Control challenges and opportunities for large offshore wind farms

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Background

► Offshore wind accepted to support the growth of wind energy

► Technology challenges include improved offshore wind energy systems design and improved control strategies (holistic approaches)

Figure 1: SuperGrid Phase 1

<table>
<thead>
<tr>
<th>Connection</th>
<th>Capacity (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dogger – Germany Offshore</td>
<td>10</td>
</tr>
<tr>
<td>Dogger – Norfolk Bank</td>
<td>5</td>
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<tr>
<td>Dogger – Firth of Forth</td>
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<tr>
<td>Dogger – Norway</td>
<td>5</td>
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<tr>
<td>Germany Offshore - Munich</td>
<td>10</td>
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<tr>
<td>London – Norfolk Bank</td>
<td>5</td>
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<tr>
<td>Norfolk Bank – Belgium Offshore</td>
<td>2</td>
</tr>
<tr>
<td><strong>SuperNode</strong></td>
<td></td>
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<tr>
<td>Belgium Offshore</td>
<td>2</td>
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<tr>
<td>Dogger - Hornsea</td>
<td>10</td>
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<tr>
<td>Germany Offshore</td>
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<td>Norfolk Bank</td>
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<td>Munich</td>
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<td>Firth of Forth</td>
<td>5</td>
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</tbody>
</table>

Source: FOSG Position paper on the EC Communication for a European Infrastructure Package, Dec 2010

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Offshore wind generation system

Complex mix of subsystems and technology

Different control objectives
Boundaries and control objectives definition

Wind Turbine Level

Wind Farm Level

Power System Level

Impact

System wide

Local

Time

Frequency control (Primary)

Frequency control (Secondary)

Active Power

Forecast

Voltage/Reactive power control

Load Mitigation

Wakes & Turbulence

Electrical disturbances (FRT)

Power Quality

--- ms --- seconds --- minutes --- hours ---

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NOWITECH Norwegian Research Centre for Offshore Wind Technology
Where/How are the boundaries defined?

► Complex task - various parties involved
► Bi-lateral (even multi-lateral) agreements in place
► Scenario dependent
► Point of Grid Code Compliance
Wind turbine level – technology evolution

Reference: Wind Energy - The Facts (www.ewea.org)

Source: Jos Bourskens, ECN
Rotor structural dynamics

Flexible structure of a wind turbine rotor

Blade bending motions

Out-of-plane blade bending

In-plane blade bending

As rotor size increases blade flexibilities become significant and need to be better represented

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Operational control

The increasing size of machines is driving control development directions. More demands are placed on the control system at the same time as low frequency dynamics issues have greater importance.

- Control systems are now being required to regulate some fatigue related dynamic loads.
- Of strong interest are the tower loads.
- The larger the wind turbine the greater the requirements.
- Must be achieved without compromising turbine performance.
- Must be achieved without increasing pitch activity.
Floating structures

- Coupled dynamics of wind turbine and platform
- Significant influence of the type of floating support structure and mooring mechanism
- The objective is still to optimise power capture while maintaining platform stability
- Control system has to be able to dampen both wind and wave driven motions balancing power quality, load mitigation and platform stability
Variable-speed wind turbines have more control flexibility and improve system efficiency and power quality.

Explore holistic (integral) control approaches.

Exploit features provided by WT power electronics.
Wind power plant operation

- Technical characteristics of wind turbine technologies are significantly different from conventional power plants
- Emulation of conventional synchronous generation and provide similar dynamic characteristics in terms of
  - Dynamic voltage control,
  - Frequency support
  - System damping, etc

Accurate modelling and control of wind turbine systems for power system studies are still a challenge
Offshore wind farm arrays

Similar to onshore arrays, but now there may be clusters of wind farms

Wind farm control objectives:

- Optimise power quality
- Minimisation of wake losses and electrical losses in cables

Enhanced controllers to coordinate turbine operation?
Offshore transmission – grid integration
9 GW Dogger Bank offshore wind site

- Developer: FOREWIND
  - SSE Renewables
  - RWE Npower Renewables
  - Statoil
  - Statkraft

- Location: 125-195km offshore
- Water depth: 18-63m
- Construction: 2014 at the earliest
Offshore transmission

► Sending and receiving networks are decoupled.
► DC transmission is not affected by cable charging currents.
► The cable power loss is lower than in an equivalent ac cable.
Dogger Bank - interconnectors

HVDC transmission
DC Grid Configurations: Meshed systems

Source: Carl Barker, Alstom
Investigate enhanced control strategies to facilitate voltage Fault Ride-Through of large offshore wind farms through offshore transmission circuits (AC and DC)

Investigate the requirements for control of offshore wind farms to contribute to onshore network performance
Fast transients and harmonics mitigation

Suitable models are required

- Improved controllers are required to mitigate fast transient events and non 50-Hz phenomenon (these may assist architecture designs and planning tasks)
- Suitable modelling platform for control design and performance assessment is necessary
Frequency support – grid code requirement

Energy storage, design and coordinated control?

Short-term primary response (synthetic inertia)

Demand-side management – coordinated control?

Role of interconnectors – intermittency, power balancing
Summary

► Floating structures should be stabilised without compromising power production and power quality (minimum pitch activity is required, and added control features provided by power electronics should be explored). Tower bending modes become an even more delicate issue.

► The possibility of enhanced active control for parked conditions (turbine stopped) need to be assessed.

► Floating turbine performance and control requirements under power grid fault conditions has so far not been explored sufficiently.

► Improved coordinated control of individual wind turbines within in the farm are required to minimise wake effects (whilst keeping electrical losses within acceptable technical and economic limits).

► Enhanced controller are necessary to facilitate wind farm dynamic performance compatible with conventional synchronous plant (i.e. to provide support to power system operation in terms of dynamic voltage and frequency control).

► Holistic/integrated control approaches are imperative.