Requirements to Cup Anemometers Applied for Power Curve Measurements under the Danish Approval Scheme for Wind Turbines.

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The Danish Energy Agency

Introduction

This recommendation specifies requirements to cup anemometers applied for Power Curve Measurements under the Danish Approval Scheme for Wind Turbines, viz. chapter 3.8.2 of "Technical Criteria for the Danish Approval Scheme for Wind turbines", Ref 5.

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Background
The deviations in cup anemometer readings and behavior, revealed in field comparisons and laboratory tests in the EU projects SITEPARIDEN and CLASSCUP has prompted the Advisory Committee under the Danish Approval Scheme to establish a sub-advisory group to advice on how these findings should affect requirements in power curve measurements.

The advisory group has come to the following recommendations.

Recommendations:

Cup anemometers shall apply to the follow requirements[1]:

Characteristics

1. The definition of the measured average wind speed for power curve measurements shall be the horizontal wind speed, which causes the wind inclination characteristics of the cup anemometer ideally to be a cosine function (wind inclination characteristics is the ratio of the response at a given inclination angle to the response at an angle of zero). All uncertainties of the cup anemometer shall be related to this wind speed definition.
2. The actual wind inclination characteristics for inclination angles from -10° to +10° and wind speeds from 5m/s to 14m/s may not deviate from the cosine function with more than +0.02 and -0.03, as indicated in Fig. 1 below.
3. The distance constant shall be below 3m, measured and determined according to IEA 11, Annex 2 and 7, Ref. 1.
4. The maximum over-speeding level shall be below +3% and above –0.5 % at 15 % turbulence intensity for sinusoidal longitudinal wind speed variations up to 2Hz, or until a frequency of which a steady over-speeding level has been reached. Measurements can be made according to procedures used in the CLASSCUP project, Ref. 2, or by alternative methods that are consistent with these procedures.
5. The friction torque $M_{friction}$ of the cup anemometer rotor at temperatures between -5°C and 40°C and wind speeds between 4m/s and 16m/s shall be less than required by the following relation:
   $$M_{friction} \leq K_f \cdot R \cdot A \cdot (K_a \omega)^{2/3}$$
   where R is the cup anemometer arm [m], A the projected cup area [m^2], ω the rotational speed [rad/s], K_a a dimensional constant equal to 1s/rad and K_f is a proportionality factor equal to 0,03N/m^2.
   Friction shall be measured by a flywheel test, in which a flywheel substitutes the cup anemometer rotor. The deceleration from a rotational speed equivalent to 20m/s down to 4m/s under steady temperature conditions for both bearings shall be measured, and the friction in the wind speed interval 4m/s to 16m/s shall be derived. The measurement procedure from the CLASSCUP project, Ref. 2, or equivalent, should be used.
6. The cup anemometer shall have a positive rotor torque from all wind directions at stand still.
7. The calibration of the cup anemometer shall be independent of wind direction.

[1] The present requirements will be revised when sufficient experience has been gained, and a revision is found appropriate

8. The linearity correlation coefficient in calibration shall meet the requirement: $r \geq 0.99995$.
9. The cup anemometer shall be CE-marked according to Ref. 4.
10. A field comparison with another cup anemometer, that meets all requirements 1-9, may not deviate by more than 1%, using the field comparison procedure described below[2].

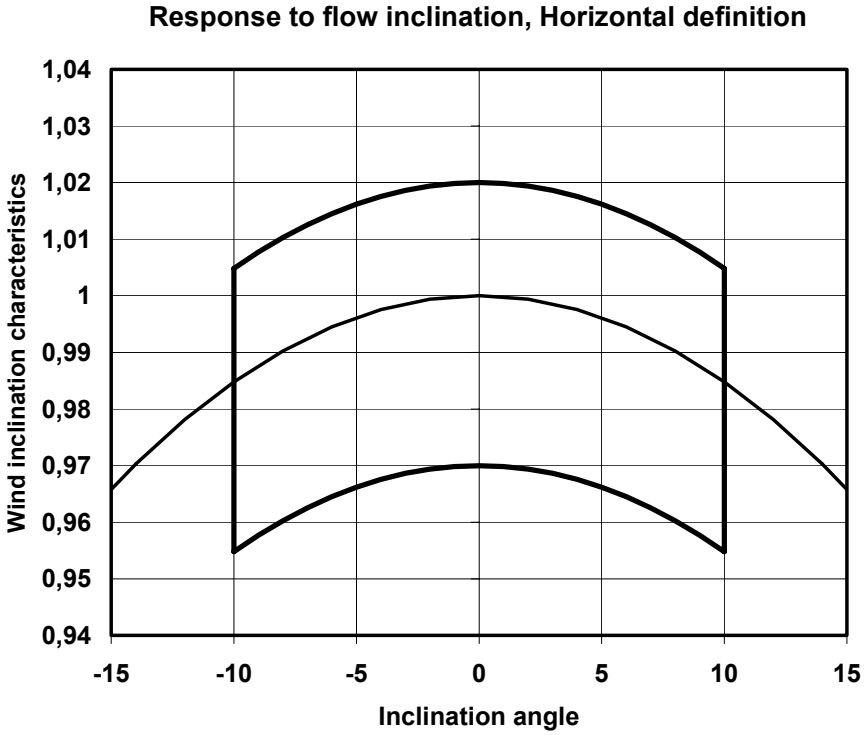

Fig. 1 Requirement bands for wind inclination characteristics

Geometry of a cup anemometer

The geometry of a cup anemometer that meet the requirements of the above-mentioned characteristics shall include the following requirements:

I. Three cups
II. Long, thin and rotational symmetric neck
III. Slender and rotational symmetric body
IV. Line connection through the bottom of the cup anemometer and the supporting tube

[2] One cup anemometer type that meet all requirements 1-9 is the RISØ P2546 cup anemometer

Field comparison procedure

The field performance of the cup anemometer shall be verified by field comparison with another cup anemometer on a 30m mast in flat terrain, which meets the requirements of IEC 61400-12, Ref. 3, for an "ideal site".

The field comparison measurements shall be made on a boom arrangement where the vertical distance from the boom to the rotor of the cup anemometer is at least 20 boom diameters. The vertical tubes that support the cup anemometers shall be identical to the ones being used for power curve measurements. The horizontal separation of the cup anemometers shall be between 1,25m and 3m.

It is recommended also to measure turbulence components with a sonic anemometer. In this case, the sonic shall be mounted so that it does not influence the cup anemometers with a separation of at least 1,25m from the anemometers.

The data analysis shall only include measurements from wind directions within ±15° relative to a direction perpendicular to the boom.

The measurements shall be performed with a sampling rate higher than 0,5Hz, and the average, standard deviation, maximum and minimum values over 10 min shall be stored.

The results of the measurements shall be plotted in a plot, with the turbulence intensity on the X-axis, and the ratio of the average values between the cup anemometer under consideration and the RISØ cup anemometer on the Y-axis.

Data shall be analyzed with the method of bins for each 1% turbulence intensity bins. The average in each bin in the interval from 3% to 15% turbulence and wind speed interval from 5m/s to 14m/s is determined. For any turbulence and wind speed bin the deviation may not be higher than the percentage in requirement 10).

References

1. IEA 11 Wind Speed Measurement and use of Cup Anemometry.
2. CLASSCUP report, Development of a Standardised Cup Anemometer suited to Wind Energy Applications, Contract JOR3-CT98-0263, June 2001.
3. IEC 61400-12 Wind turbine generator systems – Part 12: Wind turbine power performance testing.
4. IEC/EN 61326-1 Electrical equipment for measurement, control and laboratory use - EMC requirements.
5. Technical Criteria for the Danish Approval Scheme for Wind turbines.