P50 - P75 - P90 How to reduce the financial Risks of a Wind Farm Project

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Summary

For a lot of wind farms the energy production is below the expectations but it is a difficult task to distinguish if the wind potential was overestimated or if the wind farm is underperforming. In the planning and financing stage of a wind farm project a risk assessment is required quantifying all risks related to the wind farm financing (technical due diligence). Financial Modelling requires a comprehensive understanding of the project assumptions in combination with the performance of sensitivity analysis in order to define an agreed base case. The prediction and verification of the performance of the wind farm are crucial for the risk assessment and the exceedance probabilities (Pxx) of the wind farm's annual energy production. A combined method (wind farm performance warranty) is proposed for using a common reference met mast for both: site assessment and testing the performance of a complete wind farm in relation to a reference point (location of the met mast). Enhanced flow models with proven modelling capabilities also in complex terrain (DEWI Round Robin Test on Flow Models) can be used for the wind farm performance prediction and verification (wind direction-dependent wind farm power curve). This method can also be used in combination with weather derivatives (hedging) and reduces the financial risks of a wind farm project significantly.

Key words: Risk Assessment, Performance, Due Diligence, Warranties, Maintenance, Power Curve, Energy Yield

Technical Due Diligence

Banks, owners or investors contract independent experts who analyse all aspects of the wind farm planning and their related financial risks. Such risks are site assessment including wind speed measurements and long term correlation, wind farm layout, construction risk, lifetime of the components (related to the distance between the turbines), the foundation requirements, the electrical losses, noise limits, experience with the planned type of turbines and the contractual issues dealing with EPC-contracts (including energy production warranties), PPC and operation/maintenance contracts (full service contracts). The risks will be identified, quantified and minimised.

Wind Turbine Technique

There is no longstanding experience with multi-megawatt machines, but a track record of the manufacturer and the wind turbine can be used to assess the site-related risks of the used machines. It is obvious that the maintenance and repair costs and the lifetime of components of a turbine type operated in Denmark or northern Germany differ from those in complex terrain and/or reduced distances between the turbines. The certification of the wind turbine has to be in compliance with the site conditions.

The turbulence and flow inclination experienced by wind turbines in complex terrain has been evaluated under the following aspects:

- Safety and design requirements according to IEC 6100-1 in relation to the site.
- Influence of turbulence intensity on the power curve of a wind turbine.
- Influence of flow inclination on the power curve of a wind turbine.
- The cut-out hysteresis of a wind turbine at high wind speeds becomes more and more important for higher turbulence. For a turbine with significant cut-out losses measured in flat terrain these losses will increase with increasing turbulence intensity.

Wind Farm Loading

The operation experience of Megawatt-wind turbines in complex terrain show, that the complex flow conditions in complex terrain can have a serious impact on the lifetime of the wind turbine or important components like blades or gear-boxes. This is an issue which can have a serious impact on the financial state of the project, however usually is not considered detailed in the project assessment or review. So it is an important issue to lower the operational risk, especially in complex terrain by the thorough assessment of the site conditions for determination of appropriate wind turbine type respectively the correct wind turbine design.

For this DEWI establishes a comprehensive site conditions assessment, which states all parameters of the wind conditions at each wind turbines' site, which are relevant for the loading on that turbine. These parameters are obtained by the application of computational fluid dynamics methods and further procedures according the state of the art, and enclose the ambient and the wind farm turbulence, the mean and maximum wind gradients, the flow inclination, the extreme wind speeds and others. The purpose of the site conditions assessment is not only to allow the selection of the wind turbine which is appropriate for the site conditions, but also to provide a complete list of site properties, which is required by the manufacturer or certification body for a site specific design or certification of the wind turbine.

Besides the assessment of the appropriate design, the described procedures provide the base to optimize the wind farm with the aim to minimize the wind farm loading. In the first step the weighting of the different loading factors is done dependent on the design values, the damage frequency and loss expenses. Then the wind turbine siting is optimized with the aim to minimize the overall loading on the wind farm.

Energy Yield Prediction

The risks related with an energy yield prediction are influenced by

- The quality of the wind speed measurement(s) at the site
- The quality of the long term assessment (enhanced MCP-methods)
- The used flow model for the micro-siting
- The park efficiency model (shading of the turbines)
- The power performance of the machines and the related warranties

Crucial points for the economy of a wind farm are the site assessment [1] in combination with the contractual issues dealing with energy production warranties [2], [3]. Long term correlation of the wind potential is a source of uncertainties which is underestimated quite often . Enhanced MCP methods are used for the reduction of this risk.

Operation and Maintenance

From a financial point of view a long term O&M contract (including availability warranty) based on fixed prices with bonus/penalty incentives based on plant availability and performance is desirable. It is important to notice that usually availability warranties are based on percentage of time, that means an availability warranty of e.g. 97% allows the turbine to be non-available up to 3 % of time. For the risk quantification the loss of energy production due to non-availability has to be limited. If the turbine is mainly not available at low wind speeds, the 3% of time may result in less than 1 % loss of energy production. If the turbine is mainly not available at high wind speeds the 3% of time may result in up to 10 % loss of energy production. If damage payments for lower availability than the warranted availability level are agreed in combination with bonus payments for higher availability than the warranted availability level, a wind speed depending weighting function has to be defined that translates % of time into % of energy production losses. Otherwise a worst case scenario from a financier's point of view may occur that the energy production losses are 6% due to 2% non-availability at high wind speeds whilst on the other hand bonus payments have to paid as the availability in time is 1% above the warranted level.

Performance Warranties

The performance warranties guarantee that the turbines produce the energy expected from the existing wind conditions. Usually the power curve of one or several turbines within the wind farm are verified according to the IEC 61400-12 standard or the draft stages of the revision of this standard (CD, CDV 61400-121). Sometimes alternative procedures like nacelle anemometry power curve verifications [3] are agreed upon in a warranty contract. In the revision of the IEC 61400-12 standard a wind farm performance verification procedure (numbered IEC 61400-123) will be worked out where the wind farm is treated as a power plant and the performance is verified in relation to a reference mast in the vicinity of the wind farm. In this verification procedure not only the risk related to the individual power curves of the machines is included but also the risk related to the terrain (micro siting), wake effects and electrical losses.

A method is proposed for using a reference met mast for both: site assessment and testing the performance of a complete wind farm in relation to a reference point (location of the met mast). Enhanced flow models with proven modelling capabilities also in complex terrain (DEWI Round Robin Test on Flow Models) can be used for the wind farm performance calculation. This combined method reduces the financial risks of a wind farm project significantly.
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The reference point has to be chosen very carefully as it is very important how good the performance of the wind farm correlates with the wind speed at the reference location. If warranties of the performance are negotiated in relation to that met mast position a wind farm power curve matrix has to be calculated and agreed upon in a contract. The uncertainties of such a wind farm power curve are very small for a small wind farm in flat terrain and increase with increasing complexity of the terrain. In complex terrain wind speed measurements within the wind farm area at least a few months before the erection of the wind farm have to performed in parallel with the reference mast outside the wind farm area. The flow models used for the micrositing have to be tested by these measurements in order to quantify the uncertainty and thus the risk for both parties.

For this kind of warranty the P 75, P 90 or P95 energy production values (exceedance probabilities values) are higher because the uncertainties of the wind speed measurement are introduced only once whilst the power performance verification uncertainties are low as the same met mast is used for both (the highest part of the uncertainty of a power curve measurement is the wind measurement).

Conclusion

In order to reduce the financial risk of a wind farm, special attention should be given to the operation and maintenance contract (long term warranties including availability warranties in terms of losses in the energy production) and the performance warranties (wind farm performance in relation to a reference mast). Enhanced flow models should be used for the energy yield prediction and the calculation of the wind farm power curve which are validated for the type of terrain.

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[4] Strack, Riedel: State of the Art in Application of Flow Models for Micrositing; Proceedings of the DEWEK, Wilhelmshaven, 2004.