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Radar@Sea - Towards improving short-term wind (power) forecasts based on a Local Area Weather Radar (LAWR) installed at an offshore wind farm

Pierre-Julien Trombe, Pierre Pinson, Sven Creutz Thomsen, and Henrik Madsen
DTU Informatics, Technical University of Denmark, Lyngby, Denmark (pjt@imm.dtu.dk)

The ongoing deployment of wind energy indicates that its future is more likely to take place offshore in the form of large-scale wind farms. However, early examples of large-scale offshore wind farms in Denmark showed that wind power fluctuations at high frequencies (i.e. from a few minutes up to half an hour) are much more volatile than at near onshore sites, resulting in lower predictability and increasing challenges for grid integration. Furthermore, observations show that the transition from a rather calm period to a highly volatile one (and vice versa) happens almost instantaneously, leading to potential severe power shortages or excesses. As a first step towards the understanding of the factors driving these fluctuations, recent research concluded on the influence of complex and local meteorological phenomena, with specific seasonalities in the wind variability. In parallel, development of complex statistical models highlighted changes in the wind power fluctuation dynamics that could be induced by different types of meteorological conditions. These findings call for the use of extra explanatory information at fine temporal and spatial resolutions in order to improve the performance of state-of-the-art models for offshore wind power prediction. An appealing approach consists of combining on site wind power measurements along with mesoscale weather descriptors to provide informative inputs to statistical models and by extension, to local numerical weather prediction models.

The Radar@Sea project proposes to use a Local Area Weather Radar (LAWR) device as a tool to monitor and track down local meteorological phenomena in the neighbourhood of the offshore site at Horns Rev. This offshore site has two large-scale offshore wind farms for a total installed power of 369 MW. More specifically, the technology embedded in this device allows the measurement of rainfall at very high frequencies, from 1 up to 10 minute intervals, and up to 60kms from the LAWR's location. The potential benefits of this new source of information are manifold: (i) to extend the (conditional) climatologies of wind power fluctuations at Horns Rev, (ii) the improved predictability of very short-term wind power fluctuations by integrating rain intensity as a variable governing the switches in the dynamics of the wind (power) fluctuation process, (iii) to develop advanced control strategies for large offshore wind farms to reduce wind power fluctuations (i.e. avoid down regulation) and to reduce the load on wind turbines. From a more general point of view, the LAWR may allow for the monitoring of waves around the wind farms, bird studies, or for improving safety while planning maintenance works.

The present work reports the course of events experienced during the early stages of this real-world installation of a LAWR device at a large-scale offshore wind farms. Developing a synergy between the industry and the research worlds unveils some issues, and the acquired experience could be used as a reference in future developments. The project overview will include the installation and maintenance details of the LAWR device, the description of automatic and robust post processing procedures to remove noise from the radar images and allow for extracting the relevant information embedded in the images, along with plans of future investigations. From a research perspective, focus will be given to Hidden Markov Models (HMM) based approaches. Indeed, the flexibility of this class of models is expected to be beneficial in capturing the main features of offshore wind power time series (autocorrelation, non linearity and non-stationarity) along with the estimation of a sequence of states reflecting different power generation behaviors. Both point and probabilistic forecasts could then be generated conditioned upon online rainfall measurements. In addition, characterizing that state sequence with meteorological variables could lead to the creation of a catalogue of events so as to assist offshore wind farm operators. For instance, giving simple and clear information on what type of power output behavior to expect based on the severity of local climate conditions could allow to better prevent sudden and large wind power fluctuations.