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Date Issued: December 26, 2012

Report Number 12100246SHA-003
Intertek Project No: SH12100246

Miss. Zhang Qian
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Subject: Summary Test Report for the SUMEC PWA03-44-250 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 25, 2010, and in Sunite on November 12, 2012. Duration testing was completed on May 02, 2012. All testing on the PWA03-44-250 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 |
| Title: | Technical Supervisor |
| Signature: | |

| | |
|---|---|
| Reviewed by: | Joseph M Spossey |
| Title: | Small Wind Team Leader |
| Signature | |

SUMEC HARDWARE & TOOLS Co.,Ltd

Test Report No. 12100246SHA-003
Issued: December 26, 2012

# Wind Turbine Generator System
# Summary Test Report
**for the**
# Sumec PWA03-44-250

# Master Reports

| Report | Report Title | Date |
|---|---|---|
| 12061560SHA-003 | Duration Test Report | June 27, 2012 |
| Annex clause 9.6 of SH10070988-005 | Safety and Function Test Report | December 15, 2011 |
| 12061560SHA-011 | Acoustic Noise Test Report | November 25, 2012 |
| 12061560SHA-007 | 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 PWA03-44-250 horizontal-axis wind turbine. The PWA03-44-250 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 PWA03-44-250 is rated for operation at 3000 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 PWG03-10-180 synchronous permanent magnet generator. It is available as a 3 phase 180 VAC output at 27.5 Hz at 330 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-3.0-OUTD-US-W Inverter, and also to divert power to the dump load. The Inverter is rated for operation at 3 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) | 4.4 |
| Hub Height (m) | 10.2 |
| **Performance** | |
| Rated Electrical Power (kW) | 3 |
| 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 ($m^2$) | 15.198 |
| Rated Rotational Speed (rpm) | 330 |
| Design Maximum Rotational Speed (rpm) | 490 |
| 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 | PWA03.2.1 |
| Length (m) | 2.2 |
| Material / Construction | Wood core with epoxy fiber glass coated |
| Mass (kg) | 10 |
| Tip speed (m/s) | 88.47 |
| Serial number | ZY09102608 |
| **Yaw System** | |
| Wind Direction Sensor (type, location) | PWA03-44-250 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 | PWG03-10-180 |
| Type/technology | Permanent-Magnet Synchronous Generator |
| Rated voltage | 180 VAC |
| Rated power / speed | 27.5 Hz |
| Speed range | 0 – 490 RPM |
| Number of poles | 5 |
| Stator rated current | 10 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 | 20100900330 |
| **Controller** | |
| Manufacturer | SUMEC Manufacturing Venture Co., Ltd. |
| Model | PWC03-A-250 |
| Software version | Wind version 2011010102 |
| Type/technology | Full power |
| Rated voltage | 250 VDC |
| Frequency | 27.5Hz |
| Capacity | 3KVA |
| Rated current | 12.5 A |
| Cooling method | Nature air cooling |
| IP Protection | IP54 |
| Serial number | 2011012000328 |
| **Inverter** | |
| Manufacturer | Power-One Inc |
| Model | PVI-3.0-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 | 3000W |
| Rated current of Grid-side converter | 14.5 A |
| Serial number | 194266 |
| Certifications | Conforms to UL Std No. 1741<br>Certified to CSA-C22.2 No.107.1-01<br>CSA certificate No.:2096477 |
| **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 PWA03-44-250 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 | 210 mm |
| Diameter of bottom flange | 550 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 | 1.02 | -0.02 | - | 404 | 0.00 | 0.01 | 0.01 |
| 2 | 1.55 | -0.03 | - | 820 | 0.00 | 0.01 | 0.01 |
| 3 | 2.02 | -0.02 | - | 1814 | 0.00 | 0.01 | 0.01 |
| 4 | 2.46 | 0.02 | 0.14 | 1648 | 0.00 | 0.01 | 0.01 |
| 5 | 3.01 | 0.10 | 0.39 | 1366 | 0.00 | 0.01 | 0.01 |
| 6 | 3.50 | 0.17 | 0.43 | 1727 | 0.00 | 0.02 | 0.02 |
| 7 | 3.99 | 0.24 | 0.41 | 1634 | 0.00 | 0.02 | 0.02 |
| 8 | 4.50 | 0.34 | 0.40 | 1533 | 0.00 | 0.02 | 0.02 |
| 9 | 5.00 | 0.48 | 0.41 | 1360 | 0.00 | 0.03 | 0.03 |
| 10 | 5.49 | 0.65 | 0.42 | 1046 | 0.00 | 0.05 | 0.05 |
| 11 | 6.00 | 0.83 | 0.41 | 924 | 0.01 | 0.05 | 0.05 |
| 12 | 6.48 | 1.04 | 0.41 | 794 | 0.01 | 0.07 | 0.07 |
| 13 | 6.98 | 1.30 | 0.41 | 634 | 0.01 | 0.08 | 0.08 |
| 14 | 7.47 | 1.55 | 0.40 | 343 | 0.02 | 0.09 | 0.09 |
| 15 | 7.97 | 1.77 | 0.38 | 213 | 0.02 | 0.08 | 0.08 |
| 16 | 8.45 | 2.01 | 0.36 | 93 | 0.03 | 0.10 | 0.10 |
| 17 | 8.98 | 2.15 | 0.32 | 54 | 0.06 | 0.06 | 0.08 |
| 18 | 9.50 | 2.54 | 0.32 | 39 | 0.09 | 0.16 | 0.19 |
| 19 | 10.02 | 2.90 | 0.31 | 38 | 0.10 | 0.16 | 0.19 |
| 20 | 10.46 | 3.30 | 0.31 | 24 | 0.05 | 0.22 | 0.22 |
| 21 | 11.01 | 3.24 | 0.26 | 25 | 0.17 | 0.04 | 0.17 |
| 22 | 11.50 | 3.03 | 0.21 | 16 | 0.18 | 0.12 | 0.21 |
| 23 | 11.97 | 2.98 | 0.19 | 20 | 0.15 | 0.04 | 0.16 |
| 24 | 12.59 | 2.52 | 0.14 | 18 | 0.13 | 0.21 | 0.25 |
| 25 | 12.96 | 2.10 | 0.10 | 17 | 0.20 | 0.33 | 0.39 |
| 26 | 13.52 | 2.03 | 0.09 | 25 | 0.17 | 0.04 | 0.18 |
| 27 | 14.03 | 1.30 | 0.05 | 16 | 0.15 | 0.45 | 0.48 |
| 28 | 14.48 | 1.12 | 0.04 | 22 | 0.13 | 0.13 | 0.19 |
| 29 | 15.02 | 0.91 | 0.03 | 15 | 0.03 | 0.13 | 0.14 |
| 30 | 15.49 | 0.94 | 0.03 | 25 | 0.05 | 0.03 | 0.06 |
| 31 | 15.98 | 0.92 | 0.02 | 21 | 0.02 | 0.02 | 0.03 |
| 32 | 16.48 | 0.91 | 0.02 | 17 | 0.02 | 0.02 | 0.03 |
| 33 | 16.94 | 0.93 | 0.02 | 22 | 0.02 | 0.02 | 0.03 |
| 34 | 17.54 | 0.98 | 0.02 | 9 | 0.02 | 0.04 | 0.04 |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |

| | | | | |
|---|---|---|---|---|
| **Manufacture:** | SUMEC | **Standard Power Output:** | 3 | **kW** |
| **Total Number:** | 16776 | **Diameter of Wind Turbine**: | 4.4 | **m** |
| **Report Date:** | Jul 2012 | **1 min Averages** | | |

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**Table 3** – Performance at sea-level air density for the PWA03-44-250; 1.225 kg/m$^3$

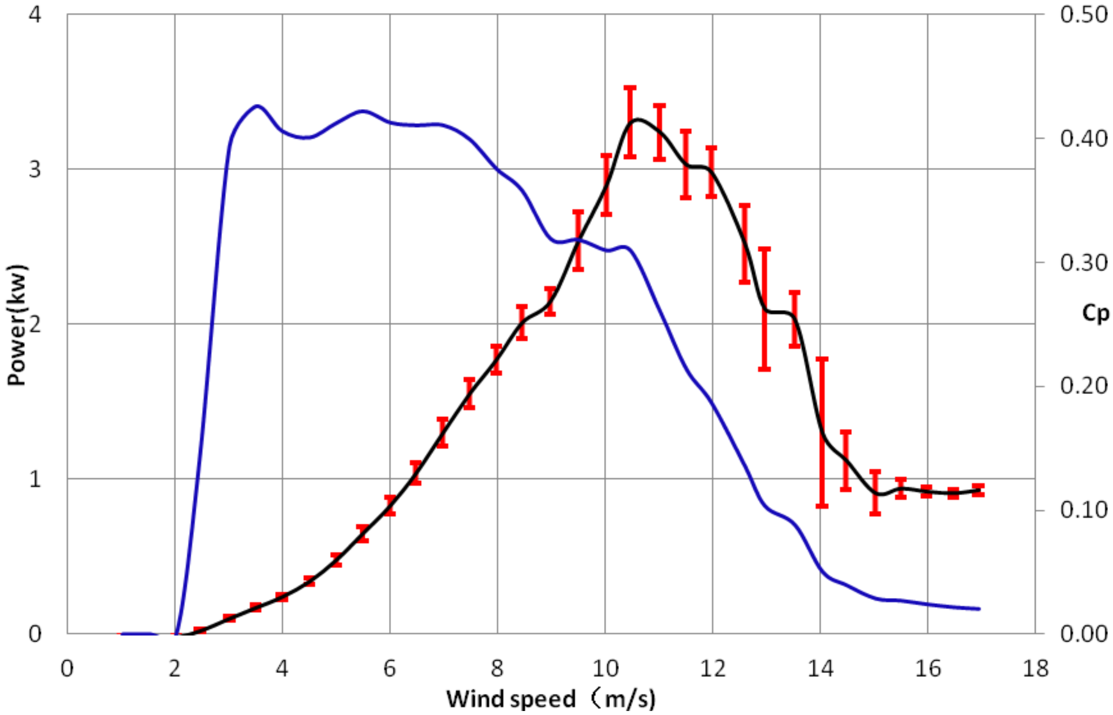


**Figure 1** – Normalized Power curve and Coefficient of performance at sea-level density for the PWA03-44-250; 1.225 kg/m$^3$

## 4.0 Acoustic Test Summary

Below is a summary of the test results for the PWA03-44-250 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.

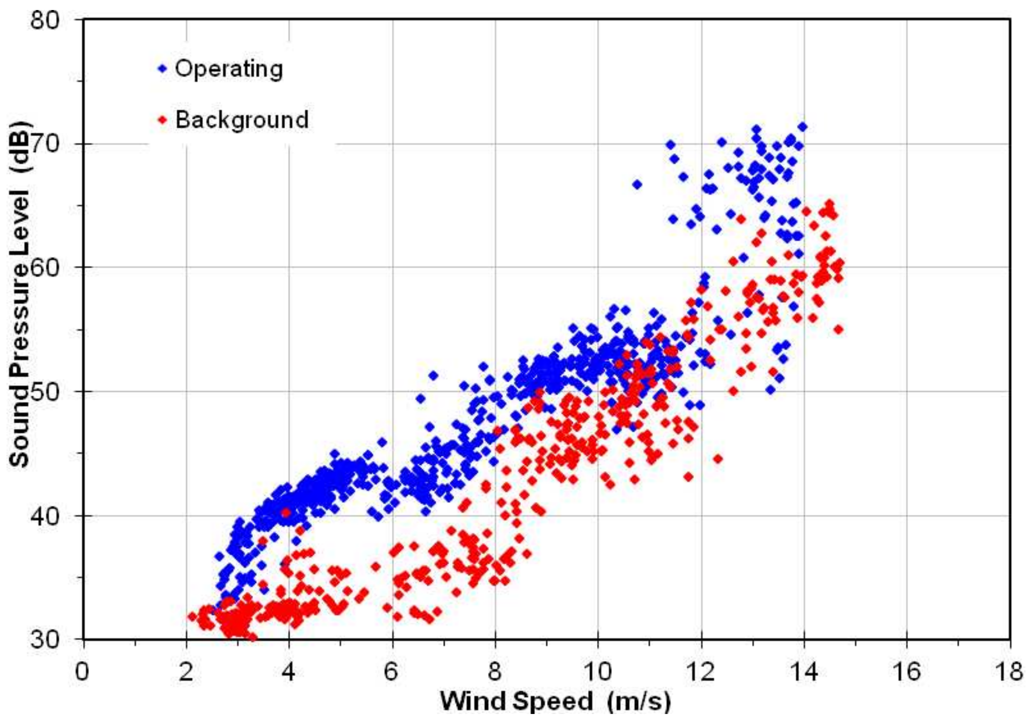


**Figure 2** – Ls+n & Ln against 10m height wind speed for the PWA03-44-250

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.

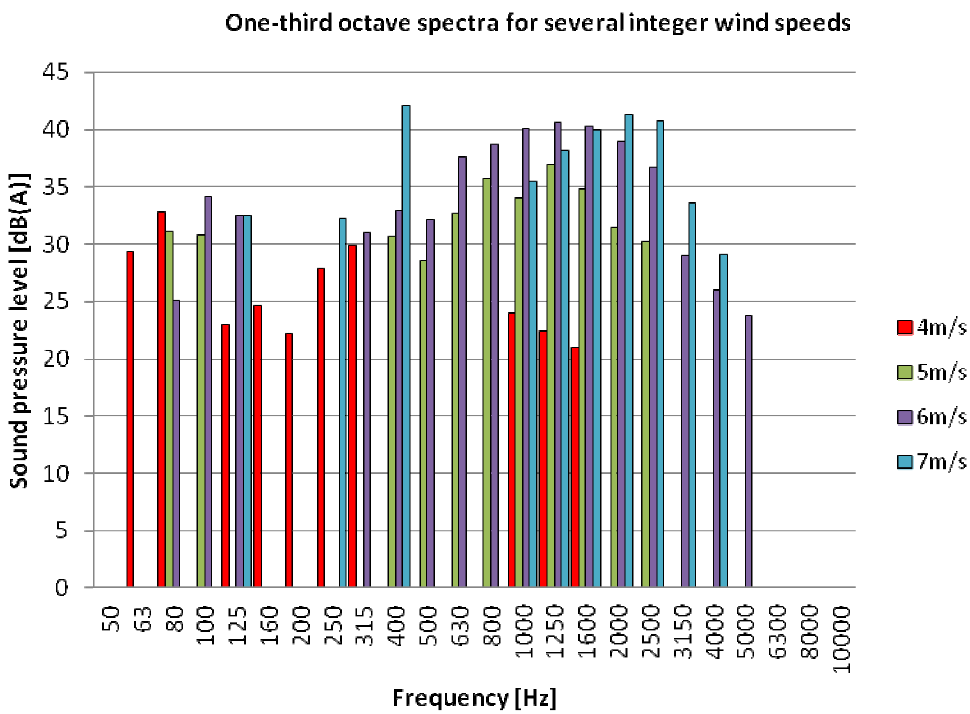


**Figure 3** – One-third octave spectra （4m/s-7m/s）

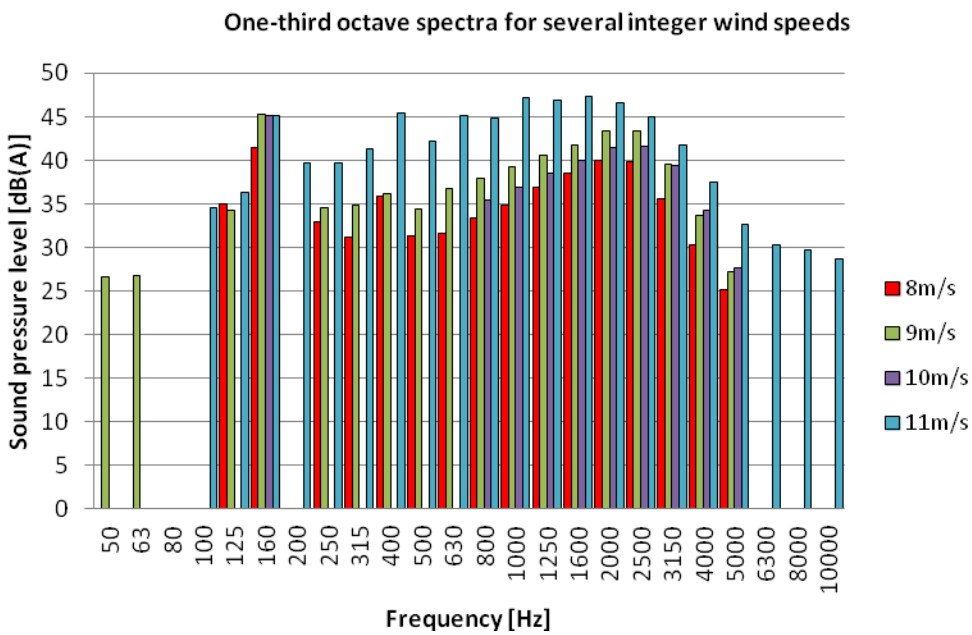


**Figure 4** – One-third octave spectra （8m/s-11m/s）

| | 4m/s | | 5m/s | | 6m/s | | 7m/s | |
|---|---|---|---|---|---|---|---|---|
| Freq [Hz] | Ls [dB(A)] | Uc [dB(A)] | Ls [dB(A)] | Uc [dB(A)] | Ls [dB(A)] | Uc [dB(A)] | Ls [dB(A)] | Uc [dB(A)] |
| 50 | - | - | 23.3 | 1.2 | - | - | - | - |
| 63 | 29.9 | 1.2 | - | - | - | - | - | - |
| 80 | 32.8 | 2.4 | 31.1 | 1.8 | *25.1 | 1.4 | - | - |
| 100 | - | - | 31.0 | 1.2 | 34.2 | 1.2 | - | - |
| 125 | *22.9 | 1.6 | - | - | 32.4 | 1.6 | 32.5 | 1.4 |
| 160 | *23.3 | 1.3 | - | - | - | - | - | - |
| 200 | *22.2 | 1.2 | - | - | - | - | - | - |
| 250 | 28.6 | 1.3 | - | - | - | - | *32.2 | 1.3 |
| 315 | 30.2 | 1.3 | - | - | *31.0 | 1.3 | - | - |
| 400 | 34.6 | 1.3 | *32.1 | 1.4 | *32.9 | 1.3 | 42.1 | 1.2 |
| 500 | 26.3 | 1.3 | *28.8 | 2.1 | *32.1 | 1.9 | - | - |
| 630 | - | - | 33.0 | 1.2 | 37.6 | 1.2 | - | - |
| 800 | *23.3 | 1.2 | 36.0 | 1.2 | 38.7 | 1.2 | - | - |
| 1000 | *24.3 | 1.3 | 35.0 | 1.2 | 40.1 | 1.2 | *35.5 | 1.7 |
| 1250 | *22.3 | 1.6 | 37.4 | 1.2 | 40.7 | 1.2 | 38.1 | 1.8 |
| 1600 | *21.0 | 1.7 | 35.6 | 1.2 | 40.3 | 1.3 | 39.9 | 1.9 |
| 2000 | - | - | 32.3 | 1.3 | 39.0 | 1.3 | 41.3 | 2.0 |
| 2500 | - | - | 30.6 | 1.3 | 36.7 | 1.3 | 40.7 | 2.3 |
| 3150 | - | - | *24.3 | 1.3 | 29.0 | 1.3 | 33.6 | 2.2 |
| 4000 | - | - | *23.2 | 1.2 | *26.0 | 1.5 | *29.1 | 2.2 |
| 5000 | - | - | - | - | *23.7 | 1.4 | - | - |
| 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

| | 8m/s | | 9m/s | | 10m/s | | 11m/s | |
|---|---|---|---|---|---|---|---|---|
| Freq [Hz] | Ls [dB(A)] | Uc [dB(A)] | Ls [dB(A)] | Uc [dB(A)] | Ls [dB(A)] | Uc [dB(A)] | Ls [dB(A)] | Uc [dB(A)] |
| 50 | - | - | *26.6 | 1.6 | - | - | - | - |
| 63 | - | - | *26.9 | 1.8 | - | - | - | - |
| 80 | - | - | - | - | - | - | - | - |
| 100 | - | - | - | - | - | - | *34.6 | 2.3 |
| 125 | 35.0 | 3.9 | 34.2 | 1.8 | - | - | *36.3 | 1.8 |
| 160 | 41.5 | 1.3 | 45.3 | 1.7 | 45.2 | 1.2 | 45.2 | 2.8 |
| 200 | - | - | - | - | - | - | 39.7 | 2.8 |
| 250 | *33.0 | 1.6 | *34.5 | 1.3 | - | - | *39.7 | 2.2 |
| 315 | *31.2 | 1.4 | *34.9 | 1.3 | - | - | 41.3 | 2.0 |
| 400 | 35.9 | 2.0 | *36.2 | 1.5 | - | - | 45.4 | 3.5 |
| 500 | *31.4 | 1.5 | *34.5 | 1.4 | - | - | 42.2 | 1.8 |
| 630 | *31.6 | 1.6 | 36.7 | 1.3 | - | - | 45.2 | 1.8 |
| 800 | *33.3 | 2.0 | 38.0 | 1.2 | *35.4 | 1.4 | 44.9 | 1.7 |
| 1000 | 34.8 | 1.6 | 39.3 | 1.2 | *36.9 | 1.4 | 47.1 | 2.0 |
| 1250 | 36.9 | 1.4 | 40.6 | 1.2 | 38.5 | 1.3 | 46.8 | 2.0 |
| 1600 | 38.6 | 1.3 | 41.7 | 1.2 | 40.0 | 1.3 | 47.3 | 1.9 |
| 2000 | 40.0 | 1.3 | 43.3 | 1.2 | 41.5 | 1.2 | 46.6 | 1.7 |
| 2500 | 39.8 | 1.3 | 43.3 | 1.2 | 41.6 | 1.2 | 44.9 | 1.7 |
| 3150 | 35.6 | 1.3 | 39.6 | 1.3 | 39.3 | 1.2 | 41.8 | 2.2 |
| 4000 | 30.4 | 1.3 | 33.7 | 1.3 | 34.2 | 1.2 | 37.5 | 2.6 |
| 5000 | *25.2 | 1.3 | *27.3 | 1.2 | *27.7 | 1.2 | *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 | 3,759.90 | 242.35 | 6.45% | 3,759.91 | Complete |
| 5 | 6,397.41 | 374.07 | 5.85% | 6,398.40 | Complete |
| 6 | 8,877.52 | 504.71 | 5.69% | 8,893.07 | Complete |
| 7 | 10,707.94 | 613.96 | 5.73% | 10,789.50 | Complete |
| 8 | 11,764.50 | 688.32 | 5.85% | 12,001.46 | Complete |
| 9 | 12,156.81 | 726.32 | 5.97% | 12,641.96 | Complete |
| 10 | 12,068.33 | 734.26 | 6.08% | 12,863.59 | Incomplete |
| 11 | 11,670.52 | 720.73 | 6.18% | 12,794.42 | Incomplete |

**Table 6 –** Estimated annual energy production of the PWA03-44-250 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** **6,397.41 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:

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

$$L_{AWEA} = L_{WA,(9.8m/s)} - 10\log\left(4\pi 60^2\right)$$

Using the equations above: **AWEA Rated Sound Level, $L_{AWEA}$: 40.9 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 | 4.0 | 40.1 | 32.9 | 39.2 | 68.3 | 1.5 |
| 5 | 4.9 | 41.9 | 34.3 | 41.1 | 70.2 | 1.2 |
| 6 | 6.0 | 43.8 | 35.3 | 43.2 | 72.3 | 1.5 |
| 7 | 6.9 | 45.8 | 37.8 | 45.1 | 74.2 | 2.3 |
| 8 | 7.9 | 48.2 | 41.4 | 47.2 | 76.3 | 2.4 |
| 9 | 9.0 | 50.8 | 44.5 | 49.6 | 78.7 | 1.3 |
| 10 | 10.0 | 54.4 | 48.3 | 53.2 | 82.3 | 1.8 |
| 11 | 11.0 | 57.6 | 51.0 | 56.5 | 85.6 | 5.8 |
| 12 | 11.9 | 62.1 | 54.2 | 61.3 | 90.4 | 7.8 |

**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: 3.24 kW**

## 8.0 Strength and Safety Test Results

The SUMEC PWA03-44-250 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 PWA03-44-250 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 PWA03-44-250 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 SH10070988-003) for the design documentation and calculation provided by Sumec with the structural design requirements of the above referenced standard.

The PWA03-44-250 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 | 3kW Tower |
|---|---|
| Tower Type | Octagonal tubular steel |
| Height | 10 m |
| Diameter of head flange | 210 mm |
| Diameter of bottom flange | 550 mm |
| Quality | 480 kg |
| Thickness | 8 mm |

**Table 8** –Tower design data for the test turbine for the PWA03-44-250

| Wind Turbine Type | - | PWA03 - 44- 250 |
|---|---|---|
| Maximum tower top forces<br>Load Case H | $F_{x\text{ - shaft}}$ (N) | 10171.51 |
| | $F_{tower}$ (N) * | 13674.75 |
| | $F_{front,\ nacelle}$ (N) ** | 695.88 |
| Maximum tower top bending moment (fore - aft)<br>Load Case B | $M_{shaft}$ (Nm) | 5023.08 |
| Maximum tower top bending moment (side - side)<br>Load Case G | $M_{x\text{ -shaft}}$ (Nm) | 751.56 |
| * Drag force on the tower, details see load report<br>** Drag force on the nacelle, details see load report | | |

**Table 9** – Tower top loads for the test turbine for the PWA03-44-250

# 10.0 Duration Test Summary

## 10.1 Operational Time

The test turbine system was installed on November 25, 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.

| | *Hours of Power Production Above(hour):* | | | *Max Wind Speed* | *TI @15m/s* | *Data Points* | $T_T$ | $T_U$ | $T_E$ | $T_N$ | *O* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Month*** | ***0m/s*** | ***9m/s*** | ***15m/s*** | ***m/s*** | ***%*** | ***Points*** | ***(hours)*** | ***(hours)*** | ***(hours)*** | ***(hours)*** | ***%*** |
| **Overall** | **5813.2** | **541.2** | **31.4** | **19.4** | **0.71** | **89** | **8732.5** | **670.9** | **181** | **257.1** | **94.9** |
| **2011** | | | | | | | | | | | |
| **Apr** | **509.5** | **93.5** | **4.8** | **17.1** | **0** | **0** | **686.3** | **45.7** | **21** | **22.7** | **96.3** |
| **May** | **421.8** | **44.7** | **6** | **17** | **1.11** | **6** | **724.8** | **70.8** | **19** | **33.3** | **94.8** |
| **Jun** | **435.8** | **32** | **5** | **16.6** | **1.13** | **16** | **697.8** | **56** | **11** | **24.2** | **96.2** |
| **Jul** | **358.7** | **4.3** | **0** | **13.4** | **0** | **0** | **715** | **61.3** | **22** | **13.2** | **97.9** |
| **Aug** | **400.2** | **10.3** | **1.3** | **14.6** | **1.12** | **8** | **733.7** | **51.8** | **35** | **17.2** | **97.3** |
| **Sep** | **457.7** | **53.8** | **1.2** | **15.9** | **1.11** | **14** | **716.5** | **43.7** | **55** | **21.2** | **96.6** |
| **Oct** | **461.2** | **42.8** | **0** | **13.5** | **0.9** | **2** | **732.7** | **47.3** | **14** | **16.2** | **97.6** |
| **Nov** | **448** | **54.2** | **11.8** | **19.4** | **1.00** | **20** | **664.8** | **66** | **4** | **7.8** | **98.7** |
| **Dec** | **415.2** | **22.5** | **1.8** | **16.4** | **1.00** | **3** | **634.8** | **58** | **0** | **12.8** | **97.8** |
| **2012** | | | | | | | | | | | |
| **Jan** | **429.7** | **29.8** | **0** | **11.3** | **0.00** | **0** | **743.3** | **51.5** | **0** | **22.5** | **96.7** |
| **Feb** | **462.5** | **44.2** | **4.7** | **18.4** | **0.60** | **6** | **682** | **48.5** | **0** | **31.3** | **95** |
| **Mar** | **548.8** | **51.8** | **5.2** | **17.6** | **1.10** | **9** | **737.2** | **52.7** | **0** | **25.7** | **96.2** |
| **Apr** | **438.3** | **57.3** | **3.7** | **16.8** | **0.80** | **5** | **215.8** | **14.8** | **0** | **6.8** | **96.6** |
| **May** | **25.8** | **0** | **0** | **8.1** | **0.00** | **0** | **47.8** | **2.8** | **0** | **2.2** | **95.1** |

**Table 10 –** Monthly and overall results of the duration test for the PWA03-44-250

## 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 **94.9%.** 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 PWA03-44-250 is deemed to **PASS the Duration Test.**

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

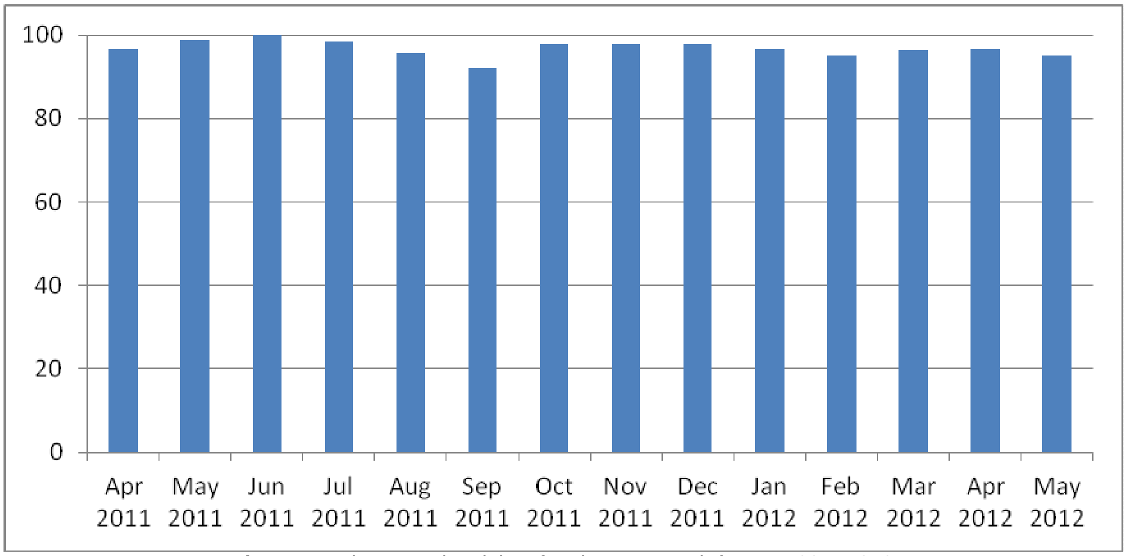


**Figure 5 –** The operational time fraction per month for PWA03-44-250

The operational time was 257.1 hours during which the turbine was non-operational ($T_N$). Total operational time amounts to 8732.5 hours. As for the time excluded from the analysis, $T_E$, which totalled 181 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 670.9 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 0.71%.

## 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.

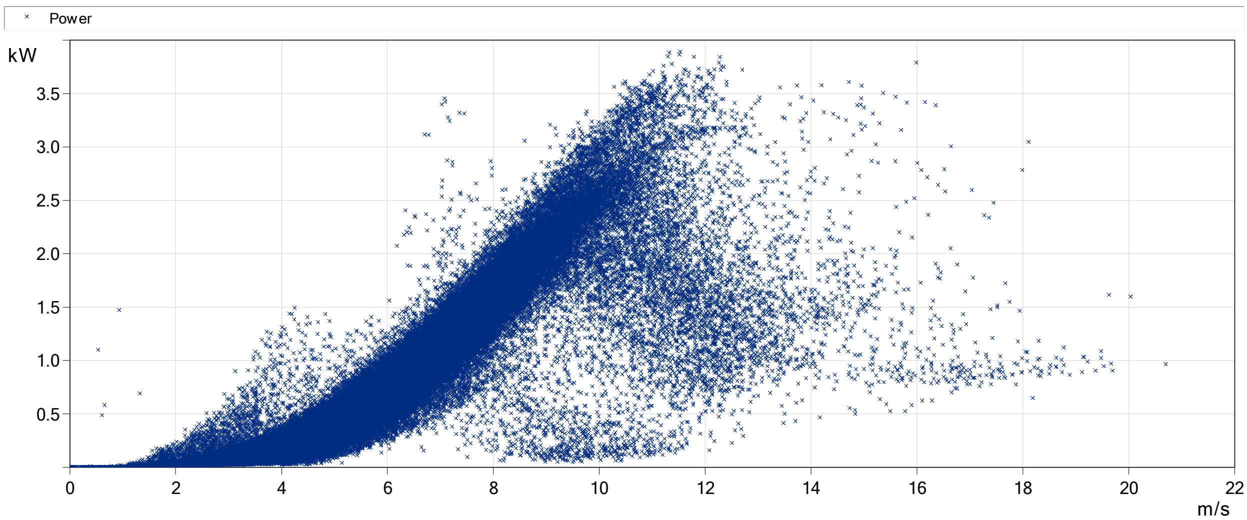


**Figure 6 –** Scatter plot of power curve

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.

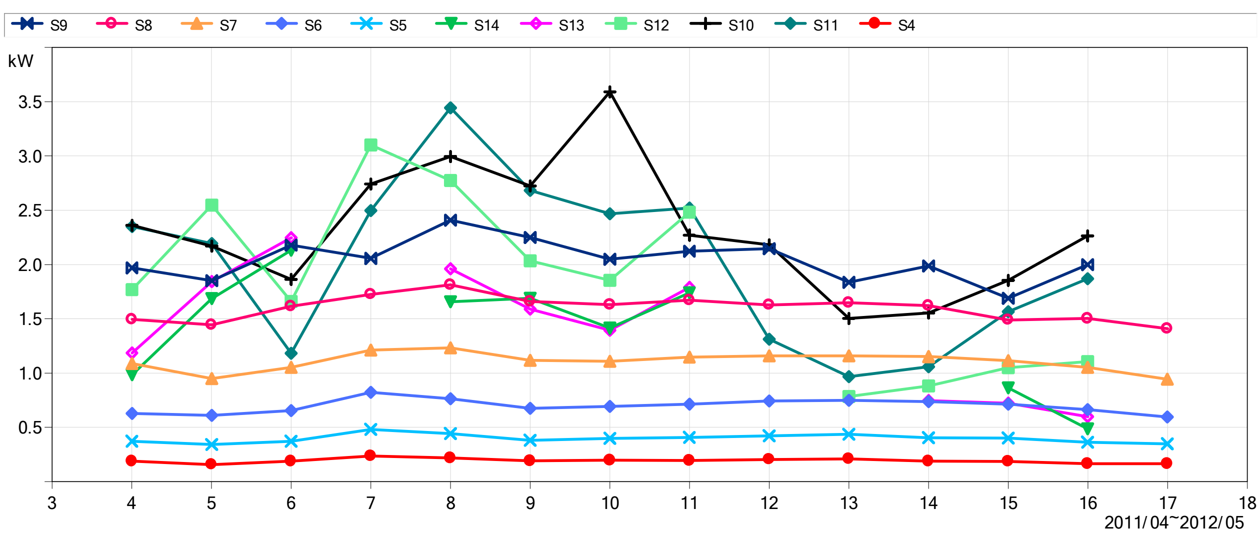


**Figure 7 –** Power level in several wind speed bins (in m/s) as a function of time

## 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 PWA03-44-250.