Summary

Since 2003 the FINO1 platform is operating in the German Bight near to the first offshore wind farm 45 km off the island of Borkum. DEWI and BSH (Federal Maritime Agency) are responsible for the technical measurements above and under the water line. Within 7 years of completed wind and meteorological measurements a reliable information basis has been founded for the development of the German offshore wind plans and the offshore research projects in the RAVE (Research at Alpha Ventus) community. More than 200 data users are already registered at the FINO data bank that is operated by BSH. Here also the data of the platforms FINO2 (Baltic Sea) and FINO3 (North Sea) are available. After completion of the first German offshore wind farm new tasks are waiting for FINO1. Besides being a source of reference wind data another major task is the study of wind farm effects and further influences connected with wind farm deployment and operation like the monitoring of hydro sound.

Introduction

The offshore wind research platform FINO1 is operating since 2003 in the German Bight, 45 km north of the island Borkum. The main task of the platform is to give insight into the offshore environmental conditions, both meteorological and oceanographical. Until August 2009 FINO1 was able to measure the undisturbed offshore conditions for almost 6 years. The data collected is used in numerous research projects and has given rise to a more reliable design basis for offshore wind turbines and significantly improves energy yield studies for wind farms. After the start of RAVE (Research at Alpha Ventus), FINO1 produces an environmental data reference for most of the research tasks. With the deployment of more and more offshore wind farms in the German Bight, the platform, together with its “sister”-platform FINO3, forms an ideal basis to study the influence of those installations on the marine environment.

Setup of Wind and Meteorological Measurements

The FINO1 platform is equipped with a complete set of meteorological sensors including 8 cup anemometers and 4 wind vanes to measure the long term wind profile of the marine boundary layer up to 103m above the Lowest Astronomical Tide (LAT). The availability is higher than 95% with the exception of the wind vanes, where the technical set up makes a filtering necessary for the heights of 50m and 70m.
WE MEASURE WIND

- wind, temperature, humidity, pressure...
- turbulence, visibility, present weather
- wind profile (SODAR)
- data acquisition

miniSoDAR
measurement of wind
wind profile
 turbulence
anywhere
 anytime
 & reliable

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WIND MEASUREMENT SOLUTIONS

autonomous power supply
- up to 10 months autonomy
- remote access via Internet
- ideal supply for heated sensors

modular data logger systems
- direct Internet access
- measured data are sent via e-mail and FTP
- integrated, intuitive web interface

wind measurement masts
- mountable lattice masts
- including complete instrumentation
- worldwide installation
List of Sensors

- Cup-Anemometer: 100m, 90m, 80m, 70m, 60m, 50m, 40m, 33m
- Wind Vanes: 90m, 70m, 50m, 33m
- Temperatures: 100m, 70m, 50m, 40m, 33m
- Humidity: 90m, 50m, 33m
- Rain: 90m, 20m
- Irradiation: 95m, 33m
- Baro. Press.: 90m, 20m

Fig. 1: Meteorological sensors at the FINO-1 platform in the German Bight and data availability from January 2004 until today.

Fig. 2: Setup of the oceanographic measurements at the FINO1-platform (source BSH).

Fig. 3: Example of FINO1 online data available to the public (http://fino.dewi.ag/fino_1day.png). The same plot exists for one week's data (http://fino.dewi.ag/fino_1week.png).

Fig. 4: Development of the mean wind speed at 103m (LAT) during six years of measurement. The blue line refers to the monthly average and the pink line to the cumulative average of the whole period. The right picture shows that a further change of the long term average can be expected.
The sample rate for the data is 1 min. For higher frequencies of the wind fluctuations three ultrasonic anemometers are available at heights of 40-80 m. Fig. 2 shows the setup of the oceanographic measurements, which consist of sensors for physical properties of the water mounted at a chain that is anchored at the sea bottom and accomplished by ADCP (Acoustic Doppler Current Profiler) and waverider buoy (sea state) measurements. The meteorological and oceanographical parameters are available to the public as can be seen in Fig. 3, more information of the project is available at http://www.fino-offshore.de.

**Long Term Time Series of the Wind Speed and the Temperature**

For wind energy applications one of the most important meteorological parameters is the mean wind speed, sampled for the longest available time period. In Fig. 4 the monthly averages of the wind speed (blue line) and the cumulative average (pink line) can be seen. During the first years the cumulative average was significantly influenced by the sea seasonal variations, now after 6 years of measurement this average converges to a value of slightly more than 10 m/s. Though 6 years of wind measurements are already quite a reliable data basis, we can still expect a further change of...
Fig. 9: The influence of alpha ventus wind turbines on the measured turbulence intensity, the peaks can be related to AV01, AV04 and AV07.

Fig. 10: Geographical positions of FINO1-3

Fig. 11: The influence of alpha ventus wind turbines to the wind speed. The met mast only gives data of the lower rotor plane area.

Fig. 12: FINO1 data at 91.5m LAT during 5/2010-4/2011 measured (top), corrected concerning the disturbance by the mast (middle) and the disturbance by Alpha Ventus (below).
this average if we look at a scale of several decades (lower graph of Fig. 4). The corresponding Weibull distribution functions can be seen on the left hand side in Fig. 5. The seasonal dependence of the distribution is shown on the right of Fig. 5. The time series for the air and water temperature is shown in Fig. 6. Daily differences are quite pronounced and play an important role in the characteristics of the marine boundary layer. On a monthly basis the time series however show a quite similar behavior.

New Tasks for FINO1

A major task of the FINO1 project is to deliver data to the German and International offshore (wind) research community. By the end of 2010 more than 200 data users were registered at the data bank operated by BSH (www.bsh.de). With the installation of the first German offshore wind farm Alpha Ventus there is a new situation for FINO1. Whereas only the western sectors are still under free flow, the measurements of wind speeds from eastern directions can give important information of the wind farm or wake effects caused by the wind turbines of Alpha Ventus. The nearest neighbour AV04 is only 400m away from FINO1. Fig. 8 shows the Weibull distribution filtered for the eastern directions where the influence of alpha ventus is given. In Fig. 9 the direction-dependent turbulence intensities are shown in comparison to the undisturbed turbulence intensity measured before the installation of Alpha Ventus, indicating a drastic increase of turbulence from the eastern directions. The peaks can be allocated to single wind turbines, mainly AV01, AV04 and AV07. Since 2009 all three FINO-platforms are in operation (see Fig. 10 for the geographical positions). A combined analysis of the data, especially between FINO1 and FINO3, provides the possibility to study how far offshore sites differ from each other and which observations from FINO1 can be generalized. For meteorological models (like WRF) it is important to have several validation points along the German Bight.

Furthermore from 2009 until 2011 a LiDAR (Light Detection And Ranging) is operating on the platform to measure the wind speed up to 250m. The data availability lies above 90%. Fig. 11 shows how the wind profile continues above 103m which is the heighest cup anemometer at FINO1.

Only the LiDAR measurements give the possibility to study the area of the whole rotor plane. In order to preserve the undisturbed long term wind measurements at FINO1, corrections were implemented based on nacelle anemometer data and CFD simulations (Fig. 12). It shows a significant change from 8.8m/s to 9.3m/s for the combined mast and park correction. Since April 2011 an additional LiDAR instrument at the converter station of the wind farm (see red circle to the south east of the wind farm in Fig. 5) completes the free flow values for the eastern directions. During the next years the whole region will be subject to offshore wind installations, so within the next decade FINO1 can be used to study the far reaching effects of wind farms on the marine boundary layer.

Conclusions

Since the beginning of the operation of the “sister” platforms FINO2 (Baltic Sea) and FINO3 (North Sea) a combined analysis of the met-ocean dataset of all three platforms will be important to understand the spatial correlation of environmental parameters offshore and to provide input data into oceanographical and meteorological models. The following items only give a short list of the future tasks of the FINO1 offshore research station:

- Completion of long term series (met-ocean)
- Reference Data for „Research at Alpha Ventus” (RAVE)
- Data Comparison with FINO 2 and 3
- Study wind farm effects small to very large size
- Additional sensors (e.g. RADAR, LiDAR, Fast Humidity, 10m Wind Speed..) and test of adopted offshore sensing
- Input data for planning offshore works

Acknowledgements

FINO is an acronym for “Research Platforms in North Sea and Baltic Sea”. RAVE is an acronym for “Research at Alpha VEntus”. Both are financed by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).