The Quality of a 48-Hours Wind Power Forecast Using the German and Danish Weather Prediction Model

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Wind power prediction systems are used operationally today. To get a local or regional prediction, the results from numerical weather prediction models operated by the weather services are refined by taking into account local influences like roughness and the power curve. Compared to measurement data, the wind power prediction partly shows up substantial errors. In this article, we will show an example how the prediction uncertainty can be diminished significantly by the simultaneous application of the output from two different weather forecast systems.
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1 Overview

In countries showing high wind energy shares in the electrical power supply grid, a "wind power weather forecast" of the expected wind power will be of growing importance. This will be applied in classical areas like control of loads and power plant scheduling as well as in the framework of a future green energy stock exchange. The typical prediction time horizon which is needed for these purposes is 3 to 48 hours. In systems currently used for wind power prediction, the general forecast from numerical weather prediction models is refined and adjusted. Due to the principle problems of numerical weather prediction, these results are basically uncertain. In this paper, a first approach to diminish this uncertainty by the simultaneous application of two different numerical weather prediction (NWP) models is shown.

2 State of the art in wind power prediction

2.1 The Model

As mentioned above, wind power prediction is based on a spatial refinement of the results from general weather forecast models. Such a refining scheme is shown in figure 1 : Starting with wind speed data from the general NWP, detail models are applied taking into account the effects from local roughness, thermal stratification of the atmosphere, and orography. Using the wind turbine power characteristics and a description of wind farm effects, a local wind power prediction is gained. Models of this kind were developed in Denmark first and in the meantime used operationally there, in Germany and in Spain. ([1], [2], [3],[4], also [5]).

Due to the uncertainty of the NWP output, the result of the wind power prediction is erroneous. Typical values of the RMSE compared to measurement data are shown in table 1 for different prediction times ([2]). This overall uncertainty of 40 % of the mean power is comparingly high. Especially in situations with high wind speed gradients, e.g. occurring if low pressure systems are passing by, in many cases the temporal development of prediction and measured wind power is differing.

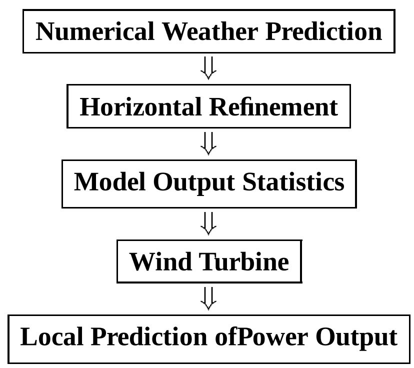

Figure 1: Principle of the spatial refinement of the numerical weather prediction leading to a local prediction of wind conditions.

Table 1: RMSE of wind power prediction (% of mean power) depending on prediction time.

Prediction Time [h]	6	12	18	24	36	48
RMSE [% Pmeas]	33	33	38	40	36	41

2.2 Approaches for improvements

To improve the practical application of wind power prediction, among others the following approaches come into consideration:

- The current uncertainty of the specific prediction could be given by means of a suitable algorithm, so it could be included into planning procedures. For that purpose a characterisation of the large scale weather situation will be used.
- The use of the outputs of different independent NWP models as input to the wind power prediction may decrease the forecast uncertainty.

We will have a look on the possibilities of the second approach. To exclude influences from additional sources of

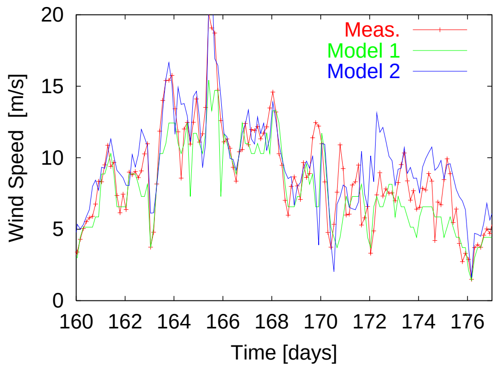

Figure 2: Typical wind speed time series of both prediction models (3 to 24 hours prediction) and measurements.

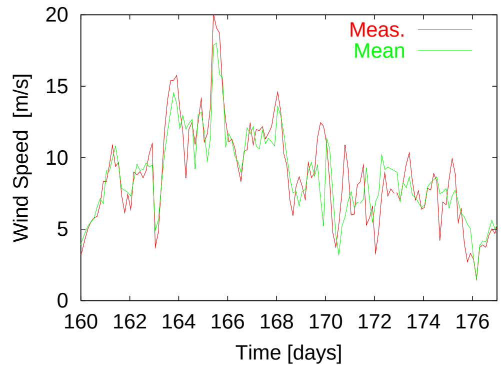

Figure 4: Time series like figure 2 of the new prediction model compared to measurements.

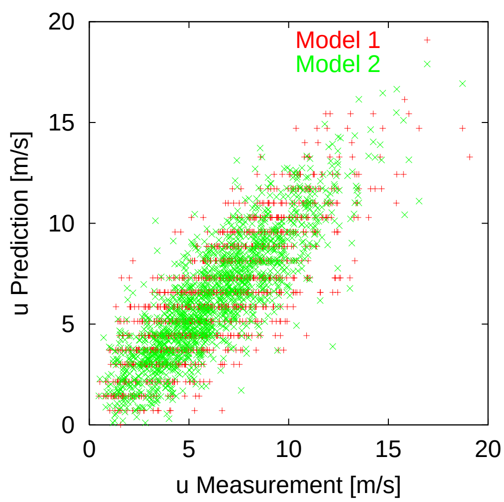

Figure 3: Scatter plot of both models each compared to measurements (data for one year).

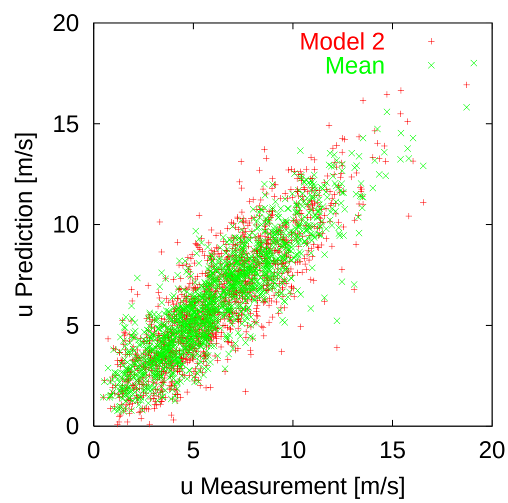

Figure 5: Scatterplot of the new prediction model ("mean") compared to measurements.

uncertainty like power curves and wind farm effects, for this investigation only wind speed data was used.

2.3 German and Danish NWP model

In the context of an EU research project ([4]), predictions on base of weather forecasts from the German and Danish weather service were used. Table 2 shows an overview of the main basic figures of the respective NWP models. For the statistical analysis of the model performance measurement data of the wind speed at 30 m height for one year (1996) were used.

Table 2: Key figures of both NWP models

Model	HIRLAM
Operator	Dan. Met. Institute
Horizontal Resolution	25 x 25 km2
Area	DK and North. Germany
Starting Points	0, 12 hrs; add. 6, 18 hrs.
Model	Deutschlandmodell
Operator	German weather service
Horizontal Resolution	15 x 15 km2
Area	Germany
Starting Points	0, 12 hrs; add. 6, 18 hrs

3 Combination of both models

The prediction quality of both models is often very different for different measurement sites. For the following investigations, an exemplary site was chosen for which both models deliver good predictions. The data basis covered one year.

In figure 2, a typical run for the 3 to 24 hours prediction values is shown for a period of about two weeks. Both models overestimate or underestimate the real trend of the wind speed quite often. Figure 3 shows the corresponding scatter plot for all data of the year 1996. Both models show a quite uniform scatter around the bisection line.

The RMSE (normalised to mean wind speed) is 28 % for model 1 and 26 % for model 2. In the following we will examine how far the prediction uncertainty can be decreased by the combination of both models.

As a simple new model based on the two models, the arithmetic mean of both predicted wind speeds was chosen:

$$\textit{Combined Forecast} = \frac{1}{2}(\textit{Model1}+\textit{Model2})$$

The resulting run of this combined prediction is shown in figure 4 for the same time interval as in figure 2. It can be seen clearly that the deviations between measurements and the new forecast decrease significantly. This also reflects in the RMSE which is reduced to 22 % (figure 5).

At this point it should be mentioned that not all measurement sites show a correlation between measurements and forecasts which is as good as the one shown here. A respective example is shown in figure 6. The scatter is substantial, the RMSE amounts to 55 %. In such cases, even using both models wouldn't lead to an improvement of the predictions.

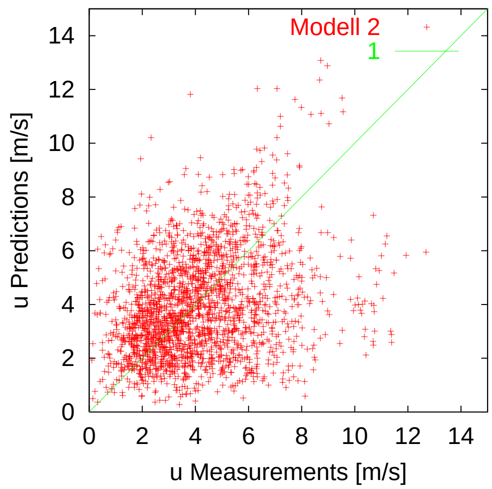

Figure 6: Scatter between prediction and measurements for one of the both model for a site which is not well predicted in the mean.

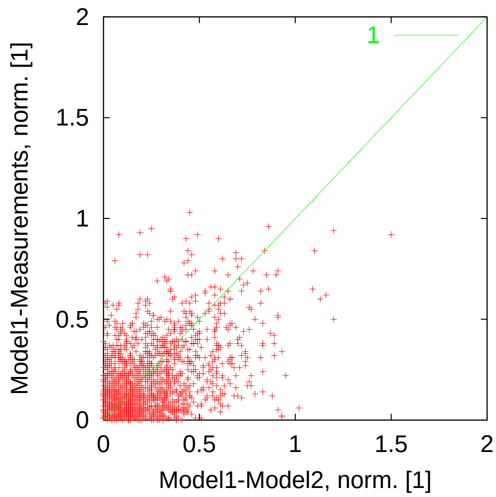

Figure 7: Scatter of the difference of the two prediction models vs. the difference of one of the models compared to measurements.

4 Model Differences and Uncertainty

As already mentioned, the prediction shows an uncertainty which most likely depends on the overall weather situation. On base of the data available, the following hypothesis should be checked:

If it is difficult to predict the wind speed in the current weather situation, it is quite probable that the two models come to forecasts which are very different from each other.

Is it possible to gain information from this difference about the uncertainty of the prediction compared to measurements?

To investigate this thesis, figure 7 shows the scatter of the difference between the two prediction values vs. the difference of model 1 to the measurements. In the resulting cloud of points, there is no obvious structure to be detected. It seems that the presumption expressed above cannot be verified.

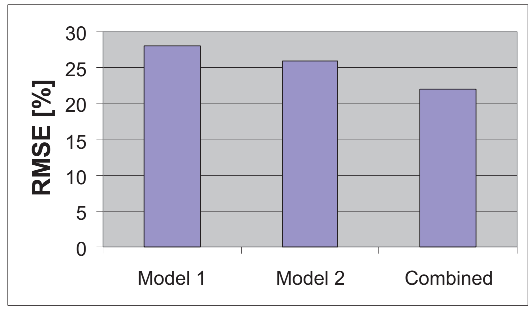

Figure 8: Comparison of the RMSE of the both original and the new model ("combined").

5 Conclusions

Wind power prediction systems are working operationally today, but the forecasts partly still show up significant uncertainties. By combining the output from two different NWP models, in principle the forecast uncertainty can be reduced compared to the single models (figure 8). To support this result, an investigation for additional sites is necessary.

6 References

[1] Lars Landberg: *Predicting the power output from wind farms.* Proceedings of the EWEC 1997, Dublin

[2] H.-P. Waldl, U. Focken, M. Lange, K. Mönnich, H.G. Beyer, A. Luig: *Spatial Smoothing Effects and Regional Differences when Predicting the PowerOutput of Wind Turbines.* Wind Power for the 21st Century, Special topic conference, Kassel 2000.

[3] L. Landberg, A. Joensen, G. Giebel, H. Madsen, T.S. Nielsen: *Zephyr - The Next Generation Prediction System.* Wind Power for the 21st Century, Special topic conference, Kassel 2000.

[4] Lars Landberg, Hans-Peter Waldl, Gregor Giebel, Ulrich Focken, Matthias Lange, Kai Mönnich, Hans Georg Beyer, Armin Luig, Jess. Joergensen: *Short-term Prediction of Regional Wind Power Production.* Final Report EU-Project JOR3-CT97-0272, 2000.

[5] www.physik.uni-oldenburg.de/ehf/wind, 2000.