

Black-start by off-shore wind turbines

Wind Turbine – Converter Interaction PROMOTioN WP3

Prof R. Blasco-Gimenez (Universitat Politecnica de Valencia –Spain)

11 November 2019, WindEurope Offshore 2019 PROMOTioN Side Event, Copenhagen



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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.

WP3 Partners



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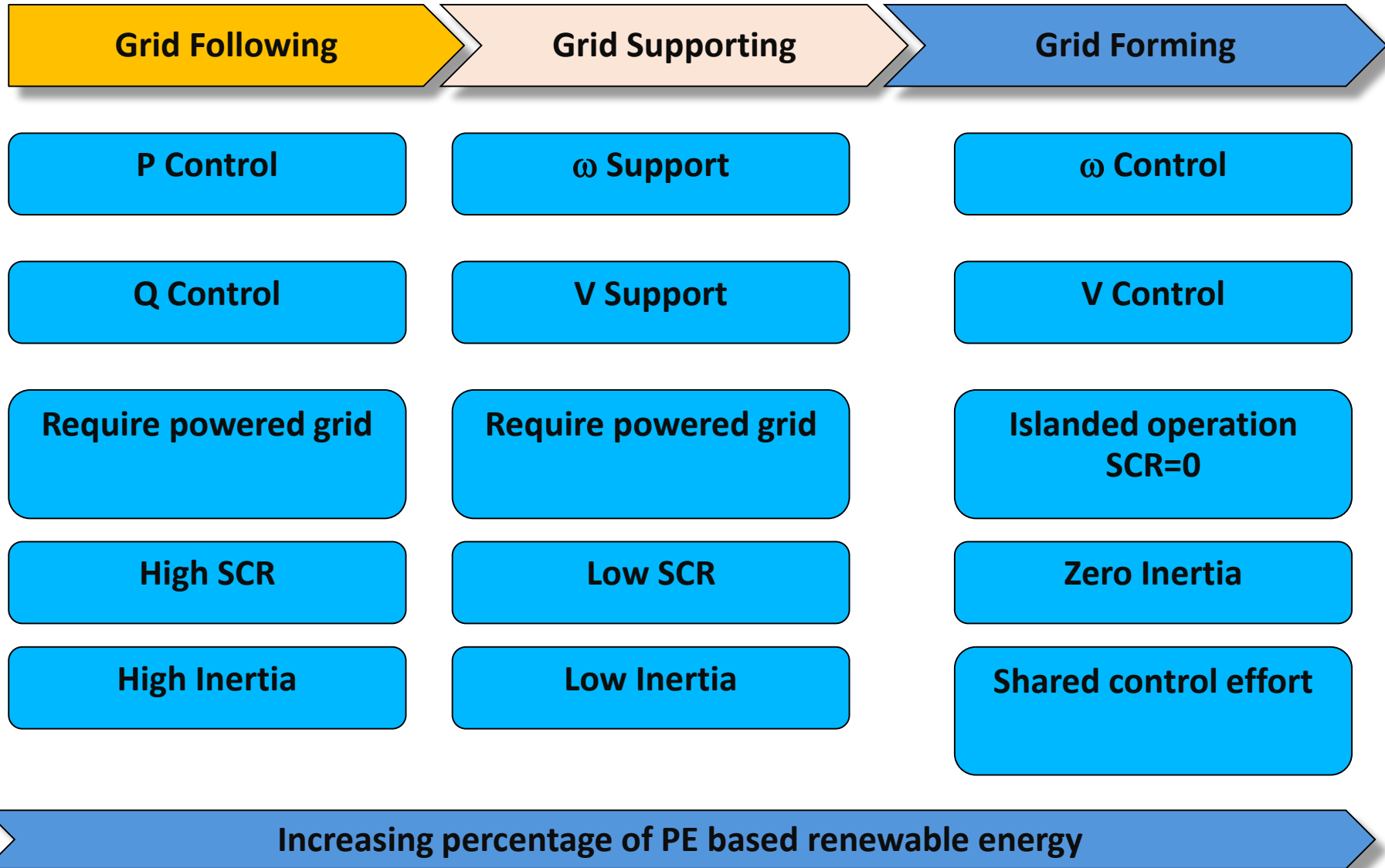




- Grid Forming Wind Turbines
- Black Start by Offshore Wind Turbines: Benchmarks
- Conclusions
- Next steps



Control capability evolution



Japan Wind Energy Association

Huge earthquake damaged 3 coal fired power plants (Tomatou-azuma power plant, 165MW in total) at about 3am on 6 Sep..

They produced about half of Hokkaido's power demand at that time.

Sudden loss of huge power supply caused frequency decrease, then remaining power plants (including wind farms) stopped one after another.

Hokkaido island has gone "black out". 303 wind turbines of 358MW at 61 sites were forced to shut down.

It needed about 40 hours to re-start whole island-wide grid system.

100MW of wind turbines & battery systems restarted 52 hours later from shut down.

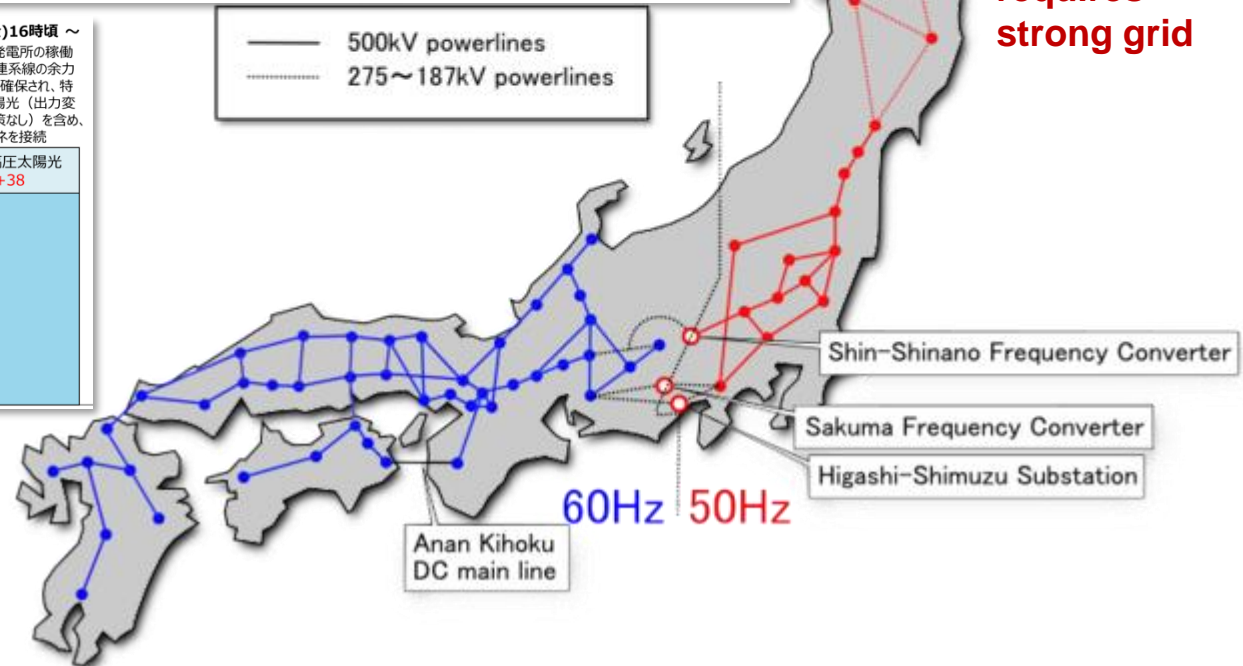
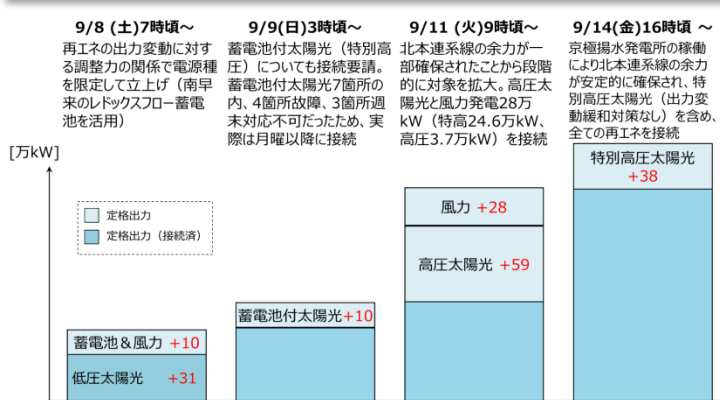
The rest of wind turbines restarted 126 - 130 hours later.

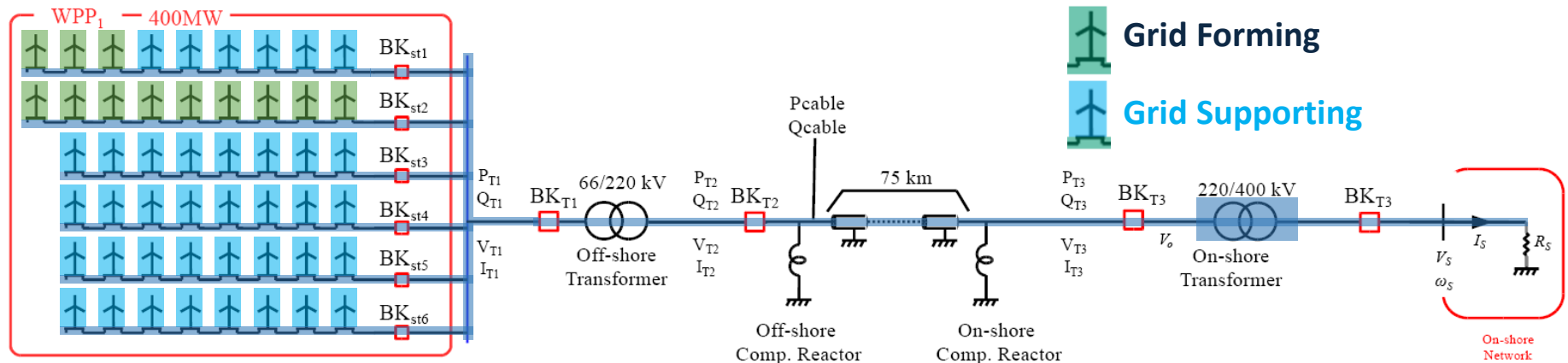
Some delay was needed to secure the grid stability.

北海道

North and Main island
DC connection line

**LCC-HVDC
requires
strong grid**





400 MW WPP
50 x 8 MW
66kV

460MVA
Trafo

75km
220kV
cable

460MVA
Trafo

Thermal
Station
Auxiliaries
40MW

Realistic transformer + cable models + no POW, no PIR

GOAL: Evaluate how much grid forming power is required. Interaction between grid forming and grid following WTGs

Issues:

- Long HVAC cable and transformer energisation
- Response to load transients (electrical, mechanical)
- Fault response and recovery with and without grid supporting WTGs

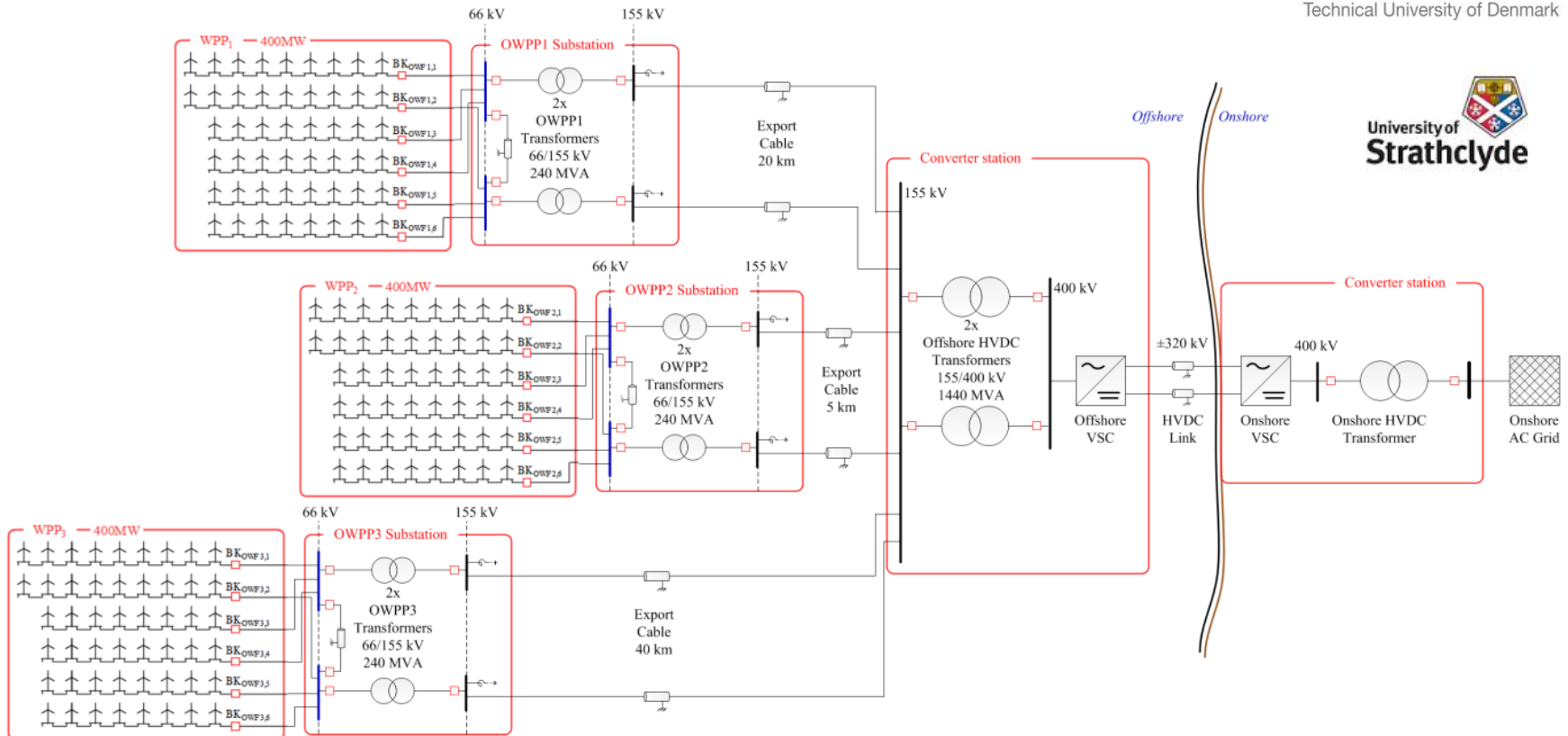
J. Martinez-Turegano, S. Añó-Villalba, S. Bernal-Pérez, R. S. Pena, and R. Blasco-Gimenez, "Mixed Grid-Forming and Grid-Following Wind Power Plants for Black Start Operation," presented at the 17th Wind Integration Workshop, Stockholm, 2018.



Case 1: Intermediate HVAC substations



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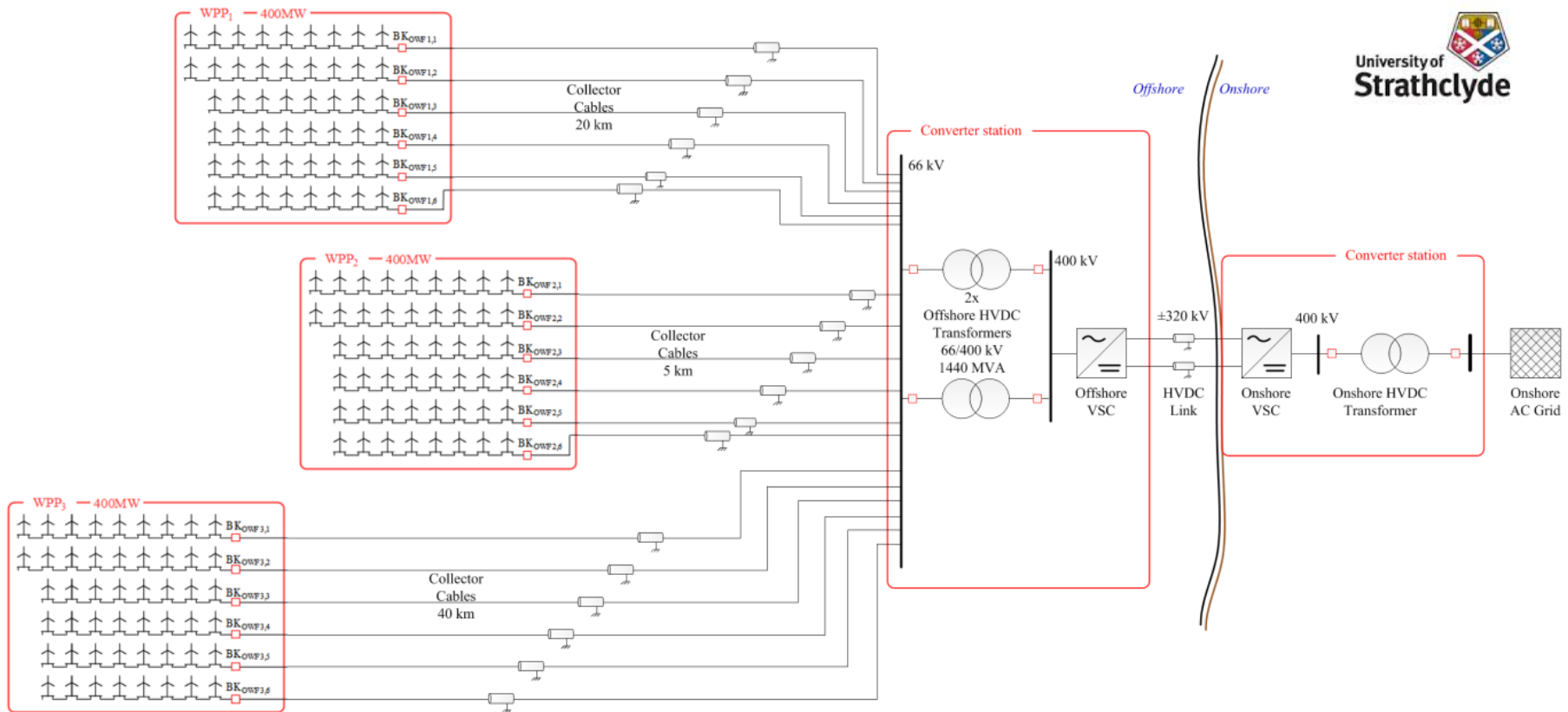
Case 2: No Intermediate HVAC substations

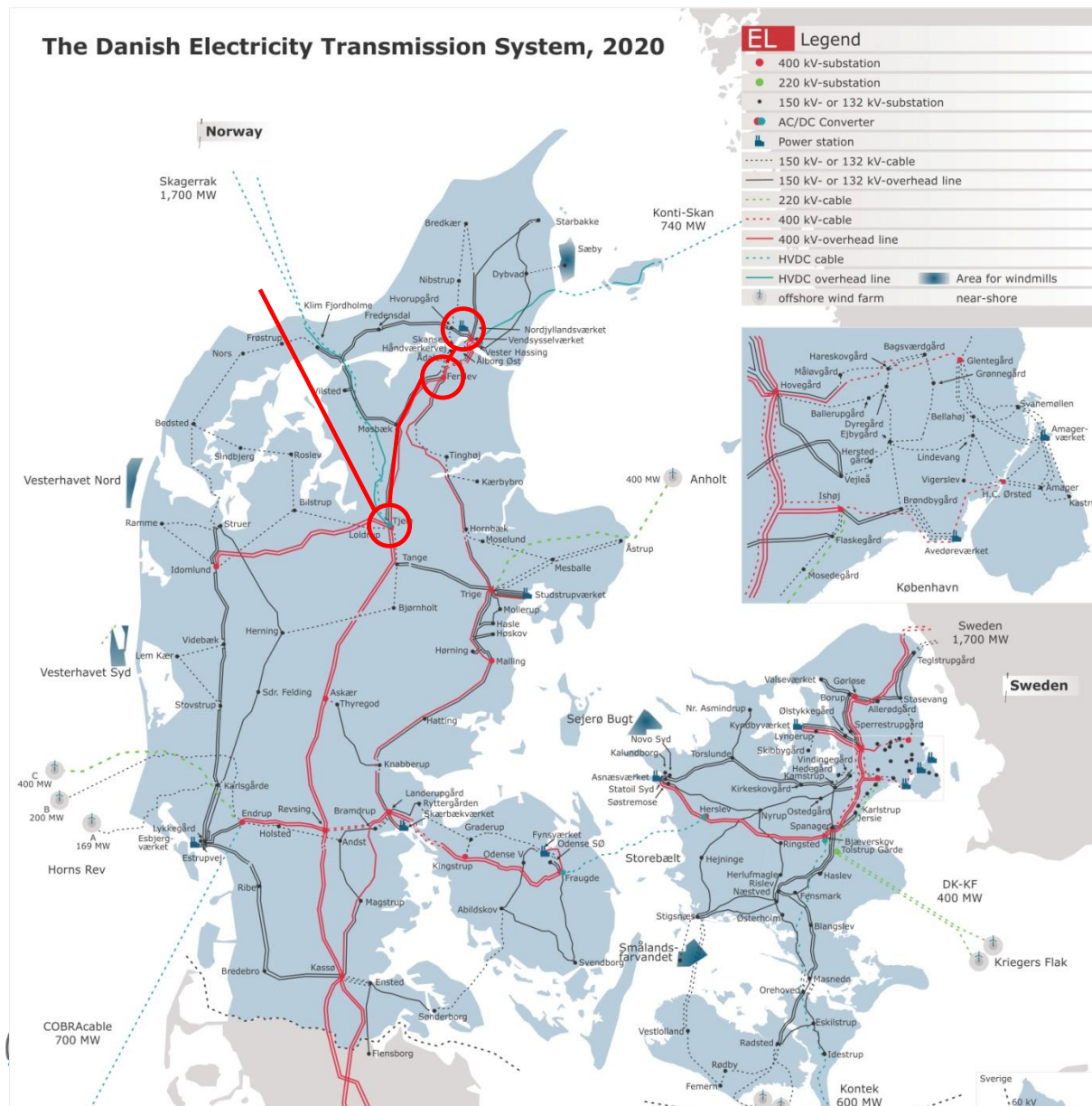


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- **Grid Forming Wind Power Plants allow for additional applications and functionality.**
 - **Improved HVDC Integration (DRU, MMC-HVDC)**
 - **Islanded operation**
 - **Black start / service restoration operation**
- **Different technical solutions are available and not all functionality requires grid forming capability**
- **Adequate control coordination can help to reduce the amount of grid forming power required for a particular application**
- **Fault recovery is very important with a large number of grid forming WTGs/WPPs, particularly if both grid forming and grid following WTGs/WPPs are considered**

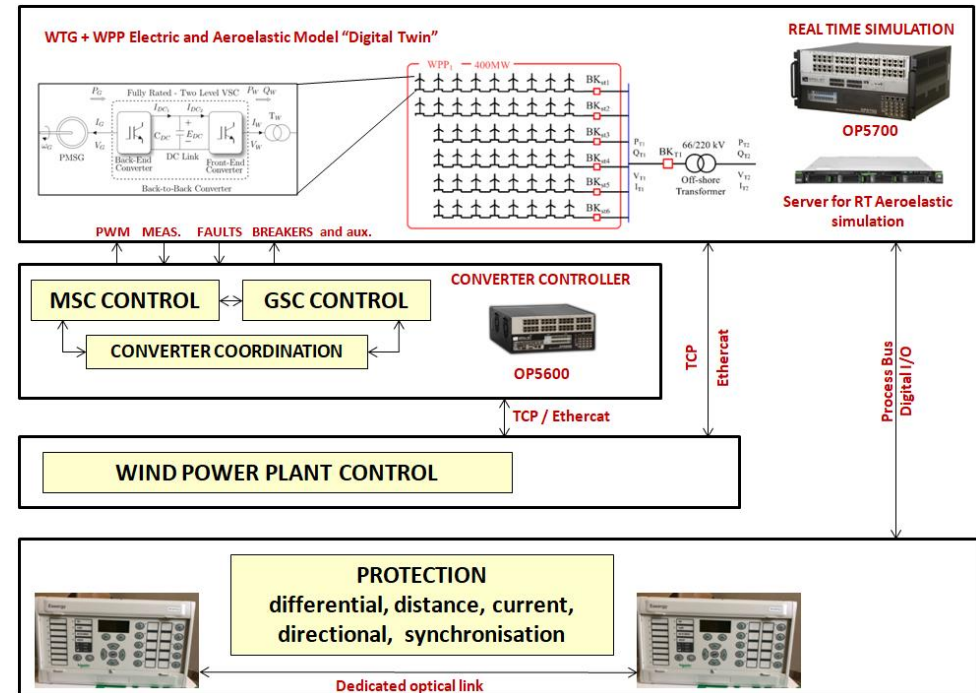


- Requirements for HVAC/HVDC black/brown start operation
- Specification of benchmark scenarios and test cases
- Specification of controller validation by simulation
- Validation of controllers
- D3.7 : Report with the compliance evaluation results using simulations (early 2020)
- D3.8 : List of requirement recommendations to adapt and extent existing grid codes

- **CHIL validation considering a large number of WTG converters**

Controller interaction and fault recovery with a large number of converters.

Protection co-ordination for Grid Forming Plants during Black-Start



APPENDIX

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MAIL info@promotion-offshore.net WEB www.promotion-offshore.net

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PROJECT COORDINATOR

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

CONTACT

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, 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 Trar SCiBreak AB

