Improvement of the European Wind Atlas Method by Spatial Interpolation of Meteorological Station Data

Hans Georg Beyer, Matthias Bromeis, Detlev Heinemann, Thomas Pahlke**, Hans-Peter Waldl*
Energy and Semiconductor Research, Department of Physics, Carl von Ossietzky Universität Oldenburg, D-26111 Oldenburg, Germany, FAX ++49 441 798-3326, e-mail: igor@ehf.uni-oldenburg.de
**Groupe Télédétection et Modélisation, Centre d'Energétique, Ecole de Mines de Paris Sophia-Antipolis, France*
***Deutsches Windenergieinstitut (DEWI), Ebertstraße 96, D-26382 Wilhelmshaven, Germany*

Abstract

The practice of using the European Wind Atlas and Wind Atlas Analysis and Application Programm (WAsP) for estimating the wind energy potential of a given site reveals uncertainties if there is no clear association to a Wind Atlas base station. This paper presents an objective approach to assess the wind energy potential which needs no assignment of a base station. This method avoids the appearance of discontinuities especially in the calculation of a spatial wind energy potential. We have investigated two types of spatial interpolation techniques.

IX

Introduction

The European Wind Atlas in combination with the Wind Atlas Analysis and Application Program (WAsP) is a widely used tool for estimating the wind energy potential for single sites as well as on a regional scale. It is based on the use of measured data for given meteorological stations (base stations). The 10-years time series of wind data are transformed to statistics of wind speed distributions and frequencies of wind direction. Taking into account the effect of obstacles, orography and roughness which have influenced the measured data, statistics of the geostrophic wind (wind at high altitudes governed only by large scale pressure fields) and the wind for standard conditions (homogeneous roughness, standard heights above ground) are calculated by means of boundary layer theory. It is assumed that these characteristics will not change over a distinctive area close to the base station. Finally the wind energy potential for any site in this area is estimated by correcting the homogeneous wind regime for the influence of the local topography at the site.

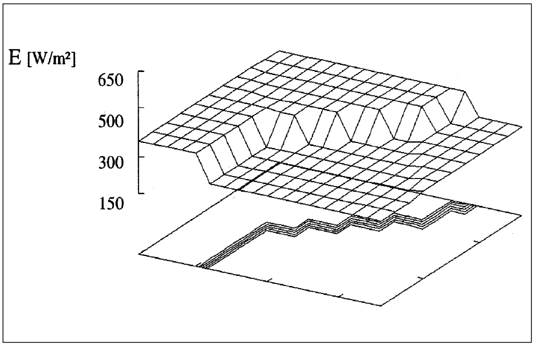

Fig. 1: Wind power density in Northwest Germany for a homogeneous roughness. The area corresponds to the rectangle shown in figure 3. The steps in the wind potential indicate the assignment problem. (1 square:10x10km²)

This procedure generally results in sufficiently accurate estimates when the association between site and base station is clear, i.e. the geostrophic wind flow is the same and the differences in surface wind flow between the site and the base station are locally forced only. However, due to a limited spatial representativeness of the base stations, their low number results in a lack of suitable meteorological data in some areas. This not only enhances uncertainties for the area but also leads to different results for the assessment of wind potential depending on the base stations assigned. These problems occur for example in Northwest Germany.

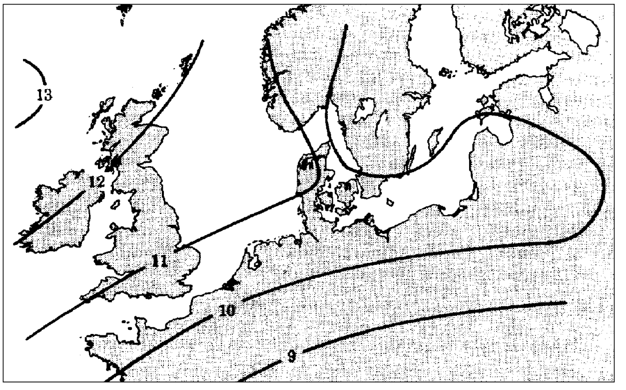

Fig. 2: Isolines of mean geostrophic wind over northern Europe as given in the European Wind Atlas. /WAsP/

As indicated by the data from the base stations Eelde (northern part of the Netherlands) and Bremen (North Germany) artificial discontinuities in the mean wind power output of wind turbines of up to 30% may occur when assessing the regional wind energy potential (figure 1). This is the result of a drastic change in the geostrophic wind field over the respective area, which is merely indicated by the regional distribution of the mean geostrophic wind field (figure 2). Similar findings for the Netherlands resulted in a linear correction of the geostrophic wind depending on the location in the country (/Verheij/ and /Rizos/). Because of the high density of stations (in total 11 stations over the country) the correction could be gained by a fit to the station data.

For Northwest-Germany only four base stations are available. For this reason we used an interpolation procedure to approach the spatial variation of wind climate. However, as will be discussed below, the introduction of some a priori knowledge is necessary.

Spatial Interpolation of Base Station Data

Different types of spatial interpolation techniques have been investigated to achieve smoother transitions between the base stations' wind energy potential. The interpolation produces additional data for WAsP to operate on a dense net of interpolated 'pseudo' base stations.

Parameters of the interpolation procedure are the base stations' frequency distribution of wind direction and the Weibull parameters for the standard conditions.

The first approach is based on a triangulation of the relevant base stations. A mesh is set up due to the location of the stations as shown in figure 3. The interpolation procedure assigns a bivariate 5th order polynom to each triangle which guarantees steady transitions to neighbouring triangles for the respective parameter of interpolation.

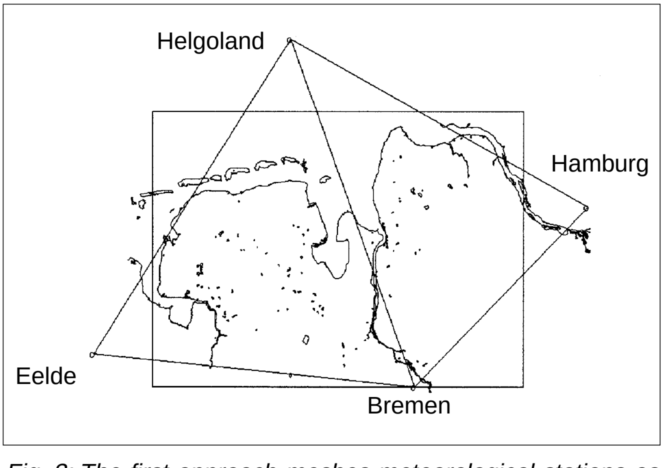

Fig. 3: The first approach meshes meteorological stations as given in the European Wind Atlas. The four stations relevant for Northwest Germany are shown. The rectangle covers an area of 170x90 km².

As the location of the base stations are independent of the true spatial pattern of the changes in the wind energy potential, the resulting data field is now smooth and correct for the sites of the base stations, although it does not necessarily reflect the true pattern.

To adjust the triangulation an heuristic generation of a denser mesh of triangulation points is taken as a second approach. It uses additional ad-hoc knowledge of the wind

regime applying experience on the choice of the best base station at various sites gained from wind turbine siting. For Northwest Germany the triangulation is thus extended using the data of the base station Eelde at selected sites at the coast and the data of the base station Bremen for inland sites. This approach results in a better resolution of the regional wind field pattern.
Both approaches generate interpolated station data which may be used to proceed with the siting methods provided by the European Wind Atlas.

Results

The spatial interpolation method has been applied to Northwest Germany. In order to seperate the influences of the triangulation from the influences of changes in the roughness, the wind power density has been calculated for a homogeneous roughness conditions. Using the generated 'pseudo' station data as meteorological input for WAsP the results reveal a smooth surface (figure 4 ,compare to figure 1). For real roughness conditions the wind energy potential for the same area is given in figure 5.
The second approach using additional stations based on siting experience forces the transition from coastal to inland wind regimes to follow more closely the shape of the coastline. Figure 5 gives the results calculated for homogeneous conditions. Estimating the wind energy potential for a real roughness leads to results presented in figure 7. The shift of the transition region causes differences in the two interpolation methods (compare figure 4 and figure 6) which may extend 25% of the estimated wind power density for single sites.
Efforts to validate these results with measured data from additional sites in the region of interest was hindered by a lack of long term data. A closer look to data available for 1-2 years showed severe problems due to the year to year variability of the wind resource. The interannual variability may surpass the expected errors of the long term resource estimation. Furthermore, as the temporal variability is not spatially homogeneous the use of an annual 'wind power index' to correct the short term measurements does not necessarily improve the situation.

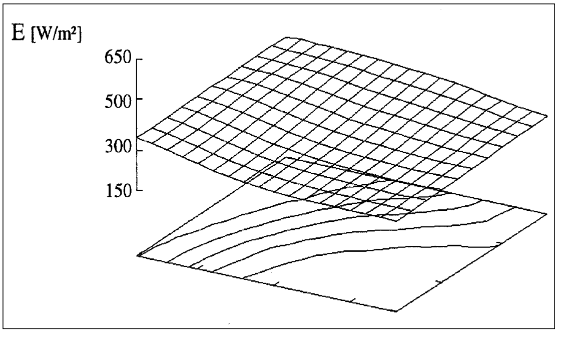

Fig. 4: Wind power density for a homogeneous roughness calculated by the interpolation method based on the triangulation shown in figure 3 and on WAsP. The calculated area corresponds to the inner rectangle of figure 3.

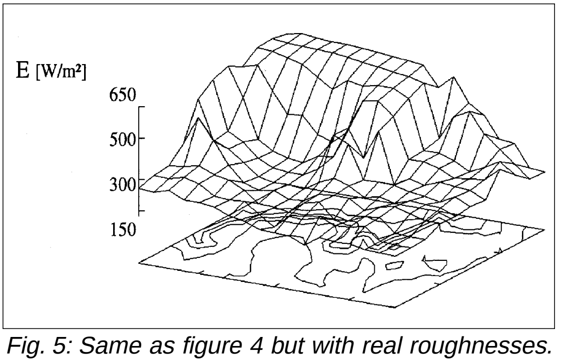

Fig. 5: Same as figure 4 but with real roughnesses. The roughness structure is dominating the pattern of the wind energy potential.

Conclusion

Wind energy potential assessment using a combination of WAsP and the spatial interpolation methods investigated reveals reasonable results. Both approaches generate a dense net of new stations with steady transitions in the case of a homogeneous roughness. The first approach leads to a wind energy potential which shows a generally slight decrease

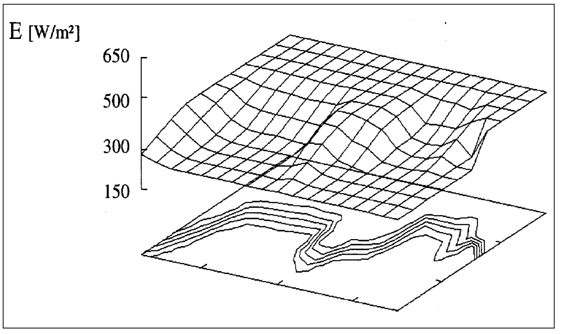

Fig. 6: Wind power density for a homogeneous roughness calculated by WAsP according to the second approach.

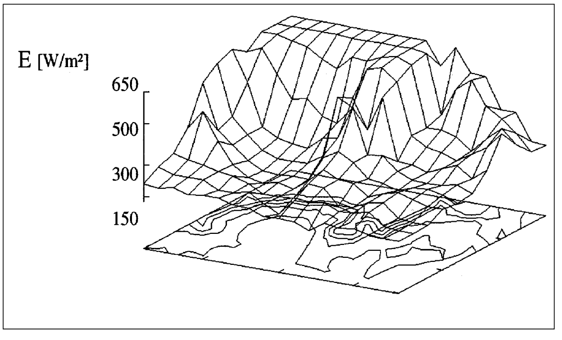

Fig. 7: Same as figure 6 but with real roughnesses.

IX

to the southeast. The second approach produces a more detailed representation of the coastal wind energy potential.

Both interpolation methods represent an objective way of estimating wind energy potential and avoid assignment problems of Wind Atlas base stations. The quality of the first approach depends on the location of base stations. With the second approach experience with siting can be introduced to the calculation procedure in an objective manner.

The large deviation between both methods indicate the importance of a refined method to use additional information on the overall shape of the wind climate. This may be realised if information on the geostrophic wind field (e.g. from the weather services) will be merged with the station data. On the other hand, long term data of wind turbine performance are now becoming available. These data may give a more objective basis for the location of additional triangulation points.

References

/Bromeis/
M. Bromeis, ''Untersuchung eines räumlichen Interpolationsverfahrens zur Erweiterung der Europäischen Wind Atlas Methode am Beispiel Nordwest-Deutschland.", Diplomarbeit, Carl von Ossietzky Universität Oldenburg, 1996.

/Preußer/
A. Preußer, "Bivariate Interpolation über Dreieckselementen durch Polynome 5. Ordnung mit C1-Kontinuität", Zeitschrift für Vermessungswesen, Volume 109, 292-301, 1984.

/Rizos/
E. Rizos, "Vergleich unterschiedlicher Verfahren zur Schätzung des Windklimas: Windatlasverfahren und statistische Auswertungen von Kurzzeitmessungen", Diplomarbeit, Carl von Ossietzky Universität Oldenburg, 1991.

/Verheij/
F.J. Verheij, L.v.d. Snoek u.a., "Handboek Energie-Opbrengsten van Windturbines", Band 1,2, Nederlandse organisatie voor toegepast natuurwetenschappelijk onderzoek, Utrecht 1989.

/Troen/
I. Troen, E.L. Petersen, "European Wind Atlas", Risø National Laboratory, Roskilde, Denmark, 1989.

/WAsP/
I. Troen, N.G. Mortensen, E.L. Petersen, "WAsP Wind Atlas Analyses and Application Programme", Risø National Laboratory, Roskilde, Denmark.