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Subject: Summary Test Report for the SUMEC PWA05-50-280 tested at DaFeng test site of Jiangsu, China for power performance test and duration test, and at Sunite test site of Inner Mongolia, China for acoustic test.

Dear Miss. Zhang Qian,

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
AWEA Small Wind Turbine Performance and Safety Standard	*AWEA 9.1*	*December 2009*	*First edition*

Original testing was performed by Intertek. A production sample was installed at the test location in Dafeng on November 23, 2010, and in Sunite on August 16, 2012. Duration testing was completed on May 02, 2012. All testing on the PWA05-50-280 turbine was conducted under Intertek Project No. SH12100246.

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 AWEA certification process.

Completed by:	Mark Dai		Reviewed by:	Joseph M Spossey
Title:	Technical Supervisor		Title:	Small Wind Team Leader
Signature:			Signature	

Wind Turbine Generator System
Summary Test Report
for the
Sumec PWA05-50-280

Master Reports

Report	Report Title	Date
12061560SHA-004	Duration Test Report	June 27, 2012
Annex clause 9.6 of SH10070988-005	Safety and Function Test Report	December 15, 2011
12061560SHA-012	Acoustic Noise Test Report	November 11, 2012
12061560SHA-008	Power Performance Test Report	June 27, 2012

1.0 Background

1.1 Background

This testing was conducted as part of the full AWEA Certification test program for the Sumec PWA05-50-280 horizontal-axis wind turbine. The PWA05-50-280 was installed at DaFeng test site of Jiangsu, China for power performance test and duration test, and at Sunite test site of Inner Mongolia, China for acoustic test. Test reports were produced by Intertek.

1.2 Description of the wind turbine

The PWA05-50-280 is rated for operation at 5000 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. The tail system is used to prevent overspeed of the turbine and generator and regulate the power output. The generator is a SUMEC PWG06-16-220 synchronous permanent magnet generator. It is available as a 3 phase 220 VAC output at 37.33 Hz at 280 RPM. A diode bridge (MSD100-16) is used to convert the 3 phase AC from the generator to DC voltage input to the Power One PVI-6000-OUTD-US-W Inverter, and also to divert power to the dump load. The Inverter is rated for operation at 6 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.

Item	Description
General Configuration	
Manufacturer	SUMEC Manufacturing Venture Co., Ltd.
Type/ technology	Direct-drive
Wind Turbine Class	Class III
Orientation (upwind / downwind)	upwind
Rotor Diameter (m)	5
Hub Height (m)	10.257
Performance	
Rated Electrical Power (kW)	5
Rated Wind Speed (m/s)	11
Cut-in Wind Speed (m/s, 10 min. mean)	3
Calculated lifetime [y]	20
Ambient temperature range for operation [℃]	-30℃ – +50℃
Annual average wind speed Vave (10 min) [m/s]	7.5
Reference wind speed Vref (10 min) [m/s]	37.5
50 year extreme wind speed Ve50 (3s) [m/s]	52.5
Rotor	
Number of Blades	3
Swept Area (m^2)	19.625
Rated Rotational Speed (rpm)	280
Design Maximum Rotational Speed (rpm)	445
Rotor Hub Type (e.g. rigid, teeter)	rigid
Coning Angle (deg)	0
Tilt Angle (deg)	0
Rated Blade Set Angle (deg)	10.75
Direction of Rotation (clockwise or counter-clockwise looking downwind)	clockwise
Blade	
Manufacturer	Jiangyin Zhiyuan Blade manufacturing Co., Ltd

Model	PWA05.2.1
Length (m)	2.5
Material / Construction	Wood core with epoxy fiber glass coated
Mass (kg)	14.4
Tip speed (m/s)	75.66
Serial number	ZY09080208
Yaw System	
Wind Direction Sensor (type, location)	PWA05-50-280 wind turbine use tail to yaw at the high wind speed, this is passive yawing method and has no active control component.
Yaw Actuator (electric, hydraulic)	
Yaw rate	
Yaw Brake manufacturer, type, location	
Generator	
Manufacturer	SUMEC Manufacturing Venture Co., Ltd.
Model	PWG06-16-220
Type/technology	Permanent-Magnet Synchronous Generator
Rated voltage	220 VAC
Rated power / speed	37.33 Hz
Speed range	0 – 445 RPM
Number of poles	8
Stator rated current	16 A
Rotor rated current	N/A
Generator insulation class	Class A
Generator Phase Connection (Delta/Wye)	Y
IP Protection	IP54
Cooling	Nature air cooling
Power factor	90%
Serial number	20100900610
Controller	
Manufacturer	SUMEC Manufacturing Venture Co., Ltd.
Model	PWC06-A-280
Software version	Wind version 2011010102
Type/technology	Full power
Rated voltage	280 VDC
Frequency	37.33Hz
Capacity	5KVA
Rated current	20 A
Cooling method	Nature air cooling
IP Protection	IP54
Serial number	2011012000646
Inverter	
Manufacturer	Power-One Inc
Model	PVI-6000-OUTD-US-W
Software version of inverter	Installer V3.1.4
Voltage range of Grid-side	211 -264 VAC
Frequency range of Grid-side	59.3 – 60.5 Hz
Capacity	6000W
Rated current of Grid-side converter	28 A
Serial number	143094
Certifications	Conforms to UL Std No. 1741 Certified to CSA-C22.2 No.107.1-01 CSA certificate No.:1841082
Grid conditions	

Nominal voltage	240 VDC
Nominal frequency	60Hz
V tolerance	0.88Vnor≤V ≤1.10Vnor
F tolerance	59.3-60.5 Hz
Control / Electrical System	
Power Regulation (e.g. pitch, stall, active stall)	Use yawing to control power. For PWA05-50-280 wind turbine, there is offsetting between rotor center and yawing center, the mechanical tail can passive yawing according to different wind speed when the wind speed exceed the yawing wind speed.
Over speed Control	Passive yawing
Tower	
Tower Type (lattice, tubular steel, tubular concrete), manufacturer	Octagonal tubular steel
Height (m)	10
Diameter of head flange	280 mm
Diameter of bottom flange	600 mm

Table 1 – Test Turbine Configuration

2.0 Objective

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

Section	Summary Results	Reference[1]
3.0	Power Performance Test Summary	6.1.2
4.0	Acoustic Test Summary	6.1.3
5.0	AWEA Rated Annual Energy	6.1.4
6.0	AWEA Rated Sound Level	6.1.5
7.0	AWEA 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
Note 1: Reference – *AWEA 9.1 Small Wind Turbine Performance and Safety Standard December 2009*

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.

Measured power curve(Database A)						
Reference air density: 1.225kg/m^3				Uncertainty Category A(kW)	Uncertainty Category B(kW)	Combined Uncertainty(kW)
Bin no.	Hub height wind speed[m/s]	Power Output[kW]	Cp	No. of Datasets(1 min. avg.)			
1	1.01	-0.05	-	316	0.00	0.01	0.01
2	1.54	-0.04	-	571	0.00	0.01	0.01
3	2.02	-0.04	-	1464	0.00	0.01	0.01
4	2.43	-0.01	-	1159	0.00	0.01	0.01
5	3.02	0.08	0.24	1284	0.00	0.01	0.01
6	3.51	0.17	0.33	1604	0.00	0.02	0.02
7	3.99	0.29	0.38	1586	0.00	0.03	0.03
8	4.50	0.43	0.39	1304	0.00	0.03	0.03
9	4.99	0.62	0.41	1096	0.00	0.05	0.05
10	5.49	0.84	0.42	985	0.00	0.06	0.06
11	5.99	1.11	0.43	801	0.00	0.08	0.08
12	6.49	1.43	0.43	652	0.01	0.10	0.10
13	7.00	1.78	0.43	486	0.01	0.11	0.11
14	7.46	2.14	0.43	296	0.01	0.13	0.14
15	7.97	2.54	0.42	168	0.02	0.14	0.15
16	8.45	2.98	0.41	99	0.03	0.18	0.18
17	8.97	3.55	0.41	44	0.06	0.23	0.23
18	9.51	3.95	0.38	27	0.10	0.16	0.19
19	9.99	4.69	0.39	27	0.10	0.35	0.37
20	10.44	5.03	0.37	17	0.11	0.18	0.21
21	10.97	5.01	0.32	17	0.16	0.05	0.17
22	11.43	5.40	0.30	15	0.14	0.22	0.26
23	11.94	5.02	0.25	15	0.24	0.21	0.32
24	12.48	4.30	0.18	11	0.25	0.38	0.45
25	12.97	4.41	0.17	22	0.25	0.08	0.26
26	13.52	3.58	0.12	11	0.26	0.46	0.53
27	14.03	3.61	0.11	19	0.19	0.04	0.19
28	14.46	3.96	0.11	10	0.51	0.27	0.58
29	14.89	4.70	0.12	11	0.25	0.58	0.63
30	15.54	4.84	0.11	10	0.17	0.09	0.19
31	15.91	4.80	0.10	11	0.33	0.06	0.34
32	16.48	4.68	0.09	13	0.24	0.09	0.26
33	16.80	4.60	0.08	2	0.56	0.10	0.57
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-

Manufacture:	SUMEC	Standard Power Output:	5	kW
Total Number:	14153	Diameter of Wind Turbine:	5	m
Report Date:	Jul 2012	1 min Averages		

Table 3 – Performance at sea-level air density for the PWA05-50-280; 1.225 kg/m^3
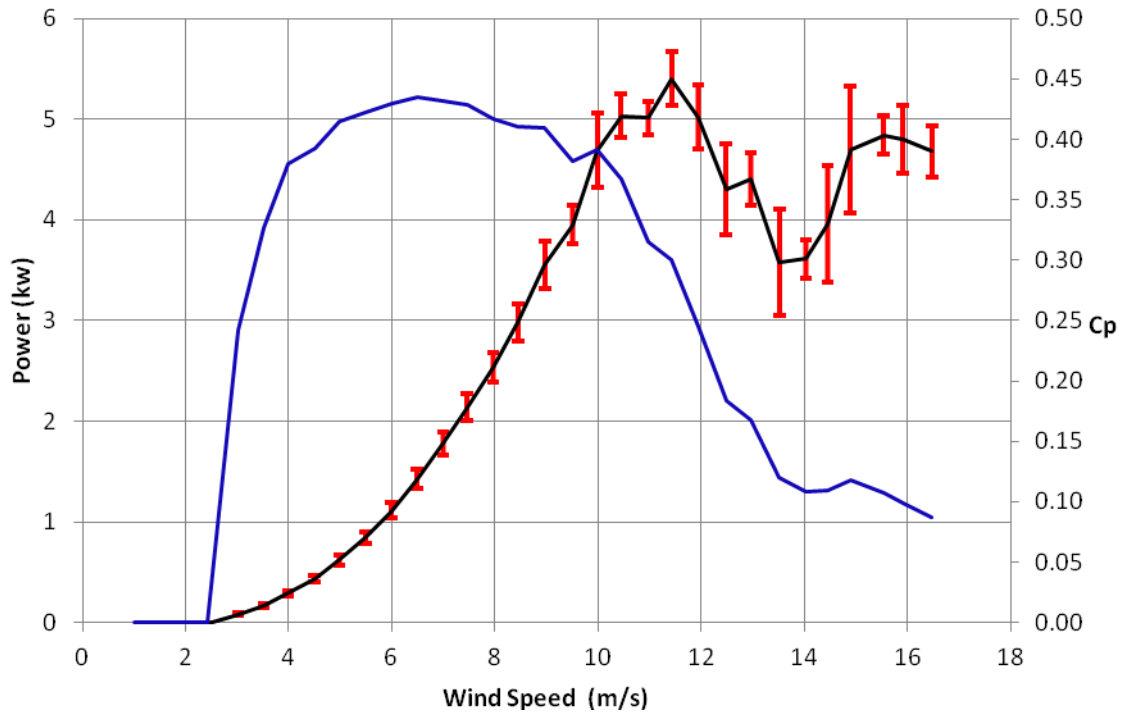
Figure 1 – Normalized Power curve and Coefficient of performance at sea-level density for the PWA05-50-280; 1.225 kg/m³

4.0 Acoustic Test Summary

Below is a summary of the test results for the PWA05-50-280 wind turbine noise over a range of wind speeds and directions. Characterizations or the turbines apparent sound power level and 1/3 octave bands are made.

Figure 2 below shows the measured data pairs. The method of bins was used to calculate the bin average turbine and background sound pressure level. The sound pressure levels at the integer wind speeds were interpolated between bins. The background correction was then applied to the bin averaged values at the integer wind speeds.

Figure 2 – Ls+n & Ln against 10m height wind speed for the PWA05-50-280
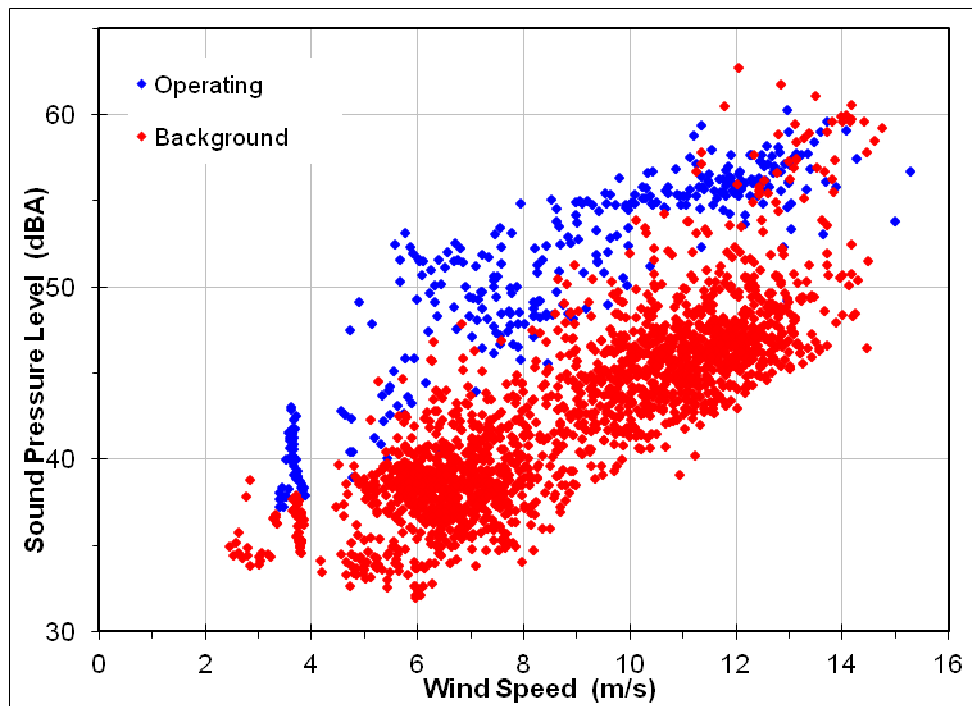
Figures 3 through 4 show the A-weighted one-third octave spectra were calculated for each bin. For several wind speeds, at the high and low frequencies, the separation between turbine and background was insufficient to report a value. Only spectra for bins, in which at least 10 data points were recorded for both turbine and background, are reported. For bands that have no value listed, the background noise was within 3dB of the overall noise. Tables 4 and 5 show one-third octave results and associated uncertainties in tabular format.
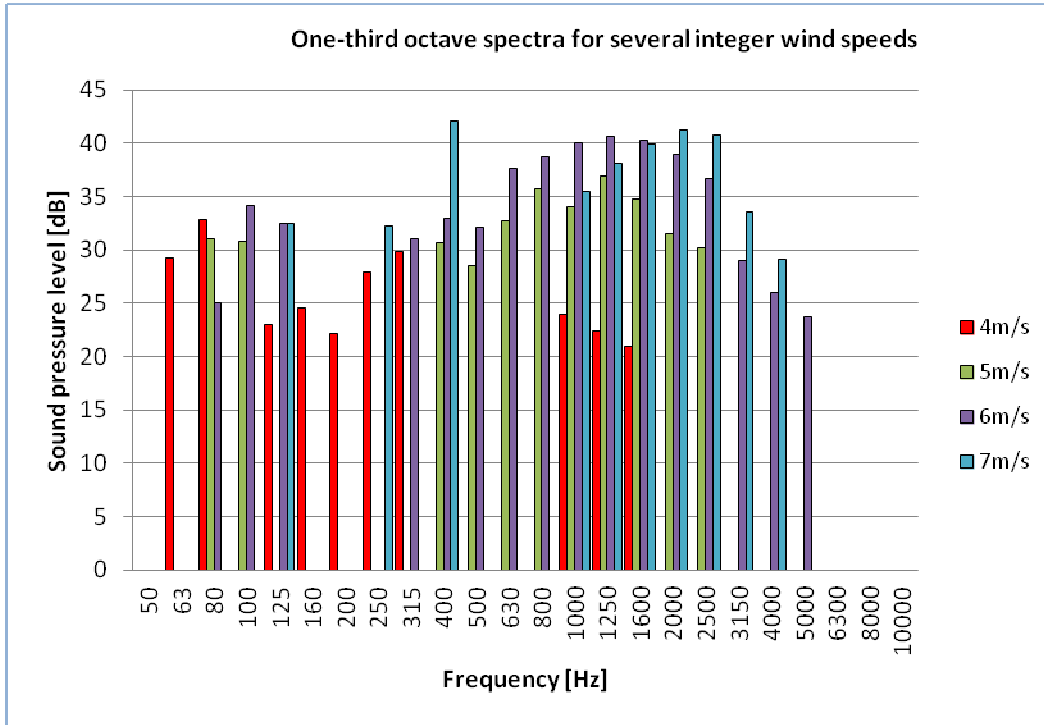
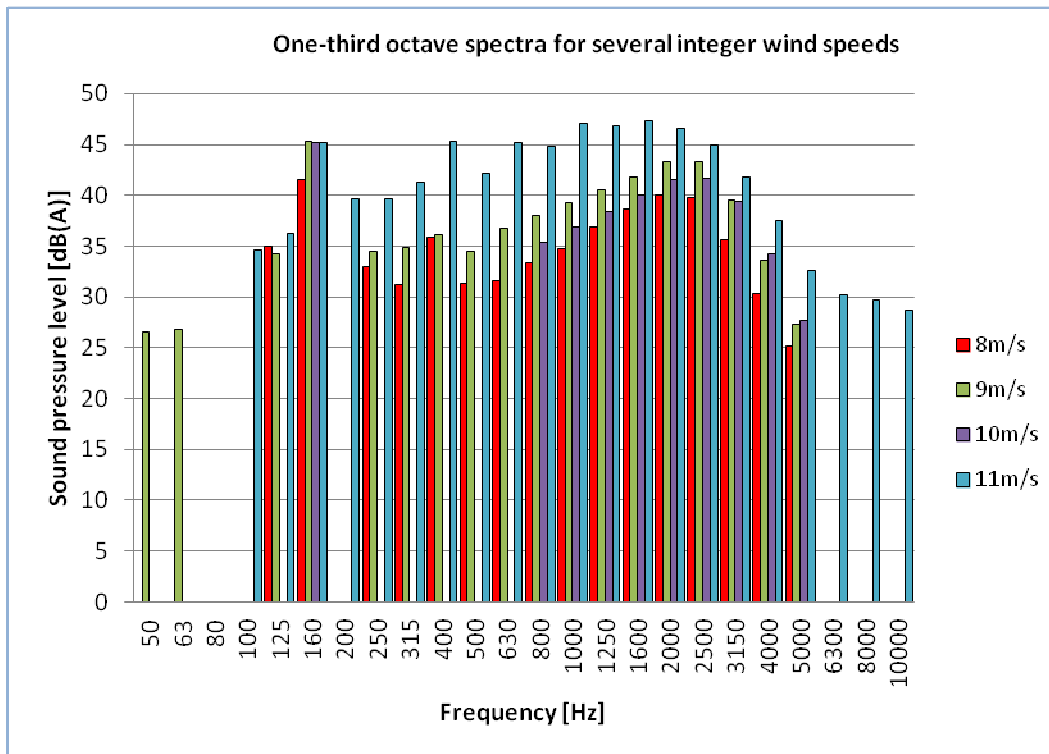**Figure 3** – One-third octave spectra （4m/s-7m/s）

Figure 4 – One-third octave spectra （8m/s-11m/s）

Freq [Hz]	4m/s Ls [dB(A)]	Uc [dB(A)]	5m/s Ls [dB(A)]	Uc [dB(A)]	6m/s Ls [dB(A)]	Uc [dB(A)]	7m/s Ls [dB(A)]	Uc [dB(A)]
50	-	-	23.3	4.1	-	-	-	-
63	29.9	2.4	-	-	-	-	-	-
80	32.8	1.2	31.1	2.6	*25.1	3.9	-	-
100	-	-	31.0	5.7	34.2	2.4	-	-
125	*22.9	1.2	-	-	32.4	6.0	32.5	1.4
160	*23.3	1.4	-	-	-	-	-	-
200	*22.2	1.3	-	-	-	-	-	-
250	28.6	1.5	-	-	-	-	*32.2	1.7
315	30.2	1.2	-	-	*31.0	2.6	-	-
400	34.6	1.2	*32.12	2.8	*32.9	1.2	42.1	4.4
500	26.3	1.2	*28.76	1.7	*32.1	2.4	-	-
630	-	-	33.0	3.3	37.6	3.3	-	-
800	*23.3	1.2	36.0	4.9	38.7	3.5	-	-
1000	*24.3	1.2	35.0	2.6	40.1	3.6	*35.5	1.5
1250	*22.3	1.2	37.4	4.4	40.7	3.0	38.1	1.5
1600	*21.0	1.2	35.6	3.9	40.3	3.2	39.9	1.2
2000	-	-	32.3	2.9	39.0	4.2	41.3	1.2
2500	-	-	30.6	3.7	36.7	3.8	40.7	1.3
3150	-	-	*24.3	1.9	29.0	2.8	33.6	1.2
4000	-	-	*23.2	2.1	*26.0	2.2	*29.1	1.2
5000	-	-	-	-	*23.7	1.6	-	-
6300	-	-	-	-	-	-	-	-
8000	-	-	-	-	-	-	-	-
10000	-	-	-	-	-	-	-	-

Table 4 – One-third octave spectra in dB (A) for several integer wind speeds (4m/s~7m/s) in 10 m height

Freq [Hz]	8m/s Ls [dB(A)]	8m/s Uc [dB(A)]	9m/s Ls [dB(A)]	9m/s Uc [dB(A)]	10m/s Ls [dB(A)]	10m/s Uc [dB(A)]	11m/s Ls [dB(A)]	11m/s Uc [dB(A)]
50	-	-	*26.6	3.8	-	-	-	-
63	-	-	*26.9	3.3	-	-	-	-
80	-	-	-	-	-	-	-	-
100	-	-	-	-	-	-	*34.6	2.3
125	35.0	2.2	34.2	2.1	-	-	*36.3	1.8
160	41.5	3.9	45.3	5.4	45.2	1.2	45.2	2.8
200	-	-	-	1.4	-	-	39.7	2.8
250	*33.0	1.5	*34.49	1.9	-	-	*39.7	2.2
315	*31.2	1.2	*34.91	1.7	-	-	41.3	2.0
400	35.9	2.3	*36.18	1.9	-	-	45.4	3.5
500	*31.4	1.2	*34.46	1.6	-	-	42.2	1.8
630	*31.6	1.3	36.7	2.2	-	-	45.2	1.8
800	*33.3	1.4	38.0	2.2	*35.37	1.3	44.9	1.7
1000	34.8	1.6	39.3	2.3	*36.85	1.6	47.1	2.0
1250	36.9	1.6	40.6	2.2	38.5	1.9	46.8	2.0
1600	38.6	2.1	41.7	2.3	40.0	2.0	47.3	1.9
2000	40.0	2.5	43.3	2.5	41.5	2.1	46.6	1.7
2500	39.8	2.4	43.3	3.0	41.6	2.2	44.9	1.7
3150	35.6	1.7	39.6	3.1	39.3	2.3	41.8	2.2
4000	30.4	1.4	33.7	2.5	34.2	2.2	37.5	2.6
5000	*25.2	1.4	*27.27	2.1	*27.66	1.7	*32.7	2.0
6300	-	-	-	-	-	-	*30.2	1.8
8000	-	-	-	-	-	-	*29.7	1.9
10000	-	-	-	-	-	-	*28.7	1.9

Table 5 – One-third octave spectra in dB (A) for several integer wind speeds (8m/s~11m/s) in 10 m height

5.0 AWEA Rated Annual Energy

Table 6 below summarizes the estimation of expected annual energy production (AEP) at sea-level air density.

Estimated annual energy production, database A (all valid data)					
Reference air density: 1.225kg/m^3					
Hub height annual average wind speed (Rayleigh) m/s	AEP-measured kWh	Standard Uncertainty in AEP-measured		AEP-extrapolated kWh	Complete if AEP measured is at least 95% of AEP extrapolated
		kWh	%		
4	5,098.46	341.02	6.69%	5,098.52	Complete
5	9,238.81	559.74	6.06%	9,246.88	Complete
6	13,524.74	772.53	5.71%	13,634.20	Complete
7	17,121.90	948.27	5.54%	17,647.52	Complete
8	19,618.65	1069.44	5.45%	21,062.65	Incomplete
9	20,992.70	1134.58	5.40%	23,841.93	Incomplete
10	21,437.54	1152.86	5.38%	25,991.94	Incomplete
11	21,207.47	1136.92	5.36%	27,531.17	Incomplete

Table 6 – Estimated annual energy production of the PWA05-50-280 at sea-level air density

An indication of "incomplete" in the far-right column of Table 6 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.

From the above table: **AWEA Rated Annual Energy   9,238.81 kWh**

6.0 AWEA Rated Sound Level

The AWEA Rated Sound Level, L_{AWEA}, is the sound level that will not be exceeded 95% of the time, assuming an average wind speed of 5 m/s (11.2 mph), a Rayleigh wind speed distribution, 100% availability, and an observer location 60 m (~ 200 ft.) from the rotor center. That means the sound pressure level at a distance of 60 m and at a wind speed of 9.8 m/s using the equation (9) in IEC 61400-11 of the sound power level.

First, the sound pressure level at 9.8 m/s is obtained interpolating between the 9 & 10 m/s bins. Then L_{AWEA} is calculated using the following equations:

$$L_{WA,(9.8m/s)} = L_{S(9.8m/s)} - 6 + 10\log(4\pi R_1^2)$$
$$L_{AWEA} = L_{WA,(9.8m/s)} - 10\log(4\pi 60^2)$$

Using the equations above: **AWEA Rated Sound Level, L_{AWEA}: 42.0 dB(A)**

Table 7 gives the calculated apparent sound power levels, with the combined uncertainty for each integer wind speed.

WS 10m	WS Ave	Ls+n [dB]	Ln [dB]	Laeq,c,k [dB]	LWA,k[dB]	Uc[dB]
4	3.7	39.9	36.5	*38.6	*67.9	1.6
5	5.1	45.7	37.7	44.9	74.2	3.2
6	6.0	46.8	38.4	46.1	75.4	4.3
7	7.1	49.7	40.0	49.2	78.5	2.3
8	8.0	51.4	42.0	50.9	80.2	2.4
9	9.0	52.2	43.6	51.5	80.8	2.5
10	10.0	54.4	45.8	53.8	83.0	2.2
11	11.1	55.3	47.5	54.5	83.7	1.6
12	12.0	56.4	49.6	55.4	84.7	1.2

Table 7. Apparent sound power level.

7.0 AWEA Rated Power

The AWEA 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:

AWEA Rated Power: 5.01 kW

8.0 Strength and Safety Test Results

The SUMEC PWA05-50-280 design file was evaluated during the months of September and December 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 PWA05-50-280 horizontal-axis wind turbine. The design file was found to be in compliance with all requirements of the above referenced standard regarding structural design. All supporting documentation is maintained within the project file.

Strength and Safety of the PWA05-50-280 was confirmed via the combination of the Intertek Safety and Function Test Report (Report No SH10070988-005) 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 Mechanical system Report (Report No SH10070988-004) for the design documentation and calculation provided by Sumec with the structural design requirements of the above referenced standard.

The PWA05-50-280 has met all of the design requirements for a **Class III** small wind turbine.

9.0 Tower Design Requirements

The report of tower design requirements has been supplied by Sumec. The following table summarizes the tower top loads and tower data from SUMEC Wind Turbine Tower Design Specification.

Tower Code	5kW Tower
Tower Type	Octagonal tubular steel
Height	10 m
Diameter of head flange	280 mm
Diameter of bottom flange	600 mm
Quality	585 kg
Thickness	8 mm

Table 8 –Tower design data for the test turbine for the PWA05-50-280

Wind Turbine Type	-	PWA05-50-280
Maximum tower top forces Load Case H	$F_{x\text{-}shaft}$ (N)	11495.65
	F_{tower} (N) *	16409.33
	$F_{front,nacelle}$ (N) **	1112.19
Maximum tower top bending moment (fore-aft) Load Case B	M_{shaft} (Nm)	8363.77
Maximum tower top bending moment (side-side) Load Case G	$M_{x\text{-}shaft}$ (Nm)	1534.96
* Drag force on the tower, details see load report		
** Drag force on the nacelle, details see load report		

Table 9 – Tower top loads for the test turbine for the PWA05-50-280

10.0 Duration Test Summary

10.1 Operational Time

The test turbine system was installed on November 23, 2010. The duration test was started on April 01, 2011. The duration test was completed on May 02, 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 13 months, or 395 days, from April 01, 2011 through May 02, 2012. .

10.3 Hours of Power Production

Table 10 below indicates the number of power production hours that were observed during the 13 month test duration.

Month	Hours of Power Production Above(hour):			Max Wind Speed	TI @15m/s	Data Points	T_T	T_U	T_E	T_N	O
	0m/s	9m/s	15m/s	m/s	%	Points	(hours)	(hours)	(hours)	(hours)	%
Overall	6001.9	485.1	28.9	19.1	0.66	119	9203.7	684.5	152	236.4	97.2
2011											
Apr	489.3	86.7	1.7	16.8	0.34	3	686.3	45.2	21	36.3	94.1
May	418	37.5	1.8	16.7	0.84	26	724.8	70.5	19	38.3	94
Jun	458.8	17.3	0.3	16.4	1.51	13	697.8	55.3	10	16.3	97.4
Jul	402.3	4.5	0	13.9	0	0	715	61.5	10	10	98.4
Aug	447	13.8	0.2	15.9	0.82	22	733.7	51	14	10.8	98.4
Sep	449.5	49.5	0.2	15.8	0.88	16	716.5	43.8	57	20.3	96.7
Oct	454	41.8	0	13.9	0.1	2	732.7	47.3	21	11.8	98.2
Nov	465.3	49	11.5	19.1	1.10	13	664.8	43.7	0	10.2	98.4
Dec	404.2	15.7	1.2	15.6	1.00	7	634.8	58	0	22.2	96.2
2012											
Jan	427.8	25.5	0	11.3	0.00	0	743.3	51.3	0	12	98.3
Feb	472	37.7	3.5	17.6	0.80	4	682	48.8	0	21.8	96.6
Mar	590.7	48.8	5.2	17.2	1.10	8	737.2	53	0	7.7	98.9
Apr	498.3	57.3	3.3	17	0.80	5	687	52.3	0	17.2	97.3
May	24.7	0	0	8.1	0.00	0	47.8	2.8	0	1.5	96.7

Table 10 – Monthly and overall results of the duration test for the PWA05-50-280

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_T is the total time period under consideration,
T_N is the time during which the turbine is known to be non-operational,
T_U is the time during which the turbine status is unknown, and
T_E 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 **92.7%**. 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 PWA05-50-280 is deemed to **PASS the Duration Test.**

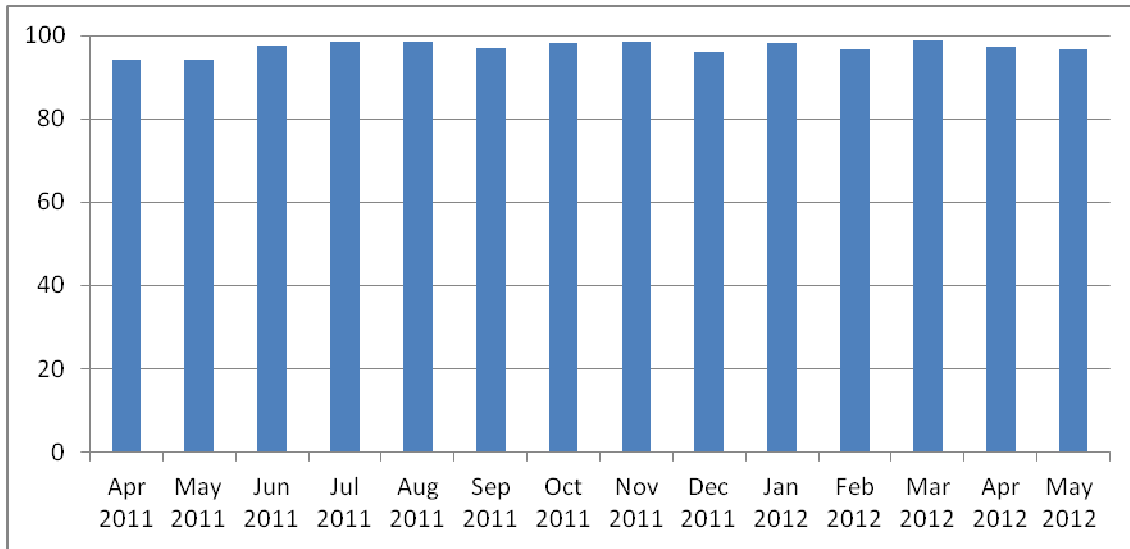Figure 5 and Table 10 show the operational time fraction per month.

Figure 5 – The operational time fraction per month for PWA05-50-280

The operational time was 236.4 hours during which the turbine was non-operational (T_N). Total operational time amounts to 9203.7 hours. As for the time excluded from the analysis, T_E, which totalled 152 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_E 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 684.5 hours of unknown time (T_U).

Table 11 shows the fault condition assignments for different situations.

Condition	T_N	T_U	T_E	No Fault
Grid Fault			X	
Over speed/Furling	X			
Emergency Stop	X			
Unwrapping of droop cable	X			
Turbine inspections	X			
Fault conditions	X			
DAS disable		X		
Lost or irresolvable data		X		
Routine maintenance	X			
Turbine in test mode			X	
Failure of external system			X	
Inspection of data acquisition			X	
Other than routine maintenance			X	
External weather conditions			X	

Table 11 – Fault condition assignments

10.5 Environmental Conditions

As an indication of the environmental conditions during the duration test, the standard requires reporting of the highest instantaneous wind speed gust and the average turbulence intensity at 15 m/s. The highest instantaneous wind speed was 23.1 m/s at 18:30 on 8th November 2011. The average turbulence intensity at 15 m/s during the duration test was 0.66%.

10.6 Power Degradation

 A factor of reliable operation is that the turbine should experience no significant power degradation. During the power degradation analysis, the average power level for each wind speed bin was plotted as a function of time over the whole test period. This plot is analyzed for any obvious trends in power production.
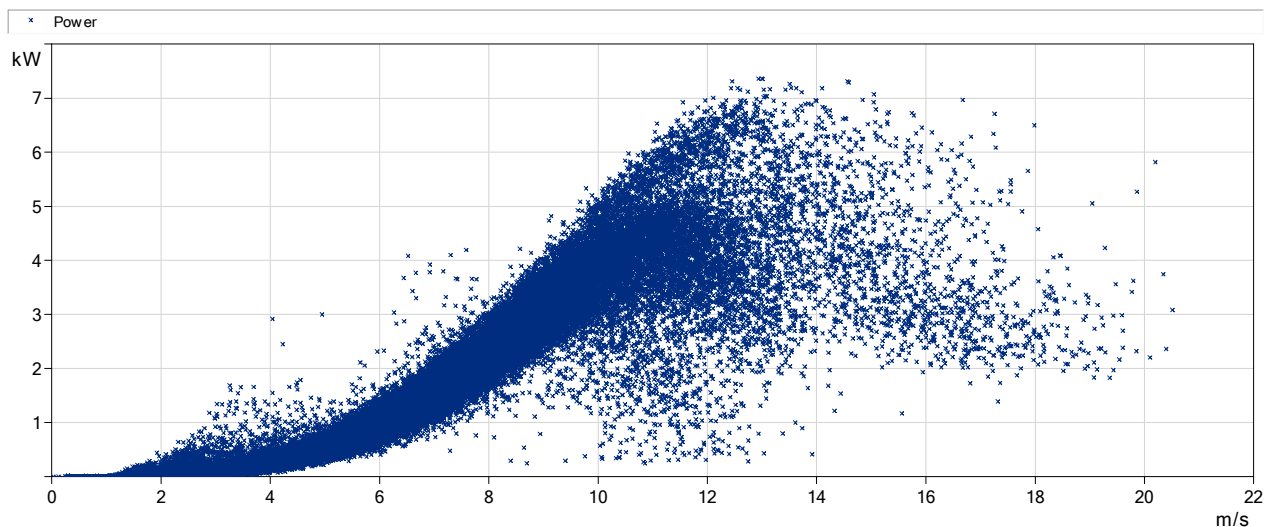

Figure 6 – Scatter plot of power curve

Figure 7 shows the power degradation plot, which gives the power level in individual wind speed bins for each month. Variations in the power levels from month-to-month are caused by control strategy optimization and air density variations. The unstable power output under high wind speed was caused by the small database.
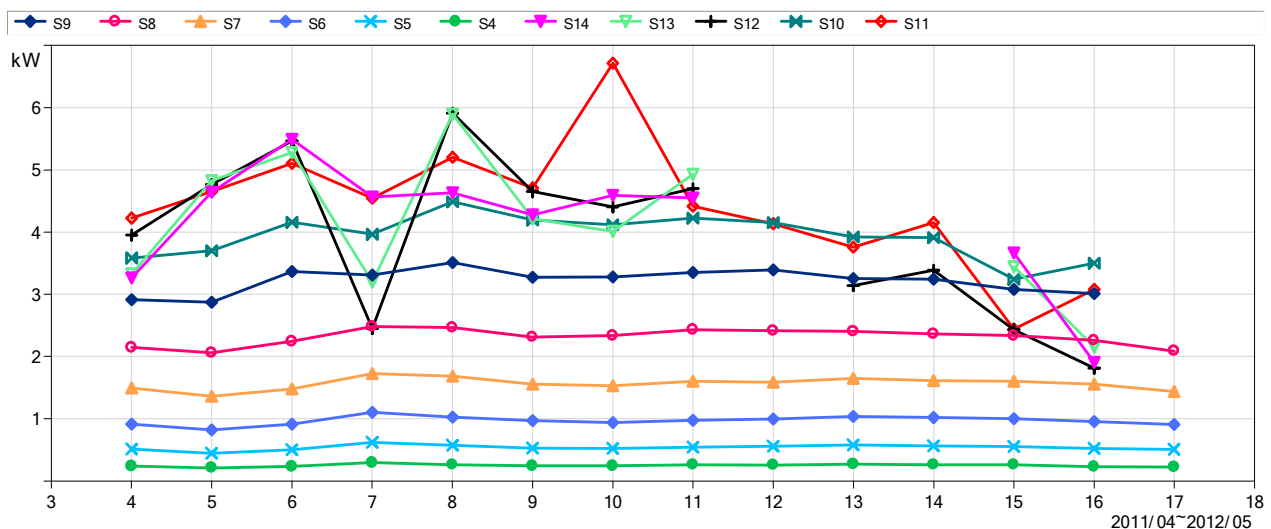

Figure 7 – Power level in several wind speed bins (in m/s) as a function of time

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 12, 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 PWA05-50-280.