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Challenges Towards the Deployment of Offshore Grids

Nicolaos A. Cutululis

DTU Vindenergi
DTU Electrical Engineering
Department of Electrical Engineering

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Agenda

- Background
- Project structure and objectives
- Challenges (and some results)
- Summary

Aknowledgments

Georgios Stamatiou *(Chalmers)*, Massimo Bongiorno, Ola Carlson

Lorenzo Zeni *(DONG)*, Bo Hesselbæk,

Poul Sørensen *(DTU)*, Anca D. Hansen

Walid Ziad El-Khatib *(DTU)*, Joachim Holbøll

Vin Cent Tai , Atsede Gualu Endegnanew *(NTNU)*, Kjetil Uhlen

Niina Helistö *(VTT)*, Juha Kiviluoma, Sanna Uski

Torsten Lund (Energinet.dk), Lennart Harnefors (ABB)

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Offshore wind power development scenarios

Source: Pure Power report, EWEA, July 2011:

2020 Baseline scenario

Total wind power**:** 230 GW

Offshore**: 40 GW**

Electricity consumption: 15.7%

2020 High scenario

Total wind power**:** 265 GW

Offshore**: 55 GW**

Electricity consumption: 18.4%

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Offshore wind power development scenarios

Country	MW installed end 2020		MW installed end 2030	
	Baseline	High	Baseline	High
Belgium	2,156	2,156	3,956	3,956
Denmark	2,811	3,211	4,611	5,811
Estonia	0	0	1,695	1,695
Finland	846	1,446	3,833	4,933
France	3,275	3,935	5,650	7,035
Germany	8,805	12,999	24,063	31,702
Ireland	1,155	2,119	3,480	4,219
Latvia	0	0	1,100	1,100
Lithuania	0	0	1,000	1,000
Netherlands	5,298	6,298	13,294	16,794
Norway	415	1,020	3,215	5,540
Poland	500	500	500	500
Russia	0	0	500	500
Sweden	1,699	3,129	6,865	8,215
UK	13,711	19,381	39,901	48,071
TOTAL	**40,671**	**56,194**	**113,663**	**141,071**

Twenties
Transmitting wind

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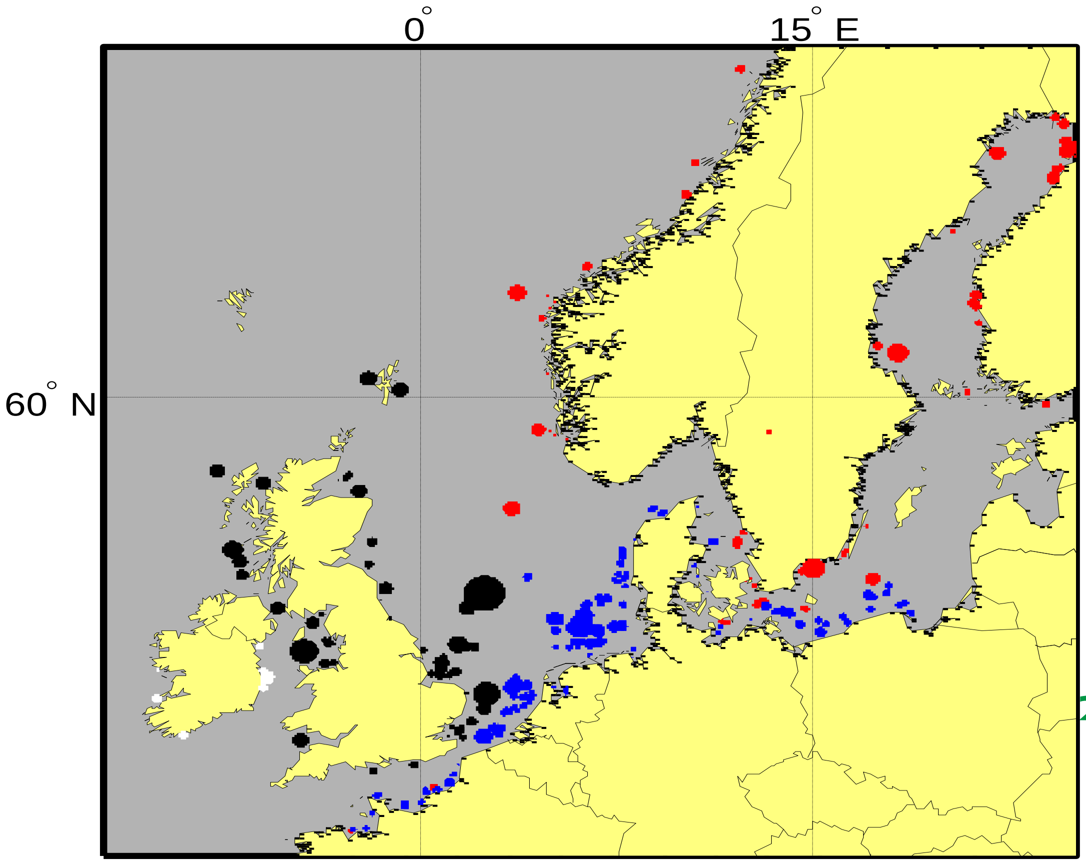
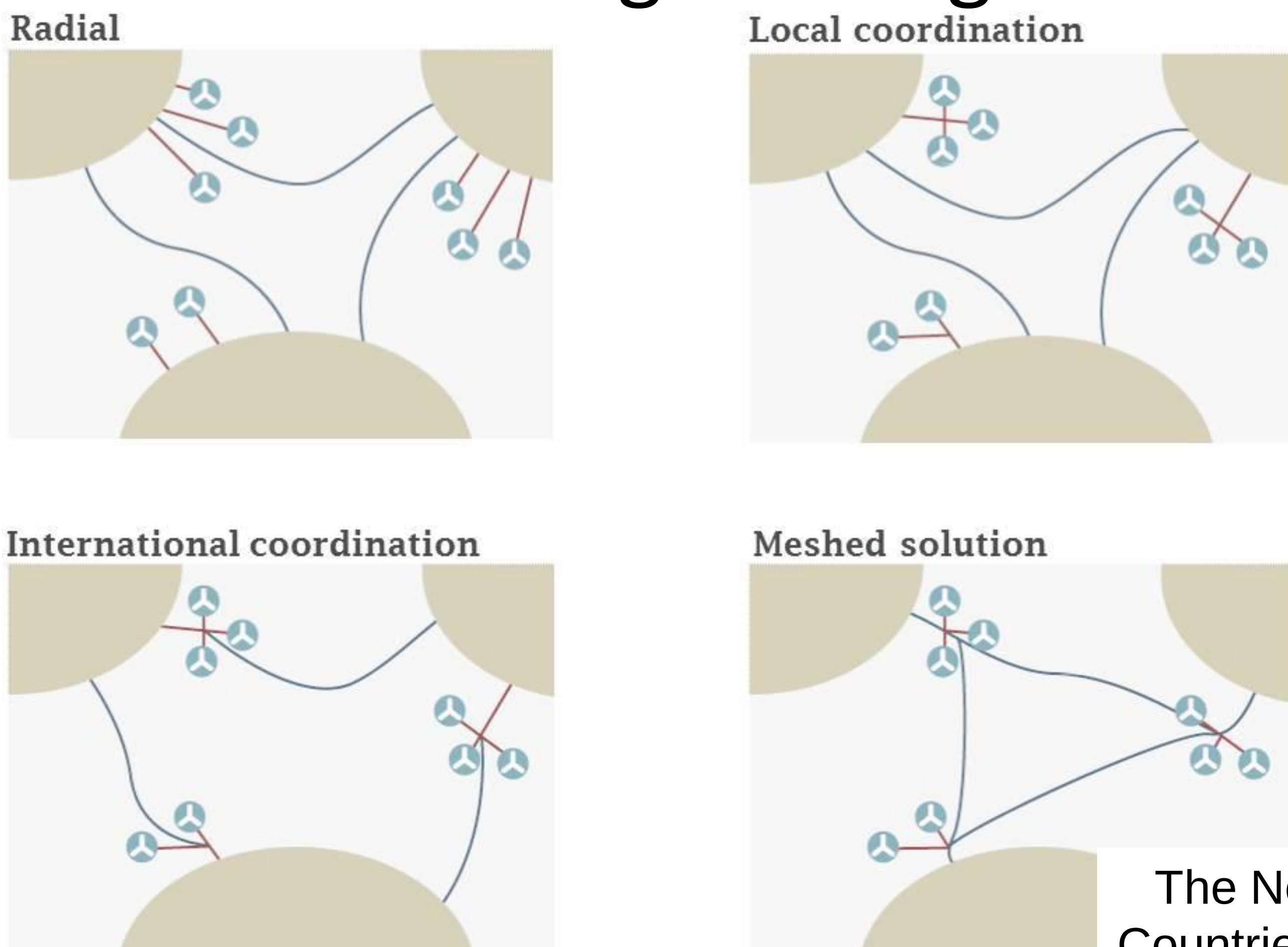
Offshore wind power development scenarios



Twenties
Transmitting wind

Offshore grid design



The North Seas Countries' Offshore Grid Initiative

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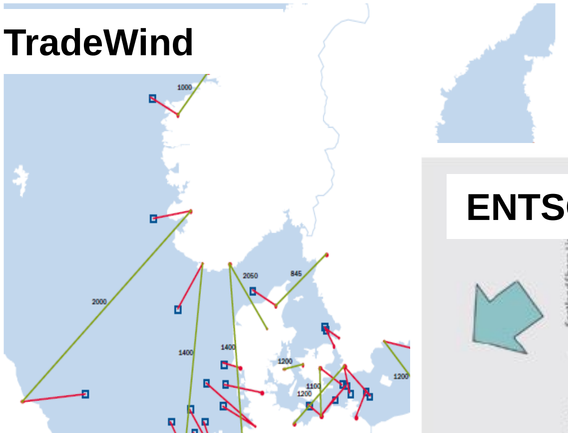
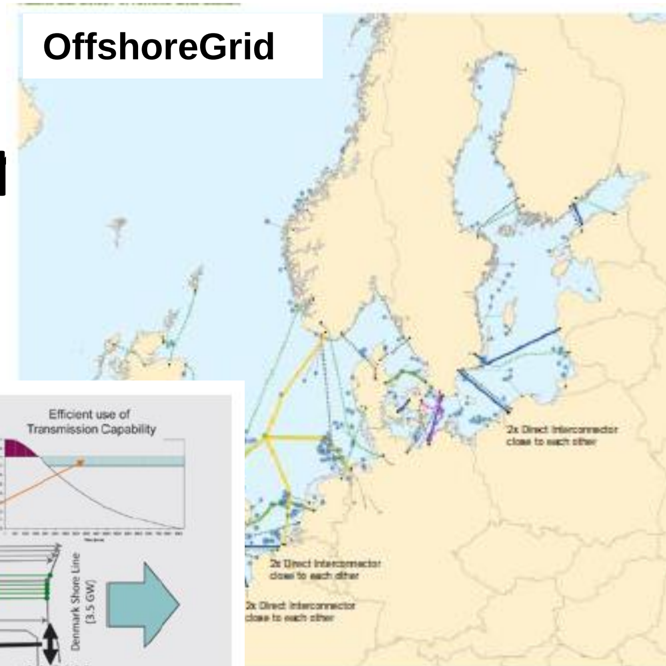
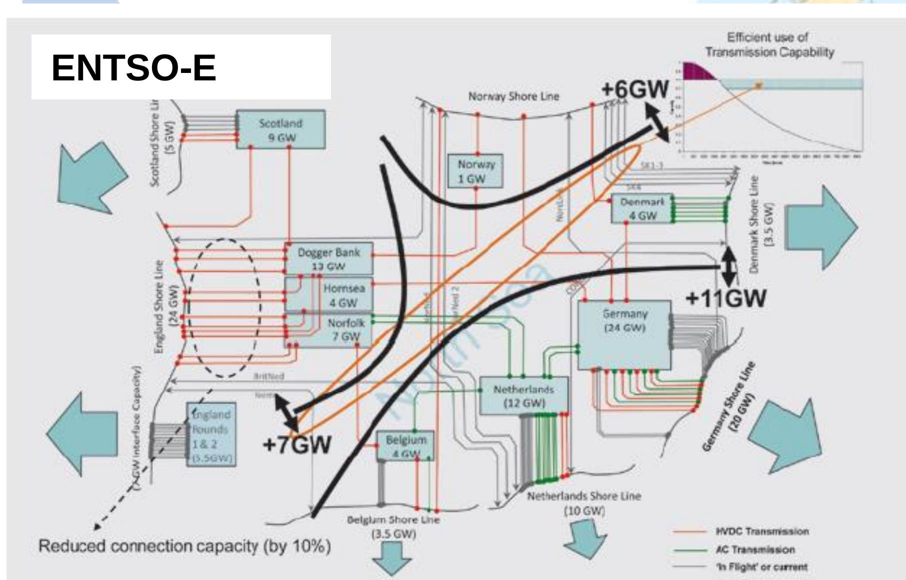
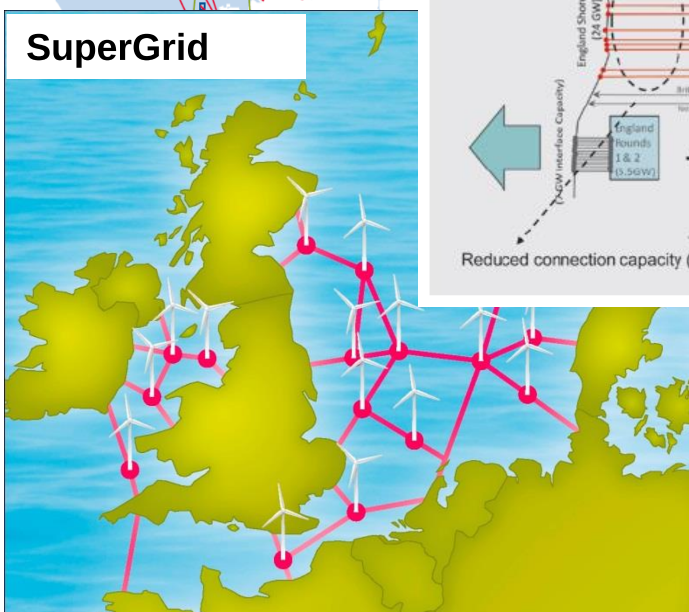
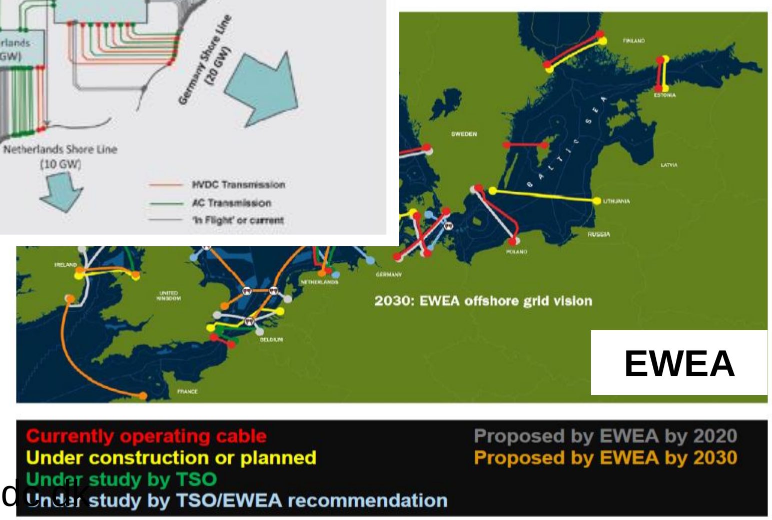
Offshore grid scen











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Project DNA

- Technical research project
- Period: 2011 – 2016;
- Budget of 18.5 NOK (2.5 M€), 60% funded by NER
- Education: 6 PhDs, 1 PostDoc
- 10 partners from Nordic countries (DK, NO, SE, FI)
- Coordinator DTU Wind Energy, Denmark

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Project partners

DTU Wind Energy
Department of Wind Energy

DTU Electrical Engineering
Department of Electrical Engineering

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Overall objective

- to support the development of the VSC based HVDC technology for future large scale offshore grids
- to improve the opportunities for the technology to support power system integration of large scale offshore wind power

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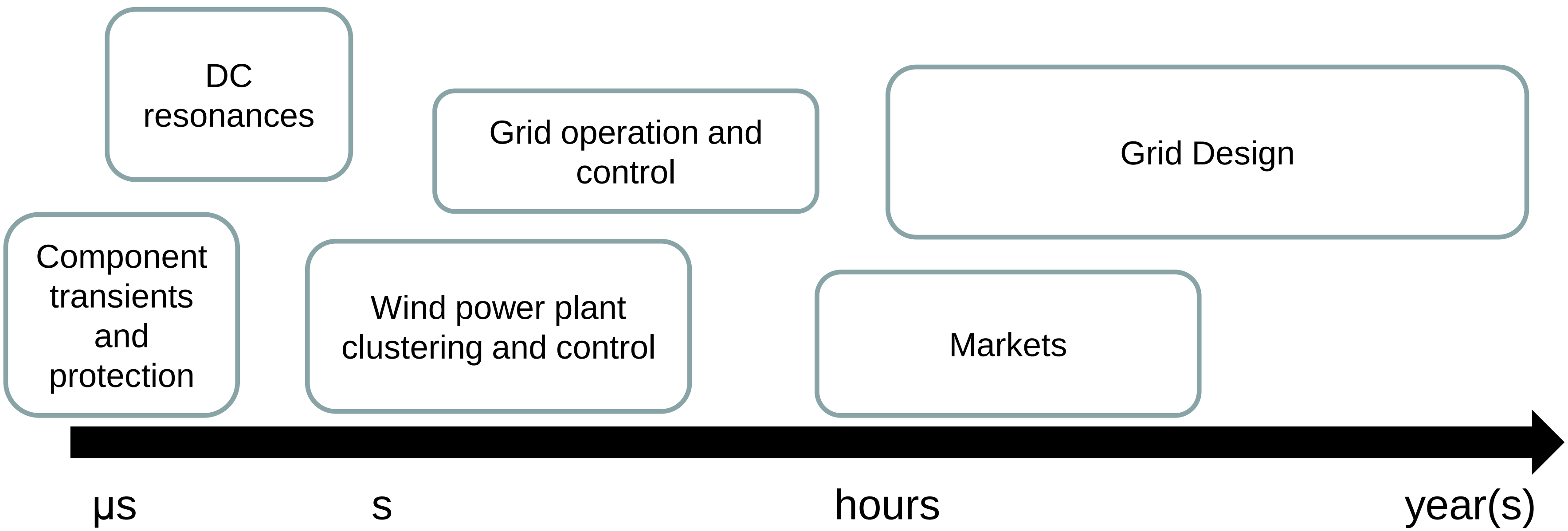
Project structure

- **Technology**
  - Component transients and protection (DTU Elektro)
  - DC resonances in MT-HVDC grids – Converter Interactions (Chalmers/ABB)
- **Operational**
  - Grid operation and control (NTNU)
  - Clustering of wind power (DTU Wind/DONG)
- **Economic**
  - Optimal grid design – NetOP (NTNU/VTT)
  - Market impacts of different grid solutions – WILMAR (VTT)

Challenges time scale



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HVDC connected WPPs

- Development of offshore grids and WPPs are interdependent:
  - Offshore grids will develop if OWPPs cost is reduced
  - Offshore grids may reduce cost of OWPPs
  - Active support from WPPs to the operation and control of offshore grids

- However:
  - Cost is still very high → economical break-even farther from shore
  - Although VSC-HVDC is mature, challenges have arisen when it is applied to WPP connection

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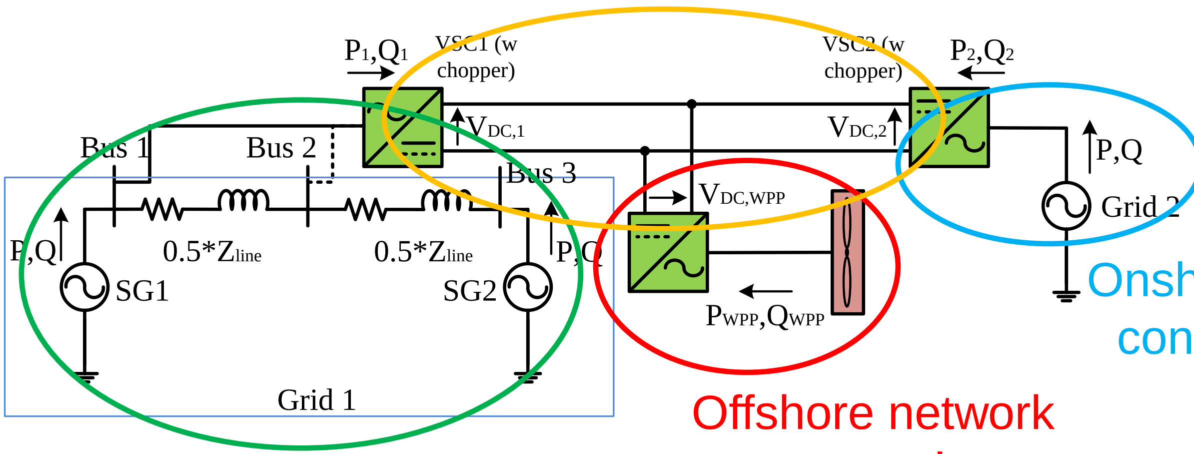
Investigation on system services provision

DC voltage control



Onshore AC voltage control and LVRT

Offshore network control

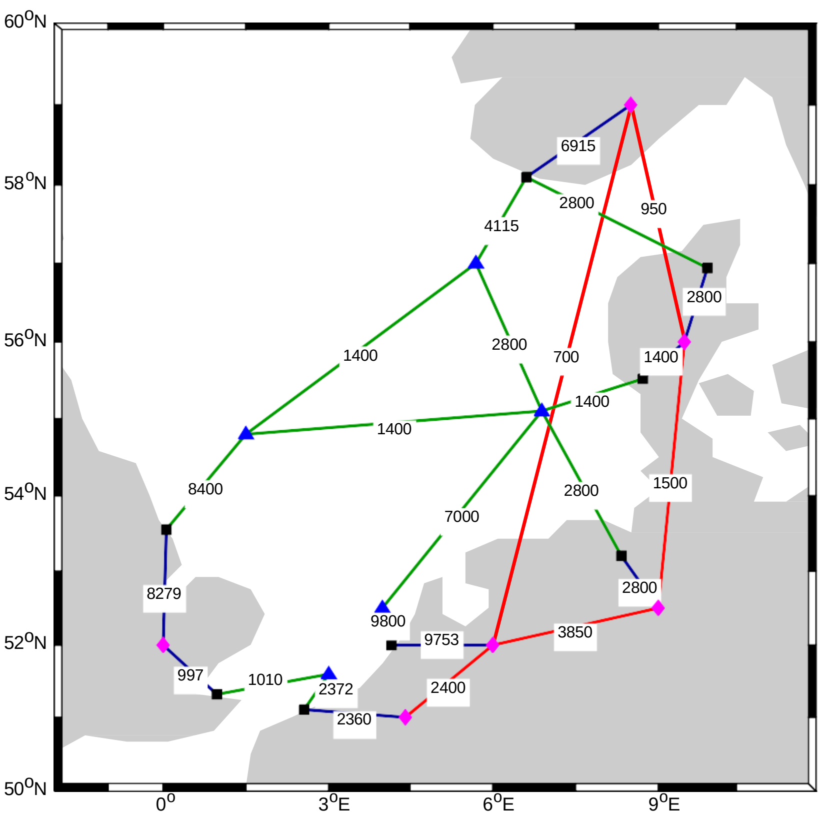
Onshore frequency control and power oscillation damping

L. Zeni et.al. from paper in Cigré session 2014

Ancillary services from OWPP

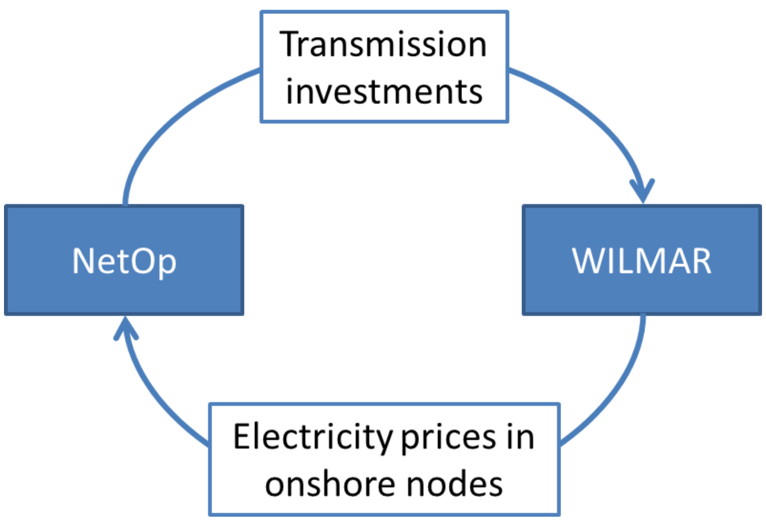
- Services with dynamics similar to AC
  - Frequency control – WPPs can contribute
  - Power Oscillation Damping – more demanding, but possible
- Voltage control
  - VSC-HVDC have excellent capabilities
- DC voltage control
  - Very fast dynamics, WPPs can contribute in steady-state
- Control of offshore AC grid
  - Integration of WPPs from different manufacturers and developers

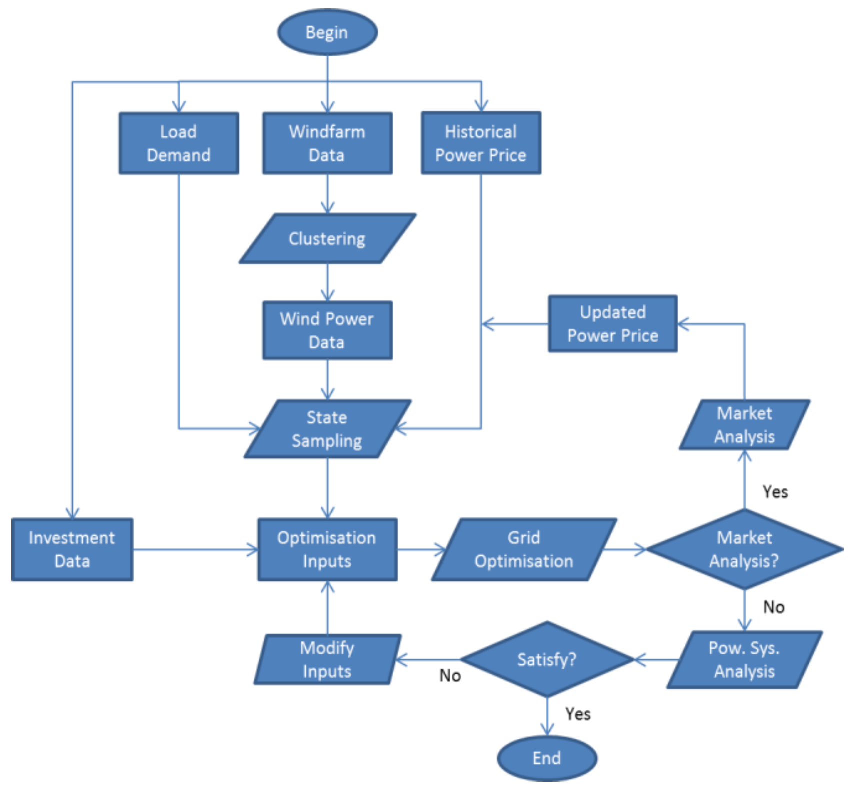
Offshore grid design



- Find an optimal grid structure taking into account:
  - Wind power variations
  - Stochastic power prices
  - On- and offshore load and generation scenarios
- Use formal optimization for a structured approach to finding good grid layouts
  - Difficult to solve ”by inspection”
  - Huge number of possible grid structures
  - ◊ Combinatorial problem solved efficiently by optimization tools
- Results:
  - Which cables to build
  - Capacity on the cables
- Gives valuable decision support, but:
- Must be combined with market/network model in an iterative procedure

Offshore grid design





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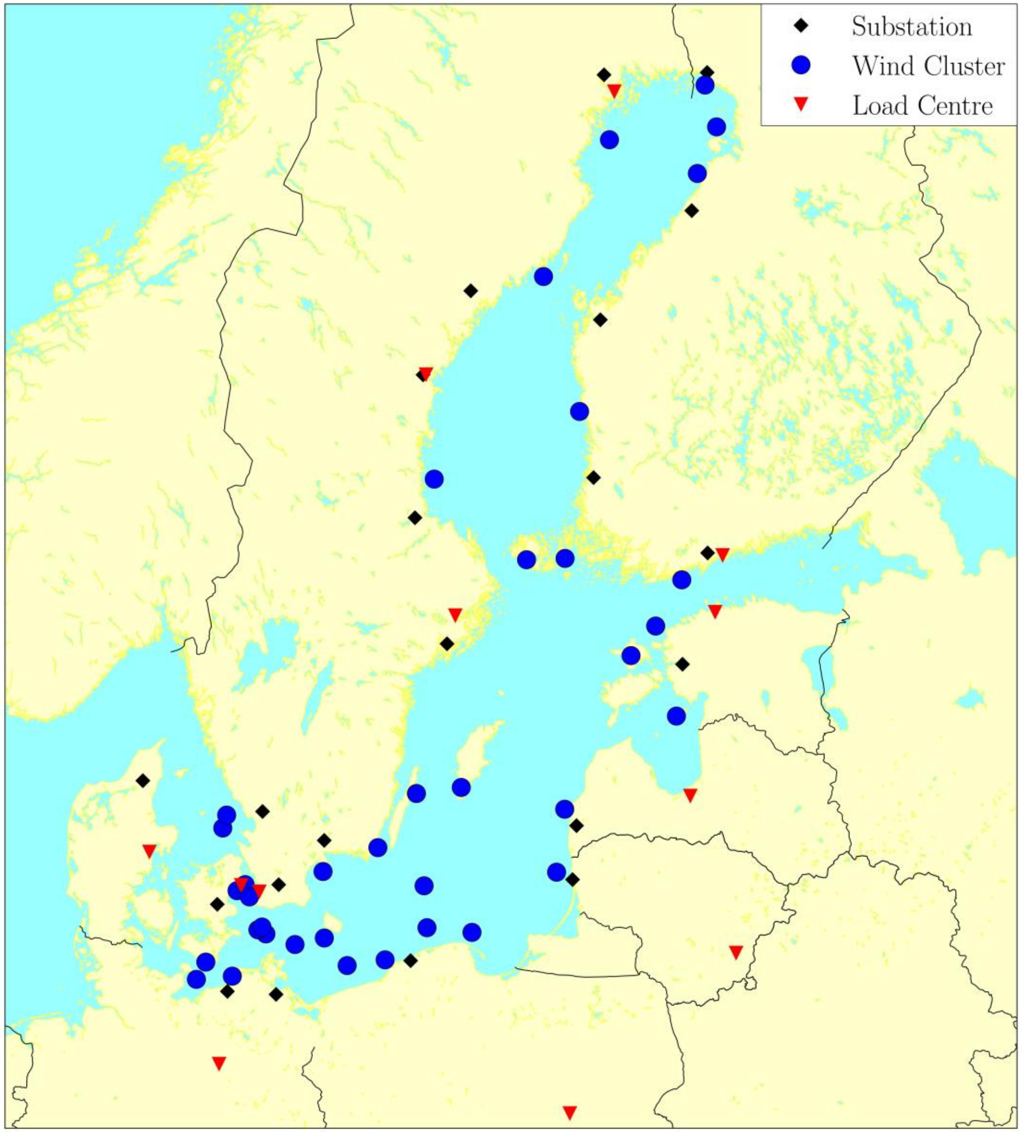
Case Study : Baltic Sea 2030



Scenario:
- Wind farms: 97
- Price areas : 12
- Onshore substations: 18

Problems:
- How to connect the wind farms to the onshore grids?
- What are the effects on the market

No. combinations:

$$2^{N(N-1)/2}$$

Clustering criteria:
- Windfarms belong to the same country
- Distance ± 200km

Total wind farm clusters: 22

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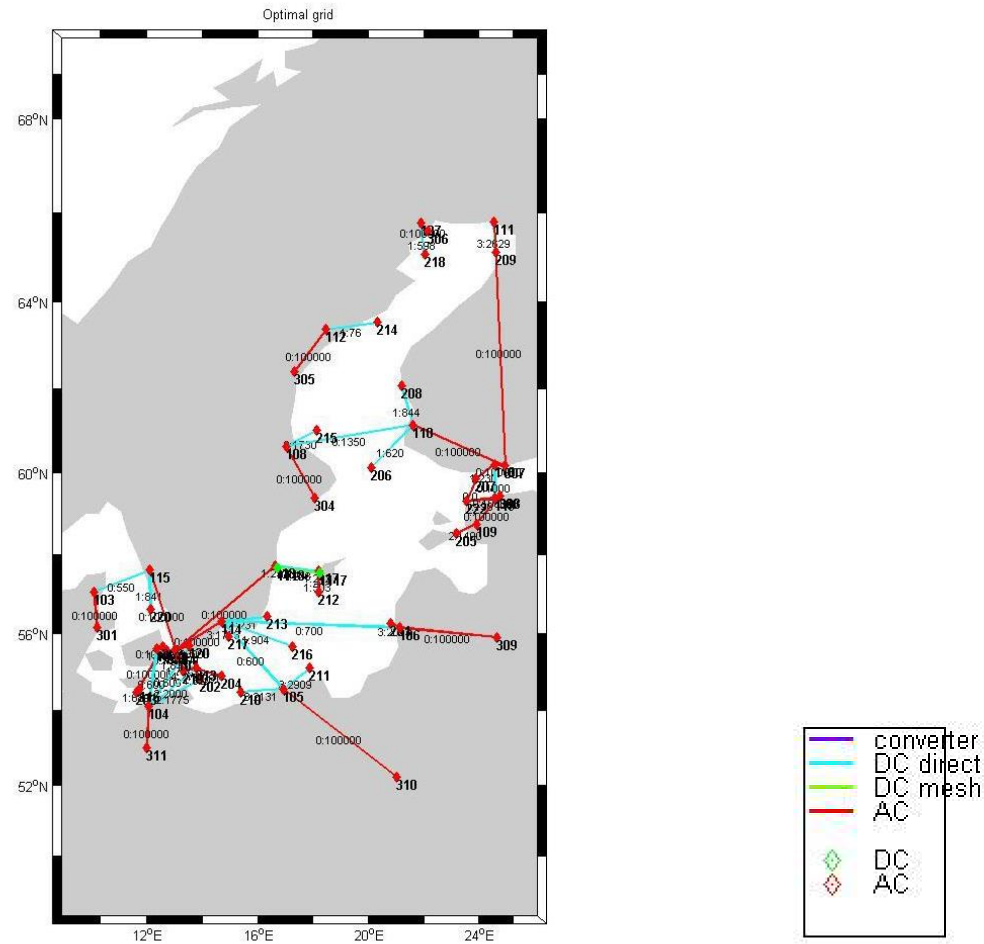
Baltic Sea 2030



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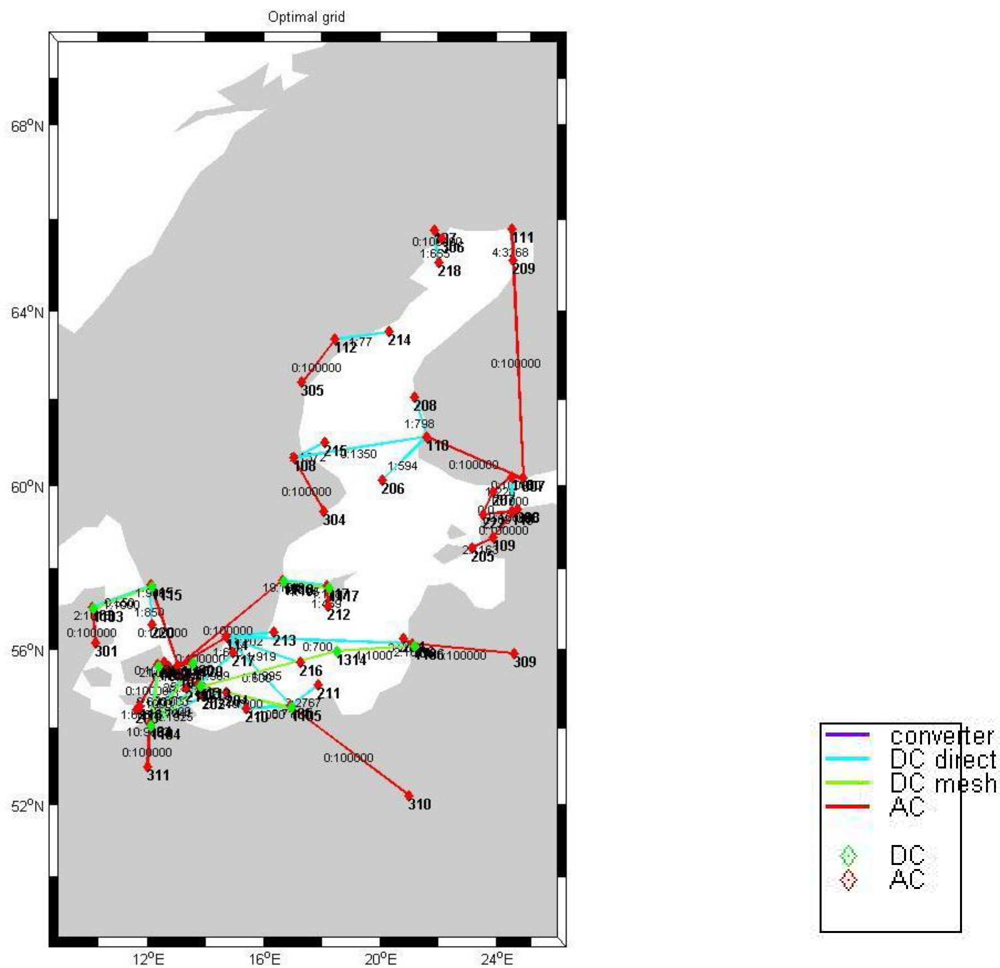
Baltic Sea 2030



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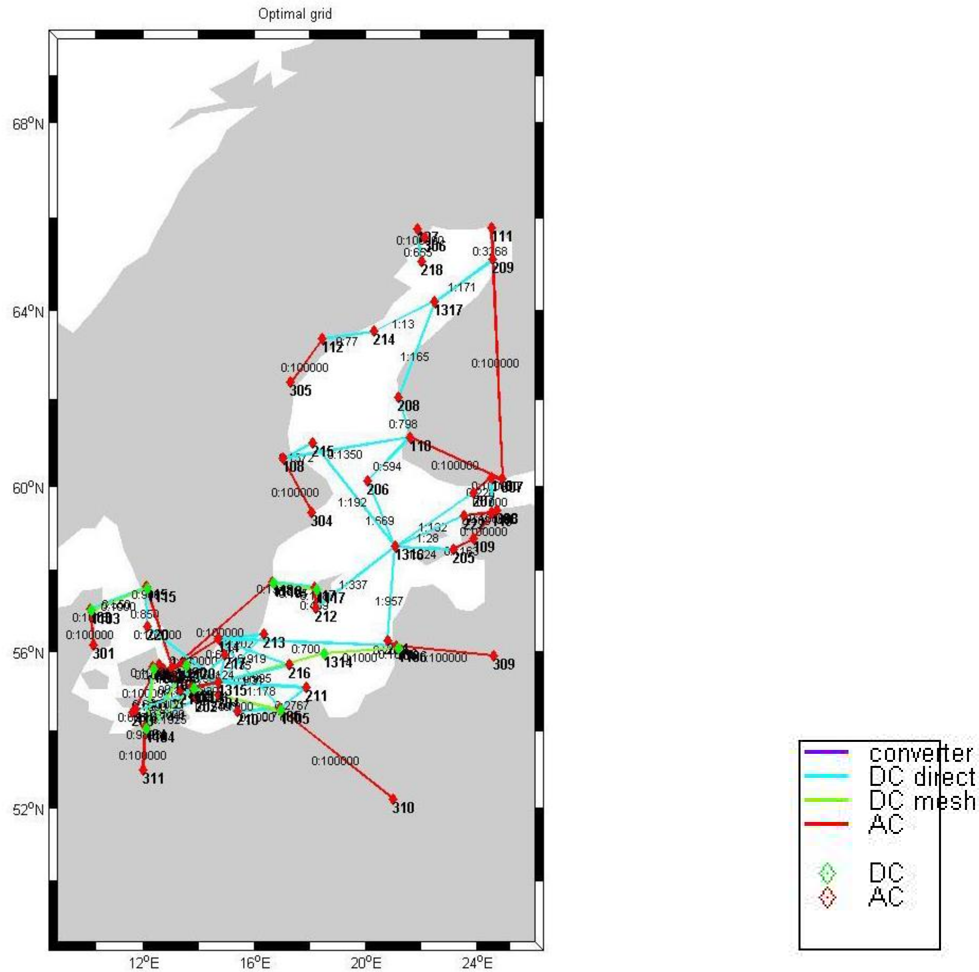
Baltic Sea 2030



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Summary

- Offshore grid is technically feasible
- Main driver are the economic benefits
  - Strong offshore grids → increased flexiblity → lower the cost of energy
- Offshore grid likely to develop in modular steps from national developments
- The main technical challenges are related to the control and protection of offshore grids and WPPs
- Several other issues not addressed…
- (more) Research needed …

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