Meteorological issues of large offshore wind parks

Stefan Emeis*
Karlsruhe Institute of Technology, Garmisch-Partenkirchen, Germany, +49 8821 183 240, stefan.emeis@kit.edu

Summary
Offshore wind parks have become so large and numerous that several new meteorology-driven issues show up: (1) deep array effects occur in the interior of large parks, thus simple overlapping of single wakes does no longer work; (2) wakes of entire wind parks can be longer than 50 km, thus mutual interference of wind parks will increase; (3) clustering of wind parks means several GW of installed power in a small area which are subject to simultaneous wind conditions, threatening the operation of the electrical grid, if the cut-off wind speed is exceeded unexpectedly in the entire German Bight.

1. Introduction

In the German Bight, 1169 wind turbines in 20 wind parks with an installed power of 5.3 GW were operated on a relatively small area of roughly 200 km by 130 km = 26000 km² at the end of 2017[1].

2. Deep array effects

If single turbine wakes start to overlap (Fig. 1) wakes can no longer be refilled from the sides but only from above and wind parks start to modify the vertical structure of the atmospheric boundary layer. This can no longer be handled by classical bottom-up wake models. Top-down models or numerical meteorological flow models are needed instead to assess the impact of the parks on the boundary layer.

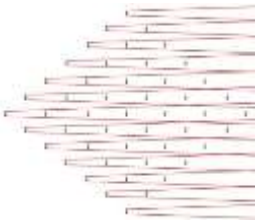

Fig. 1: Deep array effect

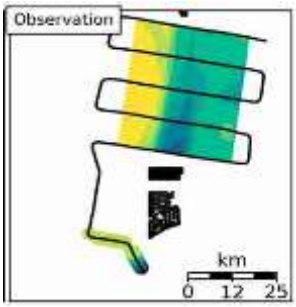

Fig. 2: Measured wind speed at hub height (90 m) behind a wind park cluster in the North Sea. Yellow: 9 m/s, blue: 6 m/s. From [2].

3. Park wakes

The research project WIPAFF financed by the German Ministry of Economic Affairs and Energy (FKZ 0325783A) offered the opportunity to investigate the far wakes of offshore wind parks from in situ aircraft measurements. Wakes of more than 50 km length could be observed (Fig. 2). This leads to mutual interference of the offshore wind parks.

4. Shut down due to cut-off wind speed

Unexpected exceeding of the cut-off wind speed of 25 m/s in larger areas of the German Bight can lead to sudden drastic drops in power production (Fig. 3). Smooth shut down procedures could be helpful to reduce the impact on the electrical grid operation.

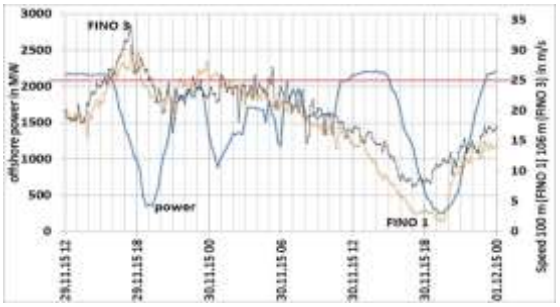

Fig. 3: North Sea offshore power output (bold blue line), 100 m wind speed at FINO 1 (thin orange line) and 106 m wind speed at FINO 3 (thin black line) for 29-30 Nov 2015.

[1] https://www.windkraft-journal.de/2018/04/18/ausbau-der-offshore-windenergie-laeuft-bis-2020-nach-plan/120133
[2] Platis, A., S.K. Siedersleben, J. Bange, A. Lampert,, K. Bärfuss,, R. Hankers, B. Canadillas, R. Foreman, J. Schulz-Stellenfleth, B. Djath, T. Neumann, S. Emeis: First in situ evidence of wakes in the far field behind offshore wind farms. Scientific Reports, 8, 2163. (2018)