DC grids for integration of large scale wind power

Zeni, Lorenzo; Sørensen, Poul Ejnar; Cutululis, Nicolaos Antonio

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OffshoreDC .dk

DTU Wind Energy
Department of Wind Energy

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Lorenzo Zeni, Poul Sørensen

Nicolaos A. Cutululis

DTU Wind Energy
Department of Wind Energy
DTU Electrical Engineering
Department of Electrical Engineering

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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: 4 PhDs
- Annual workshops
- Coordinator DTU Wind Energy, Denmark; 10 partners from Nordic countries

Project partners

DTU
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Department of Wind Energy
DTU 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 support a standardized and commercial development of the technology
- to improve the opportunities for the technology to support power system integration of large scale offshore wind power

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%

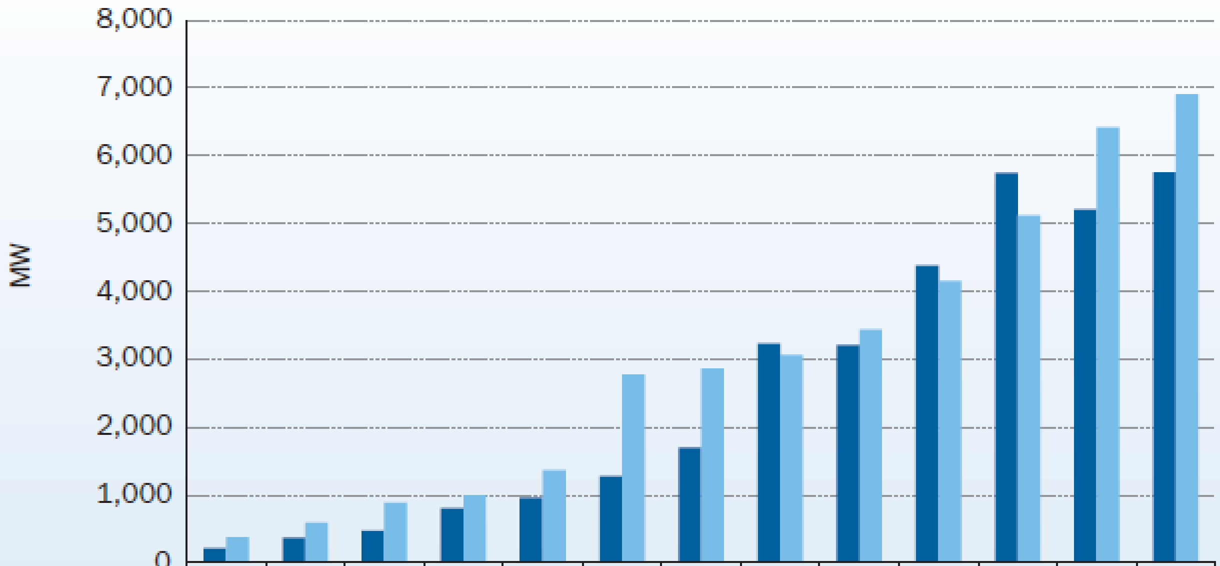
2020 High scenario

Total wind power**:** 265 GW

Offshore**: 55 GW**

Electricity consumption: 18.4%

Offshore wind power development scenarios



	1992 - 2008	1993 - 2009	1994 - 2010	1995 - 2011	1996 - 2012	1997 - 2013	1998 - 2014	1999 - 2015	2000 - 2016	2001 - 2017	2002 - 2018	2003 - 2019	2004 - 2020
Onshore (1992-2004)	215	367	470	809	962	1,277	1,697	3,225	3,205	4,377	5,743	5,203	5,749
Offshore (2008-2020)	374	584	883	1,000	1,370	2,767	2,859	3,053	3,433	4,145	5,115	6,419	6,902

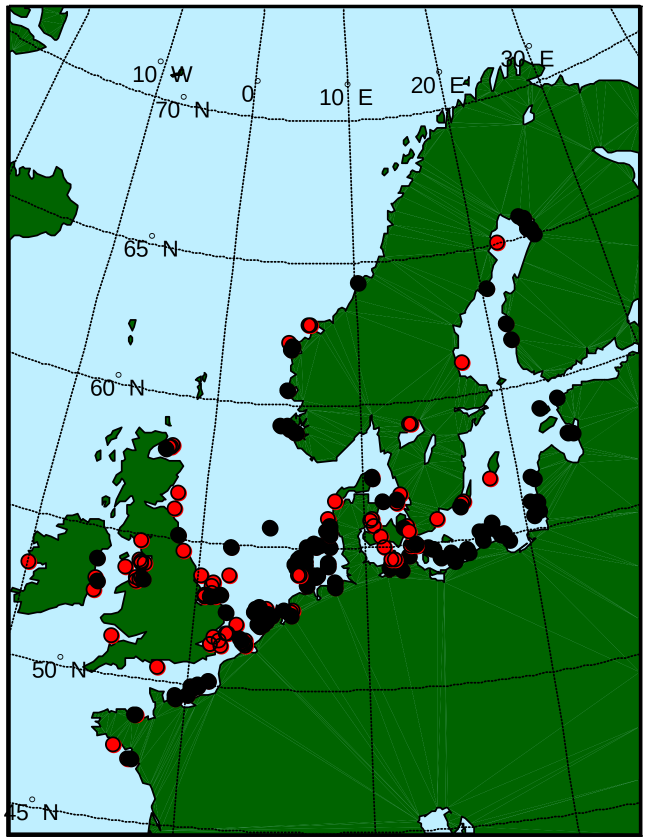
Source: EWEA 2011

Offshore wind power development scenarios

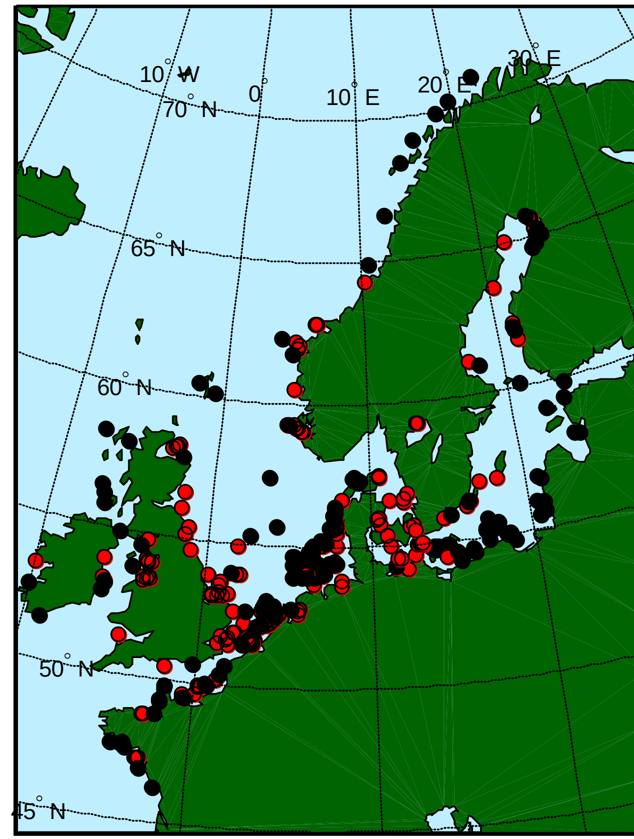
Country	MW installed end 2020		MW installed end 2030	
	Baseline	High	Baseline	High
Belgium	2,156	2,156	3,956	3,956
Denmark	2,811	3,211	4,611	5,811
Estonia	0	0	1,695	1,695
Finland	846	1,446	3,833	4,933
France	3,275	3,935	5,650	7,035
Germany	8,805	12,999	24,063	31,702
Ireland	1,155	2,119	3,480	4,219
Latvia	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**

20 20 20 Twenties
Transmitting wind

Offshore wind power development scenarios



Base scenario



High scenario

Twenties
Transmitting wind

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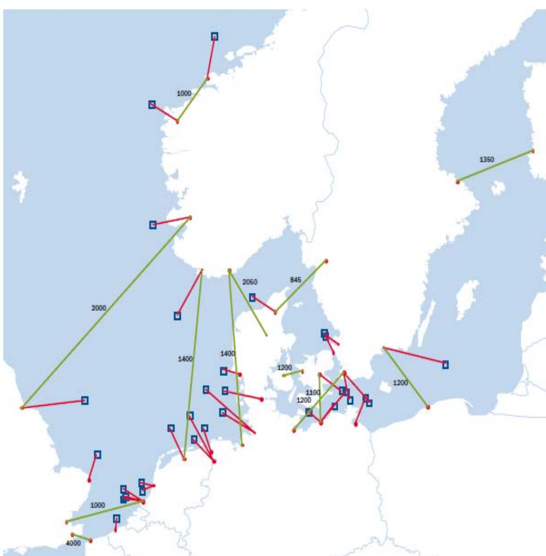
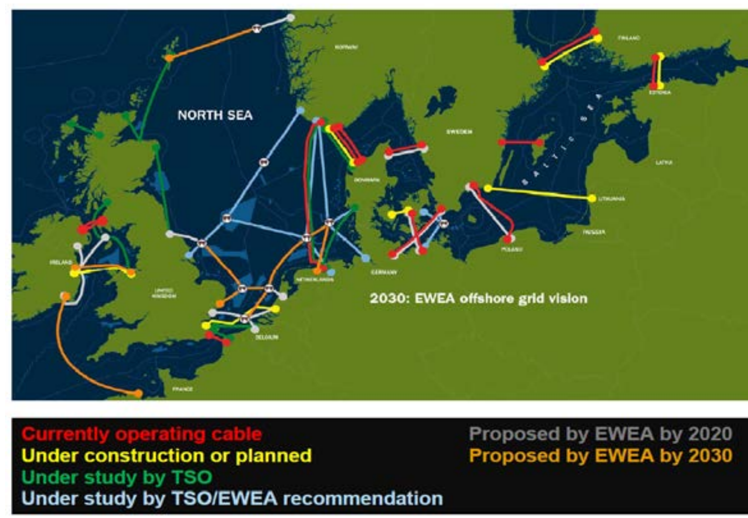
Offshore grid scenarios

- The simplest Tradewind case with separate interconnectors and offshore wind plant connections



- EWEA 2030 offshore grid vision (Jacopo Moccia Nov 2010)



Work flow

- **Technology**
  - Component transients and protection (DTU Elektro)
  - DC resonances in MT-HVDC grids – Converter Interactions (Chalmers/ABB)
- **Grid topologies**
  - Grid operation and control
  - Power system and security analysis (NTNU/SINTEF)
- **Clustering of wind power** (DTU Wind Energy/Vestas)
- **Feasibility studies** (VTT)

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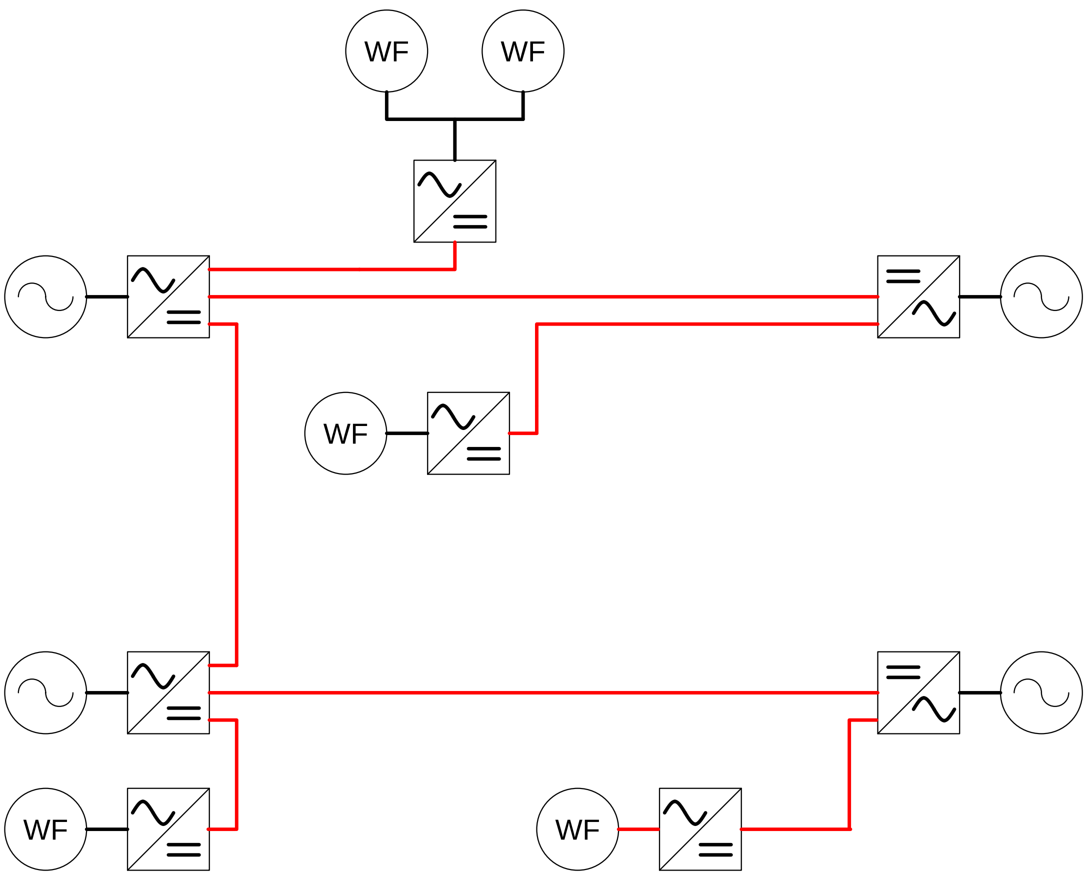
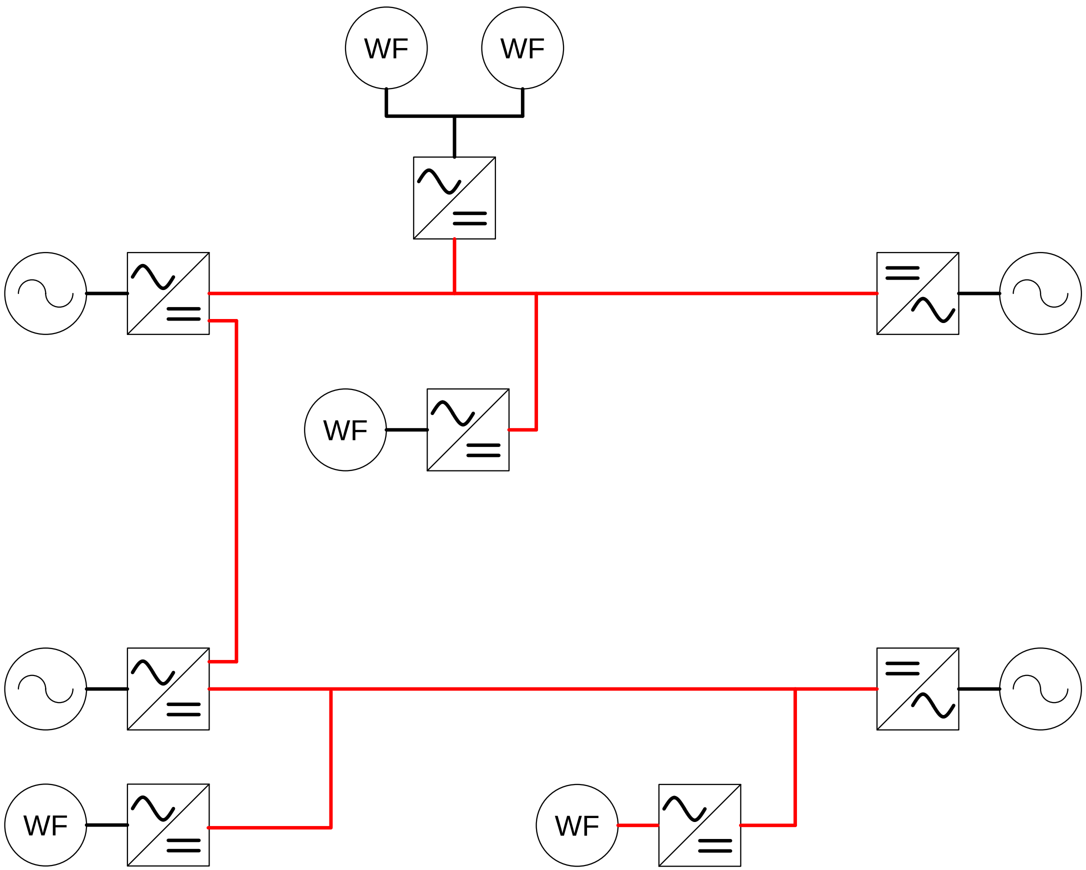
Grid topologies



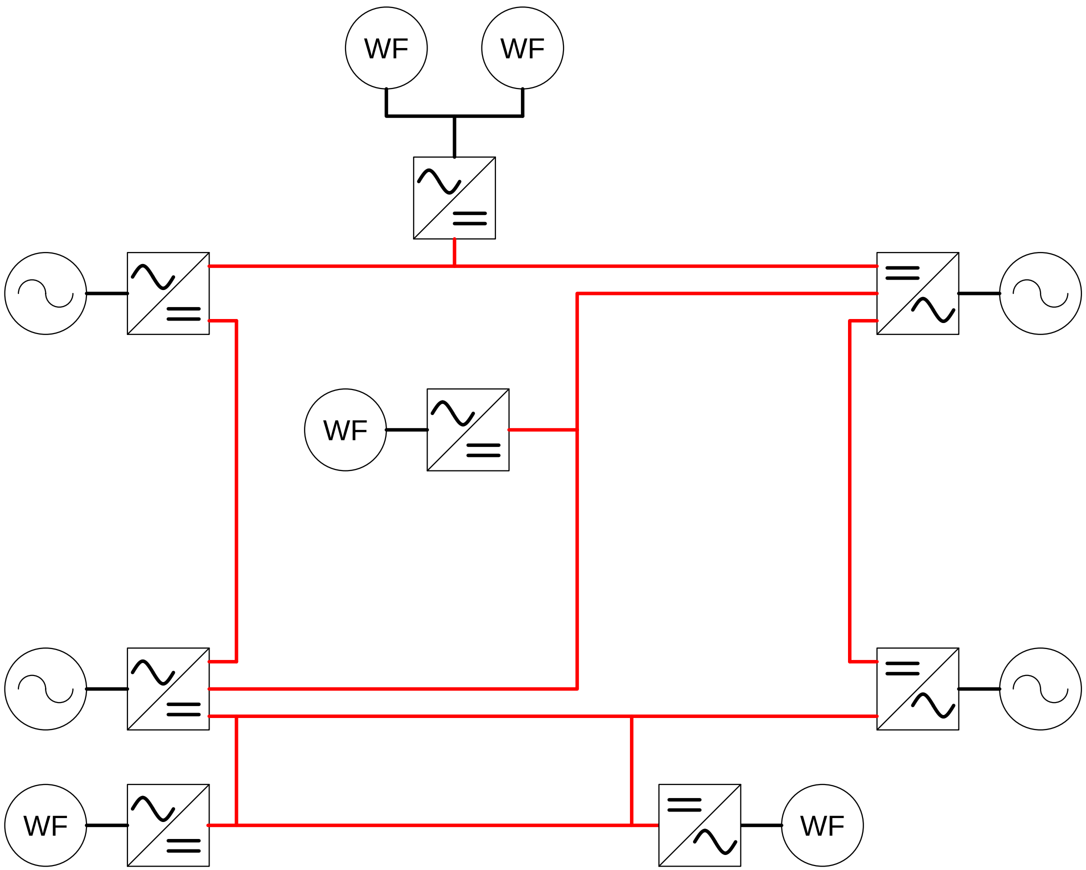
- P2P + interconnectors
- Mature technology
- Simple control
- No regulatory problems
- No need for DC breakers
- Not optimal for large scale wind power

Grid topologies



- Wind connected to interconnectors
- Adds flexibility to the system
- Could work without DC breakers
- Better use of transmission capacity
- Regulatory problems

Grid topologies



- Meshed grid
- Integrates markets and wind across areas
- Allows sharing of reserves
- DC breakers necessary
- Sophisticated control
- Regulatory problems

Work flow

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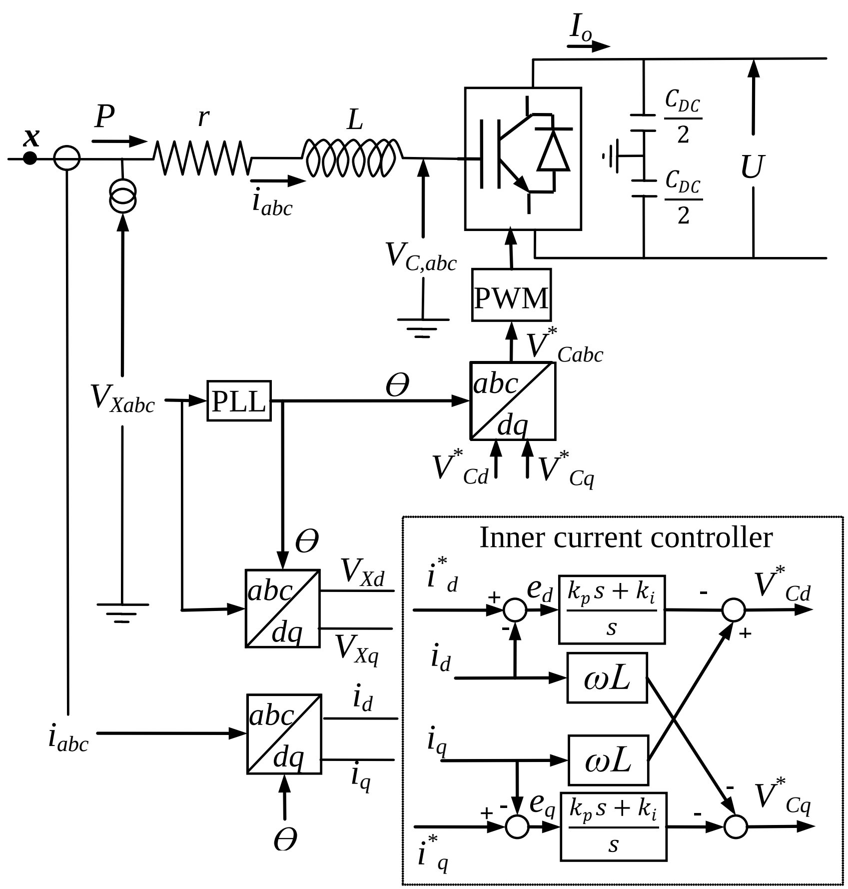
Control

Temesgen Haileselassie,
NTNU



Control

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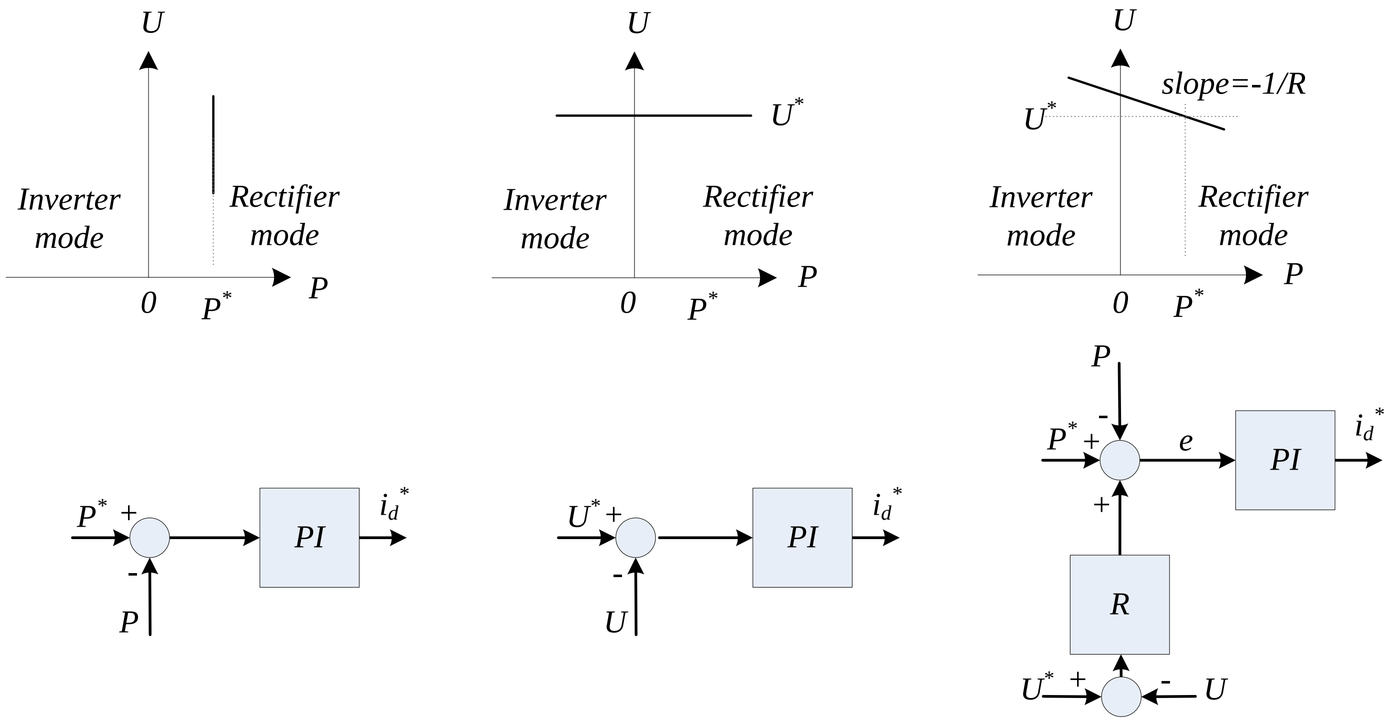

a. DC bus power controller

b. DC voltage regulator

c. DC voltage droop controller

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Ancillary services

AC systems

DC systems

Active power → Frequency

Active power → Voltage

Reactive power → Voltage

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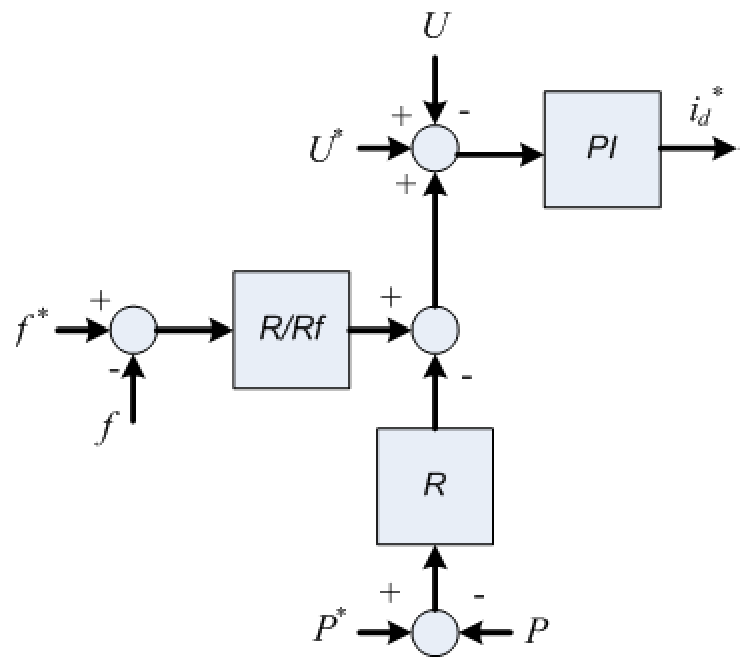
Ancillary services

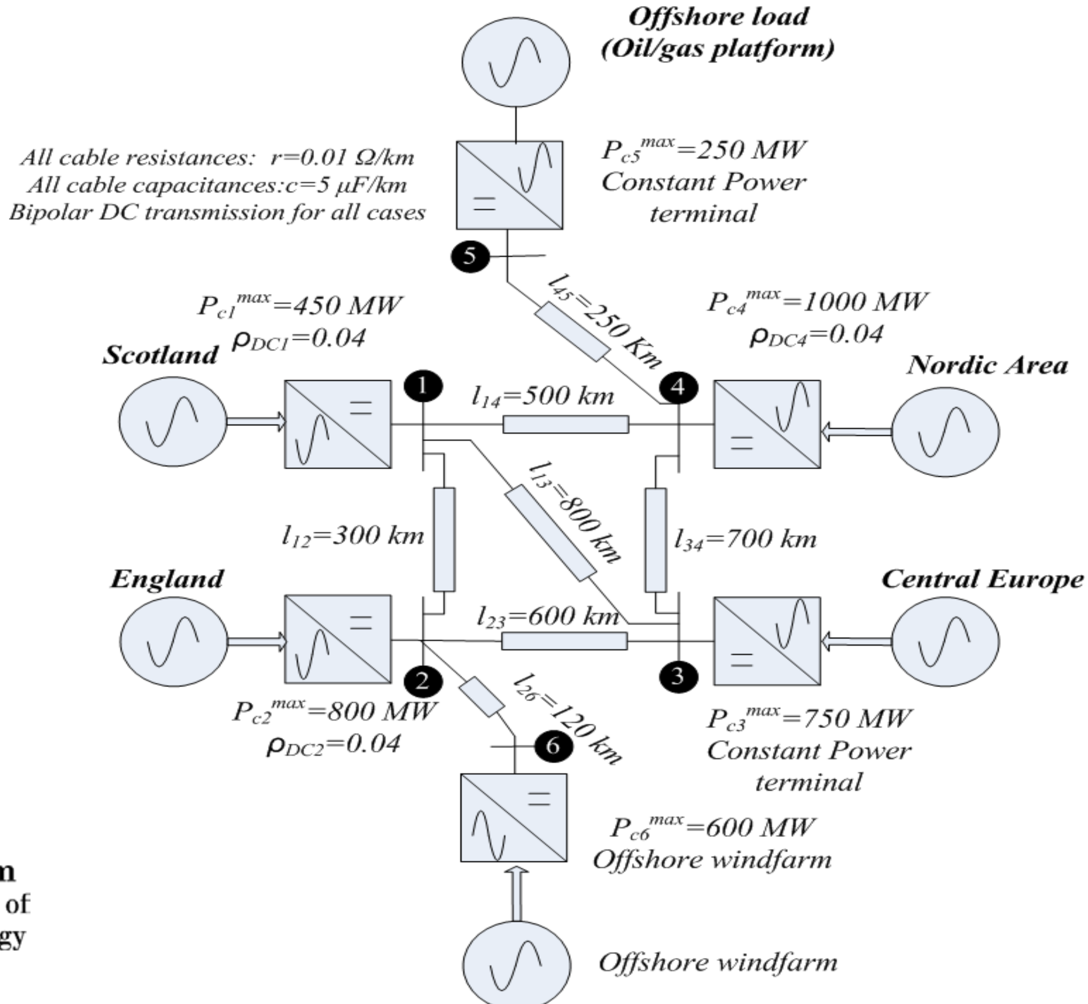
Primary frequency control

DC voltage droop

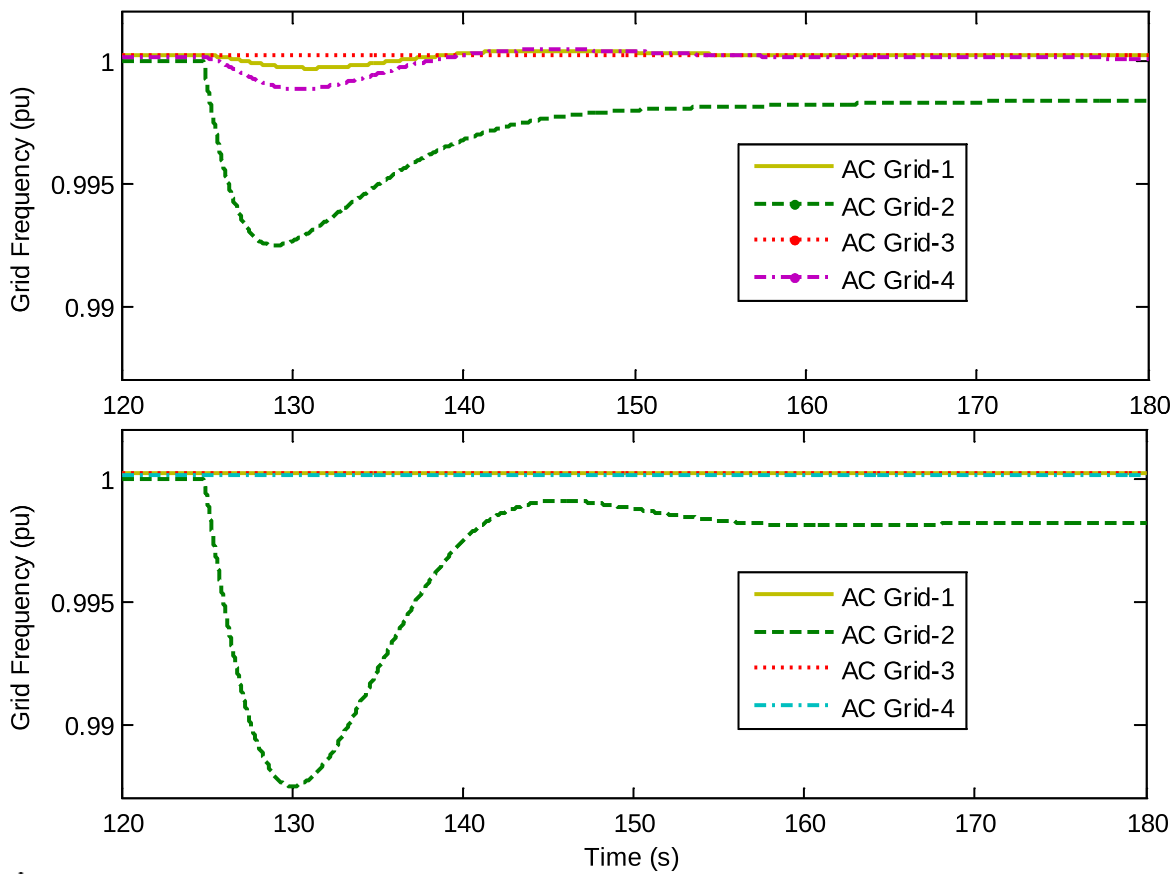
+ frequency droop



Ancillary services



Ancillary services



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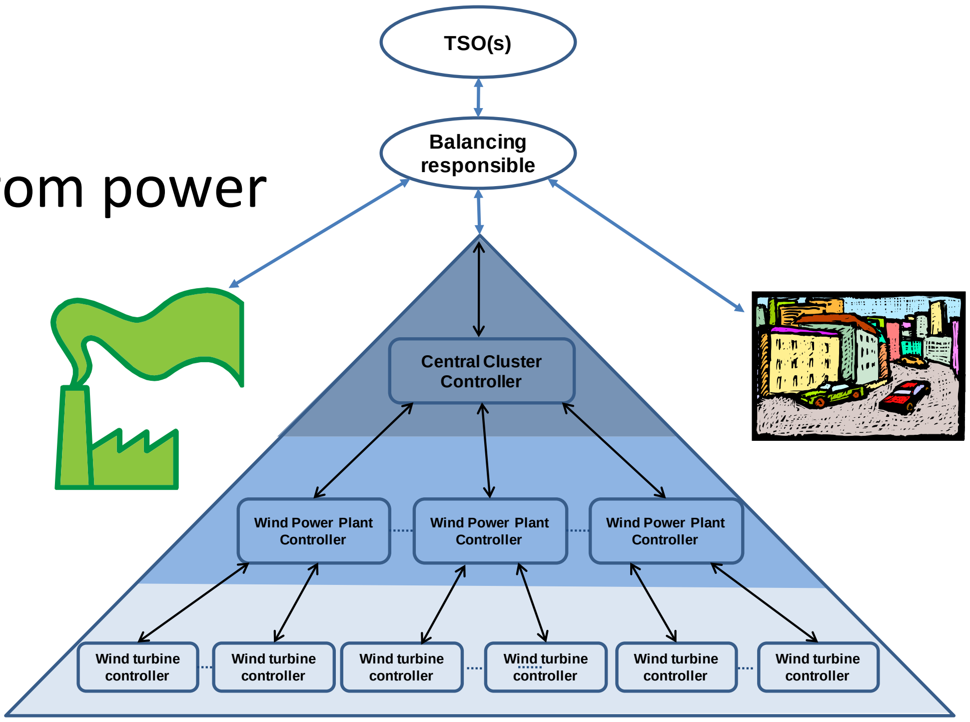
Wind clustering

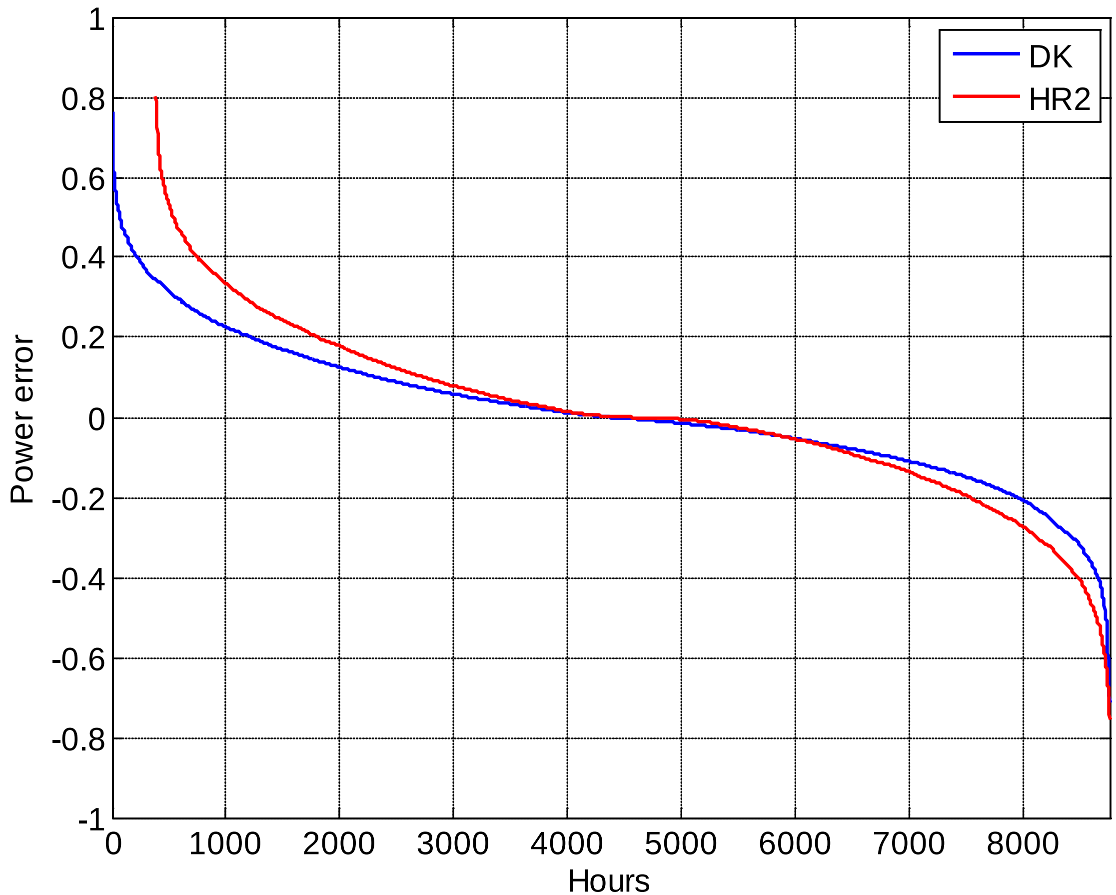
- Definition and specification of cases
  - Topologies
    - HVDC grid
    - Wind power plant
  - Control system architecture (from power system to turbine)
    - Hierarchy
    - Allocation of control tasks
    - Communication protocol



Development of control strategy

- Control tasks
  - Dispatch / power balancing tasks
    - Ancillary services of wind power plants to DC grid
      - Primary and secondary DC voltage control
    - Coordinated ancillary services of cluster to AC grid connection points
      - Primary and secondary frequency control
      - Primary and secondary AC voltage control
    - Utilisation of cluster smoothing effect
      - Reduce wind power forecast errors/fluctuations
    - Congestion management
  - Protection
  - Backup control

Reduction of wind power forecast errors



Summary

- Offshore grid is technically feasible
- Offshore grid likely to develop in modular steps from national developments
- Coordination of load flows requires sophisticated control methods
- Offshore grid can deliver ancillary services to onshore AC grids
- Control and protection of offshore grids is a challenge

Thank you!

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Contact:

Nicolaos A. Cutululis

niac@dtu.dk

www.offshoredc.dk