Ministry of Industry and Trade
General Directorate of Energy

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

FINAL REPORT

Wind Data Analysis

Thanh Hai, Thanh Phu District, Ben Tre Province

July 2013

Supported by
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Owner:

Wind Energy Project (GIZ/MoIT)

8th Floor, 85 Nguyen Du, Hai Ba Trung, Ha noi, Viet Nam

T: + 84 4 3941 2605 - (14)

F: + 84 4 3941 2606

I: www.giz.de/vietnam

www.renewableenergy.org.vn

National Consultant

Power Engineering Consulting Joint Stock Company 3 (PECC3)

32 Ngo Thoi Nhiem, District 3, Ho Chi Minh City

Responsible by: Nguyen Hoang Dung

Individual consultant

Dr. Nguyen Quoc Khanh

Hanoi

International Consultant:

German ProfEC GmbH

Südring 13, 26125 Oldenburg, Germany

Content

1 Executive Summary

PECC3 was commissioned by GIZ to conduct an assessment of long term wind resource at site Thanh Hai, Ben Tre Province under the Program "**Wind Measurement for Developing Wind Power Plan and Wind Power Project**". The program covers 10 sites scattering in provinces from the centre to the south.

At each of these sites a one-year wind speed measurement was performed with 80m measurement towers and high quality measurement sensor technology.

The following results can be highlighted for site Thanh Hai:

- The wind measurement campaign was successfully performed and high quality wind speed data were achieved, characterised by a low absence of missing data periods, consistent data sets and a low uncertainty of the measurement results (about 13.9%).
- The results of the wind measurements can be summarised in **Table 1**, which presents for each measurement site the wind climatological characteristics as Wind Speed, Weibull A-Parameter, Weibull k-Parameter and Turbulence Intensity at each measurement height as well as general climatological site characteristics as Temperature, air pressure and humidity:

80m	Wind Speed	[m/s]	**6.42**
	Weibull A-Parameter	[m/s]	**7.226**
	Weibull k-Parameter	[-]	**2.645**
	Turbulence Intensity	[-]	**0.122**
60m	Wind Speed	[m/s]	**6.18**
	Weibull A-Parameter	[m/s]	**6.954**
	Weibull k-Parameter	[-]	**2.619**
	Turbulence Intensity	[-]	**0.142**
40m	Wind Speed	[m/s]	**5.61**
	Weibull A-Parameter	[m/s]	**6.315**
	Weibull k-Parameter	[-]	**2.671**
	Turbulence Intensity	[-]	**0.161**
Site meteorological parameters	Temperature 14m	[°C]	**27.70**
	Pressure 6m	[hPa]	**1010.0**
	Relative humidity 14m	[%]	**81.40**

Table 1: Results of the wind measurement campaign in [Thanh Hai / VietNam].

Attempts were made for long-term correlation of the measurement results to long-term wind climatological data. However, this attempt was not successful due to lack of quality of all local available long-term wind data.

Even if a complete long-term correlation was not possible, PECC3 nonetheless did undertake research into the long-term wind climate valid for the region, specifically data from nearby meteorological stations in order to give a statement about the representativeness of the measurement period regarding the long-term wind climate of the region.

2 Background and Scope

The assessment of long term wind resource at Thanh Hai is carried out under the program "**Wind measurement for developing wind power plan and wind power project**" within the framework of the project " **Establishment of legal framework and technical assistance to gird connected wind power development in Viet Nam**". The program is financed by the *German Federal Ministry for Environment, Nature Conservation and Nuclear Safety* (BMU) and *The Ministry of Industry and Trade of Vietnam* (MoIT) and is implemented by *Deutsche Gesellschaft fuer International Zusammenarbeit* (GIZ) from German side and MoIT from Vietnamese side.

The program covers 10 sites with details in Table 2. The objectives of the program are to support local governments in conducting wind power planning in their provinces and at the same time supporting private developers in their wind project development.

TT	Name of site (Commune-District-Province)	Existing wind project on the site?
1	Kon Dong – Mang Yang – Gia Lai	No
2	Eaphe –Krong Pak – Daklak	No
3	Xuan Hoa–Song Cau –Phu Yen	Yes
4	Hai Ninh – Quang Ninh – Quang Binh	Yes
5	Thanh Hai – Thanh Phu – Ben Tre	No
6	La Der – IA GRAI – Gia Lai	No
7	Da Loan- Duc Trong – Lam Dong	No
8	Ea Drang – EAHLEO – Daklak	Yes
9	An Hai –Tuy An –Phu Yen	No
10	My Thanh – Phu My – Binh Dinh	No

Table 2: List of sites under the program

At each of these sites a one-year wind measurement was performed with 80m measurement tower and high quality measurement sensors.

Implementers of the project with their roles and responsibilities are briefly introduced below.

German ProfEC has been chosen as international consultant with the following responsibilities: giving advice on site selection; providing specifications for traverse, booms and geometry of installations; giving advice on installation strategy; on-site supervision, commissioning, documentation for the first system and transfer know-how in the process of conducting the work; remote supervision, advice, commissioning, documentation for each subsequent systems. The representative and contact person within German ProfEC GmbH is **Mr. Andreas Jansen** who is the Managing Director.

The Power Engineering Consulting Company No 3 (PECC3) has been chosen as local consultant with detailed responsibilities as follows: design of measurement mast, site selection, supervision of mast erection, installation of sensors for 10 systems, making electrical connections and commissioning of the systems, on-going supervision of the measurement and realization of one year wind and energy assessment. The representative and contact person within PECC3 is **Mr. Nguyen Hoang Dung**, who is the Head of Power Network Development.

To back up the program **Mr. Nguyen Quoc Khanh** has been selected. Mr. Khanh provides technical supports to PECC3 while implementing the program including the preparation of preparation of the final reports of the 10 wind measurement stations.

Nam Kinh Co Ltd is the local mast manufacturer and installer. The representative and contact person within Nam Kinh Co. Ltd. is **Mr. Phan Quoc Hao** who is the Head of Management Board.

Although the measurement is still going on at the site, this assessment is just based on a complete year data, starting from the commission date. The long term reference data at the nearby meteorological station, if exists is made available by the program owner. The assessment is also supported by technical documents which are outputs of the previous steps, to be described in the next sections.

The assessment like previous works has benefited from the technical guidance of German ProfEC which aims at making the assessment conform to relevant standards and common practices of professional wind evaluators.

Since a detailed prediction of the wind resource of future periods, including the influence of climate change, is not possible on the basis of present knowledge, it is assumed that the wind resource to be expected is in average similar to that of the past about 10 to 20 years.

3 Methodology

The wind measurement unit was commissioned in May 2012. The building and assembly of the structure of the measurement mast was conducted by Nam Kinh. Employee of PECC3 subsequently installed the measurement equipment (devices and sensors) together with Nam Kinh staff. The successful erection of the measurement structure according to specific requirements (IEC, IEA, MEASNET, etc.) was verified within a commissioning agreement between PECC3 and Nam Kinh. Subsequently for each mast at the date of starting operation a commissioning agreement was signed between PECC3 and GIZ and a commissioning report was provided through PECC3.

Concerning the setup of the measurement units it is referred to the following, previously provide reports:

- Commissioning / Installation Report on Wind Measurement Units at Thanh Hai, Ben Tre from: 1/05/2012.

The economic success of a wind energy project is basically a question of the achieved annual energy production. The energy yield is typically determined during the planning process of a project by measurements and micro-siting models. If the long-term achieved energy yield seriously falls behind the planned value, the diminished earnings can lead to the financial end of a project. Thus the economic success depends on a reliable assessment of the long-term wind energy yield. It is essential to forecast the average energy production over the live time (or depreciation time) of a wind farm project with as low as possible uncertainties attached.

To gain a reliable base for the assessment of the expected energy yield, a wind speed measurement directly at the proposed site is required. The measurement should be conducted for at least one complete year. A one-year period (if it agrees to the recommended requirements of quality) will give the necessary information for long-term correlation and estimation of the general wind climate in concern:

- Direct wind conditions at the site for different heights
- Measurement over a complete climatic period
- The local prevailing vertical wind profile

The disadvantage of this measurement is the restriction to a one-year measurement period and to a single geographical position within the wind farm area. To overcome these problems of the short-term measurements, a correlation to long-term wind conditions has to be made wherever possible and - for determination of wind conditions for the entire wind farm area - a micro-siting model has to be applied.

The long-term correlation is essential to level out the influence of the annual fluctuations of wind speed. A wind speed measurement, carried out in a good year with energy production above average, will lead to an overestimation of the expected energy yield, as long as long-term effects are not taken into account. If for example a wind speed measurement is carried out during a year, in which the energy yield is 10% higher than the average value, the subsequent annual energy production estimations - and therefore the assessment of economic efficiency - will base on a sit-

uation that results 10% better than the long-term conditions would permit. The assessment of reliable long-term wind speed conditions therefore is of vital importance for wind energy projects.

Figure 1 shows how the short-term measurements are used in combination with the long-term measurement. The upper bar represents the duration of the long-term measurement taken at the Reference Site for several years (here: 10 years). Within this bar a small partition is depicted (yellow), indicating a short-term measurement period (here one year), recorded at an identical time period as the short-term measurement, which is carried out at the proposed wind farm site (*Prediction Site*). The red bar indicates this short-term period at the Prediction Site. The lower, blue bar represents the long-term prediction that results from the Measurement Correlation and Prediction (**MCP**) procedure.

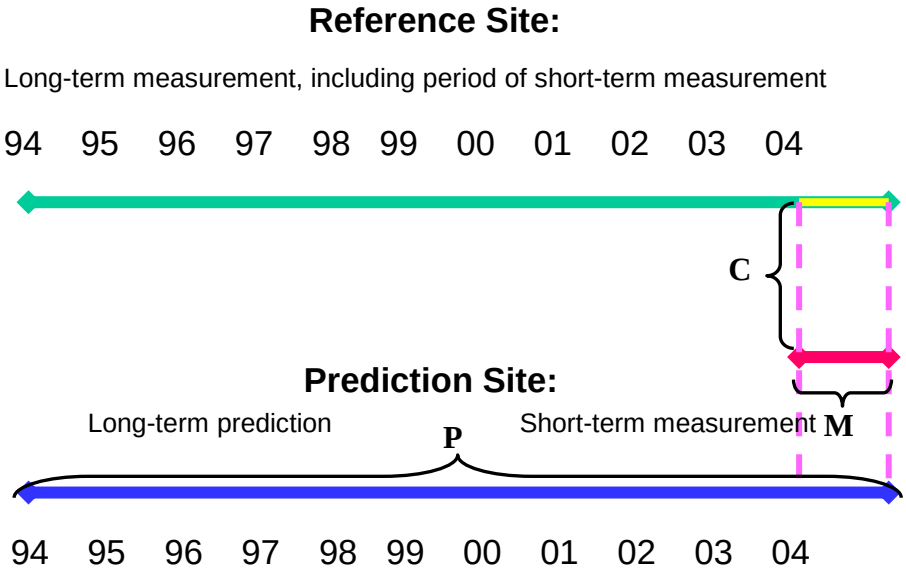


Figure 1: Long-term correlation of wind speed measurement data conform the procedure measurement, correlation and prediction (MCP)

A short-term measurement performed at the Prediction Site is first correlated with a data set of the Reference Site (long-term measurement station) for the identical time period, producing a set of correlation parameter, which will have even lower uncertainties attached the more stable the conditions at the Reference Site has been during measurement. In a second step the long-term prediction is performed for the Prediction Site by using the gained set of correlation parameter and the long-term measured data from the Reference Site.

In brief, in terms of long-term correlation three data records are required:

- A short-term measurement at the Prediction Site (one-year period)
- A long-term measurement at the Reference Site
- A short-term data set at the Reference Site, recorded within the **same** period as the short-term measurement at the Prediction Site.

A long-term measurement station at the so-called *Reference Site*, should have a recording time of 5 to 10 years or even more and should be located in an area, which

- Is near the site of the short-term measurement
- Is characterised by the same wind climatological conditions (same regional wind climate)

In most countries wind speed measurements from meteorological weather services, airports or military stations exist. These measurements usually are performed at low heights above ground level (commonly 10 to 15m height above ground level) and are therefore strongly influenced by the surrounding terrain and obstacles. These measurements thus have a big disadvantage; they are of limited accuracy and not representative for greater height levels. Their big advantage is that they are recorded over a long time period, often under stable operation conditions. This advantage makes them suitable for long-term correlation and data alignment as long as the data were recorded in a stable situation.

Unfortunately, this is not the case for Vietnam for two reasons. First, these stations are usually placed in cities or towns whereas sites under this program are quite remote. Thus, they are not experiencing the same wind climatic regimes. Second, they are available at just 4 readings per day, not suitable for correlation exercise.

This shortcoming will be evaluated in the part on uncertainty.

3.1 Considered Requirements within the Wind Potential Analysis

The measurements were performed according to the current international standards IEC 61400-121 [Ref. 1]. The most important parameters to be considered for a high quality wind speed measurement shall be given in brief.

IEC 61400-121 [Ref. 1] is a standard for measuring the behaviour between wind speed and power out-put of a wind turbine (P-V curve). Therefore it is not solely dealing with wind speed measurements, but also with required data logging and power measuring of the turbine. Nonetheless, this standard – due to its importance concerning reliable statements about wind turbines' power - contains the widest accepted requirements within its parts over wind speed measurement.

3.1.1 Documentation of the measurement station

Being able to evaluate and process the measurement data in an appropriate way and at any given time, a complete documentation about the measurement is indispensable. Therefore **Table 3** below represents the most important points that were considered during wind speed measurement.

Exact positions of the measurement station	• Geographical, UTM or similar rectangular co-ordinates
Description of the measurement set-up	• Exact measurement heights • Orientation of booms and wind vane-north-mark (given as offset to the geographical North-Pole) • Used recorder type (strip chart, digital etc.) • Installed sensors (temperature, air pressure etc.) inclusive ID-numbers

Documentation of gaps in data recording	• Total annual missing hours • Lengths of each missing period
Detailed information about changes in measurement equipment	• Reconstruction • Shift of location • Changes in surrounding
Data sheets (if available)	• Calibration data of the measurement sensors used • Changes of calibration curves and parameters • Numbers of calibration report

Table 3: Recommended documentation of the measurement station

3.1.2 Measurement mast

The measurement mast itself already influences the wind's flow. This influence was kept as low as possible. The anemometers were installed at the mast in such a way that the influence by the mast and the extension arms (booms) was kept as low as possible. Therefore the anemometers were installed in a minimum required distance to the tower. Already during calibration of anemometers the mounting shaft of these was be identical with the later outdoor installation in term of fixing mechanism and diameter.

The electric cables of the sensors were protected against influence of the weather and mechanical abrasion. Cables were laid within the tubes of the shaft and were fixed to the mast by cable ties in short distance.

3.1.3 Extension arms (Horizontal Booms)

Booms are necessary wherever measurements need to be conducted at other heights than solely at the top of the mast. The distance between mast and anemometer was kept to be more than six times the mast's diameter for lattice towers [Ref. 2].

3.1.4 Tower height and measurement heights

The ideal height of the measurement would be the hub height of the wind turbines suggested for installation.

3.1.5 Duration of the measurement campaigns

The measurement campaign with the wind measurement mast did last for a period of **one-year** as recommend by the relevant standard and professional wind evaluation. The program has been then extended to another year. An even longer time period would lower the uncertainty of the energy yield prediction. However, as said earlier, in the present report, only one year dataset is used.

3.1.6 Equipment

Wind speed measurements are carried out for a long period (≥ one year). Therefore, the chosen sensors are suitable for durable use. They can even work under extreme weather conditions. The

equipment consists of components with high quality performances and reliable characteristics. An error of 1 % in wind speed means an error of 2 to 3 % in energy yield. The anemometers and wind vanes have for this reason been **calibrated** in a wind tunnel suitable for wind energy purposes. Data sheets and calibration data of the sensors were documented and can be found in Appendix B.

3.1.7 Data recording

The time series recorded consist average values, standard deviations, minimum and maximum values for 1 0 - minute averages. The sampling interval was, 1/s (1Hz) according to [Ref. 1].

The transport and reading out of the measurement data in principle can be performed in two ways, i.e. manual read out by a site visit and direct connection of a Laptop to a data logger or GSM mobile phone data transfer. Within the present program, sites which are located remotely (relative to Ho Chi Minh city) are installed with GSM mobile phone data transfer which totals 5 sites. Prior to that, telecom signals at those sites were checked to make sure the system works.

3.1.8 Maintenance and monitoring of measurement station

To get secured measurement data a quarter-annual investigation and maintenance of the measurement station and the measurement data was performed. Due to the permanent influence of the weather the met mast and the sensors are subject to natural wear and tear.

4 Measurement Results

The following **Table 4** shows the starting date of operation for each measurement site. The finishing date represents the ceiling of this final report.

Site	Starting date	Finishing date
Thanh Hai	1.05.2012 00:00	30.04.2013 23:50

Table 4: Periods of evaluation of measurement data

The following **Table 5 - Error! Reference source not found.6** represent the most relevant parameters describing the wind climatological characteristics for each measurement site. The wind speed values in this report represent **Weibull fitted** averages. For some monthly evaluations no Weibull-Fit was possible as due to strong prevailing main wind directions not all sectors were covered by a sufficient number of measurement data (there was just no wind coming out of these directions) or the measured wind speeds were too high for an accurate derivation of a Weibull function. This however does not cause a problem for the annual consideration, which is relevant for energy yield calculations, as for this period a Weibull-Fit was possible for all stations and azimuth sectors.

The following **Table 5** represents the orientation, type, serial number and calibration parameters of the wind measurement equipment used at Thanh Hai station.

Sensor	Type	Serial	Calibration-Number	H.a.g.l. [m]	Boom orientation [°]	North label [°] / Offset	Slope	Offset
Thanh Hai	**Coordinates (UTM WGS84) X / Y: 682155.03 / 1094286.76**							
Top Anemometer	Thies 1st Class	11102432	10/8199	80	-	-	0.04581	0.255
Mid Anemometer	Thies 1st Class	11102429	10/8202	60	-	-	0.04586	0.251
Bottom Anemometer	Thies 1st Class	11102289	10/7885	40	-	-	0.04578	0.260
Wind Vane	Wind Vane Thies4.3128.00.xxx	11100814	-	80	315	135	-	-
Data Logger	Ammonit Meteo32	C100650		6	-	-	-	-
Temperature Sensor 1	P6312			14	-	-	-	-
Humidity Sensor 1	P6312			14	-	-	-	-
Barometer	Air Pressure sensor AB60			6	-	-	-	-

Table 5: Orientation, type, serial number and calibration parameters of measurement equipment at Thanh Hai station

Table 6 below summarises the measured wind climatological characteristics at Thanh Hai station.

Quantity	Month/ Unit	May 12	June 12	July 12	Aug 12	Sep 12	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	total
80 m														
Wind Speed	[m/s]	5.11	6.76	5.92	6.67	5.40	5.56	7.15	8.59	7.91	10.22	4.86	5.66	**6.42**
Weibull A-Parameter	[m/s]	5.73	7.46	6.62	7.34	6.06	6.29	7.93	9.56	8.86	11.05	5.22	6.39	**7.23**
Weibull k-Parameter	[-]	2.83	3.72	2.94	4.02	2.70	2.25	3.56	3.43	2.88	5.88	2.34	2.43	**2.65**
Turbulence Intensity [-]	**0.122**													
60 m														
Wind Speed	[m/s]	4.81	6.35	5.58	6.26	5.07	5.21	6.70	8.02	7.36	8.90	5.06	5.32	**6.18**
Weibull A-Parameter	[m/s]	5.40	7.03	6.25	6.91	5.70	5.89	7.42	8.91	8.23	9.74	5.68	6.00	**6.95**
Weibull k-Parameter	[-]	2.75	3.55	2.87	3.84	2.64	2.25	3.64	3.50	2.99	3.42	2.47	2.50	**2.62**
Turbulence Intensity [-]	**0.142**													
40 m														
Wind Speed	[m/s]	4.42	5.81	5.13	5.73	4.65	4.73	6.09	7.21	6.64	7.92	4.50	4.87	**5.61**
Weibull A-Parameter	[m/s]	4.97	6.45	5.75	6.33	5.24	5.35	6.73	8.00	7.42	8.82	5.05	5.48	**6.32**
Weibull k-Parameter	[-]	2.70	3.44	2.81	3.71	2.59	2.27	3.79	3.62	3.11	4.15	2.79	2.56	**2.67**
Turbulence Intensity [-]	**0.161**													
Further meteorological parameters														
Temperature 14m [°C]	**27.70**													
Pressure 6m [hPa]	**1010.0**													
Relative humidity 14m [%]	**81.40**													

Table 6: Monthly averages of wind meteorological characteristics in Thanh Hai

Data missed from 5/02/2013 to 09/03/2013 due to the problem of signal cable from measurement equipment to datalogger was broken.

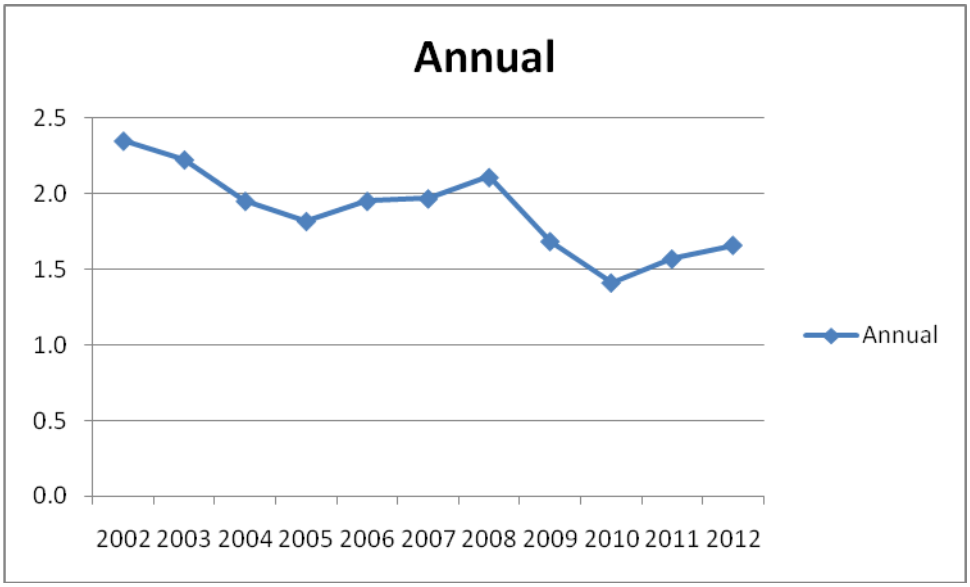
Data from 1.05.2012 to 30.04.2013 shows that a mean wind speed of 6.42 m/s is available with wind direction mainly from 80 to 100 degrees is available at 80 m high. Wind speed is distributed according to Weibull equation with parameter A=7.23 m/s and k=2.65. Wind is stronger during November and March, and weak during the remaining months, especially in May and in September.

5 Long Term Correction

The above results came from the one-year measurement from 1/05/2012 till 30/04/2013 which does not necessary represent the long term wind climate at the site. Thus, a long term correction of the results are necessary. This attempt was not successful due to lack fo quality of all available long-term data which enables the application of MCP procedure. The question on the long-term representative of the measured data remains.

However, for getting an impression of the range of variation, meteorological data from the nearest meterological stations were investigated.

Figure below shows sliding annual wind speed from 2002 to 2012 at station Ba Tri, about 28 km North from the site. It shows for any year the annual wind data varies (uncertainty) not greater than ± 13,8% the long term average value.



Although this range is not applied for the measured site, given this it might be possible to assume the same range of variation of annual wind speed for the measured site. Interpreting differently, this would mean the above results for the site could be up to 5% more or 5% less than the long term average value. This conclusion is necessary for the uncertainty evaluation, and subsequently for energy yield prediction. Naturally, this uncertainty will be reduced if a reliable source of data and/or more convincing method is used.

6 Uncertainties of the wind measurement campaign

While measuring wind speed data diverse reasons may lead to uncertainties that are attached to the measured data. Within the wind measurement campaign it was strived to reduce the uncertainties to a minimum due to application of acknowledged standards and procedures concerning the measurement equipment, the installation of the equipment, the structure of the measurement mast as well as the data checking and correction methods. Moreover, calibrated wind measurement equipment was used. However, even by considering the above means some remaining uncertainties cannot be brought to a level of zero. These uncertainties may be of systematic or statistic nature. Uncertainties belonging to the long-term variations are referring to possible deviation of the wind characteristics within the measurement period from the long term value and any statistical and systematic uncertainty introduced by the procedure, based on which data gaps were filled.

Table 7 represents the relative uncertainties attached to the wind database at the Thanh Hai:

Uncertainty Component	Comment	Uncertainty of Wind Speed [%]
Wind speed measurement		
Anemometer calibration	Uncertainty applied for whole wind tunnel calibration range	1.56 %
Anemometer mounting effects - Flow distortion - Shadow effect	Non ideal anemometer mounting	 0.6% 0.5%
Anemometer characteristics relative	Uncertainty of correction of aerodynamic overspeeding including other effects of anemometer properties	0.86%
Long-term variations	Range amplitude of meteorological data**	13.8%
Data acquisition relative to mean wind speed	Uncertainty of data recording	0.03m/s 0.1 %
Total uncertainty wind data base		**13.9%**

Table 7: Relative uncertainty of the meteorological data at Thanh Hai station in terms of wind speed. All values denote the standard uncertainty in accordance to the International Standards Organisation[1].

The results in this report are based upon generally acknowledged and state-of-the-art methods and have been neutrally conducted to the best of our knowledge and belief.

** Due to the meteorological data is not correlated with measured data so that estimating the maximum amplitude range from meteorological data.

[1] International Standards Organisation, Guide to the Expression of Uncertainty in Measurement, 1995

7 Detailed Wind Measurement Data Analysis and Evaluation

Within Appendix A for each measurement site and for each measurement height a detailed analysis report is provided.

Within this Appendix for each height one after the other important features are displayed that describe the characteristics of the wind climate at the site. The following table represents the page numbers, which is valid of each appendix A:

Measurement height / Analysis issue	**80m**	**60m**	**40m**
Statistics of records	I	II	III
Frequency Distribution of Wind Direction at 80 m	IV		
Frequency Distribution of Wind Speed	V	VI	VII
Course of Wind Speed (80m) and Wind Direction (80m) over the day	VIII		
Course of Wind Speed (80m) and Wind Direction (80m) over the months	IX		

Table 3: Wind data analysis and evaluation for all measurement stations within Appendix A

8 References

Ref. 1 IEC 61400-121: WIND TURBINES – Part 121: Power performance measurements of grid connected wind turbines

Ref. 2 IEA 1st Ed. 1999: Recommended Practices for Wind Turbine Testing and Evaluation 11. Wind Speed Measurement and use of Cup Anemometry

Appendix A – Detailed Wind Measurement Data Analysis and Evaluation

I - Statistics of records

80m height

Day	5.12	6.12	7.12	8.12	9.12	10.12	11.12	12.12	1.13	2.13	3.13	4.13
1	144	144	144	144	144	144	144	144	144	144	0	144
2	144	144	144	144	144	144	144	144	144	144	0	144
3	144	144	144	144	144	144	144	144	144	144	0	144
4	144	144	144	144	144	144	144	144	144	144	0	144
5	144	144	144	144	144	144	144	144	144	130	0	144
6	144	144	144	144	144	144	144	144	144	24	0	144
7	144	144	144	144	144	144	144	144	144	0	0	144
8	144	144	144	144	144	144	144	144	144	0	0	144
9	144	144	144	144	144	144	144	144	144	9	55	144
10	144	144	144	144	144	144	144	144	144	4	144	144
11	144	144	144	144	144	144	144	144	144	1	144	144
12	144	144	144	144	144	144	144	144	144	0	144	144
13	144	144	144	144	144	144	144	144	144	0	144	144
14	144	144	144	144	144	144	144	144	144	0	144	144
15	144	144	144	144	144	144	144	144	144	0	144	144
16	144	144	144	144	144	144	144	144	144	0	144	144
17	144	144	144	144	144	144	144	144	144	0	144	144
18	144	144	144	144	144	144	144	144	144	0	144	144
19	144	144	144	144	144	144	144	144	144	0	144	144
20	144	144	144	144	144	144	144	144	144	0	144	144
21	144	144	144	144	144	144	144	144	144	0	144	144
22	144	144	144	144	144	144	144	144	144	0	144	144
23	144	144	144	144	144	144	144	144	144	0	144	144
24	144	144	144	144	144	144	144	144	144	0	144	144
25	144	144	144	144	144	144	144	144	144	0	144	144
26	144	144	144	144	144	144	144	144	144	0	144	144
27	144	144	144	144	144	144	144	144	144	0	144	144
28	144	144	144	144	144	144	144	144	144	0	144	144
29	144	144	144	144	144	144	144	144	144		144	144
30	144	144	144	144	144	144	144	144	144		144	144
31	144		144	144		144		144	144		144	
%	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**18.5**	**72.2**	**100.0**

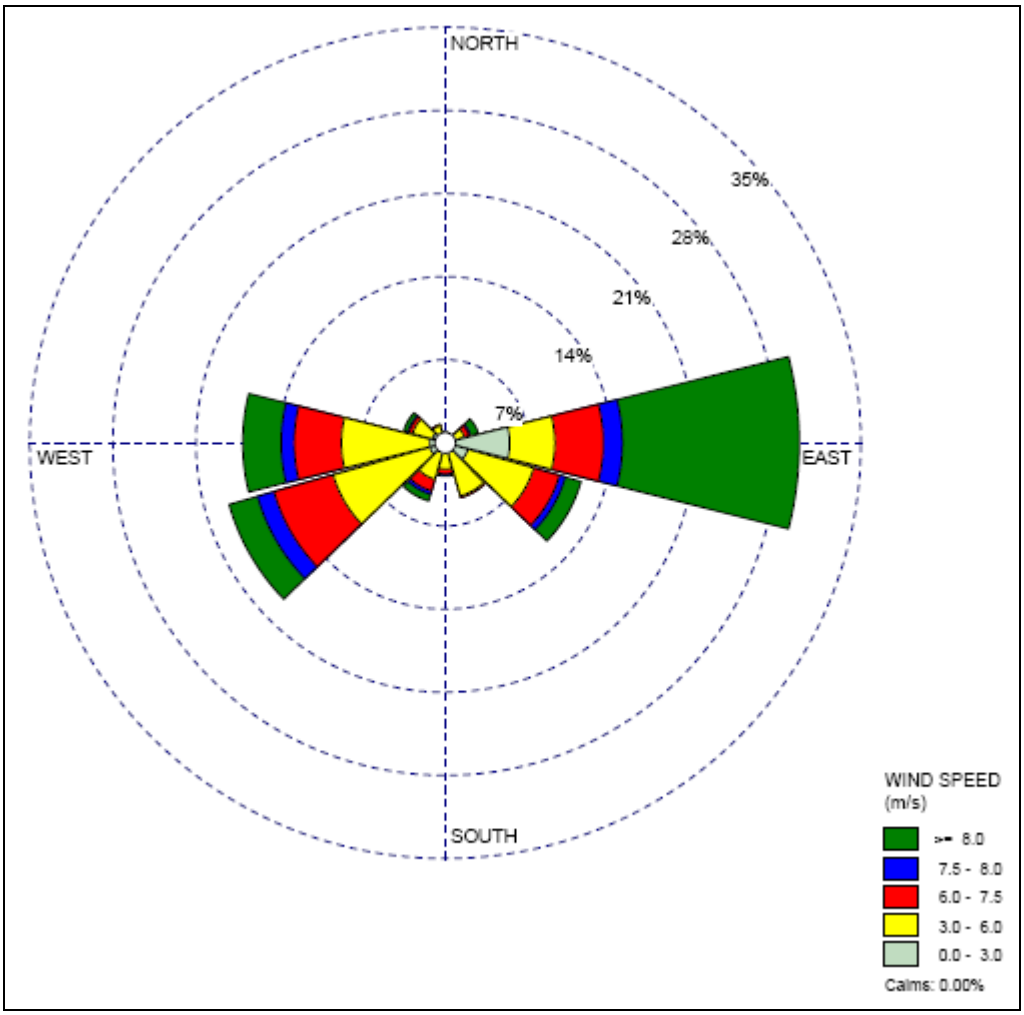
60m height

Day	5.12	6.12	7.12	8.12	9.12	10.12	11.12	12.12	1.13	2.13	3.13	4.13
1	144	144	144	144	144	144	144	144	144	144	144	144
2	144	144	144	144	144	144	144	144	144	144	26	144
3	144	144	144	144	144	144	144	144	144	144	139	144
4	144	144	144	144	144	144	144	144	144	144	139	144
5	144	144	144	144	144	144	144	144	144	135	11	144
6	144	144	144	144	144	144	144	144	144	35	25	144
7	144	144	144	144	144	144	144	144	144	1	0	144
8	143	144	144	144	144	144	144	144	144	6	0	144
9	144	144	144	144	144	144	144	144	144	39	61	144
10	144	144	144	144	144	144	144	144	144	144	144	144
11	144	144	144	144	144	144	144	144	144	103	144	144
12	144	144	144	144	144	144	144	144	144	139	144	144
13	144	144	143	144	144	144	144	144	144	133	144	144
14	144	144	144	144	144	144	144	144	144	144	144	144
15	144	144	144	144	144	144	144	144	144	144	144	144
16	144	144	144	144	144	144	144	144	144	144	144	144
17	144	144	144	144	144	144	144	144	144	144	144	144
18	144	144	144	144	144	144	144	144	144	144	144	144
19	144	144	144	144	144	144	144	144	144	144	144	144
20	144	144	144	144	144	144	144	144	144	144	144	144
21	144	144	144	144	144	144	144	144	144	130	144	144
22	144	144	144	144	144	144	144	144	144	136	144	144
23	144	144	144	144	144	144	144	144	144	49	144	144
24	144	144	144	144	144	144	144	144	144	126	144	144
25	144	144	144	144	144	144	144	144	144	144	144	144
26	144	144	144	144	144	144	144	144	144	144	144	144
27	144	144	144	144	144	144	144	144	144	144	144	144
28	144	144	144	144	144	144	144	144	144	144	144	144
29	144	144	144	144	144	144	144	144	144		144	144
30	144	144	144	144	144	144	144	144	144		144	144
31	144		144	144		144		144	144		144	
%	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**82.7**	**83.2**	**100.0**

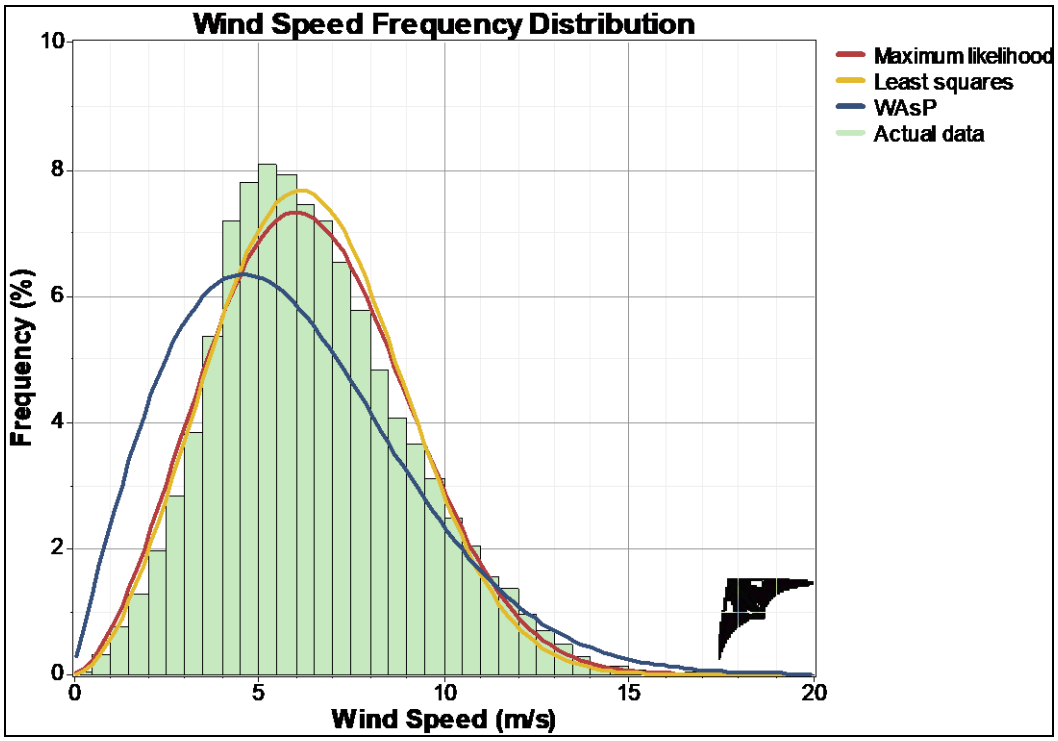
40m height

Day	5.12	6.12	7.12	8.12	9.12	10.12	11.12	12.12	1.13	2.13	3.13	4.13
1	144	144	144	144	144	144	144	144	144	144	144	144
2	144	144	144	144	144	144	144	144	144	144	26	144
3	144	144	144	144	144	144	144	144	144	144	130	144
4	144	144	144	144	144	144	144	144	144	144	130	144
5	144	144	144	144	144	144	144	144	143	135	21	144
6	144	144	144	144	144	144	144	144	144	35	0	144
7	144	144	144	144	144	144	144	144	144	2	0	144
8	144	144	144	144	144	144	144	144	144	6	0	144
9	144	144	144	144	144	144	144	144	144	39	60	144
10	144	144	144	144	144	144	144	144	144	144	144	144
11	144	144	144	144	144	144	144	144	144	104	144	144
12	144	144	144	144	144	144	144	144	144	139	144	144
13	144	144	144	144	144	144	144	144	144	133	144	144
14	144	144	144	144	144	144	144	144	144	144	144	144
15	144	144	144	144	144	144	144	144	144	144	144	144
16	144	144	144	144	144	144	144	144	144	144	144	144
17	144	144	144	144	144	144	144	144	144	144	144	144
18	144	144	144	144	141	144	144	144	144	144	144	144
19	144	144	144	144	144	144	144	144	144	144	144	144
20	144	144	144	144	144	144	144	144	144	144	144	144
21	144	144	144	144	144	144	144	144	144	131	144	144
22	144	144	144	144	144	144	144	144	144	137	144	144
23	144	144	144	144	144	144	144	144	144	48	144	144
24	144	144	144	144	144	144	144	144	144	126	144	144
25	144	144	144	144	144	144	144	144	144	144	144	144
26	144	144	144	144	144	144	144	144	144	144	144	143
27	144	144	144	144	144	144	144	144	144	144	144	144
28	144	144	144	144	144	144	144	144	144	144	144	144
29	144	144	144	144	144	144	144	144	144		144	144
30	144	144	144	144	144	144	144	144	144		144	144
31	144		144	144		144		144	144		144	
%	**100.0**	**100.0**	**100.0**	**100.0**	**99.9**	**100.0**	**100.0**	**100.0**	**100.0**	**82.8**	**82.4**	**100.0**

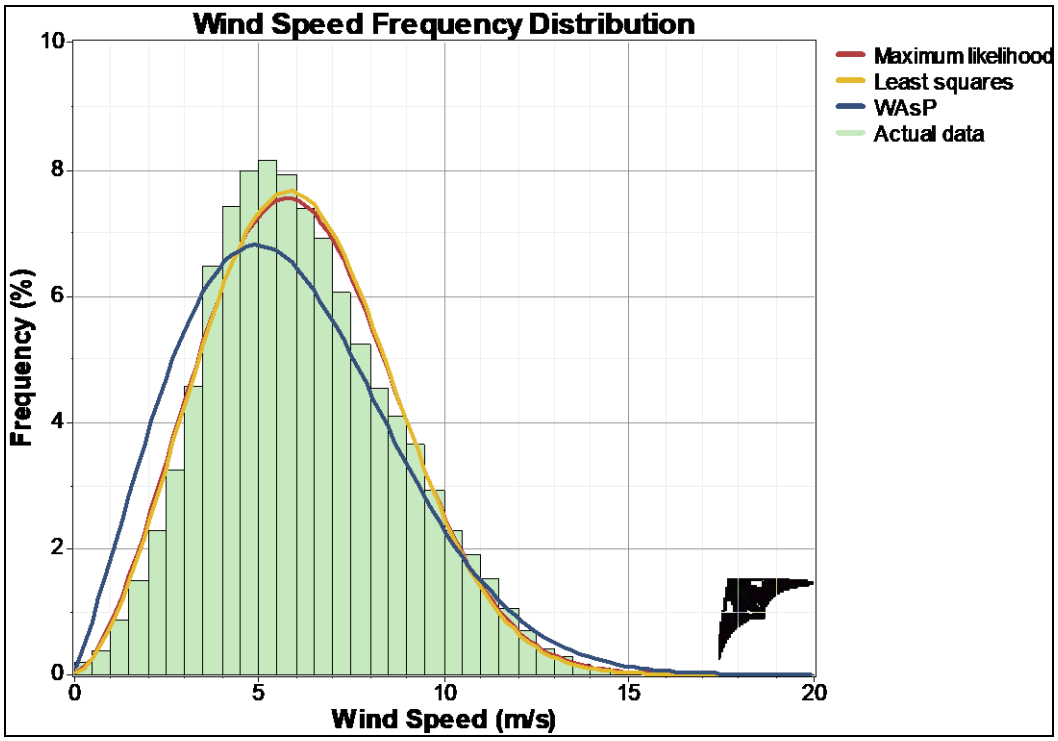
II-Frequency Distribution of Wind Direction at 80 m height at Thanh Hai Station



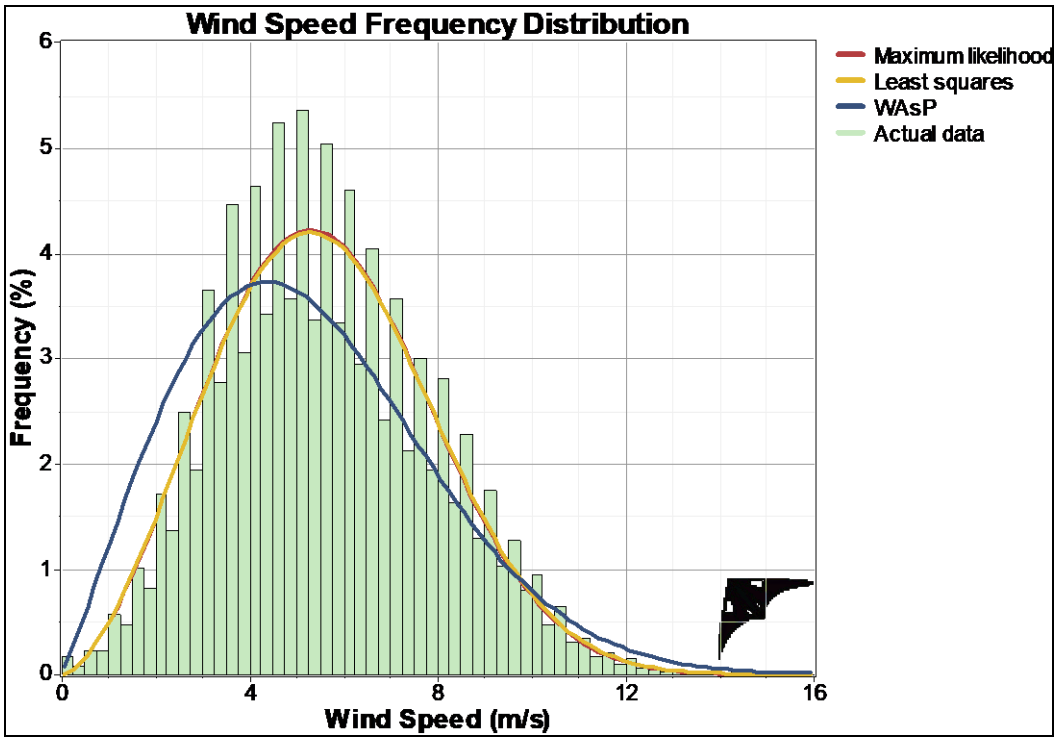
III-Frequency Distribution of Wind Speed at 80 m height at Thanh Hai Station



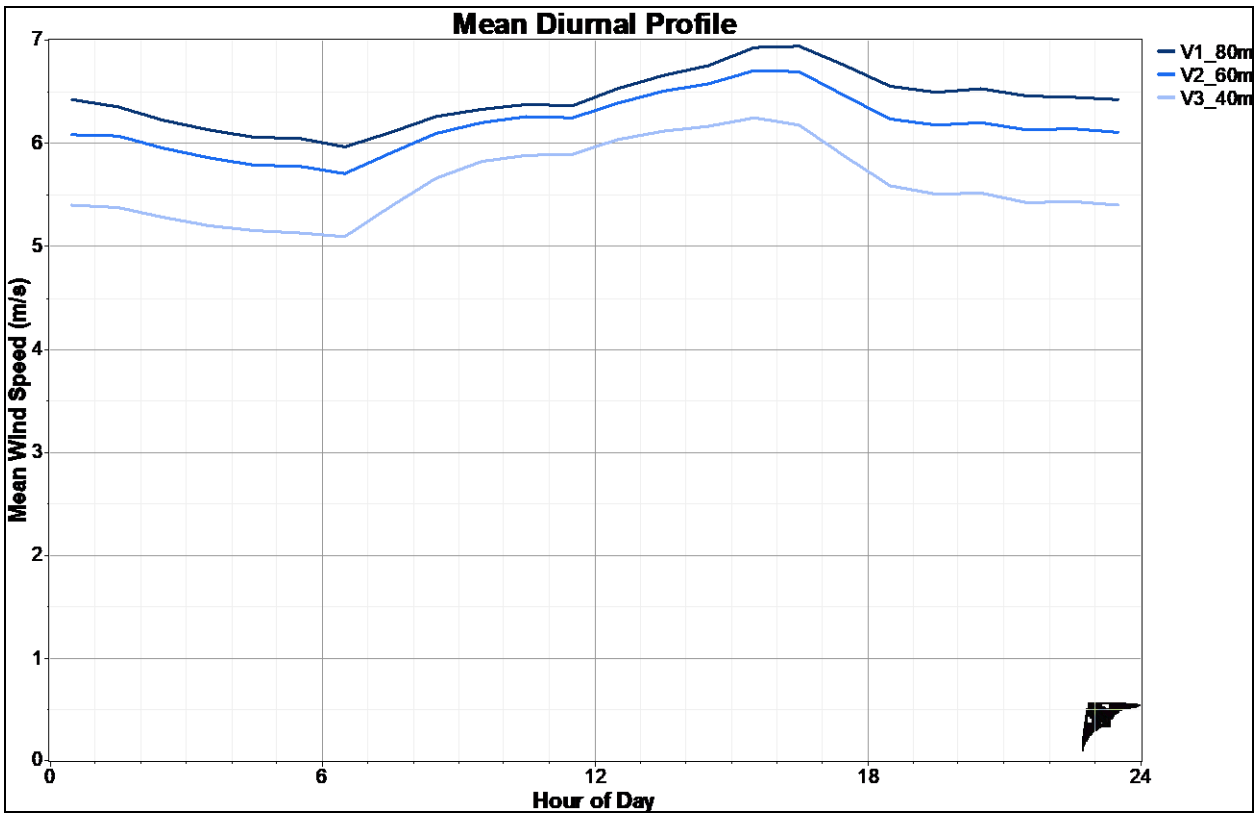
Frequency Distribution of Wind Speed at 60 m height at Thanh Hai Station



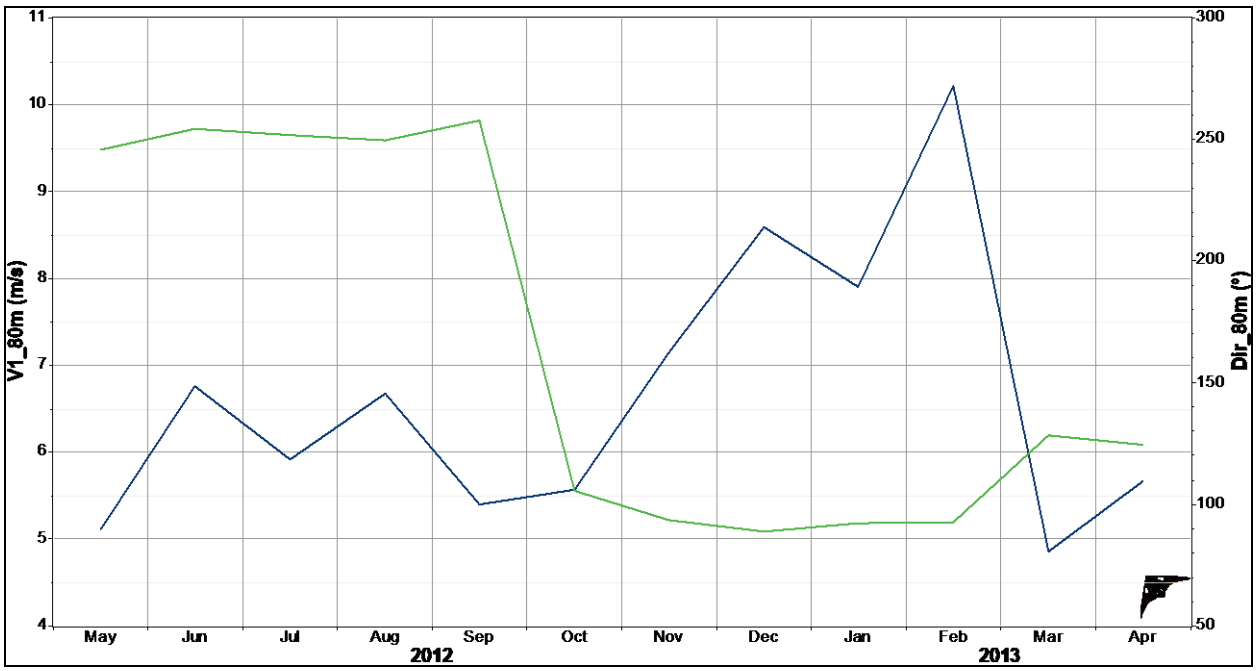
Frequency Distribution of Wind Speed at 40 m height at Thanh Hai Station



IV-Course of Wind Speed 80m, 60m and 40m over the day at Thanh Hai Station



V-Course of Wind Speed 80m and Wind Direction 80m over the months at Thanh Hai Station



Appendix B – Calibration sheets Thanh Hai

Thanh Hai Thies 1st Class Anemometer at 80m:

H-80m

DEUTSCHER KALIBRIERDIENST DKD

Kalibrierlaboratorium / Calibration laboratory
Akkreditiert durch die / *accredited by the*
Akkreditierungsstelle des Deutschen Kalibrierdienstes

Deutsche WindGuard
The Wind Professionals

Deutsche WindGuard
Wind Tunnel Services GmbH
Varel

Deutscher Akkreditierungs Rat
DAR
DKD-K- 36801

Kalibrierschein
Calibration Certificate

Kalibrierzeichen / *Calibration label*: 10/8199 | DKD-K-36801 | 11/2010

Gegenstand *Object*	4.3351.10.000
Hersteller *Manufacturer*	Thies Clima D-37083 Göttingen
Typ *Type*	4.3351.10.000
Fabrikat/Serien-Nr. *Serial number*	Body: 11102432 Cup: 11102432
Auftraggeber *Customer*	Ammonit GmbH D-10997 Berlin
Auftragsnummer *Order No.*	VT10799
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	3
Datum der Kalibrierung *Date of calibration*	27.11.2010

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Der DKD ist Unterzeichner der multi- lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DKD is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Dieser Kalibrierschein darf nur vollständig und unverändert weiterverbreitet werden. Auszüge oder Änderungen bedürfen der Genehmigung sowohl der Akkreditierungsstelle des DKD als auch des ausstellenden Kalibrierlaboratoriums. Kalibrierscheine ohne Unterschrift und Stempel haben keine Gültigkeit.
This calibration certificate may not be reproduced other than in full except with the permission of both the Accreditation Body of the DKD and the issuing laboratory. Calibration certificates without signature and seal are not valid.

Stempel *Seal*	Datum *Date*	Leiter des Kalibrierlaboratoriums *Head of the calibration laboratory*	Bearbeiter *Person in charge*
Deutscher Kalibrierdienst DKD-K- 36801	28.11.2010	Dipl. Phys. D. Westermann	Dipl. Ing. (FH) Catharina Herold

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard

Seite 2
Page

10/8199
DKD-K-36801
11/2010

Kalibriergegenstand *Object*	Anemometer		
Kalibrierverfahren *Calibration procedure*	IEC 61400 12 1 - Wind Turbine Power Performance Testing 12 2005 MEASNET - Cup Anemometer Calibration Procedure – 09 1997 ISO 3966 – Measurement of fluid in closed conduits - 1977		
Ort der Kalibrierung *Place of calibration*	Windtunnel of Deutsche WindGuard, Varel		
Messbedingungen *Test Conditions*	wind tunnel area [1]	10000 cm²	
	anemometer frontal area [2]	230 cm²	
	diameter of mounting pipe [3]	34 mm	
	blockage ratio [4]	0.023 [-]	
	blockage correction [5]	1.000 [-]	
Umgebungsbedingungen *Test conditions*	air temperature	19.3 °C	± 0.2 K
	air pressure	1009.5 hPa	± 0.3 hPa
	relative air humidity	30.4 %	± 2.0 %
Akkreditierung *Accreditation*	*08 / 2009*		
Anmerkungen *Remarks*		-	
Auswertesoftware *Software version*		5.0	

[1] Querschnittsfläche der Auslassdüse des Windkanals
[2] Vereinfachte Querschnittsfläche (Schattenwurf) des Prüflings inkl. Montagerohr
[3] Durchmesser des Montagerohrs
[4] Verhältnis von 2) zu 1)
[5] Korrekturfaktor durch die Verdrängung der Strömung durch den Prüfling
Anmerkung: Aufgrund der speziellen Konstruktion der Messstrecke ist keine Korrektur nötig.
Remark: Due to the special construction of the test section no blockage correction is necessary

Dieser Kalibrierschein wurde elektronisch erzeugt
This calibration certificate has been generated electronically

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard

Seite 3
Page

10/8199
DKD-K-36801
11/2010

Kalibrierergebnis:
Result:

Test Item (1/s)	Tunnel Speed (m/s)	Uncertainty (k=2) (m/s)
85.535	4.157	0.05
127.927	6.100	0.05
168.795	7.985	0.05
207.907	9.804	0.05
251.443	11.767	0.05
294.306	13.733	0.05
336.389	15.687	0.05
314.085	14.644	0.05
273.537	12.755	0.05
229.561	10.774	0.05
188.280	8.874	0.05
145.907	6.955	0.05
107.348	5.197	0.05

Angegeben ist die erweiterte Messunsicherheit, die sich aus der Standardmessunsicherheit durch Multiplikation mit dem Erweiterungsfaktor k=2 ergibt. Sie wurde gemäß DKD-3 ermittelt. Der Wert der Messgröße liegt mit einer Wahrscheinlichkeit von 95 % im zugeordneten Wertintervall.

Der Deutsche Kalibrierdienst ist Unterzeichner der multilateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine. Die weiteren Unterzeichner innerhalb und außerhalb Europas sind den Internetseiten von EA (www.european-accreditation.org) und ILAC (www.ilac.org) zu entnehmen.

The expanded uncertainty assigned to the mea-surement results is obtained by multiplying the standard uncertainty by the coverage factor k = 2. It has been determined in accordance with DKD-3. The value of the measurand lies within the assigned range of values with a probability of 95%.

The DKD is signatory to the multilateral agree-ments of the European co-operation for Accredita-tion (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard

Anhang
Annex

Thanh Hải 80m 10/8199

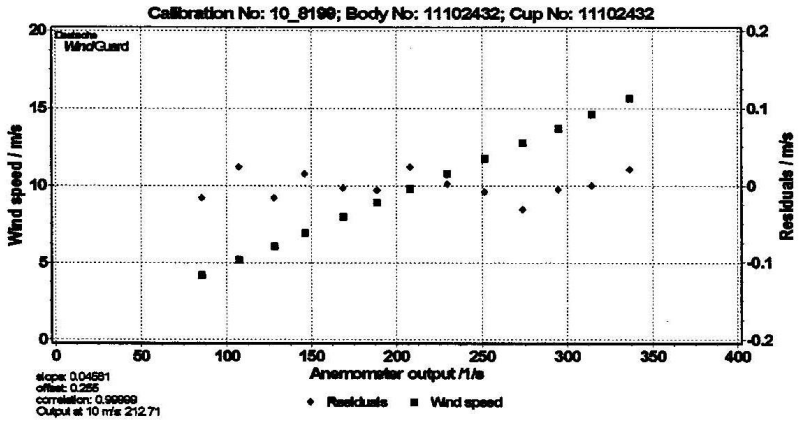
1 Detailed MEASNET[1] Calibration Results

DKD calibration no.	10/8199
Body no.	11102432
Cup no.	11102432
Date	27.11.2010
Air temperature	19.3 °C
Air pressure	1009.5 hPa
Humidity	30.4 %

Linear regression analysis

Slope	0.04581 (m/s)/(1/s) ±0.00006 (m/s)/(1/s)
Offset	0.255 m/s ±0.014 m/s
St.err(Y)	0.017 m/s
Correlation coefficient	0.999990

Remarks no



[1]) According to MEASNET Cup Anemometer Calibration Procedure 09/1997.
Deutsche WindGuard Wind Tunnel Services is accredited by MEASNET and by the Deutscher Kalibrierdienst – DKD (German Calibration Service). Registration: DKD – K – 36801

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard

Anhang
Annex

10/8199

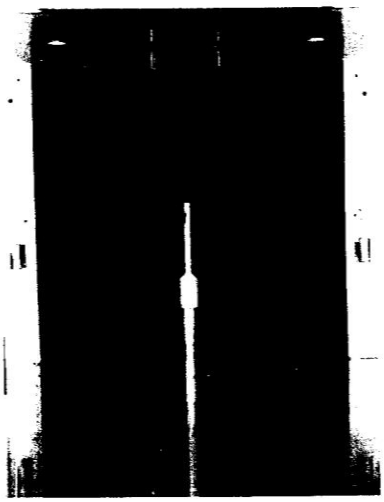
2 Instrumentation

Pos.	Sensor	Manufa.	Identification	Year
1	Pitot static tube	Airflow	483/8 Nr. 000142	02
2	Pitot static tube	Airflow	483/8 Nr. 000143	02
3	Pitot static tube	Airflow	483/8 Nr. 000144	02
4	Pitot static tube	Airflow	483/8 Nr. 000145	02
5	Pressure transducer	Setra	C 239 Nr. 1688081	02
6	Pressure transducer	Setra	C 239 Nr. 1688082	02
7	Pressure transducer	Setra	C 239 Nr. 1688083	02
8	Pressure transducer	Setra	C 239 Nr. 1688084	02
9	El. Barometer	Vaisala	100 A Nr. X2010004	02
10	El. Thermometer	Galltec	KPK 1/6-ME	02
11	El. Humidity sensor	Galltec	KPK 1/6-ME	02
12	Wind tunnel control	-	-	-
13	CAN-BUS / PC	esd	-	04
14	Anemometer		-	
15	Universal Isolator	Knick	P2700 - 98430	05

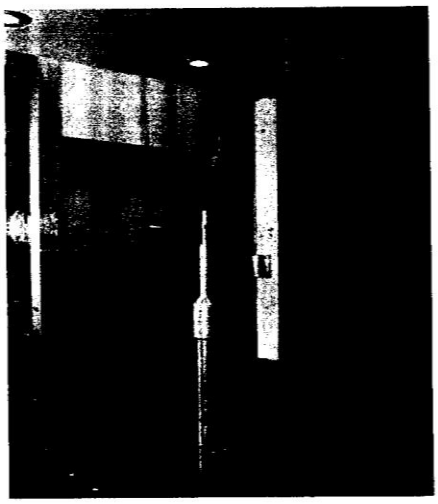
Table 1 Description of the data acquisition system

Remark: Last Re-accreditation see page 2

3 Photo of the calibration set-up



Calibration set-up of the anemometer calibration in the wind tunnel of Deutsche WindGuard, Varel. The anemometer shown is of the same type as the calibrated one.



Remark: The proportion of the set-up are not true to scale due to imaging geometry.

4 Deviation to MEASNET procedure

The calibration procedure is in all aspects in accordance with the IEC 61400-12-1 Procedure

5 References

[1] D. Westermann, 2009 - Verfahrensanweisung DKD-Kalibrierung von Windgeschwindigkeitssensoren
[2] IEC 61400-12-1 12/2005 - Wind Turbine Power Performance Testing
[3] ISO 3966 1977 - Measurement of fluid flow in closed conduits
[4] MEASNET 09 1997 - Cup Anemometer Calibration Procedure

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard

Thanh Hai Thies 1st Class Anemometer at 60m:

60m

DEUTSCHER KALIBRIERDIENST DKD

Kalibrierlaboratorium / Calibration laboratory
Akkreditiert durch die / *accredited by the*
Akkreditierungsstelle des Deutschen Kalibrierdienstes

Deutsche WindGuard
The Wind Professionals

Deutsche WindGuard
Wind Tunnel Services GmbH
Varel

Deutscher Akkreditierungs Rat
DAR
DKD-K- 36801

Kalibrierschein
Calibration Certificate

Kalibrierzeichen / *Calibration label*: 10/8202 | DKD-K-36801 | 11/2010

Gegenstand *Object*	4.3351.10.000
Hersteller *Manufacturer*	Thies Clima D-37083 Göttingen
Typ *Type*	4.3351.10.000
Fabrikat/Serien-Nr. *Serial number*	Body: 11102429 Cup: 11102429
Auftraggeber *Customer*	Ammonit GmbH D-10997 Berlin
Auftragsnummer *Order No.*	VT10799
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	3
Datum der Kalibrierung *Date of calibration*	27.11.2010

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Der DKD ist Unterzeichner der multi- lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DKD is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Dieser Kalibrierschein darf nur vollständig und unverändert weiterverbreitet werden. Auszüge oder Änderungen bedürfen der Genehmigung sowohl der Akkreditierungsstelle des DKD als auch des ausstellenden Kalibrierlaboratoriums. Kalibrierscheine ohne Unterschrift und Stempel haben keine Gültigkeit.
This calibration certificate may not be reproduced other than in full except with the permission of both the Accreditation Body of the DKD and the issuing laboratory. Calibration certificates without signature and seal are not valid.

Stempel *Seal*	Datum *Date*	Leiter des Kalibrierlaboratoriums *Head of the calibration laboratory*	Bearbeiter *Person in charge*
Deutscher Kalibrierdienst DKD-K- 36801	28.11.2010	Dipl. Phys. D. Westermann	Dipl. Ing. (FH) Catharina Herold

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard

Seite 2
Page

10/8202
DKD-K-36801
11/2010

Kalibriergegenstand *Object*	Anemometer		
Kalibrierverfahren *Calibration procedure*	IEC 61400 12 1 - Wind Turbine Power Performance Testing 12 2005 MEASNET - Cup Anemometer Calibration Procedure – 09 1997 ISO 3966 – Measurement of fluid in closed conduits - 1977		
Ort der Kalibrierung *Place of calibration*	Windtunnel of Deutsche WindGuard, Varel		
Messbedingungen *Test Conditions*	wind tunnel area [1]	10000 cm²	
	anemometer frontal area [2]	230 cm²	
	diameter of mounting pipe [3]	34 mm	
	blockage ratio [4]	0.023 [-]	
	blockage correction [5]	1.000 [-]	
Umgebungsbedingungen *Test conditions*	air temperature	19.4 °C	± 0.2 K
	air pressure	1009.4 hPa	± 0.3 hPa
	relative air humidity	30.3 %	± 2.0 %
Akkreditierung *Accreditation*	*08 / 2009*		
Anmerkungen *Remarks*		-	
Auswertesoftware *Software version*		5.0	

[1] Querschnittsfläche der Auslassdüse des Windkanals
[2] Vereinfachte Querschnittsfläche (Schattenwurf) des Prüflings inkl. Montagerohr
[3] Durchmesser des Montagerohrs
[4] Verhältnis von 2) zu 1)
[5] Korrekturfaktor durch die Verdrängung der Strömung durch den Prüfling
Anmerkung: Aufgrund der speziellen Konstruktion der Messstrecke ist keine Korrektur nötig.
Remark: Due to the special construction of the test section no blockage correction is necessary

Dieser Kalibrierschein wurde elektronisch erzeugt
This calibration certificate has been generated electronically

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard

Seite 3
Page

10/8202
DKD-K-36801
11/2010

Kalibrierergebnis:
Result:

Test Item (1/s)	Tunnel Speed (m/s)	Uncertainty (k=2) (m/s)
85.415	4.169	0.05
128.153	6.121	0.05
168.293	7.979	0.05
208.798	9.805	0.05
251.406	11.777	0.05
294.439	13.732	0.05
336.319	15.695	0.05
314.137	14.647	0.05
272.326	12.752	0.05
229.522	10.785	0.05
187.840	8.855	0.05
145.735	6.959	0.05
107.735	5.185	0.05

Angegeben ist die erweiterte Messunsicherheit, die sich aus der Standardmessunsicherheit durch Multiplikation mit dem Erweiterungsfaktor k=2 ergibt. Sie wurde gemäß DKD-3 ermittelt. Der Wert der Messgröße liegt mit einer Wahrscheinlichkeit von 95 % im zugeordneten Wertintervall.

Der Deutsche Kalibrierdienst ist Unterzeichner der multilateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine. Die weiteren Unterzeichner innerhalb und außerhalb Europas sind den Internetseiten von EA (www.european-accreditation.org) und ILAC (www.ilac.org) zu entnehmen.

The expanded uncertainty assigned to the mea-surement results is obtained by multiplying the standard uncertainty by the coverage factor k = 2. It has been determined in accordance with DKD-3. The value of the measurand lies within the assigned range of values with a probability of 95%.

The DKD is signatory to the multilateral agree-ments of the European co-operation for Accredita-tion (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard

Anhang
Annex

Thanh Hai - 60m 10/8202

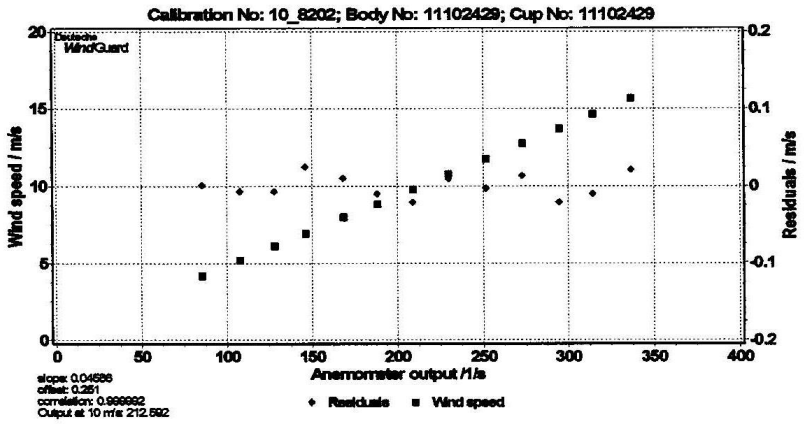
1 Detailed MEASNET[1] Calibration Results

DKD calibration no.	10/8202
Body no.	11102429
Cup no.	11102429
Date	27.11.2010
Air temperature	19.4 °C
Air pressure	1009.4 hPa
Humidity	30.3 %

Linear regression analysis

Slope	0.04586 (m/s)/(1/s) ±0.00005 (m/s)/(1/s)
Offset	0.251 m/s ±0.012 m/s
St.err(Y)	0.014 m/s
Correlation coefficient	0.999992

Remarks no



[1]) According to MEASNET Cup Anemometer Calibration Procedure 09/1997.
Deutsche WindGuard Wind Tunnel Services is accredited by MEASNET and by the Deutscher Kalibrierdienst – DKD (German Calibration Service). Registration: DKD – K – 36801

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard

Anhang
Annex

10/8202

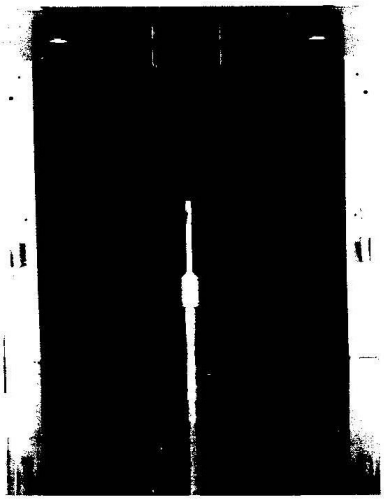
2 Instrumentation

Pos.	Sensor	Manufa.	Identification	Year
1	Pitot static tube	Airflow	483/8 Nr. 000142	02
2	Pitot static tube	Airflow	483/8 Nr. 000143	02
3	Pitot static tube	Airflow	483/8 Nr. 000144	02
4	Pitot static tube	Airflow	483/8 Nr. 000145	02
5	Pressure transducer	Setra	C 239 Nr. 1688081	02
6	Pressure transducer	Setra	C 239 Nr. 1688082	02
7	Pressure transducer	Setra	C 239 Nr. 1688083	02
8	Pressure transducer	Setra	C 239 Nr. 1688084	02
9	El. Barometer	Vaisala	100 A Nr. X2010004	02
10	El. Thermometer	Galltec	KPK 1/6-ME	02
11	El. Humidity sensor	Galltec	KPK 1/6-ME	02
12	Wind tunnel control	-	-	-
13	CAN-BUS / PC	esd	-	04
14	Anemometer		-	
15	Universal isolator	Knick	P2700 - 98430	05

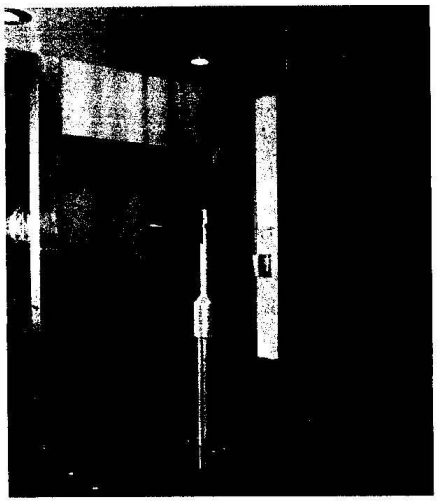
Table 1 Description of the data acquisition system

Remark: Last Re-accreditation see page 2

3 Photo of the calibration set-up



Calibration set-up of the anemometer calibration in the wind tunnel of Deutsche WindGuard, Varel. The anemometer shown is of the same type as the calibrated one.



Remark: The proportion of the set-up are not true to scale due to imaging geometry.

4 Deviation to MEASNET procedure

The calibration procedure is in all aspects in accordance with the IEC 61400-12-1 Procedure

5 References

[1] D. Westermann, 2009 - Verfahrensanweisung DKD-Kalibrierung von Windgeschwindigkeitssensoren
[2] IEC 61400-12-1 12/2005 - Wind Turbine Power Performance Testing
[3] ISO 3966 1977 - Measurement of fluid flow in closed conduits
[4] MEASNET 09 1997 - Cup Anemometer Calibration Procedure

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard

Thanh Hai Thies 1st Class Anemometer at 40m:

40m

DEUTSCHER KALIBRIERDIENST DKD

Kalibrierlaboratorium / Calibration laboratory
Akkreditiert durch die / *accredited by the*
Akkreditierungsstelle des Deutschen Kalibrierdienstes

Deutsche WindGuard
The Wind Professionals

Deutsche WindGuard
Wind Tunnel Services GmbH
Varel

Deutscher Akkreditierungs Rat
DAR
DKD-K- 36801

Kalibrierschein
Calibration Certificate

Kalibrierzeichen *Calibration label*
10/7885
DKD-K-36801
11/2010

Gegenstand *Object*	4.3351.10.000
Hersteller *Manufacturer*	Thies Clima D-37083 Göttingen
Typ *Type*	4.3351.10.000
Fabrikat/Serien-Nr. *Serial number*	Body: 11102289 Cup: 11102289
Auftraggeber *Customer*	Ammonit GmbH D-10997 Berlin
Auftragsnummer *Order No.*	VT10764
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	3
Datum der Kalibrierung *Date of calibration*	15.11.2010

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Der DKD ist Unterzeichner der multi- lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DKD is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Dieser Kalibrierschein darf nur vollständig und unverändert weiterverbreitet werden. Auszüge oder Änderungen bedürfen der Genehmigung sowohl der Akkreditierungsstelle des DKD als auch des ausstellenden Kalibrierlaboratoriums. Kalibrierscheine ohne Unterschrift und Stempel haben keine Gültigkeit.
This calibration certificate may not be reproduced other than in full except with the permission of both the Accreditation Body of the DKD and the issuing laboratory. Calibration certificates without signature and seal are not valid.

Stempel *Seal*	Datum *Date*	Leiter des Kalibrierlaboratoriums *Head of the calibration laboratory*	Bearbeiter *Person in charge*
Deutscher Kalibrierdienst DKD-K-36801	15.11.2010	Dipl. Phys. D. Westermann	Dipl. Ing. (FH) Catharina Herold

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard

Seite 2
Page

10/7885
DKD-K-36801
11/2010

Kalibriergegenstand *Object*	Anemometer		
Kalibrierverfahren *Calibration procedure*	IEC 61400 12 1 - Wind Turbine Power Performance Testing 12 2005 MEASNET - Cup Anemometer Calibration Procedure – 09 1997 ISO 3966 – Measurement of fluid in closed conduits - 1977		
Ort der Kalibrierung *Place of calibration*	Windtunnel of Deutsche WindGuard, Varel		
Messbedingungen *Test Conditions*	wind tunnel area [1]	10000 cm²	
	anemometer frontal area [2]	230 cm²	
	diameter of mounting pipe [3]	34 mm	
	blockage ratio [4]	0.023 [-]	
	blockage correction [5]	1.000 [-]	
Umgebungsbedingungen *Test conditions*	air temperature	21.5 °C	± 0.2 K
	air pressure	1016.7 hPa	± 0.3 hPa
	relative air humidity	42.0 %	± 2.0 %
Akkreditierung *Accreditation*	*08 / 2009*		
Anmerkungen *Remarks*	-		
Auswertesoftware *Software version*	5.0		

[1] Querschnittsfläche der Auslassdüse des Windkanals
[2] Vereinfachte Querschnittsfläche (Schattenwurf) des Prüflings inkl. Montagerohr
[3] Durchmesser des Montagerohrs
[4] Verhältnis von 2) zu 1)
[5] Korrekturfaktor durch die Verdrängung der Strömung durch den Prüfling
Anmerkung: Aufgrund der speziellen Konstruktion der Messstrecke ist keine Korrektur nötig.
Remark: Due to the special construction of the test section no blockage correction is necessary

Dieser Kalibrierschein wurde elektronisch erzeugt
This calibration certificate has been generated electronically

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard

Seite 3
Page

10/7885
DKD-K-36801
11/2010

Kalibrierergebnis:
Result:

Test Item (1/s)	Tunnel Speed (m/s)	Uncertainty (k=2) (m/s)
85.697	4.159	0.05
127.151	6.090	0.05
168.969	7.984	0.05
208.336	9.813	0.05
252.142	11.782	0.05
294.817	13.748	0.05
337.922	15.702	0.05
314.898	14.668	0.05
272.204	12.768	0.05
229.225	10.794	0.05
188.063	8.853	0.05
146.144	6.968	0.05
107.601	5.179	0.05

Angegeben ist die erweiterte Messunsicherheit, die sich aus der Standardmessunsicherheit durch Multiplikation mit dem Erweiterungsfaktor k=2 ergibt. Sie wurde gemäß DKD-3 ermittelt. Der Wert der Messgröße liegt mit einer Wahrscheinlichkeit von 95 % im zugeordneten Wertintervall.

Der Deutsche Kalibrierdienst ist Unterzeichner der multilateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine. Die weiteren Unterzeichner innerhalb und außerhalb Europas sind den Internetseiten von EA (www.european-accreditation.org) und ILAC (www.ilac.org) zu entnehmen.

The expanded uncertainty assigned to the mea-surement results is obtained by multiplying the standard uncertainty by the coverage factor k = 2. It has been determined in accordance with DKD-3. The value of the measurand lies within the assigned range of values with a probability of 95%.

The DKD is signatory to the multilateral agree-ments of the European co-operation for Accredita-tion (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard

Anhang
Annex

Thanh Hải 40m 10/7885

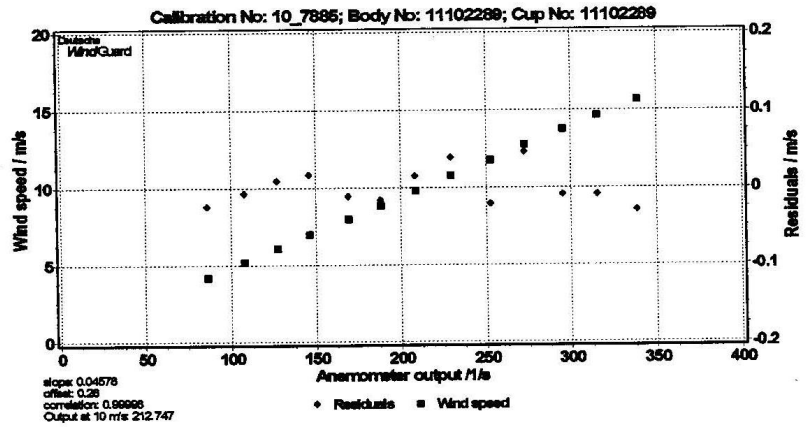
1 Detailed MEASNET[1] Calibration Results

DKD calibration no.	10/7885
Body no.	11102289
Cup no.	11102289
Date	15.11.2010
Air temperature	21.5 °C
Air pressure	1016.7 hPa
Humidity	42.0 %

Linear regression analysis

Slope	0.04578 (m/s)/(1/s) ±0.00009 (m/s)/(1/s)
Offset	0.260 m/s ±0.020 m/s
St.err(Y)	0.025 m/s
Correlation coefficient	0.999980

Remarks no



[1]) According to MEASNET Cup Anemometer Calibration Procedure 09/1997.
Deutsche WindGuard Wind Tunnel Services is accredited by MEASNET and by the Deutscher Kalibrierdienst – DKD (German Calibration Service). Registration: DKD – K – 36801

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard

Anhang
Annex

10/7885

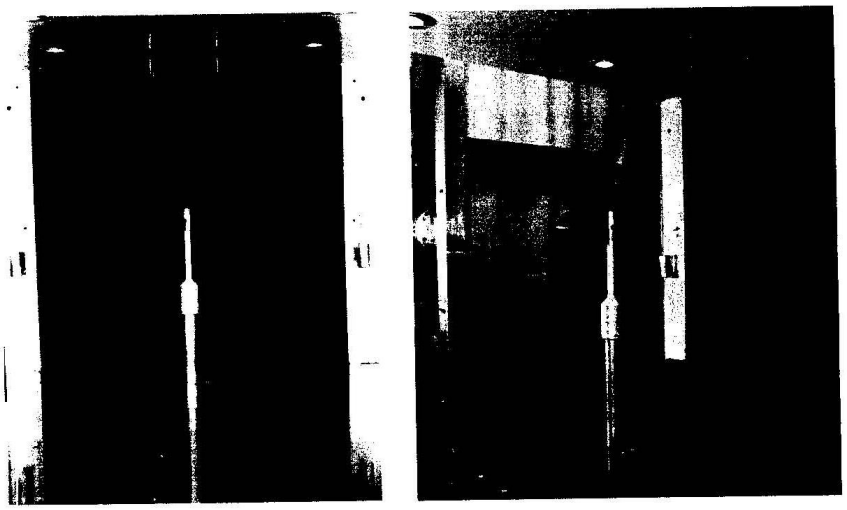
2 Instrumentation

Pos.	Sensor	Manufa.	Identification	Year
1	Pitot static tube	Airflow	483/8 Nr. 000142	02
2	Pitot static tube	Airflow	483/8 Nr. 000143	02
3	Pitot static tube	Airflow	483/8 Nr. 000144	02
4	Pitot static tube	Airflow	483/8 Nr. 000145	02
5	Pressure transducer	Setra	C 239 Nr. 1688081	02
6	Pressure transducer	Setra	C 239 Nr. 1688082	02
7	Pressure transducer	Setra	C 239 Nr. 1688083	02
8	Pressure transducer	Setra	C 239 Nr. 1688084	02
9	El. Barometer	Vaisala	100 A Nr. X2010004	02
10	El. Thermometer	Galltec	KPK 1/6-ME	02
11	El. Humidity sensor	Galltec	KPK 1/6-ME	02
12	Wind tunnel control	-	-	-
13	CAN-BUS / PC	esd	-	04
14	Anemometer		-	
15	Universal isolator	Knick	P2700 - 98430	05

Table 1 Description of the data acquisition system

Remark: Last Re-accreditation see page 2

3 Photo of the calibration set-up



Calibration set-up of the anemometer calibration in the wind tunnel of Deutsche WindGuard, Varel. The anemometer shown is of the same type as the calibrated one.

Remark: The proportion of the set-up are not true to scale due to imaging geometry.

4 Deviation to MEASNET procedure

The calibration procedure is in all aspects in accordance with the IEC 61400-12-1 Procedure

5 References

[1] D. Westermann, 2009 - Verfahrensanweisung DKD-Kalibrierung von Windgeschwindigkeitssensoren
[2] IEC 61400-12-1 12/2005 - Wind Turbine Power Performance Testing
[3] ISO 3966 1977 - Measurement of fluid flow in closed conduits
[4] MEASNET 09 1997 - Cup Anemometer Calibration Procedure

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Deutsche WindGuard