WIND POTENTIAL ASSESSMENT AND MICROSITING: OVERVIEW OF THE STATE OF THE ART

Martin STRACK
Dr. Helmut KLUG

INTRODUCTION

The widely used standard methods for wind potential assessment are the European Wind Atlas Methods [1] developed by Risø National Laboratory, Roskilde, Denmark, by means of the "Wind Atlas Analysis and Application Program" (WASP). The aim of the lecture "Micrositing" is to explain the European Wind Atlas Methods and to show its application for wind potential assessment and wind farm calculation, under special consideration of its limitations and possible improvements of the reliability. Furthermore concepts and practical experience with other approaches (e.g. AIOLOS flow model) for wind potential assessment will be shown.

FUNDAMENTALS OF THE EUROPEAN WIND ATLAS PROCEDURES

For calculating the wind energy potential of a given site, long-term measurements (or long-term extrapolated measurements by means of appropriate MCP-methods) from a meteorological station have to be available (meteorological base data). Site and measurement station should be in the same area with the same wind climatic conditions (up to 100 km distance in flat, a few kilometres in complex terrain), so that wind conditions in great heights (geostrophic winds) are comparable.

The wind speed measured at a meteorological station depends on two factors: the regional weather conditions in an area within some hundred kilometres and the topography (orography, roughness, obstacles) in an area up to 10 kilometres.

The "European Wind Atlas" is a calculation procedure which corrects site specific measurement data according to the influences of the topography and extrapolates these data to a general non site specific, regional wind climate (wind atlas data, "WASP lib" data). To calculate the wind climate at another site from this general wind climate, the same procedures are used in opposite way, taking into account the site specific topography (Figure 1). The model is based on the physical principals of flows in atmospheric boundary layers and it takes into account following effects: the reduction of wind speed caused by vegetation and other surface roughness, shadow effects of buildings and other obstacles and changes in wind speed as well as wind direction caused by orographic effects (mountains, valleys). Due to some simplifications these models have known limitations, which lead to uncertainties especially in situations with steep orography (increased uncertainty of spatial wind variation and vertical wind profiles) and in situations with strong effects of near obstacles (e.g. for a low measurement height).

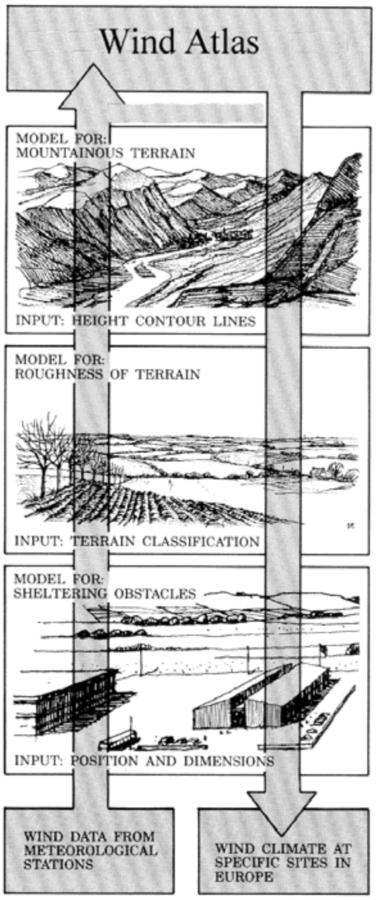


Figure 1: Sketch of the priciple of the Wind Atlas Procedure (taken from [1])

For application of this model the surrounding of the site under consideration (and of the meteorological base) is described in assigning roughness lengths to the surface characteristics; the positions and heights of obstacles are determined and an orographic map of the surrounding is made. Changes of roughness lengths and orography should be taken into account within a distance of approximately 10 km.

Based on this site description the average wind speed and wind statistics at the site can be calculated from the regional wind climate. In detail, for a specific height the frequency distribution of the wind speed (Weibull distribution) is calculated for each of 12 wind direction sectors. With this site specific distributions and the power curve of each single WT the average annual energy yield is calculated.

To do a correct selection and assessment of the input data, considerable experience with the principles and sensitiveness of the wind atlas method is required. The meteorological base has a great influence on the result and has to be selected appropriate concerning its location and measuring period.

WIND FARM CALCULATION

To calculate the energy yield of a wind farm, the annual energy yield of the single wind turbines has to be calculated as well as the energy yield losses caused by mutual shading effects (Figure 2). This calculations are performed on basis of the "Park Model" developed by Risø National Laboratory, Denmark. The used mathematical model of the wake of WTs was developed by N.O. Jensen in Risø.

Basic input data for this calculation are the frequency distributions of the wind speed at each turbine position of the planned wind farm, consisting of the A and k parameters of the Weibull distributions. These quantities are calculated according to the European Wind Atlas methods (see above).

The model of a wake behind a wind turbine uses impulse and mass conservation to determine the wind speed behind the rotor. A linear expansion of wake is assumed. The wind speed deficit inside the wake is calculated using the thrust coefficient curve c_t, whereas the opening angle depends on the turbulence intensity and can be calculated using empirical relations.

To calculate a wind farm the installation geometry of the farm and the overlapping of the single wakes has to be taken into account. For this the Park model uses a method of linear wake-superposition.

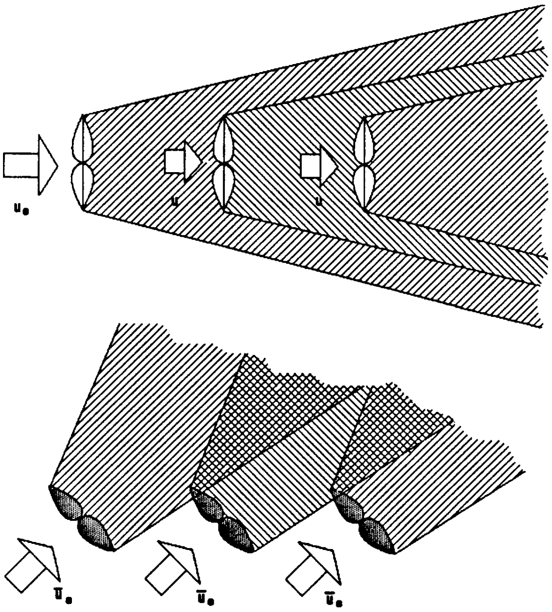


Figure 2: Priciple of mutual shading of wind turbines

Summarising the calculation procedure uses the following input data:

- WTs-characteristic, i.e. power curve P(v), thrust coefficient curve $c_t(v)$, hub height and diameter of the rotor
- coordinates of each WT of the wind farm
- meteorological data for the turbine positions (Weibull distribution)

The results of the wind farm calculation are the energy yield and the wind farm efficiency, for each wind turbine and for the whole farm. The total farm efficiency is the ratio of the total electrical energy of the farm (taking into account wake losses) to the sum of the energy of all single WTs on the assumption of an undisturbed flow.

By varying the converters' distances and the wind farm geometry a maximal wind farm efficiency respectively a maximal total energy yield can be determined. The optimal farm configuration depends on the wind speed and particularly on the wind direction distribution at the wind farm site, the wind turbine characteristics and the available wind farm area. Additional optimization parameters, particularly sound emission limits and economic terms, can be included in the optimization process.

METEOROLOGICAL INPUT DATA

The reliability of the wind potential assessment and energy yield calculation strongly depends on the quality of the meteorological input data used for the calculations. For complex terrain a wind measurement directly at the site is required for a reliable result.

The data sets recorded on the proposed wind farm area are valid only for a relatively short time period. For a long-term determination of wind speed and energy yield the long-term measurement should cover a period of at least 10 years, otherwise the results are influenced by seasonal and inter-annual wind variations.

Usually at the wind farm site measurement data for a time period of several months are available. With long-term wind data of a suitable meteorological measurement station in the same region the measured short time data can be extrapolated to long-term data using Measure-Correlate-Predict (MCP) Methods. Applying these methods the simultaneously measured time series data are compared and evaluated to test whether the wind speed and the wind direction measurements of the two stations correlate. If the correlation results are satisfying and a good relation between the two site exists, the measured data of the long-term site can be converted to the site in the wind farm.

This conversion procedure should be done with sector dependent correction factors of wind direction and wind speed as a result of the correlation procedure. Sophisticated MCP-Methods can enhance the reliability of this procedure and hence of the energy yield results significantely [2].

UNCERTAINTY OF THE RESULTS

In flat terrain the European Wind Atlas Models should work well, so the reliability depends on the quality of the meteorological input data. Since in this type of terrain wind measurements are often considered as not neccesary, one has to rely on meteorological stations e.g. existant for purpose of weather observations. To ensure the suitability of such stations, the measurement should be subject to a close investigation and a verification of the results should be performed [3].

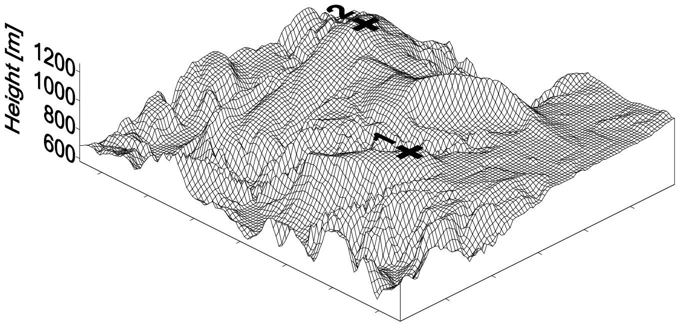
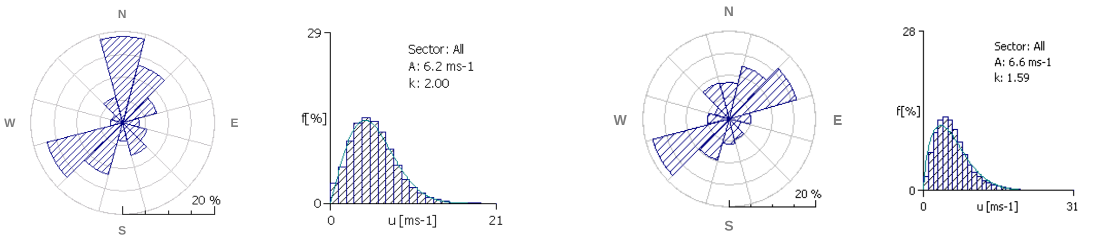


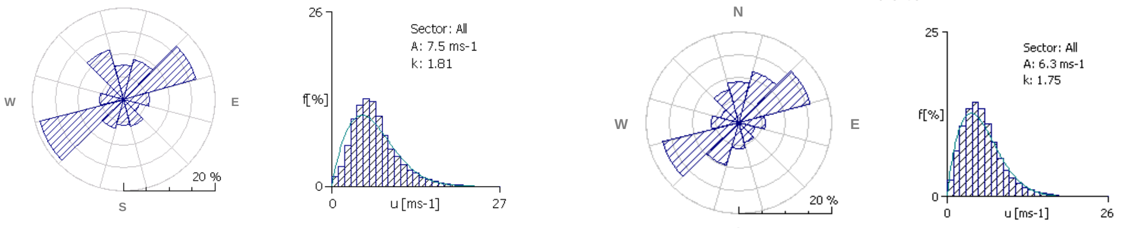
Figure 3: The orographic structure of the investigated test area (shown are 8 × 9 km)

Reliable wind potential assessment and micrositing in complex terrain is still is a difficult problem, because the European Wind Atlas Methods do have known limitations and considerable uncertainties. In the frame of the research project "Improved Tools to Predict Wind Energy Production in Mountain" ("MOWIE") funded by the European Union various sites in complex terrain and under different climatic conditions were investigated. Several European partners examined the uncertainty of different micrositing models with the aim to improve the methods for wind resource assessment. Among them the German Wind Energy Institute has performed extensive test calculations using the European Wind Atlas Methods and various flow models of different complexity: a three dimensional non-hydrostatic flow model [4], a mass consistent flow model (AIOLOS, [5]) and a linearized flow model. Several areas with complex terrain (e.g. Figure 3), located in central and southern Europe, partial equipped with simultaneous high quality measurements, were used to verify the calculations. The results of these investigations were used to compare the uncertainties of the different models with consideration of wind energy utilization (Figure 4, Table 1). Please note that the presented calculations are based on the data of mast 2, which is located in a distance of about 7 km to mast 1.



Mast 1 – measured (22 m height)

Mast 1 – calculated with WASP based on Mast 2 data



Mast 2 – measured (39 m height)

Mast 1 – calculated with AIOLOS based on Mast 2 data

Figure 4: Comparison of measured and calculated wind direction and wind speed distributions for Mast 1 and Mast 2 (both from the identical period 07/1996 - 07/1997).

Result for Mast 1	measured	calculated WASP	calculated AIOLOS
wind speed [m/s]	5.5	5.9	5.6
Weibull A [m/s]	6.2	6.6	6.3
Weibull k [-]	2.00	1.59	1.75
Deviation in Energy Yield		+32%	+14%

The investigation showed an interesting effect of presumable orographic induced wind direction turn, which could not be calculated by WASP or AIOLOS. This example will be subject of further investigation to clarify the question, if more sophisticated models lead to a distinct better result. The results of the AIOLOS were quite well for the presented example. This model will be subject to further examinations to clarify if this can be generalised.

CONCLUSION

Comparing the distances between the investigated sites with the currently usual wind farm dimensions leads to the conclusion, that the realisation of wind farm projects in complex terrain on base of only one measurement still bears a considerable uncertainty.

As outlook possible enhancements of the micrositing methods and micrositing concepts beeing developed and verified by DEWI are shown. For this the handling of data of more than one measurement mast by appropriate weightning algorithms is essential. The enhanced micrositing concepts include short term measurements and/or SODAR wind profile measurements in combination with sophisticated MCP procedures to determine the wind field over the entire wind farm area. This is complemented by further enhancement and development of sufficient flow models for micrositing and its connection to measurement data.

REFERENCES

[1] I. Troen, E.L. Petersen: European Wind Atlas. Risø National Laboratory, Denmark, 1989.
[2] V. Riedel, M. Strack, H.P. Waldl: Robust Approximation of functional Relationships between Meteorological Data: Alternative Measure-Correlate-Predict Algorithms. Proceedings EWEC 2001, Copenhagen, in Press.
[3] G. Gerdes, T. Pahlke; M. Strack; A. Westerhellweg: Verification of Energy Yield Prognosis (in German). Proceedings DEWEC 2000, Wilhelmshaven, 2000.
[4] D. Heinemann, H.T. Mengelkamp, M. Strack, H.P. Waldl: Experiences with the Application of the Non-Hydrostatic Mesoscale Model GESIMA for assessing Wind Potential in Complex Terrain. Proceedings EWEC 99, Nice, 1999.
[5] M. Strack, G. Gerdes, T. Pahlke, U. Focken: Wind Potential Assessment in Complex Terrain: Verification of WASP and Investigation of Improvements by Integration of Flow Models of Different Complexity. Proceedings DEWEC 2000, Wilhelmshaven, 2000.