

OPERATIONAL FOLLOW-UP OF WIND TURBINES ANALYSING 10-MINUTES PRODUCTION DATA

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Abstract

A methodology is presented that allows the comparison of the performance of a single wind turbine relative to the neighbouring wind turbines within the same wind farm. Additionally, the investigation of the relative temporal development of each wind turbine performance within the wind farm is possible.

The method is based on 10-minutes production and nacelle anemometer data as provided by the SCADA system of the wind farm. The advantage is that these input data are always available to the operator. The introduced methodology includes a cross-plausibility check of the operational data, a detailed analysis and filtering of the operational data in order to identify and filter out possible abnormal operational modes.

Within this investigation, it will be explained and shown how the under-performance of a single wind turbine within a wind farm can be detected prior to taking the decision of implementing a power curve measurement. Limitations and advantages of this procedure will be discussed in detail.

1. Motivation

Once a wind farm is in operation, it is expected that it produces the energy as prognosticated within the energy yield assessment, considering systematic losses. Such a prognosis is based on the assumption that all wind turbines within the farm are operated with optimal performance. This can be verified by an operational follow-up of the wind turbines, which allows to examine the relative temporal development of each wind turbine performance within the wind farm and allows the comparison of the performance of a single wind turbine relative to the neighbouring wind turbines. After having performed the data evaluation, well-directed measures for an optimisation of the wind turbines can be performed.

Subsequently, a post energy yield assessment can be done, which is based on operational data. As a result, lower uncertainties compared to the first energy yield assessment may lead to better conditions for a re-financing of the wind farm.

This paper concentrates on the relative comparison of the wind turbines and its optimisation.

2. Approach

For performing an operational data analysis of the complete wind farm, it is necessary to perform a detailed investigation of each individual wind turbine behaviour. We want to know in detail whether the

- energy output of the wind turbines in the farm is comparable,
- development of wind farm performance is ok,
- WT-problems exist,
- technical wind farm optimisation was successful.

For this we need information about the normal operation behaviour of each WT. This means that losses due to WT maintenance & availability, special operating conditions, grid availability, wake & topographic effects must not be considered.

For determining the normal operation behaviour we need at least 10 min production data, 10 min wind speed data (nacelle anemometer), temperature data, and a reference power curve, which will normally be the guaranteed one.

Further information like 10 min wind direction data (if sectoral analysis is required), availability and status codes of the WT's and the air pressure would allow a more detailed investigation of the farm operation.

All these information are available to all wind farm operators utilising SCADA systems.

3. Application of Method (Case Study)

Using the above mentioned data, power curves for each WT are created. This is done by first performing an air-density correction of each data point, then the power data are scattered over the wind data (see example in Figure 1). This scatter includes erroneous data and has a quite large scatter. Applying a reasonable filtering with respect to outliers and zero-values leads to power curves that with small standard deviation and that are of acceptable quality with respect to the planned purpose (Figure 2). Eventually the data are bin-averaged to gain a defined power curve.

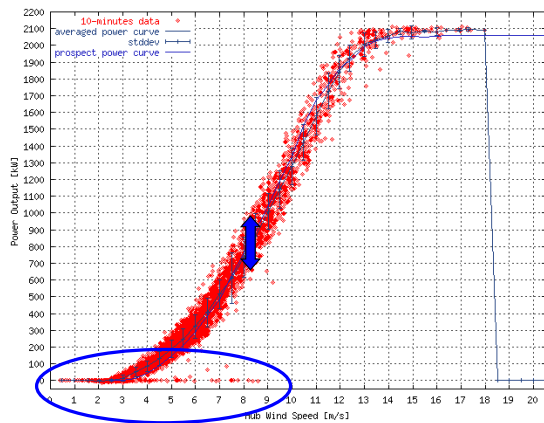


Figure 1: Scatter of power versus wind speed without any filtering. Furthermore, the averaged power curve, the prospect power curve and the standard deviation of the scatter points are shown.

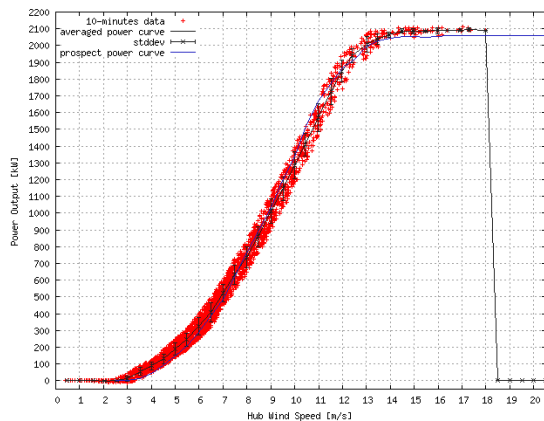


Figure 2: Scatter of power versus wind speed after filtering.

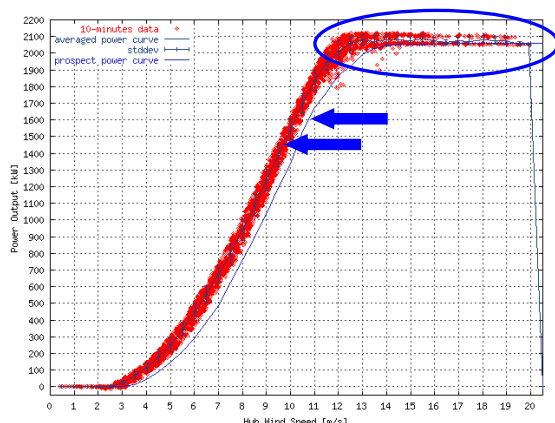


Figure 3: Example of possible effects.

Figure 3 shows as an example two effects that can occur during data evaluation:

- 1.) The scatter points are shifted to lower wind speeds compared to the prospect power curve. This effect is very likely caused by using the nacelle anemometer, which "sees" less wind behind the rotor, or is caused by calibration or mounting influences. This means that this shift is not real, and clearly shows that the presented method is not usable for the determination of absolute energy yields of the individual wind turbines or the wind farm. Instead, it can reasonably be used for a relative comparison of the wind turbines within the wind farm.
- 2.) The regarded wind turbine has during the investigated period two different rated power values. I.e. for a period of time the wind turbine was not running at its optimum and was not working correct.

For a comparison of the wind turbines and of an investigation of the temporal development it is necessary to remove the wrong data caused by the error described under 2.).

Nevertheless, in connection with the status code analysis it is also useful for problem detection and solving. In this case, after looking into the table of possible status codes and evaluation of the WT-status, it was identified that the power reduction was due to transformer overheating.

When the power curves are created for every month, the temporal development of the power output & possible seasonal effects can be investigated.

By connecting these power curves with the average wind conditions at site, the energy yield for normal operation can be determined. Be aware that this energy yield is not true in absolute terms, but that it can be used in a relative way to compare individual wind turbines and investigate the development of the wind farm performance.

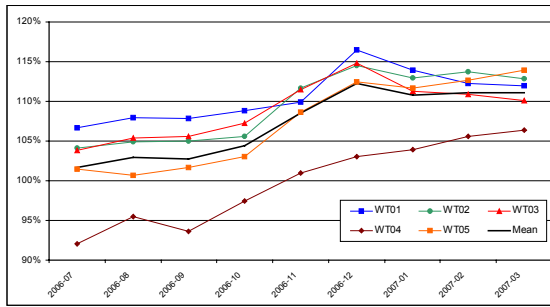


Figure 4: Energy output of the wind turbines relative to the reference (prospect) power curve.

4. Results

As a result, Figure 4 shows the development of the relative energy output of each wind turbine, taking the power output of the prospect power curve as reference (=100%).

Mainly two conclusions can be drawn from this example diagram:

- 1.) All energy outputs have an upward trend and an overall energy increase with time. This means that the wind farm has been optimised over the regarded months of operation, gaining an increase of energy of about 10%.
- 2.) The variation between the power output of the individual WT's has been significantly reduced, indicating that all WT's have a nearly identical "normal" operation behaviour.

Only WT04 differs from the other wind turbines, and has not the power output it should have for a reason that could not be clarified.

At this point the question arises whether what we see here is clearly a matter of energy output. The answer to this question is "no". Possibly we see an effect of the nacelle wind speed. Therefore Figure 5 shows a comparison between the nacelle wind speeds by presenting the monthly wind speed ratios compared to the average value. It can be seen clearly that in the beginning a part of the under-performance of WT04 was due to deviations between the measured nacelle wind speeds. This was solved in December 2006, from this date on the wind speeds measured are within a reasonable common variation width.

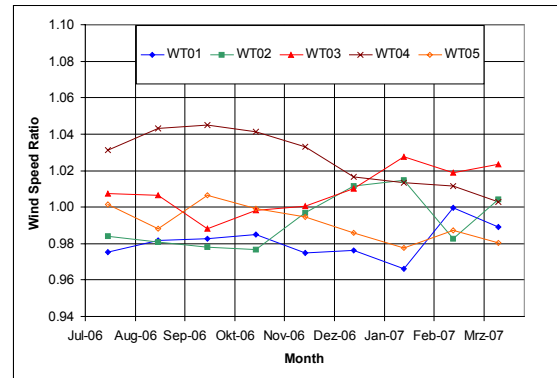


Figure 5: Variation of nacelle anemometer wind speeds.

5. Conclusion and Outlook

Advantages of the presented method are:

- All input data are normally available
- It gives a quick overview over wind farm performance
- It was successfully applied for relative energy comparison
- The development of relative performance is well recognisable
- The status code analysis allows error detection and problem solving

Limitations of the presented method are:

- Simple Approach, not compliant with IEC-norms
- No absolute energy determination possible
- No replacement for power curve measurements
- Recognised effects can be due to nacelle anemometer
- Uncertainty of method is strongly depending on quality and consistency of wind measurement
- SCADA-channels are limited, therefore not all settings can be checked and not all problems can be identified

Further possibilities of the presented method are the integration of other parameters as e.g. the active power/rotational speed ratio, which could deliver information about WT-control changes, or directional investigations.

Possible improvements of this method can be gained e.g. by a uniform mounting of calibrated instruments, which would improve the accuracy of the results.

The integration of more WT-settings in the SCADA system would allow further error detection and problem solving.