ISET-Wind-Index

Assessment of the Annual Available Wind Energy

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Abstract

Particularly in years with wind speeds that are clearly below average, dissatisfaction of operators and even liquidity problems are sparked through the unexpected low annual power production. An objective standard for the evaluation of the respective "wind year" is required for the internal estimation of the performance of wind farms, and for justification to share owners and banks. The annual wind conditions are composed from such a multitude of meteorological situations, differing from location to location, that the available wind energy at every individual location develops totally differently. A single code is therefore not sufficient to describe the "wind year" in Germany and, moreover, the evaluation of annual available wind energy must be carried out separately for the smallest areas possible.

With the support of the *Gothaer Rückversicherungen AG*, a procedure has been developed at ISET which provides the proportion of the respective annual available wind energy, in relation to the long-term average available wind energy, for each 10 km x 10 km sized plan area in Germany. This amount, the ISET-Wind-Index, is founded on wind measurements at locations that are typical for wind energy use and therefore presents an objective standard. The measurement grid is part of the "Scientific Measurement and Evaluation Programme" (WMEP), which accompanies the "250 MW Wind" project of the *German Federal Ministry for Economy and Labour*.

The ISET-Wind-Index, which will be regularly updated, provides an objective standard for the estimation of annual available wind energy and forms a basis for the development of an insurance product which safeguards against the risk of insolvency in particularly weak wind years.

Regional and Temporal Variation of the Annual Available Wind Energy

The temporal variation of the available wind energy was first evaluated according to five 50-year measurement series of wind speed, from the *Deutschen Wetterdienstes* (DWD), in order to clearly demonstrate the problem of particularly weak wind years. According to these evaluations, a fictitious wind turbine delivered only 60% of the average annual yield in the worst wind year of the past decades, and even 155% in the best year. The 245 annual results fluctuate approximately "normally distributed", but not totally symmetrically, around the average value. 62 of the annual results lay beneath 95% of the average, 64 were over 105%. When deviations of ± 5 % are seen as minor fluctuations, the available wind in roughly half of the years was approximately average and around 25% of all annual results carried clearly low yields (Fig. 1). The connection between wind speed and power production, which is explained later, was utilised for the more graphic depiction of fluctuations in annual wind energy potential.

Excepting the principally similar fluctuation spread of annual average values around the long-term average value, the depiction also reveals a clear difference in the temporal development of the five long-term time series. In this way e.g. the maximum and minimum annual average value in different years is measured and the extreme values of the individual measurement series deviate from the long-term average in different strengths (see Fig. 2).

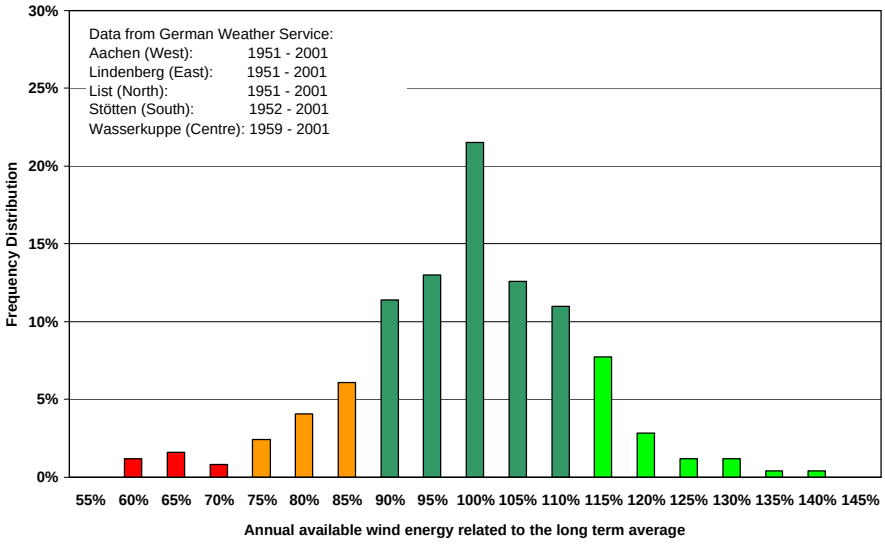

Fig. 1: Frequency Distribution of Weak or Strong Wind Years around the 50 Year Average Value

These preliminary examinations show that it is not possible to divide the areas of Germany into fixed regions with the same temporal development of available wind energy. Moreover, the assessment of available wind energy must be carried out for the smallest areas possible in context of the longest time series possible.

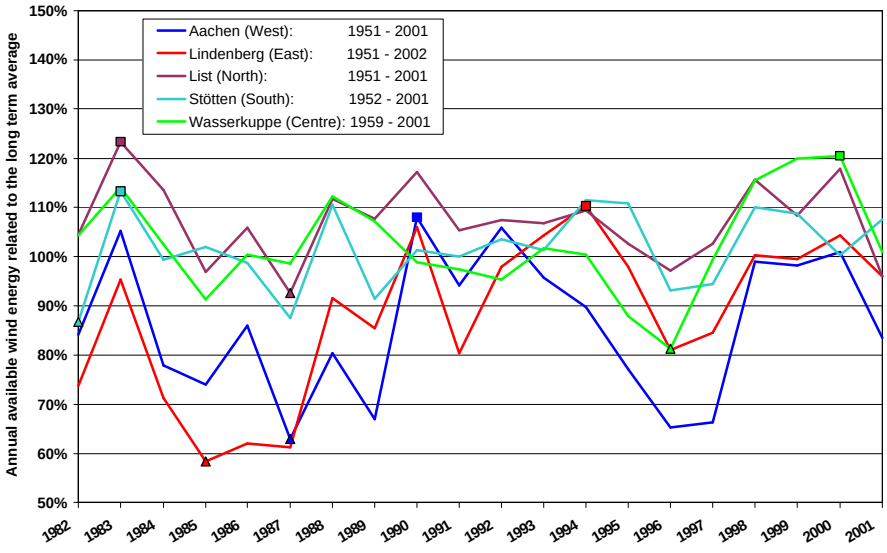

Fig. 2: Fluctuation of the Annual Average Wind Potential at Five different DWD Stations, related to the 50 Year Average Value

Dependency of Power Production on the Annual Wind Speed

For the estimation of how above or below average wind speeds effect the annual power production, a reminder must first be made: The power held in wind at a particular moment increases, or decreases, with the third power of the instantaneous wind speed. This does not apply for the instantaneous power delivery of a wind turbine, as the efficiency of the conversion of the wind power into electrical power varies strongly with the wind speed.

With the help of the annual power production of 1,500 wind turbines in the WMEP, some with already ten operational years, an approximation of the connection between power production and wind speed was determined empirically. The comparability of operational results was achieved through specific selection of the wind turbines and through an arithmetical compensation of different turbine hub heights and different frequency distributions of wind speeds.

In fact, the diverse parameters, which influence the annual power production, cause a clear scattering despite the compensations mentioned. Nevertheless, a clear tendency can be identified, which can be described with an approximation function. Within certain limits of the annual wind speed, the connection with annual power production can be described with quite sufficient accuracy through a quadratic parabola function. A more complicated equation was found for calculating the Wind-Index, which incorporates the effect of power regulation of WTs at high wind speeds.

Data Basis of the ISET-Wind-Index

The procedure for the evaluation of annual available wind energy, developed by ISET, is based on data from the reference wind measurement grid, which is converted to the surroundings of the measurement stations. This measurement grid is currently (at 06/2003) made up of 60 stations with almost consistently 30 m masts and additional five 50 m masts.

Fig. 3: Measurement Locations in Reference Wind Measurement Grid

The measurement data is uniformly converted to 50 m height and data gaps are filled through the transformation of measurement data from neighbouring stations. So, from 1993 to today, a record of 10 years data series has been assembled, which is supplemented with the new measurement data each year. For all measurement locations regular monthly, annual and long-term averages are acquired and updated.

Determination of Wind Speeds and the Wind Index

For the immediate surroundings of measurement locations, it is accepted that the available wind energy develops similarly as at the measurement site itself. For further removed areas, the annual wind speeds of the five closest measurement stations are interpolated to an average value.

It is thereby assumed that a grid of 10 km x 10 km sized plan areas presents a sufficiently fine subdivision of the total area of Germany. This transference calculation, from the measurement locations to the 3,800 plan areas, takes into account the distance between the respective measurement station and the plan area to be calculated, weighting the measured wind speeds in the inverted proportion of the distance.

For all plan areas and for all years, the relation of the annual power production to the long-term average annual power production is calculated from the relation of the annual average value to the long-term average values of wind speed. The relation of annual power production to the long-term average power production, the ISET-Wind-Index, describes the percentage of the long-term average annual available wind energy that is available in a particular year.

Presentation and Use of the ISET-Wind-Index

The 3,800 indexes calculated for one particular year are classed to illustrate the results (Fig. 4). The calculation for the past nine years shows that it is actually not possible to firmly define standardised regions with a uniform Wind-Index in advance. Moreover, it becomes clear that new results occur from year to year as to which areas are especially frequently affected by weather fronts, or which are particularly seldom affected.

The operational results of individual wind turbines deviate, however, noticeably from this Wind-Index. The ISET-Wind-Index is not able to consider special conditions at location or particular turbine behaviour or stoppage periods. The ISET-Wind-Index characterises more the principle available wind energy of a year, for a particular area.

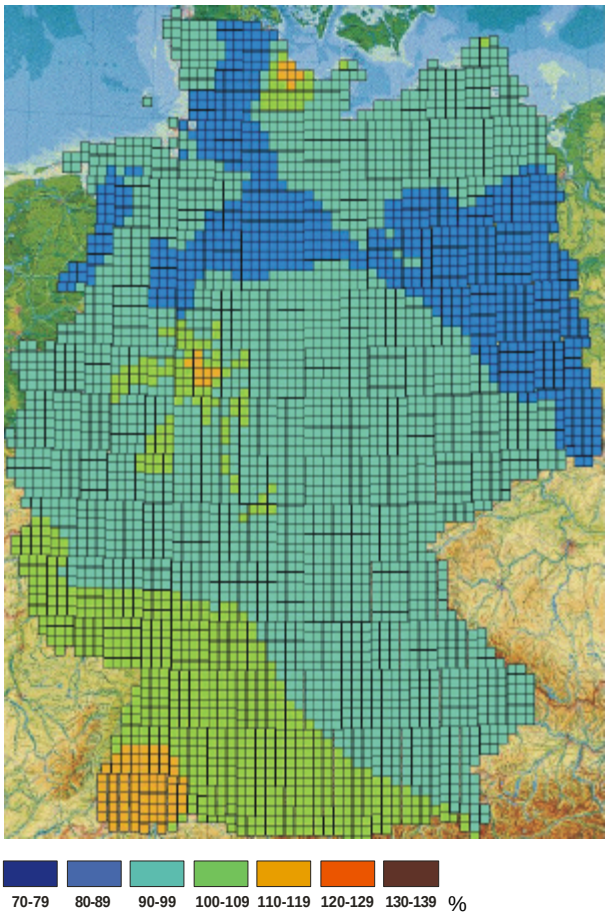

Fig. 4: ISET-Wind-Index for the Years 2002

Conclusion

The evaluations of the long-term measurement series underline how strongly the available wind energy can deviate above, but also below, long-term averages in individual years. This Wind-Index offers the operators of wind farms a conceivable objective estimation of the efficiency of the wind turbines. As the financing of wind farms generally assumes a constant annual income, a risk exists, of losing liquidity in particularly unfavourable years, which should not be underestimated. The Wind-Index allows the justification of a loss of income in such years to be neutrally grounded in the face of shareowners or banks.

References

/1/ M. Durstewitz, C. Enßlin, B. Hahn, M. Hoppe-Kilpper, K. Rohrig: „Windenergiereport Deutschland 2002 – Jahresauswertung des WMEP“, ISET-Schriftenreihe, Institut für Solare Energieversorgungstechnik, Kassel, 2002