DC grids for integration of large scale wind power

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Publication date:
2012

Citation (APA):
DC grids for integration of large scale wind power

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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
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Project partners

DTU Wind Energy
Department of Wind Energy

DTU Electrical Engineering
Department of Electrical Engineering

Vestas

DONG energy

ENERGINET.DK

AALBORG UNIVERSITY

CHALMERS

ABB
Power and productivity
for a better world™

SINTEF
NTNU – Trondheim
Norwegian University of
Science and Technology

Statnett

29-03-2012
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
## Offshore wind power development scenarios

<table>
<thead>
<tr>
<th>Country</th>
<th>MW installed end 2020</th>
<th>MW installed end 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>High</td>
</tr>
<tr>
<td>Belgium</td>
<td>2,156</td>
<td>2,156</td>
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<tr>
<td>Denmark</td>
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<td>3,211</td>
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<tr>
<td>Estonia</td>
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<td>Finland</td>
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<td>1,446</td>
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<td>France</td>
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<td>3,935</td>
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<tr>
<td>Germany</td>
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<td>12,999</td>
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<tr>
<td>Ireland</td>
<td>1,155</td>
<td>2,119</td>
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<tr>
<td>Latvia</td>
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<td>0</td>
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<tr>
<td>Lithuania</td>
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<tr>
<td>Netherlands</td>
<td>5,298</td>
<td>6,298</td>
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<tr>
<td>Norway</td>
<td>415</td>
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<tr>
<td>Poland</td>
<td>500</td>
<td>500</td>
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<tr>
<td>Russia</td>
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<tr>
<td>Sweden</td>
<td>1,699</td>
<td>3,129</td>
</tr>
<tr>
<td>UK</td>
<td>13,711</td>
<td>19,381</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>40,671</strong></td>
<td><strong>56,194</strong></td>
</tr>
</tbody>
</table>
Offshore wind power development scenarios

Base scenario

High scenario

2020

2030

29-03-2012
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
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Control

Temesgen Haileselassie, NTNU

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Temesgen Haileselassie, NTNU

**Control**

a. DC bus power controller

\[ P^* + \rightarrow PI \rightarrow i_d^* \rightarrow P \]

b. DC voltage regulator

\[ U^* + \rightarrow PI \rightarrow i_d^* \rightarrow U \]

c. DC voltage droop controller

\[ U^* \rightarrow R \rightarrow U \]

\[ U \rightarrow PI \rightarrow e \rightarrow PI \]

\[ P^* + \rightarrow e \rightarrow P \]

\[ U^* + \rightarrow e \rightarrow U \]

\[ slope = -1/R \]
Ancillary services

DC systems

Active power $\rightarrow$ Frequency
Reactive power $\rightarrow$ Voltage
Ancillary services

Primary frequency control

DC voltage droop
+ frequency droop
Ancillary services

Offshore load (Oil/gas platform)

Scotland

Nordic Area

England

Central Europe

All cable resistances: $r=0.01 \Omega/km$
All cable capacitances: $c=5 \mu F/km$
Bipolar DC transmission for all cases

$P_{c1}^{\text{max}}=450 \text{ MW}$
$\rho_{DC1}=0.04$

$l_{14}=500 \text{ km}$

$l_{12}=300 \text{ km}$

$P_{c2}^{\text{max}}=800 \text{ MW}$
$\rho_{DC2}=0.04$

$l_{26}=120 \text{ km}$

$l_{2}=800 \text{ km}$

$l_{34}=700 \text{ km}$

$l_{3}=600 \text{ km}$

$P_{c3}^{\text{max}}=750 \text{ MW}$
$\rho_{DC3}=0.04$

$P_{c5}^{\text{max}}=250 \text{ MW}$
$\rho_{DC5}=0.04$

$P_{c6}^{\text{max}}=600 \text{ MW}$

Offshore windfarm

Offshore windfarm

Offshore load

Offshore windfarm
Ancillary services

Grid Frequency (pu) vs Time (s)

- AC Grid-1
- AC Grid-2
- AC Grid-3
- AC Grid-4

Grid Frequency (pu)

Time (s)
Work flow

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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!

OffshoreDC Workshop,
2 October 2012 - ABB, Västerås, Sweden

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