Measurements for the wind industry: Moving beyond the 10-minute averaged data

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Abstract

The standard measurement practice in the wind industry has established the use of 10-minute averaged data. This practice has been based on research under the meteorological scope, which examines the time scales of the natural wind phenomena. However, this averaging period might be improperly large for the wind energy industry, as the time scales of the wind energy conversion are far different. Modern wind turbines which present improved operational characteristics, respond to changes in the wind in a fraction of this period. Yet their power curve validation relies on measurements averaged over a period in which the actual wind presents high variations in the real field, while other meteorological factors appear stable. Prior to the power curve test, the wind resource assessment of a site which is based on 10-minute averaged data might overlook variations in the wind power density which are captured by the wind turbine, but are neglected as the data is averaged for a 10-minute interval. This effect could be of higher significance especially in the cut-in wind speed region. All the above could lead to discrepancy between the assessment wind data, the calculated wind turbine yield and the actual energy yield. The possibilities of reducing this discrepancy by using a smaller averaging period, and disengaging the measurements for the wind energy industry from the 10-minute averaging practice are examined in this work.

Objectives

The objective of the study is focused on investigating the effect of the averaging period of wind data, on parameters that concern both the wind resource assessment of a site, as well as the power curve measurement, especially in the cut-in wind speed range. This is a special wind speed region where 10-minute averaged data can lead to problems in the measurements and the results, due to the much smaller time scale of the wind turbine behavior (with possible successive cut-in and stops) compared to the averaging period of the data. In addition, the site assessment parameters may provide different results by varying the averaging period, thus affecting the project siting and financial assessment stages.

Methods

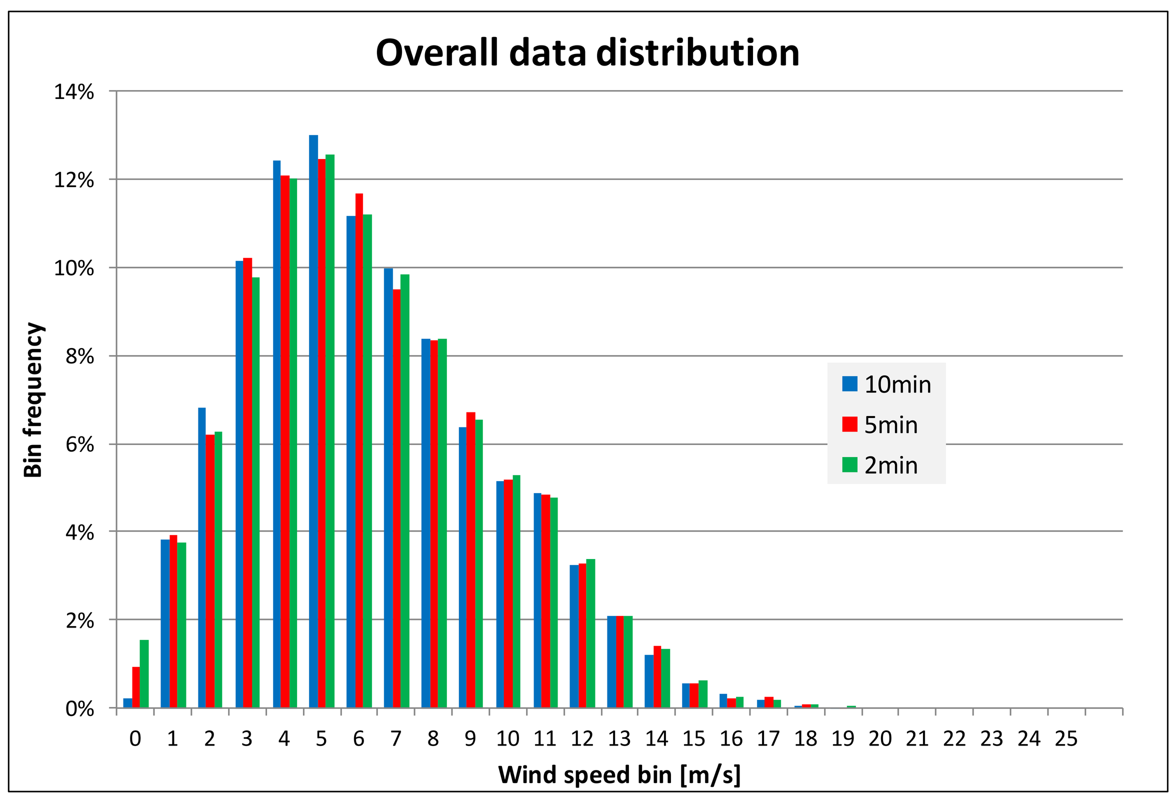
The methodology of the investigation is summarized in the following steps:

1. Obtain raw wind data that are averaged over a period of 1 minute. The available data are from a certified wind mast, referring to the period 20 Dec 2012 - 25 Jan 2013 and are sampled at 1Hz.
2. Process and re-average the wind time series over a period of 2, 5 and 10 minutes.
3. Investigate the variation in the following parameters, according to the averaging period case:
   a. The overall data distribution.
   b. The average wind speed, turbulence intensity, gust and Weibull fit parameters.
   c. The wind direction distribution and its maximum change between successive data.
   d. The average power density of the site.

The selected parameters under investigation are commonly used for both the site assessment and the power curve measurements. Another parameter which is also investigated, is the **total data file size**. Nowadays memory storage is cheaper, more affordable and reliable and less energy and space-consuming. Therefore data storage and handling is no longer an issue as it was in early wind measuring systems.

Results

The effect of the averaging period on the data distribution is presented in the following graph:



The graph shows variations in the resulting frequencies, which are significant at low wind speeds. This region is of special interest in the power curve measurements.
The following table summarizes the general parameters that describe the wind data, for each one of the three cases of averaging.

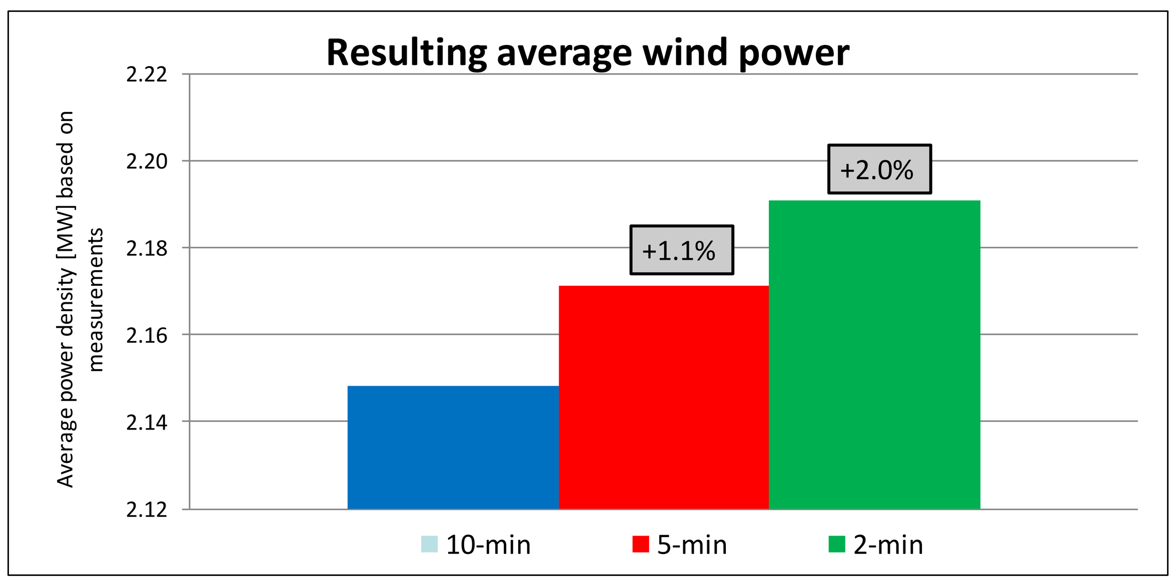
Parameter / averaging period	10 minutes	5 minutes	2 minutes
Average wind speed [m/s]	6.802	6.801	6.801
Mean turbulence intensity at 15 m/s [%]	15.11	15.18	15.14
Maximum gust [m/s]	**26.4**	**27.3**	**28.4**
Weibull shape factor	2.17	2.16	2.15
Weibull scale factor [m/s]	7.64	7.65	7.67

The results show that while the total average parameters remain unaffected by the averaging period modification, some "local" (frequency distribution at low wind speeds) and instantaneous (maximum wind gust) parameters show measurable and interesting variations.

This is better shown in the following results that concern the maximum direction change between successive data in each time series:

Parameter / averaging period	10 minutes	5 minutes	2 minutes
Maximum direction difference between successive data	347.55	352.32	358.20
Difference from 10-minute averaged data	-	4.8°	**10.7°**

A significant difference of **10.7°** is detected between the measurements averaged over 10 and 2 minutes. In this way, variations that can affect the site assessment (due to changes in the calculated wake effects) or the power curve measurements (due to changes in the acceptable direction sectors) are smoothed-out with the increase of the averaging period.
The total average wind power (concerning a diameter of 90m) resulting from each case is shown below:



The analysis shows that a **2%** in the total average wind power of a site is neglected due to the large averaging period of the wind data. Sites with higher average wind speed and stronger gusts may go beyond this 2% loss.
Finally, the data files size for approximately one month of measurements, according to each case, is summarized in the following table:

Parameter / averaging period	10 minutes	5 minutes	2 minutes
Data file size [kB]	291	580	1449

Conclusions

The effect of the averaging period on the measurement results presents several cases where differences with the standard 10-minute period are detected. While the general results remain largely unaffected, some parameters that can affect the site assessment or the power curve validation present interesting variations.
The results show that a case of wind measurements *and a power curve validation*, over a larger period with a proposed 2-minute averaged data, will provide more clear results and an increase in the overall information. This in turn will support the move towards a new measurement practice which makes use of smaller averaging periods, increasing the wind data representativeness.