UPGRADE VALIDATION
A description of the Power Curve validation methodology.

WWW.POWERCURVE.DK
WHY VALIDATION IS IMPORTANT
How well a wind turbine performs is dependent on many factors, and it should come as no surprise that the wind itself plays a central role.

Nevertheless, the stochastic nature of wind poses a major challenge when trying to optimize operations. It can be hard to tell if a given change or tendency in performance is caused by an upgrade or simply by coinciding weather changes.

Regardless, turbine owners need a degree of assurance that an investment is going to pay off.

We therefore conduct rigorous on-site tests to make sure we account not only for turbine type and blade condition, but also for the unpredictable nature of the wind.

OUR VALIDATION PROCESS
Demonstrating the effectiveness of any upgrade is no simple task. At Power Curve, we have made numerous reflections upon this issue, which are described in the following pages.

To account for differences in local wind conditions, we use the side-by-side method. This entails comparing the test turbine to a neighboring reference turbine.

To account for seasonal wind patterns, we base our analyses on 6-12 months of SCADA data logs both before and after we equip the test turbines with vortex generators.

Ultimately, this allows us to provide statistically reliable estimates on a case-by-case basis for how well our upgrades perform on our client’s specific fleet of turbines.

Vortex generator solutions
POWER UPGRADES FOR TURBINE BLADES

Our upgrade designs are based on vortex generator technology, and we use materials designed to survive the harsh environment in which turbine blades operate. We take great pride in being able to provide clear evidence on a case-by-case basis that our add-on solutions do indeed provide increases in AEP of 2-6%.
SIDE-BY-SIDE EVALUATION IS A WIDELY ACCEPTED METHOD FOR COMPARING THE PERFORMANCE OF WIND TURBINES. IT ENSURES THAT WIND CONDITIONS FOR THE TWO TURBINES ARE AS SIMILAR AS POSSIBLE DURING DATA LOGGING.

Based on blade condition and service histories, pairs of neighboring turbines are selected; one to be upgraded and one for reference. Using time-synchronized SCADA data from before and after VG installation, the difference in power production can then be used to evaluate the performance of the upgraded turbine.

Reference turbine
Reference turbine
Ref

Power Curve-upgraded turbine
Power Curve-upgraded turbine
PCU

6-12 months
pre-upgrade

6-12 months
post-upgrade

INSTALLATION OF
VORTEX GENERATORS

Side-by-side evaluation
OUR METHOD FOR VALIDATING PERFORMANCE
**SCADA data**

LOGGING TURBINE PERFORMANCE

### TIME-SYNCHRONIZED SCADA DATA

In order to reliably estimate the improvement in energy production, a quality set of SCADA data is crucial. Data entries need to be time-synchronized between each pair of test and reference turbine. A few missing data points here and there are of less importance.

Commonly, SCADA data is logged in the form of 10-minute averages. Parameters logged include date, time, power production, wind speed and yaw. Date, time and power production are usually enough to evaluate the performance of a given turbine.

The required period of data collection depends on the quality of the data. For instance, non-representative wind patterns or long periods of turbine downtime can be reasons for extending the measurement campaign.

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A quality set of SCADA data is key to validating the improvement gained from our upgrades.

### Data quality assurance

REFINING SCADA LOGS

**FILTERING**

Logging 10-minute power averages for 12-24 months naturally produces a large set of data. Even though the turbines operate without interruption, some inaccuracies are practically unavoidable.

We carefully investigate the data we receive and filter it in a semi-automated process. For one, we filter out data points where one of the two turbines has cut out.

Once we have refined the dataset, it is ready to be implemented in the Power Curve Data Analyzer for evaluation.
Power binning
ORGANIZING SCADA LOGS

In the side-by-side method, data is divided into power bins, meaning that we group the 10-minute averages into intervals of power production. This allows us to investigate differences in turbine performance in relation to wind speed.

The size of the intervals depends on the amount of SCADA data after filtering and on the rated power of the turbines.

Typically, 5-10% of the rated power is a reasonable interval size, i.e. 50-100 kW bins for a 1 MW turbine.

In practice, the power output of the two turbines in a given 10-minute span may fall under different power intervals. Therefore, we designate either the PCU or the REF turbine as ‘master’ and the other as ‘slave’. We then assign the given data point to the bin dictated by the master’s power output, regardless of the slave’s output. This allows for direct comparison between the two turbines.

While the process of binning data in a conventional spreadsheet application can be both time-consuming and impractical, the Power Curve Data Analyzer facilitates a much easier process. The user defines the bin intervals and any other parameters or filters for the analysis, and the tool does the work.

We evaluate the difference in power production for each bin by determining the difference between the REF and the PCU both before and after VG installation. We then find the average change for each bin, and weighted by the annual wind distribution, the change in energy production is established for each bin.
THE IMPORTANCE OF VALIDATION

Annual energy production (AEP) is a key indicator for turbine performance and provides vital input for business decisions.

To translate our test results into AEP, we base our evaluation on the change in power output before and after the PCU turbine is upgraded.

The power production is then distributed with a Weibull distribution, using mean wind speeds for the site and the expected annual uptime percentage for the turbine.

The Weibull distribution can be shaped to fit the wind climate found from the SCADA data.

When calculating the AEP improvement, we utilize the OEM-defined power curve to give the relation between measured power and the corresponding wind speed.

With the site-specific wind climate characterized by Weibull parameters, we can project the measured power improvement to a full-year AEP equivalent.

It goes without saying that a two-year testing period produces a tremendous amount of data. We have developed the Power Curve Data Analyzer to make the analysis of this data much less cumbersome.

The user defines a certain wind sector, power range, wind speed range, average wind speed and power bin size for calculating the expected change in AEP.