WIND DATA EVALUATION AND TREATMENT OF MEASURED DATA

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ABSTRACT

This presentation focuses on how to evaluate wind data from a proposed site, treatment of the acquired wind data and avoiding various traps based on practical experience. The prime target of the presentation is to offer user-friendly tools and advices for this purpose and to try preventing serious calculation errors caused by uncritical use of the measured data.

INTRODUCTION

An essential ingredient in any Wind Energy Calculation is Wind Data from or near the proposed Wind Farm. The high number of loggers now erected all over Turkey is the basis for the further development of the Wind Energy Sector in Turkey. During the past 2 years EMD has performed a very large number of project studies as independent consultants. In connection with these projects (many of which are performed in Turkey) we have analysed and utilised wind data from many types of loggers in Turkey, Great Britain, Germany, Sweden, Spain, Greece, France, Latvia, Poland, Norway and the USA. In this lecture I will present our experiences with the evaluation of wind measurement with emphasis on the following subjects:

1 BASIC SCREENING OF THE RAW WIND DATA

The first step in any of the below described evaluations is making a basic screening of the measured wind data. This basic screening of the data from the logger should take place every time the chip in the logger is changed or at least once a month in order to avoid extended periods of useless data caused by errors or malfunctions of the logger that easily could be corrected.

It is not a must to be a "spreadsheet wizard" in order to treat measured wind data. A user-friendly and cheap software tool makes it possible to make preliminary screening of the wind data. The tools can also be used for a current quality control of the measured data in order to correct malfunctions or wrong calibration of the logger. This can prevent extended periods of useless or faulty data, which can be devastating for a project.

The software program WindPRO can perform a detailed scanning of the logged data. The data does normally not have to be treated first, but can be loaded directly into the program. The following printouts are presently available:

- Figure showing data period and missing data.
- Figure showing time series data illustrated as:

  A: Radar-curve showing direction and speed for each measure point.
  B: Table showing monthly mean values of wind speed in m/s.
  C: Diurnal plot, where direction and wind speed are averaged according to the time of day.
  D: Seasonal graph, where average wind speed and direction are shown as a function of the month.
  E: Time series showing wind speed, direction and turbulence intensity as function of time.

- Tab-file indicating number of observations divided into sector and wind speed bins.
- Figure showing the tab-file data and the Weibull-fitted data illustrated as:

  A: Graph showing the tab-file data together with the Weibull-fitted data for all sectors.
  B: Radar graph showing wind speed and direction frequency.
  C: Figure showing turbulence intensity as a function of wind speed.
  D: Radar graph showing turbulence as a function of direction.

- Graph showing the tab-file data together with the Weibull-fitted data for each of the e.g. 12 sectors.
- Figure showing total Weibull-fitted data as a table and as graphs for each sector. The sectors are given different colors on the graph for easier identification.

But one thing is the possible printouts of the logged data. A much more important matter is the interactive control and treatment of the logged data. (If time permits) I'll give you a brief introduction to these multiple options in WindPRO.

When you are screening the data it is important to look for the following things which are typically seen when the data is of bad quality or when the site is so extreme that it is not possible to calculate using WAsP (or any other wind calculation model for that matter):

- Extreme wind speed values
- Same wind speed for extended periods of time
- Same wind direction on several subsequent measurements
- High turbulence intensity at high wind speeds
- Sectors with extreme wind gradient exponents, which means sectors with extremely radical changes in wind speed between two measurement heights
- No Weibull-fit for one or more sectors, which means the it is not possible to change the measured data into a smooth Weibull-curve

For those with a particular interest in this subject, I'll be happy to demonstrate the data scanning possibilities in WindPRO in more detail on my laptop. Just ask me for a meeting.

2 WIND DATA EVALUATION WITH ONLY ONE MET. MAST AVAILABLE

On a site where only measured wind data from one met. mast is available the evaluation procedure is the following:

A.   Screening of the wind data as described above
B.   Roughness classification. The roughness must be evaluated in a radius of at least 20 km wide around the borders of the area. The roughness of the terrain must be classified based on the amount of forests, lakes, cities, wind breaks, scattered houses, scattered trees etc. in this zone. This must be done in a digital format, which can be read by WAsP. The easiest way of doing that is using the software WindPRO.
C.   Treatment of height contours. Information is required concerning elevations in the landscape within the area to be investigated in a radius of at least 5 km from the met. mast. This is achieved with the use of digital height contour lines. There should be digital height contour lines for every 10m elevation. The easiest way of doing that is using the software WindPRO.
D.   Treatment of local obstacles. Within a 1,000m radius of the measurement equipment, influence of local obstacles must be taken into account. The easiest way of doing that is using the software WindPRO.
E.   Creation of a regional Wind Atlas also called local Wind Statistics.

All the above is just the preliminary work that takes place before the evaluation of the calculated wind statistics.

The calculated wind statistics can be controlled the following ways:

- Follow the above steps B, C and D for a site with existing WTG's with known production data (and preferably also availability data plus a wind energy index for the region). Existing WTG's are often referred to as control WTG's. A control WTG is a wind turbine located usually within 5 km's where the used Wind Statistics, roughness classification and height contours are used to calculate a predicted production. This production is then compared with the actual production of the WTG.
- The energy level of the calculated wind statistics can be compared with other wind statistics within 200 Km's from the site center. When wind statistics (*.lib files) are entered into or calculated with WindPRO an index figure for each files is calculated. The Index numbers are for **flat terrain, roughness class 1 and height above ground 40m**.

Index numbers for flat terrain Roughness Class 1, 40m above ground level	Relative level to 3,000 kWh/m2/år	Energy (kWh/m2/år) content in the wind
Demo site 10m Met. mast	149 %	4,470
Demo Harbour 30m Met. mast Long-term Data	144 %	4,320
Demo Hill 10m Met. mast	144 %	4,320

For Turkey the closest country to use in comparisons is Greece where a high number of wind statistics were calculated all over Greece and the Greek islands when Risoe made the European Wind Atlas. As I'm sure you are aware some of the Greek islands are quite close to the Turkish mainland and therefore useful for comparing the energy level of the wind statistics.

The comparisons can naturally also take place where wind statistics for more measurement masts are calculated or for more measurement heights.

When wind statistics from other projects in the region can be obtained, they are of course also good for comparisons.

3 WIND DATA EVALUATION WITH TWO OR MORE MET. MASTS AVAILABLE

The procedure is identical with the one performed with only one logger, except now it must be done several times.

There is an important control function, which can only be performed when one or more measurement masts are available:

Use the created wind statistics from one measurement mast together with the site evaluation to predict the measurement results from the other logger and vice versa.

4 WIND DATA EVALUATION WITH ONE OR MORE LOCAL MET. MAST(S) AND LONG TERM WIND DATA AVAILABLE

- A. Screening of the wind data as described above
- B. Long-term correlation of the measured wind data. The locally measured wind data is compared and analysed hour by hour with wind data from a reference Met. mast, which have measured the wind for an extended period of time (several years). If the analysis shows satisfactory consistency/correlation, the short-term data (the locally measured data) can be corrected and become representative for a longer period of time. The method is called MCP (**M**easure **C**orrelate **P**redict).

The correlation analysis and correction of the measured wind data is performed in a number of phases. The first 2 phases is the correlation analysis or evaluation of whether it is possible to use Long-term met mast as a long term reference at all and phase 3-7 is the long term correction of the Demo Weibull table to make it suitable for long-term predictions of the wind climate:

Phase 1.   Preliminary data treatment (in Excel)

Based on the raw wind data from Demo and Long-term met mast Met station respectively a dataset of matching dates and times is established, which means that all measurements with non-identical timestamps are left out. The corresponding measurements are then split up in 12 sectors each covering 30° of the 360° on the compass. Sector one covers from 345° to 15°, sector 2 covers the next 30° moving clockwise and so on. The measured wind speeds are grouped in bins each covering 1 m/s. The wind speed values are rounded so Calm is 0-0.5m/s, the group 1m/s covers 0.5-1.5m/s, group 2m/s covers 1.5-2.5m/s and so on.

This set of data is the basis for the correlation analysis.

Phase 2.   Correlation analysis

On the basis of the matching dataset the correlation analysis is performed in a number of steps, which is:

1. Graphical check of corresponding wind speeds. A graph showing the wind speed as a function of the date is calculated. The recorded date is on the X-axis and the wind speed on the Y-axis.
2. A table displaying the statistical basis for the analysis is calculated
3. A ratio of correspondence for each timestamp is calculated by dividing the wind speed at Demo with the wind speed at the Long-term met mast Met station. A pivot table is established showing the average ratio for each wind speed bin and sector:

4. The pivot table described above is made into a series of graphs (one for each of the 12 sectors) showing the ratio as a function of the wind speed:
5. Another pivot table displaying sector match is established:
   This table shows the number of measurements (with identical time stamp), where and how the wind directions for Long-term met mast Met station and Demo respectively corresponds.
6. The overall conclusion of the correlation is that the two sets of data……

Phase 3   Establishing a Weibull table with short-term met mast data.

A Weibull table containing Weibull-fitted mean wind speed (the A-parameter), k-parameter and frequency for each of the 12 sectors is established for the short-term met. mast data using the WindPRO Meteo-object as the calculator.

Phase 4   Establishing a Weibull table with long-term met mast data.

A Weibull table containing Weibull-fitted mean wind speed (the A-parameter), k-parameter and frequency for each of the 12 sectors is established for the long-term (complete) met mast period using the WindPRO as the calculator.

Phase 5   Establishing a correction table with long-term met mast data.

A correction ratio table is calculated dividing the long-term value with the short-term value for each separate sector, e.g.:
Sector 1 A-value long-term/Sector 1 A-value short-term

Phase 6 Establishing a corrected Demo Weibull table.

A Demo Weibull table containing Weibull-fitted mean wind speed (the A-parameter), k-parameter and frequency for each of the 12 sectors is established using the WindPRO Meteo-object as the calculator. Each cell in this Weibull table is then multiplied with the corresponding correction factor from the correction ratio table. The result of this is a long-term corrected Weibull table. This Weibull table is the basis for creating a corrected wind statistics**.**

Now the steps described in section 2 (step B and on) can be applied.

For those with a particular interest in this subject, I'll be happy to demonstrate the two methods in more detail on my laptop. Just ask me for a meeting.

5.GENERAL ADVICE REGARDING ACQUISITION OF USABLE WIND DATA.

A list of easy-to-use advises regarding acquisition and preliminary evaluation of wind data concludes this presentation:

		Advice's regarding acquisition and preliminary evaluation of wind data
	1	Avoid placing the logger on the highest point. The wind profile isn't typical there.
	2	Avoid placing the logger right on the edge of a steep elevation. The wind profile is very typical there
	3	Find the exact location of the met mast. Use good maps. Log the position with a good GPS. E.g. Gamin E-treks is easy to use and of very high quality
	4	Take careful notes on the location of local obstacles. Anything higher than a quarter of the height of the met mast in a radius of 1,000m should be marked on a local map. This could e.g. be big stones, trees, buildings or sheds.
Please note		With a 10m met mast this means that anything above 2.5m within 1 km of the mast will influence the measurements.
Please note		With a 30m met mast this means that anything above 7.5m within 1 km of the mast will influence the measurements.
	5	Be careful to put the zero marking on the met mast in the correct direction: Straight North
Please note		If this is not done due to technical difficulties, take careful notes on what direction North is pointing in order to turn the direction of the data when they are treated.
	6	Be sure that the anometer and the wind vane can turn freely.
	7	Screen the logged data every time the chip is changed or at least once a month. Look out for the following in particular:
	8	Extreme wind speed values
	9	Same wind speed for extended periods of time
	10	Same direction on several subsequent measurements
	11	High turbulence intensity at high wind speeds

ABOUT THE WRITER

Lars-Bo Albinus has performed complex energy calculations for big WTG projects in numerous countries e.g. Turkey, Denmark, Sweden, Norway, United Kingdom, Germany, Spain, France, Italy, Greece, The Philippines, Latvia, the USA and more. Many of the studies have included site inspections performed on foot, by car, plane, boat and helicopter. This has often included detailed wind data analysis, long-term wind data correlation (MCP) in many cases and detailed roughness evaluation and height contour treatment. He has also performed a large number of visualizations. He has played a major role in developing a new and very detailed Wind Resource Map of Denmark using the latest computer data handling technology. He is responsible for the WindPRO Windturbine Catalogue. Through his work he is always up-to-date with the latest WTG-technology. Finally he has given many tailor-made and open courses in the software program WindPRO in which he is a super-user.