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Advances in the Treatment of the Influence of Meteorological Variables on Wind Turbine Power Curves in Warranties

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Introduction

Wind turbine power curves are influenced by meteorological conditions, e.g. by the turbulence intensity and the wind shear. This must be considered for power curve warranties. Wind turbine suppliers cannot overtake the risk that a warranted power curve is not met due to site specific meteorological conditions significantly different from the reference conditions of the warranted power curve. On the other hand, for wind farm developers and operators the real world power curve examined at their wind farm site is the relevant measure for economic considerations and should ideally be warranted. Advanced procedures how to deal with this conflict have been developed over the past years in the frame of designing and negotiating power curve warranties and within the work of different harmonisation groups [1], [2].

Key Features of Different Methods

Method	Pros	Cons
1 data filtering	no assumptions on model approaches needed, direct filtering out of effects	often significant amount of data filtered out (30%-80%): increased measurement period, sometimes test impossible
	no consideration of uncertainties needed (higher effective warranty level)	if filter range large: more data, but still significant influence of meteorological variables within filter range possible
	higher cost of REWS measurement may be avoided	if filter range small: lack of data
		warranted and verified power curve may not be representative for the site conditions (real world power curve as preferred for wind resource assessments not met)
		gap in most present warranties: no treatment of deviations of meteorological conditions at reference measurement position and turbine position, danger of filtering out wrong range
2 data normalisation (REWS, shear/veer, turbulence, flow inclination)	full method description for shear/veer and turbulence normalisation given in CDV IEC 61400-12-1, Ed.2 [1]	not all turbulence effects covered by normalisation
	method for normalisation in terms of flow inclination available [3]	REWS approach critical at very high wind shear
	no data loss by filtering	measurement of REWS more expensive than measurement of hub height wind speed, especially in complex terrain
	gaps of normalisation procedures addressed by uncertainty approaches in CDV IEC 61400-12,1 Ed.2	significant uncertainty remains due to shortcomings of normalisation methods
	normalisation procedures can be used to convert warranted power curve to site specific conditions for wind resource assessments	transfer of meteorological variables from reference measurement position to turbine position only poorly treated in CDV IEC 61400-12-1, Ed. 2
3 additional uncertainties (no normalisation, no filtering)	uncertainty models provided in CDV IEC 61400-12-1, Ed.2	high uncertainty, lowering of effective warranty level
	no data loss by filtering	warranted power curve may not be representative for the site conditions
	higher cost of REWS measurement avoided	
	uncertainty approach also applicable for wind resource assessments	
4 warranty of site specific power curve	warranted power curve representative for site conditions (wind resource assessment more realistic)	sometimes difficult to determine site specific conditions for designing site specific power curve; OEM's have problems to get detailed information from customers
	no data loss by filtering	
	uncertainties due to meteorological effects reduced (higher effective warranty level)	some uncertainties of power curve verification remain due to deviation of meteorological conditions in measurement period from mean conditions (e.g. seasonal effects)
	higher cost of REWS measurement may be avoided at power curve test	more expensive REWS measurement preferable for site evaluation to determine shear/veer conditions
5 inner / outer range approach [4]	no data loss by filtering	warranted power curve may not be representative for the site conditions (real world power curve as preferred for wind resource assessments not met)
	simple application	uncertainty of power curve testing data in outer range rather difficult to determine
	higher cost of REWS measurement may be avoided	definition of inner /outer range problematic (arbitration), some influence also in inner range possible
6 warranty of power curve simulation model (black box model of wind turbine provides power values for the environmental conditions present in each 10-minute period)	no data loss by filtering	high effort for OEM for setting up black box model
	model expected being more accurate than normalisation procedures of CDV IEC 61400-12-1, Ed.2	likely REWS measurement required, higher cost
	no consideration of uncertainties needed (higher effective warranty level)	unclear how black box model will be provided and warranted (full model to be provided in frame of TSA negotiations)
	influence of seasonal effects covered (advantage over method 4)	hidden issues possible due to lack of experience, e.g. power curve interpolation problem [5]
	model can be used for wind resource assessments	

Conclusions

Classical data filtering (method 1) has found to be problematic in practice. Data normalisation to reference conditions (method 2) or coverage of the effects by additional uncertainties (method 3) according to [1] are useful alternatives. However in case of method 2, the application of the REWS approach in complex terrain is hardly feasible due to very high cost. The warranty of site specific power curves (method 4) is clearly preferable and can be combined with methods 1, 2 or 3 to cover deviations of the meteorological effects in the testing period from the mean conditions. The inner/outer range approach (method 5) sounds simple, but in reality it is no real technical solution. Method 6 is promising but lacks practical experience.

References

[1] CDV IEC 61400-12-1, Ed. 2, Wind turbines - Part 12-1: Power performance measurements of electricity producing wind turbines, July 2015

[2] Power Curve Working Group , www.pcwg.org

[3] I. Lezaun Mas, REWS, Presentation at Power Curve Group Meeting, April 2014, Roskilde

[4] T. Blodau,, Review of Inner/Outer Range Proposal, Presentation at Power Curve Group Meeting, May 2013, Hamburg

[5] A. Albers, Understanding the Power Curve Interpolation Issue, Presentation at Power Curve Group Meeting, March 2016, Hamburg