PO.008

Power Curve Analysis using high-resolution SCADA Data

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Abstract

Power curve analysis of wind turbines is generally based on the 10-minutes time averaged SCADA data. Since the majority of the turbine dynamics happen on smaller time scales, the 10-minute time averaging can introduce inaccuracies in the analysis.

In the present study, the power curve of a modern multi-megawatt wind turbine is analysed by means of high-resolution SCADA data.

Data is collected by means of the OPC server of the turbine manufacturer, with the highest frequency available (of the order of few seconds). This results in roughly 3 millions data points over a period of 10 months, the corresponding power curve is shown in Fig. 1.

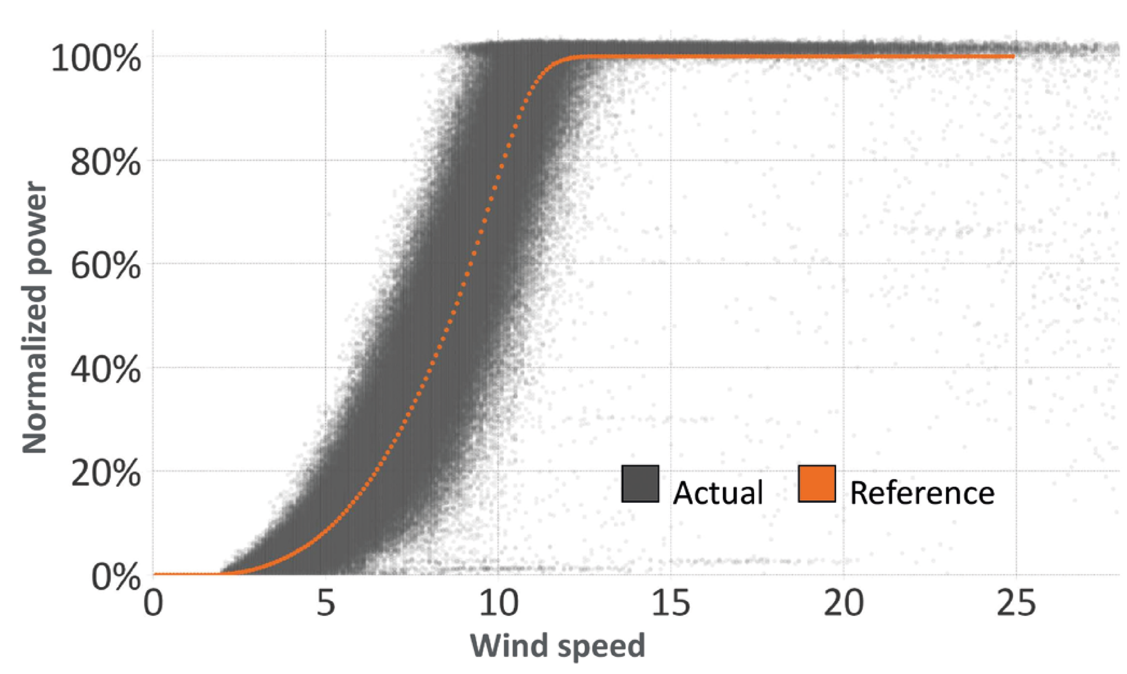

Fig. 1: Power curve obtained from raw data (grey dots) and reference power curve from OEM (orange dots).

As a reference, the power curve obtained by applying 10-minutes time averaging on the raw data set, according to IEC guidelines [1], is presented in Fig. 2.

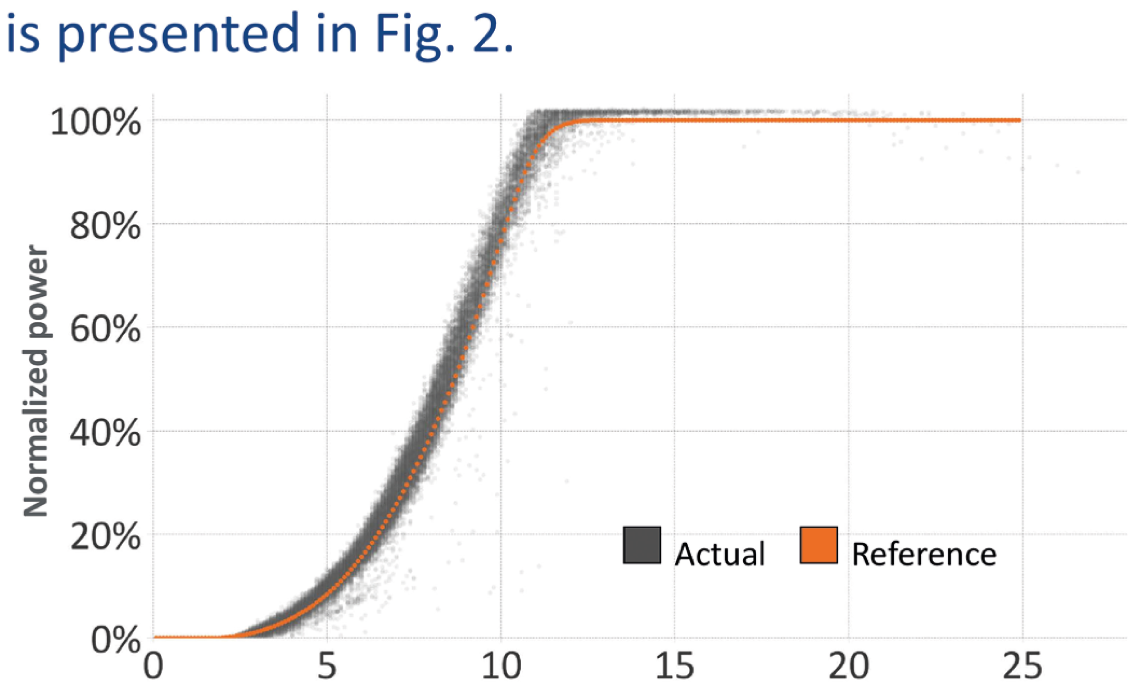

Fig. 2: Power curve obtained from 10-minute averaged data.

Objectives

1) Describe the effect of turbine dynamics, like response to wind speed ramps or fast wind direction changes, on the performance assessed using 10-minutes time averages.

2) Proposition of an alternative approach for power curve analysis based on the application of "stationarity" conditions on high-resolution SCADA data.

Turbine Dynamics

The effects on the power curve of upwards and downwards ramps of wind speed are presented in Fig. 3. The fast change in wind speed causes the points on the power curve to deviate from the reference line.

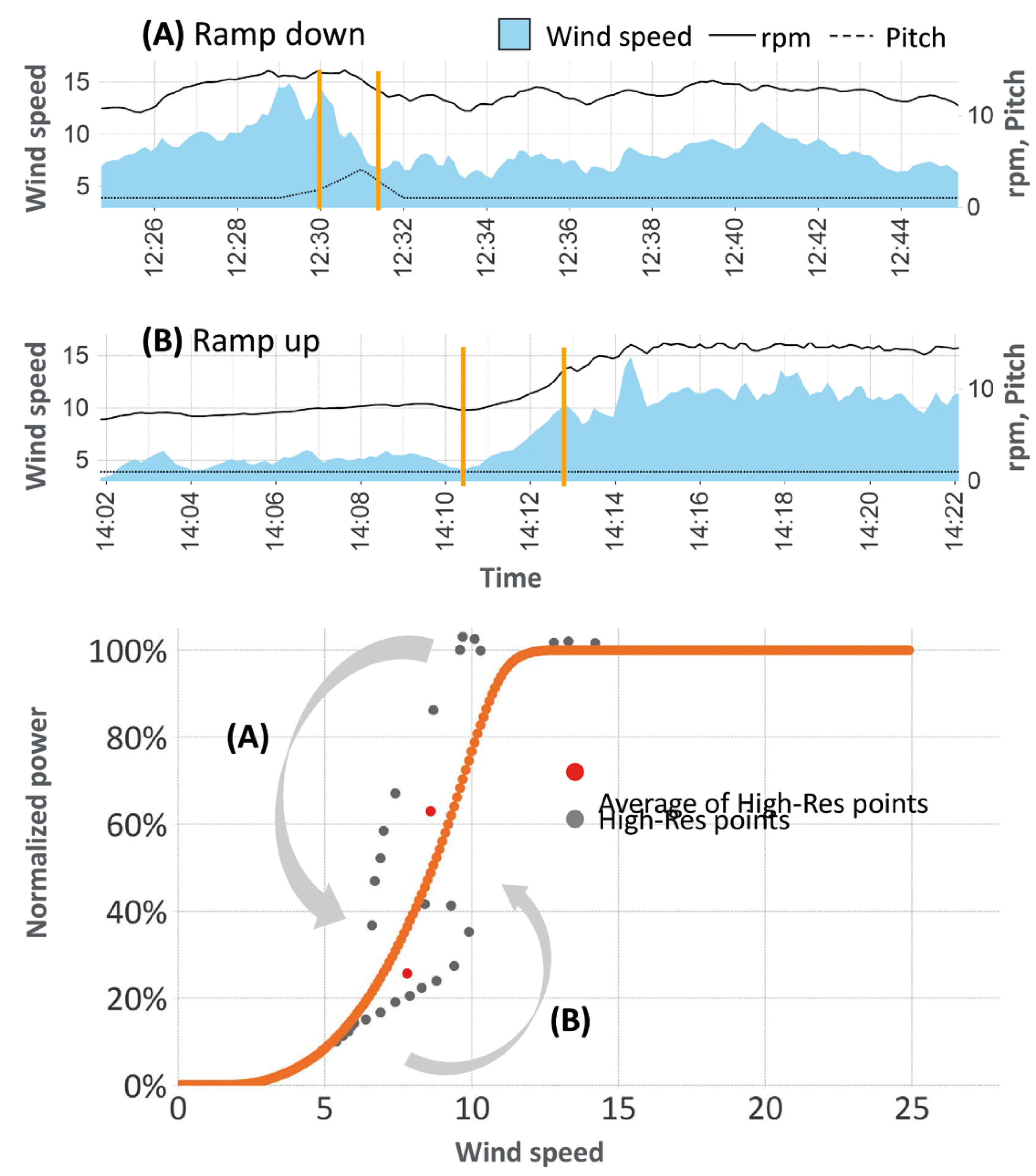

Fig. 3: Analysis of downwards and upwards wind speed ramps. The points on the left-hand side of the reference power curve refer to the downwards ramp, while those on the right-hand side refer to the upwards ramp. The two examined ramps are identified with vertical orange lines in the two upper charts.

Fig. 4 shows the effect of turbine yawing on the power curve. Within one 10 minutes interval (C+D), the wind direction changes considerably at constant nacelle position.

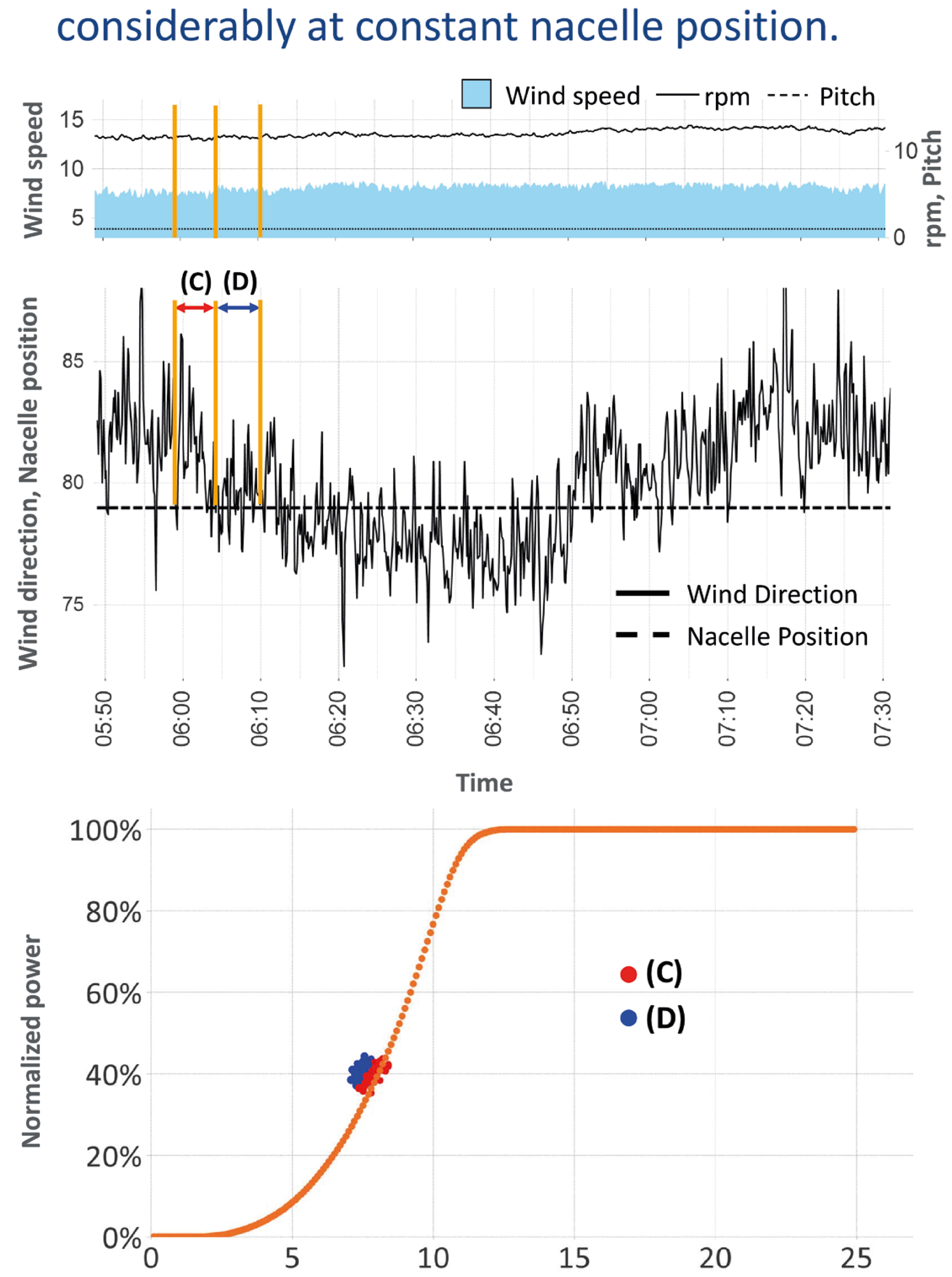

Fig. 4: Analysis of turbine yawing. The points shown on the power curve refer to the intervals identified with vertical orange lines in the two upper charts.

"Stationarity"

On the high-resolution SCADA data, "stationarity" conditions are applied in terms of data filters imposing limitations to the standard deviation (σ) of the wind speed (v) and the wind direction (θ) during different time intervals (Δt).

$$\left(\sigma(v) < a \ AND \ \sigma(\theta) < b\right)\Big|_{\Delta t = c}$$

Filter 1: a = 1m/s, b= 8deg, c = 2mins

Filter 2: a = 0.5m/s, b = 4deg, c = 2mins

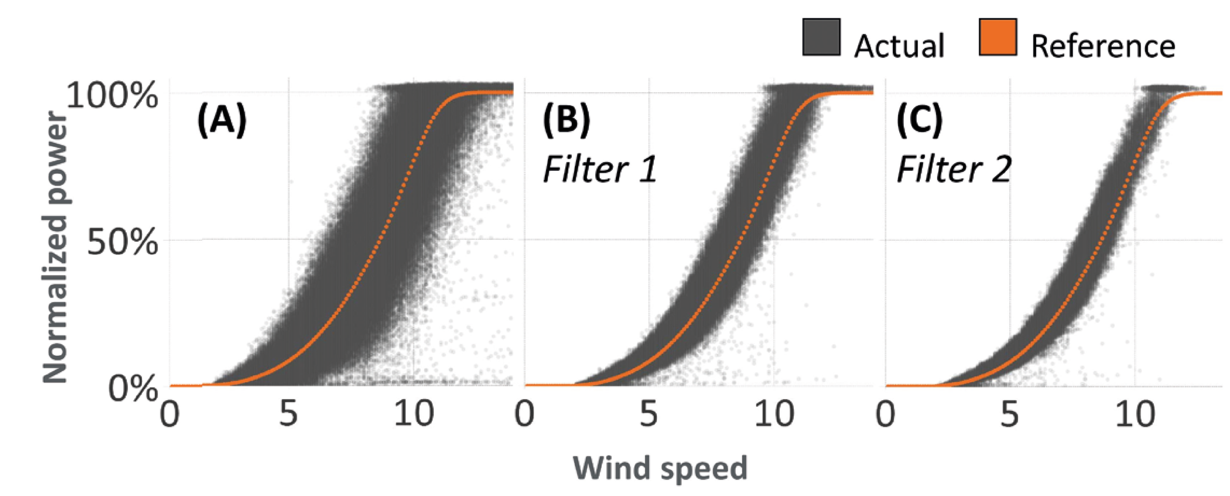

Fig. 5: Effect on the power curve of the "stationarity" conditions. Case (A) is the original power curve as in Fig.1.

Method of bins

Finally, the method of bins is applied, according to the IEC guideline [1]. As can be seen from Fig. 6, the power curve obtained with the more stringent "stationarity" condition, *Filter 2*, is shifted towards higher power outputs.

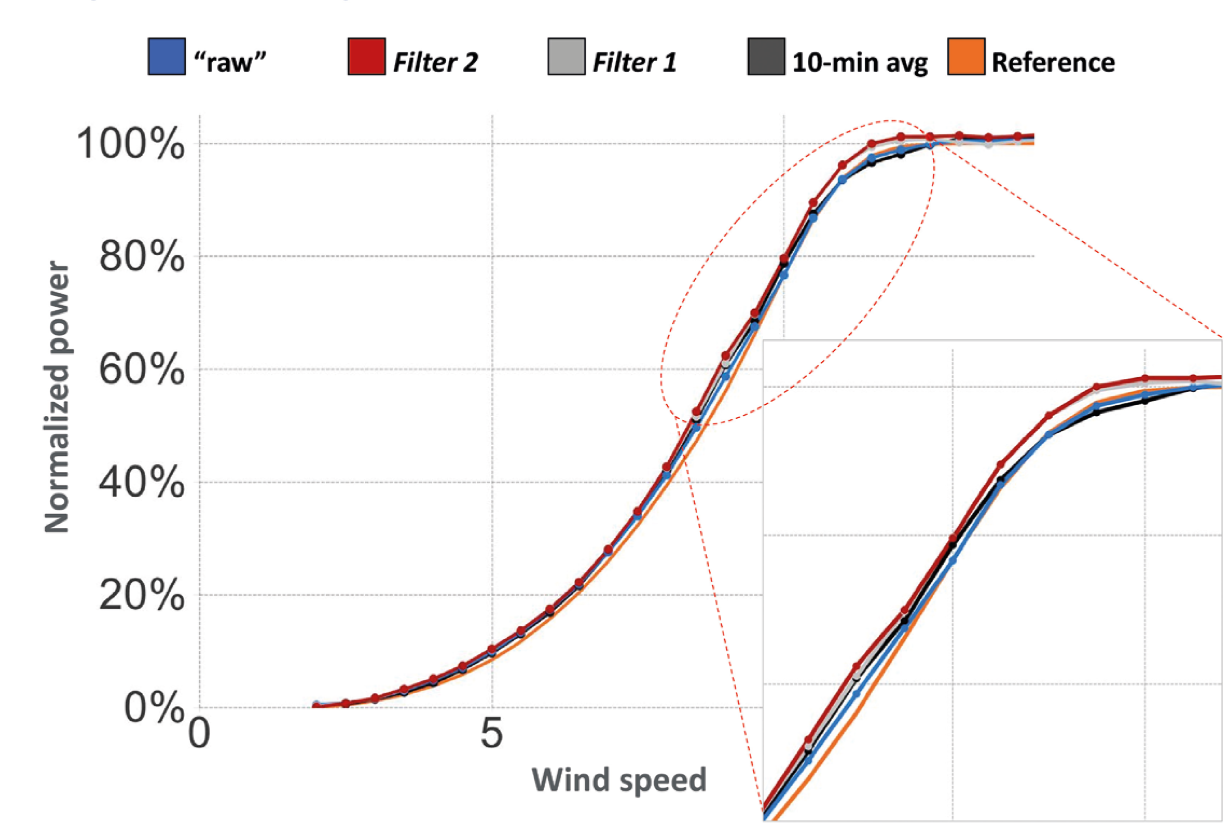

Fig. 6: Average power curves according to IEC [1]. "raw" is based on the power curve shown in Fig. 1 without applying any "stationarity" condition, while "10-min avg" is obtained from the power curve of Fig. 2.

Conclusions

High-resolution SCADA data can provide deeper insights into understanding the power curve performance of a wind turbine compared to 10-minutes time averaged data. When utilising high-resolution SCADA data, "stationarity" conditions should be applied in order to eliminate the effects of turbine dynamics.

References

1. IEC 61400-12-2, *Wind Turbines – Part 12-2: Power performance of electricity-producing wind turbines based on nacelle anemometry.* First edition, International Electrotechnical Commission, 2013.