PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

WP16

Harmonic Resonance Analysis

PROMOTioN WP 16
By Peter Vaessen and Yin Sun – DNV GL
28.02.2019
PROMOTioN & MIGRATE Joint Workshop

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

Agenda

- DNV GL Involvement in WP 16
- Motivation for Impedance-based Stability Assessment
- Analytical Implementation and Validation
- Update on the CHIL Setup and Future Work
- Schedule

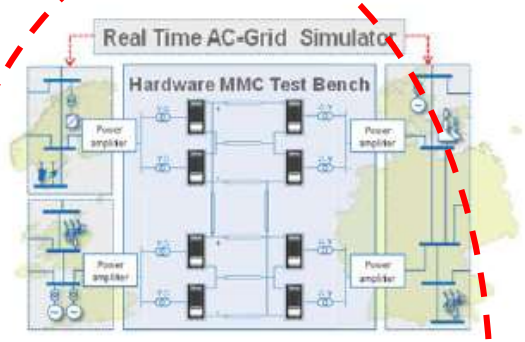
© PROMOTiON – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Agenda

- DNV GL Involvement in WP 16
- Motivation for Impedance-based Stability Assessment
- Analytical Implementation and Validation
- Update on the CHIL Setup and Future Work
- Schedule

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

Introduction – PROMOTioN Demonstrators

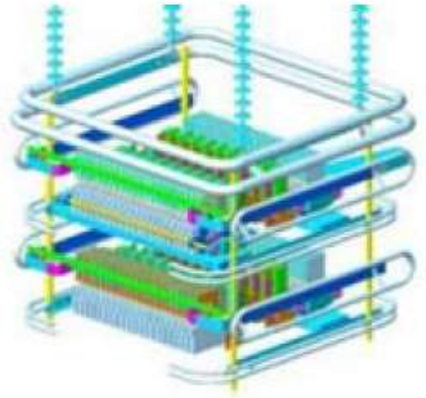


HVDC network control

MMC test bench
RWTH Aachen
Aachen, Germany

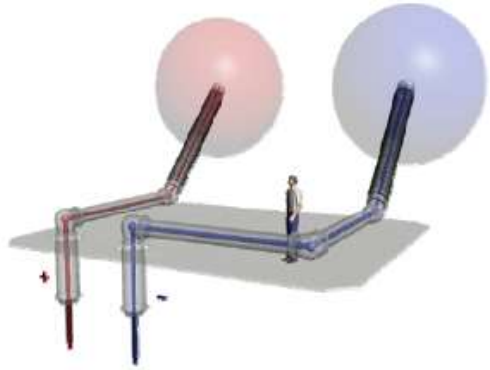
HVDC network protection

Multi-terminal test centre
SSE Transmission
Glasgow, UK



HVDC circuit breakers

KEMA High Voltage Lab
DNV GL
Arnhem, Netherlands

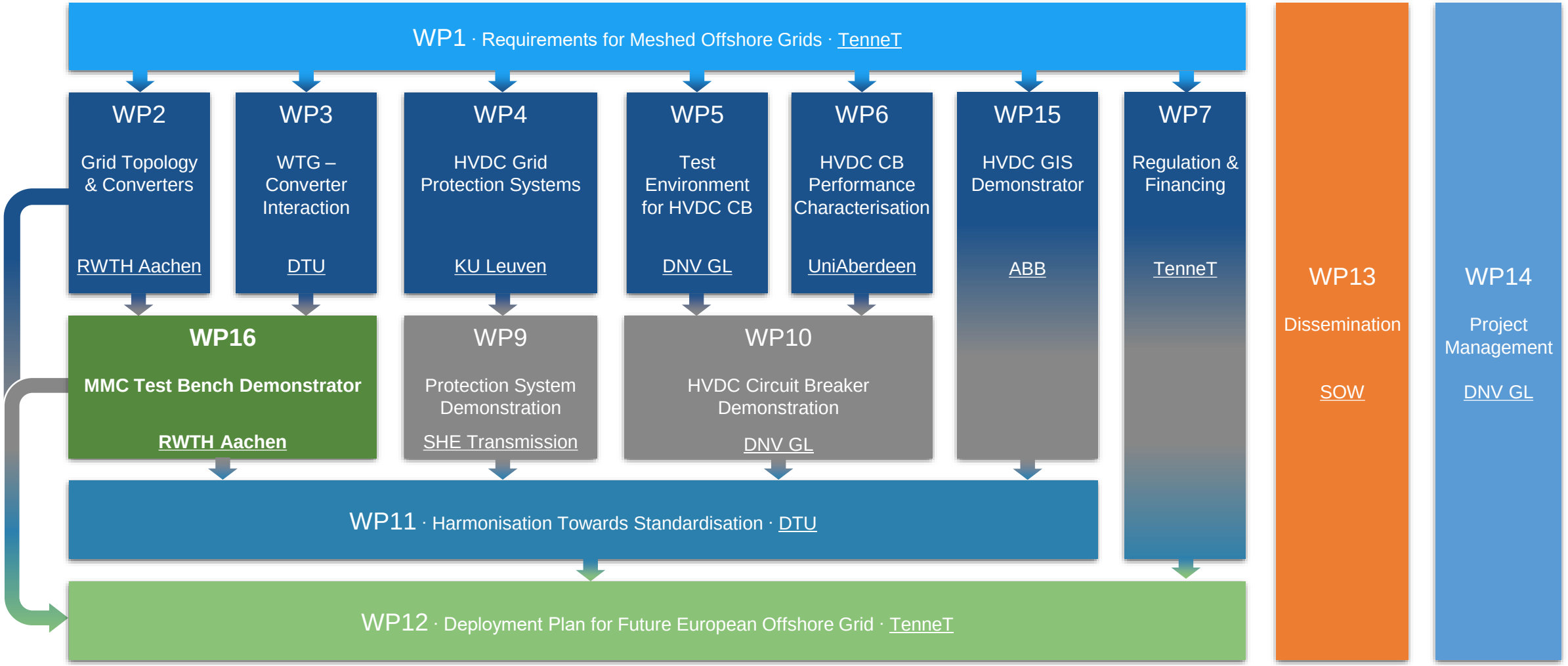


HVDC gas insulated system

KEMA High Voltage Lab
DNV GL
Arnhem, Netherlands

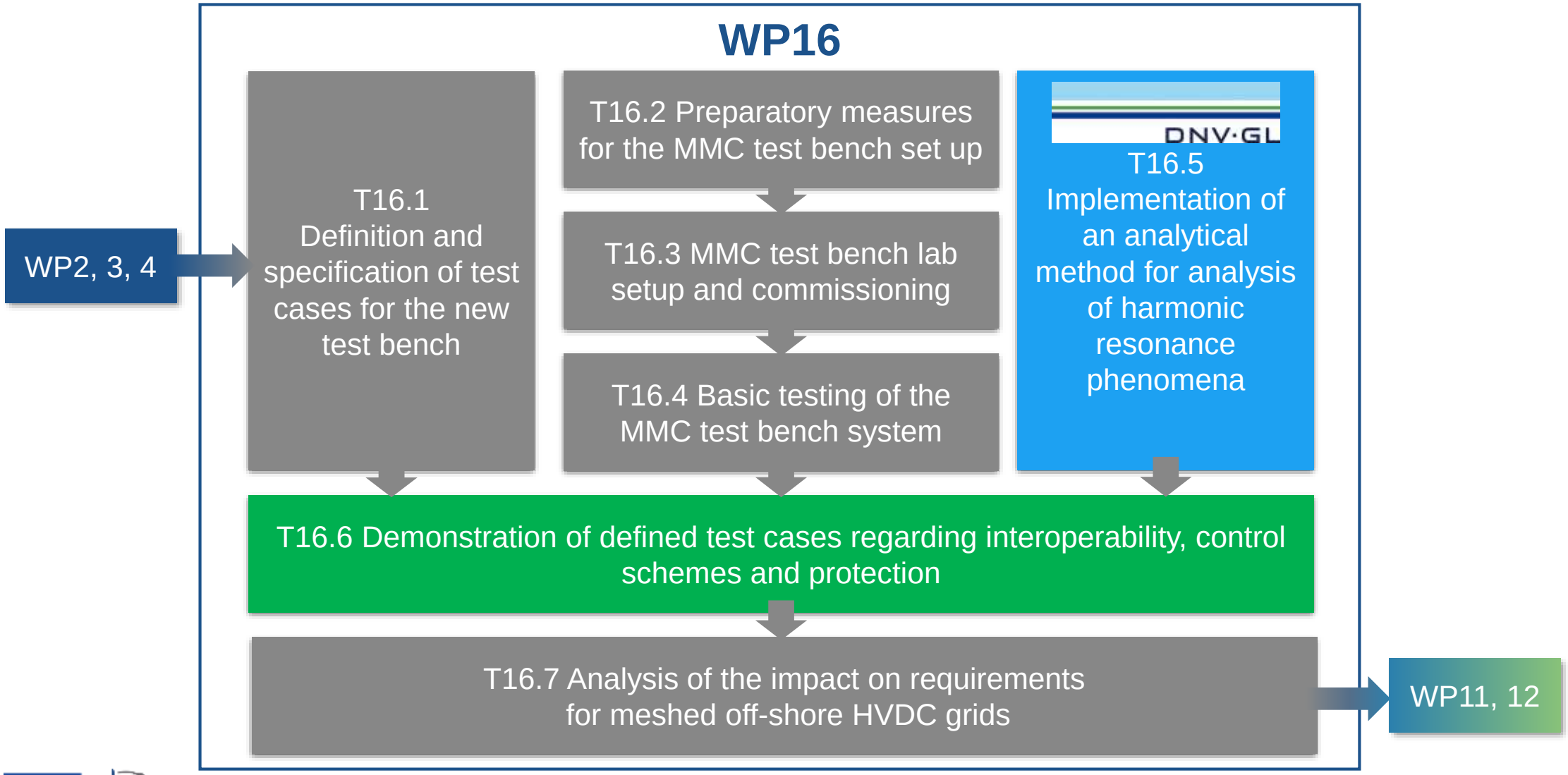
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Work Packages



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

Task Structure



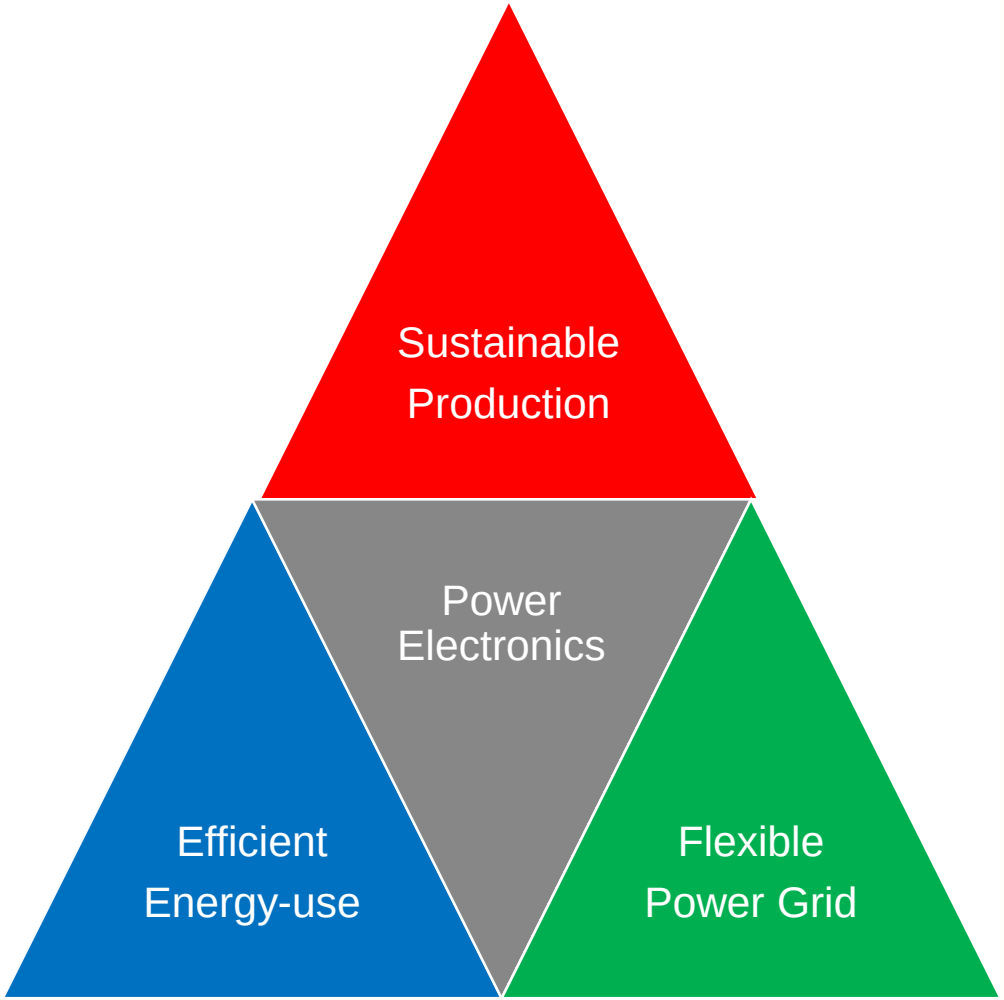
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

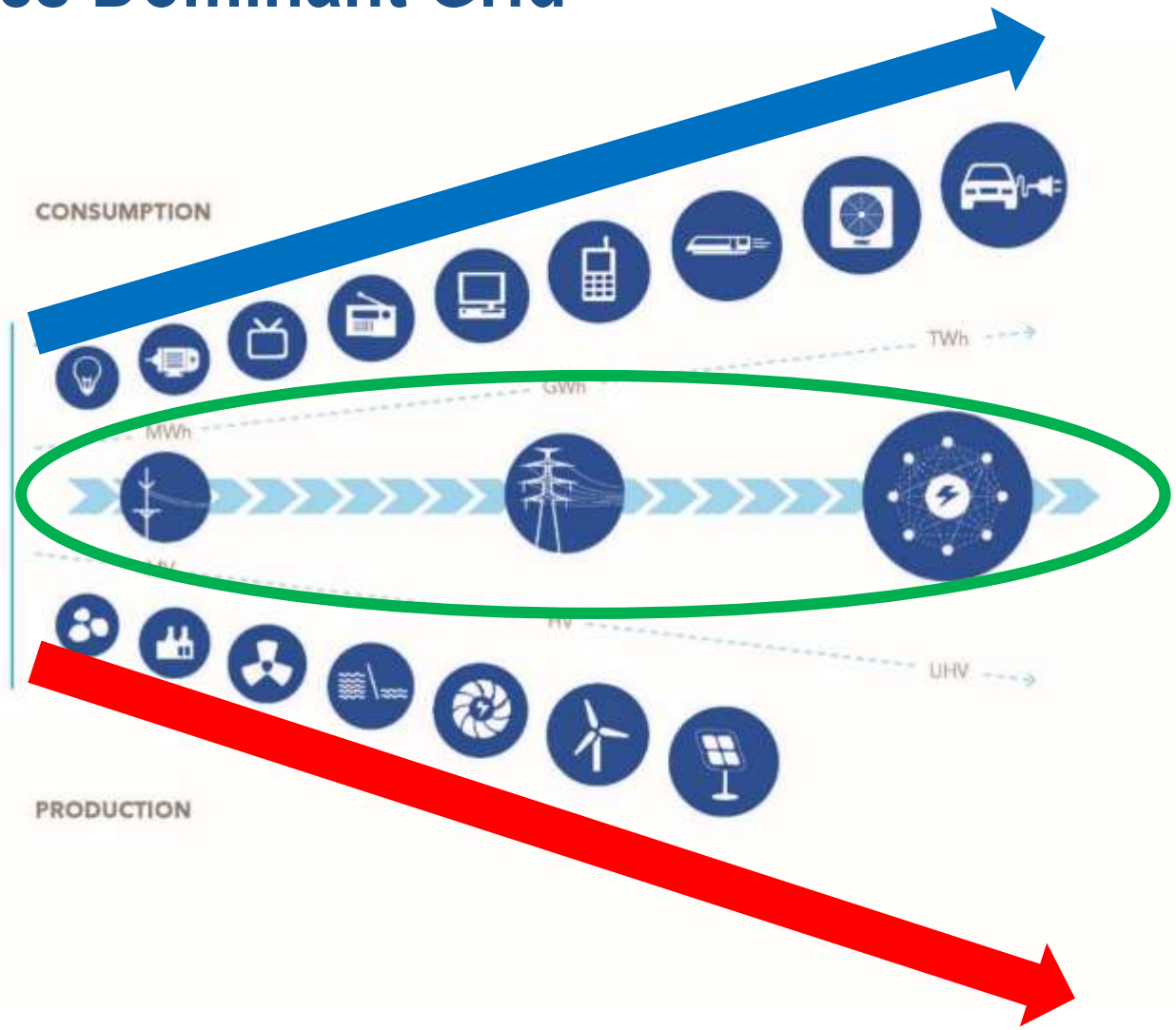
Agenda

- DNV GL Involvement in WP 16
- Motivation for Impedance-based Stability Assessment
- Analytical Implementation and Validation
- Update on the CHIL Setup and Future Work
- Schedule

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

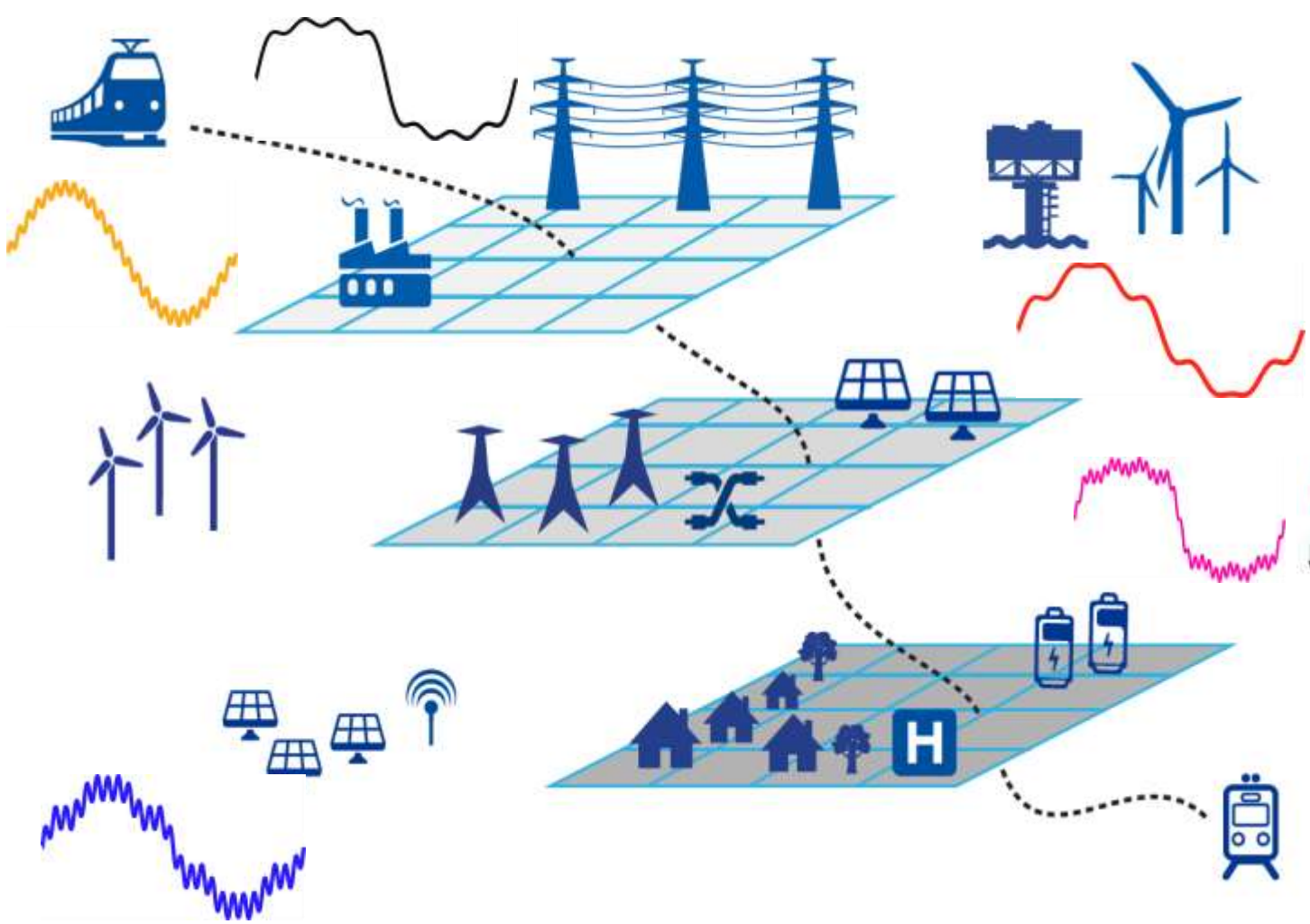
Motivation – Power Electronics Dominant Grid

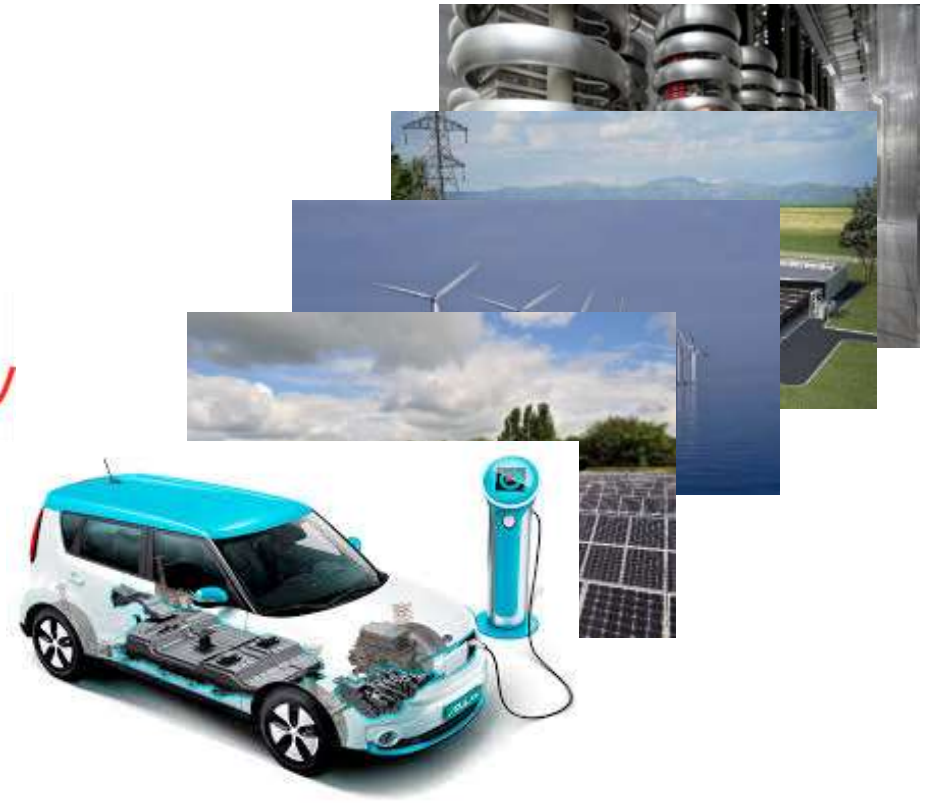




© PROMOTiON – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Motivation – Power Electronics Dominant Grid





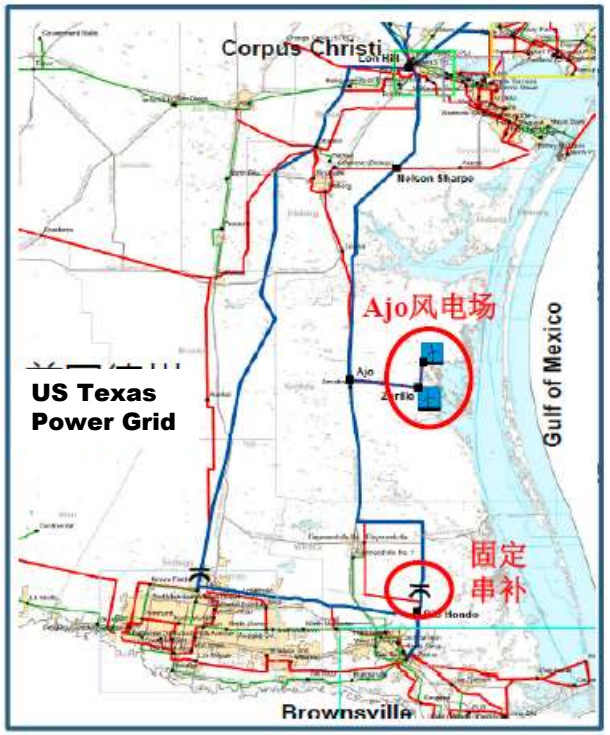
© PROMOTiON – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Harmonic Oscillation Issues - 1

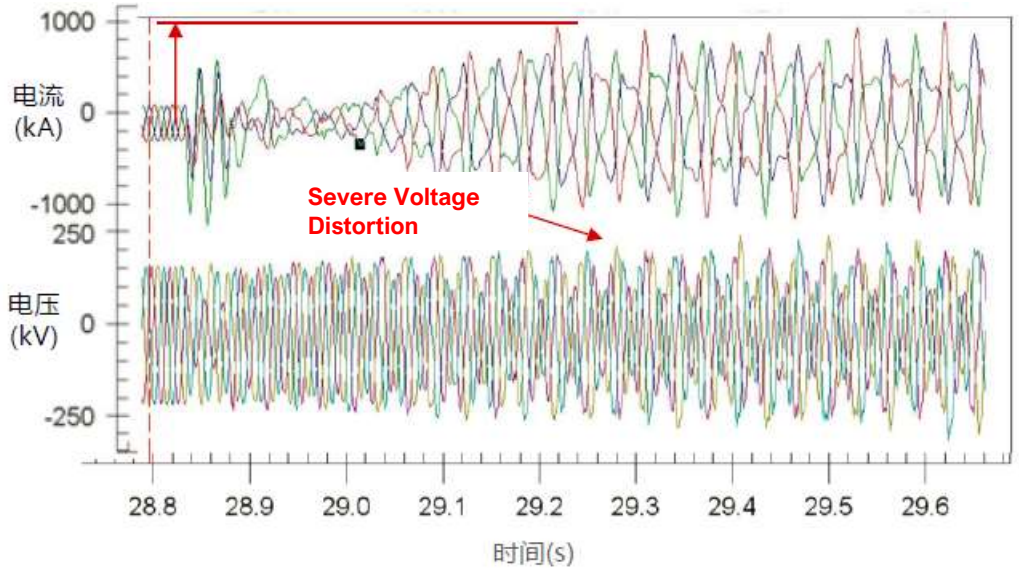
Wind Farm Oscillation in Texas, USA (2009)

Oct, 2009 – First time happened

In Ajo wind farm with 20 Hz oscillation



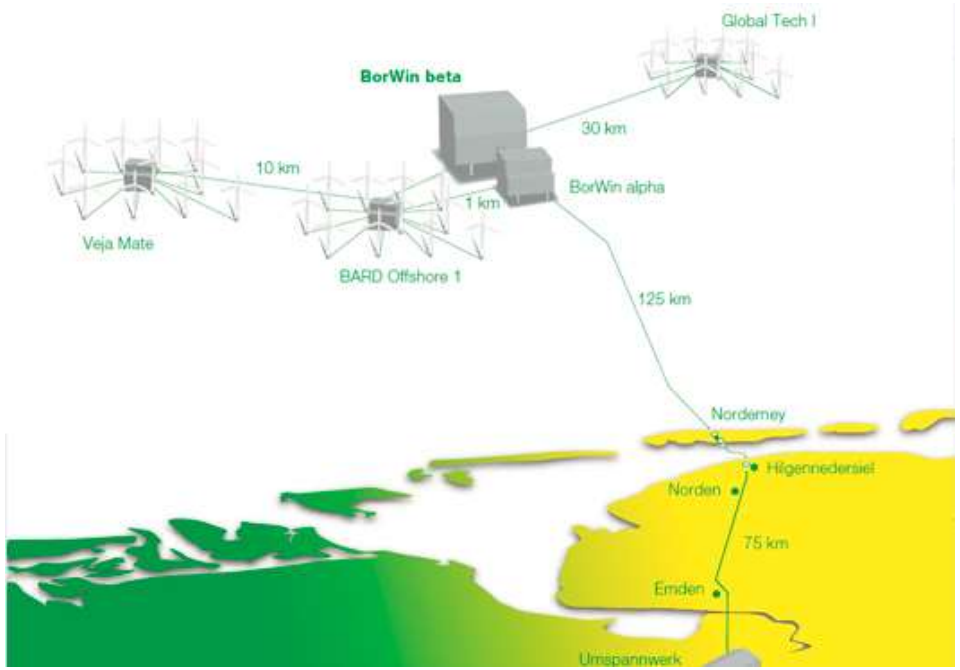
1. Line fault cause the trip of Ajo – Netson overhead line, and make the DFIG connect to the power network via highly capacitive compensated line.
2. Cause current/voltage with a increase of 20 Hz component. System voltage above 2 pu
3. Damage of cross-bar and trip of wind turbines

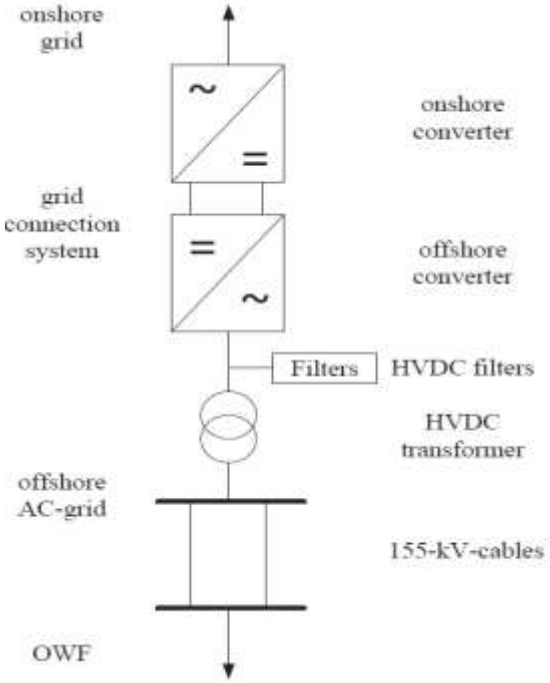


© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Harmonic Oscillation Issues – 2 (1)

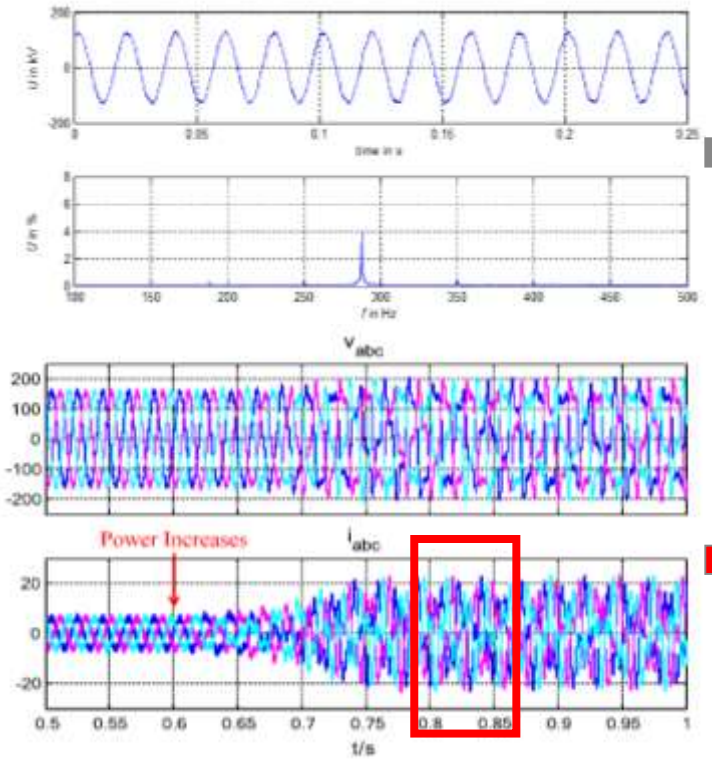
- North Sea BorWin offshore wind farm high frequency oscillation
  1. North Sea BorWin alpha VSC-HVDC platform for offshore wind farm connection, Wind farm installed capacity 400 MW
  2. 2014 Jun ~ Sep, several times of high frequency oscillations with oscillation frequency around 250 – 350 Hz, cause the VSC-HVDC and wind farm out of operation, and result in several millions of EURO loss





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

Harmonic Oscillation Issues – 2 (2)



Non-characteristic harmonic

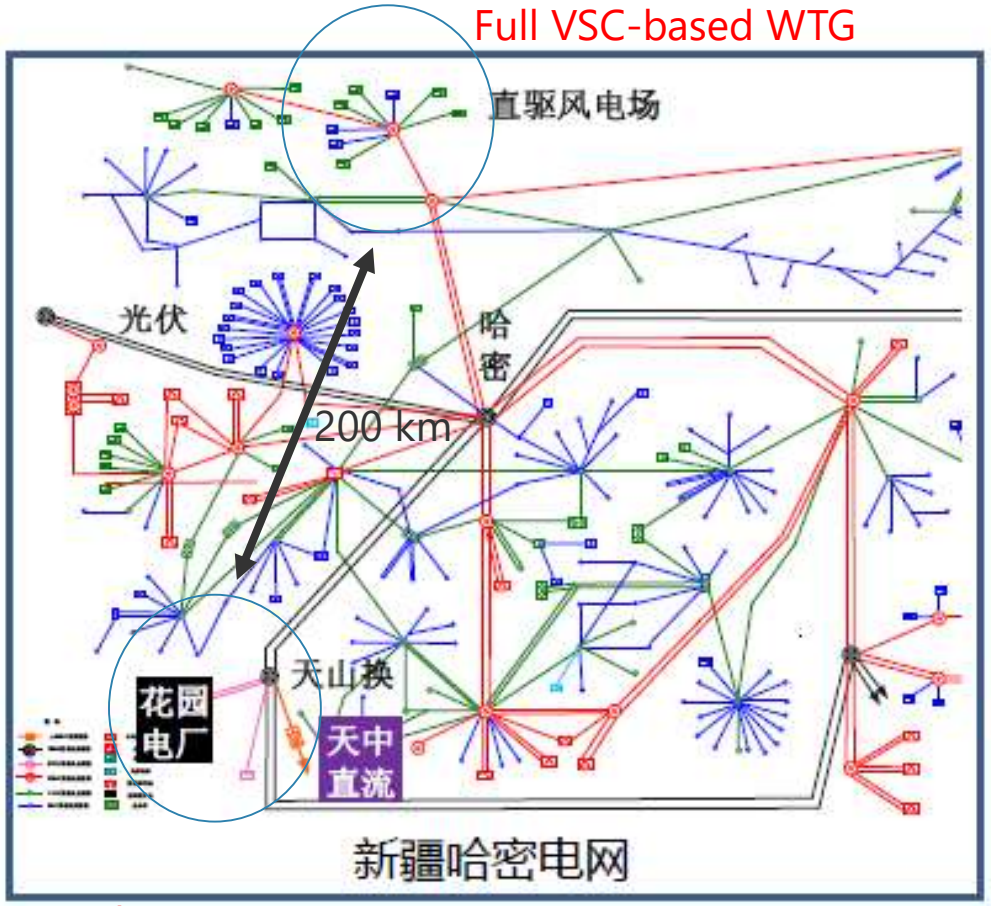
(i.e. 289 Hz)

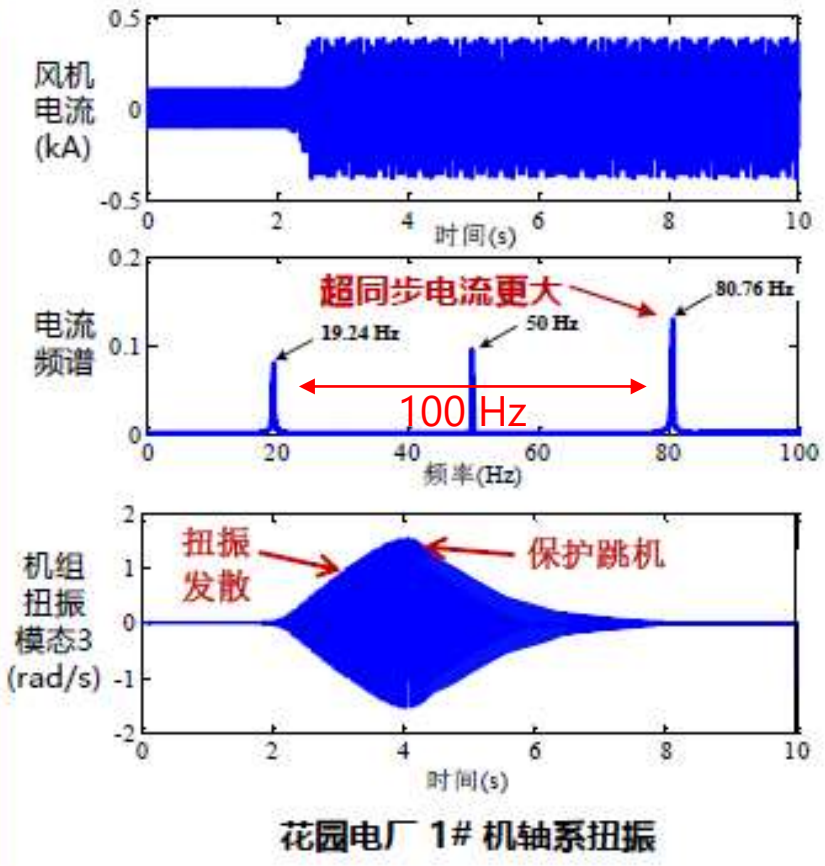
Setpoint dependent harmonic oscillation

Source: J. Sun, C. Buchhagen, and M. Greve, "Impedance Modeling and Simulation of Wind Turbines for Power System Harmonic Analysis", Session 3A-1, Wind Integration Workshop 2017, Berlin, Germany.

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

Harmonic Oscillation Issues – 3 (1)

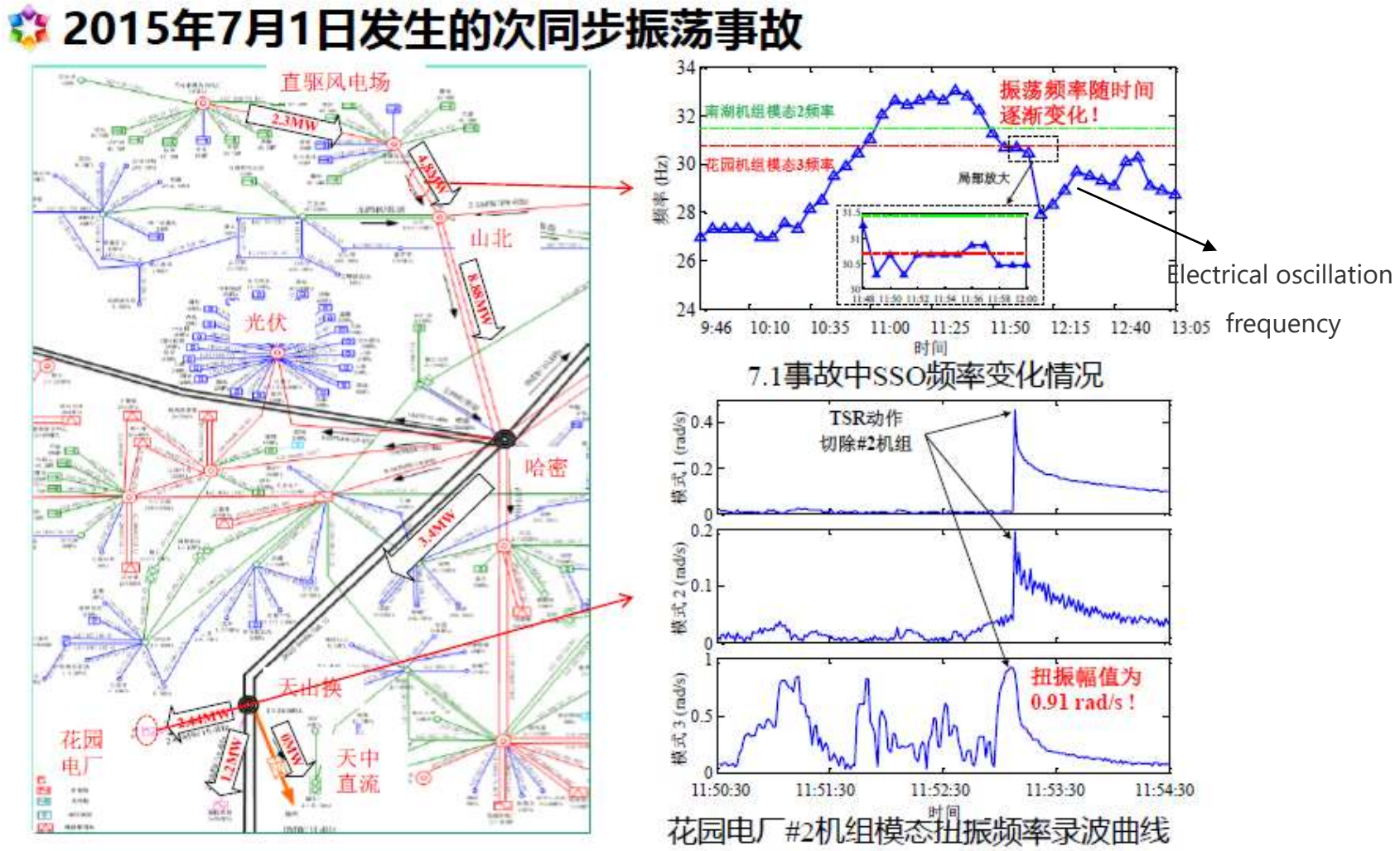




Source:Prof. Dr. Xiaorong Xie, Tsinghua University, 8th SGCC Power System Modelling Conference, Suzhou, China

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

Harmonic Oscillation Issues – 3 (2)



Source:Prof. Dr. Xiaorong Xie, Tsinghua University, 8th SGCC Power System Modelling Conference, Suzhou, China

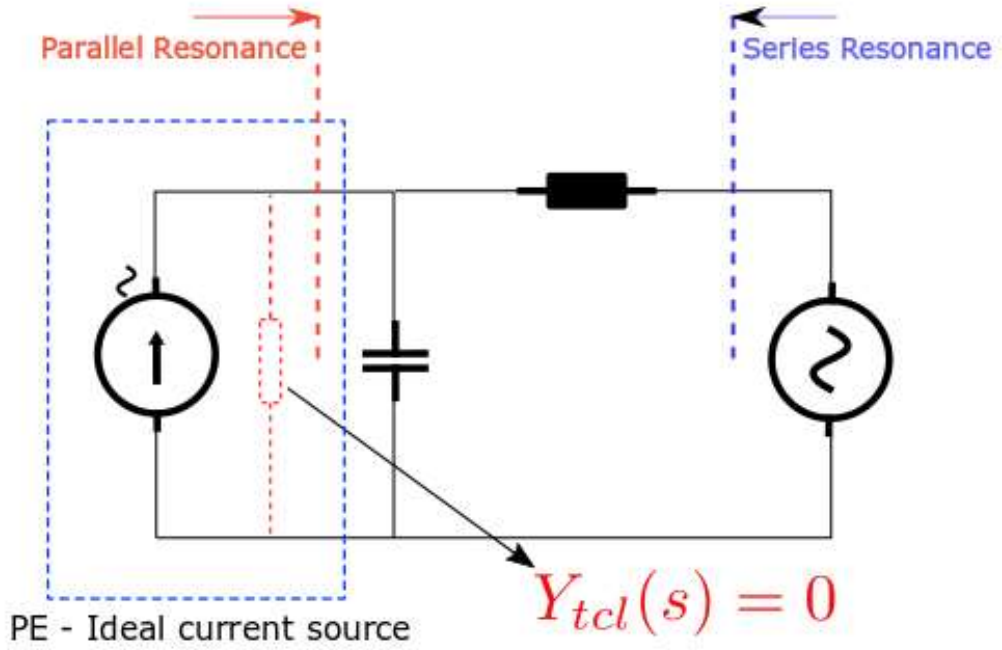
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

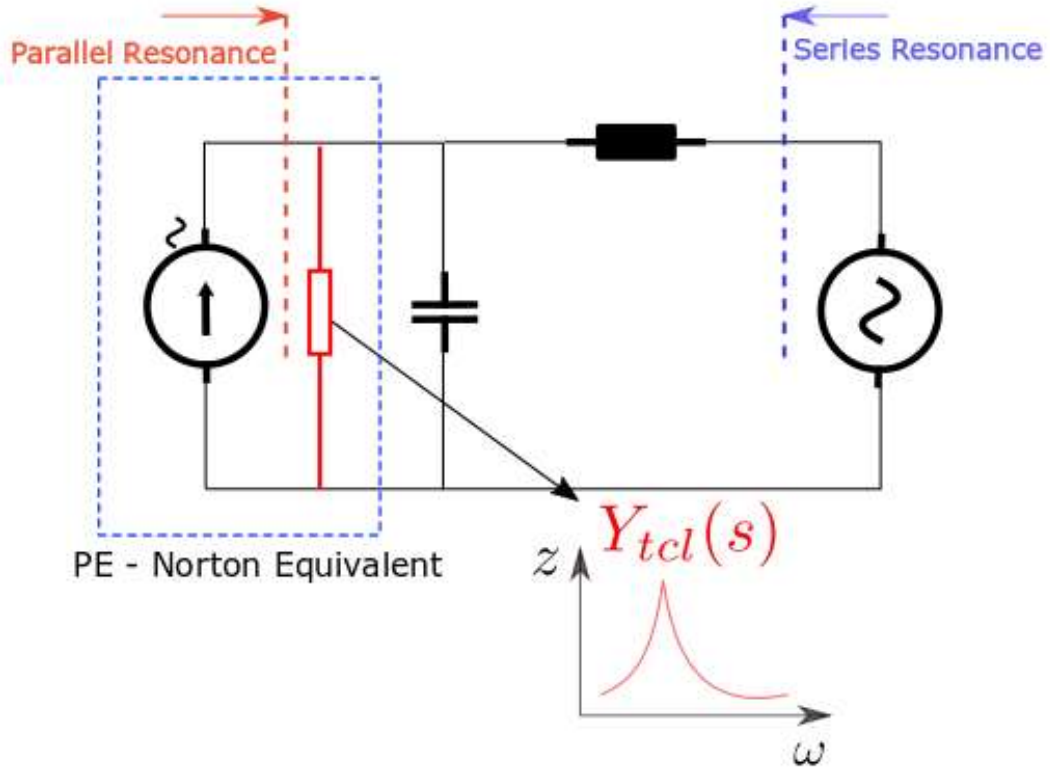
Agenda

- DNV GL Involvement in WP 16
- Motivation for Impedance-based Stability Assessment
- Analytical Implementation (D16.5) and Measurement/Validation (D16.6)
- Update on the CHIL Setup and Future Work
- Schedule

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

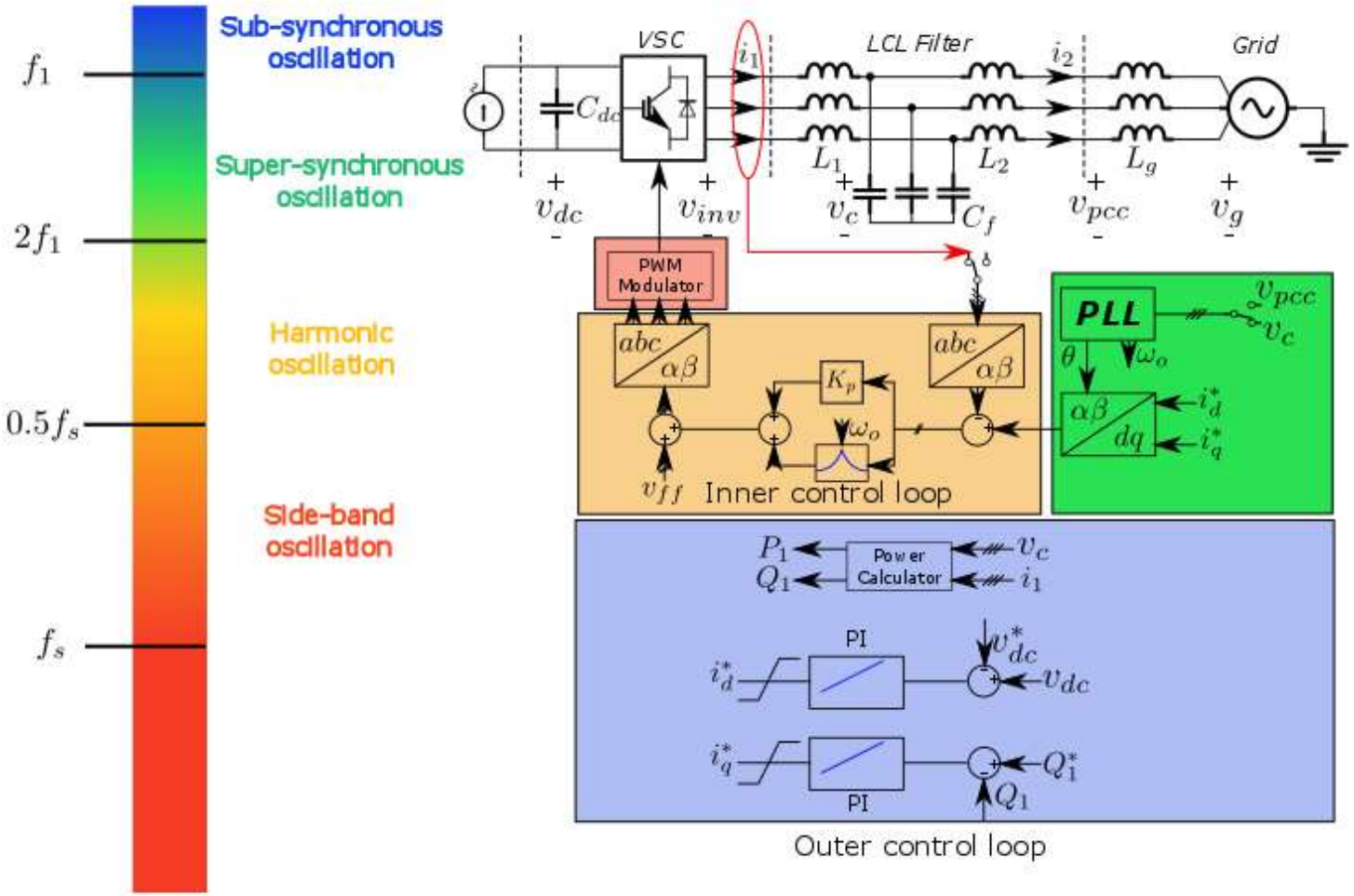
Representation of the Input Admittance of VSC





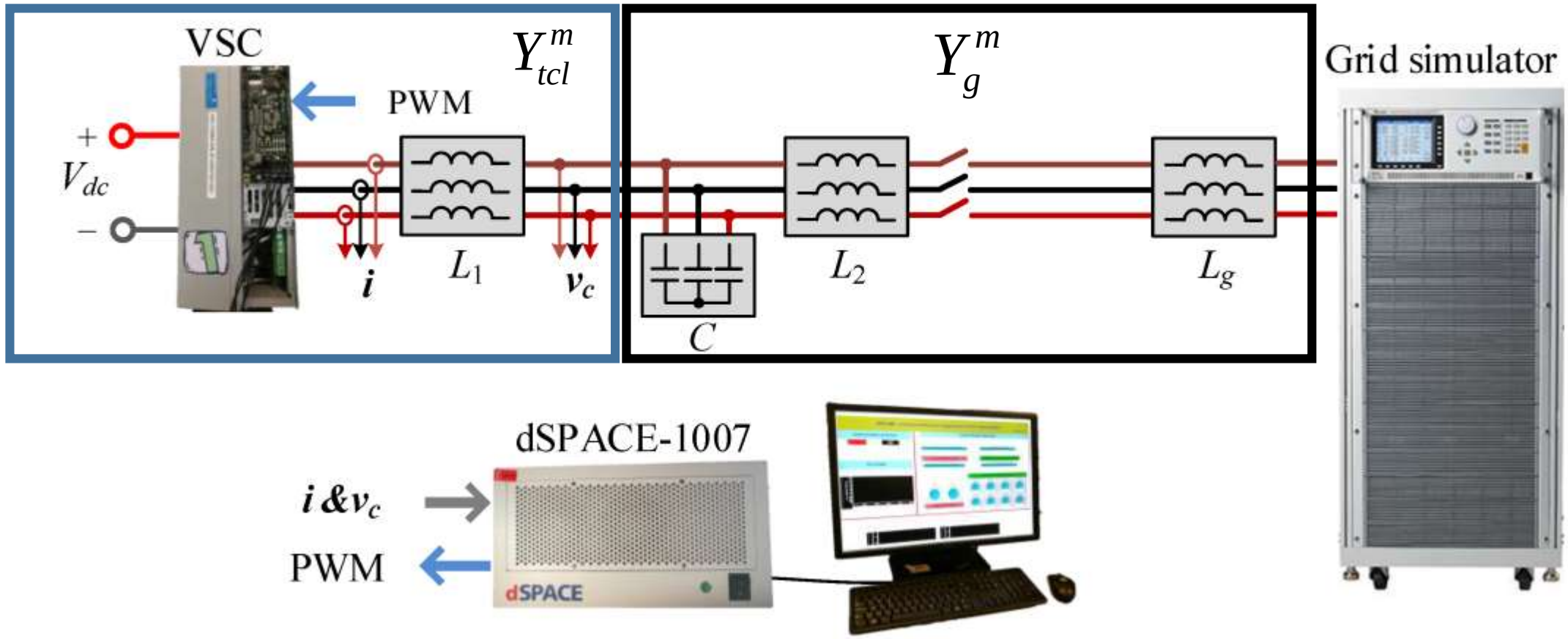
© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Control and Stability of VSC-Interfaced Devices



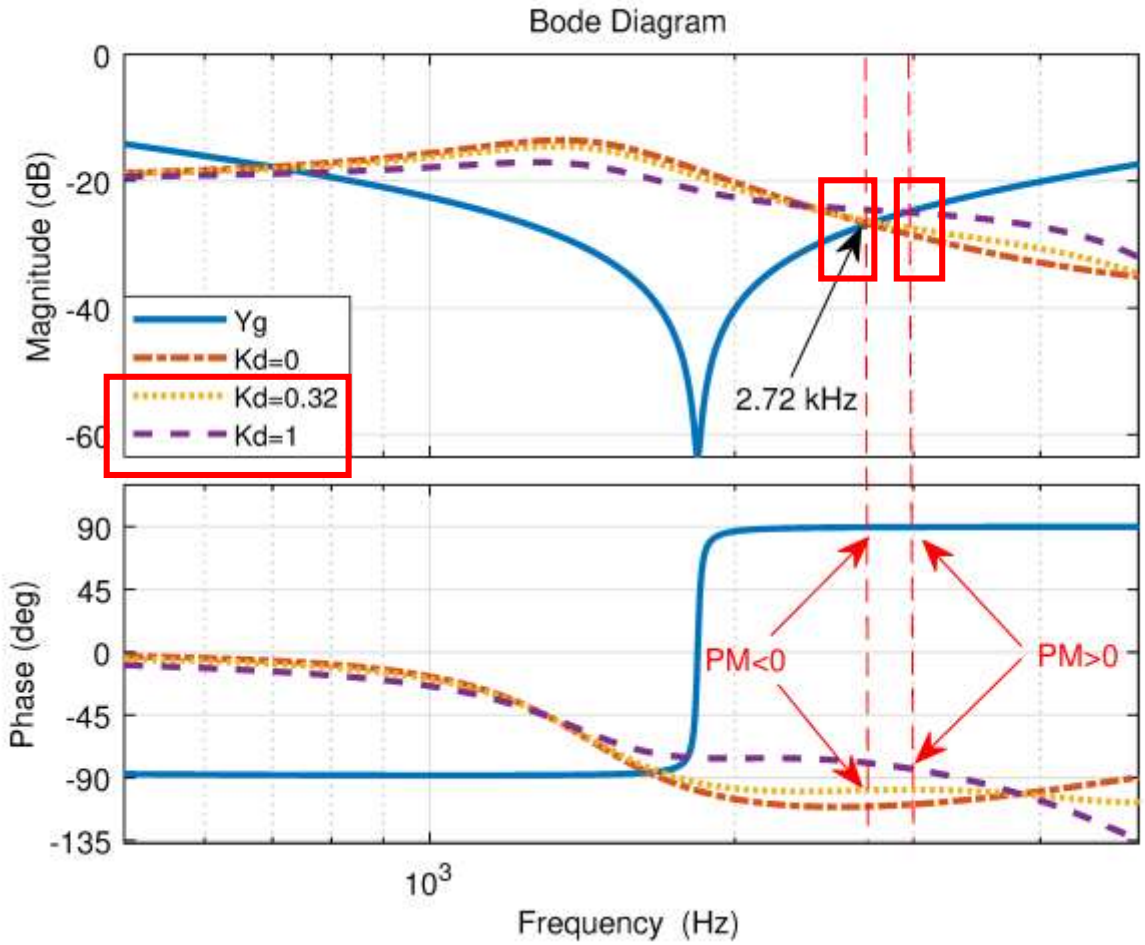
© PROMOTiON – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

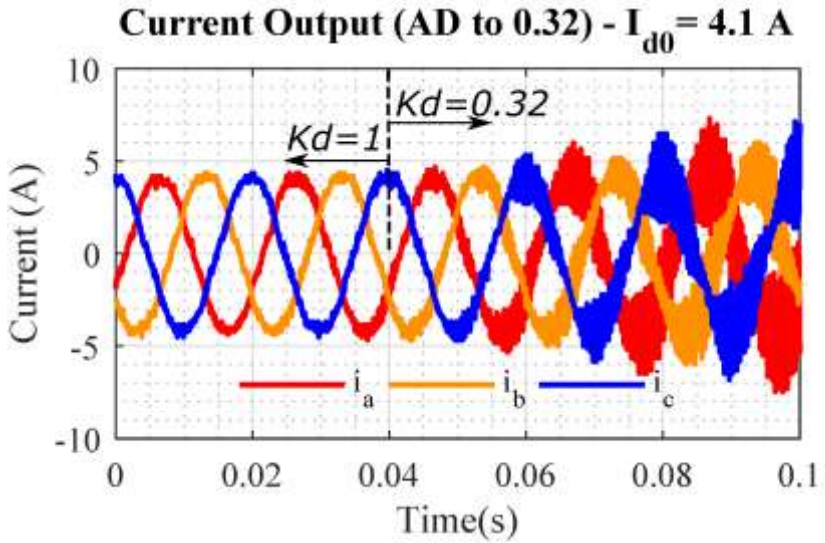
D16.5 – kW Lab Verification Test setup

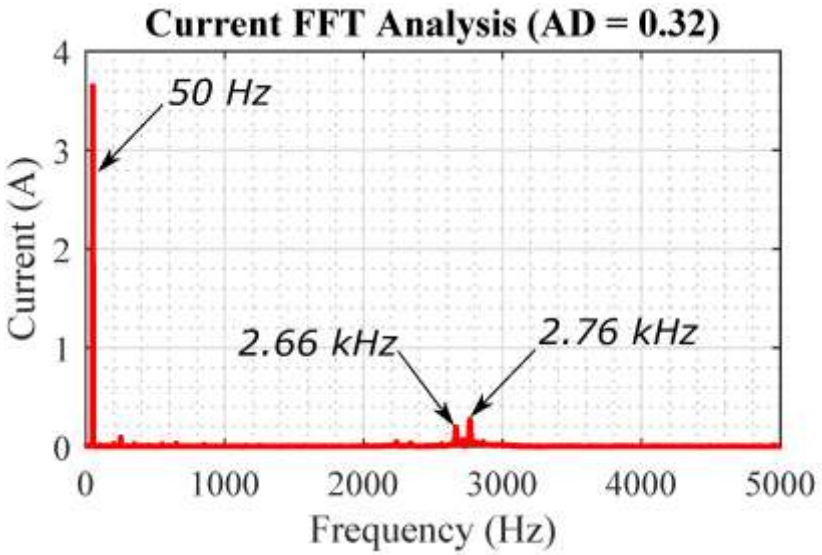


© PROMOTiON – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

D16.5 – kW Lab Verification Test setup Results （1）





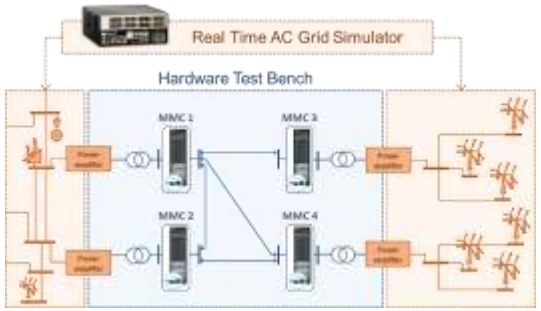


© PROMOTiON – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

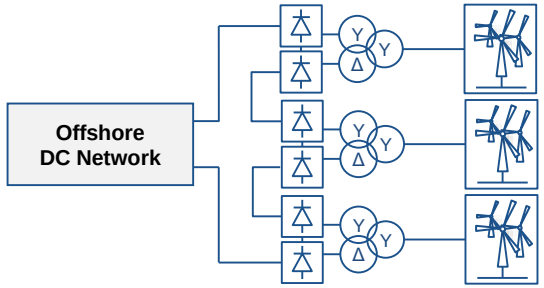
Deliverable D16.5

Implementation of an analytical method for analysis of harmonic resonance phenomena

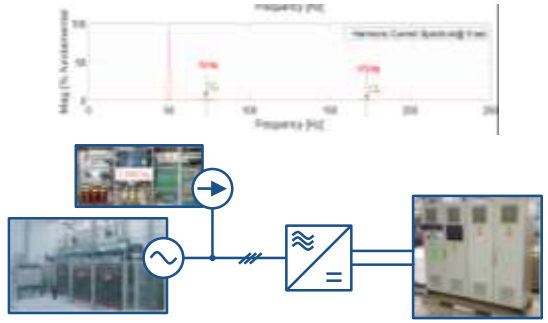
MMC-HVDC



Grid-forming WTG



Grid-following WTG



RWTH AACHEN UNIVERSITY

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

DNV·GL

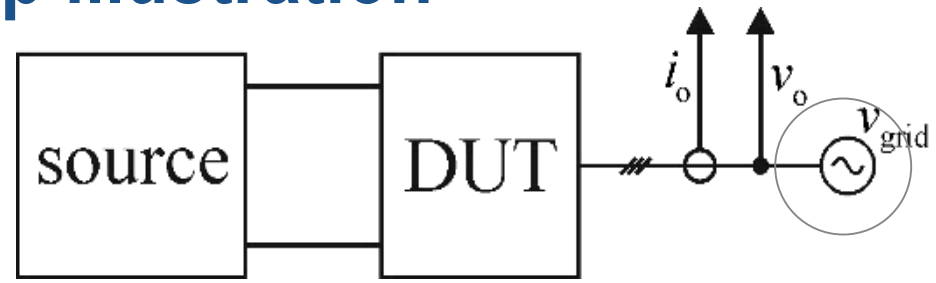
KTH VETENSKAP OCH KONST

DTU

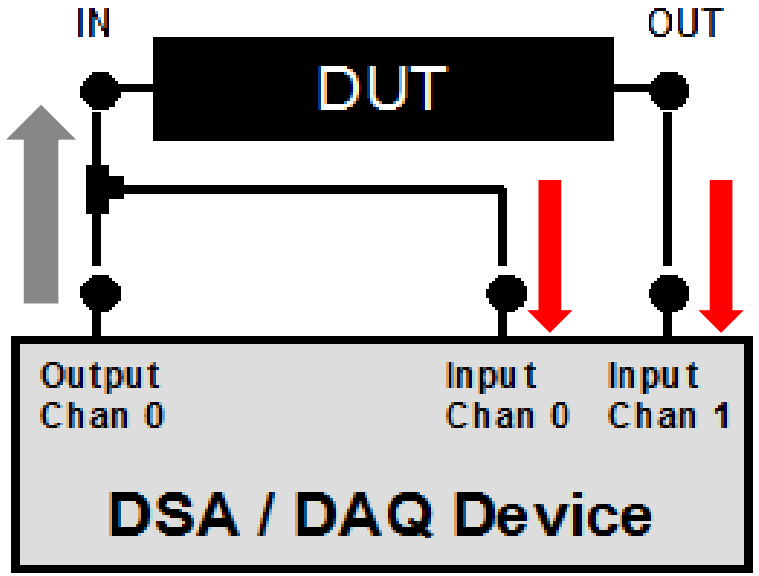
Ørsted

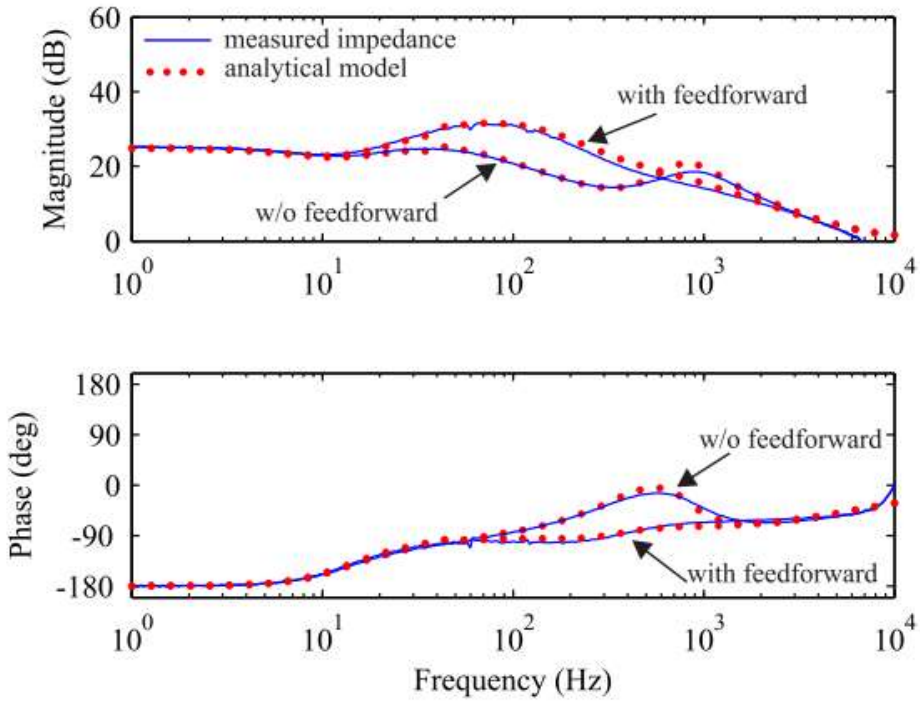
© PROMOTiON – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

D16.6 - Input Admittance Measurement and Validation
kW setup illustration



Measurement setup – 10 kW DUT

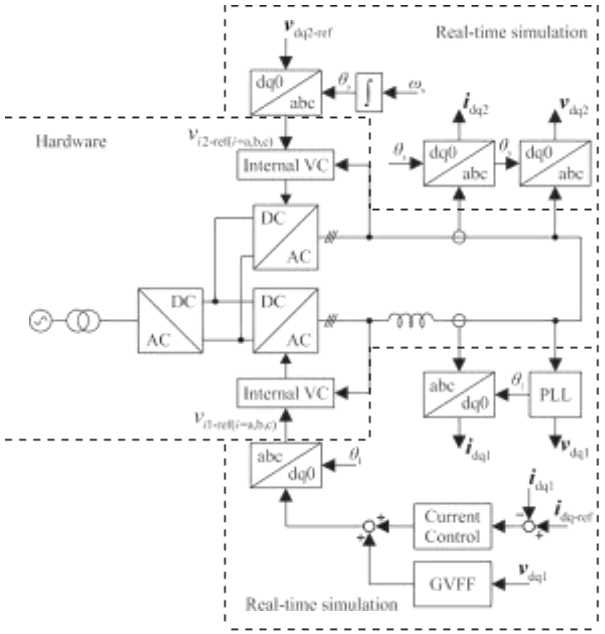


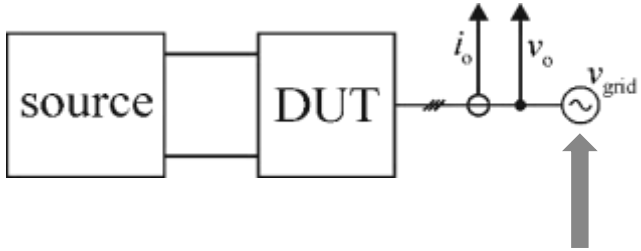


Source: courtesy of Tampere University of Technology, Finland.

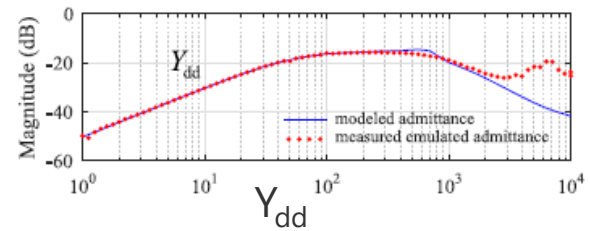
© PROMOTiON – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

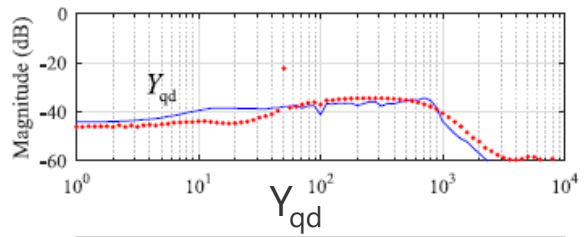
Input Admittance Measurement – DNV GL kW Setup Egston Back-to-Back



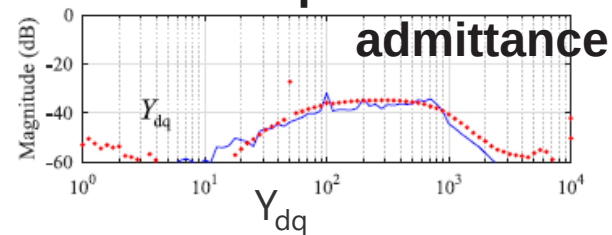


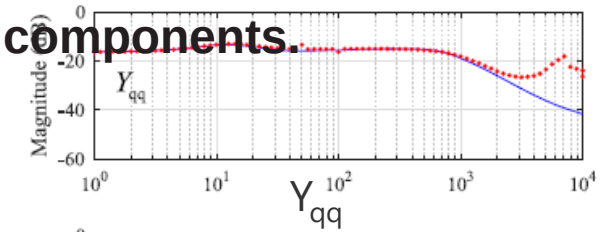
Perturbation





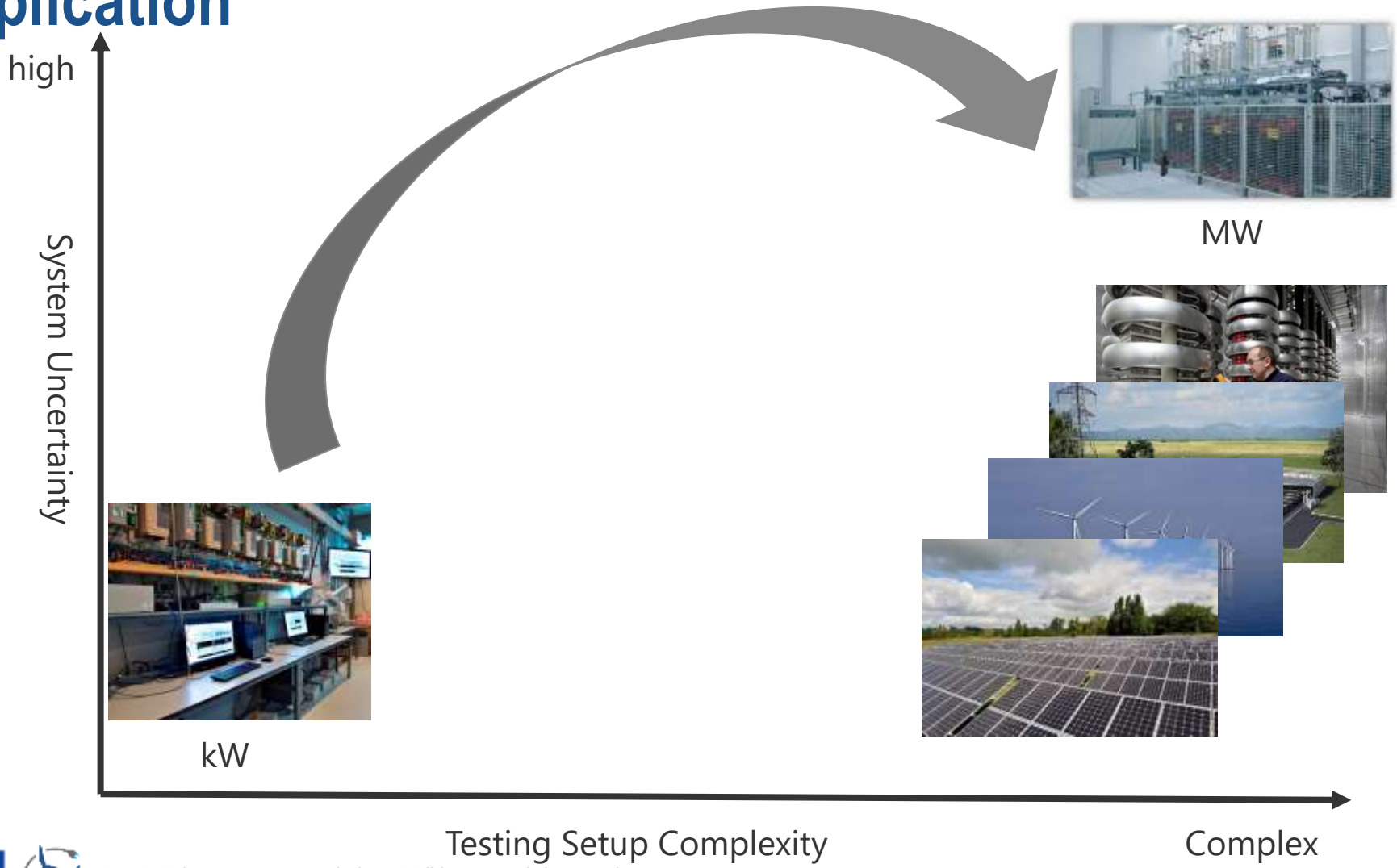
Comparison of modelled and measured admittance components.





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

Challenges of VSC Input-Admittance Measurement for MW Application



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

Agenda

- DNV GL Involvement in WP 16
- Motivation for Impedance-based Stability Assessment
- Analytical Implementation and Validation
- Update on the CHIL Setup and Future Work
- Schedule

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

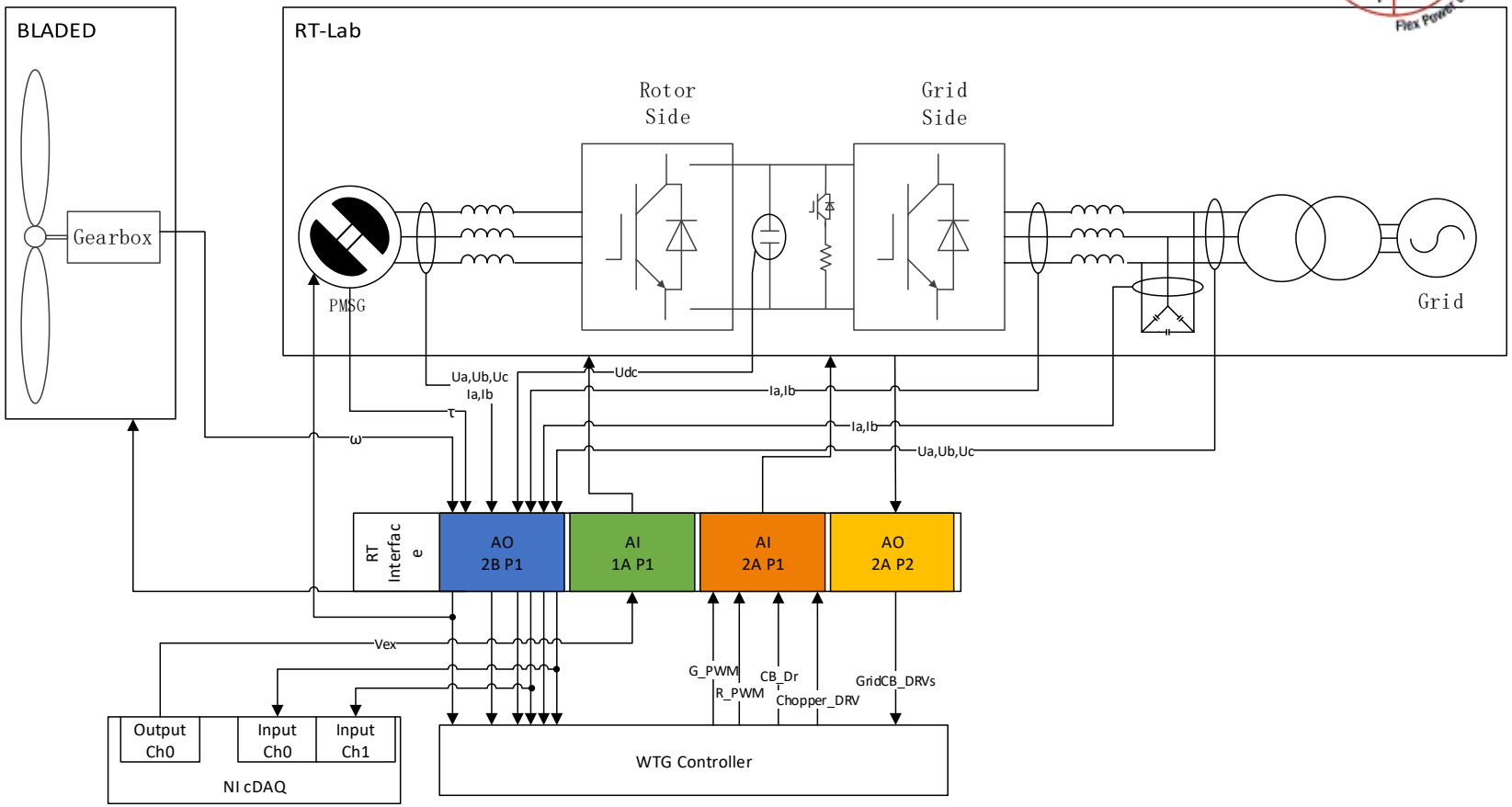
CHIL Setup – Model

2

PROMOTioN – WP16.5 – Task 4 – FPGL Test Setups

CHIL WTG – Input Admittance Measurement

DETAIL CONNECTION

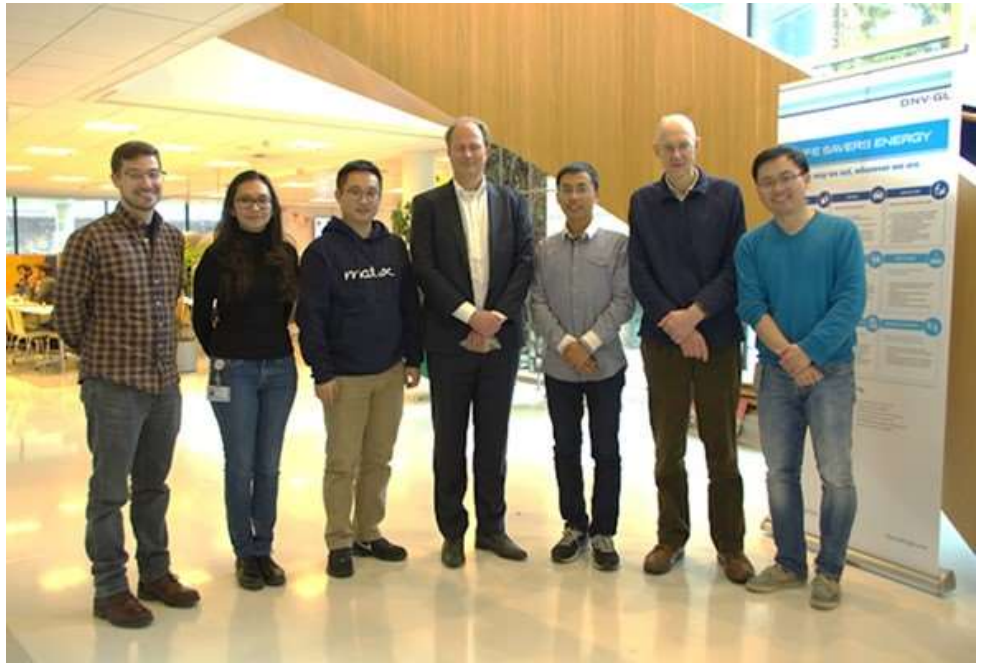


© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

WTG CHIL Test System

Achievements:

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



FPGA compensation for PWM input

CPU only

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

MW-Level Benchmarking

Achievements:

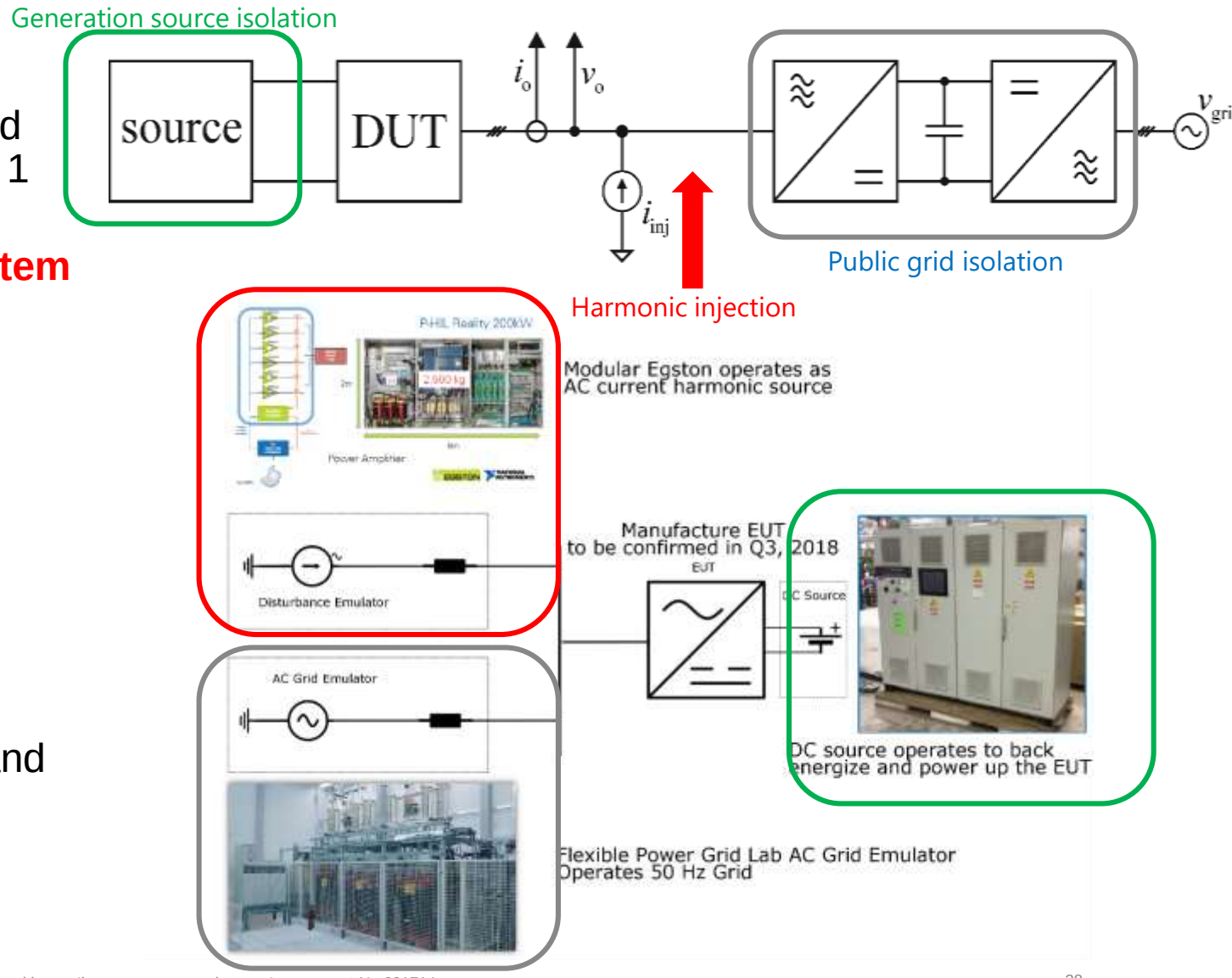
- Specification and acquisition of the wind turbine converter controller replica and 1 MW physical converter
- **Commissioning of WT CHIL test system**

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
- Commissioning of 1 MW Inverter



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

28

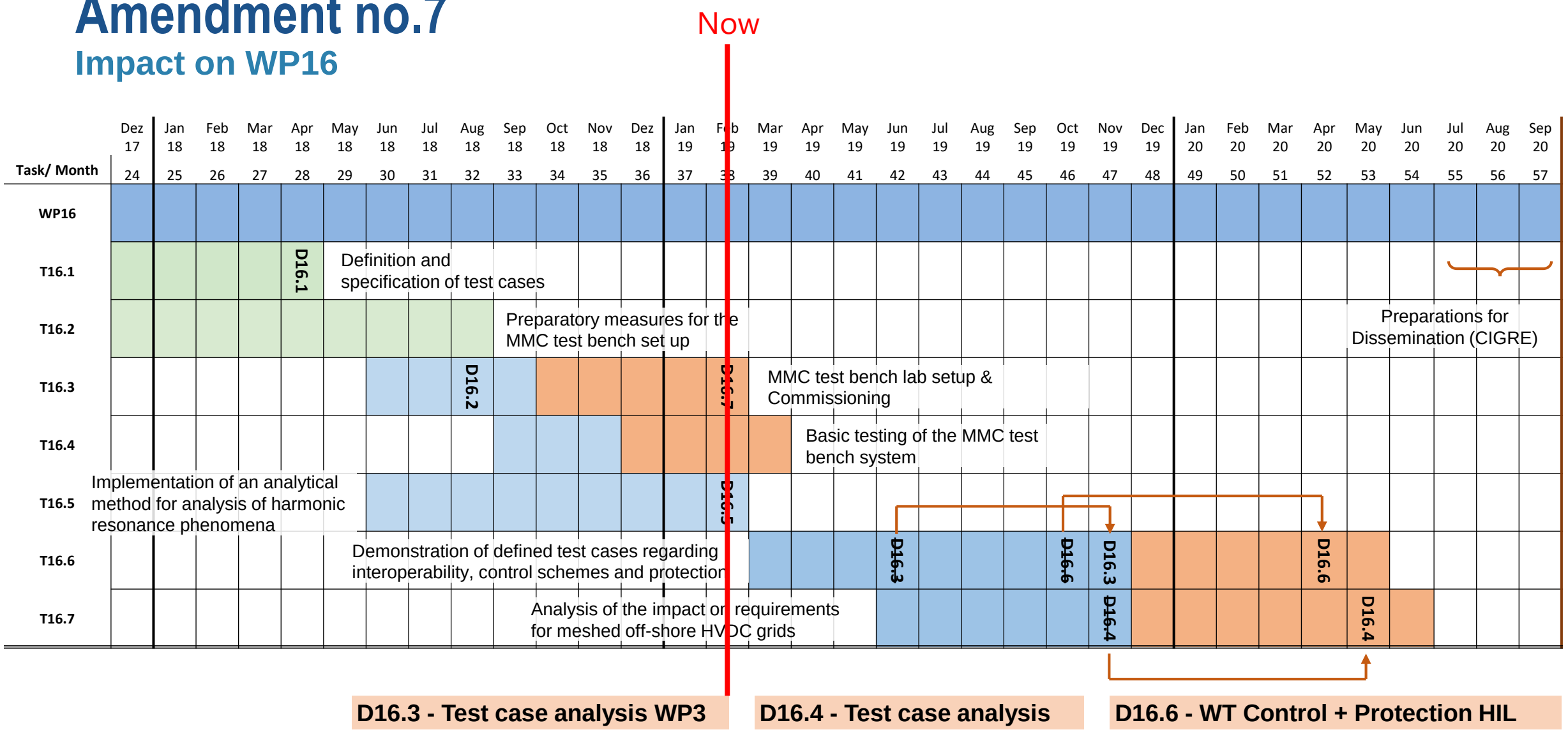
Agenda

- DNV GL Involvement in WP 16
- Motivation for Impedance-based Stability Assessment
- Analytical Implementation and Validation
- Update on the CHIL Setup and Future Work
- Schedule

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

Amendment no.7

Impact on WP16



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

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

Any Questions?

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

APPENDIX

DISCLAIMER & PARTNERS

COPYRIGHT

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

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

PROJECT COORDINATOR

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

CONTACT

Philipp Ruffing
Work package 16 leader
ruffing@ifht.rwth-aachen.de

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, Statoil ASA, 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, Iberdrola Renovables Energía, S.A., European Association of the Electricity Transmission & Distribution Equipment and Services Industry, University of Strathclyde, ADWEN Offshore, S.L., Prysmian, Rijksuniversiteit Groningen, MHI Vestas Offshore Wind AS, Energinet.dk, Scottish Hydro Electric Transmission plc, SCiBreak AB

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