FLUCTUATIONS IN ANNUAL WIND ENERGY POTENTIAL

A METHOD FOR RISK ANALYSIS AND LONG TERM CORRELATION

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Abstract

Energy yields of wind energy converters are subject to the natural temporal variations of wind and wind energy potential. They can fluctuate in the range of several 10 % from year to year in central Europe, for instance. Therefore wind energy projects are affected by uncertainties not only in determining the long term production but also by annual and short period fluctuations. For the same reason, long term correlation of production data coming from existing wind farms is connected with high uncertainties when using classical and simplified approaches.

The report shows risk analysis methods estimating the uncertainties and introduces a new method for long term correlation of production data and to determine the uncertainties and the transgression probability of wind energy potential for wind energy projects for different periods.

1 Introduction

The presented proceeding for the determination of long-term purchases and for risk analysis of a wind farm project with regard to yield fluctuation due to the irregular wind offer is attractive for existing wind farms as well as for projects in planning.

Normally the described procedure for existing wind farms is divided into two parts: performance, meaning the examination of the past operational behaviour of the wind farm and the long-term correlation, thus the determination of the expected operational behaviour for longer periods. For new planned wind farms there will be also done an analysis according to the expected volatility for annual and several years yields.

The performance analysis takes a look at the operational behaviour of several WEC´ s – typically in a wind farm – with regard to possible disturbances and irregulations. First information is normally the time-dependant technical availabilities of the WEC as well as information about the wind offer in this period. The result is a confrontation of the actual and the theoretically possible operational behaviour.

The following long-term correlation means the determination of an idealized energy yield during a long period. It is assumed that the WEC will not have any irregularities or disturbances during the whole period so that it can be operated according to the results of the performance analysis.

2 Execution of performance analysis

For the performance analysis typically information of the monthly WEC yield and availability is available. As information for the wind offer the produced wind index due to 3.5 is used.

The analysis is done in a two-stage method:

1. Identification of implausible month yields.
2. Reconstruction of possible yield.

2.1 Identification of implausible month yields

This partial step of the analysis bases on availabilities; on the comparison with yields of other WEC´ s; as well as on the comparison with the wind index.

2.1.1 Analysis of availabilities

For the analysis of availabilities a threshold value (e.g. 90 %) is used. If the monthly availability is lower than this value; this month is characterized as implausible.

2.1.2 Analysis of neighbouring WEC´ s

The analysis about the comparison of the WEC´ s is done throughout a linear regression on the basis of the least square error. The resulting residuals, where the pretended confidence period (e.g. 95%) is totally below the found regression line, according to the comparison of the WEC these months will be characterized as implausible.

The following procedure depends on the size of the wind farm:

For wind farms with at least three WEC´ s the month value for a WEC is characterized as implausible, if the above described comparison is implausible for at least two WEC´ s.

For wind farms with two WEC´ s the month value is implausible if the comparison with one other WEC was implausible.

In the case of a single WEC this analysis is indeed not possible.

2.1.3 Analysis with the wind index

This analysis is the same like the proceeding described in 2.1.2 for two WEC´ s within a wind farm. Due to the normally worse correlation of the index with the yields the confidence periods used here are higher. (e.g. 60 %).

2.2 Determination of the possibly month yield

For month yields which have been characterized as implausible due to the above described method, the reconstruction of the possible yield is as follows:

With first priority the yield will be determined throughout a regression with the neighbour WEC for which the month yield was plausible. In the determination of the therefore necessary regression parameter there are only used those months which are not found in 2.1.2. Thus there will be a second regression with only plausible months. For the expected month yield there will be used the average value of all yields determined in such a way.

If this method is not possible due to the yields are implausible in this month (e. g. grid problems in the whole farm) for the reconstruction there will be used the wind index – the method itself stays the same.

For plausible months the expected yield will be calculated due to the quotient of the actual yield and availability.

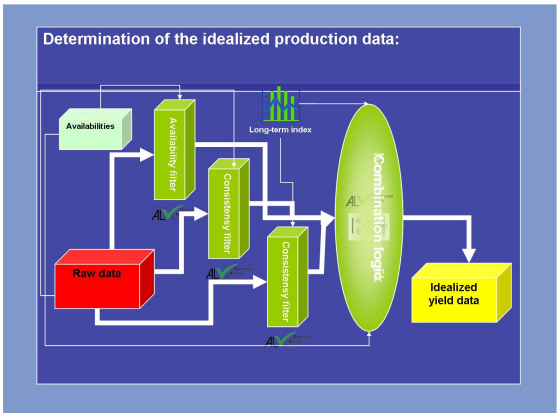

Figure: Data processing, filtering and reconstruction of turbine production data

3 Determination of long-term purchases

3.1 Name origin and introduction

The determination of a long-term correlation means the following: the determination of an expected long-term yield based on actual information of yields and availabilities of existing WEC´ s or wind farms. A present method therefore is the use of so-called wind indices. A wind index is a raw - typically a percentage value – which shall quantify the wind offer for a certain period. There are existing periods of one month but also other periods (3 month indices, one year indices). As the wind offer depends strongly on the region, each wind indices is also connected to one certain region and can therefore only be used for that region.

Most important for the index is the physical size. According to the average wind velocity, the energy content of the wind (both in different heights to the ground) as well as to the energy yield of a WEC you can calculate an index. It is trivial that indices based on different reference sizes cannot be used for another physical size without sophisticated analyze of the connection between them.

Due to the index information and the yield information for a typically very short time period, one can produce in different ways, a long-term purchase.

3.2 Reference time of a wind index

Due to the index it is often asked about the reference time period. At first, we have to notice that for wind energy purposes this is not the real question. Instead the wind offer during the coming financial time period or at least the production age of a WEC is the most interesting– thus the next 10 to 20 years. Compared to the long-term reference time there are at least the following two differences:

1. Based on the available meteorological data one can derive surely that in the past the wind offer was also irregular during such periods of 10 to 20 years.
2. Due to many observations and analysis one can say that a climate changing has already started. Supposing that for the wind energy the wind offer will also be involved, it is the question in which way and how much it will change in the mentioned periods.

According to the last question AL-PRO has the opinion that it is nowadays not possible to make a serious quantifying statement regarding the global climate changing. One has to take into account that there is a rest risk which has to be included in the risk analysis.

Due to available data of different time periods it is possible to analyze the statistical risk and to calculate the transgression probabilities.

At this point it is again the question about an available reference time area. Therefore we have firstly to point out that there is not the only and best quite right reference time area due to the already named reasons. Furthermore in different climate zones there are different time periods which are good for use. In regions with huge irregularities in wind offer you have to take longer time periods than in regions with constant climatic conditions.

To choose the largest available time period, which at a first view might be considerable, is not in general the best way to do. Firstly it is more complicated to get the data for producing a long-term purchase due to the necessary consistence of the data. The other reason is that it is not desirable to use data from the very past because of the already started climate changing.

In discussions on that topic in tthe recent past experts often came to the result that a time period of the last 30 years would be the best for North and Middle Europe. After several analyses with the available data AL-PRO came to the same opinion. Possibly the time periods might differ a little due to the different regions. On the one hand the difference is very small; on the other hand it is the advantage of a general one. With regard that the last point is the most important one they chose the time period from 1975 to 2004 for the following analysis.

3.3 Computation of a possible wind index

Due to the previous explanations it results that for further considerations a unique index data base is necessary, at least the years 1975 until 2004. In addition the production time period of the wind farm which is to be analyzed must be available. Furthermore a longer period with regard to the volatility considerations is desirable.

In the following the production of this index is represented in the case that a yield index with a short time period already exists, e.g. the German BDB index was chosen.

In that case that in the region there is no index existing, the WWA index produced according to 3.5 is used without

modification. The represented method can therefore be used worldwide.

3.4 The BDB wind index

The so-called German BDB index [1] of the company ENVECO is often the basis for the determination of the long-term energy yields of WEC´ s in Germany. The basis for the determination of the BDB index is the production data of many WEC´ s. Those are collected monthly, reproduced and changed before given free – monthly - for the 25 regions. There exist several publications due to methods, proceedings and quality of the index.

According to regionally connected index rows one found out constantly good up to very good correlations with coefficients of correlation clearly over 0,9.

A main aspect according to the index is the question about the reference time. Hereby we are talking about the period from 1989 to 2002 – thus 14 years define the 100% level of the index. Meanwhile, experts often say that this period is not a good choice as a long term reference – probably the level might be too high. In that case the danger would be that during the determination of a long-term purchase with the index the yields and expectations would also be too high.

3.5 Determination of a World Wind Atlas (WWA) index, long-term analyze of the BDB index

The World Wind Atlas is released by the company Sander & Partner for the past years until 1950 [1]. The WWA indicates the wind direction and velocity in a worldwide grid network with a mesh size of 2,5° and for the heights of 50m and 500m above ground. There are four records available per day (0, 6, 12, 18 o´ clock UTC). The data is derived from the NCAR/NCEP reanalysis database [2].

To be able to compare these values with WEC yields and yield indices it was done the following:

At first it will be determined for each grid point of 5°East, 47 North to 15 East, 55°North the monthly Weibull-distribution of the wind values in a height of 50m above ground since 1950. Afterwards based on the determined distribution it was determined the expected monthly energy yield for the most common types of WEC´ s.

The values are changed and converted in a yield index, which is regarding the reference size comparable with the yield data of WEC´ s or existing production indices (e.g. the BDB index in Germany). The difference between a yield and a pure energy index is that in this case the high energy values are observed with regard to the behaviour of a WEC while reaching the rated power. These in such a way received indices are called in the following WWA index.

The WWA index was compared with the BDB index and also examined for fundamental plausibility. According to regionally connected index series one found out constantly good to very good correlations with coefficients of correlation clearly over 0,9.

Afterwards the connection of the WWA index and the BDB index of each region was examined due to linear multiple regression as well as with the use of neural net. For both methods are used 75% of the available data (time period from 1989 to 2004) in order to find the parameters for the regression as well as for training of the net. The rest - thus 25% - was used for proof and validation. For data series of the WWA index they used the best correlated data series with regionally purchase – the lowest limit for correlation was at a coefficient of 0,9, in single cases this was proofed and additionally sometimes a little modified.

In the following all possible topologies of a neural Elman net with 3 layer up to a size of 10x10x1 neurons are tested and trained with 1.000 training series. The best net was then confronted with the multiple linear regression. In nearly every cases with only one exception (region 13 of the BDB index) the neural net did better results. As basis for the following observations therefore it is only used the neural net.

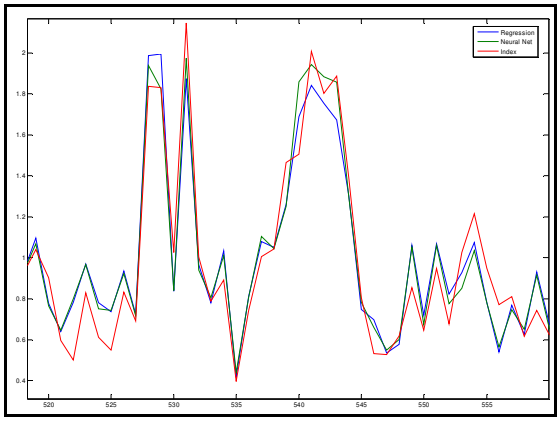

Figure: The BDB index and the multiple regression as well as a neural net map

With the found net a map of the WWA index to the BDB index can be realized. This was done for the period 1950 to 2004. On basis of the period 1975 to 2004 it is determined the period from 1989 to 2002. In nearly all regions the result was that this period was above the period of 1975 to 2004. In general you can say that the difference gets less if you go from the North-East to the South-West. The BDB regions in the North and especially in the East for the period of 1989 to 2002 are 5% above the period from 1975 to 2004. In the South and South-West the differences are less or there are even no differences.

For the following analysis the BDB index was modified as follows:

- For the period in which no wind index data exist , this new index determined by neural net can be used. In the case that there is no yield index available, the WWA index will be used directly.
- For the period in which BDB index data exist, the wind index will be transformed according to the found relationship of the two reference time areas.

These two partial indices will be joined together and it results a continuing index from 1950 until today.

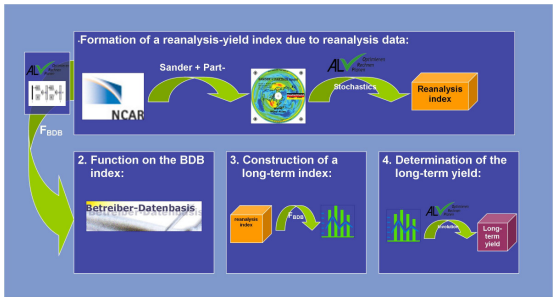

Figure: Graphical representation of the building of a long term index

3.6 Determination of the expected energy yield for the reference time area

For the determination of the expected energy yield according to the reference time area, in principle it is the same like the determination of the connection between the BDB index and the World Wind Atlas. It is a map regulation of the found wind index - see last paragraph - to the WEC yields of the wind farm.

In contrast to the described proceeding in the paragraph before no neural nets are usually used here. Therefore the map on basis of a linear regression between index and yield of each WEC is realized. Only those values are used which are not filtered in the described proceeding in 2.1.3 .

The reason for this proceeding is the typically available period of time – thus at best some years, which can be regarded for the determination of the map relationship. For the training of a neural net this data base is often not sufficient.

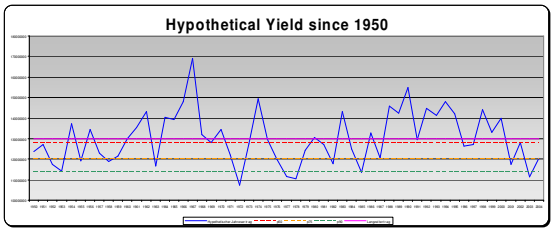

Figure: Back Projection of hypothetical yield

With the found map relationship there will be produced hypothetical yields for the time period through a back projection.

3.7 Volatility of the wind offer; transgression probabilities

For the determination of the values P_{75} und P_{95} an analysis of the wind offer volatility was made for the entire period due to the World Wind Atlas, thus from 1950 to 2004. Due to the long period it results a large data base. The volatility for the desired time period (typically 1, 2, 5, 10 und 15 years) can be produced through a back projection and a flowing average.

According to the distribution of annual yields in North Europe one cannot proceed from a normal distribution. Nevertheless the acceptance of a normal distribution for the combination of probabilities seems to be permissible as the deviations are not very large. Typically the found distributions are not symmetrical so that the value P50 for a operational year is not as high as the predictand – it is located below. Interpreted this means that the probability of wind years below average is higher than the probability of the rare high above wind years, but these are therefore clearly above the predictand.

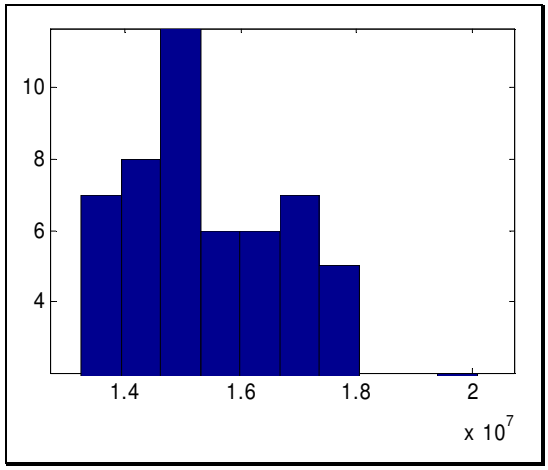

Figure: Quantity of years against the annual yield

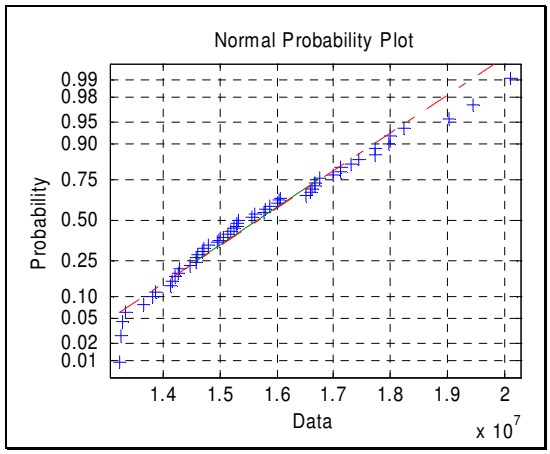

Figure: Distribution of annual yield compared to normal probability

For the determination of the process-determined uncertainties please take a look on the following four as linear independently accepted uncertainty components:

- Reference time areas.
- Map involution assignment.
- Map WWA index – wind index
- Yield correction

In case of determined yields due to a complete wind report the determination of uncertainties will be done regarding the actual guidelines and regulations.

The results and values for transgression probabilities for the yields of different production periods are calculated due to the volatility of the wind offer – combined with the uncertainties. They represent the risk of the project with regard to the expected wind offer in a very detailed way.

References

[1] World Wind Atlas (WWA): digital wind atlas, Sander+Partner GmbH/Switzerland; www.sander-partner.ch

[2] National Center for Atmospheric Research (NCAR), Boulder, Colorado, USA; www.ncep.ucar.edu/ncar. National Centers for Environmental Prediction

(NCEP), Camp Springs, Maryland, USA; www.ncep.noaa.gov

[3] H. Häuser, J. Keiler, Windindex aus Betreiber-Datenbasis, Ingenieur-Werkstatt für Energietechnik, Dorfstr. 14, D-24594 Rade