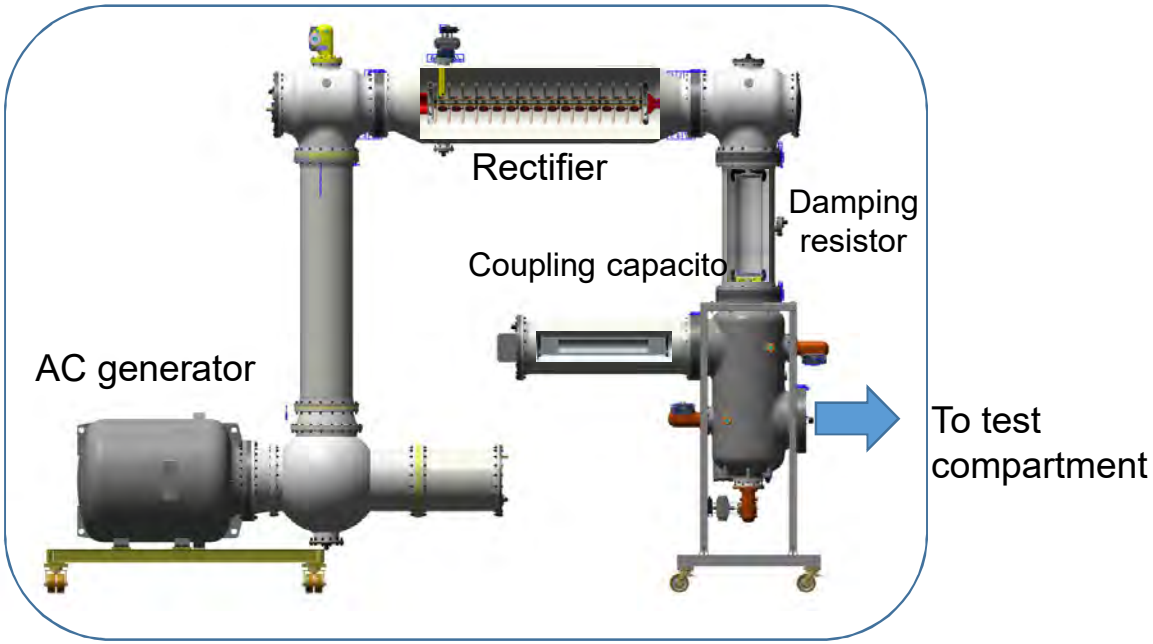
PROMOTioN WP15.2

Subtask 15.2.5

- Long term PD behavior for SF6 and SF6 alternative gases with defects
  - Two kind of defect: protrusion on HV busbar and metallic particle on spacer surface
  - Different measuring systems
  - Different gases

Test circuit



Task	Progress	Expected date
Test circuit design and development	✓	
Test circuit supply		2019 March
Assembling		2019 April
Validation tests		2019 May
Beginning of test		2019 June

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Task Structure

WP15 – HVDC GIS technology demonstrator

WP1

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WP11

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Achievements: assembly

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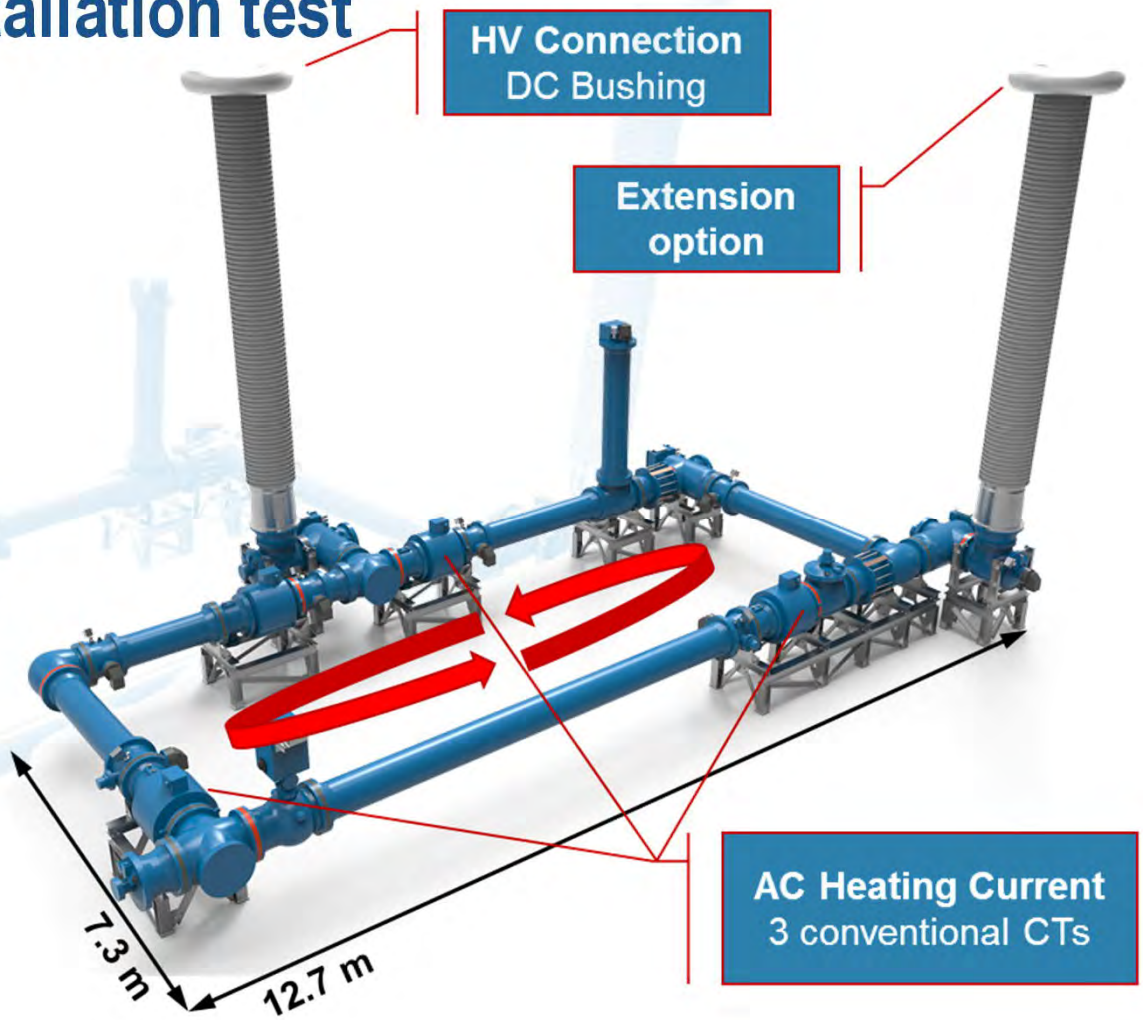
Achievements: prototype installation test

Nominal DC voltage U_n	± 320	kV_{dc}
Rated DC voltage U_r	± 350	kV_{dc}
Rated superimposed LI withstand voltage U_P / U_r		
Lightning impulse voltage	± 1050	kV
DC voltage	± 350	kV_{dc}
Rated superimposed SI withstand voltage U_S / U_r		
Switching impulse voltage	± 950	kV
DC voltage	± 350	kV_{dc}
Rated DC withstand voltage to earth U_w	± 610	kV_{dc}



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Achievements: test program

D15.2 Document on test requirements, procedures and methods

- HVDC GIS prototype installation test procedure

Pre-Tests	BLOCK 1 60 days DC (+ or -) HL or ZL SIM LI/SI 10 C/O	2	3	AC PD	4	5	BLOCK 6 60 days DC (+ or -) HL or ZL SIM LI/SI 10 C/O	BLOCK 7 30 days LC (+ and -) SIM LI/SI	add. Tests

Nov. 2018 — 14 month — Dec. 2019

Monitoring
Gas density
PD: UHF/Optical/HFCT
Arc Detection
Enclosure Temperature

ZL = zero load (zero heating)
HL = high load (continuous heating)
LC = load cycle,
SIM = Superimposed switching and lighting impulse voltage test
ACPD = AC partial discharge measurement at U_{ac}

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Achievements: status

Step	Test	Conditions	Load	
1.	Thermal cycle pre-test	Heating up to steady state with I_{eqac} or I_r	LC / HL	✓
2.	AC PD measurement	Pre-stress at U_{acpre}; PD measurement at U_{acpd}.	ZL	✓
3.	DC PD measurement	Pre-stress at $\pm U_{dcpre}$; PD measurement with $\pm U_{dcpd}$.	ZL	✓
4.	Lightning impulse test	LI voltage U_{TP}	ZL	✓
5.	Switching impulse test	SI voltage U_{TS}	ZL	✓
6.	Superimposed LI test	Positive and negative rated DC voltage U_r and U_{TP}	ZL	
7.	Superimposed SI test	Positive and negative rated DC voltage U_r and U_{TS}	ZL	
8.	Polarity reversal test	Polarity reversal $\pm U_T$	ZL / HL	

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Interactions With Other Work Packages (WP11)

- Workshop: HVDC GIS WP 15 HVDC GIS prototype installation test
  - 26 participants
  - Presentations of WP 15 tasks
  - Information from other manufacturer
  - Visit of prototype installation
  - Discussion with Cigré and IEC

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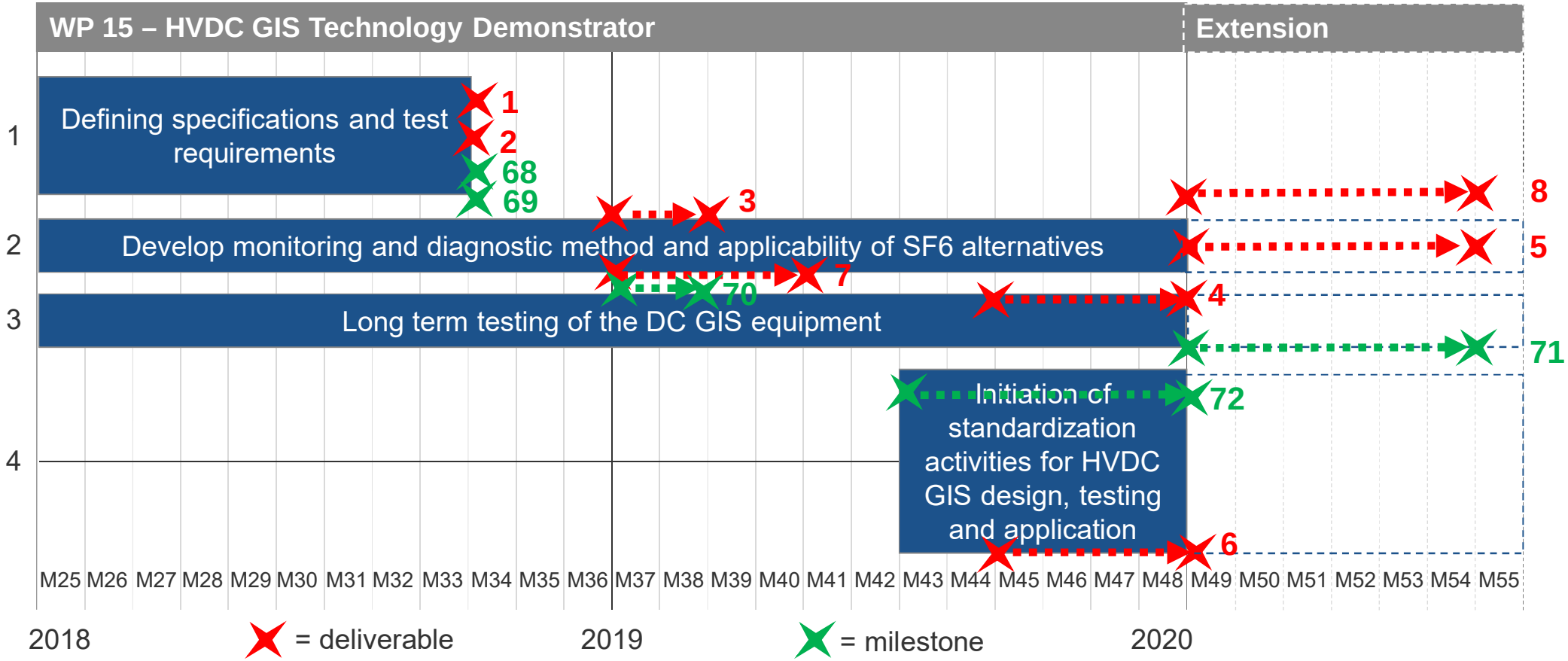
Planning



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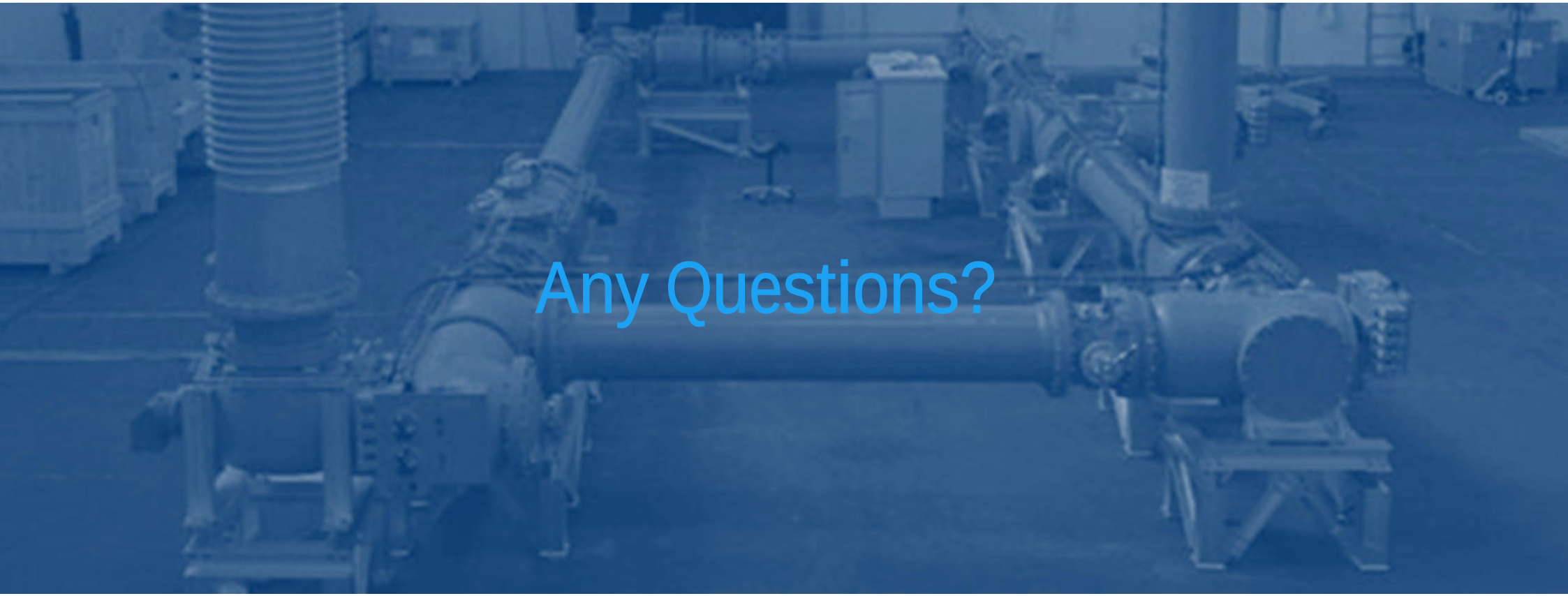

Any Questions?

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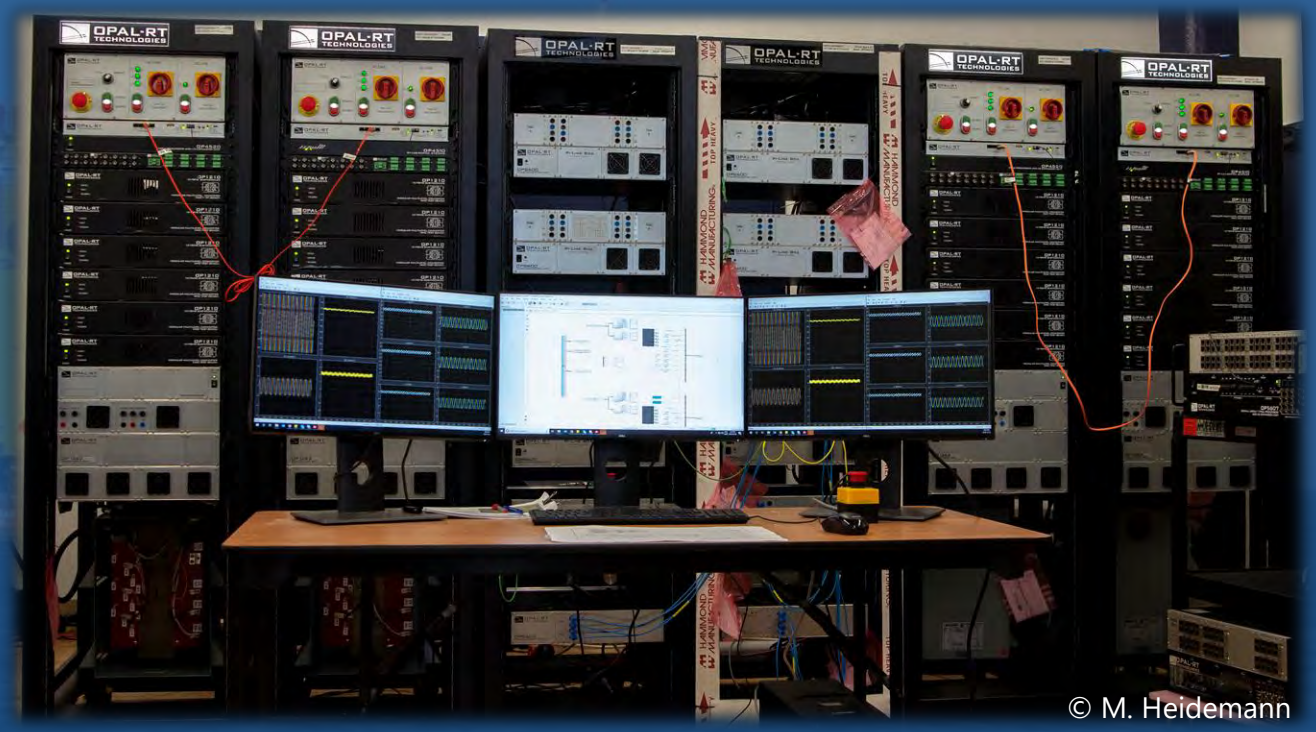
PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

WP16

MMC Test Bench Demonstrator



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Plenary Session 10.12.2018

Philipp Ruffing – RWTH Aachen

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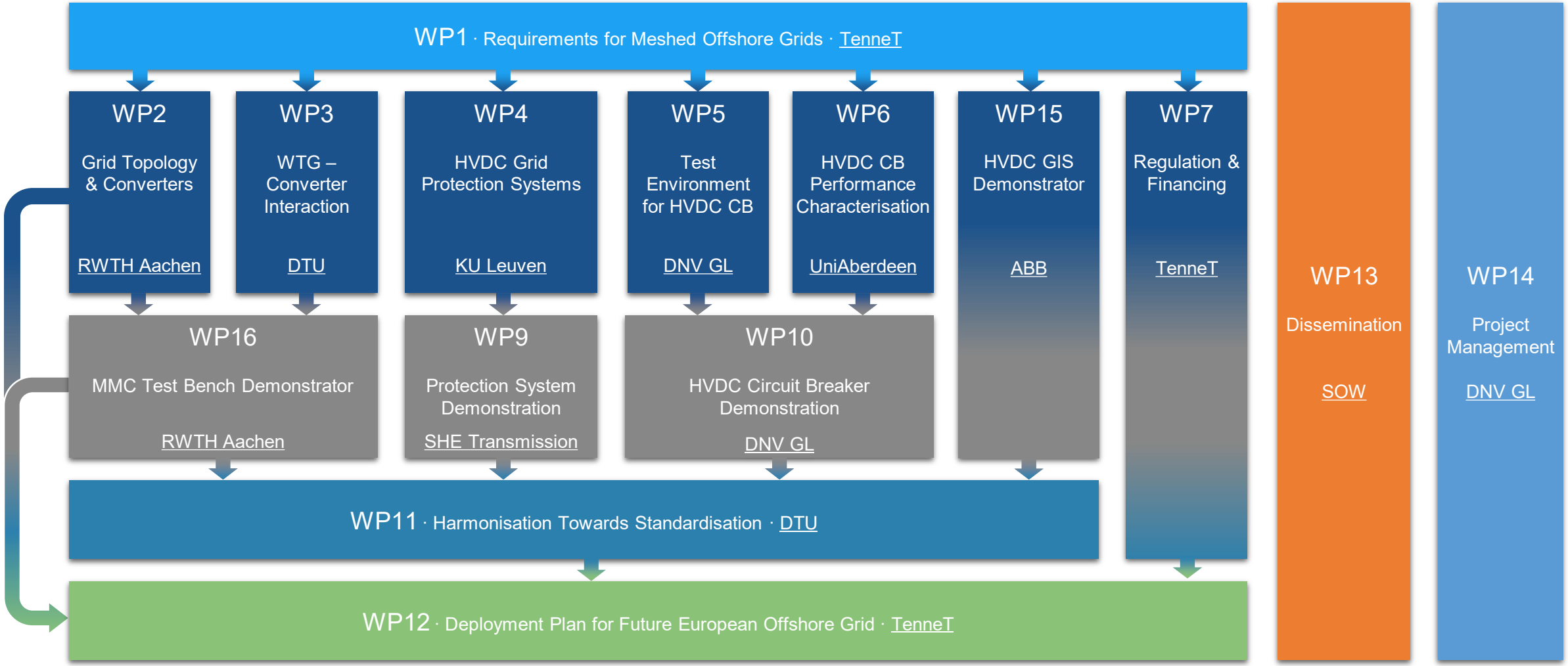
Work Packages



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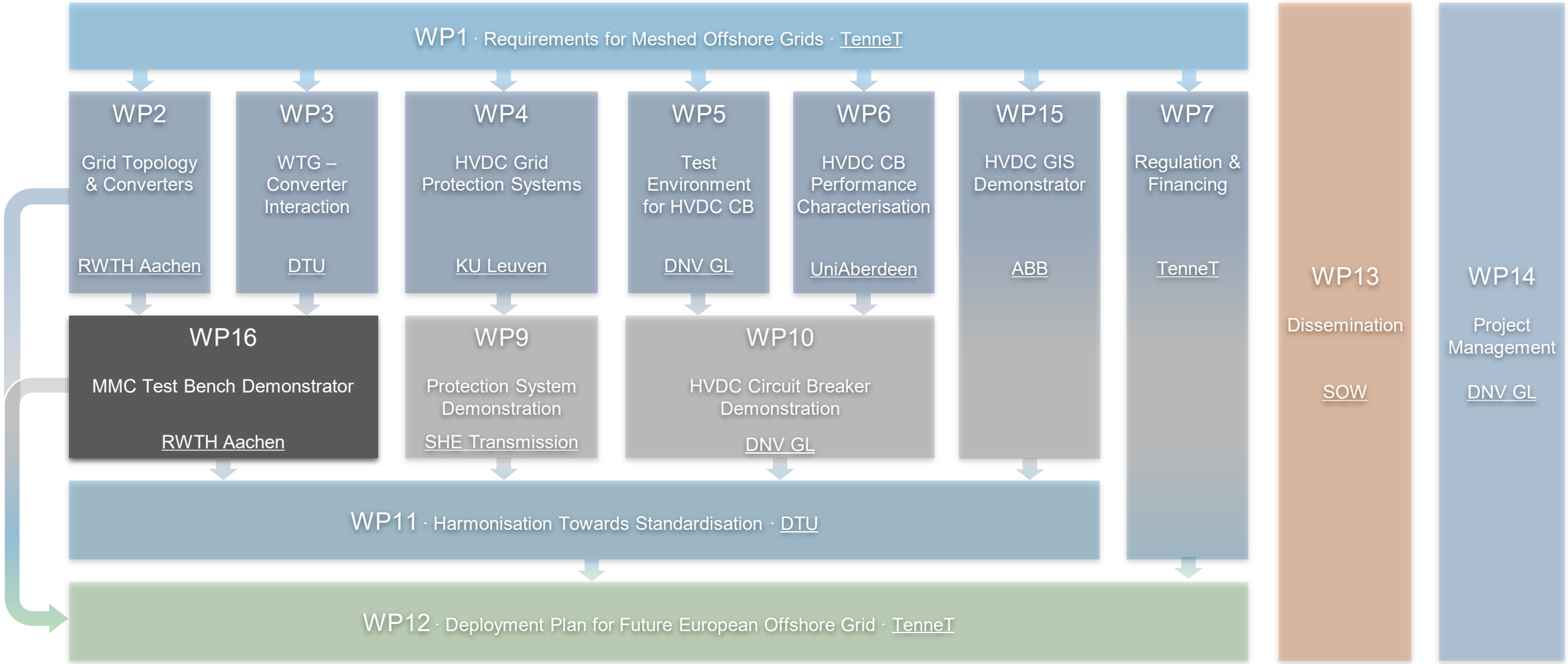
Work Packages



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Overview and Objectives of WP16

Motivation:

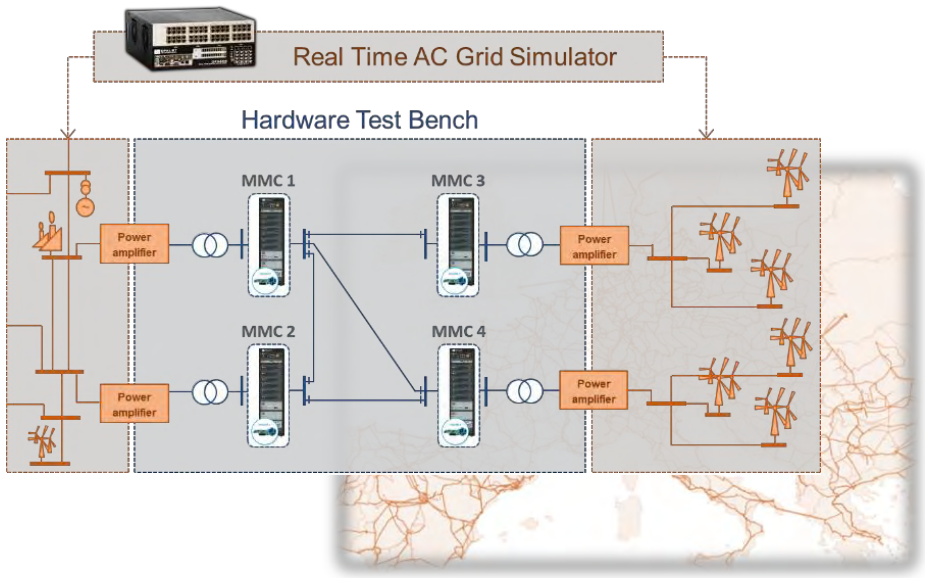
- Meshed offshore DC systems lead to novel challenges for TSOs, manufacturers and grid planners
- Experience missing concerning
  - Multi-terminal operation
  - Interaction with the large AC transmission systems
  - Interaction with offshore wind farms

Work Package 16: Investigation regarding the operation and control of meshed HVDC system

✓ Power Hardware in the Loop (PHiL)

✓ Control Hardware in the Loop (CHiL)

✓ Real-Time Simulation (RTS)



Objectives:

- **Demonstration** of applicability of developed controls and simulation models of PROMOTioN
- **Technical de-risking** for the deployment and continuous operation of meshed HVDC systems
- **Improvement** of certainty for road mapping process and standardization efforts

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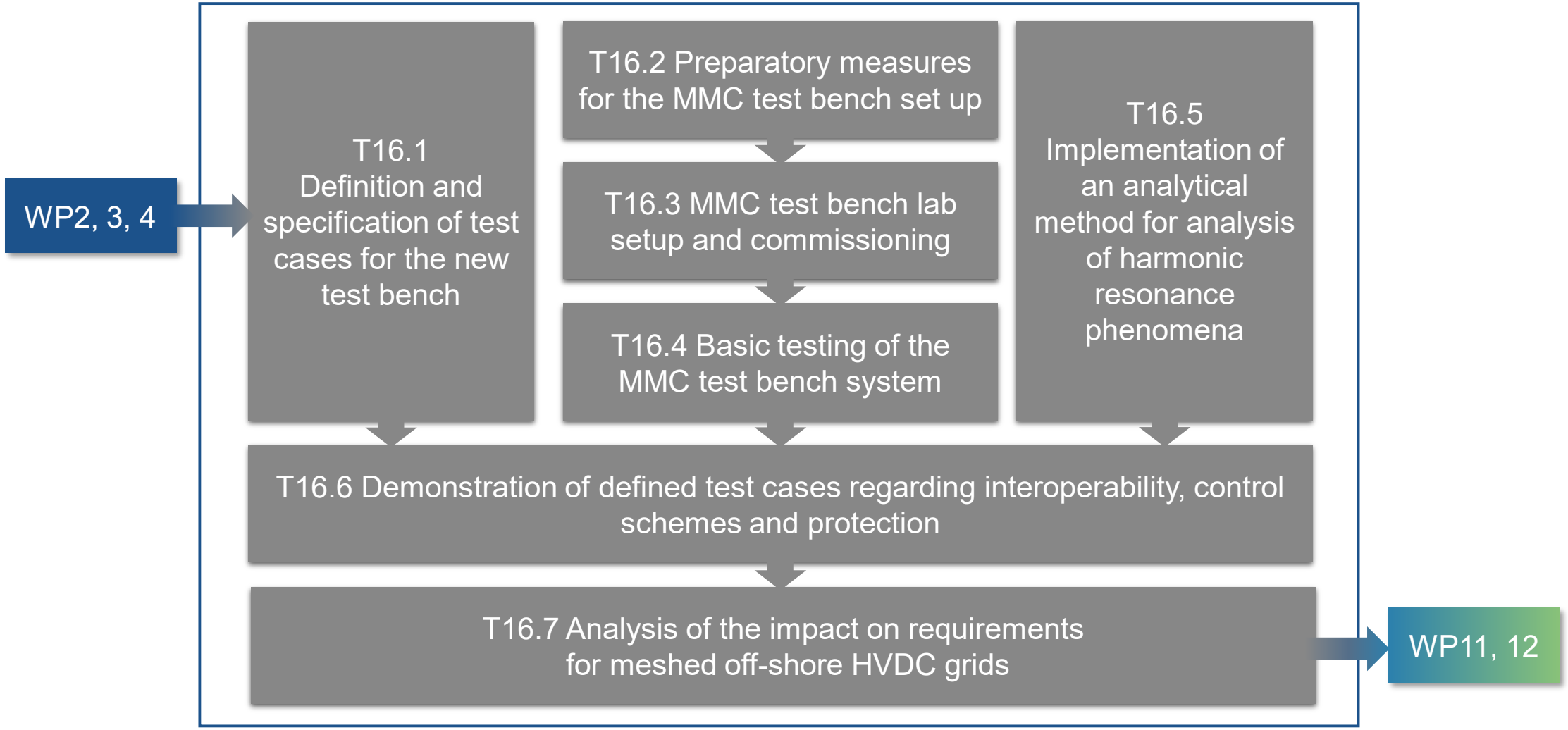
Task Structure of WP16



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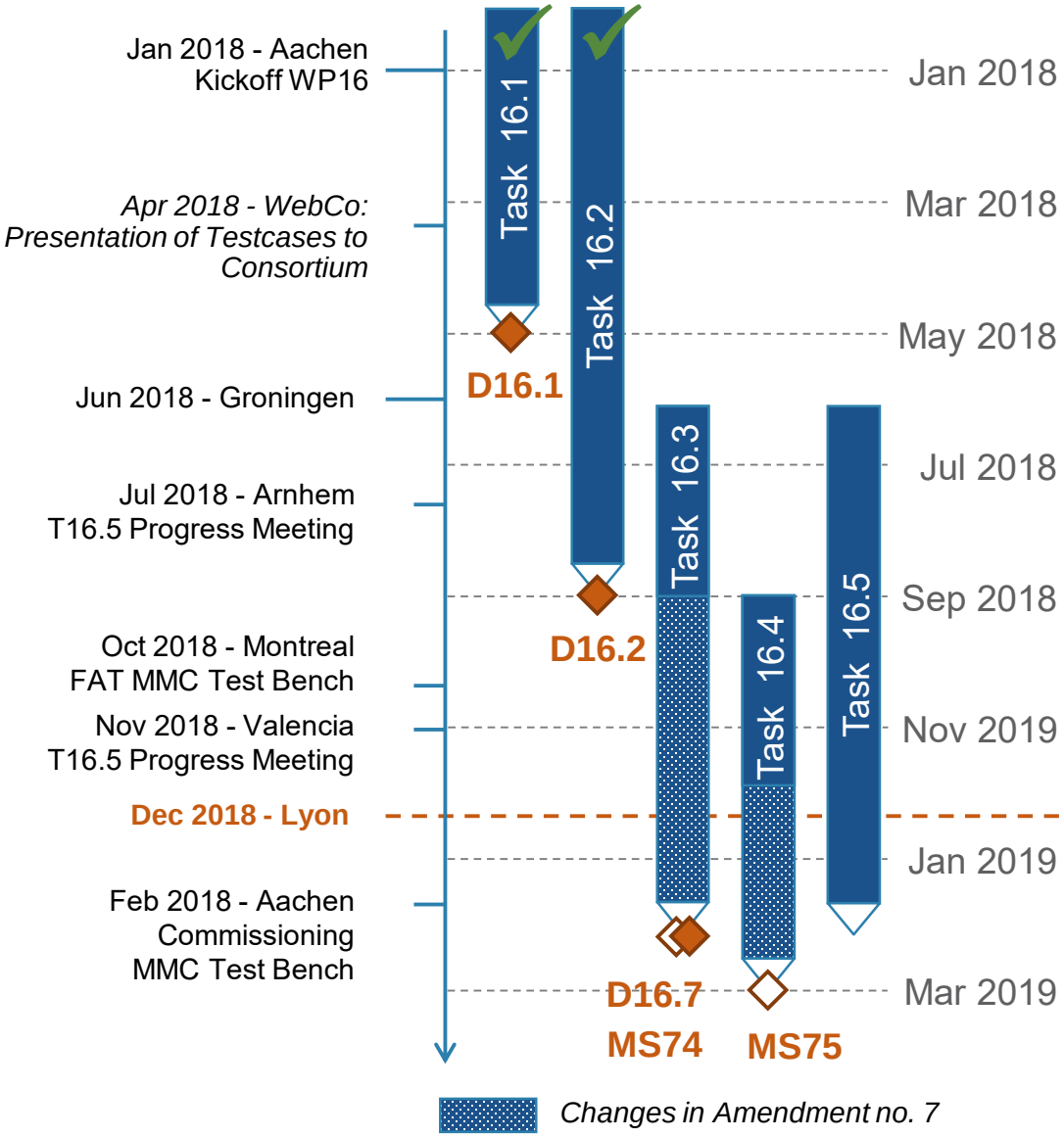
Progress

Milestones & Deliverables

MS / D	Due	Topic	
D16.1	28 (Apr 18)	Test case overview	✓
MS73	28 (Apr 18)	All test cases defined (alignment with WP2 and consortium)	✓
D16.2	32 (Aug 18)	Lab documentation	✓
D16.5	38 (Feb 19)	Analytical approach of converter impedance modelling	
MS74	32 → 38 (Feb 19)	Set up completed	
MS75	35 → 39 (Mar 19)	First tests completed	
D16.7	38 (Feb 19)	Update D16.2 *(new)*	
D16.3	47 (Nov 19)	Test case analysis for WP3	
D16.6	52 (Apr 20)	Test case analysis: WT Control + Protection HIL	
D16.4	53 (Mai 20)	Test case analysis WP3	



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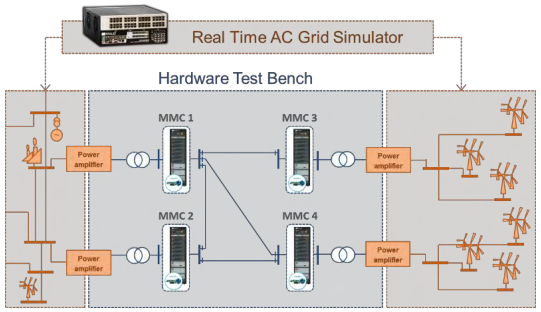
Deliverable 16.1

Definition and Specification of Test Cases

MTDC Test Bench - PHiL

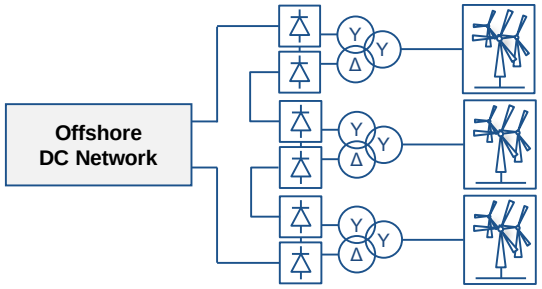


Test Cases

Demonstration of the controllability and interoperability offshore MTDC networks

- Grid & converter configurations
- Interaction MTDC network and OWP
- MTDC and OWP fault handling
- AC grid support with meshed offshore grids

Diode Rectifier Unit - CHiL

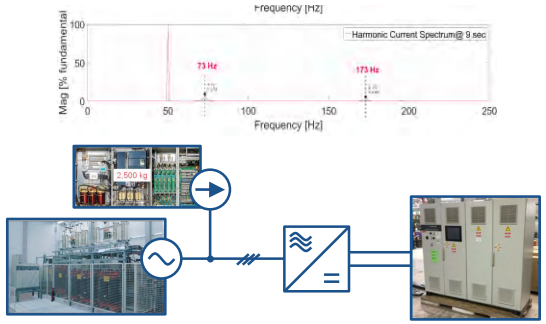


Test Cases

Demonstration of the operation of DRU-enabled wind turbine control systems

- in multi-terminal HVDC systems
- with actual wind turbine controls
- with commercial protection hardware
- black and brown start operation for wind farms in islanded control

Harmonic Resonance Studies



Test Cases

- Development and validation of impedance models of wind turbine and HVDC converters
- Analysis of harmonic stability and potential interactions of active components and the AC grid

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Deliverable 16.2

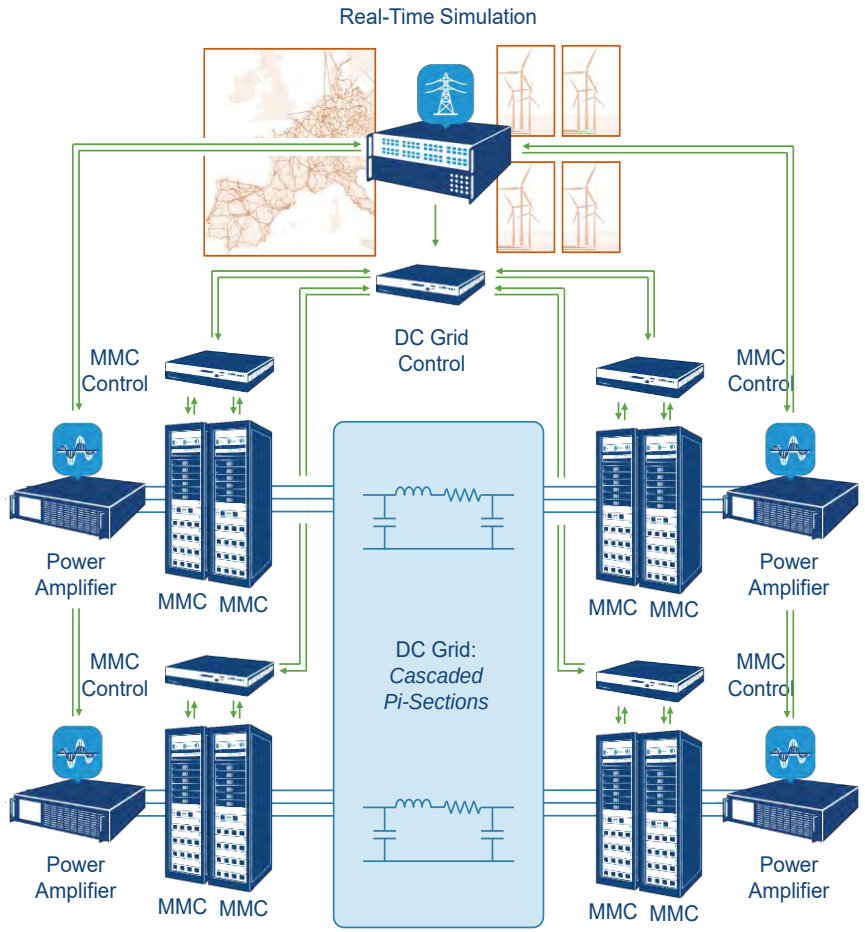
Lab Documentation of the MMC Test Bench

Detailed description of MMC Test Bench:

- Converters, transmission line, transformers, …
- Real-Time Simulators
- Power Amplifiers
- Laboratory Facilities

➢ Update after commissioning of the MMC Test Bench lab

Nominal DC Voltage	$V_{DC,n}$	400 V
Nominal DC Current	$I_{DC,n}$	15 A
Nominal Output Power	$P_{DC,n}$	6 kW
Nominal AC Voltage per phase	$V_{AC,1}/V_{AC,2}$	400/208 V (3ph-LL)
Nominal AC RMS current at fundamental frequency	I_{AC}	16.7 A
MOSFET Switching Frequency	f_{sw}	0-10 kHz
Number of Cells (Submodules)	n_{SM}	10
Nominal Cell Voltage	$V_{c,n}$	40 V
Cell Capacitor	C_{SM}	4.92 mF
Arm inductor	L_{Arm}	2.5 mH



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MTDC Test Bench - PHiL


FAT in Montreal – © M. Heidemann

Achievements:

- Specification (D16.2) and acquisition of the MMC test bench system (Manufacturer: OPAL-RT)
- Control model development
- Testing on “Digital Twin” of the laboratory MMCs
- Successful Factory Acceptance Test in Montreal

Stepping Stones:

- Delay in acquisition/delivery of the MMC Test Bench system → December 2018

Next Steps

- System setup in Jan19 & commissioning (beginning of Feb19) → MS79
- Comparison between simulation and PHIL (Mar19)
- Execution of the defined test cases (starting in Apr19)

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Diode Rectifier Unit - CHiL

Achievements:

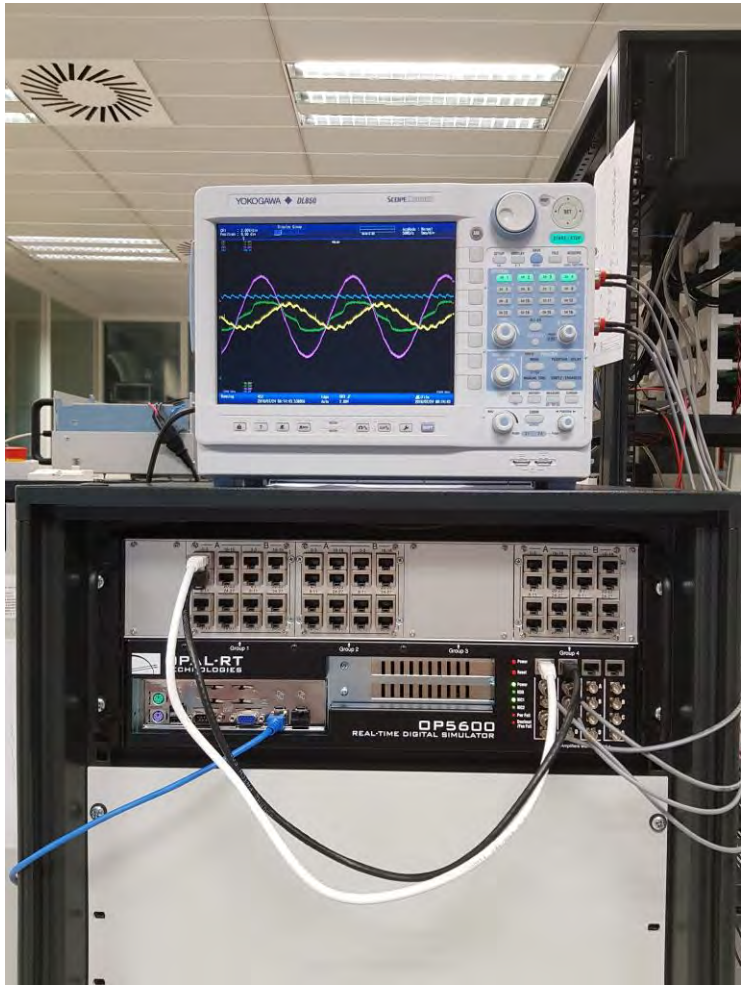
- Implementation of DRU models and wind turbine controls from WP3 on real-time simulators (RTS)
- Development of an interface for the integration of external control and protection hardware to RTS
- ➢ CHIL Protection Real-Time demonstrator prototype completed

Stepping Stones:

- Delay in acquisition/delivery of commercial relays P543 MiCOM: 5433CR1BM0H98M (Schneider)

Next Steps

- CHIL Protection Real-Time demonstrator prototype completion MS79 (M46 – Oct19)



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Harmonic Resonance Studies

Achievements:

- Specification and acquisition of the wind turbine converter controller replica and 1 MW physical converter
- Commissioning of WT PHIL test system

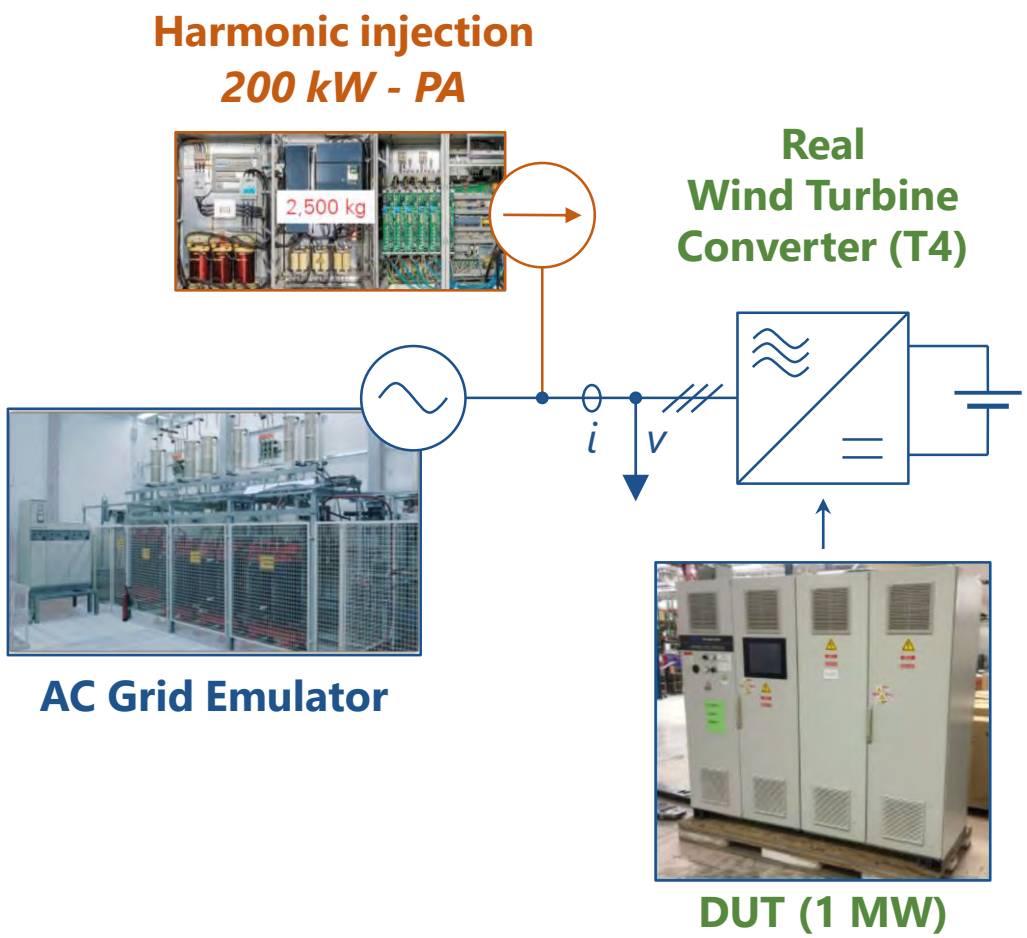
Stepping Stones:

- Logistics of 1 MW physical Inverter
- Measurement methodology for input admittance and validation method

Next Steps

- CHIL input admittance measurement and validation methodology development
- ➢ **D16.5: Implementation of an Analytical Method for Analysis of Harmonic Resonance Phenomena (M38)**
- Commissioning of 1 MW Inverter

Flexible Power Grid Lab @ DNV GL



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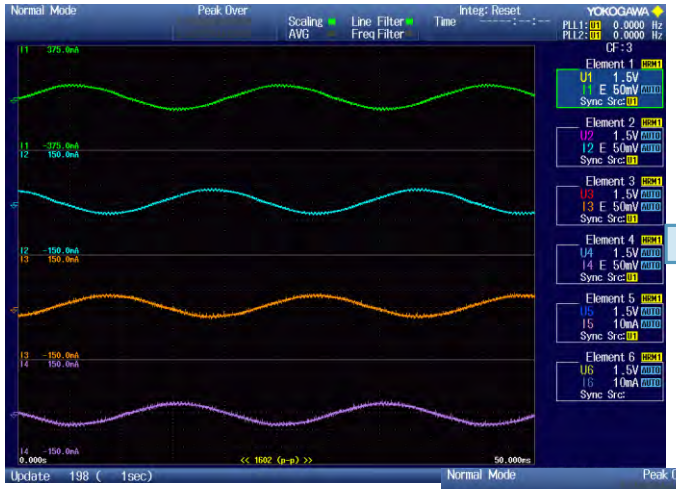
11

Wind Turbine PHIL Test System

Achievements:

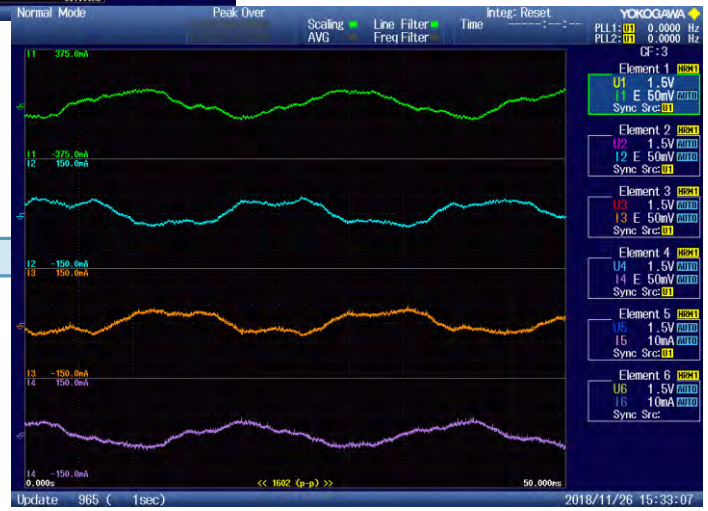
- Commissioning of WT PHIL test system
- Accurate FPGA sampling compensation enabled for the PWM input.
- Back-to-Back wind turbine model is built in matlab/simulink

Converter Currents:



FPGA compensation for PWM input

CPU only



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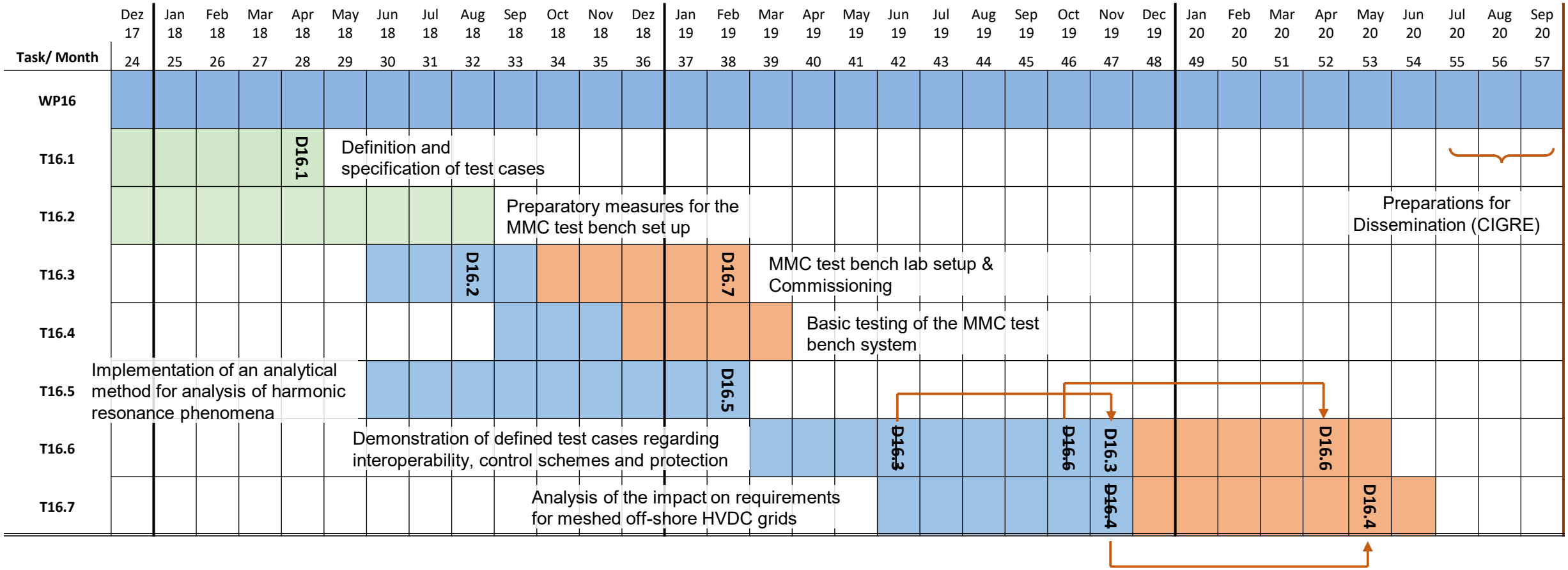
Amendment no.7

Impact on WP16



D16.3 - Test case analysis WP3 **D16.4 - Test case analysis** **D16.6 - WT Control + Protection HIL**

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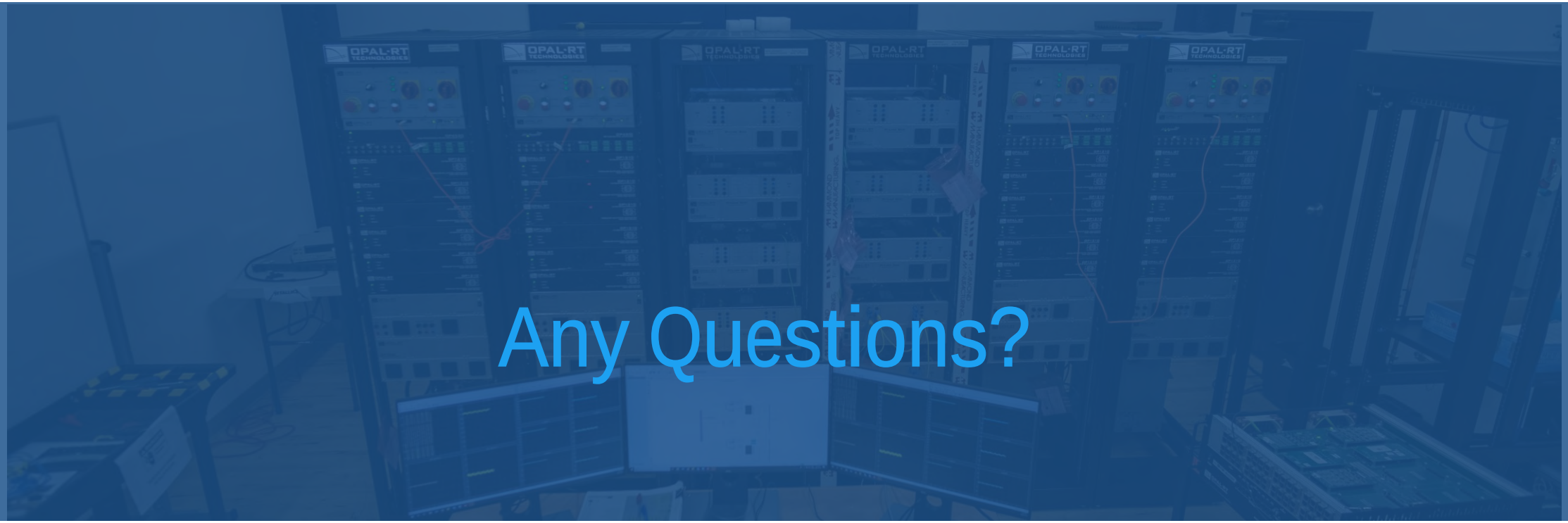

Any Questions?

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APPENDIX

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PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

WP 12 GA Vote Slides

Alignment on the CBA

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

Agenda

Introduction

Voting block 1: (Tim: Vote 5, 6 & 7)

Voting block 2: (Yongtao: Vote 1)

Lunch

Voting block 3: (Olivier: Vote 2, 3 & 4)

Updates Topologies & Security (Olivier & Dirk)

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Introduction on GA votes
John (TenneT)

What does Choice mean?

Why a voting session:

1. Within PROMOTioN WP12 is intended to build consensus. A lot of positive work is done outside these meetings, but we wish to include the whole GA

2. The Concepts we are developing represent “realistic options” to ILLUSTRATE potential outcomes:
   1. Reality will almost certainly be different
   2. We cannot calculate out all potential solutions.

3. The voting process is not strictly necessary, and we can in most cases live with a “Yes” or a “No”.
   1. However a “No” requires an alternative realistic solution, provided by the person or organisation objecting to the sum.
   2. This may also lead to timing delays as WP12 works through the new assumptions.

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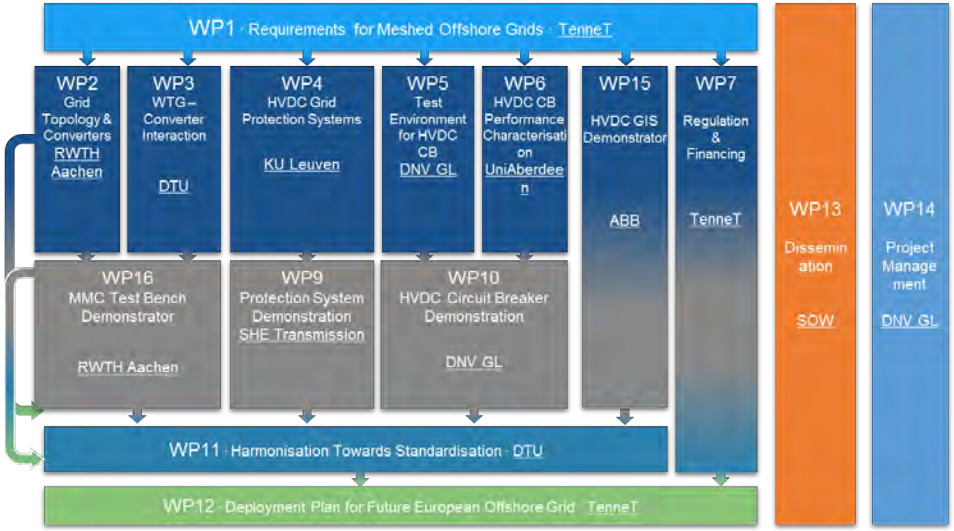
Important points



1. The formulation of the Grant Agreements indicates a flow of Conclusions and Recommendations to WP12
2. We realise that this is unreasonable and have been working on a dialogue
3. WP12 was also late in signalling to other WPs the scale of the Grid to be proposed.
4. Good cooperation received from other WPs, and inputs and assumptions for modelling are based on these.

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What does choice mean?

1. In an illustration, different choices could have been made, both in Topology and in Technical choice.

2. Our assumptions represent:
   1. ambition: e.g. in the choice of a Voltage and in the scope of the topology and
   2. reserve, e.g. in the grid constraints, which while constantly under review, are difficult to change.

3. If there is time, some sensitivities checking different options may be done, if we have straight outcomes and extra time

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Consequences of non-agreement

1. In the CBA we do have to make assumptions to get to real topologies. These illustrate Concepts/Scenarios.

2. **Without agreement on basic assumptions, D12.2 and D12.3 cannot continue and PROMOTioN will be delayed**

3. We will include the options and arguments leading to the decision in the analysis, but cannot calculate each potential technical solution.
   1. We need to limit what we take into account
   2. We need to tighten the Deployment plan scope

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Process of voting

1. The vote is introduced

2. Argumentation for the votes are given
   1. Questions can be asked during the presentation
   2. Please save comments/opinions till after

3. The vote is brought up on the screen

4. The floor is opened for discussion
   1. We have to stick to schedule otherwise we will not finish

5. At a set time (indicated by DNV GL): Voting will happen

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Voting block 1: (Vote: 5, 6, 7)

Tim Kroezen (TenneT)

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The use of Diode Rectifier Units is not taken into account quantitatively in the CBA, but its use could be described as future option.

November 28, 2018

The use of Diode Rectifier Units is not taken into account quantitatively in the CBA

- DRUs can
  - Work in combination with offshore wind (PROMOTioN WP3 has done work on the AC side)
  - Offer a savings potential for radial grids (due to reduced size/weight)
- Deployment plan to be built on “generic” converters. Simple calculations on potential savings for DRUs can be made.
  - E.g. for radial grid → calculate costs saved if platforms are smaller (where information is available)
- So far, there are no conclusions on whether meshing works for DRUs. Thus, it cannot be taken into account for the CBA.

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Vote 5: The use of Diode Rectifier Units is not taken into account quantitatively in the CBA, but its use could be described as future option.

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PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

DC/DC converters remain out of the technical scope of PROMOTioN (1). A financial margin is applied to account for potentially required investments.

November 28, 2018

DC/DC converters remain out of the technical scope of PROMOTioN (1). However, due to the possible need for advanced power flow control, an additional financial margin is applied to account for potentially required investments.

- Within PROMOTioN no detailed research has been carried out on DC/DC converter requirements. As DC/DC converters were taken out of scope in WP 1.

- However, given the complexity of the proposed topologies, DC/DC converters may be required.

- Therefore, PROMOTioN will perform the CBA without taking DC/DC converters into account, but will account for an additional financial investment requirement.

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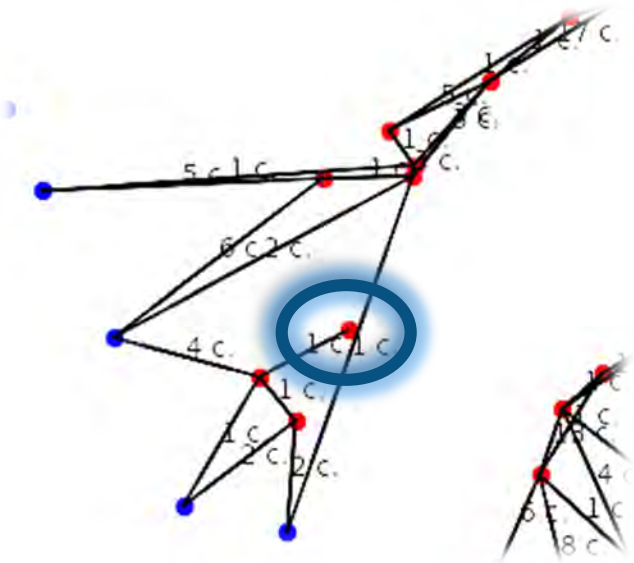
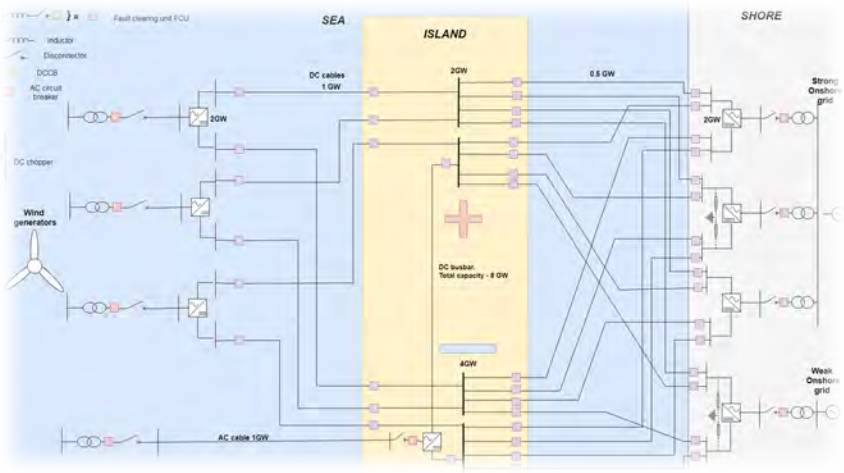
Can we control power flow in complex structures?





We do not know, and we do not have the time to research it within PROMOTioN (1).

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Vote 6: DC/DC converters remain out of the technical scope of PROMOTioN (1). However, due to the possible need for advanced power flow control, an additional financial margin is applied to account for potentially required investments.

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PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

HVDC MOGs will consist of true bipole connections (within PROMOTioN). For Radial connections monopoles are allowed.

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HVDC MOGs will consist of true bipole connections (within PROMOTioN)

- We do not anticipate that the combination of monopoles and bipoles is realistic.

- For radial connections: monopoles are allowed

- For meshed grid structures true bipole connections are required for protection & control in more complex grid structures.

- Maximum capacity used per pole will comply with current maximum allowed loss of infeed for the respective area; an increase of this maximum is not anticipated.

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PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Vote 7: HVDC MOGs will consist of true bipole connections (within PROMOTioN). For radial connection monopoles are allowed.

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Voting block 2: (Vote 1)

Yongtao Yang (DNV GL Norway)

Vote 1

The GA accepts the current cost document for use in the CBA

- ↗Document to be circulated separately
- ↗Presentation and Discussion took place in Brussels
- ↗Is additional discussion required – please inform Cees/John

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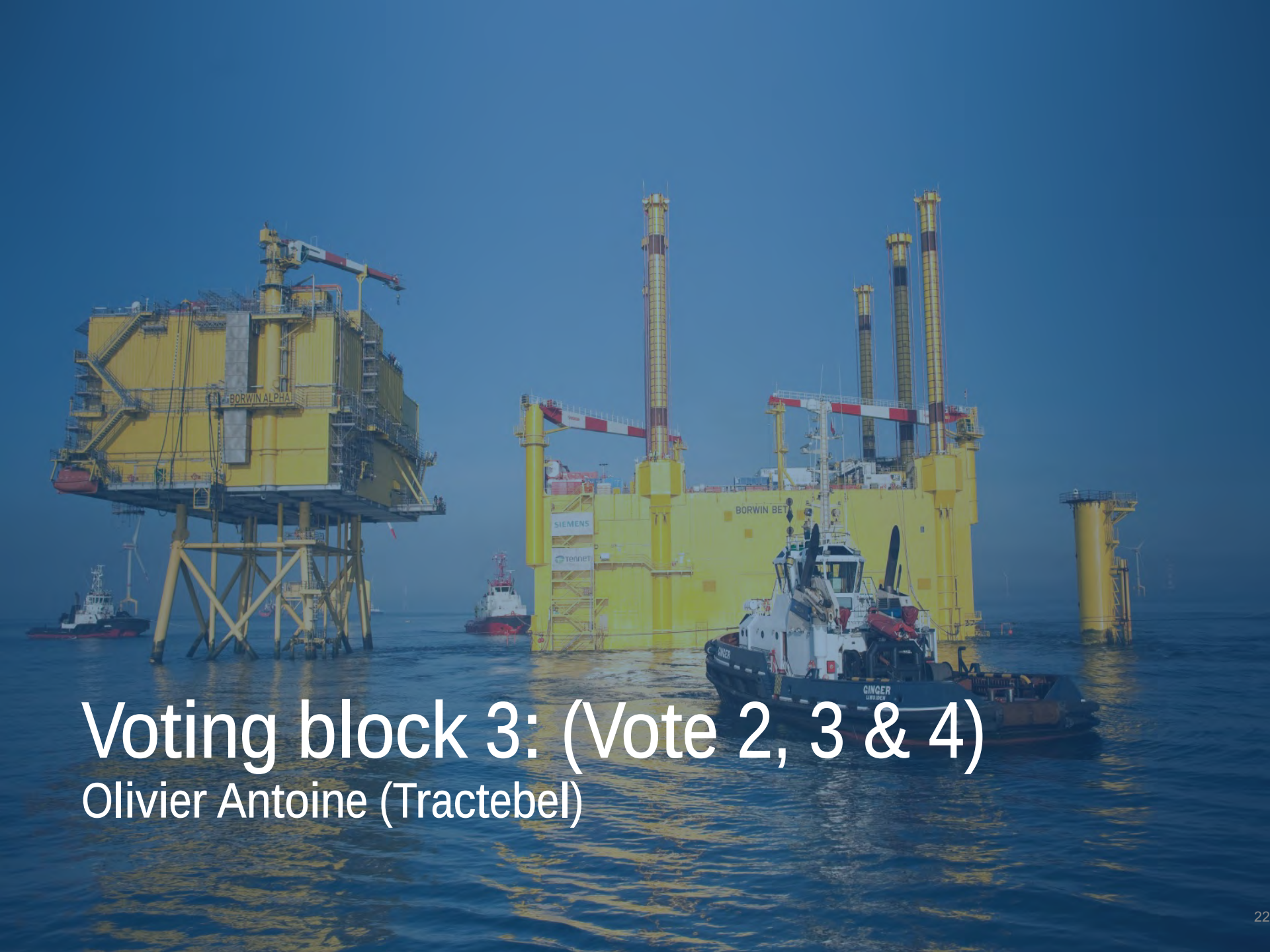

Voting block 3: (Vote 2, 3 & 4)

Olivier Antoine (Tractebel)

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

The GA accepts the 525kV as the overall used voltage for the CBA

Vote 2

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CONTENT

- General considerations
- Proposition

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General considerations

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Cigré TB684 - Recommended voltages for HVDC grids

	Design for target power value		Design for highest available power		AC to DC conversion
Recommended DC voltage	**Power range GW**	**Over head**	**Available cable voltages ***		**AC voltage (ph–ph)**
± 100, 150, 200 kV	Application specific	No inherent limit	EXTR	MI	
± 250 kV	< 0.5				245 kV
± 320 kV	(0.5) – 1.0		320 kV	Used commer-cially	362 kV
± 400 kV	(1.0) – 1.5		Tested		362 kV & 420 kV
± 500 kV	(1.5) – 3.0		525 kV		550 kV
± 600 kV	(3.0) – 4.0			600 kV	
± 800 kV	(4.0) – 8.0				
± 1100 kV	< 12				

* Corresponding DC voltages
As of end 2016

Question: will the MOG use 320kV, 525kV or higher voltage levels?

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Recent projects

- ↗NordLink
  - ↗1.4 GW
  - ↗623 km
  - ↗±525 kV
- ↗ElecLink
  - ↗1.0 GW
  - ↗69 km
  - ↗±320 kV
- ↗NEMO Link
  - ↗1.0 GW
  - ↗140 km
  - ↗±400 kV
- ↗North Sea Link
  - ↗1.4 GW
  - ↗730 km
  - ↗±515 kV
- ↗IFA2
  - ↗1.0 GW
  - ↗204 km
  - ↗±320 kV
- ↗ALEGrO
  - ↗1.0 GW
  - ↗90 km
  - ↗±320 kV

For 1 GW, the voltage level is limited to 320-400 kV, but 525 kV is used already for 1.4 GW

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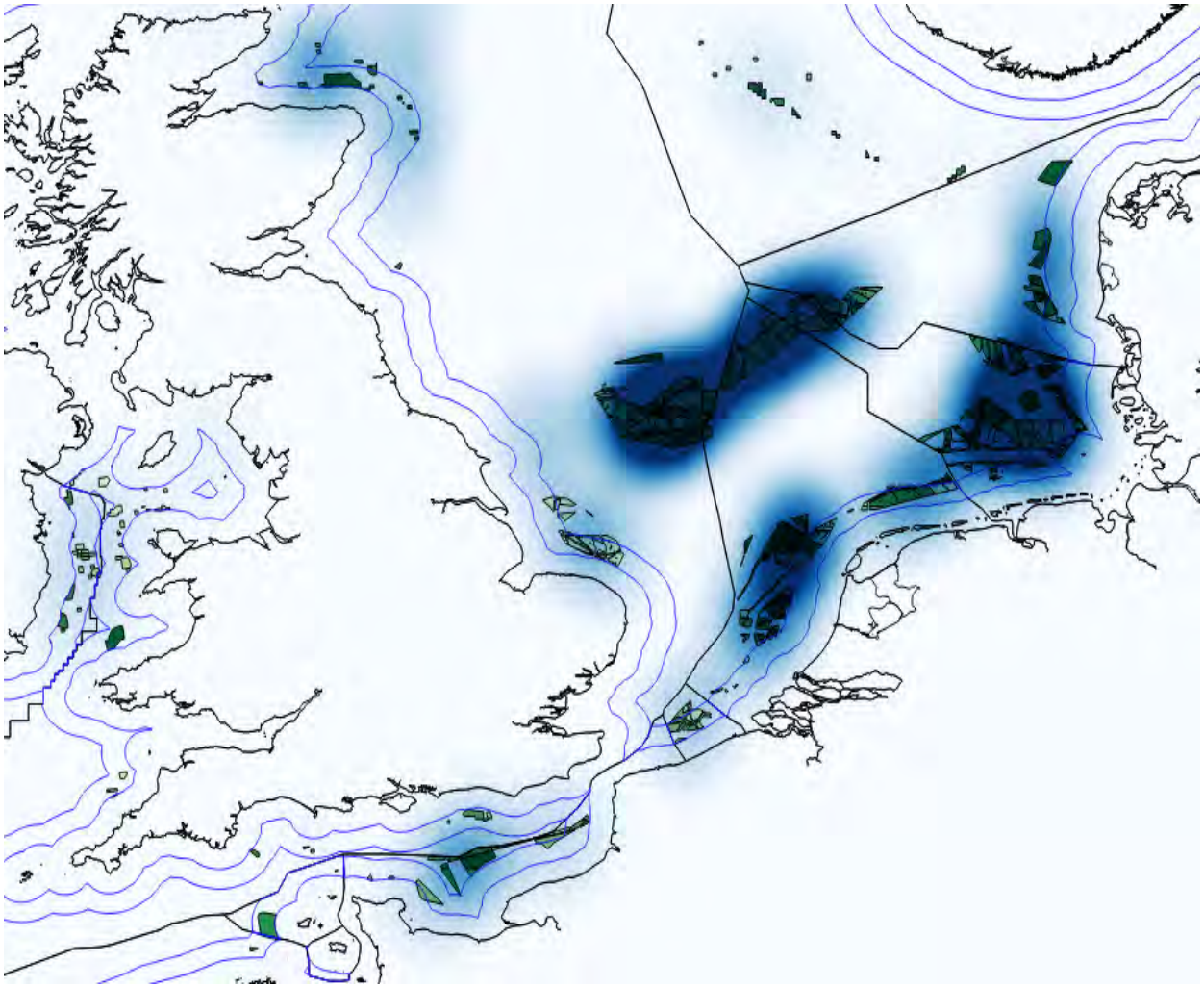
High scenario (~200GW in 2050)



North Seas
= North Sea
+ Skagerrak
+ Kattegat
+ Irish Sea
+ Channel

A meshed grid is not going to connect the North Sea to the Channel and to the Irish Sea…

Most of the off-shore wind farms will be installed in the North Sea

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

Proposition

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Proposition

- Use of two voltage levels
  - North Sea: 525 kV
    - High amounts of offshore wind energy to evacuate
    - Maximum loss of power infeed higher than 1400MW
    - Maximum length ~300km
  - Irish Sea + Channel: 320 kV
    - A few GWs spread
    - Maximum loss of power infeed limited to 700MW

- Impact:
  - Simplifying assumption
  - Encourage meshing in the development of topologies
  - Provide adequate topologies for a CBA analysis

Voltage (kV)	Rating of the pair (MW)
±320	700
	900
	1200
±525	1000
	1400
	1600
	2000

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Vote 2

The GA accepts 320kV as voltage level used in the Channel and Irish sea, and 525kV as the voltage used in the North Sea for the CBA?

- ↗Yes
- ↗No
- ↗Abstention

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PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Vote 2: The GA accepts the 525kV as the overall used voltage for the CBA. (And 325kV for low English channel / iris sea)

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PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

The GA accepts the current maximum infeed losses as security limitation Vote 3

November 27, 2018

What are planning criteria?

- In a nutshell: reliability (adequacy & security) requirements
  - The power system must be able to accommodate power flows and endure contingencies while staying within acceptable working conditions
- Transmission planning criteria typically cover
  - The system states and the contingencies (including faults) to study
  - The acceptable system operating limits in normal operation (pre-contingency) and post-contingency states
  - The acceptable response of the system to outages and to fault disturbances

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General ideas

- We do <u>not</u> want a hard N-1 constraint on offshore grids such that the offshore grid has to withstand the loss of any single element without offshore wind curtailment
- However, as the offshore grid is part of the European power system, we want some form of N-1 security
  - A single contingency in the offshore grid should not lead to major disturbances in the onshore grid
    - E.g. it should not lead to load shedding
  - The impact on the onshore grid should be limited to the maximum loss of power infeed

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Planning criteria used in the development of the topologies

- Planning criteria under normal operating conditions
  - Deterministic operating conditions: grid is sized to evacuate all the installed off-shore wind
  - No curtailment allowed when all equipment are available (i.e. DC lines within their thermal and voltage limits)
- Planning criteria post-contingency:
  - Stability of the DC-grid must be maintained
    - No uncontrolled cascading outage is allowed (but the disconnection of an offshore wind farm radially connected, or an action of an automatic Remedial Action Scheme is allowed)
    - Electrical variables (e.g. power flows, voltages) must be within emergency operating limits just after the contingency, once the automatic voltage droops of converter controller have stabilized the system, and they should go back to normal (continuous) operating limits after system adjustments.
  - Stability of the AC-grid must be maintained
    - No changes to the existing planning criteria
  - No load shedding is allowed
  - It is proposed to consider as single contingency the loss of a converter, the loss of a cable with or without a fault and the loss of an overhead line (OHL) with or without a fault

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Proposition

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In practice

- Cables and converters are sized to evacuate all the wind power production in all operating conditions when all equipment are in service
- The DC-grid is designed to limit the permanent loss of power infeed into a specific synchronous area below the currently used reference incident
    - Continental Europe: 3 GW
    - Nordic: 1.35 GW
    - GB: 1.85 GW
    - Ireland: 0.5 GW

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The GA accepts the current maximum infeed losses as N-1 security criterion

↗Yes

↗No (proposition of another criterion?)

↗Abstention

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PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Vote 3: The GA accepts the current maximum infeed losses as security limitation

Continental Europe: 3 GW
Nordic: 1.35 GW
GB: 1.85 GW
Ireland: 0.5 GW

November 27, 2018

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

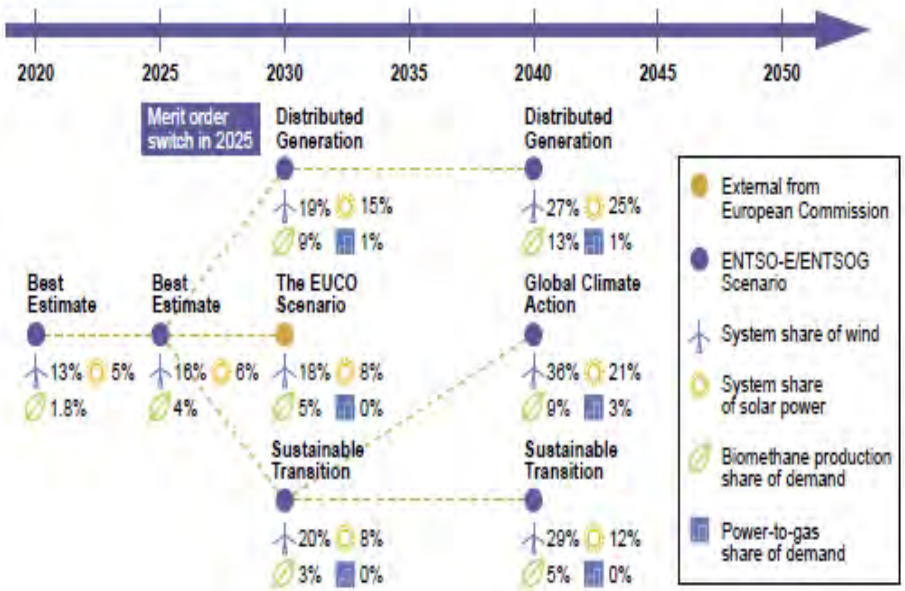
The GA accepts the Load & Onshore generation profiles from TYNDP as input for the CBA with extrapolation to 2050 Vote 4

November 28, 2018

Scenarios of the TYNDP2018 as a basis

- Already designed with assessment of transmission assets in mind
- Familiar to many stakeholders and the EC

Figure 1: The scenario building framework for TYNDP 2018. Renewable Energy Systems (RES) share of demand for electricity and gas



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Matching PROMOTioN with 2030/2040 ENTSO-E scenarios

Distributed Generation — Low offshore

- DG scenario is about distributed solutions and therefore sees higher solar deployment.
- It is also of interest to maintain one scenario with a high ratio of solar to wind generation

Global Climate Action — High offshore

- GCA has highest overall RES penetration (by 2040), so it makes sense to combine this with the High offshore.

Sustainable Transition — Central offshore

- ST has a lower RES penetration than GCA, so it makes sense to combine it with the Central offshore

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Adjustments

- Adjustments are necessary
  - Not exactly the same offshore wind capacity in the North Seas!
- Proposition : adjust the on-shore RES (wind, PV) in the ENTSO-E scenarios in the least intrusive manner by trying to respect the following principles
  - Total dispatchable RES production (onshore + offshore + solar PV) remains constant
  - Ratio Solar PV to onshore wind remains constant
  - Distribution of technologies between countries remains constant

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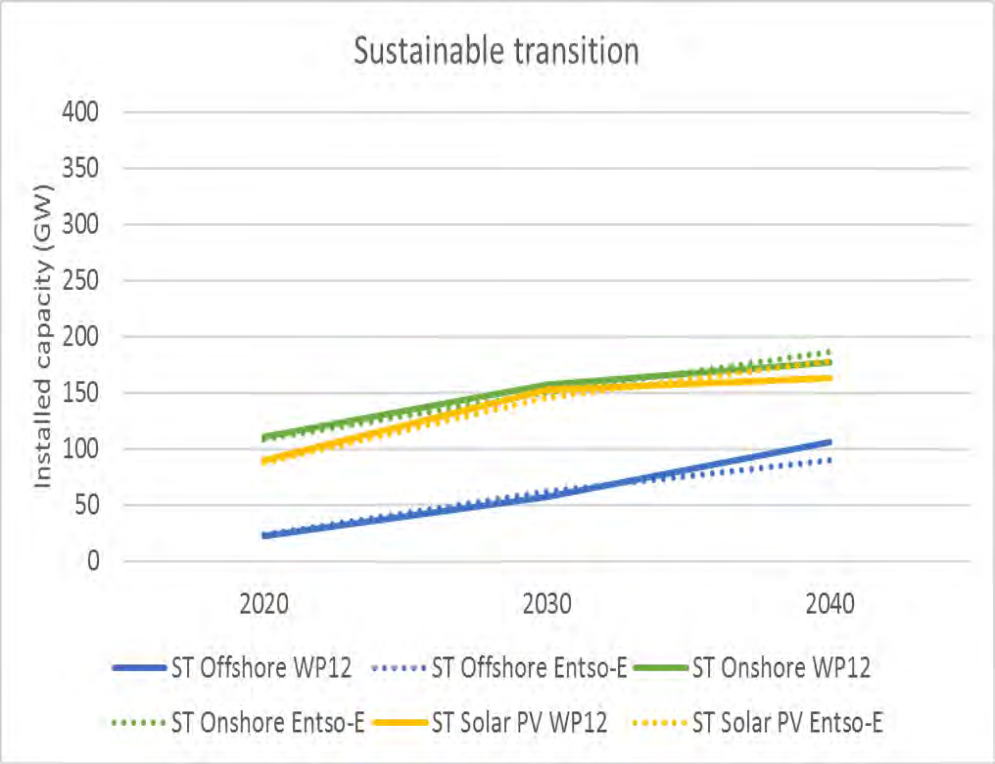
Adjustments

- Reworked Sustainable Transition (ST)
  - Amount of non-dispatchable RES remains limited after adjustment
  - The adjustment is closely in line with the initial ENTSO-E scenario



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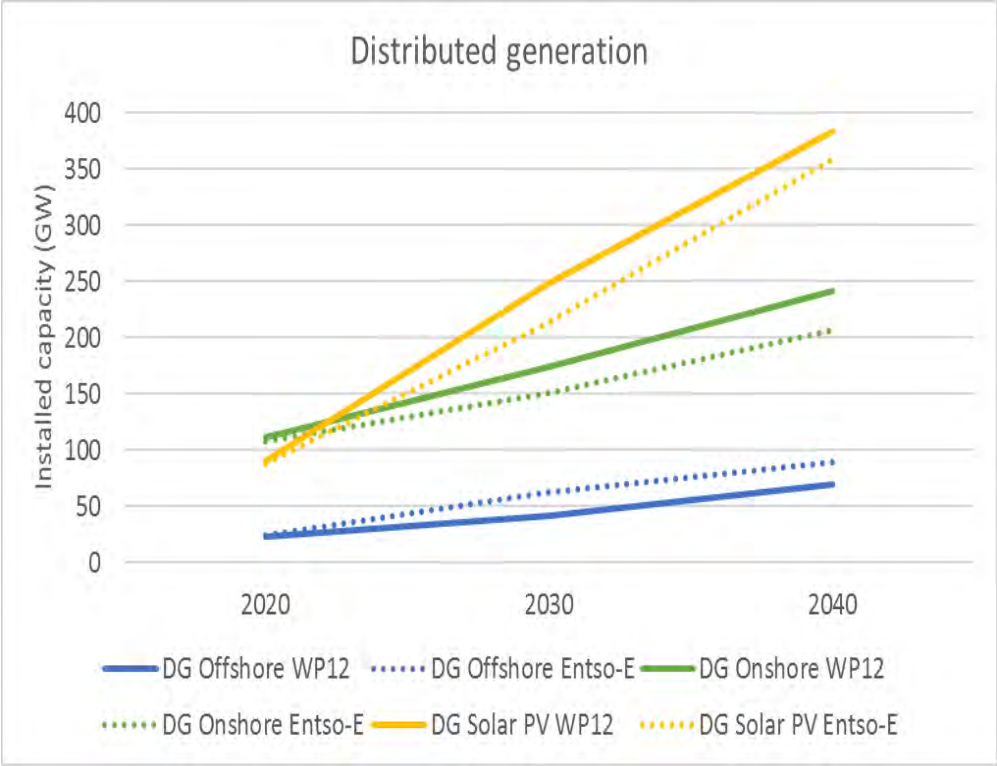
Adjustments

- Reworked Distributed Generation (DG)
  - Solar PV remains the strongest in terms of capacity
  - Offshore wind is adjusted downwards. This is compensated by an increase in onshore wind and solar PV



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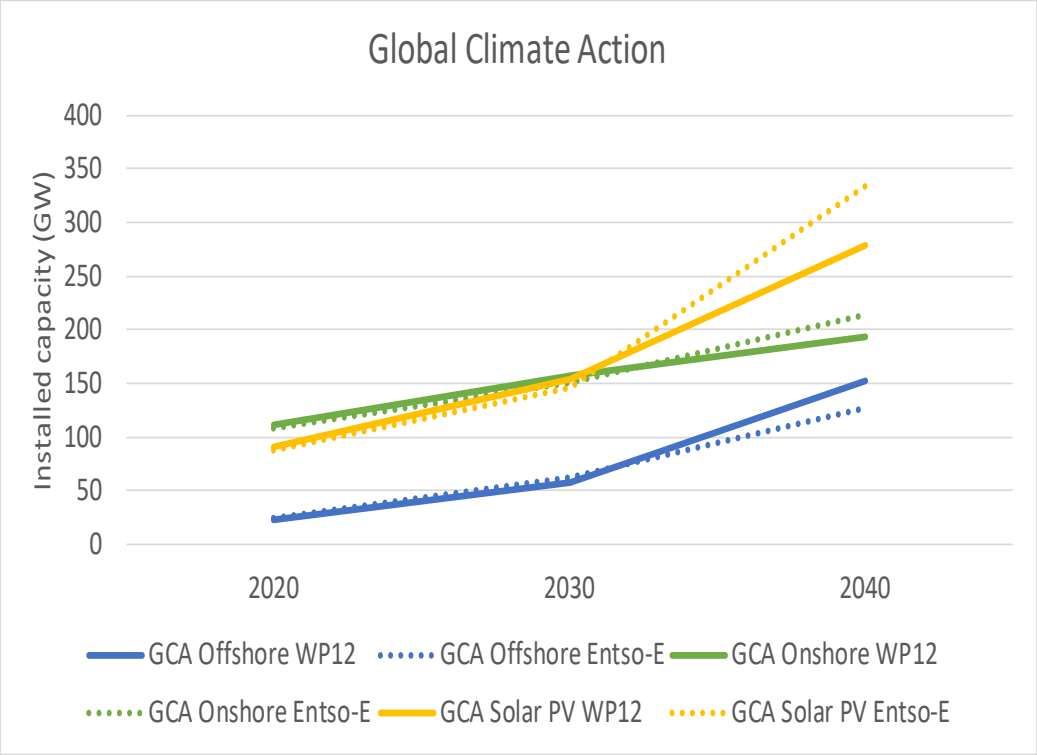
Adjustments

- Reworked Global Climate Action ((ST-)GCA)
  - Higher amount of non-dispatchable RES is kept compared to other scenarios.
  - The increase in offshore wind generation is compensated by a decrease in onshore wind and PV



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Extrapolation to 2050

- Main assumptions
  - Demand: Continue with weighted average growth rate of 2035-2040 (all the countries grow in parallel)
  - RES: Continue growth rate; maintain tech proportions; ensure 2050 targets are met
  - System load factor: Continue growth rate of 2020-2040
  - Fuel prices: Hold flat at 2040 value

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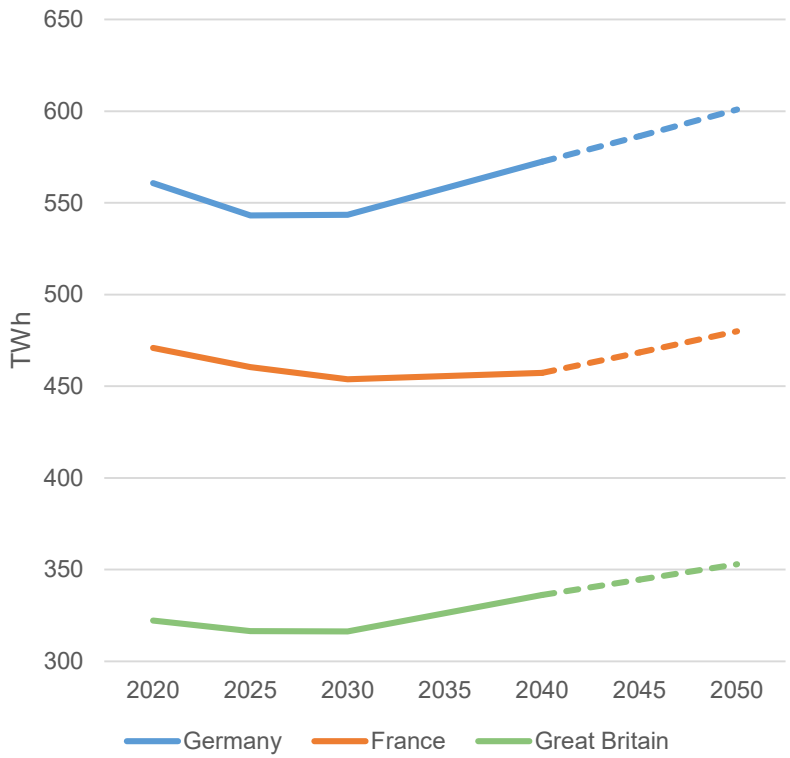
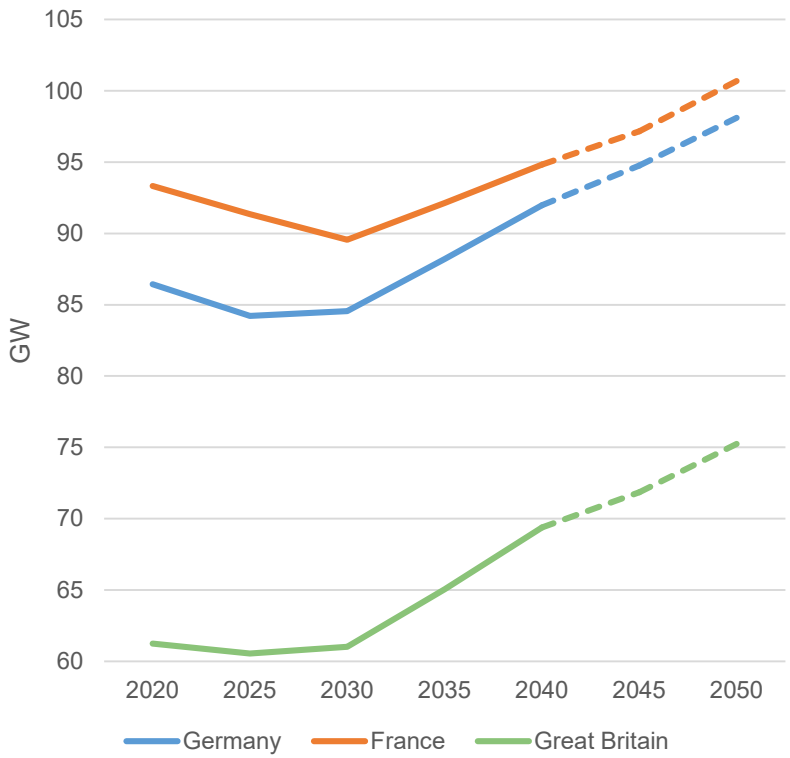
Extrapolation to 2050

↗Example: energy and peak load projections GCA





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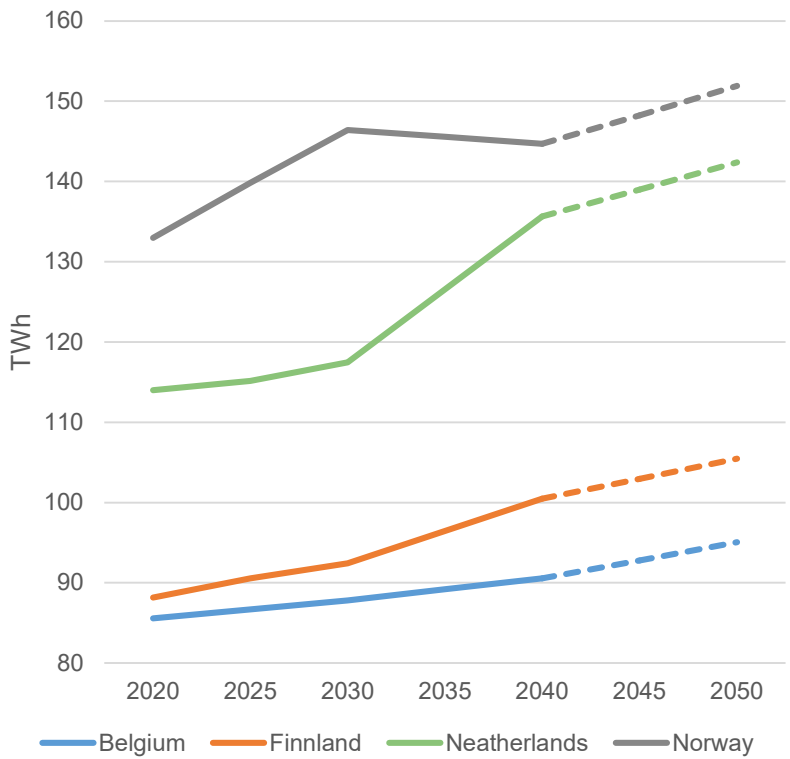
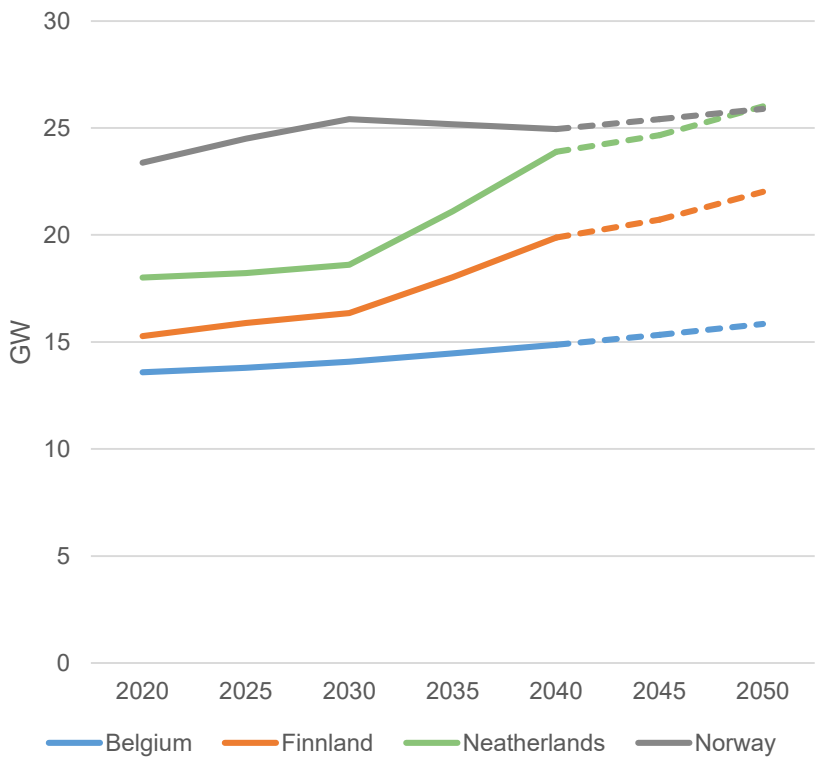
Extrapolation to 2050

↗Example: energy and peak load projections GCA





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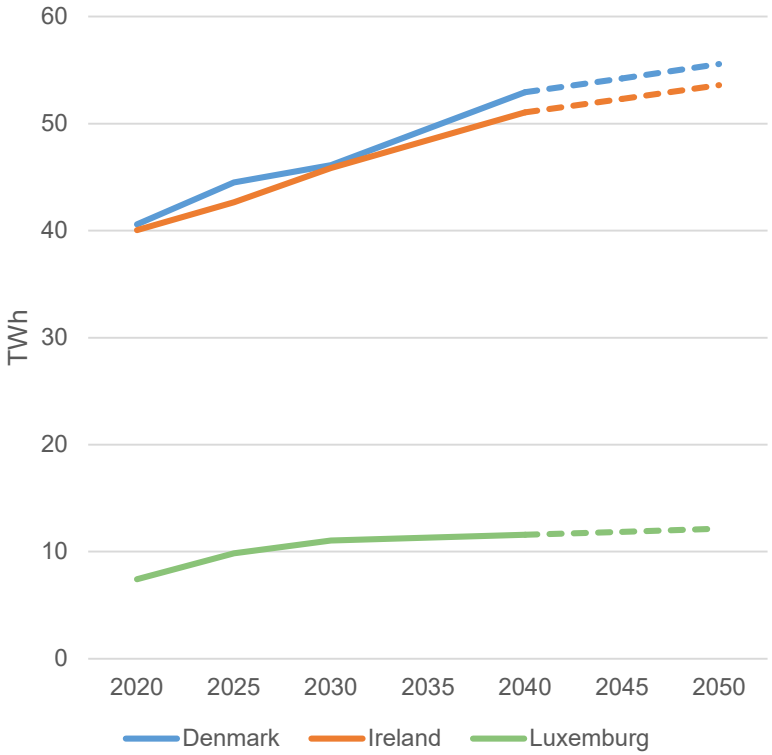
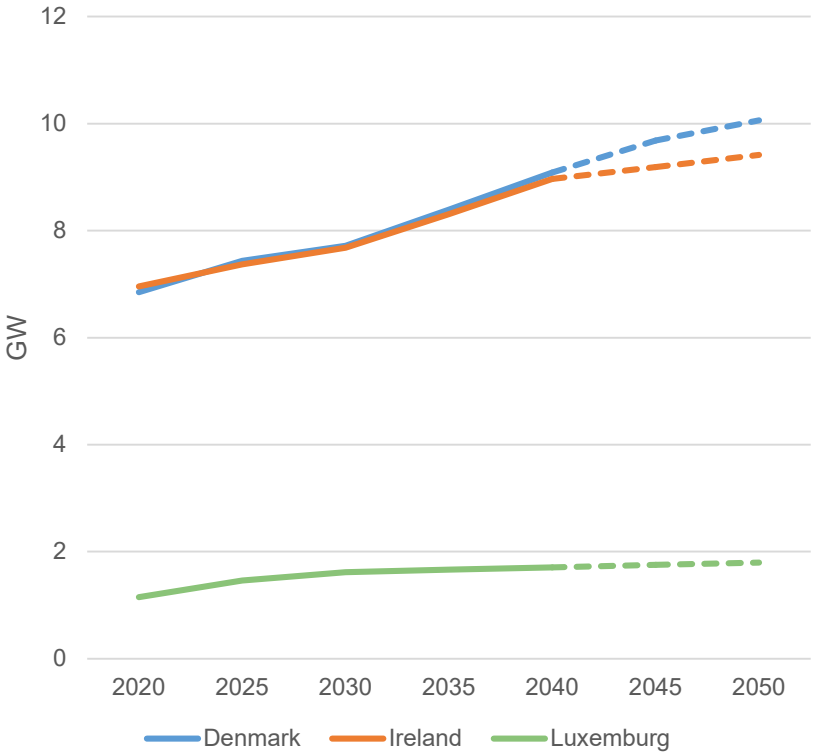
Extrapolation to 2050

↗Example: energy and peak load projections GCA

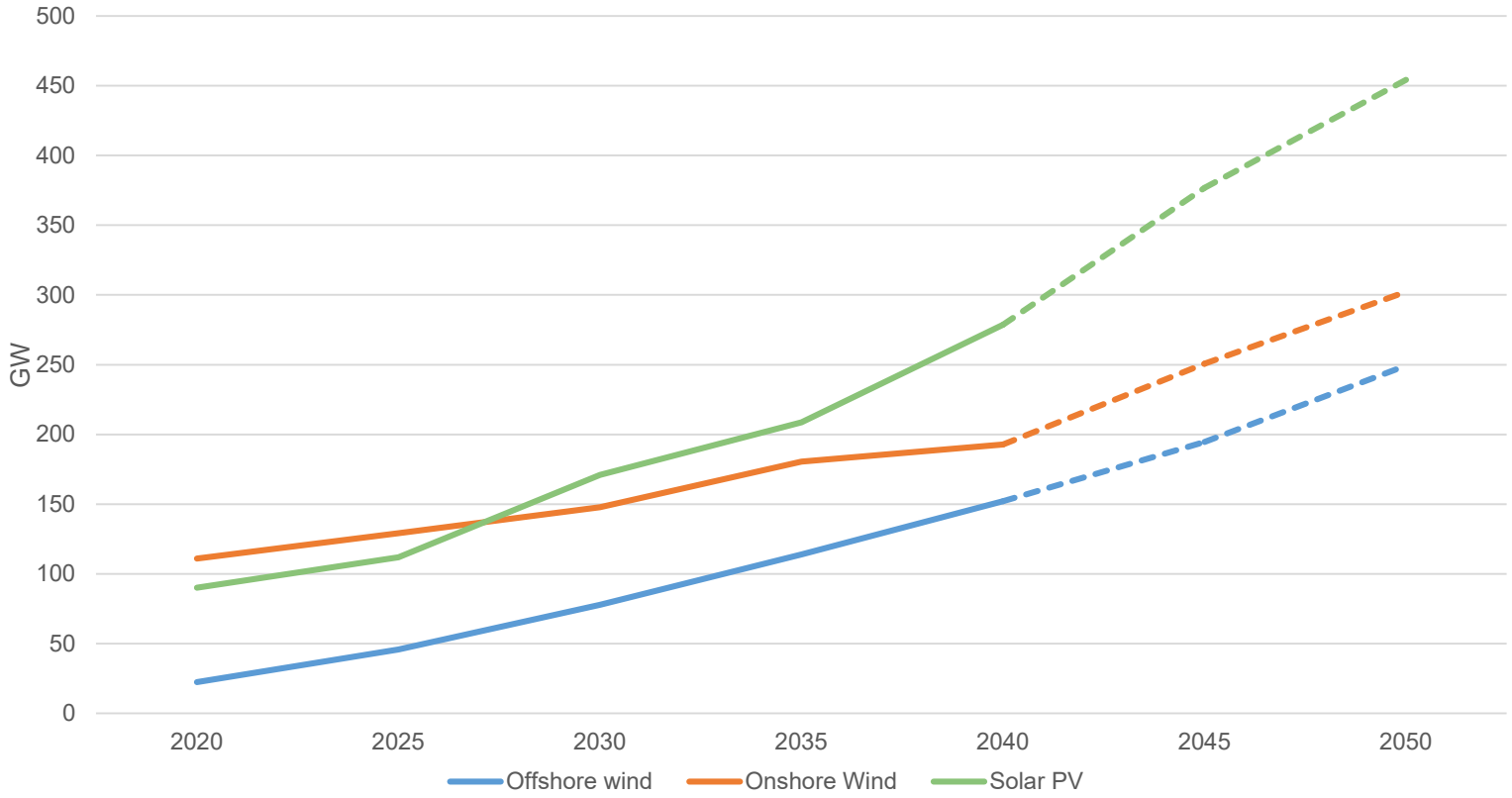




This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Extrapolation to 2050

↗Example: RES capacity GCA



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PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Vote 4: The GA accepts the Load & Onshore generation profiles from TYNDP as input for the CBA with extrapolation to 2050

November 28, 2018

Updates on Topologies & Security

Olivier Antoine (Tractebel)
Dirk van Hertem (KU Leuven)

NO Vote

Topology Update

↗Olivier & Pierre to deliver at meeting

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

NO Vote

Protection Systems Update

↗Dirk to deliver at meeting

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

NOTES: GENERAL ASSEMBLY

Aachen meeting chosen dates are 11, 12 and 13 June 2019
First day should be WP meetings
Second day plenary session and visit to RWTH Aachen labs
Third day General Assembly followed by PMG

GA does not object to the DRAFT Grant Agreement being sent to Mariana for preparation

29 partners present, quorum reached and votes valid

Poul: The wording should be changed from '…but its use could be described…' to '….but its use will be described…' even though agrees that technology is not yet mature enough and not enough is known yet, but this should be taken into account

Karim: DRU is cost saving option. If cost without it is OK, DRU will make it better assuming that it does not increase elsewhere. How do we assure ourselves that no other unknown large costs may appear during development of the technology?

Ramon: does not agree with statement that no conclusions are available that meshing with DRU works. Early work shows that it is controllable, but requires further study.

Tim: WP12 happy to include qualitative discussion on benefits and challenges of using DRU in topologies but not as a quantitative factor in the development of a topology, because not enough is known yet.

John: the use of DRU might balance the topology development towards radial if it does not work well with meshed

Dirk: All votes are associated with disclaimers to guide the vote. The disclaimers need to be complete and correct, and ideally should be included and elaborated in a document

Yash: We should make sure that treatment of DRU in CBA should be aligned with earlier choices in the project

Dragan: DRU can be made to work in any case with DC/DC converter, there is no technical barrier. But why include a technology which Siemens offers who pulled out of the project

Poul: We should be very clear on the potential of DRU in reducing the costs to society, supported by sound analysis

Karim: Coordinator should make sure omitting DRU is not in breach of contract (GA).

Poul: The minimum is that even though we do not take the DRU into account in the CBA, there should be a thorough explanation of the potential of including DRU in a public deliverable

John: a retrospective indication of savings could be given in all potential sites where a DRU could have been used, but not clear where technical application is

Ramon/Dragan: No technical hurdles, either with DC/DC converter or through advanced control strategies. A potential way to get out is to include a thorough technical analysis of the topologies and the applicability and potential benefit of applying the DRU

Dirk: it is clear that technologies in 2050 cannot be predicted. But a small test case could be included which illustrates the benefits on a high level. Maybe CBA should be made less technology sensitive on for example generic converter

Andreas: further to Poul's comment, it should read '….but its use will be qualitatively described…'

Paul Neilson: There should be at least a high-level description of the aggregated impact that the availability of the technology could have

Cees: change it to ..its use and potential impact…

Alexander: this is a good description in its current form

Dirk: We can let vote go through, but disclaimers should be detailed in document

Final vote text is: The use of diode rectifier units is not taken into account for the full system CBA , but its use and potential impact will be described as future options

Dragan gives in promptu 'crash-course' on DC/DC converters

Karim: Why do we need DC/DC converters in green-field network development in which bottlenecks can be avoided? What is the vote about, is it about completely leaving the option of DC/DC converters out?

Dragan, because different voltage levels or technologies will be used by different users which will need to be interfaced

Dragan: dual active bridge will cost about two VSC converters of same voltage and current rating. Second presented option will cost about 1,3 times as much.

Yongtao: we need to think of strategic placement, they will not need to be used everywhere

Philipp: for a power flow converter a substantially reduced cost could be realized when using series MV converters

Dragan: TRL is still very low so it is not considered in CIGRE WG

Dirk: Other options to prevent flow problems exist such as dispatch or extra cables, but it can be solved with complete power flow studies but this is out of scope for PROMOTioN. But a fixed extra margin is too simplistic. In any case, the DC/DC converter can only improve on the case without

Tim: the cost is associated with the burden of power flow control, not a DC/DC converter specifically. It leaves the technological implementation out,

Wei: Very difficult to say yes or no,

Cees: abstain is option

VOTE text changed to: DC/DC converters remain out of the technical scope of PROMOTioN. The use of power flow controlling options will be described qualitatively.

Cees: did all technical WPs indicate that bipole is required?

Dragan: some demo work is done on monopole systems. This requires additional description, justification and clarification. The systems can be connected using DC/DC converter anyway.

Dirk/Dragan: sufficient knowledge is generated in PROMOTioN to demonstrate technology readiness of bipole technology

Dirk: future solution is probably mixed, advantages and disadvantages to both, bipole might be 20% more expensive than monopole, but it should be fine to say for PROMOTioN to simply use bipole for the analysis

Dragan: if choice is made, it should be same for all concepts for matters of comparison

Bruno: main determinant of choice is the system behaviour during faults and voltage vs current stresses. Bipole is reasonable for large systems as it avoids overvoltages during faults

Lorenzo: Is 525 kV bipole technology in the short term? And does true bipole mean three cables (i.e. metallic return)?

Tim: This is looking into the future where it is reasonable to assume their availability and volume still to be acceptably low, and Yes

Andreas, A timeline on production capacity and TRL should be included in deployment plan to address supply chain limitations qualitatively

Staffan: does it mean that extension of asymmetrical monopoles to bipole is considered?

Tim: no, we plan blocks of several bipoles at each time period

Olivier: It must be clear that when considering 525 kV bipoles there could be restrictions on the development of the DC grid per synchronous area due to maximum loss of infeed

Tim: this is clear, it is also the case for 320 kV systems for Ireland. It is also the reason that higher voltages such as 640 kV and 800 kV are not considered

Dirk: Why do we need to pick converter configuration? Can we not simply stick to power corridors?

Tim: no we need the level of detail for costing purposes. The choice of voltage level and configuration is illustrative and to provide a basis for calculation, it is not considered to be a prescriptive conclusion

Dirk: How will you model the difference between monopoles and bipoles?

Tim: Cost and redundancy.

Philipp: Will metallic return be the same as HV poles or a cheaper one?

Tim: it will be a cheaper separate cable

Final vote text: WP12 assumes the use of bipoles with metallic returns for its calculations of MOGs. For point-to-point connection monopoles are allowed.

Manufacturers voluntarily leave the room and abstain from vote: Staffan (SCiBreak), Uwe (ABB), Alexander (Siemens), Dimitris (Prysmian), Ito (Mitsubishi)

Christina: Is this a public document?

YY: Not yet, this is ongoing work, but it is supposed to be a public document

Lorenzo: There are large uncertainties (such as 525 kV platform cost). How will you handle that in WP12? Like a sensitivity analysis?

YY: Perhaps adjust for water depth and location

Lorenzo: Is the 30% margin stated in the cost to be added to the stated uncertainty?

YY: yes

Dirk, will the report be public, or open for feedback, or closed within consortium?

YY: until OEMs agree, it will not be published. It is not a formal document so there is no dissemination level.

Dirk: it might be good to try and publish it as it may help discussions in general. We should be as open as possible and keep the possibility open to accept corrections or more information

Andreas: this will also be very useful in the stakeholder communication

Karim: the numbers must be generated in accordance to the EU law and then they could be published

Paul: in addition there is also a commercial interest from the included OEMs which may be protected

Dragan: it is not clear how a 525 kV pole leads to 1,4 GW loss of infeed. Have you considered common mode faults?

Romaine: The choice of voltage level is related to the geographically specific loss of infeed, this is different in UK, Scand, Mainland EU, and Ireland, hence different voltages being proposed

Paul Neilson: Is the Channel meant to be the English Channel

Final vote text: The GA accepts the 525 kV as the overall used voltage for the CBA (and 320 kV for the English channel/Irish sea)

Dirk: the chosen approach is reasonable to get started

Ramon: is this based on a grid that is sized to be able to export all wind power generation so that no curtailment takes place?

Romain: Yes, although curtailment could be applied during emergency operation

Yash: Output from WP1 is that n-1 criteria should be applied offshore. This should be checked for consistency

John: No, but it was discussed that offshore grid should not violate n-1 criteria onshore

Yash: needs more clarification. Onshore n-1 means no shedding of load, only in case of n-2 this is allowed.

Romain: different definitions of n-1 are used. In promotion it means no shed of load in case of loss of one grid component (could be cable, or converter (pole), etc.)

Andreas: We should be aware that values of max loss of infeed could change in future

John, very difficult to change, envisaged to stay constant for the next 20 years

Henrik, these values have been determined by considering the level of risk behind it which could be considered

Karim: the idea is to be conservative but have a choice that can be calculated with

Dirk: the values are very likely to change due to dropping system inertia and commercial pressure, it is not clear how these will change, but simply a boundary condition for the calculations

Paul Neilson: The adopted security criterion does not consider redundancy

Romain: that si correct, but it might and it will impact the sizing of the cables and substation

Final vote text: The GA accepts the current maximum loss of power infeed following a contingency on the DC grid as security criterion

Poul: are the scenarios capacity or energy?

Romaine: it is in terms of production

Dirk: 50GW adjustments to scenarios are not small changes, they can have significant impact

Prad: Does it mean that the adjustment of the scenarios leads to a change of technologies within the scenarios and have you considered if this has an impact on other aspects of the scenarios? E.g. 50 GW extra offshore wind instead of 50GW onshore solar can have profound impact on onshore grid development

Dirk: also geographical spreading of scenario changes across Europe should be considered. Using ENTSO-E scenarios is safe, but changing them means opening up debate about the parameters

Prad: assumption that fuel prices do not change is too strong

Andreas: should follow trend

Karim: we take TYNDP scenarios onshore and do not change it

Bruno: why did we make adjustments?

Poul: alternative is to use entso-e data, but this is not very optimistic for offshore wind

Lorenzo: We need to increase the values in the project to meet the high scenario target

John: low and medium scenarios align with TYNDP, only the high scenario exceeds it

Romaine: to conclude, no problem to use the TYNDP, but the way the scenarios are adjusted must be better explained.

Dirk: is it acceptable to follow TYNDP for the low and medium scenarios, and only adapt the high one?

Andreas: GA can agree on acceptance of TYNDP laod and gen profiles as basis for CBA up to 2040, but how extrapolation is done up to 2050 must be better explained

Romaine: the vote will be held as is, but with a detailed disclaimer

Results voting

No	The GA accepts:	Yes	No	Abs	Result
1	the current cost document for use in the CBA	23	0	7[1)]	accepted
2	the 525 kV as the overall used voltage for the CBA (and 320 kV for the English channel/Irish sea)	26	1	3	accepted
3	the current maximum loss of power infeed following a contingency on the DC grid as security criterion	27	0	3	accepted
4	the Load & Onshore generation profiles from TYNDP as input for Cost Benefit Analysis (CBA) with extrapolation to 2050	28	0	2	accepted
5	the use of diode rectifier units is not taken into account for the full system CBA , but its use and potential impact will be described as future options	25	1	4	accepted
6	That the DC/DC converters remain out of the technical scope of PROMOTioN. The use of power flow controlling options will be described qualitatively	26	1	3	accepted
7	That WP12 assumes the use of bipoles with metallic returns for its calculations of MOGs. For point-to-point connection monopoles are allowed.	25	1	4	accepted

[1)] 2 abstained, 5 manufacturers did not vote