Reassessing a wind farm's potential

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Abstract:

The ever-growing database of offshore wind farm production data provides the opportunity to improve the understanding of wind energy potential at existing and future sites significantly. In principle, the wind turbines provide a dense measurement system of the wind conditions. These need to be distinguished from all other factors that drive production at the site.

The 'post-construction analysis' of the wind farm production data can provide the tools for this exercise. The industry-wide goal should be to make full use of the potential of the production data in order to gain a better understanding of offshore wind farm performance in the past and in the future.

The results of a post-construction analysis of production data can have major implications not only for the shareholders of a particular wind farm, but also for the industry as a whole.

For wind farm operators, insights into wind farm performance can have a decisive influence on detailed follow-up investigations or negotiations with manufacturers.

Wind farm shareholders, on the other hand, can refer to the results in connection with refinancing and the selling of shares. For operators of multiple wind farms, the question also presents itself of what can be learned from the performance of the farms and the portfolio to date for future projects.

The industry-wide implications became more than evident when a press release from one of the largest offshore shareholders, Ørsted, created quite a stir in 2019, claiming that revenues of around two percent lower should be assumed when planning offshore wind farms. Internal data analyses had revealed that the wind farm wakes, and the large-scale blockage of the flow had been significantly underestimated in the yield assessments up to that point. In an industry where yield projections are generally calculated using similar models, the report created unease about the validity of the applied methods. The question of how credible the projections were and whether fundamental investigations of all methods are necessary has been a topic of lively discussion ever since.

The issue for the wind farm operators is that, especially in the early years of a wind farm's operation, the pre-construction site assessment is the only reference for the measured production. This assessment usually relies on a short-term wind measurement campaign at usually just one or few locations across the site's area. The projection to the whole site area and to the operational period as well as the estimation of the wind farm downtimes and wind turbine component failures all have to rely on models or educated guesses. However, with the right reference data, an analysis of the first months of operation can already reduce the uncertainty about the farm's long-term potential.

So, which data needs to be manipulated for the wind farm to reveal its potential?

First, the performance assessment of wind farms only makes sense in relation to the prevailing wind conditions. In 2017, Fraunhofer IWES addressed the lack of offshore wind indexes with highly resolved numerical weather simulations aggregated in the Fraunhofer Offshore Wind Index (FROENIX). Offshore, these optimized meteorological simulations can provide a precise estimate of the wind resource. The indexing of the wind farm production already prevents many unnecessary discussions about the state of the wind farm in months or years with a low wind resource.

Second, corrections for technical downtime and enforced power restrictions by the electric grid operator need to be applied to unmask the production potential at the site. This can be done by calculating the amount of underproduction during these periods. An onshore guideline for this procedure exists in the German Technical Guideline 10 (TR10). However, for application offshore, the different characteristics of offshore sites and wind farms need to be considered.

Due to the low level of atmospheric turbulence and the large farm sizes compared with onshore farms in Europe, the main reason for intra-farm differences in the wind resource is the reduction of wind speed due to wakes of other turbines and wind farms. Wake losses reduce the efficiency of a typical offshore wind farm by about 40% in

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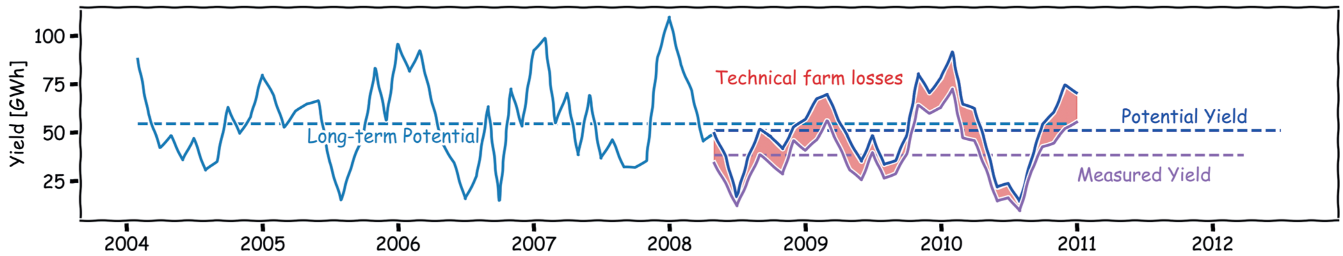

The post-construction analysis' task is to quantify the farm's yield losses based on the production data to date. The combination with meteorological data makes it possible for the determined potential of the farm in the operating period to be projected over its entire lifespan. Schematic sketch. © Fraunhofer IWES

some wind speed ranges and external wakes of other wind farms can reduce the wind resource even at distances of up to 100 km. Thus, it is crucial that this influence is considered when calculating any lost production quantity.

The Fraunhofer IWES uses a data-driven model approach to address this issue. Using the production data as learning data for a physics-based model renders a precise representation of the wind farm's response to changing wind conditions possible. As a result, the tailored model allows the potential yield of the wind farm to be calculated during the historical production period that can be indexed by the prevailing wind conditions from the meteorological model to derive a long-term estimate.

The main value for this production-based long-term estimate for wind farm shareholders is that it provides greater certainty about the future energy yield compared with previous yield assessments. The reason for this is that the production data already provide a reference of how measured wind conditions are converted to electrical energy at the site. Any uncertainties stemming from the assumptions that had to be made before construction can therefore be omitted. The reduction of future yield uncertainties leads de facto directly to the wind farm having a higher financial value.

However, the possibilities with a tailored wind farm model do not end with a more precise long-term energy yield estimate. It also makes it possible to answer a far larger number of questions. For example: How much would the park actually have been able to generate during grid supply outages as well as during feed-in management? Or: what effects do existing and future neighboring parks have on the expected yield and can previous data already confirm this?

As wind turbines extract less energy from the flow during curtailed performance due to feed-in management, they consequently leave more energy available for downstream turbines. This interdependence needs to be considered for proper estimation of the potential production of the wind farm during feed-in management, a problem which grows in complexity when not only the wind farm under consideration, but also upstream wind farms are operating under restrictions.

Due to the time-resolving nature of the trained model, feed-in management compensation can, in principle, not only be calculated for the past operational period but also, when coupled to market-price models and electrolyzers or batteries, for example, for future scenario calculations.

Conclusion

Production data of offshore wind farms offer enormous potential to reduce the uncertainties of offshore site assessment and the projection of the wind farms' future production. Technical downtimes, grid restrictions, and the mutual interaction of the turbines through their wakes, however, require new solutions for evaluating the potential of the farm during the recorded production period.

Wind farm models trained with a production data basis offer the possibility of not only addressing this issue, but also providing a solid basis for future scenario calculations that focus, for example, on different offshore wind energy expansion scenarios or on time-resolved price-market fluctuations and the integration of hydrogen production.

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