ONLINE-SUPERVISION AND PREDICTION OF 3.000 MW WIND POWER

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1. INTRODUCTION

The development of wind power has been a success story in Europe. A great level of installed capacity has already been achieved, and major growth is still predicted.

When considering an installed capacity of over 12,000 MW in Europe [1], the EWEA target of 40,000 MW by 2010 seems easily attainable[2]. Wind-generated power now constitutes a noticeable percentage of the total electrical power consumed, and also exceeds the base load on the network in some utility areas. This indicates that wind is becoming a major factor in electricity supply, and in balancing consumer demand with power production.

A major barrier to the integration of wind power into the grid exists in its variability. Because of its dependence on the weather, the output cannot be guaranteed at any particular time. This makes planning the overall balance of the grid difficult, and biases utilities against the use of wind power.

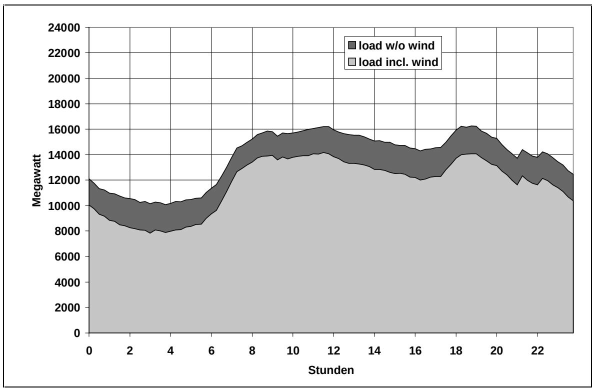

Figure 1: Typically load profile of E.ON Netz GmbH

Accurate monitoring and forecasting of power inputs from all wind turbine generator systems (WTGS) into the grid will improve the perception of wind power and considerably increase its market value. The improved integration of wind generation into the electrical power system will lead to new assessment and a higher capacity level.

Therefore, a procedure is required, which determines the actual and expected wind power in a precise and detailed manner, and conveys this information to the power system management as well as to the wind farm operators.

The development and verification of this procedure depends on three steps:

- the exact statistical analysis of observed power inputs from WTGS in the supply areas concerned
- the online monitoring of wind power inputs
- the precise determination of the expected wind power

2. PREVIOUS INVESTIGATIONS

In order to investigate the wind power input within wide-ranging supply areas more closely, ISET was commissioned by a large utility company to provide the evaluation and statistical analysis of a representative wind generation curve for the total supply area. The analysis is based on measurement data from the “250 MW Wind“ programme. The calculated curves were examined with respect to the power duration, the power gradients and the frequencies of variations of different time intervals. The results of these investigations provided valuable information concerning the time characteristics of the contemporaneous wind power input in large supply areas.

3. ONLINE ACQUISITION AND PROJECTION

Apart from meteorological data, important parameters for the generation schedules of large utility companies are, for example, the relevant expected load, the availability of the power station, the balance of electricity exchange with other utility companies, and also the consideration of necessary power reserves.

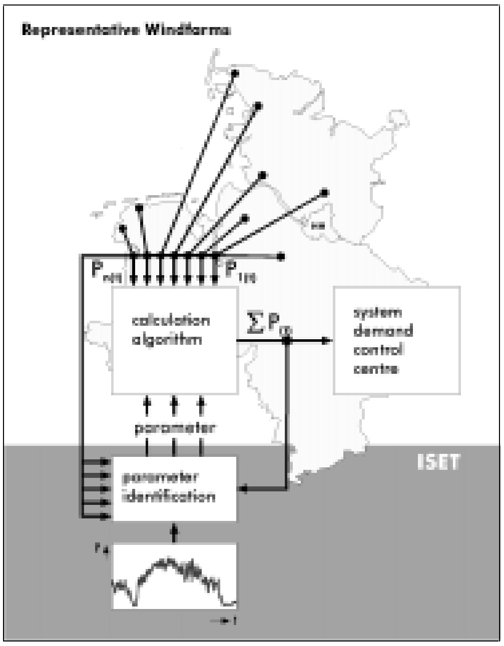

Figure 2: Online Acquisition and Projection

The most precise procedure for obtaining basis data for load prediction can be considered to be the online acquisition of the power contribution of all WTGS operated in a supply area. However, the equipping of all WTGs with measurement systems is hardly realistic.

Online monitoring requires an evaluation model which allows the observed time power output of representative wind farms to be transmitted to the total feed-in from WTGs of a larger supply area. In co-operation with one of the major European power transmission utilities, the PreussenElektra Netz GmbH (PEN), ISET has successfully developed an online monitoring system, which is able to provide the current wind power generation of about 3.0 GW from all plants distributed over the utility supply area (see Figure 1).

This model transforms the observed power output from representative wind farms into the total wind power input into the grid. The determination of the wind farms, and the development of the transformation algorithm, are based on the long-term experience of the "250 MW Wind" programme and its extensive stock of measurement data and evaluations [3].

The actual wind power input is determined by extensive equation systems and parameters, which consider various conditions, such as the spatial distribution of WTGs or environmental influences. The observed data from the selected wind farms is thereby transmitted online to the control centre.

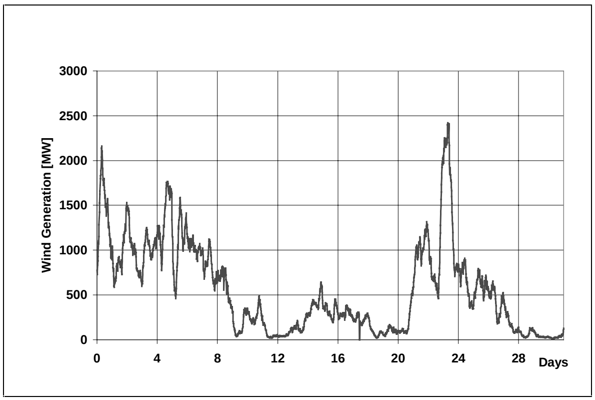

Figure 3: Power Output of 3000 MW Wind Capacity

The wind generation curves evaluated online (see Figure 3) are retrospectively compared with curves computed by the "Spatial Extrapolation based Power Calculation Model", **SEPCaMo**, and are continually conformed and improved by means of parameter optimising.

SEPCaMo generates data concerning simultaneously fed-in wind power from all WTGS in arbitrarily defined supply areas, through the evaluation of observed power and wind signals provided by the data acquisition network of the WMEP. To achieve this, measured wind and power data at selected locations, is transferred to all WTGs operating in the close proximity (see Figure 4).

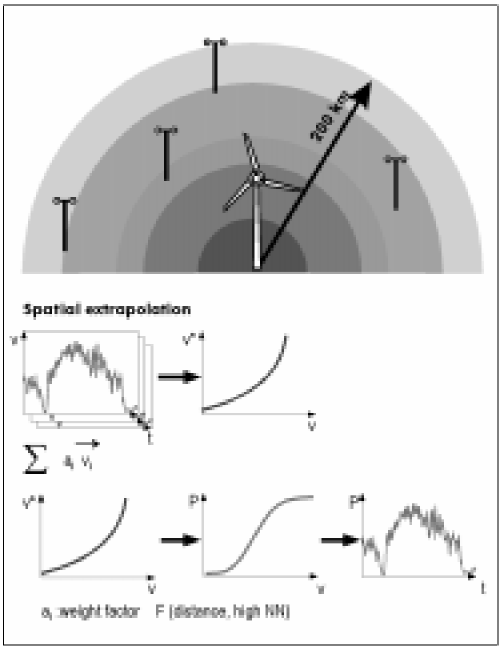

Figure 4: Extrapolation of Power and Wind Data

This regular testing and conforming of parameters obtains a high level of precision for the described procedure. Figure. 4 depicts a part of the total power output of 4,800 WTs with a nominal power of 3,080 MW in January 2001, computed by the online monitoring model in comparison to the power output computed by SEPCaMo. The difference (RMSE) between both curves amounts to 4.5 % of the nominal power.

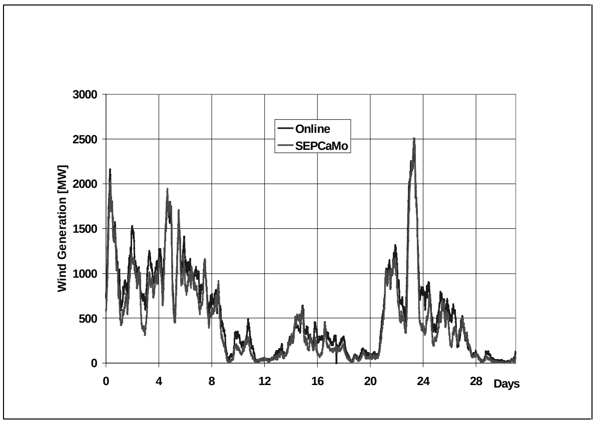

Figure 5: Model Outputs

4. SHORT-TERM PREDICTION

Network operators of major energy supply utilities and electricity transmission companies currently make use of NWP and Artificial Neural Networks (ANN) to predict the general level of electricity demand. Furthermore, the capability of ANNs, for the prediction of the power output of WTGS, was examined by several institutes [4],[5]. ANNs operate by emulating the way a human brain functions. Their advantages over standard computing are that they can both 'learn' from experience, and 'guess' or interpolate results, even when their inputs are contradictory or incomplete.

In co-operation with the E.ON Netz, Lahmeyer International and the Fördergemeinschaft Windenergie, ISET develops a wind power prediction model. This model is effectively based on a hybrid of three proven approaches:

- the accurate numerical weather prediction provided by the "Deutscher Wetterdienst (DWD)"
- the determination of the accessory WTG power output, using ANNs
- the transformation of the predicted power to the total power input into the utilities' grid by the online-model.

The inputs to the ANN include the observed power from WTGS and the predicted wind speed and direction from the DWD. The model is trained, using past wind and power data, to recognise the relationships between variations in the wind and the power output of the WTs.

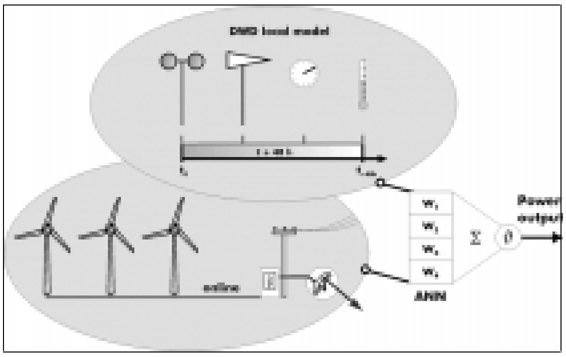

Figure 6: ANN Inputs

These trained networks compute the predicted wind power output of the representative wind farms which is used for input of the online model. Therefore the online model allows a prediction of the total wind power feed-in of large utility supply areas, based on only a few locations with predicted wind speed.

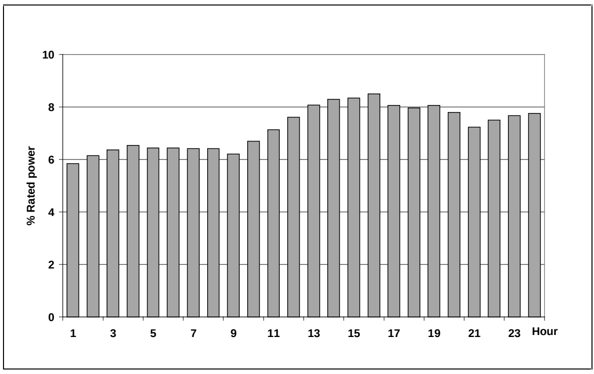

Figure 7: Short-term Prediction

Figure 7 depicts the deviation (RMSE) of the (daily) forecasts for the next day up to 24 hours of the total wind power of E.ON Netz from September 2000 to February 2001 to the observed data. The forecasts are computed at 8:00 and the resolution is 1 hour mean values. The total error between predicted and observed power is about 10 % of the installed capacity.

As the presented model for the online monitoring and prediction of large wind capacity can be adapted to various terrain as well to offshore wind farms and different supply system structures, it is of special importance for European power generating utilities with rising wind capacity.

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