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Date Issued: 16 November 2012  
Revised: 11 January 2013

Report Number 11053879LHD-001  
Intertek Project No: 11053879

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Subject: Summary Test Report for the Sonkyo Energy Windspot 3.5 tested at the CIEMAT/CEDER testing location in Northern Spain.

Dear Mr. Crespo,

This test report summarises the results of the evaluation and tests of the above referenced equipment to the requirements contained in the following standards:

Title	Reference	Date	Revision
<i>BWEA Small Wind Turbine Performance and Safety Standard</i>		<i>29 Feb 2008</i>	<i>First edition</i>

Original testing was authorized by Intertek Purchase Order No 2011-139, dated April 11, 2011. A production sample was installed at the test location in Spain on October 4, 2011. Duration testing was completed on May 13, 2012. All testing on the Windspot 3.5 turbine was conducted under Intertek Project No. G100386839.

This report was authorised by Intertek Purchase Order No 2011-218, dated July 06, 2011.

If there are any questions regarding the results contained in this report, or any of the other services offered by Intertek, please do not hesitate to contact the signatories on this report.

Please note, this Test Report on its own does not represent authorization for the use of any Intertek certification marks. Completed test reports for Duration, Power Performance, Acoustic, and Strength and Safety, are required to complete the MCS/BWEA certification process.

Completed by:	Nick Jones
Title:	Consultant Engineer
Signature:	<i>Original Signature On File</i>

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# Wind Turbine Generator System Summary Test Report for the Sonkyo Energy Windspot 3.5





Sonkyo Energy S.L.

Test Report No. 11053879LHD-001  
Issued: 16 November 2012  
Revised: 11 January 2013

## Revision History

Revised by	Section	Description of change	Date
-	-	None	-
Prepared by: K Sweeney <i>Kevin Sweeney</i>	-	Master Reports updated	11 January 2012
	1.2	Wind Turbine Class added	
	4.0	Immision SPL levels changed	
		New Noise label	
Reviewed by: N Jones <i>N.A. Jones</i>	6.0	Immision SPL level changed	
	8.0	Para 1, standard no. added	

## Master Reports

Report	Report Title	Date
P2011-0708-DUR-IEC	Duration Test Report	28 November 2012
P2011-0708-FUN-IEC	Safety and Function Test Report	03 December 2012
P2011-0708-RUI-BWEA	Acoustic Noise Test Report	28 November 2012
P2011-0708-CUR-BWEA	Power Performance Test Report	27 November 2012



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## 1.0 Background

### 1.1 Background

This testing was conducted as part of the full BWEA Certification test program for the Sonkyo Energy Windspot 3.5 horizontal-axis wind turbine. The Windspot 3.5 was installed at the CIEMAT/CEDER test location in Northern Spain. Test reports were produced by CIEMAT/CEDER and reviewed and accepted by Intertek.

### 1.2 Description of the wind turbine

The Windspot 3.5 is rated for operation at 3500 W at wind speeds of 11-12 m/s (24.6 mph – 26.8 mph). The turbine is a 3-bladed upwind horizontal-axis wind turbine (HAWT) with passive yaw and pitch control. The pitch system utilizes the centrifugal forces of the turbine to pitch the blades to prevent overspeed of the turbine and generator and regulate the power output. The generator is a Ginlong GL-PMG-3500 synchronous permanent magnet generator. It is available as a 3 phase 24-48-110-220 VAC output at 50-60 hz at 200 RPM. A Ginlong rectifier box (W4G-20K) is used to convert the 3 phase AC from the generator to DC voltage input to the Power One PVI-4.2-OUTD-FR-W Inverter, and also to divert power to the dump load. The Inverter is rated for operation at 4.2 kW, and operates on a Maximum Power Point Tracking (MPPT) algorithm for load control of the turbine

A summary of the test turbine configuration and manufacturer's declared ratings can be found in Table 1 below.

<b>General Information</b>	
Wind Turbine Serial Number	001761
Manufacturer	SONKYO ENERGY
Model	WINDSPOT 3.5
Type	Horizontal axis
Year of production	2011
Owner	SONKYO ENERGY
Installation Date	04/10/2011
First operation Date	28/10/2011
<b>Design parameters</b>	
Rated Power	3.5 kW
Rated Wind Speed	12 m/s
Designed Wind Speed (m/s)	14 m/s
Wind Turbine Class	IV
Power Regulation	Centrifugal and damped passive pitch control.
Cut-in Wind Speed	3 m/s
Cut-out Wind Speed	None
<b>Rotor</b>	
Position (Upwind or Downwind)	Upwind
Rotor Diameter	4.1 m



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Horizontal distance from the rotor centre to the tower axis	0.3 m
Rated Rotational Speed	250 rpm
Rotational Speed Range	0-300 rpm
Swept Area	13.2 m <sup>2</sup>
Yaw Orientation	Passive System: Tail boom
<b>Blades</b>	
Number of Blades	3
Manufacturer	Sonkyo energy
Blade set identification	001761
Model	Design by manufacturer
Pitch	Passive variable pitch
Material	Polyester/Glass Fiber
Length	1.75 m
<b>Generator</b>	
Manufacturer	GINLONG
Model	GL-PMG-3500
Type	Synchronous PMG
Nominal Speed (r.p.m.)	250
Number of phases / Vout	3 phases, 400V <sub>ac</sub>
Number of poles	20
Nominal Power (W)	3500
Rotor Inertia (Kg.m <sup>2</sup> )	0.066
Phase Resistance (Ohms)	2.7
<b>Tower</b>	
Type	Tilt-up tubular
Hub Height	18.15 m
<b>Wind Turbine Control System</b>	
Device	Inverter: Power-one Aurora
Software Version	Aurora Installer v.3.1.4
Status Signals	None
<b>Connection</b>	
Grid-connected	
Voltage and tolerance (V)	230 ± 5 %
Frequency and tolerance (Hz)	50 ± 2.5 %

<b>Voltage Regulation System</b>	
Manufacturer	GINLONG Technologies
Model	W4G-20K
Serial Number	001761
Nominal Voltage	$V_{max} = 500 V_{AC}$
<b>Inverter</b>	
Manufacturer	POWER ONE
Model	PVI-4.2-OUTD-FR-W
Serial Number	655094
Nominal Power	4.2 kW
Efficiency	≈ 95%
Inverter Adjustment	MPPT Algorithm
Resistance between inverter and charge *	0.004 Ohms
* It has been measured with a multimeter between the wire extremes which length was around 1 m.	
<b>Dumping Resistance</b>	
Voltage Range	400 VDC
Resistive Power	4 kW
<b>Voltage Adjustments</b>	
Over Voltage	245 V
Under Voltage	200 V
<b>Electrical Connection</b>	
Type	RZ1-K (AS)
Voltage	0.6 / 1 KV
Conductor	Copper, flexible wire
Insulation	Cross-linked Polyethylene, XLPE
Dimensions	4x16 mm <sup>2</sup> / 52 m length
Connections between wind turbine and charge	See Electrical Layout (point 3.2)

**Table 1** – Test Turbine Configuration



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## 2.0 Objective

The purpose of this test report is to provide a summary of the following:

Section	Summary Results	Reference,
3.0	Power Performance Test Summary	6.1.2
4.0	Acoustic Test Summary	6.1.3
5.0	BWEA Rated Annual Energy	6.1.4
6.0	BWEA Rated Sound Level	6.1.5
7.0	BWEA Rated Power	6.1.6
8.0	Wind Turbine Strength and Safety Summary	6.1.7
9.0	Tower Design Summary	6.1.8
10.0	Duration Test Summary	6.1.9

**Table 2** – Report content

### 3.0 Power Performance Test Summary

Below is a summary of the power performance test results. Table 3 shows the tabulated power performance results with measurement uncertainty, and Figure 1 shows the power curve normalized to sea-level air density.

POWER PERFORMANCE							
Bin N <sup>o</sup>	Measured Power Curve Air density 1.225 kg/m <sup>3</sup>				Category A Uncertainty	Category B Uncertainty	Combined Uncertainty
	Hub height wind speed V <sub>i</sub> (m/s)	Output power P <sub>i</sub> (W)	C <sub>p</sub> <sub>i</sub> (Rotor swept area 13.2 m <sup>2</sup> )	Number of 1-minute data set N <sub>i</sub>	Standard Uncertainty S <sub>i</sub> (W)	Standard Uncertainty U <sub>i</sub> (W)	Standard Uncertainty U <sub>c</sub> (W)
1	0.24	1.04	8.85	7	0.13	0.3	0.33
2	0.51	1.04	0.98	290	0.02	0.01	0.02
3	1.02	1.1	0.13	381	0.03	0.01	0.04
4	1.52	1.22	0.04	621	0.06	0.02	0.06
5	2.01	1.38	0.02	703	0.1	0.03	0.1
6	2.5	4.03	0.03	759	0.37	0.47	0.6
7	3	13.75	0.06	675	0.82	1.77	1.95
8	3.5	40.75	0.12	652	2.02	5.14	5.53
9	3.99	95.48	0.19	615	3.39	11.12	11.62
10	4.5	184.36	0.25	667	4.02	18.44	18.87
11	4.99	282.74	0.28	658	4.41	22.76	23.18
12	5.5	411.76	0.31	645	4.18	29.8	30.09
13	5.99	553.36	0.32	638	3.09	36.24	36.37
14	6.49	709.09	0.32	556	3.39	40.57	40.71
15	7	874.1	0.32	460	4.33	44.83	45.03
16	7.51	1044.12	0.31	457	6.23	48.56	48.96
17	8.01	1272.56	0.31	520	6.44	68.85	69.15
18	8.51	1513.32	0.3	541	7.2	75.06	75.41
19	9.01	1814.93	0.31	614	6.77	99.98	100.21
20	9.51	2130.14	0.31	730	7.09	107.01	107.24
21	10.01	2485.91	0.31	792	7	128.27	128.46
22	10.5	2839.74	0.3	845	7.82	132.6	132.83
23	11	3201.95	0.3	786	8.64	139.62	139.88
24	11.49	3498.7	0.29	700	6.71	122.33	122.51
25	12	3688.02	0.26	518	5.83	83.99	84.19
26	12.49	3781.71	0.24	428	6.5	53.77	54.16
27	12.98	3868.5	0.22	320	4.81	52.47	52.69
28	13.47	3925.3	0.2	254	4.05	45.23	45.41
29	13.99	3959.16	0.18	236	4.41	40.12	40.36
30	14.49	4003.58	0.16	167	4.06	43.25	43.44
31	14.99	4047.24	0.15	169	4.1	43.63	43.82
32	15.49	4082.02	0.14	114	4.97	42.12	42.41
33	16	4109.02	0.12	85	5.96	41.05	41.48
34	16.5	4133.65	0.11	77	5.18	40.96	41.29
35	17.02	4164.58	0.1	62	5.76	42.36	42.75
36	17.5	4195.63	0.1	81	2.51	43.51	43.58
37	17.98	4201.36	0.09	59	2.63	39.53	39.62
38	18.49	4215.85	0.08	52	1.78	40.42	40.46
39	19	4219.49	0.08	49	1.61	39.61	39.64
40	19.51	4222.64	0.07	35	1.9	39.62	39.67
41	19.99	4222.3	0.07	24	2.28	39.57	39.64
42	20.55	4227.18	0.06	26	1.8	39.72	39.76
43	21.02	4226.97	0.06	22	1.25	39.62	39.64
44	21.47	4229.74	0.05	12	2.41	39.7	39.77

Table 3 – Power performance tabulated data for the Windspot 3.5



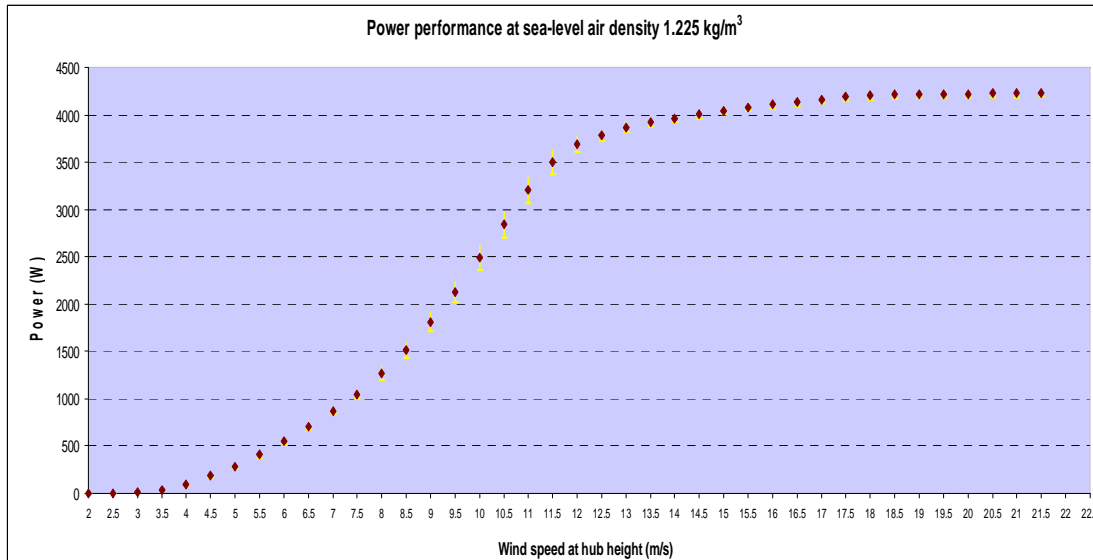


Figure 1 – Normalized sea-level air density power curve for the Windspot 3.5

#### 4.0 Acoustic Test Summary

Below is a summary of the test results for the Windspot 3.5 wind turbine noise over a range of wind speeds and directions. Characterizations of the turbines apparent sound power level, 1/3 octave bands and tonality are made.

Acoustic noise data was gathered on 4 separate days (9<sup>th</sup> May, 5<sup>th</sup>, 6<sup>th</sup> & 7<sup>th</sup> June 2012). The wind direction varied from South to West (187° to 260°). Meteorological data has been gathered continuously since November 11, 2011.

The resulting acoustic performance for normal operation in accordance with the BWEA standard is as follows:

Wind speed dependence: 1.2 dB/m/s

Immision Sound Pressure Level at 60m  $L_{p,60m}$ : 41.1 dB(A)

Immision Sound Pressure Level at 25m  $L_{p,25m}$ : 48.6 dB(A)

ACOUSTIC NOISE LEVELS				
<b>Turbine Maker:</b>	Sonkyo Energy		<b>Model:</b>	Windspot 3.5
NOISE EMISSION LEVEL				NOISE PENALTY
Sound Power LWd,8 m/s dB(A)	<b>84.6</b>	Noise Slope SdB (dB/m/s)	<b>1.2</b>	<b>NO</b>

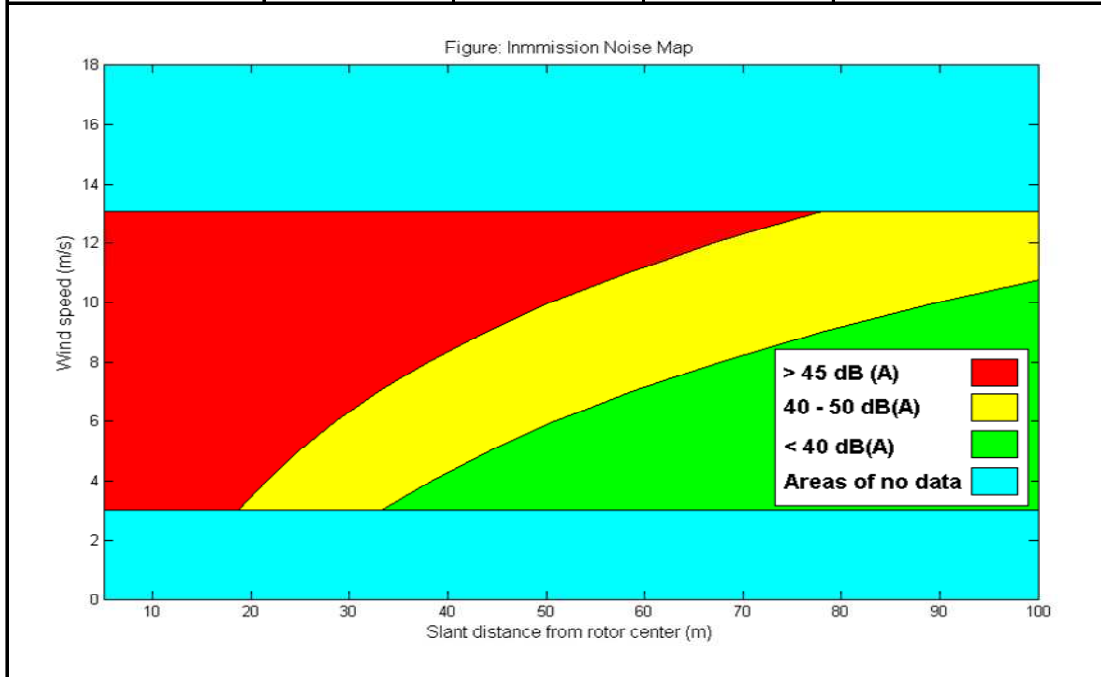


Figure 2 – Noise Immision Map for Windspot 3.5

## 5.0 BWEA Reference Annual Energy

Table 4 below summarizes the estimation of expected annual energy production (AEP) at sea-level air density.

Estimated Annual Energy Production Sea-level air density 1.225 kg/m <sup>3</sup> Cut-out wind speed 25 m/s					
Hub height annual average wind speed	AEP- Measured (Measured Power Curve)	Standard Uncertainty in AEP-Measured		AEP-Extrapolated	Complete
		Combined Uncertainty			
m/s	kWh	kWh	%	kWh	
4	2447	154.68	6	2447	Complete
<b>5</b>	<b>4824</b>	<b>256.98</b>	<b>5</b>	<b>4824</b>	<b>Complete</b>
6	7748	350.23	5	7750	Complete
7	10828	418.01	4	10849	Complete
8	13713	458.97	3	13825	Complete
9	16151	478.14	3	16489	Complete
10	18003	481.33	3	18723	Complete
11	19243	473.44	2	20462	Incomplete

**Table 4** – Estimated annual energy production of the Windspot 3.5 at sea-level air density

An indication of “incomplete” in the far-right column of Table 4 does not imply that the database for the test is incomplete. “Incomplete” means that AEP-Measured is not within 95% of AEP-extrapolated. AEP-extrapolated is an estimated extrapolation of annual energy production, where:

- AEP-Measured assumes zero power below cut-in wind speed and between the highest valid wind speed bin and cut-out wind speed, and
- AEP-Extrapolated assumes zero power below cut-in wind speed and constant power between the highest valid wind speed bin and cut-out wind speed.



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## 6.0 BWEA Rated Sound Level

From the summary presented in section 4.0 of this report:

**BWEA Reference 60 Sound Level,  $L_{p,60m}$ :**                      **41.1 dB(A)**

## 7.0 BWEA Reference Power at 11.0 m/s (24.6 mph)

The BWEA Rated Power is the wind turbine's power output at 11 m/s (24.6 mph) per the power curve from IEC 61400-12-1. From Table 3 above:

**BWEA Reference Output Power (11.0 m/s):**      **3.202 kW**



### 8.0 Strength and Safety Test Results

The Sonkyo Energy design file was evaluated during the months of July and October 2012. The design file is with regards to simplified load model compliance. The design file indicates ultimate and fatigue loading analysis, as well as final material and load factors of safety, for the Windspot 3.5 horizontal-axis wind turbine. The design file was found to be in compliance with all requirements of IEC 61400-2: 2006 regarding structural design. All supporting documentation is maintained within the project file.

Strength and Safety of the Windspot 3.5 was confirmed via the combination of the CIEMAT/CEDER Safety and Function Test Report in compliance with clause 9.6 of *IEC 61400-2 Wind Turbines – Part 2: Design requirements for small wind turbines; second edition dated Marcy 2006*, and the Intertek Letter of Conformance (Report No 100386839CRT-001a) for the design documentation and calculation provided by Sonkyo Energy with the structural design requirements of the above referenced standard.

The Windspot 3.5 has met all of the design requirements for a **Class IV** small wind turbine.

### 9.0 Tower Top Loads

Table 5 below summarizes the top tower top loads and tower data. This data has been supplied by Sonkyo Energy.

PART		
NAME	TOWER TOP	
REFERENCE	20030062	
REVISION	B	
MATERIAL		
DESIGNATION	STEEL S275	According to --
TENSILE STRENGTH, YIELD	275.00	MPa
FATIGUE SAFETY FACTOR	1.90	-

Euronorm	Germany	UK	USA	France								
EN10025	Din 17100	BS4380	ASTM	NFA 35-501	%C	%Mn	%Si	%S	%P	Yield min	Tensile	
S185	S185		A283B	A33								
S235		40A	A283C		0.22max	1.60max	0.60max	0.60max	0.045max	185	310/540	
S235JR	S137-2	40B	A283C-A		0.17max	1.40max	-	0.045	0.045	235	360/510	
S235JO	S137-3 U	40C		E24-2	0.17max	1.40max	-	0.040	0.040	235	360/510	
S235J2G3	S137-3 N	40D		E24-4	0.17max	1.40max	-	0.035	0.035	235	360/510	
S275		43A			0.25max	1.60max	0.60max	0.60max	0.045max	275	430/580	
S275JR	S144-2	43B	A283C-A		0.21max	1.60max	-	0.045max	0.045max	275	430/580	
S275JO	S144-3 U	43C	A578Gr70	E28-3	0.18max	1.60max	-	0.040max	0.040max	275	430/580	
S355		50A	A572Gr50		0.23max	1.60max	0.60max	0.050max	0.050max	355	490/630	
S355JR		50B	-		0.23max	1.60max	0.65max	0.045max	0.045max	355	490/630	
S355JO	S152-3 U	50C	A441		0.22max	1.60max	0.60max	0.40max	0.040max	355	490/630	
S355J2G3	S152-3 N	50D			0.20max	1.60max	0.65max	0.035max	0.035max	355	490/630	
S355J2G4					0.20max	1.60max	0.65max	0.035max	0.035max	355	490/630	

GEOMETRY		
EXTERNAL DIAMETER	121.00	mm
INTERNAL DIAMETER	101.00	mm
THICKNESS	10.00	mm
HEIGHT	2030.00	mm

RESTRAINTS		
Clamp in contact surface with TOWER		

LOADS		
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Aero generator weight	1850	N
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Fatigue		
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Fy	1850	N
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Fx	650.00	N
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Mz	227.50	Nm
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Tensile strength, ultimate		
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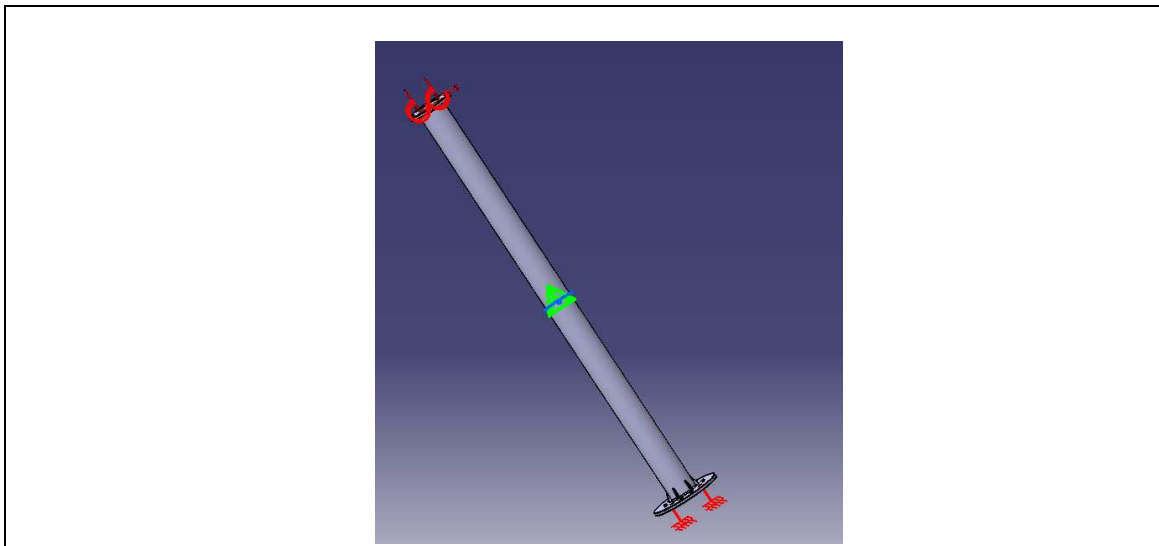
Fy	1850	N
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Fx	4500	N
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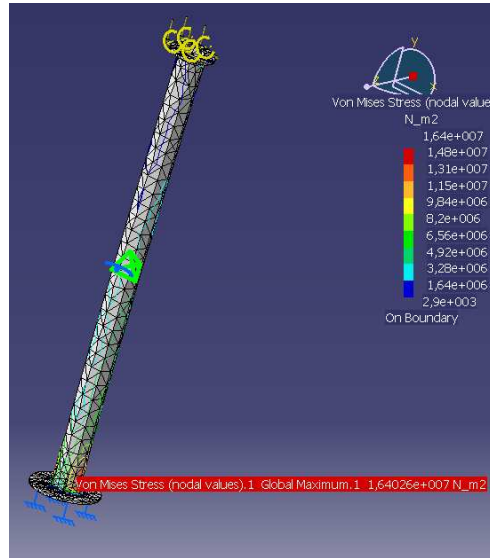
Mz	1700.00	Nm
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FINITE ELEMENT SIMULATION		
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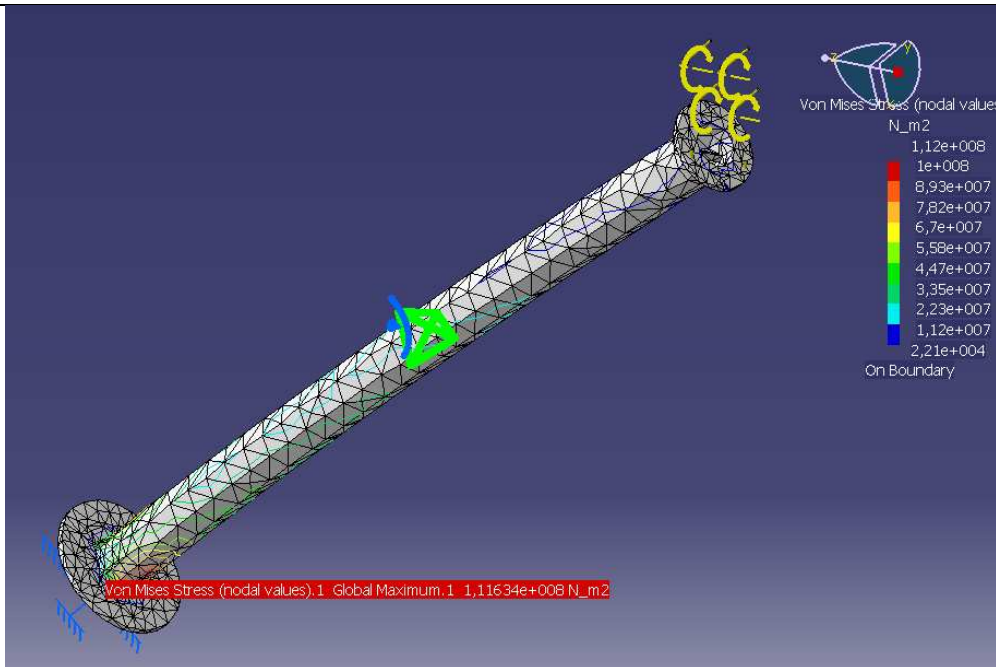
Loads modeling		
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### Fatigue



### Tensile strength, ultimate



RESULTS		
Maximum tensile stress (fatigue)	16.40	MPa
Fatigue safety factor	16.77	-
Maximum tensile stress	111	MPa
Safety factor	2.48	-
Date	2/14/2011	
<b>APPROVED</b>	<b>OK</b>	

Table 5 – Tower top loads and design data for the test turbine for the Windspot 3.5

## 10.0 Duration Test Summary

### 10.1 Operational Time

The test turbine system was installed on October 4, 2012. The system was ready for testing on November 11, 2012. The duration test was completed on May 13, 2012, after sufficient data was collected to satisfy the hourly test requirements

### 10.2 Months of Operation

The duration test was conducted over a period of 6 months, or 184 days, from November 11, 2012 through May 13, 2012. .

### 10.3 Hours of Power Production

Table 6 below indicates the number of power production hours that were observed during the 6 month test duration. Note that the duration test hours are with reference to Class I results; even though the design conformity is for a Class IV turbine.

Hours of Power Production			
IEC SWT Class I {10 m/s – V <sub>ave</sub> }			
Wind Speed	Measured	Required	Pass/Fail
> cut in	3307.83	2500	Pass
> 1.2 V <sub>ave</sub>	849.33	250	Pass
> 1.8 V <sub>ave</sub>	330.83	25	Pass
> 15 m/s	529.00	25	Pass

Table 6 – Duration test hourly power production results for the Windspot 3.5

### 10.4 Operational Time Fraction

The operational time fraction is defined by the following equation:

$$O = \frac{T_T - T_N - T_U - T_E}{T_T - T_U - T_E} \times 100 \%$$

where:

T<sub>T</sub> is the total time period under consideration,  
 T<sub>N</sub> is the time during which the turbine is known to be non-operational,  
 T<sub>U</sub> is the time during which the turbine status is unknown, and  
 T<sub>E</sub> is the time which is excluded in the analysis.





The **overall operational time fraction** of the combined wind turbine system in the total test period was **100.0 %**. The pass criteria for this parameter is 90% (*IEC 61400-2 Wind turbines – Part 2: Design requirements for small wind turbine Clause 9.4.2.1*); therefore the Windspot 3.5 is deemed to **PASS the Duration Test**.

Table 7 below displays the values that were used for determination of overall operational time fraction.

Operational Time Fraction Values	
Variable	Hours
T <sub>T</sub>	4402.80
T <sub>N</sub>	0.00
T <sub>U</sub>	237.98
T <sub>E</sub>	529.74

Table 7 – Hourly results for operational time fraction values for the {Model} turbine

No operational time was detected during which the turbine was non-operational (T<sub>N</sub>). Total operational time amounts to 4402.8 hours. As for the time excluded from the analysis, T<sub>E</sub>, which totalled 237.98 hours, the most prominent problem was due to failure of the grid. It was observed that these failures occurred almost always at the same time. This happened because the circuit breaker protecting the wind turbine disconnected the circuit when the public lighting of the wind farm control booth was switched on for the adjacent wind farm. Likewise, some T<sub>E</sub> data have been discarded since other tests were being performed while collecting data for the test duration. Some time lost due to DAS inspection was also detected. There were 529.73 hours of unknown time (T<sub>U</sub>).

### 10.5 Environmental Conditions

In order to understand environmental conditions over the testing period, several wind speed statistics were required by the Standard. These values are summarized in Table 8 below.

Environmental Conditions During Test Period	
Description	Value
Highest instantaneous wind speed	43.95 m/s
Average turbulence intensity at 15 m/s	8.18 %

Table 8 – Environmental conditions during test

### 10.6 Power Degradation

No significant power degradation over the test period at comparable wind speeds was recorded.

### 10.7 Dynamic Behavior

During the test period the turbine and tower were observed for any potentially harmful turbine or tower dynamics. The turbine was observed over a wide range of wind speeds. During these observations there was no presence of any observable problems.

### 10.8 Post-Test Inspection

The post test inspection was performed on June 26, 2012. There were no significant findings that would relate to excessive wear, degradation, or corrosion that would lead to potentially harmful situations over the expected 20 year life of the Windspot 3.5.