

PREVIENTO

REGIONAL WIND POWER PREDICTION WITH RISK CONTROL

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In recent years much research has been done in the field of wind power forecasting. Developed wind power prediction systems like *Previento* are able to calculate power forecasts for single wind farms quite well with advanced methods. Not much effort has been done to produce regional forecasts with an ensemble of wind farms. In this paper we calculate the number of representatives in a region which are necessary for a best possible regional forecast. Besides an regional wind power forecast itself the uncertainty of the forecast as a measure of the risk is calculated. For this purpose the prevailing weather situations, the behaviour of the power curve and the regional distribution of wind farms is considered.

1. Overview of *Previento*

Previento is a system for wind power prediction which has been developed at the University of Oldenburg and is in operational use for more than two years. The system follows the physical approach of modelling the relevant physical phenomena of the boundary layer which influence the power output of a wind farm. Based on a numerical weather prediction model (in our case the *Lokalmodell* of the German Weather Service) the wind speed at hub height is calculated. The coarse forecast of the weather prediction model is refined considering the environment of the specific site, e.g. orography and surface roughness. Furthermore the thermal stability of the atmosphere is modeled in detail. Especially for hubheights above 50 m the influence of the thermal stratification is very important. With help of farm layout and the turbine power curves in the wind farm the output of the farm is calculated. The detailed prediction system is described in [1]. Figure 1 shows an overview of the system.

2. Regional Forecast

In most cases forecasts are not required for single sites but for large regions like the supply area of electric utilities or nationwide for trading purposes.

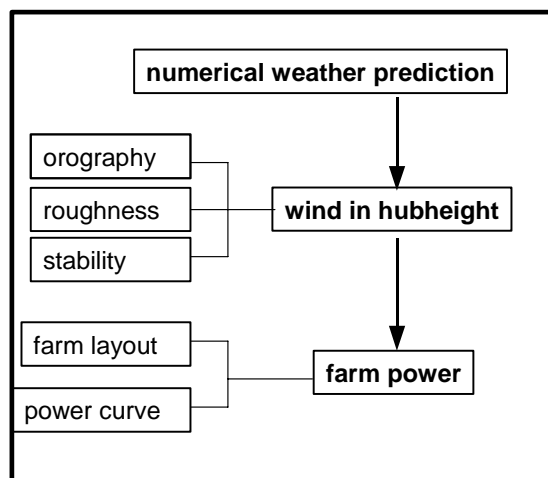


Figure 1: Overview of wind power prediction system *Previento* for single wind farms.

The most accurate method to calculate the power prediction of an ensemble of wind farms is to separately calculate the power output for each wind farm in the region and generate the sum. This would require the description of orography and roughness for each turbine – an unfeasible effort for a country like Germany with more than 10000 turbines installed. To overcome this problem a set of representative sites has been chosen, for which a detailed prediction is made. The regional

forecast then is calculated by an upscaling algorithm considering a “small” site description including hub height, type and mesoscale roughness, which is possible to obtain for all turbines.

In this procedure we have to consider smoothing effects which lead to a decrease of the error and fluctuations in the regional forecast. Figure 2 shows the power output of one turbine compared to the output of 30 turbines distributed over northern Germany. The reduction of the fluctuations is obvious.

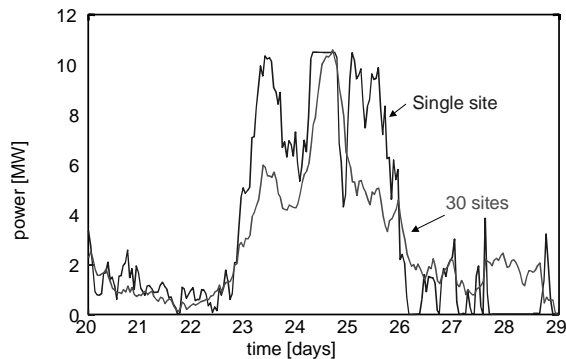


Figure 2: Power output of a single wind turbine compared to the output of 30 turbines distributed over northern Germany.

The question to answer is: How many representatives are necessary to get the best benefit out of smoothing effects?

For this purpose we calculated the impact of this effect on the error of the *Previento* prediction. Figure 3 shows the reduction of the error for a regional forecast depending on the number of sites in the region. The size of the region is constant, in this case 730 km, which is approximately the size of Germany. The reduction of the error does not continue to decrease if more than around 50 sites are chosen. This means a comparatively small number of representative sites is sufficient for a regional prediction. More details of the calculation procedure and the data base can be found in [2].

An important quantity for the grid integration of wind power is the gradient of the power production. Here we have considered the decrease of the power gradients of the regional power forecast. As a statistical measure the variance of the time series has been calculated. Figure 4 shows the reductions of the variance for a regional forecast as a function of the number of sites in a region (here 730 km). Again the reduction decreases with an increasing number of sites in the region but

saturation now occurs with approximately only 20 turbines.

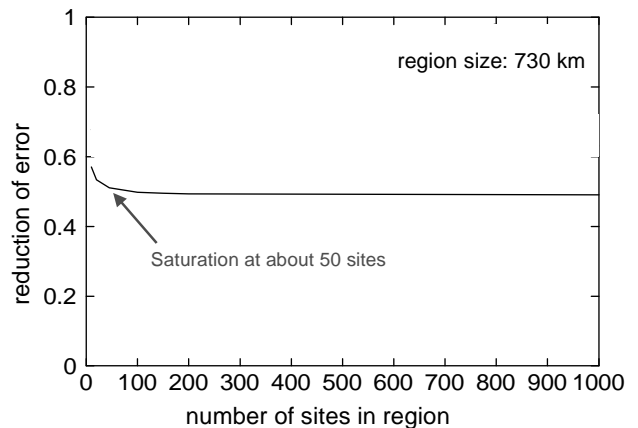


Figure 3: Reduction of the error of a regional forecast compared to a single site versus number of sites in the region. A fast saturation of the reduction of the error can be seen.

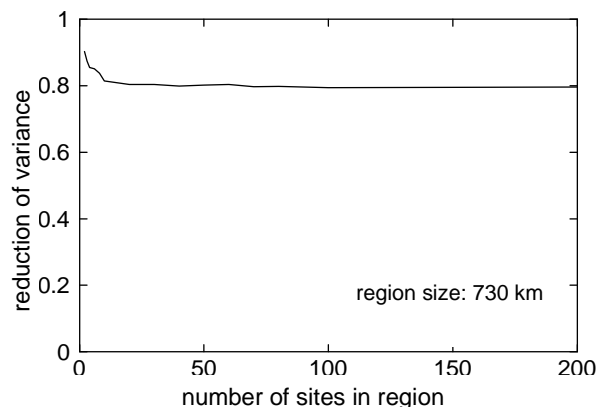


Figure 4: Reduction of the variance of a regional forecast as a function of the number of sites in the region. The variance is a measure of the fluctuations.

As a result, for a region of the given size the smoothing effect is described with sufficient accuracy using only 50 representative sites. The upscaling procedure for Germany is shown in figure 5. The whole region is divided into nearly 50 subregions with equal installed capacity. For each subregion a representative site is chosen with respect to orography and roughness of the subregion. We choose large wind farms to include already a large share of the installed capacity in the subregion in detail. The sum of all subregions provides the regional forecast.

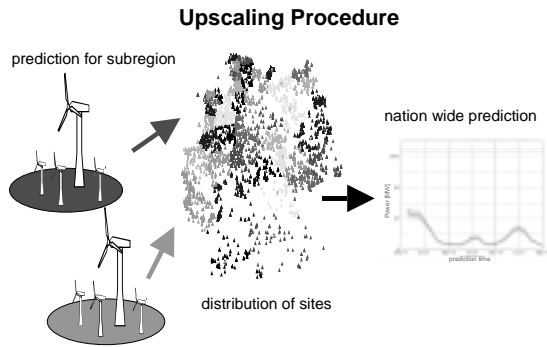


Figure 5: Upscaling procedure of **Previento**. For each subregion an representative site is chosen. The detailed prediction for this representative is scaled up to the subregion. The regional forecast is obtained considering the total distribution of the sites..

3. Risk Control

The complexity of the weather will probably never allow for perfect wind power forecasts leaving always a risk in trusting the forecast. The aim is to provide the user with additional information concerning the specific forecast situation to enable an assessment the risk of relying on the wind power forecast. *Previento* provides the uncertainty of the forecast in addition to the power forecast itself.

Figure 6 shows the 3 steps of calculating the uncertainty of the regional power prediction.

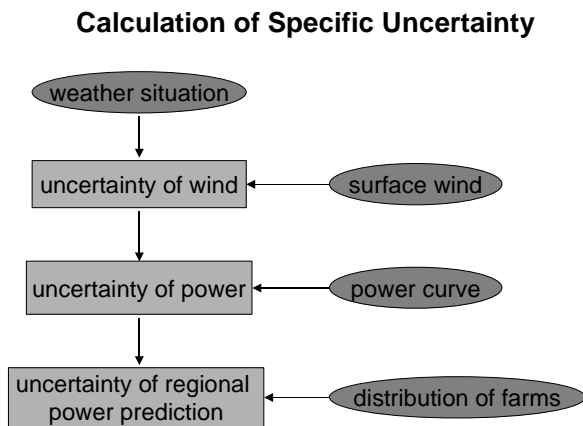


Figure 6: Calculation scheme for the uncertainty of the regional power prediction for each specific forecast situation as a basis for a risk control system.

The prediction system *Previento* is based on the numerical weather prediction of the weather services. In a first step the uncertainty of the wind speed forecast depending on the

prevailing weather situation is calculated. The idea is to classify all weather situations in those which can be well predicted and which cannot. As an example figure 7 shows a situation with fast moving low pressure systems in northern Europe. This situation is typical for storms in spring and autumn with typically larger uncertainties of the numerical weather prediction models. In contrast to this stable high pressure situations occurring more often in summer and winter show smaller uncertainties.

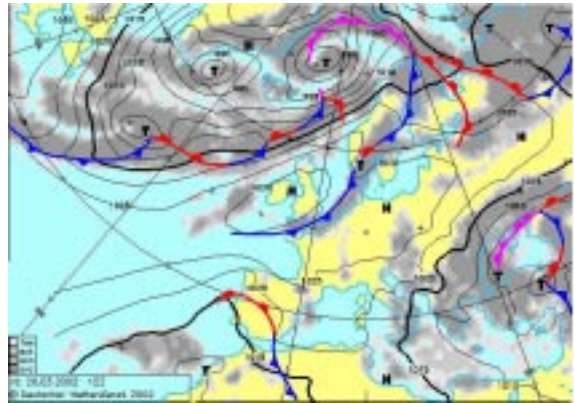


Figure 7: Fast moving low pressure system over northern europe. The uncertainty of the predicted wind speed is high for these situations.

The next step in calculating the accuracy of the forecast is the calculation of the power output of single windfarms. The same size of uncertainty in wind speed can lead to different uncertainties in power output as shown in figure 8.

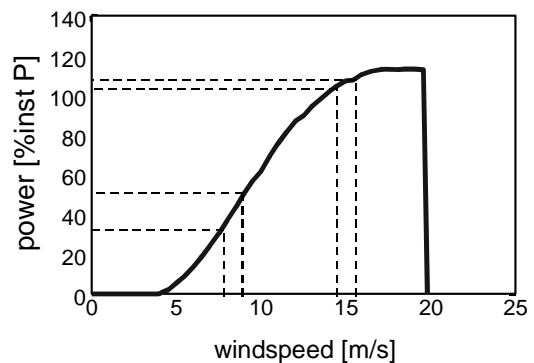


Figure 8: Powercurve of a single turbine. The uncertainty of the wind speed results in different uncertainties in power output due to the slope of the curve.

Figure 9 shows an example of a 48 hours forecast for one subregion. In the first three hours the power is predicted with only small

uncertainties because the turbine operates with its rated power and the power curve shows only a small slope. The maximum of uncertainty can be seen for half the rated power.

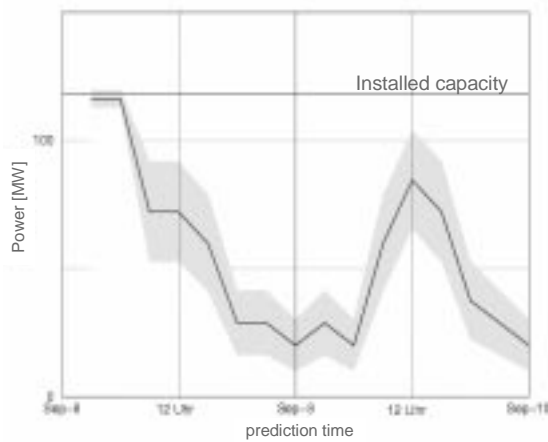


Figure 9: Example of an 48 hours forecast for a subregion. The grey field shows the uncertainty of the forecast as an 85% confidence intervall.

The uncertainty of the complete region is calculated from the uncertainty of each subregion considering the correlation of the uncertainty of all subregions. Therefore the total uncertainty decreases due to smoothing effects similar to the error of the forecast.[3]. Figure 10 shows an example of the uncertainty of the regional forecast..

4. Resume

Based on wind power forecasts for single sites an algorithm to calculate the wind power output for a region which means an ensemble of wind farms is developed. It is possible to calculate the optimal number of representative sites in a certain region to reach the best benefit out of smoothing effects. We could show that the fluctuations of the regional power output is described well.

To provide the user with additional information about the risk of the forecast the uncertainty of the specific forecast situation is provided together with the wind power prediction. The uncertainty of a regional wind power forecast depends on the specific weather situation, the behaviour of the wind turbine and the distribution of the wind farms in the region.

Regional Uncertainty

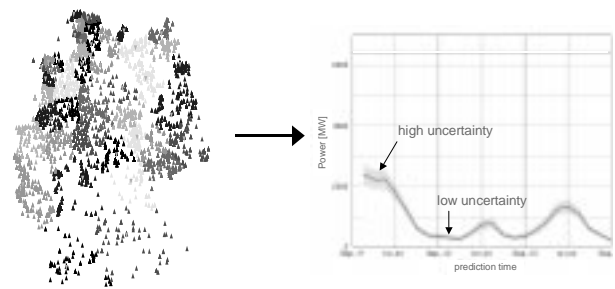


Figure 10: The uncertainty of a specific prediction situation of an regional forecast is calculated under consideration of the distribution of all turbines in Germany.

Acknowledgement

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References:

- [1] H.G. Beyer, D. Heinemann, H. Mellinghoff, K. Mönnich, H.P. Waldl: *Forecast of Regional Power Output of Wind Turbines*. Proceedings of the EWEC 1999, Nice
- [2] U. Focken, M. Lange, K. Mönnich, H.P. Waldl, H.G. Beyer, A. Luig: *Short-term prediction of the aggregated power output of wind farms – a statistical analysis of the reduction of the prediction error by spatial smoothing effects*. J. Wind Eng. Ind. Aerodyn. 90 (3) (2002) 231-246
- [3] M. Lange, D. Heinemann. *Accuracy of Short Term Wind Power Predictions Depending on Meteorological Conditions*. Proceedings of the Global Windpower 2002, Paris