Calibration Uncertainty Parameters in MEASNET Wind Tunnels used for Anemometer Calibration

September 2012

on behalf of the MEASNET anemometer expert group

Rev 0

1 Introduction

The ongoing technological progress within the wind energy industry is demanding a more precise understanding of all relevant parameters when it comes to power curve measurements. The most important factor is the measurement of wind speed with a requirement of an ongoing reduction of uncertainty. The precise wind tunnel calibration of anemometers is of great importance since it is one important factor contributing to the uncertainty when it comes to wind speed measurements.

All MEASNET institutions apply the up-to-date procedures in anemometer calibration as described in the IEC61400-12-1/2005/Annex F and MEASNET procedure. The compliance to the requirements of the current international standards of anemometer calibrations provided by MEASNET members is further verified by the results of the Round Robin exercises run by MEASNET regularly for the last 15 years.
The constant improvement of the quality of the measurements provided by its members remains a fundamental aim for MEASNET. In this sense,
in June 2011 it was decided within the Measnet anemometer calibration expert group to arrange an intercomparison test (**ICT**) among all Measnet members aiming in defining the wind tunnel related uncertainty parameters at every individual wind tunnel and evaluate possible methods for their correction. Five anemometers with different operating principles and varying sizes were tested in all Measnet wind tunnels, following a predetermined procedure.

Anemometers of the following types were assessed:

- **Young propeller anemometer** (type RM Young 27106)
  The propeller type anemometer was chosen because it has virtually no blockage effects and very linear behaviour of the indicated wind speed with respect to tunnel speed
- **Thies Classic anemometer** (Thies Classic 4.3303.22.000D)
  The Thies Classic anemometer is one of the largest commonly used cup anemometers in terms of frontal area. An unmodified “Classic” rotating counter clockwise **CCW** and a modified “Classic” rotating clockwise **CW**, were used to identify a possible horizontal gradient in the wind tunnel.
- **Thies First Class Advance** (TFCA) anemometer (Type 4.3350.XX.000)
  The Thies First Class Advance anemometer is widely used and an ample amount of experience about the performance for that anemometer type is present. An unmodified TFCA with its rotor turning counter clockwise **CCW** and a modified TFCA with its rotor rotating clockwise **CW** are used to identify a possible horizontal gradient in the wind tunnel.

The following institutes participated in the Inter Comparison Test

- CRES, CENTER FOR RENEWABLE ENERGY SOURCES AND SAVING, Greece
- DEWI, Deutsches Windenergie Institut GmbH, Germany
- DWG, Deutsche WindGuard Wind Tunnel Services GmbH, Germany (”tunnel DWG WT2“)
- IDR/UPM, Instituto Universitario de Microgravedad “Ignacio Da Riva”, Spain
- SOH, Svend Ole Hansen ApS, Denmark (tunnel SOH ”S1”)
- WICO, WIND-consult, Ingenieurgesellschaft für umweltschonende Energiewandlung mbH, Germany

2 Test procedure

19 different wind tunnel tests with varying parameter settings have been conducted. In total, almost 70 calibration runs were carried out by each institute. This documents the time and effort that needed to be put in by each institute to realize this project. The table below gives an overview of the parameters /instruments tested during the inter comparison test (ICT).

CW* denotes clockwise ; bp** denotes baseplate

Test	run	Sensor	Measure-ments
Identify the UNC in reference speed measurement	1A1	Propeller	5
	1A2	standard Classic	5
	1A3	standard TFCA	5
Variation along the flow (x direction)	1B1	Propeller	7
	1B2	standard Classic	7
	1B3	standard TFCA	7
Flow quality (horizontal gradient)	1C1	modfied Classic turning **CW***	1
	1C2	standard Classic	1
	1C3	modified TFCA turning **CW***	1
	1C4	standard TFCA	1
Variation with mounting height (z direction)	1D1	Propeller	7
	1D2	standard Classic	7
	1D3	standard TFCA	7
Influence of base plate	1E1 with bp**	Propeller	2
	1E1 without bp**		
	1E2 with bp**	standard Classic	2
	1E2 without bp**		
	1E3 with bp**	standard TFCA	2
	1E3 without bp**		

3 Data analysis

The measured data of the ICT per institute was gathered by ECN. After all data was turned in, the findings of all participating wind tunnels was distributed among the anemometer expert group. Therefore the findings of other expert group members were only available after the completion of all ICT measurements (blind test).

4 Overview Results / Findings

- Test results for the Thies First Class Advance type anemometer are coherent to the results of the last Measnet round robin. The Thies Classic and Young Propeller type anemometer have not been tested in the last Measnet round robin test and therefore no statement of the ICT results with respect to the round robin tests for those anemometers can be made here
- The inter comparison test has shown that not all parameters influencing the calibration results are well enough understood
- Further research (as of IEC document 591) shall be conducted incorporating “large” wind tunnels to further identify and comprehend the aerodynamics of anemometer calibrations in wind tunnels and develop correction factors enabling to transfer the findings in the large tunnel to smaller wind tunnels
- Even though a turbulence dependency upon the calibration results using data of this ICT is not evident, further investigation from a possible influence of varying turbulence structures upon the wind tunnel calibration results shall be assessed

5 Identified sources of uncertainty within the ICT

The identification of uncertainty parameters within this inter comparison test were thought of to further improve the transferability of the calibration results among Measnet institutes, therefore giving the possibility to enhance the anemometer calibration results within the measnet community. At least five main sources of uncertainty for wind tunnel anemometer calibrations could be identified through the findings of this inter comparison test.

- Determination of the undisturbed wind speed (reference wind speed measurement within the empty test section) and the transfer function (position factor) specifying the speed at the location of the anemometer in relation to the location of the reference wind speed measuring position
- Influence upon the reference wind speed measurement due to the presence of the anemometer
- Quality of the flow with respect to time and space within limits of the anemometers measurement volume
- Mounting setup of the anemometer during calibration
- Test section design and the influence it has upon the wind speed “seen” by the anemometer

6 Improvements of calibration uncertainty in the near future

The result of this ICT tests has shown that the reduction of uncertainties and the transferability of wind tunnel calibration results require detailed knowledge of all relevant parameters. Indispensible to attain precise calibration results is the implementation of a “high quality” wind tunnel following state of the art design guidelines. The aerodynamic influence from the presence of the anemometer in the wind tunnel upon the calibration results is of complex nature. Some parameters may very well influence each other making it more challenging to identify the cause and effect chain. Additional tests listed below will help to further lower the uncertainties during anemometer calibration in the near future.

- Definition of a revised procedure on how to assess the reference wind speed in the empty test section in order to establish the transfer function (position factor) specifying the speed at the location of the anemometer in relation to the location of the reference wind speed measuring position
- A more detailed definition of the permissible limits of the flow quality with respect to time and space within limitations of the anemometers measurement volume
- Research (as of IEC document 591) shall be conducted incorporating “large” wind tunnels with different measurement layouts to further identify and comprehend the aerodynamics of anemometer calibrations in wind tunnels, and will enable that calibration results in wind tunnels with different configurations will show smaller scatter and come closer to universally accepted wind speed reference values.
- Even though the results of this ICT test do not suggest a turbulence dependency upon the calibration results, further investigation from a possible influence of varying turbulence structures upon the wind tunnel calibration results shall be assessed and how it can be transferred to measurements performed in the open field with its turbulence structure of varying degree

A kick off meeting defining above details shall be conducted among the Measnet anemometer calibration expert group, beginning not later than Dec. 2012. The above tasks shall be concluded within a time period of 12 month.