Technical Risks related to Wind Farm Financing

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The reliability of the economy of a wind farm is based on the accuracy of the assumed inputs for the energy yield prediction. Wind potential assessment and the power performance of the turbines are the most crucial points. The following risks are to be taken into account by evaluating a wind farm project (due diligence):

1. Wind Speed Measurements

The site assessment starts with one (or several) wind speed measurements (preferably at hub height). The uncertainties related to wind speed measurements are varying between 3 and 20 (!) % in terms of energy production depending on the quality of the measurement system and the anemometer calibration (see IEA Recommendation 11: Wind Speed Measurement and Use of Cup Anemometry /1/). Not only the mounting, the quality and calibration of the anemometers is important, but also the regular plausibility check of the data.

Anemometer Calibrations performed by Laboratories accredited according to MEASNET guarantee high quality calibrations and low uncertainties (see International Round Robin Test /2/)

The used type of aneomemeter has an essential influence on the results of wind speed measurements. Even for anemometers calibrated according to the latest standards recent comparisons of different types of anemometers in the open field have uncovered significant deviations between wind speed maesurements in the order of 2 % /3/.

2. Model Calculations

If the wind speed measurement is not located directly at the wind farm site, a transformation of the measured data by means of a meteorological or fluid model has to be performed. The European Wind Atlas Method /4/ has established a standard method for this purpose, however with known limitations and uncertainties. According to application experience the results should regarded to be relieable only in the case of no or only weak orographic influence, no near obstacle influence and generally an equilibrium state of the lower atmosphere (e.g. no near drastic roughness changes). Since the reliability of the whole procedure depends strongly on the quality and reliability of the meteorological input data, all meteorological input data should be subject to a close assessment and verification.

In complex terrain the prediction error applying the European Wind Atlas Methods easily could exceed 30% of the energy yield, even if the meteorological base data are of high quality and only a few kilometres away /5/. So the European Wind Atlas Methods should be used for extrapolation of the measured wind conditions only over short distances and height differences, and even in these cases the applicability should be closely examined and tested. Orographic induced local separation and shading effects, which are not handled by the model, could lead to considerable local prediction errors.

More sophisticated flow models have been investigated and can lead to better predictions (/5/, /6/), but mostly the results cannot be generalized and extensive verification and application experience is not available yet.

It must be emphasized that within the due diligence procedure the widely used practise to provide a third party opinion does lower the risk of an error in processing the data, but does not necessarily lower the uncertainty of the calculated results, especially if the third party result bases on the same calculation model.

As consequence of the experience a large wind farm area should be equipped with more than one measurement mast with measuring heights near the hub height to ensure a reliable planning basis. By means of the application of sophisticated correlation procedures a modularized concept including one probing mast and the installation of additional shortest term masts or SODAR measurements in a later planning stage a realizable concept can be developed to ensure a reliable planning basis.

3. MCP- Measure-Correlate Predict

For processing measured wind data Measure-Correlate-Predict (MCP) Methods are used to extrapolate the data to a longer term perid. The application of those methods meet two main requirements: The extrapolation of measured wind data (e.g. one year) to long term period (e.g. ten years) to decrease the influence of inter-annual variations, and the extrapolation of shortest term wind data (e.g. 4 months) or SODAR data to a whole years period to get an exhaustive wind data information. Due to the seasonal variation the latter case has the higher demands on the used MCP-method and also on the data.

Recently developed sophisticated MCP procedures /7/ are able to adjust to the specific site conditions and capable to extrapolate shortest term measurements with good accuracy. In Fig.1 the error for a MCP prediciton for a period of one year is shown in dependence of the number of months used for correlation (the error has been calculated as percentage error in energy yield of a common wind turbine). The results base on test with 9 pairs of high quality measurement masts in different terrain and distance. Due to the number of 9 pairs of sites, we dispense with calculating means and standard deviations, but instead of this the median and upper and lower quartiles are calculated.

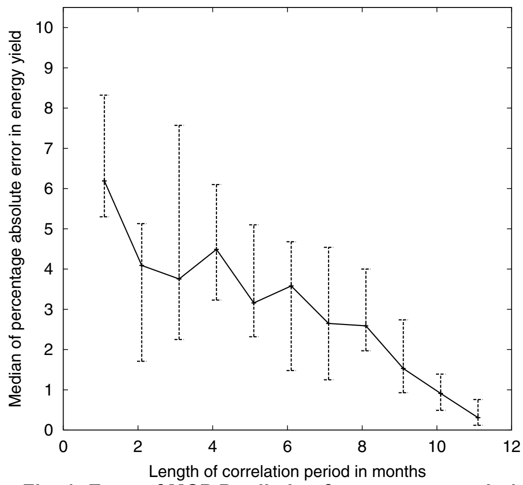

Fig. 1: Error of MCP Prediction for one years period in dependence of the length of correlation period (the mean and upper/lower quartiles are shown).

It can be seen that a 4 months period could be extrapolated to one year with a mean accuracy of 4.5% in energy yield (quartiles: 3%-6%). These values cannot be generalized for every site and are of course valid for the used MCP method only. The accuracy has to be assessed for each site by individual tests before applying.

But it can be shown that results better than the expected accuracy of the calculation models can be achieved by MCP methods in combination with shortest term measurements. So it seems to be realistic to perform a measurement-MCP combination instead of a third party model calculation within a due diligance procedure.

4. SODAR

Then a so called **micro siting** is performed in order to determine the wind potential at each turbines position within the wind farm area. The micro siting is usually done with a flow model and/or a mobile **SODAR** system. **SODAR** is a kind of acoustic radar with which we can measure the wind seed up to a height of 150 m with 5 m resolution (see Fig. 2). This system is very flexible and can be easily transported from one site within the wind farm to another site of planned turbine positions.

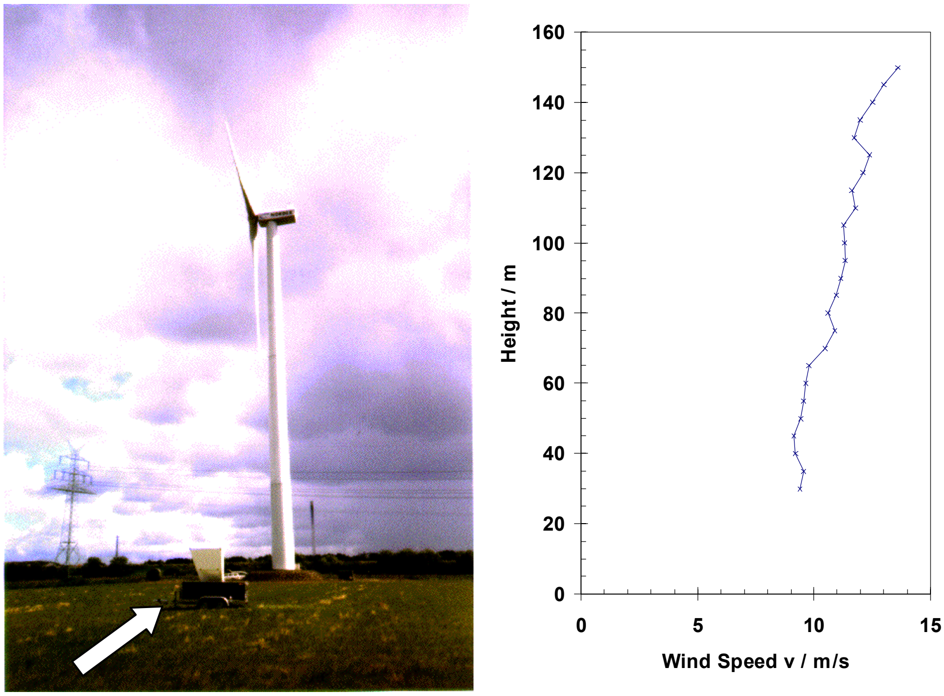

Fig. 2: Measurement of the wind profile on the DEWI Test Site.

5. Power Performance/Energy Production

Next the **wind farm efficiency** has to be determined taking the wake effects of the turbines into account. Finally with the help of a measured power curve the **energy yield** of the wind farm has to be calculated taking the guaranteed **availability** and the guaranteed **power curve** of the turbines into account.

The **plausibility check** of a guaranteed **power curve** is a very complex task within the due diligence work. Questions have to be answered like: according to which standard and which quality assurance system the power curve is measured. Is the turbine planned in the project technically identical to the measured power curve (use of stall strips or vortex generators, contamination of blades, changes in the blade angle, noise reduction measures which influence the performance of the turbine) ? Which type of anemometer is used for the power curve measurement (see chapter 1 and /3/)? As explained in /3/ the power curves of different wind turbines cannot be compared if different types of anemometers are used. If the wind speed measurements for the site assessment were performed with a different type of anemometer than the power curve measurement (guaranteed power curve by the manufacturer) correction factors have to be applied.

6. Contractual Matters

The verification method of the power performance has to be defined in the contract in all details in order to reduce the financial risks to an acceptable limit. A verification of the power performance can be done by several methods:

- Measurements according to IEC 61400-12: Wind Turbines Power Performance Testing, 1998. A met mast at hub height is necessary. If the terrain is even slightly complex (slopes greater then 3 to 5 %) prior to the erection of the wind turbines and the power performance verification measurement a site calibration with two met masts is required. That means that any guarantee on a power curve based on IEC is useless in complex terrain if there was no site calibration performed before the wind farm was built.

- Power performance verifications with the nacelle anemometer. The advantages and shortcomings of this method are described in /8/.
- Power performance guarantees in relation to a reference wind speed at a reference location defined in the contract. This kind of guarantee includes all the technical risks related to the power curve of each individual wind turbine and its availability, the micro siting and the wind farm efficiency.

If relevant acoustic noise parameters (sound power level, tonality) of the turbine are guaranteed or the turbine is operated in an noise reduced modus for specific conditions (e.g. at night time or for certain wind directions) the noise parameters should be guaranteed in combination with the related power curve.

7. Conclusions

Wind speed measurements at one reference location within the planned wind farm area in combination with short term mast or SODAR measurements reduce the financial risk related to wind farm planning significantly. The uncertainty associated with the energy yield is greater if no measured power curve measured by an accredited laboratory is available. The type of anemometer type and its calibration has to be checked in order to avoid inconsistencies in the predicted energy production. The verification method of the power performance has to be defined in the contract in all details in order to reduce the financial risks to an acceptable limit

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