PREVIENTO

REGIONAL WIND POWER PREDICTION WITH RISK CONTROL

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ABSTRACT: Common wind power prediction systems provide the expected power output of single wind farms up to three days in advance. However, operational use requires more information: a reliable forecast of the aggregated power output of many wind farms in a large area and an estimate of the expected uncertainty of the prediction. We investigated the statistical effects of combining the forecast for spatially dispersed wind farms in a region and implemented a new algorithm to extrapolate from few representative sites to many sites in a region. To assess the risk of relying on a prediction the expected uncertainty has to be available for individual forecast situations. We found that the impact of the prevailing meteorological situation on the forecast accuracy has to be taken into account as well as the non-linear power curve with its error amplifying effect. The results of our investigations were included in the development of the wind power prediction system *Previento* giving a regional forecast with an individual error estimate.
Keywords: Wind Power Prediction, Utility-Integration, Uncertainty Analysis

1 OVERVIEW OF PREVIENTO

Previento is a system for wind power prediction which has been developed at the University of Oldenburg being in operational use for several years. The system follows a physical approach of modelling the relevant physical phenomena of the boundary layer determining the power output of wind farms. 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 hubheigths above 50 m the influence of the thermal stratification is very important. With help of farm layout and the turbine power curves the output of the farm is calculated. The detailed prediction system is described in [1]. Figure 1 shows an overview of the system.

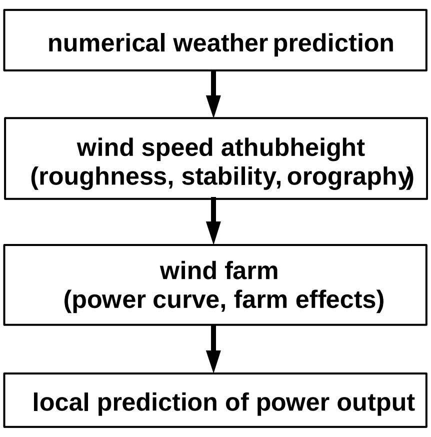


Figure 1: Overview of wind power prediction system Previento for single wind farms

2 REGIONAL FORECAST

In practical use wind power forecasts are not required for single sites but for large regions, e.g. the supply area of electric utilities or even nationwide for trading purposes. The most accurate method to calculate the power prediction of an ensemble of wind farms is to seperately 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 which would be an unfeasible effort for a country like Germany with more than 10000 turbines installed.

To overcome this problem a set of representative sites has to be chosen, for which a detailed prediction is made. The regional forecast is then calculated by an upscaling algorithm considering a simple site description with easily available parameters like hub height, machine type and mesoscale roughness. In this procedure we have to consider statistical smoothing effects leading to a decrease of the prediction error and less fluctuations in the timeseries of the regional forecast. Figure 2 shows the power ouput of one turbine compared to the aggregated output of 30 turbines distributed over northern Germany. The reduction of the fluctuations is obvious.

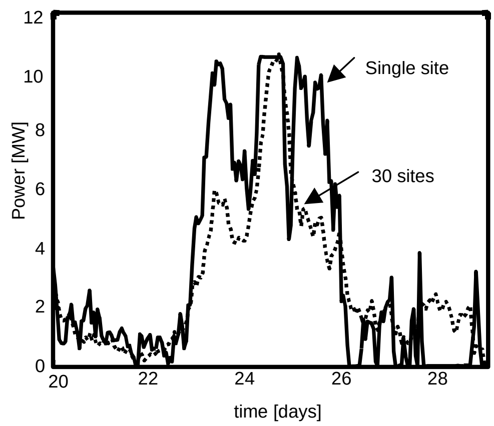
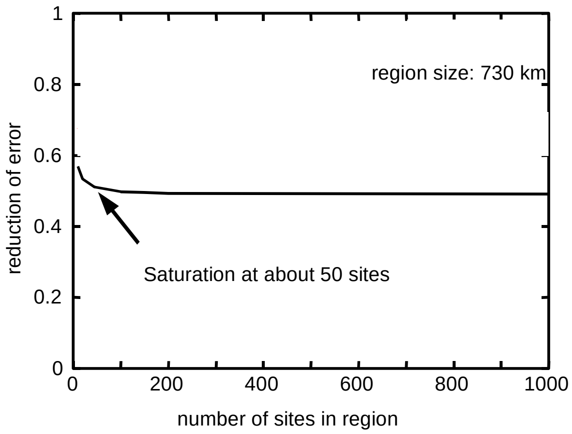


Figure 2: Power output of a single wind turbine compared to the aggregated output of 30 turbines distributed over northern Germany.

One key issue is: How many representative sites are necessary to get the best benefit out of the smoothing effects? For this purpose we calculated the impact of the spatial smoothing on the error of *Previento*'s 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].

Figure 3: Reduction of the error of a regional prediction



compared to a single site versus number of sites in region. A fast saturation of the error reduction can be seen.

An important quantity for the grid integration of wind power is the temporal 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. The reduction of the variance for a regional forecast as a function of the number of sites in a region shows a similar behaviour as the error. Again the reduction decreases with an increasing number of sites in the region but saturation now occurs with approximately only 20 turbines.

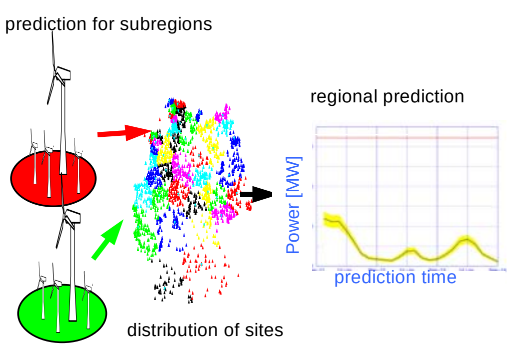


Figure 4: Upscaling procedure of Previento. For each subregion a representative site is chosen. The detailed prediction for this representative is scaled up to the subregion. The regional forecast is the total of the predictions for the subregions.

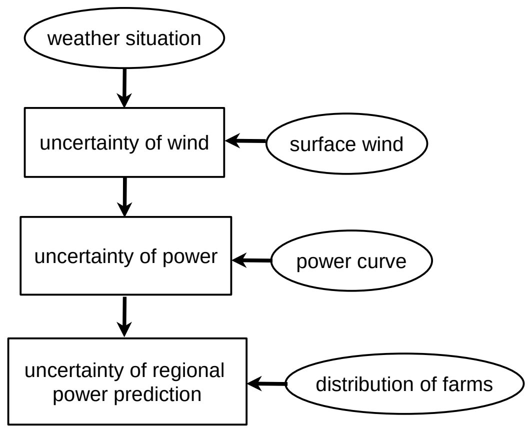
As a result, for a region of a given size the smoothing effect is described with sufficient accuracy using only 50 representative sites. The upscaling procedure for Germany is shown in figure 4. The whole region is divided into nearly 50 subregions with equal installed capacity. For each subregion one representative site is chosen considering orography and roughness of the subregion. Preferably, we use large wind farms as representatives to include a substantial share of the installed capacity in the subregion in detail. The sum of all subregions provides the regional forecast.

3 RISK CONTROL

The complexity of the governing equations will probably never allow for perfect wind power forecasts leaving always a risk for wrong predictions. The aim is to provide the user with additional information concerning the specific forecast situation to enable an assessment of the risk of relying on the wind power forecast. *Previento* provides the uncertainty of the forecast in addition to the power forecast itself. Figure 5 shows the necessary steps of calculating the uncertainty of the regional power prediction. The prediction system *Previento* is based on the numerical weather prediction of the weather services.

Figure 5: Calculation scheme for the uncertainty of the regional power prediction for each specific forecast situation as a basis of the risk control system.

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 those which



cannot. As an example figure 6 shows a situation with fast moving low pressure systems over Central 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 occuring more often in summer and winter show smaller uncertainties.

The next step in calculating the accuracy of the forecast is the calculation of the power output of single windfarms. Due to the non-linear power curve the same

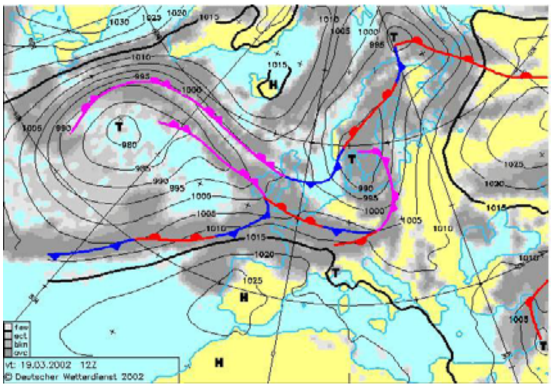


Figure 6: Fast moving low pressure system over Central Europe. The uncertainty of the predicted wind speed is high for these situations.

amount of uncertainty in wind speed can lead to different uncertainties in the predicted power output as shown in figure 7. In particular, in the range of medium wind speeds the steep slope of the power curve magnifies initial errors in the wind speed prediction leading to larger errors in the power forecast.

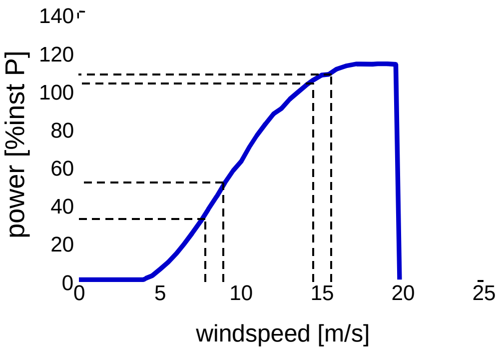


Figure 7: Due to the non-linear power curve the uncertainty of the wind speed results in different uncertainties of the power prediction.

Figure 8 shows an example of a 48 hours forecast for one subregion with an uncertainty range that takes the effect of the power curve into account. In the first three hours the power is predicted with only small uncertainties because the turbine operates at its rated power and the power curve has only a small slope. The maximum of uncertainty can be seen for half the rated power. The uncertainty of the complete region is calculated from the uncertainty of each subregion considering the spatial correlations of the prediction error of all subregions. Therefore, the total uncertainty decreases due to smoothing effects similar to the error of the forecast [3]. Figure 9 shows an example of the uncertainty of the regional forecast.

4 RESUME

Based on wind power forecasts for single sites an algorithm to predict the aggregated power output of many wind farms in a region has been developed. Statistical analysis allows for choosing the optimal number of representative sites in a certain region to benefit most from smoothing effects. We found that the size of the region determines the magnitude of the error reduction and the decrease of fluctuations compared to a single site. To provide users with additional information about the risk of relying on the forecast the uncertainty of the specific forecast situation is given 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 wind farms in the region. The results of our investigations were implemented in the wind power prediction system *Previento*.

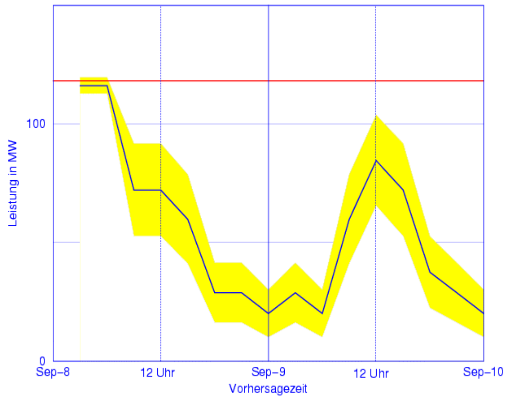


Figure 8: Example of an 48 hour forecast for a subregion. The grey area shows the expected uncertainty of the forecast.

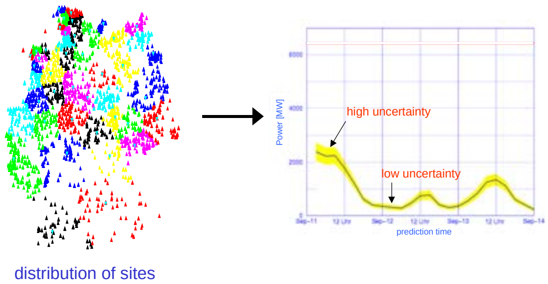


Figure 9: The uncertainty of a specific prediction time of a regional forecast is calculated under consideration of the distribution of turbines in the region.

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