



REPORT

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Test Summary Report Giraffe 2.0 Hybrid Wind-Solar Power Station - for wind: according to IEC 61400-2 2013 Annex M - for solar: measurement report (5 appendices)

Summary

This report has been prepared in accordance with the requirements of IEC 61400-2 Edition 3:2013 in order to provide a summary of testing in support of consumer labelling in accordance with Annex M of the standard.

The Giraffe is a wooden construction including a hybrid system of both wind and solar energy production. The above mentioned standard IEC 61400-2 is solely dedicated for consumer labelling of the wind turbine part. The appendices to this report even include stated measurements of the solar performance of the Giraffe, however, this is not part of the consumer labelling as it is not based on a certain standard and such can be considered as information only.

The requirements of ISO/IEC 17025 and relevant standards used to define the test requirements (e.g. IEC 61400-12-1) have been fulfilled by using calibrated instruments, competent personnel and documented methods. The test organization is accredited for acoustic noise measurement (SWEDAC Ackred.nr. 1002) according to IEC 61400-11. For the other tests carried out the organization is following the established quality system adopted and qualified for ISO 17025.

Revision History

Date	Revised by	Description of Changes
2016-06-27	-	First issue
2016-06-29	Tanja Tränkle	Explanation turbine class; Turbulence intensity; Declared Sound Power Level;

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References

IEC 61400-2:2013 Wind turbines – Part 2: Small wind turbines

IEC 61400-11:2011 Wind turbines – Part 11: Acoustic noise measurement techniques

IEC 61400-12-1:2005 Wind turbines Part 12-1: Power performance measurements of electricity producing wind turbines

Description of the hybrid system

The Giraffe 2.0 Hybrid Wind-Solar Power Station of InnoVentum AB consists of a laminated wood structure hosting a Sonkyo Energy Windspot 3.5 kW. The Windspot 3.5 kW is a horizontal axis machine with a 3-blade upwind rotor with variable pitch blades.

The test object also hosts 24pcs of ITS Innotech Solar Eco Plus E250 solar panels with 6 kW total installed power. The panels are facing south, three columns of the panels are angled from the north-south centerline to the west, the other three columns are angled outwards to the east.



Figure 1: Giraffe 2.0 Hybrid Wind-Solar Power Station

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

Table 1: Turbine configuration

responsible vendor	Innoventum AB Turning Torso office 275, Lilla Varvsgatan 14, 211 15 Malmö, Sweden
wind turbine model	Windspot 3,5 kW mounted on InnoVentum Giraffe 2.0
manufacturer of Windspot 3,5 kW	Sonkyo Energy
model	Windspot 3.5 kW
serial number generator	004285
serial number blades	40 030 902
serial number tail	40 000 014
support structure	InnoVentum Giraffe 2.0 wood structure
general description of main components	- Main body + generator + variable pitch - 1 Tail - 1 Blades set (3 blades) - 1 Controller (on-grid type) - 1 Inverter - 1 Dump Load (diversion load)
reference power (W or kW) (according to test)	2 746 W (@11 m/s)
reference annual energy (kWh/yr) (according to test)	4 760 kWh (@5 m/s), 7 324 kWh (@6 m/s)
hub height	12 m
rotor diameter (m) (if applicable)	4,05 m
swept area (m ²)	12,9 m ²
number of blades	3
upwind or downwind rotor (if applicable)	Upwind
VAWT or HAWT or other	HAWT
tower top weight (kg)	165 kg
description of protection and shutdown system	Passive centrifugal variable pitch system with shock absorber. Electric brake.
description of yaw mechanism	Passive system: tail
direction of rotation	Clockwise (viewed upwind)
rotor speed and/or tip speed range (r/min and/or m/s) (according to test)	250 rpm
cut-in wind speed (m/s)	3 m/s
cut-out wind speed (m/s)	None
extreme wind speed (3-s gust during test period)	34 m/s
SWT class (as designed, and if available as tested)	Giraffe 2.0 tested according to class IV; (Windspot 3.5 kW in other configurations designed and tested according to class I)
power form	Unstable Vac out from generator Rectified to Vdc in controller Monophase 230 Vac – 50 Hz after inverter

maximum output power (per definitions, giving the P60 as a minimum)	4 200 W
maximum output voltage (per definitions, giving the U0,2 as a minimum)	264 Vac
maximum output current(s) (per definitions, giving the i60 as a minimum)	20 Amp
declared sound power level at a wind speed of 8 m/s (dB(A)) (according to test)	81 dB (A) @ 8 m/s
operating temperature range (°C)	-20 °C / 50 °C
available support structures;	Steel tower 12/18 m; Wooden tower 12 m (tested)
design life (years)	25

Power Performance Testing

In order to show the turbine's performance at each wind speed following table (Table 2) is providing the power curve statistics (corrected to an air density of 1,225kg/m³) including uncertainty.

Table 2: Measured Power Curve

Measured Power Curve							
Reference air density: 1,225 kg/m ³					Category A	Category B	Combined uncertainty
Bin no.	Hub height wind speed (m/s)	Power output (W)	C _P	No of data sets (1 min avg.)	Standard uncertainty S _i (W)	Standard uncertainty u _i (W)	Standard uncertainty u _{ci} (W)
2	1,0	0	0,01	321	0,0	0,0	0,0
3	1,5	0	0,00	629	0,0	0,0	0,0
4	2,0	0	0,00	1 047	0,0	0,0	0,0
5	2,5	4	0,03	1 476	0,3	0,7	0,8
6	3,0	37	0,17	1 439	0,5	6,8	6,9
7	3,5	77	0,22	3 156	0,5	9,8	9,8
8	4,0	132	0,26	4 431	0,7	14,2	14,2
9	4,5	209	0,29	5 544	0,9	21,3	21,3
10	5,0	303	0,31	5 939	1,0	27,7	27,7
11	5,5	414	0,32	6 087	1,3	35,6	35,6
12	6,0	549	0,32	5 534	1,7	45,3	45,3
13	6,5	702	0,32	5 171	2,0	55,0	55,0
14	7,0	875	0,32	4 845	2,4	64,8	64,8
15	7,5	1 075	0,32	4 546	2,8	80,9	81,0
16	8,0	1 305	0,32	3 927	3,4	98,0	98,0
17	8,5	1 563	0,32	6 654	4,2	114,9	114,9
18	9,0	1 824	0,32	2 660	5,0	122,8	122,9
19	9,5	2 109	0,31	2 276	5,5	139,3	139,4
20	10,0	2 368	0,30	2 011	6,3	132,8	132,9

21	10,5	2 588	0,28	1 870	6,2	117,5	117,6
22	11,0	2 746	0,26	1 518	6,2	90,8	91,1
23	11,5	2 869	0,24	1 263	6,5	74,7	75,0
24	12,0	2 985	0,22	977	5,8	74,4	74,6
25	12,5	3 070	0,20	679	7,7	57,7	58,2
26	13,0	3 144	0,18	568	6,8	53,7	53,9
27	13,5	3 228	0,17	413	7,4	61,8	62,2
28	14,0	3 294	0,15	311	12,3	52,1	53,5
29	14,5	3 355	0,14	260	12,3	51,1	52,6
30	15,0	3 409	0,13	248	18,3	47,6	51,0
31	15,5	3 459	0,12	197	21,8	46,7	51,5
32	16,0	3 529	0,11	189	17,7	63,0	65,4
33	16,5	3 564	0,10	157	26,8	39,5	47,7
34	17,0	3 665	0,10	116	6,6	95,5	95,8
35	17,5	3 705	0,09	91	8,1	42,8	43,5
36	17,9	3 690	0,08	62	45,9	33,1	56,5

Maximum Recorded Power: 4 156 W vid 24 m/s hub height wind speed (1 min average).

Observed ambient temperature range during duration test -12 to +32 °C (observed 8 km off the test site).

In order to show the turbine’s performance at each wind speed, following graph (Figure 2) is providing power output in W at each wind speed. The dotted lines are indicating the standard uncertainty on power output in both directions.

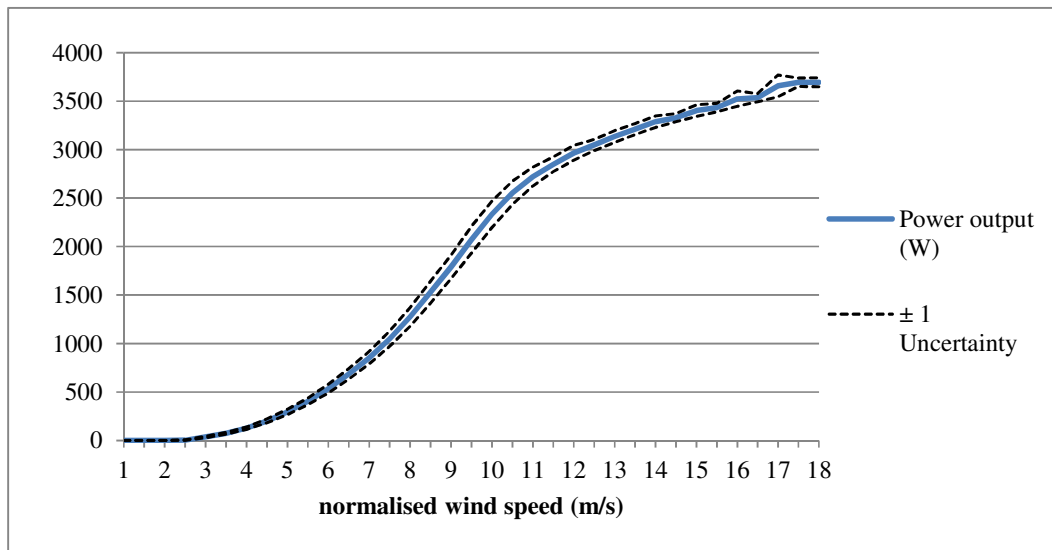


Figure 2: Measured power curve at sea level air density 1,225 kg/m³

The data sets of small wind turbines are collected in 1 minute intervals with a sampling rate of 1 Hz (in contrast to 10 minute intervals with a sampling rate of 1 Hz for large wind turbines). The variation in wind speed and power output is therefore of much less interest when the average is taken in 1 minute intervals. Scatter data within 1 minute intervals and associated scatter plots are therefore omitted.

Annual Energy Production

Table 3 is showing an estimate of the total energy production of a wind turbine during a one-year period by applying the measured power curve to different reference wind speed frequency distributions at hub height, assuming 100 % availability.

Table 3: Estimated annual energy production (air density at sea level)

Estimated annual energy production (database A) Reference air density: 1,225 kg/m ³ . No cut-out wind speed (extrapolation by constant power from last bin)					
Hub height annual avg. wind speed (Rayleigh) (m/s)	AEP- measured (kWh)	Standard uncertainty in AEP (kWh)	Standard uncertainty in AEP (%)	AEP- extrapolated (kWh)	Complete / incomplete
4	2 533	203	8 %	2 533	Complete
5	4 760	324	7 %	4 762	Complete
6	7 324	422	6 %	7 352	Complete
7	9 814	486	5 %	9 993	Complete
8	11 888	518	4 %	12 480	Complete
9	13 364	527	4 %	14 688	Incomplete
10	14 231	529	4 %	16 535	Incomplete
11	14 577	500	3 %	17 970	Incomplete

**AEP Measured is less than 95% of AEP extrapolated, see IEC 61400-12-1:2005 part 8.3*

Reference Annual Energy: 4 760 kWh at 5 m/s annual average wind speed

Acoustic Noise Measurement

The acoustic noise test was conducted in accordance with IEC 61400-11. Wind speeds are shown at hub height.

Table 4: Apparent A-weighted sound power level, L_{WA}, for different wind speeds at hub height

Wind speed (m/s)	7	8	9	10	11
L _{WA} (dB)	78	81	83	85*	88*

**Values marked with an asterisk means that background measurements according to standard have not been fulfilled for these wind speeds, why background correction from wind speed 9 m/s has been used for calculation of these values. This approximation may overvalue the sound power level from the wind turbine somewhat at these wind speeds.*

Declared Sound Power Level: 85 dB(A) at 8 m/s

Duration Test Summary

The following table (Table 5) is providing an overview of the general duration test requirements according to IEC 61400-2:2013 part 13.4.

Table 5: Duration Test Summary

Criteria	Result	Note
Min. 6 months operation	10,5 months	Completed
Min. 2 500 h of power production in any wind speed	8 100 h	Completed
Min. 250 h of power production in winds of 7,2 m/s	1 592 h	Completed
Min. 25 h of power production in winds of 10,8 m/s	411 h	Completed
Min. 10 min of wind in 15 m/s	57 h	Completed
Turbulence intensity at 15 m/s recorded	11,08 %	Record only
Operational time fraction of at least 90 %	100 %	Completed
Max. instantaneous wind speed recorded (maximum observed 3-s gust)	34 m/s	Record only
No major failure of the turbine or components in the turbine system	Passed	Completed
No significant wear, corrosion, or damages to the turbine components	Passed	Completed
No significant degradation of produced power at comparable wind speeds	Passed	Completed

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Appendices

- Appendix 1: 4P05805-R02 Revision 1 Ljudeffektnivå hos vindkraftverk Giraffe V2
- Appendix 2: 4P05805-R03 rev. 1 Performance analysis of solar power production for the Giraffe 2.0 hybrid wind-solar power station
- Appendix 3: 4P05805-R04 rev. 4 Performance analysis of wind power according to IEC 61400-12-1:2006 for the Giraffe 2.0 hybrid wind-solar power station
- Appendix 4: 4P05805-R05 Duration Test Report Giraffe 2.0 Hybrid Wind-Solar Power Station for wind power production according to IEC 61400-2 2013 part 13.4
- Appendix 5: Consumer label



Appendix 1

4P05805-R02 Revision 1 Ljudeffektnivå hos vindkraftverk Giraffe V2



Appendix 2

4P05805-R03 rev. 1 Performance analysis of solar power production for the Giraffe 2.0 hybrid wind-solar power station



Appendix 3

4P05805-R04 rev. 4 Performance analysis of wind power according to IEC 61400-12-1:2006 for the Giraffe 2.0 hybrid wind-solar power station



Appendix 4

4P05805-R05 Duration Test Report Giraffe 2.0 Hybrid Wind-Solar Power Station for wind power production according to IEC 61400-2 2013 part 13.4

Appendix 5

Consumer Label

Test Results	
Manufacturer	InnoVentum AB
Model	Giraffe 2.0
Reference Annual Energy (wind power production only) measured at 5 m/s average wind speed, sea-level normalized; actual production will vary depending on site conditions	4 760 kWh/yr
Declared Sound Power Level at 8 m/s	85 dB(A)
Turbine Test Class (I-IV or S for Special)	IV
Tested by	SP Technical Research Institute of Sweden Ref: 4P05805
Published Date	2016-06-29
For more information, see http://www.sp.se/sv/index/services/certprod/certprodprofil/energi/vind/Sidor/default.aspx	

Giraffe 2.0 also includes solar panels besides the above evaluated small wind turbine. Electric energy production of the solar panels normalized to average annual irradiation in the city of Malmö, Sweden (during 2000-2014) is 5 911 kWh/yr.

This is not covered by the standards for consumer label of small wind turbines "IEC 61400-2:2013 Wind turbines – Part 2: Small wind turbines".

Reference: 4P05805-R03 Performance analysis of solar power production for the Giraffe 2.0 hybrid wind-solar power station