Analysis of cyclone Xaver (2013) for offshore wind energy

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Introduction

Cyclone Xaver (December 2013) was an extreme weather event which affected northern Europe, yielding a record of wind power generation. On 4 December, 2013 Xaver was initiated southeasterly of Greenland. During its formation, the upper air conditions intensified the cyclonic circulation and the system progressed southeasterly. The cyclone was continuously deepening during its movement towards Scandinavian Peninsula. In total, Xaver influenced an extensive region of North Europe, moving gradually from southeastern Greenland to the Baltic Sea, passing over the northern shore of United Kingdom, the North Sea and Scandinavia. The cyclone was accompanied by gale-force winds over North Sea and exceptionally low values of the core mean sea level pressure.

Weather Conditions

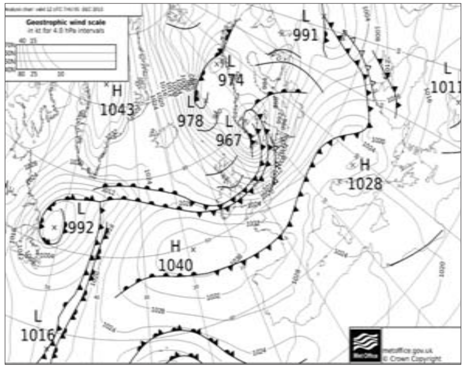

Figure 1. Surface pressure analysis map (hPa) on 5 December at 12:00 UTC, derived from UK Metoffice surface analyses archive. Cyclone Xaver is the low pressure system with its centre at 967 hPa.

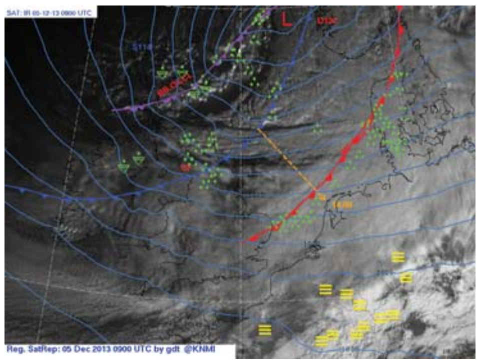

Figure 2. Regional SatRep over the North Sea on 5 December at 09:00 UTC, archived by http://www.knmi.nl/satrep

Energy Prices

Wind turbines set energy production records higher than 26000 MW, decreasing the power spot prices lower than 25 €/MWh. However in Denmark the shut down of wind turbines led to increase of the power spot prices up to 580 DKK/MWh.

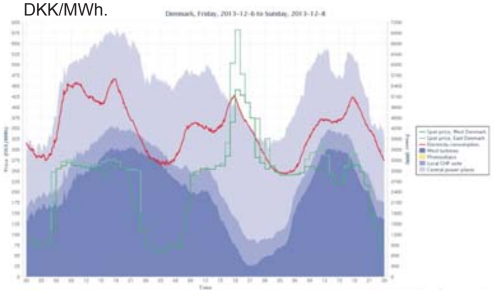

Figure 3. Energy spot prices and production during Cyclone Xaver in Denmark (source: EMD International A/S)

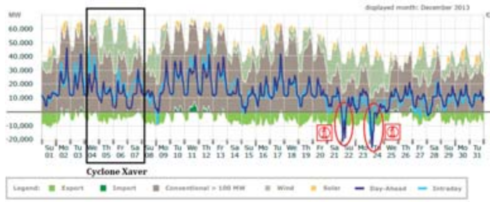

Figure 4. Energy spot prices and production, December 2013 in Germany [1]

Model & Evaluation

The Weather Research & Forecasting Model (WRF) ARW version 3.5 [2] was utilized for the simulation of cyclone Xaver. The numerical experiment used a 822 × 626 horizontal grid mesh, with horizontal resolution 5 km × 5 km, time step of 30 s and 50 vertical levels stretching from surface to 50 hPa. The simulation period was 84 hours, from 4 December, 2013 at 00:00 UTC to 7 December, 2013 at 12:00 UTC. Figure 5 illustrates the evaluation of the modelled wind speed with observations at 100 m at FINO 1, 2 and 3 [3].

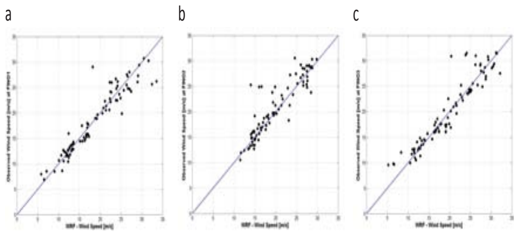

Figure 5. Scatter plots of model and observed wind speed (a-c) at FINO1-3 during 4 December, 2013 to 7 December, 2013

Cyclone Track

Figure 6. Mean sea level pressure in hPa (yellow) and maximum wind power density in W/m^2 at 100 m (red) tracks for cyclone Xaver as simulated by WRF model.

Wind Power

Figure 7 reveals information for the entire period under simulation. Figure 7 (a) presents the sum of hours that modelled wind speed at 100 m resides within the range 11-25 m/s (rated output wind speed). On the other hand Figure 7 (b) shows the sum of hours for extreme modelled wind speeds at 100 m, higher than 25 m/s (cut out wind speed). Figure 7 (a) shows the modelled wind speed ranging within 11-25 m/s approximately for 35 hours over the North Sea while the Baltic Sea displays higher frequencies, reaching up to 70 hours at some regions.

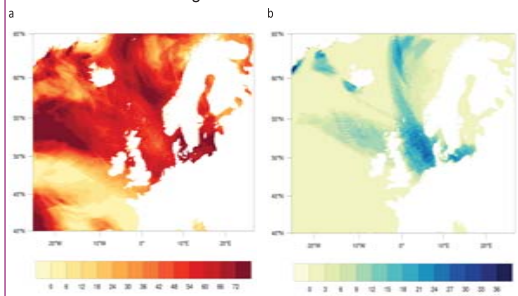

Figure 7 Sum of hours for wind speed at 100 m within the range 11-25 m/s (a), exceeding 25 m/s (b) for the period 4 December, 2013 at 00:00 UTC to 7 December, 2013 at 12:00 UTC as simulated by WRF model.

Figure 8 presents the simulated average wind power density for the period 5 December, 2013 06:00 UTC – 5 December, 2013 12:00 UTC for two 100 m (a) and 200 m (b). North Sea region is characterized by relatively high average wind power density. Especially for areas far away from the shore, wind power density exceeds 8000 W/m^2 at 100 m, ten times higher than the typical annual mean WPD for the area, and reaches 10000 W/m^2 at 200 m. On the contrary for regions outside the North Sea the values are equivalent to 4000 W/m^2.

Figure 8 (c) showcases the percentage increase of the wind power density between 200 m and 100 m. For the largest part of the North Sea the percentage increase ranges within 15% to 20%. Some regions of the North Sea, such as easterly of UK, display an increase that exceeds 25%.

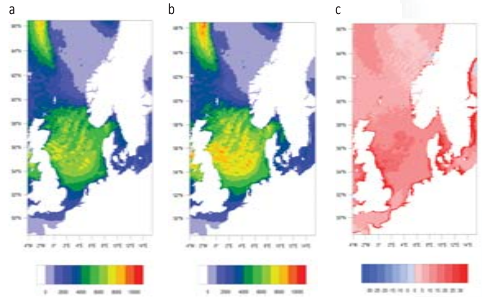

Figure 8. Average wind power density (W/m^2) for the period 5 December, 2013 06:00 UTC – 5 December, 2013 12:00 UTC at 100 m (a), and 200 m (b) and the percentage increase (%) of the wind power density between 200 m and 100 m (c).

Conclusions

The current study presented an analysis of a severe cyclone, namely Xaver, with respect to the offshore wind energy as simulated by the WRF model.

- The focus of the study is on the extended region of the North Sea and the Baltic Sea.
- High values of wind power density at 100 m and 200 m occurred over the North Sea, surpassing 18000 W/m^2, twenty two times higher than the typical annual mean WPD for the North Sea.
- The sum of hours for which the wind turbines perform to their utmost capacity (11-25 m/s) is ca 40 over the North Sea and ca 70 over the Baltic Sea.
- The sum of hours with wind speed at 100 m, exceeding 25 m/s, is more than 30 over the North Sea.
- A comparison of average wind power density between the height levels 100 m and 200 m showcased 15% to 20% increase at 200 m for the largest part of the North Sea with particular regions exceeding 25%.

Acknowledgements

1.Wind data from FINO 1, 2 and 3 platforms provided by BMWi (Bundesministerium fuer Wirtschaft und Energie, Federal Ministry for Economic Affairs and Energy) and the PTJ (Projekttraeger Juelich, project executing organisation).

2. The ACDG of Harokopio University of Athens is gratefully acknowledged for the provision of the numerical model WRF and the computer infrastructure to perform the simulations.

References

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