Special issues concerning wind power prediction for offshore wind farms

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Up to date, several operational systems for the prediction of the power output from wind farms are available. Typical prediction time horizon is 2 to 3 days. Due to the farm size, for offshore installations, this power forecast will be even more important than for onshore applications. Regarding the special meteorological and geographical conditions existing prediction systems must be extended and adopted for offshore use. In physical models, this concerns mainly the description of the water surface roughness, thermal stability effects and wind farm shadowing. Central part of our contribution is a comparison between these requirements for physical models and the current need for development. As an outlook, we discuss the expected power output fluctuations from offshore wind farms, i.e. during passing storm fronts.

Introduction

Currently there are different operational systems for prediction of the power output from wind farms 2 to 3 days ahead (e.g. *Prediktor*, *WPPT* in Denmark, *Previento* and the ISET-System in Germany). Due to the size of the installations, such a prediction will be even more important than onshore. Besides classical applications, especially for power brokerage and power plant scheduling, new fields of application are arising. Examples are the control of the wind farm power output, planning of M&R and the operational control of additional energy systems like hydrogen production and storing.

Wind power prediction: the technique

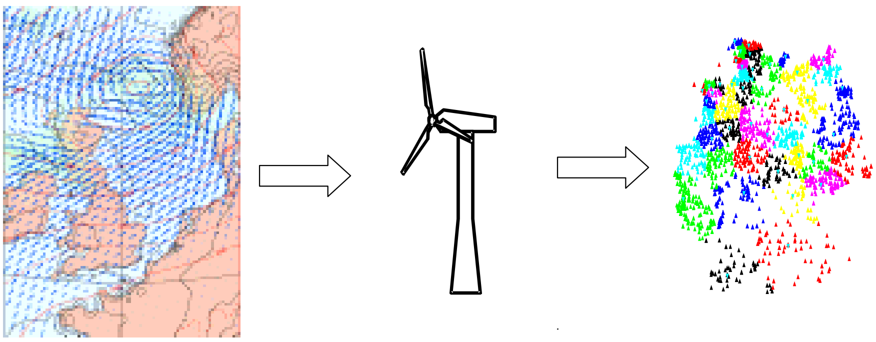
Fundamentally, wind power predictions for more than 3 hours ahead are based on numerical weather forecasts (nwp) delivered by the according weather services. In general, a prediction of the surface wind is used to gain a power prediction by a transformation process (figure 1). The systems currently available could be divided up roughly into two classes: systems on base of pure statistical methods and approaches which implement a transformation on base of physical and meteorological models.

Statistical Modeling

For these class of methods historical data from as well wind power predictions as wind power measurements is needed. On base of these data, by the application of correlation methods (neural networks, multi-dimensional regression) a transformation between the weather service prediction and the according wind power output is gained.
This transformation can be applied for the future to get a wind power prediction with the numerical weather forecasts data as input.

Physical Approaches

In contrary to statistical methods a modeling approach on base of the according physical and meteorological laws is applied. Mostly the 10m-Niveau wind speed is extrapolated to hub height and then the power output is determined. As additional input, local circumstances like local surface roughness, thermal stability and wind farm effects are taken into account (figure 2).



Numerical Weather Prediction (wind speed)   Wind farm power output   Regional Power

Figure 1: Principle of wind power prediction from the numerical weather prediction to the regional wind power.

Comparison
Due to the different methodical approaches, the methods show up different advantages and disadvantages. Statistical methods have the big pro that they do not assume any insight into the basic physical effects. Furthermore, in general they are operated adaptive, i.e. changes in the prediction system, e.g. new versions of the nwp, are taken into account automatically after some relaxation time.

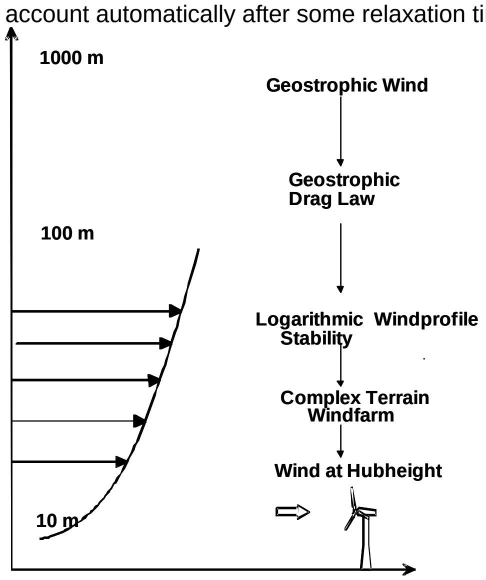


Figure 2: Local refinement of the numerical prediction with physical models

On the other hand, it is crucial that historical measuring data is available and of good quality. Insuffiencies of these data would be „learned“ by the correlation methods. Especially for the application of neural networks, it must be taken into account that they need a sufficient number of measurement-prediction tuples. In situations with low density of data, e.g for high wind speeds, neural networks can show up significant uncertainties or even unpredictable behavior.

In contrast, physical models have the advantage that they are independent from measuring data and an adaptation of parameters could be implemented quickly. Admittedly such changes must be implemented by hand. Moreover, physical modeling presumes an according understanding of the underlying processes. For some phenomena, this is not available per se, but is topic of current research (e.g. thermal stratification and vertical wind speed profile). Nevertheless, the big advantage of physical approaches is that the use of measuring data is dispensable.

Prediction System Previento
In recent years at the University of Oldenburg the wind power prediction system *Previento* was developed. This system is operational now for approximately three years. Basis of the transformation here is the physical modeling of the lower atmosphere including thermal stability and wind farm effects. Apart from the forecast itself, Previento also calculates an uncertainty range for the respective forecast depending on the current weather situation. Operator of the prediction system is Overspeed.

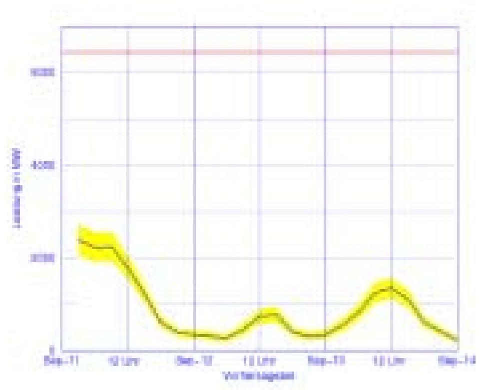


Figure 3:Power prediction from Previento. The yellow band gives the prediction uncertainty.

Offshore-Meteorology

Thermal stratification
The meteorological situation offshore differs in some cases clearly from the one onshore. More frequently, stable and unstable thermal situations are found, which are onshore, at least with higher wind velocities, in most cases neutral or quasi-neutral. The reason for this characteristic lies in the fact that the temperature of the water changes seasonally only slowly due to the high heat capacity. For example, cool air meets still relatively warm water in autumn, which leads tendentious to an unstable layering. The low roughness of the sea surface enforces the influence of this effect on the vertical wind profile.

Smoothing effects
Compared to onshore installations, very large farms will be installed offshore concentrated on a relatively small area. Together with the homogeneous roughness of the environment, much higher fluctuations of power output must be expected than known onshore. In particular this will be the case during passing of storm fronts.

Offshore Windfarms

Shadowing effects
Additionally to the general meteorological conditions the wind power is influenced by wind farm shadowing effects. These depend on wind velocity and direction, the thermal stratification and the geometric layout of the farm. For the projected large, relatively homogeneous farms changes of the wind direction can cause relatively high fluctuations of power output.

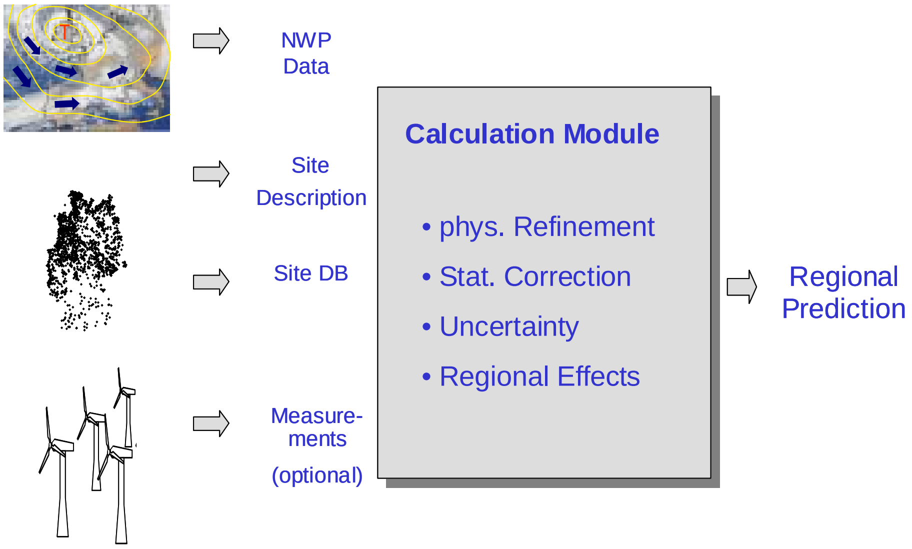


Figure 4: Priciple function of the prediction system Previento

Cut-off Effects

Generally wind turbines are switched off at high wind velocities, typically between 25 and 30 m/s. Due to the homogeneous environment, in offshore farms in principle a kind of a domino effect could occur. Assumed, the free wind velocity increases continuously during a storm. With reaching the cut-off velocity the first row of the farm is shutdown. Up to this time the second row was facing a reduced wind speed due to shadowing effects. By the shut down of the first wind turbines this shadowing is missing now, the second row now faces the undisturbed high free wind speed is shut down also. In total, the whole farm could be switched off from the grid by this domino effect in a few minutes which means a very high power gradient.

Conclusion

We have seen that the meteorological situation is very different offshore from onshore. Especially wind farm effects play a more pronounced role than known from onshore installations. In order to integrate this behavior into a wind power prediction a physical modeling of the appropriate effects is indispensable. In particular, extreme situations such as storms do not occur frequently enough in order to be able to reflected by a statistic regression procedure. On the other hand the effects of these storm situations are significant on the operation of the conventional power stations.

In order to be able to model the specified effects adequately, still substantially R&D efforts are necessary. In particular this applies to the description of the smoothing effects and the behavior of the wind farms during periods with high wind velocities. In the course of the EU project *Anemos,* several of the above mentioned fields of necessary development will be addressed.

Links

www.previento.de
www.anemos.com
www.ehf.uni-oldenburg.de