Effect of averaging time in wind speed measurements on energy production estimates

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1 Introduction

Power curves are typically constructed using simultaneous wind-speed and power measurements, according to the IEC 61400-12-1 standard [1]. These time series of wind speed and power are typically sampled at 1 Hz. To ensure sufficient correlation between both time series, the 1 Hz samples are averaged over a certain time interval, τ, as a pre-processing step, before the binning into a power curve. According to the standard, τ should be 10 minutes for large wind turbines and 1 minute for small ones. The power curve obtained from a given data set will obviously depend on the choice of averaging interval, but the difference is small [2].

To predict the annual energy production (AEP), the power curve is combined with a wind speed probability function (Rayleigh, Weibull) or on-site measurements. These wind data also depend on the averaging time, as pointed out by Brothers and Arthur [3]. Elliott and Infield [2] recently showed that an inconsistent averaging time for the power curve and the wind data causes a systematic error in the estimated AEP. Yet often hourly wind speed data (e.g. from meteorological stations) are combined with 1'-averaged power curve data for small wind turbines [4–6] and 10'- data for large ones [7]. In this paper, we suggest a technique to compensate the power curve for differences in averaging time between the power curve and the wind data.

2 Approach

Our compensation of the power curve for inconsistent τ is inspired by the correction for turbulence intensity (TI) [8–10]. The TI is defined as the average standard deviation per bin divided by the mean wind speed in the bin. These standard deviations are the square root of the variances obtained during preprocessing, when the 1 Hz samples are averaged over τ. The TI thus clearly also

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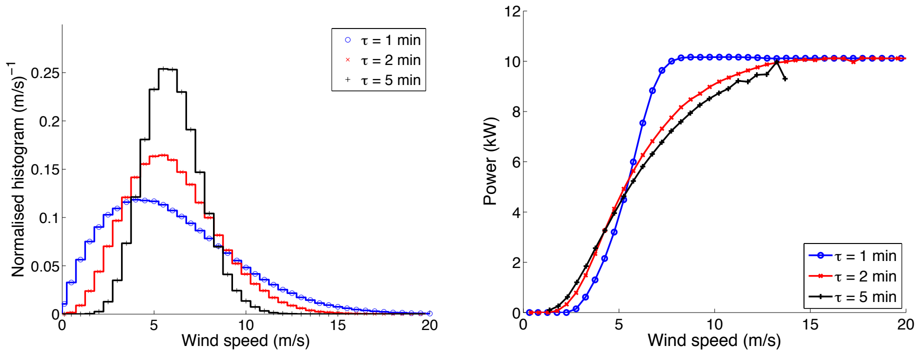

Figure 1: Effect of increased averaging times on the wind speed normalised histograms (left) and the power curve (right). The averaging times shown are 1 minute (circles), 2 minutes (crosses) and 5 minutes (pluses). The mean power output (integral of the product of the like curves left and right) is always the same.

depends on τ: when τ increases, more variation can be expected in the interval, and thus TI will be higher. On the other hand, the variance of the ensemble of τ-averaged data points will be lower.

These effects are illustrated in Figure 1, showing power curves for three different averaging times: 1, 2, and 5 minutes, calculated from one set of simulated uncorrelated Weibull-distributed wind data and corresponding power data. (One should note that we excluded autocorrelation in the wind to overemphasize the effect of the averaging time variation.) The increase in τ is very similar to an increase in TI. The question that this article addresses then is: can we compensate for differences in averaging time in a similar way that we can compensate for turbulence effects?

3 Main body

For a given τ, the TI can be calculated from wind speed data provided the data are available at sufficiently-high sample frequency, say 1 Hz. The TI can be calculated either directly (through averaging) or indirectly via the power spectral density function (PSD) of the wind data [8, 11].

When long-term high-frequency wind data are available, we suggest to average the data with an averaging time equal to that of the power curve. Often, however, only low-frequency (e.g. hourly) data are available for a long period. In that case, we propose to perform a short-term high-frequency wind speed measurement campaign to derive the PSD of the site. With this PSD, the TI of the site can be derived for any τ, and the power curve can be compensated to match with the long-term wind data.

We illustrate our approach for two sites, A and B, where 10 days of data sampled at 1 Hz and 4 Hz were available. We deliberately selected two sites with distinct wind climates: one with a very low wind speed and high turbulence, and one with a higher mean and lower turbulence. Site A has a mean wind speed of 3.1 m/s (at 15 m height) over the measured period and a high TI (32.2 % at 10 minute averaging time). Site B has a decent mean wind speed of 6.7 m/s (at 27 m height) over the period considered, and a markedly lower TI (6.9 %, again at 10 minute averaging time).

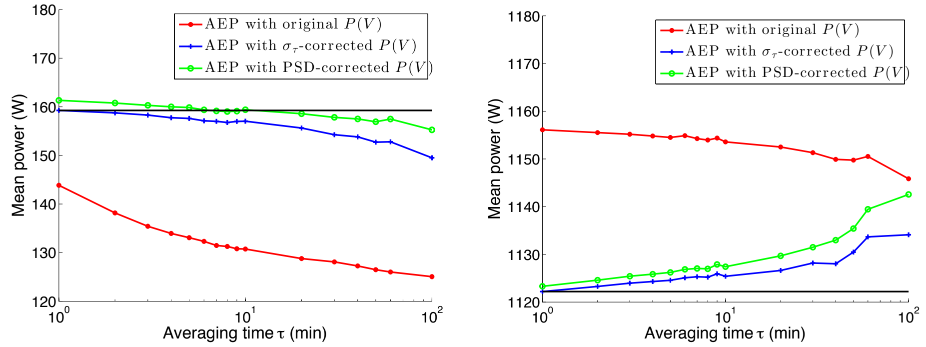

Figure 2: Mean power estimate as a function of the averaging time used. The line with circles shows the estimate with the power curve corrected from the power spectral density function. Site A is left, site B right.

Figure 2 shows the estimated mean power as a function of the averaging time τ of the wind data, based on a power curve with a fixed τ of 1 minute. Simply correcting for TI already yields a considerable difference (compare the shift between the red and blue curves at τ = 1'). For larger τ, and using the consistent τ = 1' for wind and power as benchmark (i.e. the black line originating from the blue curve at τ = 1'), the uncorrected estimate decreases (the downward slope of the red curve) as this estimate is not compensated for the increasing averaging time. The compensated power curves are much more horizontal, as well for the direct method (blue curve) as for the indirect method via the PSD (green curve). The compensated power curve is clearly more robust for changes in τ. Yet the method still leaves a residual difference for the compensated estimates (blue and green curves versus the black line), especially at higher τ.

4 Conclusions

In this article, we show how a power curve can be compensated for an inconsistency in averaging time, τ, between wind speed data and the power curve. This compensation really is a correction for the turbulence intensity (TI), which varies with averaging time in a systematic way.

When long-term high-frequency wind data are available, we suggest to average the data so that the averaging times of the wind data and power curve match. When only low-frequency data are available, we propose to perform a short-term high-frequency wind speed measurement campaign to derive the power spectral density (PSD) function of the site. With this PSD, the TI of the site can be derived for the τ of the power curve, and the power curve can be compensated to match with the long-term wind data.

5 Learning objectives

- Understand how inconsistent averaging times between power curve and wind data affect energy yield predictions.
- Compare the effects of turbulence and averaging times on power curve estimates.
- Evaluate how power curves can be compensated for differences in averaging time when compensating for turbulence.

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