Radar@Sea - Towards improving short-term wind power forecasts

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Background

Large-scale offshore wind farms will provide significant amounts of energy in the near future. Nowadays, in the north of Europe, the production of a single of these offshore wind farms can already meet the yearly consumption of about 200000 households. However, the high volatility of the power generation of these wind farms and its lack of predictability make that:

- power producers can not optimally **value the wind ressource**,
- Transmission System Operators face growing challenges in **balancing production and consumption**.

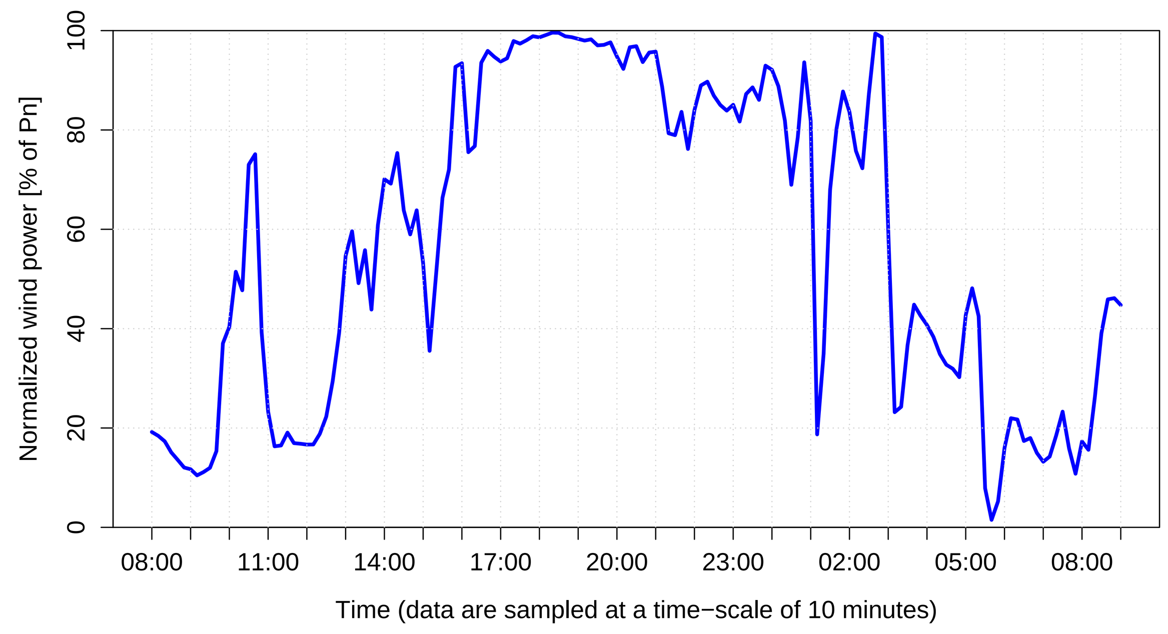
Accurate wind power forecasts could help in overcoming these problems.

Motivation

Integrating wind power into electricity grids is an operation that takes place at time-scales from a few minutes up to half an hour. At such time-scales, and for individual wind farms, offshore wind power fluctuations of an amplitude larger than 60% of the nominal power of the wind farm have already been observed [1]. Extreme wind speed variability has been identified as a key factor [2], but the origins of such severe events are still not clear. It is assumed that wind power generation is influenced by more complex meteorological phenomena.

Offshore wind power data insights provided by statistical models [3] highlight frequent and almost instantaneous changes in the behaviour of wind farms. However, **forecasts generated by the same models have a relatively limited accuracy which calls for extra inputs**. Ideally, these inputs would be generated at high frequencies and would contain spatio-temporal information of the meteorological conditions in the neighborhood of offshore wind farms.

Question: (How) Can we improve the predictability of such wind power fluctuations?



Radar@Sea

Radar@Sea is an applied research project in which it is assumed that **rain is a marker for weather conditions generating complex wind power fluctuations**.

Goals:

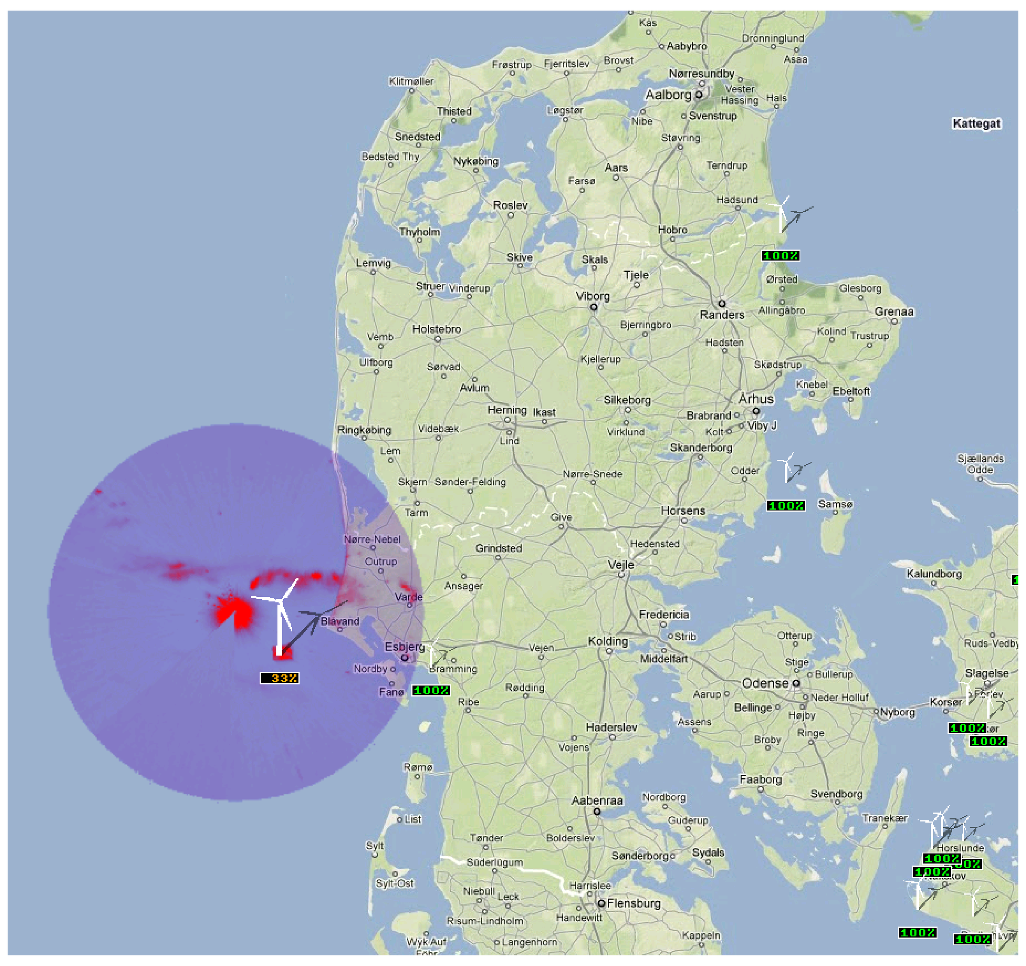
- to demonstrate the interest of detecting rain fronts at high frequencies to prevent unexpected wind power fluctuations,
- to evaluate the **influence of rain on wind power fluctuations**,
- **to improve wind power predictability** by integrating new inputs,
- **to propose operational solutions** for wind power production management.

Partners:

- wind farm operators and energy producers such as **DONG Energy** and **Vattenfall**,
- **DHI**, a research organisation with strong competences in weather radars,
- the **Technical University of Denmark** (the National Laboratory for Sustainable Energy - Risø - and the Department of Informatics) with many years of experience in wind power and meteorology.

Experimental design

A **Local Area Weather Radar (LAWR) device** is installed on the transformer platform of the Horns Rev 2 wind farm, approximately 30km off the west coast of Denmark, in the North Sea. It can detect rainfalls in a radius of 60km. The wind farm of interest is Horns Rev 1 (see image below) and consists of 80 turbines with a total capacity of 160MW.



Project structure

1. The experimental part:

- radar installation and calibration,
- onsite maintenance,
- continuous data collection,

DHI has experience in these fields and already operated a radar at Horns Rev, in the frame of a bird watch study.

2. Data mining:

- extraction of informative spatio-temporal variables,
- highlighting the influence of rain on the different regimes of wind power fluctuations (creation of a catalogue of events) from a statistical perspective,
- extending the understanding of the wind power climatology at Horns Rev and reveal the importance of rain along with thermal stability and wind direction/speed.

3. Improving the methodology for very short-term wind power predictability:

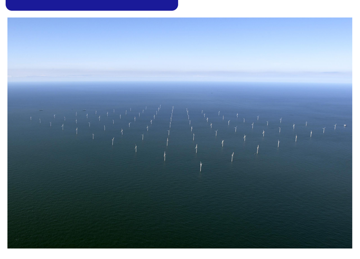
- developement of regime-switching models able to account for rain events and generate forecasts accordingly,
- elaboration of new data assimilation techniques for short-term updates of local meteorological models (potential application: correction of phase errors),
- characterization of spatio-temporal aspects of wind power forecasts errors.

4. Applications for improving wind farm controllability:

- wind power fluctuation reduction through regime-switching approaches based on rain front detection and high resolution wind power forecasts from WP3 (limit ramp-down strategies),
- storm-ride-through control, potentially involving a cascading approach as the front goes through the wind farm in order to avoid cutting out wind turbines all at once.

Timeline

May 2009

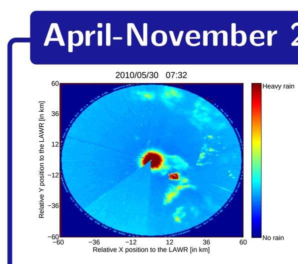


Official start of the Radar@Sea project, for a duration of 3.5 years.

March 2010

Installation of the LAWR device on the transformer platform of the Horns Rev 2 wind farm.

April-November 2010



First data collection campaign (radar in rain mode).

November 2010

First maintenance operation due to a technical problem with the LAWR device (gear box broken). Images are missing over a period of 20 days.

January-March 2011

Data collection campaign with the LAWR device in wave mode. This mode is used for measuring wave heights. A potential application is to determine when sea conditions are suitable for offshore maintenance operations on wind turbines.

April-December 2011

The second data collection campaign starts in April 2011. The LAWR device is expected to be in rain mode for the remaining part of 2011.

2012

Further campaigns for 2012 have not been planned yet. They will depend on the needs for extra data.

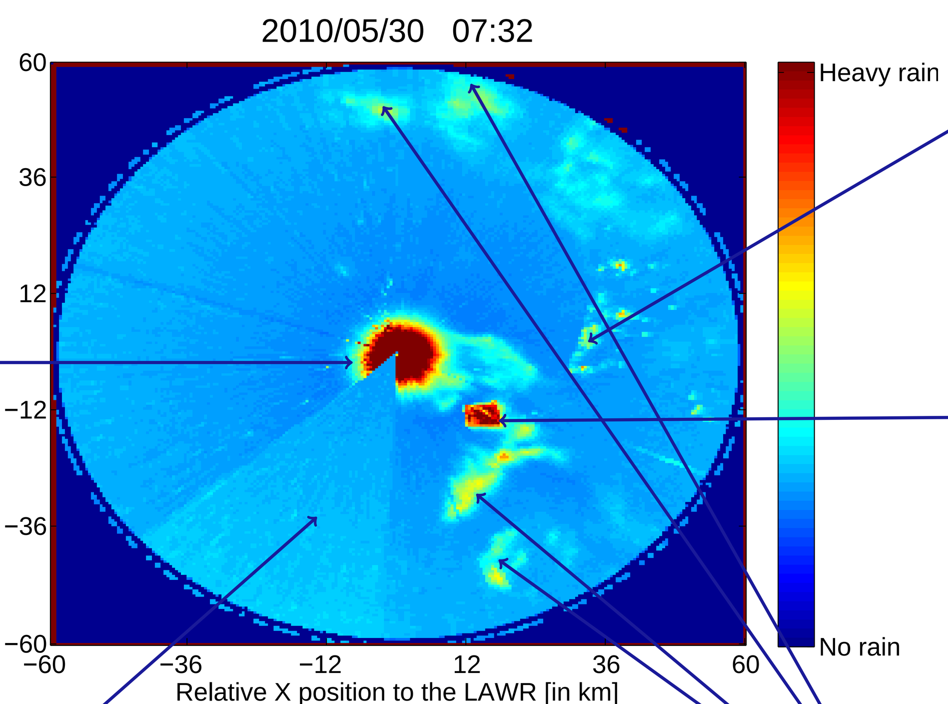
December 2012

Project completion is expected for the 4th quarter of 2012.

2010 — 2011 — 2012 — 2013

Rain or not?

Operating a LAWR device in an operational environment as challenging as offshore conditions raises some issues.



Sea Clutter

Sea clutter refers to (undesirable) echoes from the waves. Since the LAWR device is sometimes used for measuring wave heights, the fence usually used for blocking potential wave echoes was removed from the installation settings.

Ground clutter

Ground clutter refers to (undesirable) echoes from ground obstacles. In that case, the west coast of Denmark.

Horns Rev 1

This clutter is due to the wind turbines of the Horns Rev 1 wind farm.

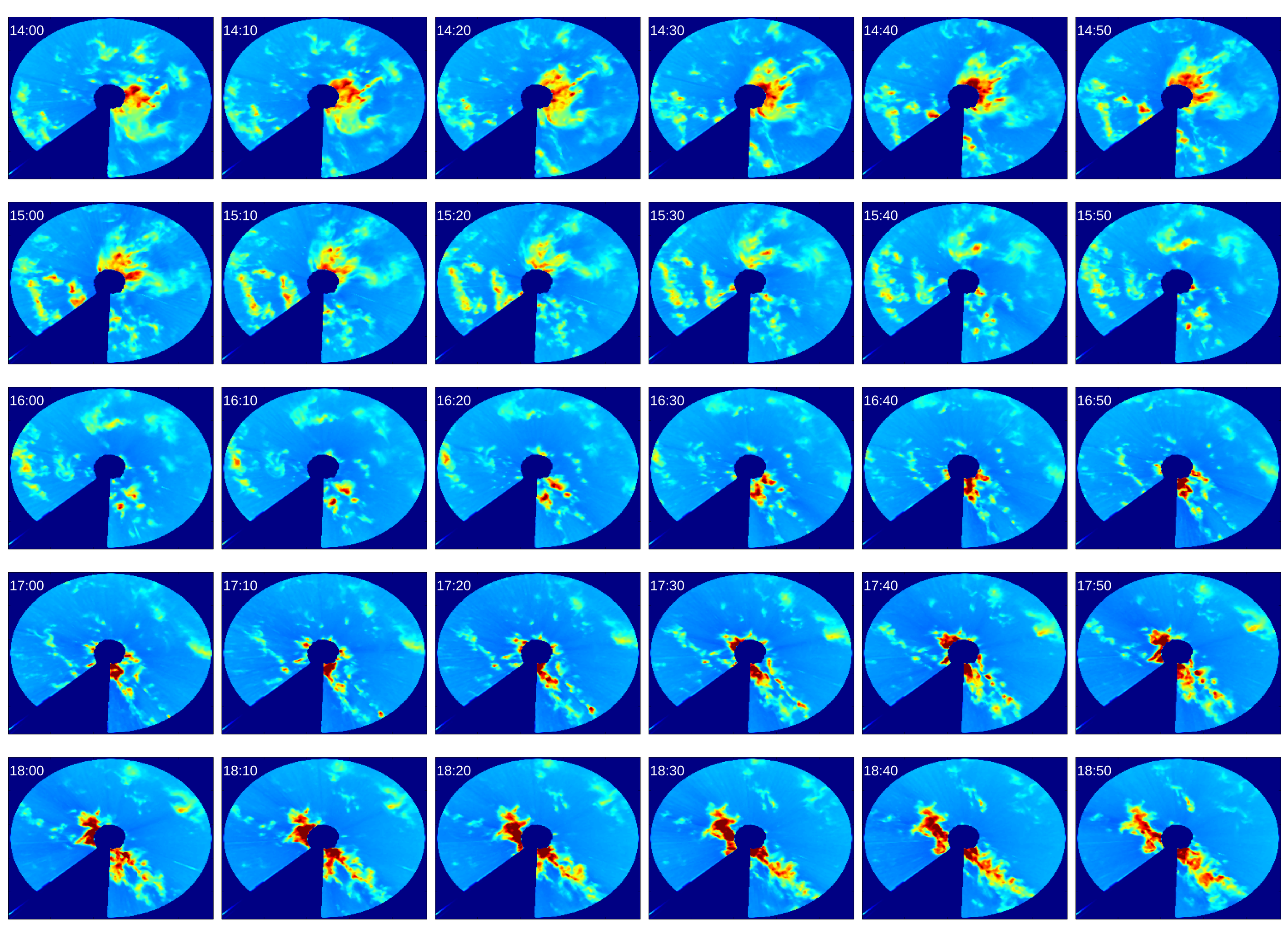
Blind area

The idea of installing a radar on the transformer platform of Horns Rev 2 came up after the latter was built up. This non informative area is the result of physical obstacles on the platform preventing the LAWR device from scanning in the south west directions.

Rain cells

These echoes are linked to rain cells. Rain can occur in different ways. It can then be characterized with respect to its intensity, time duration and spatial scale.

Example of rain events (30/05/2010)



References

[1] Akhmatov V (2007). Influence of wind direction on intense power fluctuations in large offshore wind farms on the North Sea. *Wind Engineering*, 31: 59-64.

[2] Vincent C, Giebel G, Pinson P and Madsen H (2010). Resolving nonstationary spectral information in wind speed time series using the Hilbert-Huang transform. *Journal of Applied Meteorology and Climatology*, 49: 253-269.

[3] Pinson P and Madsen H (2011). Adaptive modelling and forecasting of offshore wind power fluctuations with Markov-switching autoregressive models. *Journal of Forecasting* (In Press).

Acknowledgement

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DHI — DONG energy — VATTENFALL