Wind Farm Power Performance Verification

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Wind energy projects are growing and there is an increasing demand to monitor not only the performance of a single turbine but of a complete wind farm. This change in demand is reflected by the current development in the IEC 61400-12-x standards. Investors in large projects will be interested in simple methods to monitor the performance of projects and to go into details if required. The article describes the general possibilities that can be gained from seeing the wind farm as a utility and presents the current development in the IEC standardization process.

1. Single turbines

The standard approach to measure the power curve of a wind turbine has not changed with the introduction of the new IEC 61400-12-1 [1] in December 2005: A met mast is placed in a certain distance ahead of the turbine; a calibrated cup anemometer is used to measure the wind speed at hub height. Further signals are recorded from the mast and the machine. The power curve is calculated for a certain air density for data pairs of wind speed and power. Wind direction is used to select valid wind direction sectors. The basic setup can only be used, if the terrain conditions do not exceed certain defined values. If they do, a measured site calibrations is required prior to the power curve measurement. If a site calibration has not been performed for a turbine that is located in complex terrain, there are only very expensive ways to measure the power curve of a single turbine.

The IEC 61400-12-2 currently under development will offer greater flexibility to assess the power curve of a single turbine using the nacelle anemometer and a transfer function to the free wind. It is measured once using the classic setup with a met tower. Once the relation is established, it can be transferred to other locations without the need to install a tower again. A second task group of the IEC 61400-12-2 is working on the field of numerical site calibration. The application or combination of the two approaches will allow the assessment of the power curves of several wind turbines in one farm using to some degree a technology that comes with the turbine in place. This is already a step that broadens the data base for a wind farm assessment. In typical warranty contracts quite often three turbines out of a set of 20 to 30 are tested. The average result of the measurement is then taken as a measure to decide if the warranty level has been reached or not. If, on the other hand, all turbines that have a IEC 61400-12-1 compliant measurement sector, can be assessed there might maybe 50 % or more of the parks turbines that enter the statistics. Even if the uncertainties of such a measurement are higher, the number of turbines can lead to an overall reduced uncertainty.

2. The wind farm as a utility

The power performance of a wind farm is influenced not only by the underlying power curves. There are several other factors contributing. First, the wind conditions (wind speed, direction, shear, turbulence) vary between turbine locations, especially when it is a complex terrain case. Secondly some turbines are likely to be in the wake of the next machine. The availability of the machines must be taken into account and should be analysed in relation to production losses. Finally there are the electrical grid losses to the network feed in point.
The approach of the IEC 61400-12-3 makes two proposals: Measuring the power curve of a wind farm and secondly the establishing a reference wind farm power curve for comparison purposes.

3. Measured wind farm power curve

The measurement of the wind farm power curve requires a previous wind monitoring at the site in advance. One or more met masts shall be placed around the wind farm in order to allow for wind measurements in all main wind directions that are not influenced by the farm itself. This way there will be an undisturbed wind speed and wind direction measurement at hub height for most relevant situations available. The number of towers around a site depends largely on the layout of the farm, its size and the terrain complexity. Another set of towers is located in the wind farm area and correlation data base is established that allows to assess the wind direction and wind speed relation to the long term monitoring towers.

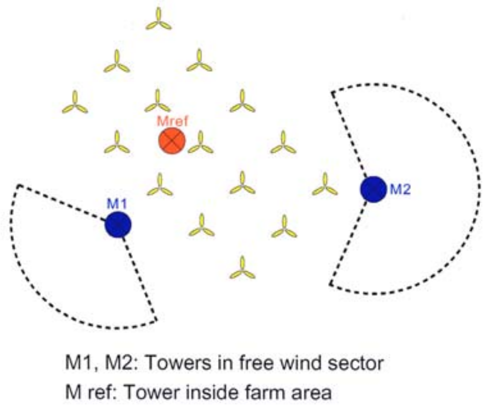

Figure 1 Possible placement of two wind measurements outside the proposed farm area and one mast inside the wind farm. The mast in the wind farm is dismanteled after installation of the turbines.

Having this data base established, it is possible to determine the undisturbed wind conditions in the wind farm area during the operational phase of the turbine. The data is helpful in two ways: First any model that is used to predict the wind farm be-haviour should be able to reproduce the wind

measurements in the wind farm area. Furthermore this data will be later used to determine the nominal power output of the wind farm, based on a model that takes all the effects into account.
The measurement of the wind farm power curve consists of the determination of the free wind and the power output of the wind farm at the network feed in point. The evaluation will be performed for every sector of the wind farm, depending on the complexity of the terrain the sector width will range from 10 to 30 degrees.

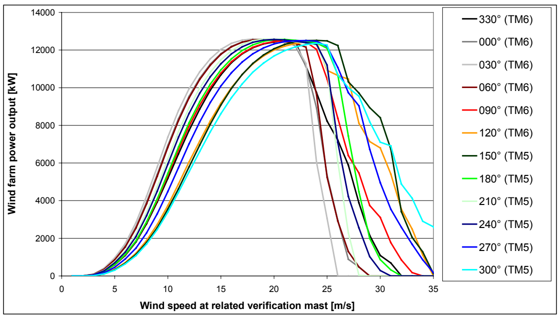

Figure 2 Example for a direction dependend set of wind farm power curves.

4. Availability

The wind farm shall be in normal operation which includes a certain amount of service time. Thus all data should be used in general with some exceptions made for example for grid failure or turbine repair service.
This approach takes the point of view of the wind farm operator who has calculated a certain amount of time for the necessary maintenance. In order to have a realistic approach to a large wind farm, these downtime should be included. Otherwise it will be hard for a large wind farm to have a common data base with all wind turbines running.

5. Air Density

Unlike in the previous measurement approaches the air density is not a variable for which the wind farm power curve is corrected. Instead the measurements shall be performed for a complete year even if this means that scatter in the data base is increased. This way it is ensured that conditions are taken into account based on an average site air density that can be calculated with good precision from the terrain elevation and average air temperature. The advantage of working with a average site air density is the straight forward application of a two dimensional matrix that uses only wind speed and wind direction as inputs to deliver the 10 minute average energy output of the wind farm.

6. Possible further analysis of the data

There are mainly four different reasons for a performance below expectations of a wind farm:

- Poor wind year
- Micrositing study does not describe conditions in the farm correctly
- Power curve shortfall
- Availability of turbine too low.

In any of these cases the methods mentioned before allow to assess the points individually.
The annual wind year condition can be directly read from the tower data for the freestanding towers. This way any calculation based on wind indexes is obsolete.
Furthermore there is quite often a long term correction of the annual wind conditions in the micrositing study that is based on a meteorological station in the vicinity. If we assume that the measurement at that site has not changed, then the calculation method used in the micrositing study can be applied to recent data. The value for the measured annual wind speed in the farm should be reproduced. The deviation between the two numbers gives an indication on the quality of the modelling. If the deviation grows from year to year one could even argue that it is biased.

The micrositing study can be tested against the data from the correlation measurement with the towers outside and inside the wind farm area. The model s used should be able to verify the wind conditions. Furthermore it is possible to later use freestanding turbines as anemometers (or use the nacelle anemometer data together with a transfer function) and analyse the wind regime at that specific location against the model calculations.
The power curve can be tested together with the methods described for the measurement of single turbines.
The availability can be statistically analyzed to assess any possible correlation with wind speeds and to test that the time of unavailability is equally distributed over all wind speeds.

7. Discussion

The reduction to just the two variables wind speed and wind direction makes the application very easy. The main question will be the modelling of all effects that contribute to the annual power performance of a wind farm. The wind model is certainly of major influence here. However, any micrositing study for a wind farm should have made assumptions on the terrain induced effects, the wind shear, the turbulence, average air density, availability and grid losses. It is also possible that the power performance matrix already exists in the calculation procedure of the wind farm energy yield calculation. The question will be if the involved parties can agree to use such an approach as a reference in a power performance evaluation of the wind farm.

References

[1] IEC 61400-12-1, Power performance measurements of electricity producing turbines, Ed 1, 2005/01