Using SoDAR Wind Speed Measurements for Wind Turbine Power Curves

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Abstract

A power curve measurement campaign was conducted on two multi-megawatt wind turbines using wind measurements from a Second Wind Triton SoDAR and a 100 m meteorological tower. The study was conducted in flat terrain using 5 months of data, including a large range of wind conditions from both windy season and non-windy season periods. The data set was filtered to exclude biasing effects attributed to site conditions (wakes from nearby turbines, etc.), to the meteorological tower (tower shadow, precipitation, etc.) and to the SoDAR (unfavorable atmospheric and acoustic conditions). For comparison, power curves were generated with hub height wind measurements from both the SoDAR and anemometer data. Different data processing methods are also compared, including time averaging of wind and power data, binning by wind shear, and generating short term power curves with random subsets.

Wind turbine power curves are essential in many aspects of wind energy. The IEC Wind Energy Standards for Performance Measurement Techniques has a formalized a power curve methodology[1] that is widely accepted and used whenever practical or contractually mandated. Less involved techniques may have more utility for applications such as O&M diagnostics, where it is important to reach a result in as short a time as possible. Because SoDAR instruments like the Second Wind Triton are so easily deployed, they are an obvious choice for obtaining wind speed measurements from hub height and above. This paper demonstrates that 10-minute wind speed measurements from a SoDAR can be used for power curves with minimal data processing. While this study did span several months of data, the results also show that the curve converges well with just a few days data. While the specific turbine type, rating, and specified power curve were not known in this case, the repeatability of the result suggests that major discrepancies or changes in a turbine’s power curve could be easily detected.

Methods

The two power curves for turbine T1 compared below were derived from hub-height wind speed measurements from the Triton and the met mast. Good agreement is achieved in the mean power curves, while the Triton shows slightly more variability.

To explore the affects of extreme wind shear, the data set was categorized by ten-minute power-law shear coefficient; Low (<0.3), Med(0.3 to 0.6), and High (>0.6), which has no data >9 m/s. Surprisingly, the low/Med power curve comparison shows very little difference.

To demonstrate that the power curve converges even with relatively short data sets (few points per wind speed bin), the filtered data set was randomly re-sampled to contain only 1, 2, and 4 days of ten-minute records. Even the single day power curve agrees well over the range of wind conditions included.

Results

The recorded data consisted of 23180 ten-minute records spanning approximately five months. Data filters were applied to remove peculiarities, as described in Table 1. The remaining data set had 7347 records, with the distributions shown in Figure 2.

Using a 1-hour moving average filter to smooth the power and wind speed data, the variability in the Triton based power curve is reduced somewhat. The mean power curve is unaffected, except at the knee.

This study was conducted without knowledge of the specified power curve for the turbines, so there is no reference curve to compare with. However, the power curves generated with anemometer and SoDAR measurements are nearly identical. The mean curves match within reasonable expectations for an un-calibrated site. The SoDAR’s higher standard deviation is an indication of additional scatter in the ten-minute wind speed measurements. This scatter can be reduced with a moving average filter, but this may or may not be beneficial for some applications, because filtering also smooths machine related scatter, which is often of interest.

Data from different shear levels produced nearly identical mean and standard deviation values. This result has the surprising implication that, at least with this data set, there is no apparent benefit to aggregating measurements from above and below hub height into an effective wind speed. We hope to study sites with different shear profiles and turbines to see if this result is common. The convergence of short term, re-sampled data suggests that even brief campaigns can be used to assess performance. The power curve for off-axis turbine T2 is also shown to be satisfactory, suggesting that a single remote sensing device can be used for several campaigns at once.

Conclusions

This study was conducted without knowledge of the specified power curve for the turbines, so there is no reference curve to compare with. However, the power curves generated with anemometer and SoDAR measurements are nearly identical. The mean curves match within reasonable expectations for an un-calibrated site. The SoDAR’s higher standard deviation is an indication of additional scatter in the ten-minute wind speed measurements. This scatter can be reduced with a moving average filter, but this may or may not be beneficial for some applications, because filtering also smooths machine related scatter, which is often of interest.

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References


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