Nacelle Anemometer Power Curve Measurements

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1. Case-study Results

ArcVera performed IEC-61400-12-1 power curve (PC) measurements on 6 wind turbines at 3 different projects. ArcVera used the Nacelle Transfer Function (NTF) to derive free wind speed and evaluate the impact on the AEP compared to 61400-12-1 procedures. The average and standard deviation of the AEP difference between NTF and 61400-12-1 procedures vary with the Rayleigh wind speed. Table 1 shows that average AEP deviations are 1% and standard deviation is 1.3% when Rayleigh wind speeds are 8 m/s.

***The wind turbine model variant A-2 at Project A is the same OEM and rotor diameter as the other turbines at other sites, but has 10% lower rated power.**

2. Can the NTF from a turbine at one site be used for a turbine at a different site?

As shown above, once an NTF is derived at a turbine, the free wind speeds at that turbine can be recreated with good accuracy.

			Rayleigh Wind Speed (m/s)					
Project	**WTG**	**Model**	**5**	**6**	**7**	**8**	**9**	**10**
H	H-1	Same	-1.4%	-1.1%	-1.1%	-1.2%	-1.4%	-1.6%
H	H-2	Same	-0.4%	-0.3%	-0.1%	0.1%	0.3%	0.5%
H	H-3	Same	2.0%	1.7%	1.3%	0.9%	0.6%	0.3%
I	I-1	Same	-0.9%	-0.9%	-1.3%	-2.1%	-3.0%	-3.9%
A	A-1	Same	-3.0%	-2.5%	-2.3%	-2.5%	-3.0%	-3.4%
A	A-2	Variant*	-4.2%	-2.3%	-1.4%	-0.9%	-0.6%	-0.4%
		Average	-1.3%	-0.9%	-0.8%	**-1.0%**	-1.2%	-1.4%
	Standard Deviation		2.2%	1.5%	1.2%	**1.3%**	1.6%	1.9%

Table 1: Deviation between AEP using NTF corrected nacelle anemometers and IEC compliant met tower data

Project	WTG	Model	Slope	Offset	Slope (zero offset)
H	H-1	Same	0.941	0.221	0.962
H	H-2	Same	0.947	0.237	0.966
H	H-3	Same	0.945	0.242	0.964
I	I-1	Same	**1.156**	-0.353	**1.124**
A	A-1	Same	0.985	0.029	0.988
A	A-2	Variant	0.997	-0.138	0.985

Table 2: Nacelle Transfer Function (NTF) at six sites

Table 2 above shows that the NTF within a site for turbines of the same OEM and rotor diameter are remarkably similar. For instance, the standard deviation (STDEV) of the NTF for the three turbines at Project H is only 0.2%. Similarly, the two turbines at Project A have similar NTF, with only 0.2% STDEV even though one turbine has 10% lower rated power. If we average the NTF at Project H and compare to average NTF at Project A, STDEV is 1.6%. **This means we can typically use NTF from one site at another site with reasonable uncertainty.** However, NTF at Project I shows 16% higher wind speeds than the lowest NTF and 12% above the average of the others. This anomalous NTF could potentially be a result of improperly entered controller settings or yaw misalignment or physical flow conditions at the site such inflow angle. A strong quality control program should identify outlier nacelle transfer functions. In fact, that is one of the advantages of testing all wind turbines in a wind farm using nacelle anemometer testing. In this case, the NTF from Project I would be excluded since it is a 2 standard deviation outlier. However, once outliers are removed, it may still be best to use an ensemble of data to minimize the impact of site specific factors that cannot be removed.

Also, the ensemble of data will give an indication of the uncertainty of the analysis. Best practice would be to use NTF from at least six turbines from at least three sites in order to reduce the impact of site specific factors.

If the outlier from Project I were not removed, this ensemble approach would reduce standard deviation of slope to 6%. This is within the 8-11% uncertainty range we are targeting for this method. Removing the outlier gives standard deviation of slope of 1.25%.

3. Final Remarks

This paper shows the importance of quality assurance when using the NTF derived from one site to apply to another site. An example is given where the slope of the NTF from one site varied by 16% from the slope at another site. By removing the outlier, standard deviation of slope is reduced to 1.25%. If the outlier is not removed, standard deviation of the slopes can be reduced to 6% by using an ensemble approach using data from all six turbines at three sites. Careful quality assurance of the NTF will both reduce uncertainty and give an indication of the magnitude of the resulting uncertainty. Future work will analyze NTF from additional projects and cross compare AEP using NTF from turbines at other sites.

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