PO.005

Assessing wind turbine performance upgrades using only 10-minute SCADA data

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Abstract

Wind turbine operators and owners are presented a range of performance enhancing retrofit options by OEMs and third parties. Such offerings are accompanied by specific details of the expected performance improvements in terms of AEP (Annual Energy Production).

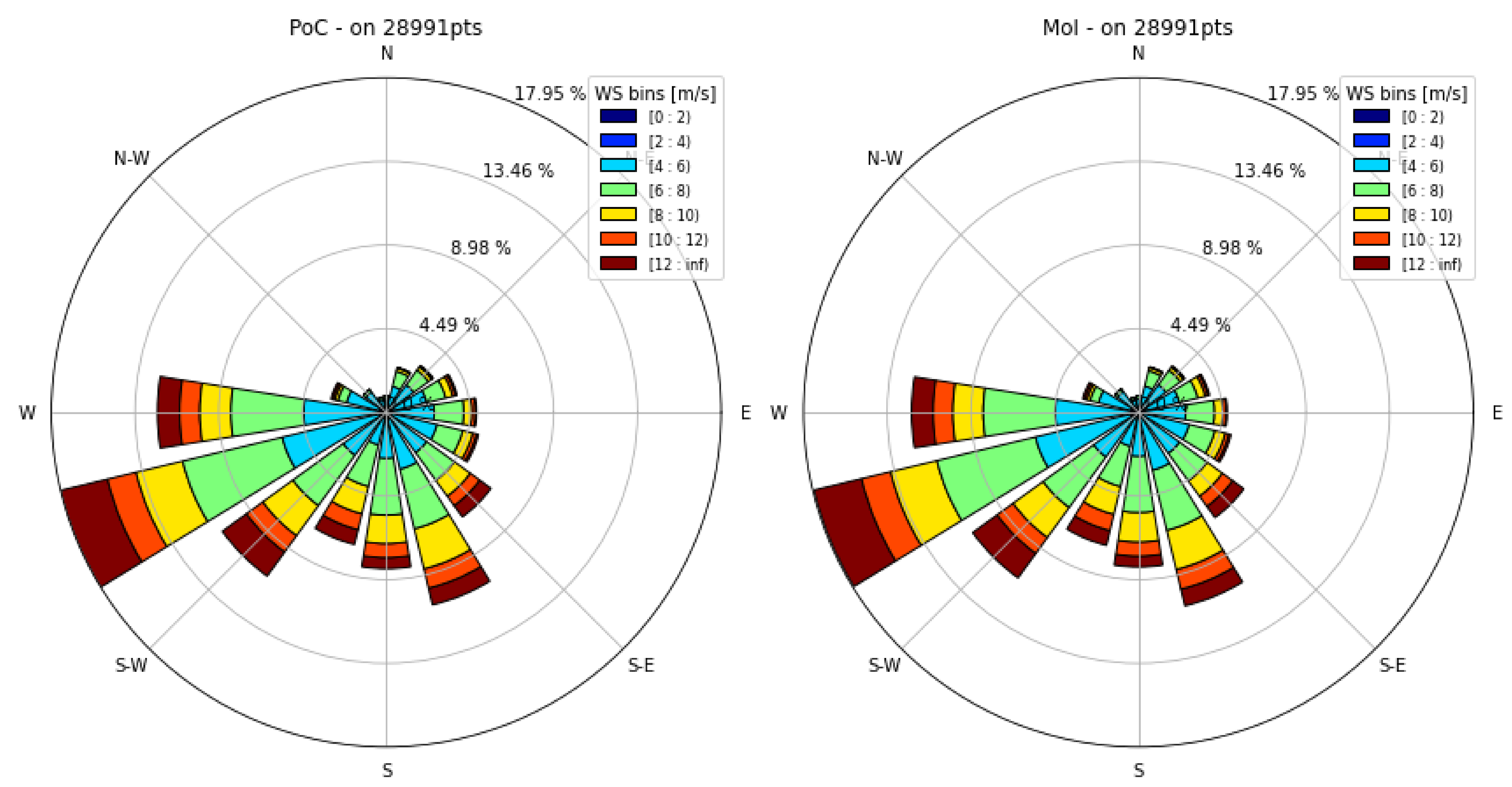
These claims can be very difficult to verify independently. The current best practice for AEP gain verification, as dictated by the IEC, would involve a PCV (power curve verification) campaign before and after the retrofit is performed on the turbine. These campaigns require the use of additional and independent wind measurement device(s).

Unfortunately, the cost of carrying out such verification campaigns is sometimes higher than the retrofit itself, and therefore can only be performed on selected candidate turbines of a wind farm. This results in relatively high levels of uncertainty surrounding the overall gain that can be achieved at a wind farm or fleet level.

In this study we investigated the use of SCADA 10-minute data as a pragmatic means of quickly and efficiently assessing potential AEP gains.

Method

1. We **gather 10-minute SCADA data before and after the installation of the retrofit(s)** to evaluate the impact on wind turbine performance, aiming for a timeframe of **12-months** or more before and **6-months** or more after the installation for accuracy.
2. Using only the 10-minute dataset, we **automatically filter out periods of abnormal turbine operation**, using state detection algorithms to ensure strict filtering and optimal data quality without the need for event logs.
3. **To enhance the dataset**, we couple the filtered 10-minute dataset **with** external environmental data from a **weather API** provider. Depending on the location of the turbine, this allows us to obtain new variables such as pressure, temperature, humidity, rainfall, and snow events. These additional variables enable us to perform air density correction and further filtering.
4. We **match 10-minute data points from "before" and "after" periods, based on all environmental variables** to allow accurate comparison and evaluation of turbine performance, ensuring both datasets cover the same ranges of conditions and events, and eliminating environmental variation that may affect the results. Properly matching each environmental variable in both the "before" and "after" datasets is crucial for reliable results. **Finally, the statistical distribution of each environment variable should be identical in both datasets.**



The graph presented above illustrates the similarity between the windrose plots generated from the processed datasets before (left), and after (right) the upgrade.

5. Finally, we perform a **standard PCV analysis on both datasets**, similar to the IEC process, and calculate the AEP using the wind distribution from the entire dataset.

Core assumption & limitation

This comparison analysis is highly dependent on the **Ceteris Paribus assumption**, which assumes that all relevant variables are held constant, except the one being studied. In our case, we assume that the sensor measuring the environmental variables remain unchanged throughout the periods, while the power output has the potential to change due to the retrofit.

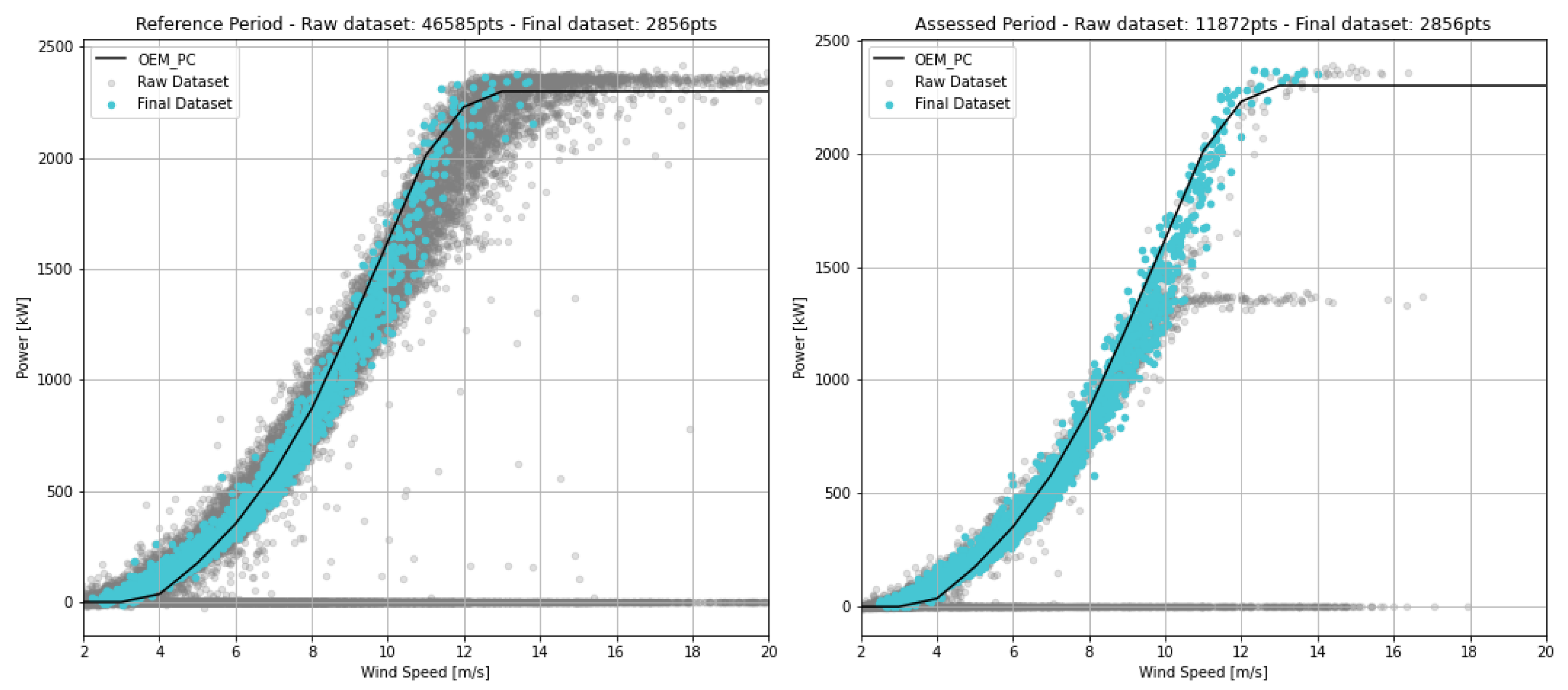
However, the longer the analysis period, the greater the likelihood that this assumption may be false. For example, **changes or defects in the nacelle anemometry or controller updates can occur, potentially affecting the accuracy of the analysis.**

To mitigate this risk, we have developed several pre-processing steps as well as a set of best-practice guidelines that should be followed. Nevertheless, the key to ensuring data quality **is a clear and strict planning of the retrofit campaign**.

Results

Once all pre-processing steps have been applied to the dataset, the data analyst should obtain two datasets where the wind turbine was in normal operation and the environmental conditions were precisely identical. This filtered and pre-processed dataset can then be used for the assessment of the upgrade.

Ceteris Paribus, a comparison is now possible.



Example of filtered and processed datasets before (left), and after (right) the upgrade. In grey, the raw dataset, in blue the final processed dataset, ready for PCV analysis.

Once the AEP is calculated for both the "before" and "after" periods, the influence of the upgrade on AEP, or the **"DELTA AEP"** can be computed. Through our experience, we found that aggregating these deltas at the wind farm level and **studying the general trend in results provides insights** into the actual gains of retrofit installations, particularly **when the wind farm includes control turbines** that did not receive upgrades.

Regarding uncertainties

When using SCADA data for portfolio-level analysis, it is almost **impossible to obtain calibration reports** and mounting information **for each sensor of each turbine**. In many cases, sensors such as nacelle anemometers and temperature sensors do not even undergo any traceable calibration. Due to these limitations, it is not possible to perform a full propagation of uncertainties (Type A+B) in a SCADA-based analysis.

Therefore, in the current implementation, we have restricted our analysis to provide **only Type A uncertainties**, i.e. statistical uncertainties.

Conclusions

- 10-minute **SCADA data can be used for assessing wind turbine upgrades** with a careful pre-processing of the dataset and a clear campaign planning.
- **Trend analysis over a large wind farm campaign** can provide valuable insights on the quality of wind turbine retrofits, often surpassing those obtained from a standard ad-hoc PCV campaigns.
- This **method offers a pragmatic and cost-effective approach** for wind farm operators and owners who wish to assess the effectiveness of retrofits.

References

1. *Electrotechnical Commission (IEC). Power Performance Measurements of Electricity Producing Wind Turbines; IEC 61400-12-1 Ed. 2; International Electrotechnical Commission: Geneva, Switzerland, 2017*

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