2nd Grid Integration of Offshore Wind Energy

“Practical challenges and new technologies for offshore grids and wind integration”.

Designing and Operating Wind Farm Clusters

Dipl.-Ing. Mariano Faiella, Fraunhofer IWES
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Content

- Clustering Offshore Wind Farms
- Ancillary Services Provided by Wind Farm Clusters
- Software Tools
- Conclusions
Clustering Offshore Wind Farms

- High availability of Ancillary Services due to:
  - Smoothing effect over large areas
  - Higher predictability (in case of reduced variability)
  - Higher opportunities to participate in markets
  - Higher complexity for optimizations

\[
P_{\text{Cluster}} \times Q_{\text{Cluster}} = \left( \sum_{i=1}^{n} P_i \right) + P_{\text{Losses}} + \left( \sum_{i=1}^{n} Q_i \right) + Q_{\text{Losses}}
\]
Voltage Problems
Grid Code Requirements

Fault-Ride Through (LVRT-HVRT)

- WTG should **stay connected** in case of a grid fault

**LVRT:**

- range where only a disconnection through system automatics is admissible
- selective disconnection of generators depending on their state

**HVRT:**

- lower value of the voltage range

Source: Transmission Code 2007. VDN e.V.

Source: Australian HVRT requirement
Voltage Support
Grid Code Requirements

Voltage support in case of a normal grid operation

- defining possible operational ranges

Source: TransmissionCode 2007. VDN e.V.

Operating points inside the solid lines are a basic range.
Frequency Control
Grid Code Requirements

- Continuous balancing of power
- Different types of control reserve

Positive and negative reserve is necessary

Sources: ENTSO-E NCIG/ ENTSO Balance Management Harmonisation and Integration; Amprion GmbH (http://www.amprion.net/en/control-energy)
Frequency Support
Grid Code Requirements

Frequency support in case of a normal grid operation

- decreasing active power output of the WTGs in order to offer a positive contribution to the control reserve

Sources: Wind Turbines Connected to Grids with Voltages above 100 kV (Energienet.dk)
Technical Research and Solutions: Fraunhofer IWES
Objective → preparation of European electricity system for large-scale integration of wind energy.

- Design, development & validation of new tools.
- Wind Farm Cluster Management System (WCMS).
- Development of control strategies.
- Associated methodology for providing power reserve with wind power.
1. WCMS TSO Level
2. WCMS WF operator level
3. WF controller
4. Wind Farms
Research: Wind on the Grid

Operational Tool

Figure 64 – Wind farm cluster “Pinhal Interior” (Source: IWES)

Source: Power Reserve Provision with Wind Farms - A. Gesino
Providing control possibilities of the WF relating its onshore PCC

- Congestion or voltages problems could be detected **in advance** due to forecasts

- Operated as an expanded Wind Farm controller

Source: RAVE Project
Research: RAVE Project
Operational & Simulation Tool

Providing control possibilities of the WF relating its onshore PCC

WTG

\[ \cos \varphi_{WF} = 1.0 \]

PCC
Providing control possibilities of the WF relating its onshore PCC

- WTGs operating with $\cos \varphi = 1.0$
- Minimum active power for the selected time interval based on forecast data
- Information about minimum active power provision within the next hours

Source: Screenshot (cut-out) of the developed program
Research: RAVE Project

Operational & Simulation Tool

Providing control possibilities of the WF relating its onshore PCC

Examples:

\[ P_{\text{max}}, \cos \varphi = 0.98 \text{ ind.} \quad P_{\text{max}}, Q = -5 \text{ Mvar} \quad P = 30 \text{ MW}, Q = -10 \text{ Mvar} \]
### Research: RAVE Project

**Operational & Simulation Tool**

- **Gross values**
  - (sum of WF values)

- **Net values at PCC**
  - (incl. e.g. grid losses)

### Graphical Representation

<table>
<thead>
<tr>
<th>ΔP / cos φ - operation</th>
<th>P / cos φ - operation</th>
<th>P\textsubscript{max} / Q\textsubscript{fixed} - operation</th>
</tr>
</thead>
</table>

- **ΔP operation**
- **different kind of reactive power value necessary**

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Research: RAVE Project
Operational & Simulation Tool

Providing voltage and utilization information
Research: EERA-DTOC

Design Tool

What is EERA-DTOC

Software tool > for design phase

Integrated and validated design tool combining the state-of-the-art:

- Wake Effects (WP1)
- Yield (WP3)
- Electrical models (WP2)

Product Vision

A robust, efficient, easy to use and flexible tool created to facilitate the optimized design of individual and clusters of offshore wind farms.
Target (main) Users

The prospective users of EERA DTOC fall into the following primary categories:

**Strategic Planners**
- Design process at the highest level
- Commonly responsible the definition of project boundaries
- Determine what infrastructure should be created to accommodate projects
- Goals of a strategic planner may include:
  - Achieving a legislated target for installed capacity.
  - Minimizing the cost of energy to consumers.
  - Ensuring the security of the supply of energy to consumers.

**Project Developers**
- working within the broad project definitions determined by strategic planners.
- The primary goal of a project developer will be to maximize their financial return.
WP2: „Interconnection Optimisation and Power Plant System Services“

Objectives:

• to develop a **design tool** and **procedure** for the **optimisation** of the electrical design of offshore wind farm clusters…

• ….including the provision of power plant system services by the cluster.

Participants in WP2:
Research: EERA-DTOC
Design Tool

- Fraunhofer IWES
- SINTEF
- Strath
- Statoil
- Hexicon
- Risoe DTU
- Fraunhofer IWES
- CIEMAT

WCMS model
Analysis of the availability of power plant system services

Grid Codes compliance
PSS/e & PSCAD/EMTDC
Transient analysis

NET-OP model
Grid optimization
Steady-state

Analysis on variability & predictability

CorWind model

Off-shore development
Wake modelling
Conclusions/ Possible solutions

- Need for technical and operational **improvements**
- WPP/WFC shall **provide (more) Ancillary Services** in future scenarios
- WPP/WFC can/ shall take part in **congestion management** strategies
- **ICT solutions** should be improved/ widely used → SmartGrids
- Integration of commercial and technical platforms is required
- **Advanced control techniques** and software solutions are required