



Wind Turbine Generator System Safety and Function Test Report for the Entegriety EW50 Wind Turbine

Joe Smith, Arlinda Huskey, Dave Jager, and
Jerry Hur
National Renewable Energy Laboratory

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Safety and Function Test Report for the Entegrity EW50 Wind Turbine

Conducted for

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Conducted by

**National Wind Technology Center
National Renewable Energy Laboratory
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7 November 2012

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1. Background

This test was conducted as part of the U.S. Department of Energy's (DOE) Independent Testing project. This project was established to help reduce the barriers to wind energy expansion by providing independent testing results for small turbines. Five turbines were tested at the National Wind Technology Center (NWTC) as part of round one of this project. Safety and function testing is one of up to five tests that may be performed on the turbines, including duration, power performance, noise, and power quality tests. Test results provide manufacturers with reports that can be used to fulfill part of the requirements for small wind turbine certification.

The test equipment includes an Entegri Wind Systems EW50 wind turbine mounted on a 30.5-m (100-ft) monopole tower manufactured for the EW50 by Maico Industries, Inc. The controller was manufactured by Orbital A/S. Concrete mat foundation was installed per Entegri designs by a third party, under contract to National Renewable Energy Laboratory (NREL). The system was installed in March 2009 by the NWTC Site Operations group with guidance and assistance from several Entegri personnel.

2. Test Objective

The objective of this test was to:

- Verify whether the test turbine displays the behavior predicted in the design
- Determine whether provisions relating to personnel safety are properly implemented
- Characterize the dynamic behavior of the wind turbine at rated and higher wind speeds.

NREL does not limit the safety and function test to features described in the wind turbine documentation. NREL also inspects—possibly tests—and reports on features that are required by IEC 61400-2 and that might not be described in the wind turbine documentation. NREL conducted this test in accordance with Section 9.6 of the IEC standard, “Wind Turbines—Part 2: Design Requirements for Small Wind Turbines,” IEC 61400-2, second edition, 2006-03.

3. Description of Test Turbine and Setup

The test turbine was an Entegri EW50 wind turbine. The EW50 is a downwind, 3-blade, passive-yaw, horizontal-axis wind turbine, manufactured by Entegri Wind Systems Inc. The blades are fixed pitch, and the turbine employs an asynchronous generator and operates at a fixed speed to deliver three-phase electric power at 60 Hz. Table 1 lists the configuration of the Entegri EW50 that was tested at the NWTC. Figure 1 is a picture of the EW50 at the NWTC.

Table 1 Test turbine configuration

Turbine manufacturer and address	Entegrity Wind Systems Inc 4855 Riverbend Rd.; Ste 100 Boulder, CO 80301
Model name	EW50
Production date	January 2009
Gearbox serial number	543132-007
Generator serial number	C0812180024
Design nominal voltage at terminals	415-600 Vac
Maximum current at terminals	108 A
Design frequency at terminals	60 Hz
SWT class	II
Design 50-year extreme wind speed, V_{e50}	59.5 m/s
Rotor Diameter	14.9 m
Hub Height (vertical center of rotor)	31.1 m
Tower Type	30.5-m (100-ft) freestanding monopole
Rated Electrical Power	50 kW
Rated Wind Speed (lowest wind speed at which turbine produces rated power)	11.3 m/s
Rated rotor speed (lowest rotor speed at which turbine produces rated power)	65 rpm
Rotor speed range	64-70 rpm
Fixed or variable pitch	Fixed with tip brake
Number of Blades	3
Blade Tip Pitch Angle	5.14° to 5.17° at 75% span
Blade make, type, serial number	Entegrity, epoxy/glass fiber, 7.2 m, 150 kg, s/n: 284, 285, 283
Description of control system (device and software version)	TMC microprocessor by Orbital A/S in Entegrity enclosure version: "EW15 2.031"

Measurements verified the rotor diameter and hub height. Rated power and rated wind speed listed in the table are as published by Entegrity.

The test turbine is located at site 1E.1 at the NWTC, which is approximately 8 km south of Boulder, Colorado. The terrain is mostly flat with short vegetation. The site has prevailing winds bearing approximately 290 degrees relative to true north.

Figure 2 shows the general electrical arrangement. The wire run from the controller at the base of the tower to the point of grid connection at the data shed is approximately 100 m. The connection is made using 1/0 American Wire Gauge (AWG) wire for the three hot lines and neutral line, with a #2 AWG wire for the ground wire. The data shed houses the power instrumentation, disconnect switch, and data acquisition system. The transformer was located outside and adjacent to the data shed, which first stepped the voltage up to 480 V and then to 13.2 kV for the NREL grid.



**Figure 1 Entegriy EW50 test turbine at the NWTC
(Photo by Joe Smith, NREL, PIX# 22243)**

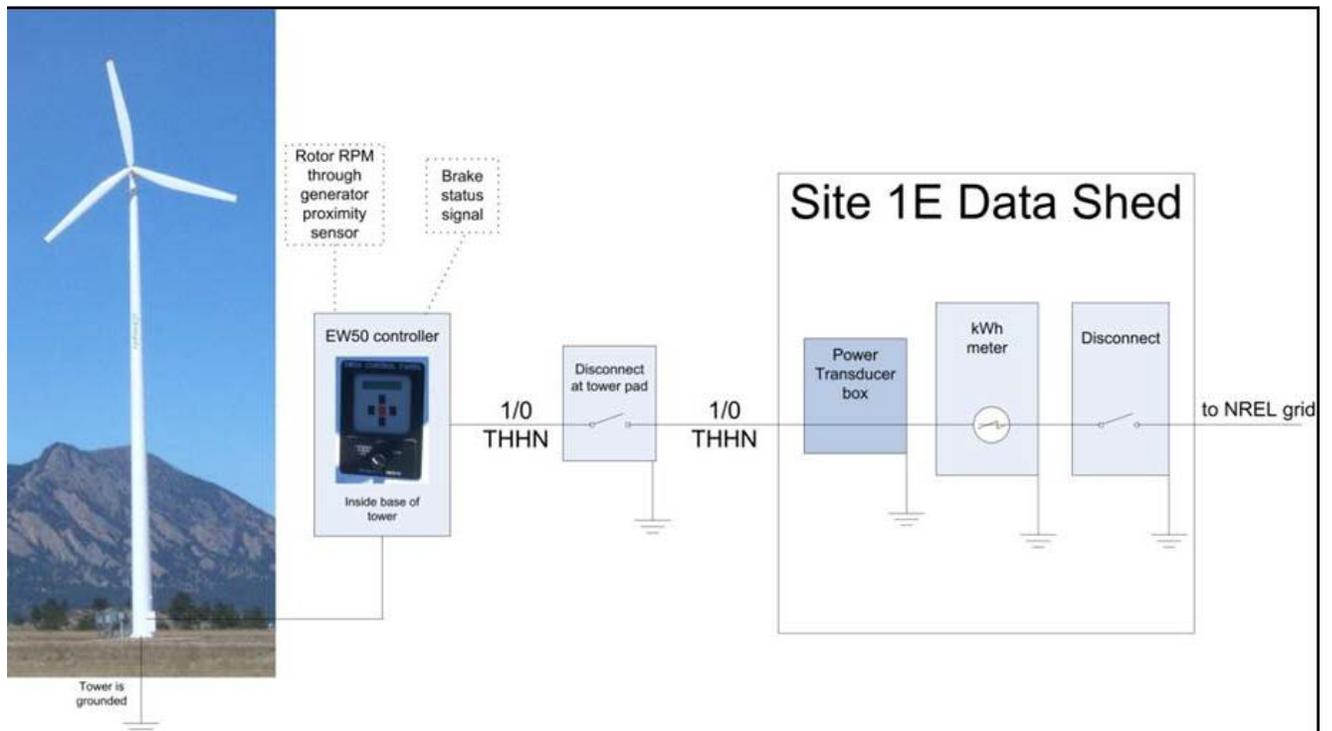


Figure 2 Electrical single-line drawing of EW50 installation

4. Instrumentation

The following parameters were measured in this test: wind speed, wind direction, electrical power, rotor speed, and grid voltage. The rotor speed was measured using a proximity sensor on the turbine generator shaft (this signal is also a controller input). An indication of turbine status was obtained by measuring the voltage of the grid and turbine brake voltage in the controller. The instruments used for these measurements are listed in Table 2. The calibration sheets for the instruments used for this safety and function test are included in Appendix A.

Table 2 Equipment used in the power performance test

Instrument	Make and Model	Serial Number	Calibration Due Date
Power transducer	Ohio Semitronics, DMT 1040E	07070473	12 Feb 10 9 Feb 11
Current transformers	Ohio Semitronics, 12974	001293045 001235428 001293049	Calibrated with power transducer
Primary anemometer	Thies, First Class	0707884 0609010	25 Feb 10 22 July 11
Reference anemometer	NRG, Max 40	179500049025	n/a
Wind vane	Met One, 020C with Aluminum Vane	U1477 W1474	25 Feb 10 24 Feb 11
Rotor speed	from controller Weidmuller WOS 1 (p/n 827539) Optocoupler	n/a	n/a
Turbine status; brake status	from controller Weidmuller WOS 1 (p/n 827539) Optocoupler	n/a	n/a
Data acquisition system	Compact DAQ w/LabView cDAQ backplane (9172) NI 9229 NI 9205 NI 9229 NI 9205	12E4CEB 13DEC38 13E3D05 12CBC7A 12ECB77	n/a 10 Nov 09 12 Nov 09 18 Jan 11 18 Jan 11

5. Procedure

Safety and function testing can involve some risk to personnel and to equipment. By incorporating appropriate controls into testing procedures, NREL endeavors to accomplish its tasks with minimal risk. This test report documents these controls in areas where they might have influenced the results obtained.

5.1. Control and Protection System Functions

In the list below, turbine response was observed for each major response category (startup, normal shutdown, emergency shutdown). If faults or other actions cause one of these major responses, NREL simulates the appropriate faulting action and verifies that the control and protection system appropriately sensed the condition, and provide an indication of an appropriate response. This procedure enables, for example, all the E-stop functions to be checked without exposing the turbine to multiple, potentially damaging stops. These checks are designated by the term “behavior” in the list below.

1. Power control
2. Rotor speed control
3. Yaw orientation

4. Startup
 - a. Normal operation – winds rising above cut-in
 - b. After maintenance or fault clearance at design wind speed or greater
 - c. Maintenance of fault conditions at design wind speed or greater
5. Normal shutdown
6. Emergency shutdown during operation
7. Behavior upon excessive vibration
8. Behavior upon loss of load
9. Turbine specific checks

5.2. Personnel Safety Provisions

The second part of the test procedure is to evaluate provisions for personnel safety. For this turbine, the following list of NWTC-standardized safety and function issues were reviewed:

1. Safety instructions
2. Climbing
3. Standing place, platforms, and floors
4. Electrical and grounding system
5. Fire resistance and control
6. Fire extinguisher
7. Emergency stop buttons
8. Lock-out / tag-out provisions
9. Interlock on electrical cabinets
10. Safety signs
11. Unauthorized changing of control settings
12. Lightning protection
13. Presence and functioning of rotor and yaw lock

5.3. Dynamic Behavior

NREL staff observed the turbine at all operating wind speeds to note the dynamic behavior of the turbine, including (but not limited to) vibration, yaw behavior, and noise.

6. Results

The results reported here are based on the test conducted from April 2009 through October 2010. The majority of controller settings were tested in October 2010.

6.1. Control and Protection System Functions

NREL limited testing to investigation of single-fault failures and has not investigated failures of “safe life” components, e.g., NREL did not investigate the tower, and considered it a “safe life” component. NREL does not make judgments on whether such failures are likely, or whether additional features in the control and protection system are needed to protect against such consequences.

Power control

Figure 3 and Figure 4 show that the power output of the turbine system is limited. The power curve scatter plot is characteristic of a stall-regulated wind turbine, as expected. There are large negative power events shown in Figure 3, which occur as the turbine is motoring up to an aerodynamically efficient speed in winds around cut-in. This behavior is programmed into the controller.

Rotor speed control

The EW50 is a constant-rotational-speed turbine when it is generating (see Figure 5).

Figure 8 shows the rotor speed versus wind speed. Some hysteresis can be seen in wind speeds between 3 and 7 m/s, which is around cut-in. The scatter data reveal a second horizontal grouping at 63 rpm between 8 and 15 m/s; this value is lower than the main line, which has a slight positive slope. This secondary line occurs when the EW50 is operating in an upwind orientation.

The tip brakes are held in place with an electromagnet. The magnet holds the brake in place as the rotor is spinning. In the event of an over speed, the brakes would deploy centripetally, and slow the rotor speed before the parking brake is deployed. In the case of a grid failure, the electromagnet loses its magnetism and the brakes deploy, slowing the rotor speed before the parking brake is deployed. After the tip brakes are deployed and the parking brake stops the rotor, springs retract the tip brakes and return them to their pre-deployment position.

Yaw orientation

The EW50 is a downwind, passive yaw turbine. NREL observed yaw behavior frequently during the test period and compared yaw position with the nearby wind vane's indication of wind direction. Yaw error could be significant. Winds of greater than 6 m/s were needed to yaw the turbine into a downwind position, while the controller is programmed for a cut-in at 4.5 m/s. If the winds were perpendicular to the rotor, the winds might need to be even higher to yaw the turbine to the downwind position.

During operation, the turbine would yaw around the average wind direction. During some yaw events, the rotor was observed to yaw approximately 60 degrees in one second. In gusty winds, the turbine on many occasions turned upwind in lulls, and was trapped in the upwind position when the wind speed increased. This upwind operation can be seen in the secondary curve in Figure 4 and Figure 7. In Figure 4 this secondary curve is most clearly visible by the maximum values (red) which are around 7 kW between 7 and 10 m/s. The average values (blue) are partially obscured in this plot, so in Figure 7 only the average power production values are plotted against wind speed for upwind operation. It is notable that in upwind operation, the power peaks between 8 and 10 m/s, above which it tends to go negative.

Spring weather at the NWTC is usually gusty, and an analysis during several months of spring-time operation was performed. Results showed the EW50 operating in the upwind orientation about 3% of the time. This resulted in an approximate 5% loss of energy because the turbine consumed power during dips in gusty wind conditions in order to maintain operational rotor speed, thus lowering its power production curve.

The droop cable can over twist. There are connectors intended to decouple the droop cables, in order to prevent them from over twisting. However, because of the strain relief installation, these connectors were isolated from the twisting, and they will not decouple before the cables over twist. See Figure 18, which shows that the cables above the strain relief are twisted, and the cables are untwisted below the strain relief; the decoupling connectors are below the strain relief. Once during the 18 months of operation the cable was untwisted by decoupling the connectors and untwisting the cables. Figure 18 shows the level of cable twist after approximately one year at the NWTC. The Entegriy 6-month inspection record lists checking for cable twist.

Startup

The controller is programmed for a 4.5-m/s cut-in wind speed. The EW50 has an anemometer on the generator to measure the wind speed. When the 10-minute average wind speed was above cut-in, the brake on the high-speed shaft (parking brake) would release, the tip-brakes would be energized (holding them in operating position), and the rotor could freewheel. When the rotor reaches a speed of 64 rpm (1800 for the generator) the generator connects to the grid. With the generator connected to the grid, the rotor spins between 62 to 65 rpm.

The EW50 also has a motor-up function. If the winds are above programmed cut-in speed (4.5 m/s) and the rotor does not reach 64 rpm, the generator connects to the grid and behaves as a motor in order to spin the rotor. Because the NWTC's air density is approximately 80% of sea level, the wind speed needs to be above 5.5 m/s for the EW50 to freewheel up to 64 rpm. The difference between the programmed cut-in and the necessary winds to operate the EW50 resulted in many motor-up events during the test period. This sequence of events can be seen in Figure 6.

Figure 6 shows that winds were greater than 4.5 m/s and the controller released the brakes and freewheeled for 10 minutes. However, the winds were not high enough for the rotor to reach an operational speed of 64 rpm. The generator motored-up the rotor, consuming just over 130 kW for approximately one second, and the rotor nearly reached operating speed. With the inertia of the spinning rotor, the rotor speed was maintained for about six minutes. After six minutes, the winds were strong enough to increase the rotor speed to operational speed and the generator connected to the grid. When the contactors connected the generator to the grid, the rotor speed was fixed between 62 and 65 rpm. When the gust that accelerated the rotor passed, the generator began consuming power to keep the rotor at operational speed. This can be seen by the slightly negative power output in the last minute of Figure 6.

Normal shutdown

If the EW50 consumes power for 10 minutes, the controller will deploy the tip brakes. The tip brakes slow the rotor to approximately 18 rpm, which is 500 rpm for the generator. The parking brake is then deployed, which quickly brings the turbine to a stop. If the tip brakes cannot slow the turbine in 30 seconds, the parking brake is deployed. This 30-second delay between tip brakes and parking brake can be seen in Figure 12.

This turbine has a cut-out wind speed. It will deploy its brakes if the 10-minute average wind speed is 25 m/s or more.

Emergency shutdown during operation from any operating condition

Turning the rotary switch on the controller panel to “stop” will first decrease the rotor speed, by deploying the tip brakes. Then the parking brake is deployed when the rotor slows to approximately 18 rpm (generator is at 500 rpm) or 30 seconds has elapsed since tip deployment. The parking brake is applied to the high-speed shaft, and it quickly brings the turbine to a stop. Figure 9 and Figure 12 show stops commanded by the rotary switch on the controller panel. Figure 12 shows that the parking brake was deployed after 30 seconds. This type of stop is identical to normal shutdown.

Behavior upon excessive vibration

The turbine has no means to sense excessive vibration or to shut down should excessive vibration occur. The IEC turbine design standards require such sensors on large turbines but not on turbines smaller than 200 m².

Behavior upon loss of load

In the event of a grid outage, the EW50 will come to a stop in the manner described above in “Emergency shutdown during operation from any operating condition,” and as shown in Figure 9 and Figure 12.

During the test at NREL, the controller’s universal power supply (UPS) failed and was put into bypass mode. In normal operation, the parking brake’s solenoid is energized through the controller’s UPS, and the brake pads are held off of the brake disk. Without the UPS, the parking brake deploys at the same time as the tip brakes, and the rotor comes to a sudden stop. This event is shown in Figure 10.

Turbine-specific checks

The EW50 controller has several set points. Some of these were tested by changing the set points and witnessing the turbine behavior.

One test was on the setting for generator over speed. The normal generator over speed condition is set at 1890 rpm. The test event involved changing the generator’s over speed limit to a level near operating condition, specifically 1801 rpm. The turbine started as normal, and when the generator speed reached the new over speed set point, it stopped by deploying brakes. The controller recorded the error type and time. Figure 12 shows this event. The EW50 operated as designed.

Other tests that included changed controller set points were:

- Test generator over power: Power output greater than 45 kW for 10 s, from the standard set point of 75 kW for 300 s
- Test rotor speed: Rotor speed greater than 64 rpm, from 70 rpm
- Test grid balance: Current difference between lines greater than 5 A, from 30 A
- Test low grid frequency: Grid Frequency less than 60.2 Hz, from 59 Hz
- Test high grid frequency: Grid Frequency greater than 60.2 Hz, from 61 Hz

For each of these tests the EW50 operated as designed.

6.2. Personnel Safety Provisions

Safety instructions

NREL received a 2008 edition of the “EW50 wind turbine user manual.” The manual provided a guide to operating the controller (manufactured by Orbital A/S), turbine limit settings and wiring diagrams. Some of the Orbital wind turbine controller settings did not apply to the EW50, such as the yaw functions. The manual did not provide any safety instructions to the owner. While the Orbital wind turbine controller was extensively covered, there was no mention of the rotary stop switch on the controller’s front panel, the yaw lock cable inside the tower, nor safe operating instructions. Some of the drawings referenced previous models of the EW50 design.

Entegriy does not provide an installation manual to the owner because the company’s personnel install all the turbines. Foundation specifications were provided by Entegriy and NREL contracted a third party to install the foundations.

There are 6-month and 1-year maintenance checklists, and these services were scheduled to be performed by Entegriy personnel.

NREL checked the manual to determine if the safety instructions addressed requirements in the IEC small turbine design standard and found the following issues:

- There are no instructions to disengage the load and/or energy sources
- There are no instructions to stop and secure the rotor. Although the Orbital controller has a “stop” command, it is not described beyond “stop turbine”.
- There are no instructions to stop and secure the yaw mechanism. Although there is a yaw lock mechanism to secure the yaw, it was not documented.

Climbing

The monopole tower comes with an external ladder and safety cable to access the turbine. However, these were not installed on the turbine NREL tested, and therefore no comments can be made on ladder safety provisions.

There is an internal ladder to access the auxiliary controller cabinets. This ladder does not allow the climber to get much more than 3 m above the turbine foundation.

Standing places, platforms, and floors

There is a small, very narrow platform near the top of the tower. A person could stand on it, but would have to be tied off to the nacelle to prevent falling off. There is no railing or hand hold for this platform. There is no ladder to this platform, so the user must access this platform for an aerial lift or similar method.

Electrical and grounding system

The user manual includes single-line drawings of the electrical system and pin-outs for the controller. The installation checklist includes the line “Electrical system grounded to electrical code requirements.” The heavy gauge wire (1/0 AWG) had to be routed through the panel differently than Entegriy’s usual installations in order to meet code. The tower was also

grounded, but this inspection task is not listed in the installation checklist that was provided to NREL. The single-line drawings show that the tower is grounded.

Fire resistance and control

The controller has a generator temperature circuit breaker and a lightning suppressor. These components are connected to the controller, and when activated they will shut down the turbine and provide an error code that can be accessed through the control panel. There is a temperature sensor in the control cabinet, but it controls a heater, which is activated when the temperature is less than -5°C . A high-temperature reading from the cabinet temperature sensor does not lead to turbine shutdown or produce fault codes.

Fire extinguisher

NREL provided a fire extinguisher in the building that housed the inverters. The manufacturer does not provide fire extinguishers or recommend that they be installed.

Emergency stop button

The turbine has a stop button on the front of the control panel, which is shown in Figure 13.

However, if grid power is lost while the rotary switch is set to “stop”, and controller power is restored, the turbine will act as if it is in “run.” Turning the switch to “control power off” prevents this type of unintentional run.

Lock-out / tag-out provisions

The EW50 manual does not identify a means to re-energize and secure the turbine. NREL wrote its own procedure and followed it when performing up-tower and electrical inspections on the EW50.

Interlock on electrical cabinets

There are no interlocks on the controller enclosure.

Safety signs

1. There is a warning to “Disconnect power supply before servicing” on the lower right corner of the EW50 controller enclosure, see Figure 16.
2. NREL added labels indicating the voltage levels on all enclosures, electrical panels, and disconnects, as well as a notice for authorized use only, see Figure 14, Figure 15, and Figure 16.

Unauthorized changing of control settings

The controller settings can be changed by any user familiar with the menu system; there is no password protection on the controller. The controller is inside the tower, and the tower door has hasps that could be locked. When personnel were not accessing the controller, this door was always locked at the NWTC.

Entegri personnel could access the controller through a remote log-on. They could change the control settings; however, it was requested that they not change the settings while the turbine was being tested at the NWTC. The settings were checked several times throughout the test to verify the setting remained the same as when the test started.

Lighting protection

The turbine has a lightning suppressor module in the control panel, and if a high-voltage-potential event occurs, the module is designed to protect the rest of the turbine and generate an error code, which can be accessed through the controller. The tower was grounded as a precaution against lightning.

During the test period, no direct or nearby lightning strikes were observed.

Presence of rotor and yaw lock

The EW50 was delivered with a yaw lock mechanism, in the form of a spring loaded pin, which inserts between bolts on the yaw ring. However the wire clamps holding the pin appear to have loosened (or never were tight enough) and the pin slowly moved into position. During this slow failure the yawing motion of the turbine bent the pin over into an inoperable position and scraped most of the bolts in the yaw ring; see Figure 17.

Documentation

Most of the EW50 manuals that were provided to NREL were in draft form. Some of the documentation was confusing, with references to EW50, EW15, and AOC 15/50 turbine models. Many of the manuals were for Entegriy's internal use because Entegriy personnel install and maintain the fleet of EW50 turbines. In these Entegriy internal documents there were inaccuracies, such the weights of the base section of the monopole tower and the generator/gearbox assembly. What is provided to a prospective owner in the "EW50 Wind Turbine User Manual" (2008 edition) is insufficient for the safe operation of the EW50. However, the owner is not expected to interact with the turbine in a technical manner. This manual comes with the controller, and is located in a pocket inside the control panel door.

NREL checked the manuals and documentation to determine if the turbine met the documentation requirements in the IEC small turbine design standard and noted many issues. The following information was lacking in the documentation provided to NREL:

- How to properly use the front panel rotary switch
- How to secure the yaw mechanism
- How to de-energize the system
- How to safely climb the tower
- What to do in case of a non-auto restarting error.

6.3. Dynamic Behavior

The operation was observed by NREL personnel for at least 5 minutes at wind speeds of approximately 5 m/s, 10 m/s, 15 m/s, and 20 m/s for a total observation period of at least 1 hour.

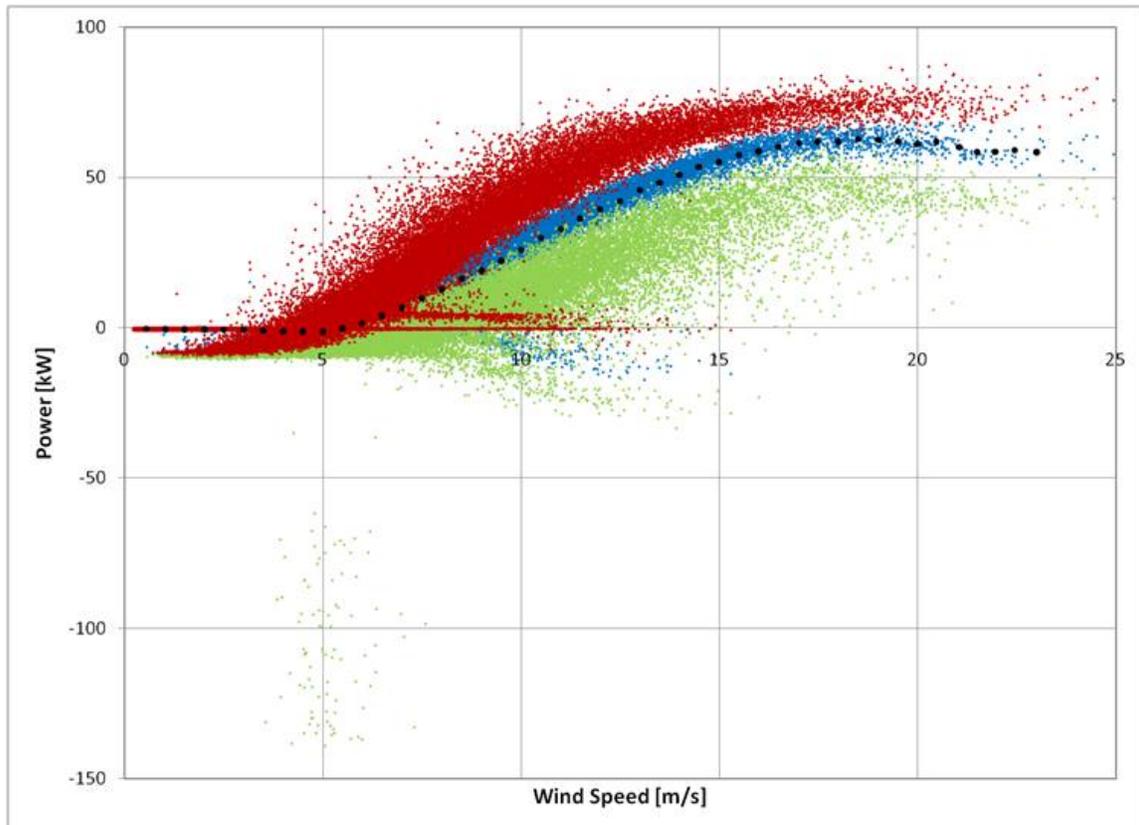
NREL did not measure accelerations on the EW50.

The EW50 produced a significant amount of gearbox noise. When the generator was operating at synchronous speed, the turbine was relatively quiet, but it was not quiet when the generator was operating at sub-synchronous or super-synchronous speed. Significant amount of noise was produced when the brakes were deployed. The parking brake deployment slams the tip brakes back to their stow/operate position and cause a shudder through the entire turbine.

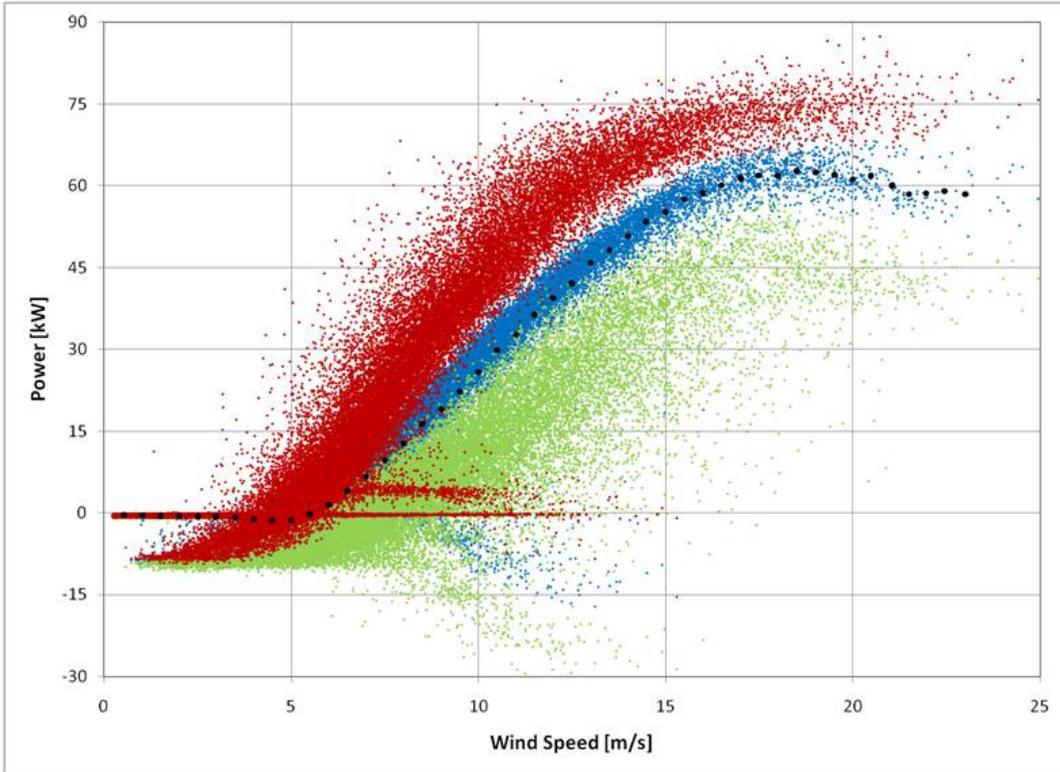
Although vibrations could be felt in the tower and sometimes seen, the vibrations were not deemed excessive.

Yaw oscillations could be severe at times, particularly in gusty winds. The rotor was seen to swing 60 degrees in approximately one second. In gusty winds, the rotor could get stuck upwind, a position, which, in winds below approximately 10 m/s, appeared almost as dynamically stable as the downwind orientation. In winds above 15 m/s the turbine rarely operated in the upwind position.

6.4. Graphs and Plots of Turbine Responses



**Figure 3 Power response to wind speed, 1-minute data
(Red–maxima, Green–minima, Blue–average, Black–bin average)**



**Figure 4 Resized power axis of Figure 3.
(Red–maxima, Green–minima, Blue–average, Black–bin average)**

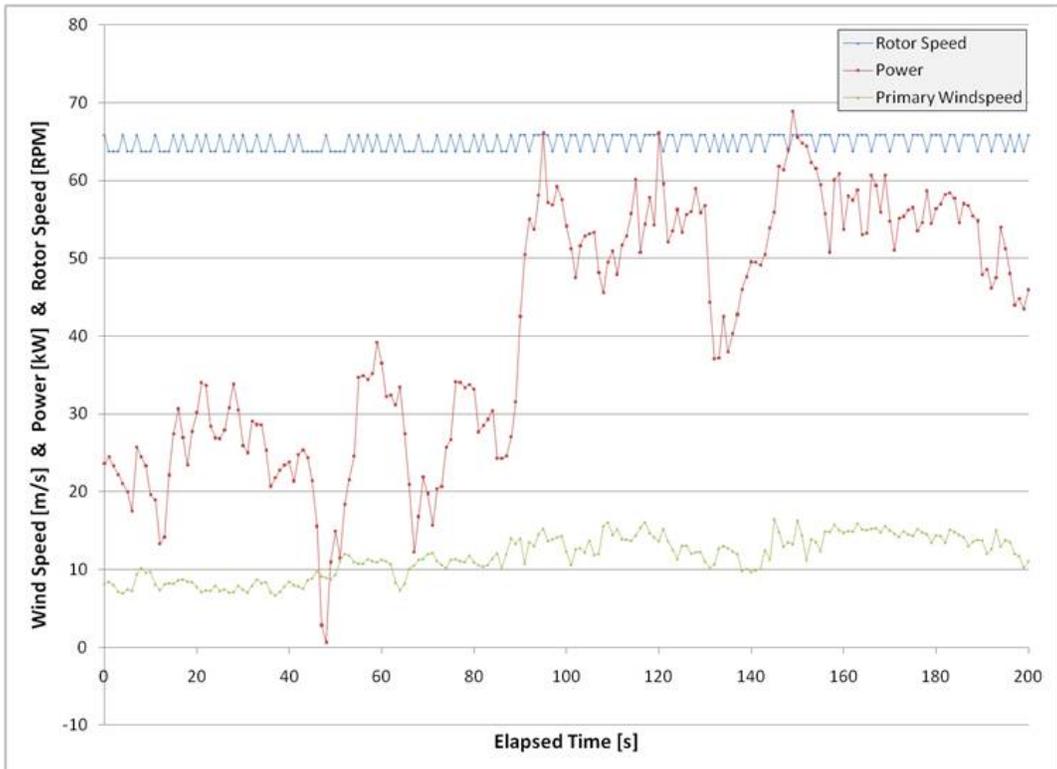


Figure 5 Normal operation in winds around rated wind speed, 1-Hz data

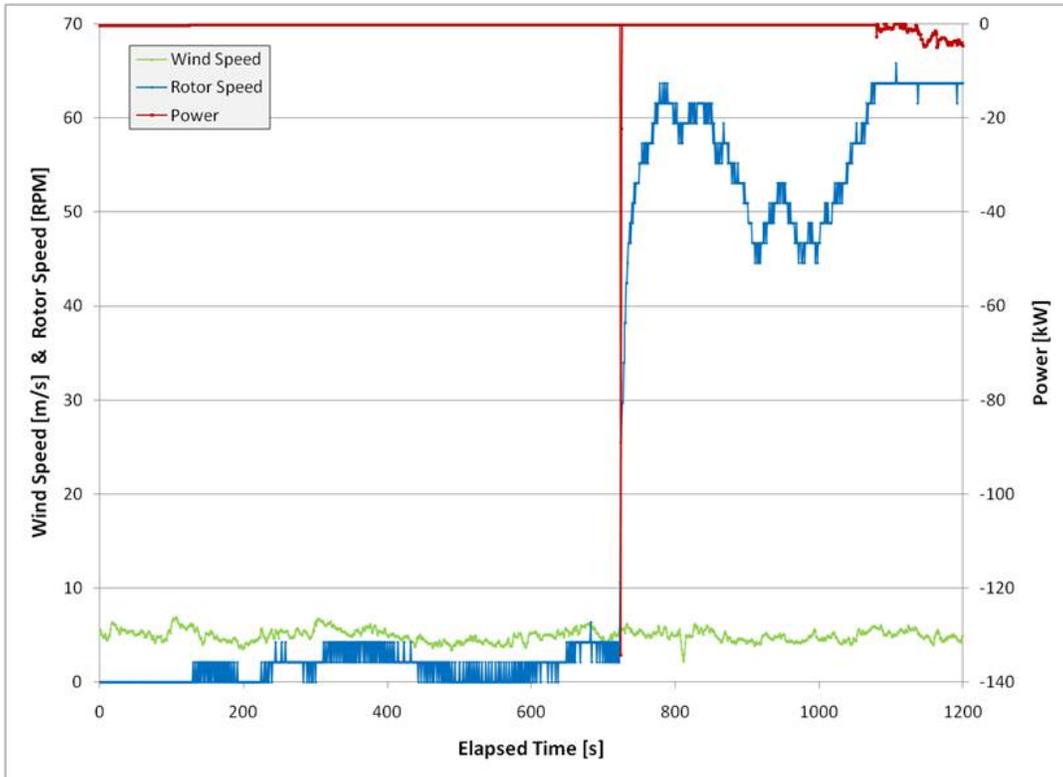


Figure 6 Motor-up in winds around cut-in; 1-Hz data, showing 20 minutes

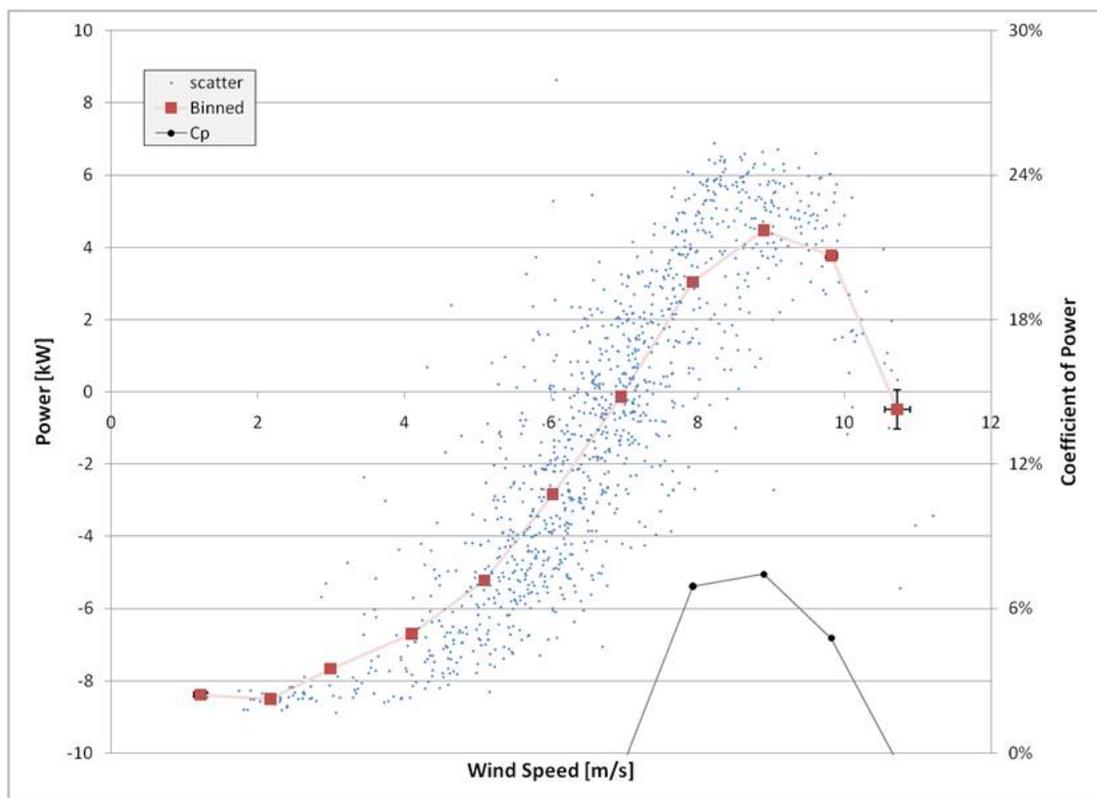


Figure 7 Upwind Power and Cp curves; 10-second data

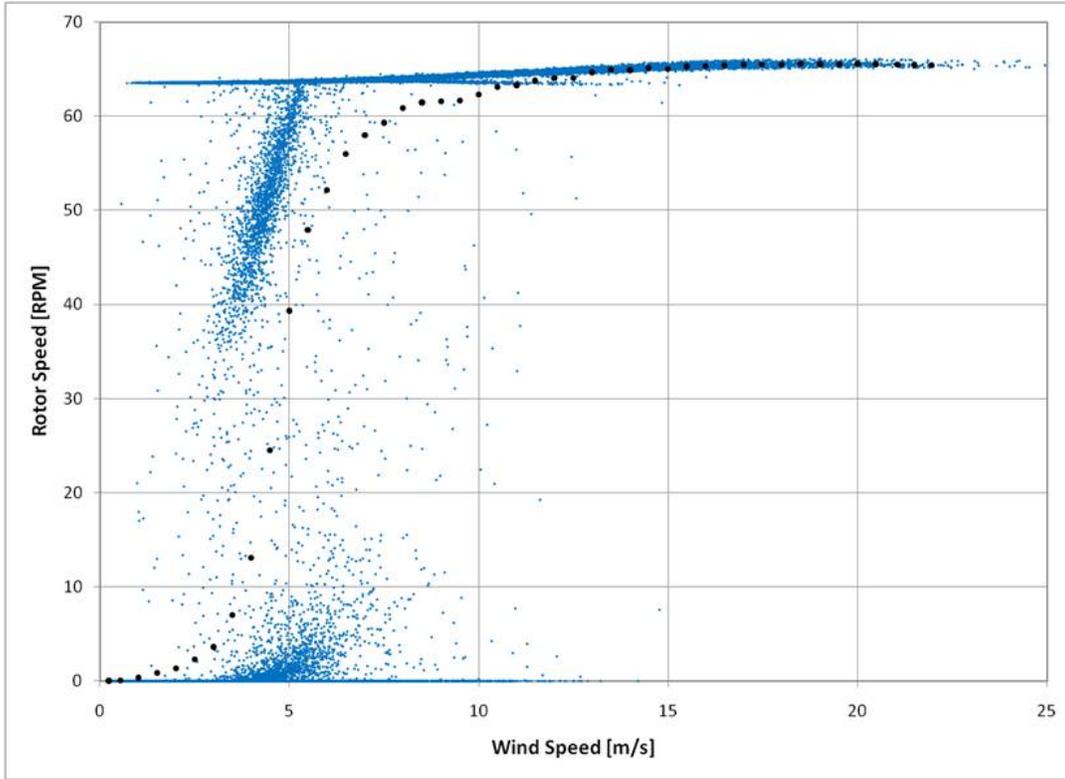


Figure 8 Rotor speed as a function of wind speed, bin averages in black; 1-minute data

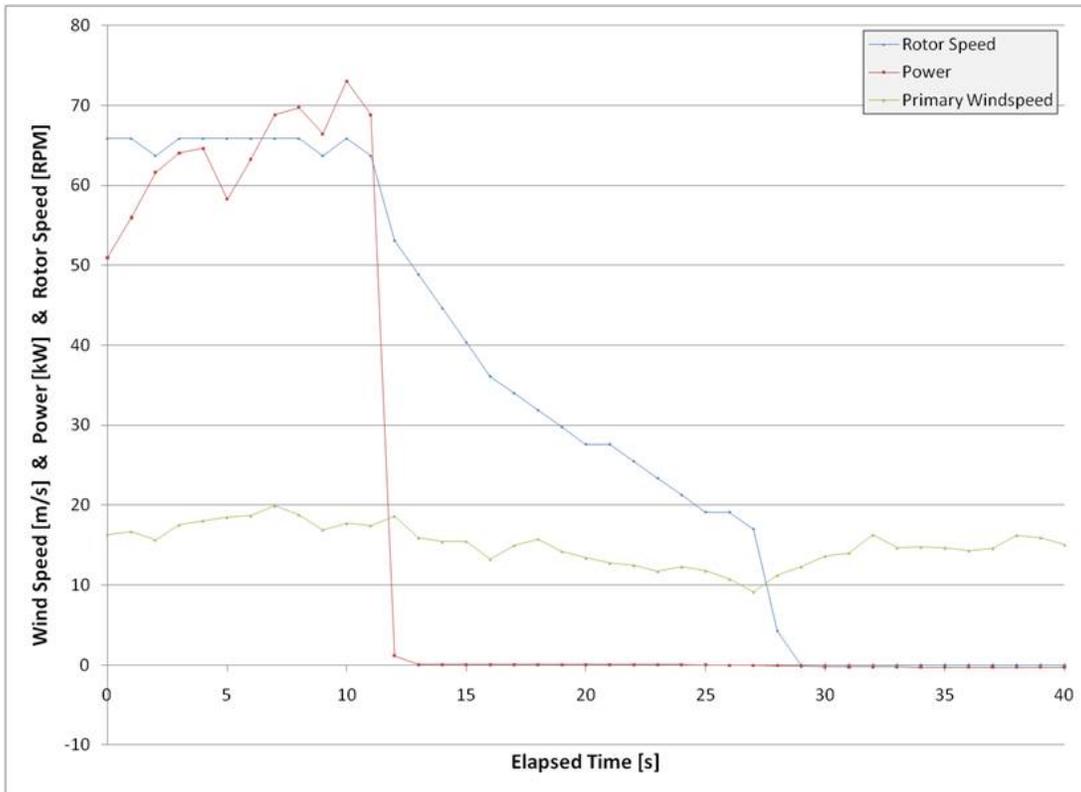


Figure 9 Control panel rotary switch to “Stop” winds above rated; 1-Hz data

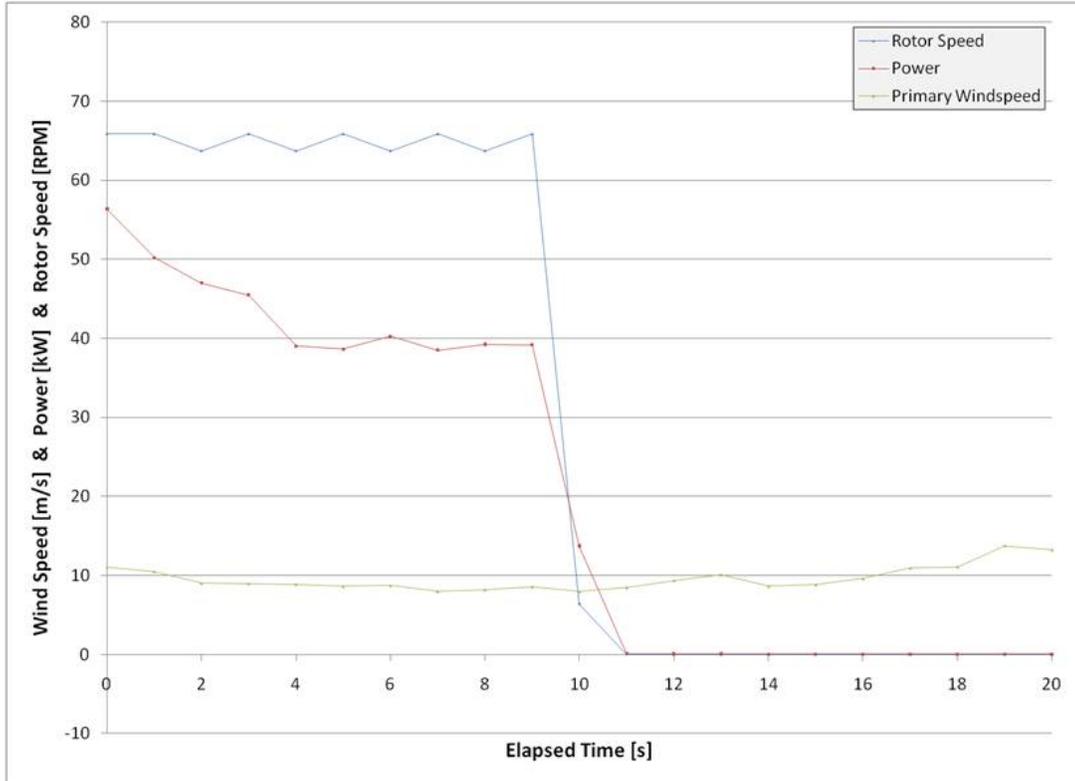


Figure 10 Grid disconnect; without controller UPS, brakes act immediately; 1-Hz data

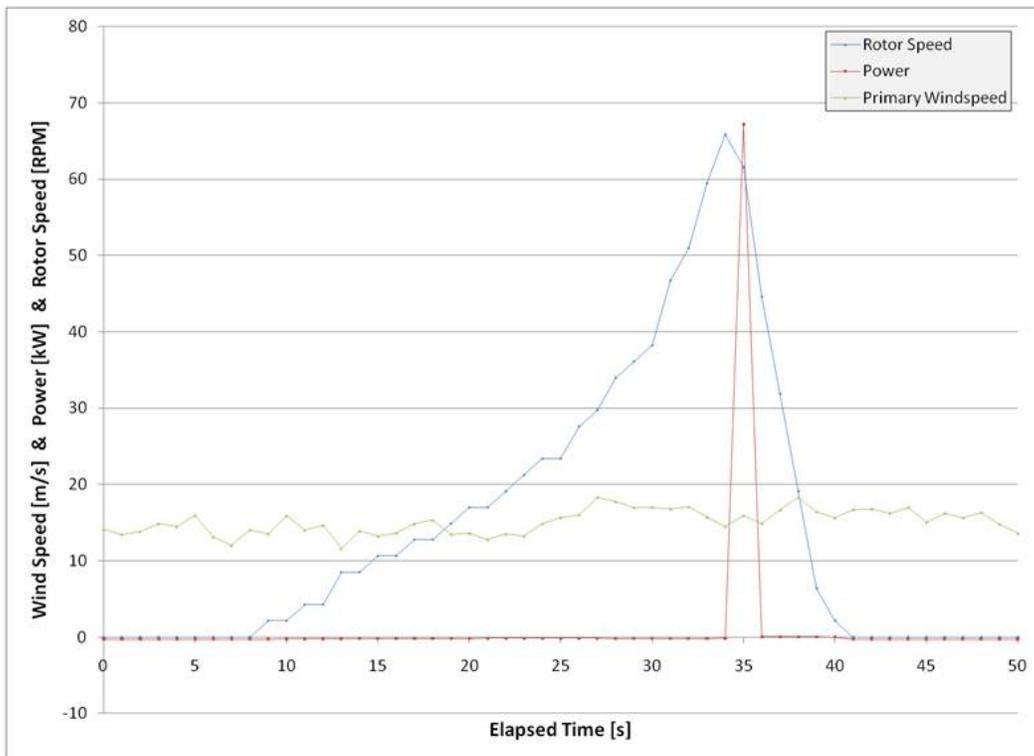


Figure 11 Restart in winds greater than rated; generator over-speed detected (altered set points); 1-Hz data

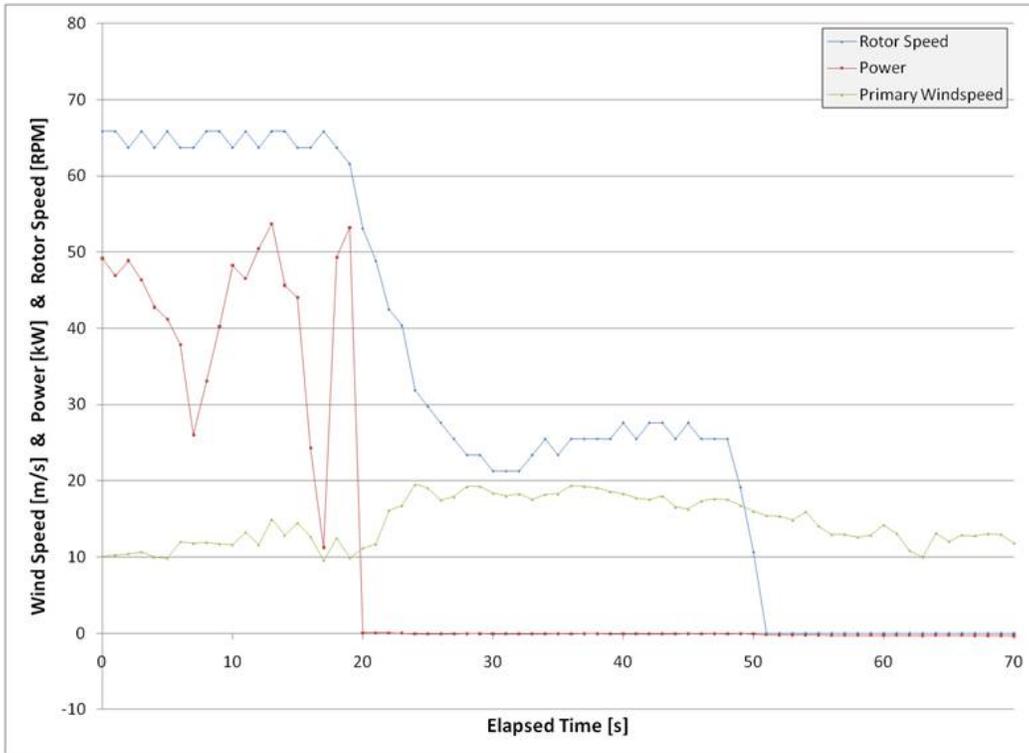


Figure 12 Commanded “Stop” in gusty winds; tip brakes deployed for 30 seconds, then parking brake engages to stop rotor; 1-Hz data



Figure 13 Control panel, showing a rotary switch (Photo by Joe Smith, NREL PIX# 22247)



Figure 14 Signs on outer enclosure of control panel; “Notice” sticker added by NREL
(Photo by Joe Smith, NREL PIX# 22244)



**Figure 15 EW50 lockable disconnect switch at data shed
(Photo by Joe Smith, NREL PIX# 22242)**



**Figure 16 Warning sign on outer cover of EW50 control panel
(Photo by Joe Smith, NREL PIX# 22245)**



**Figure 17 Bent yaw lock pin and cosmetically damaged yaw ring bolts
(Photo by Joe Smith, NREL PIX# 22249)**

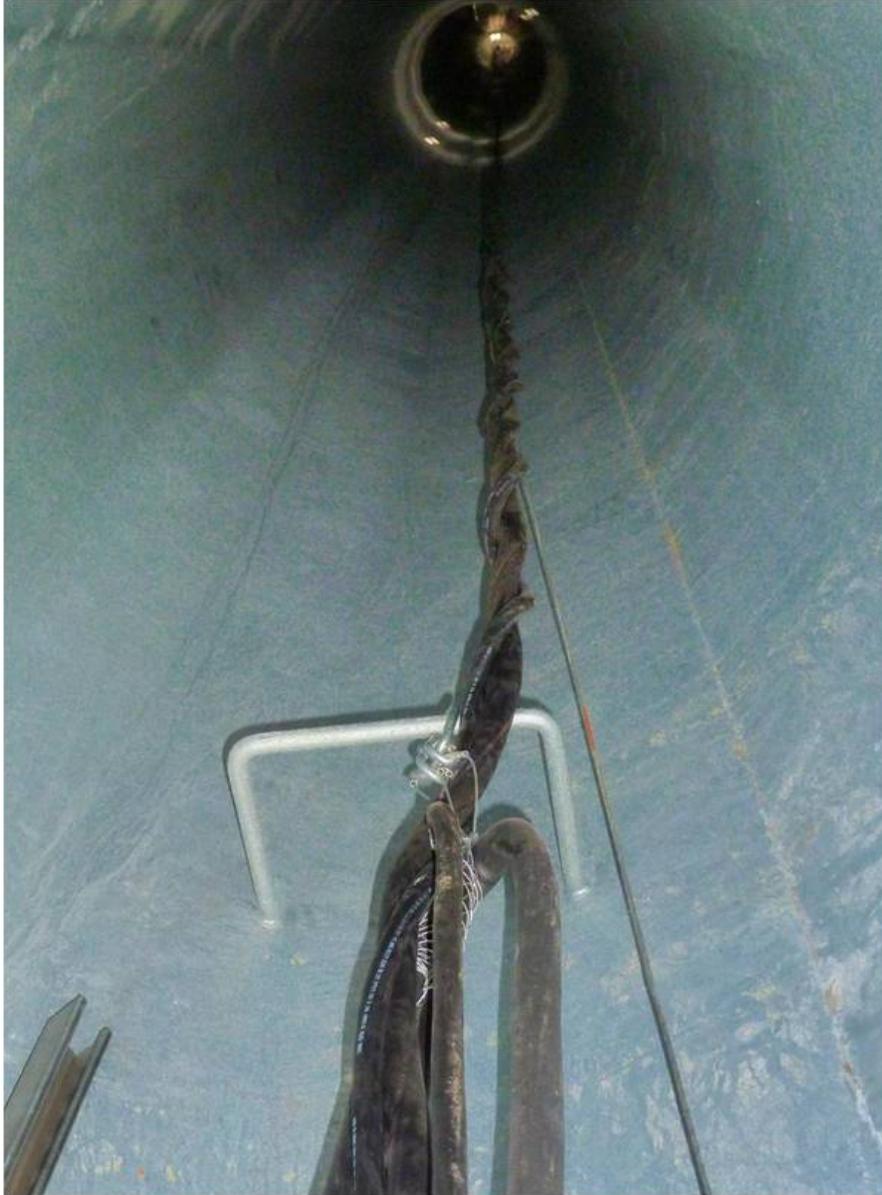


Figure 18 Strain relief prevents the cable twist from transferring to the cable decouples at the tower base (Photo by Joe Smith, NREL PIX# 22240)

7. Exceptions

7.1. Exceptions to the Standard

None.

7.2. Exceptions to NWTC Quality Assurance System

The DAS modules were used beyond the calibration due dates. These were calibrated post-test and were found to have held their calibrations for the test period. Appendix A includes the post-test calibration sheets.

8. Reference Document List

“EW50 Wind Turbine User Manual” (2008 edition)

“EW50 Orbital controller standard limit settings” (27 March 2009)

“EW50 Commissioning Documents”

“EW50/EW15 1 year advanced inspection record”

“EW50/EW15 6 month inspection record”

A. Appendix - Equipment Calibration Sheets

- A.1. Primary anemometer calibration sheet; 1st instrument; installed 25 February 2009, removed 24 February 2010
- A.2. Primary anemometer pre-test calibration; 2nd instrument; installed 24 February 2010, removed 23 July 2010
- A.3. Primary anemometer pre-test calibration; 3rd instrument; installed 23 July 2010, used until end of test
- A.4. Power transducer calibration sheet; installed 25 February 2009, removed 8 February 2010
- A.5. Power transducer calibration sheet; recalibrated and reinstalled on 19 February 2010, used until end of test
- A.6. Wind vane calibration sheet; 1st instrument; installed 25 February 2009, removed 24 February 2010
- A.7. Wind vane calibration sheet; 2nd instrument; installed 24 February 2010, used until end of test
- A.8. NI 9229 data acquisition module calibration; 1st module; installed 25 February 2009, removed 3 Feb 2010 (calibration pasted due)
- A.9. NI 9205 data acquisition module calibration; 1st module; installed 25 February 2009, removed 3 February 2010 (calibration pasted due)
- A.10. NI 9229 data acquisition module post-test calibration; 1st module
- A.11. NI 9205 data acquisition module post-test calibration; 1st module
- A.12. NI 9229 data acquisition module calibration; 2nd module; installed 3 February 2010, used until end of test
- A.13. NI 9205 data acquisition module calibration; 2nd instrument; installed 3 February 2010, used until end of test

1 Detailed MEASNET¹ Calibration Results

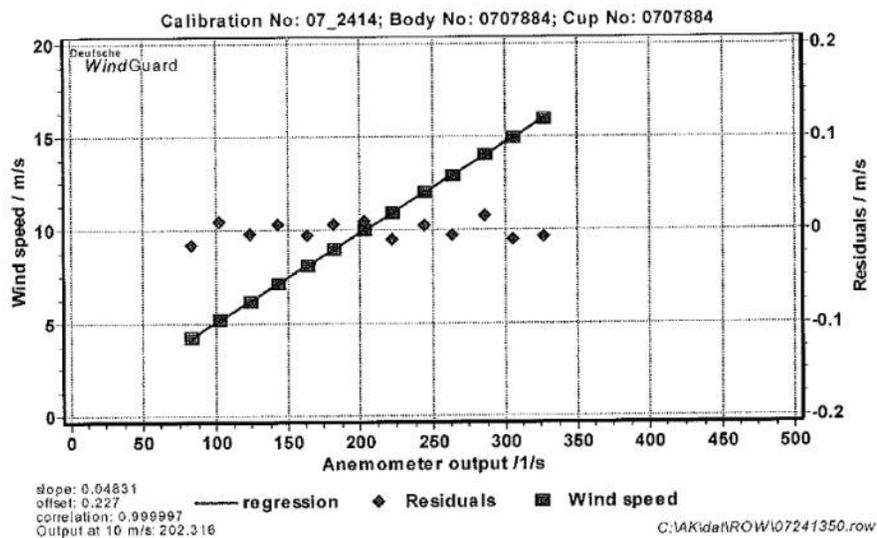
DKD calibration no. 07_2414
Body no. 0707884
Cup no. 0707884
Date 24.07.2007
Air temperature 23.1 deg
Air pressure 995.6 hPa
Humidity 56.6 %



Linear regression analysis

Slope 0.04831 (m/s)/(1/s) ±0.00004 (m/s)/(1/s)
Offset 0.227 m/s ±0.008 m/s
St.err(Y) 0.006 m/s
Correlation coefficient 0.999997

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) and Physikalisch Technische Bundesanstalt – PTB (Federal Office for Physics and Technique). Registration: DKD – K – 36801

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



Figure A.1. Primary anemometer calibration sheet; 1st instrument; installed 25Feb09, removed 24Feb10

1 Detailed MEASNET¹ Calibration Results

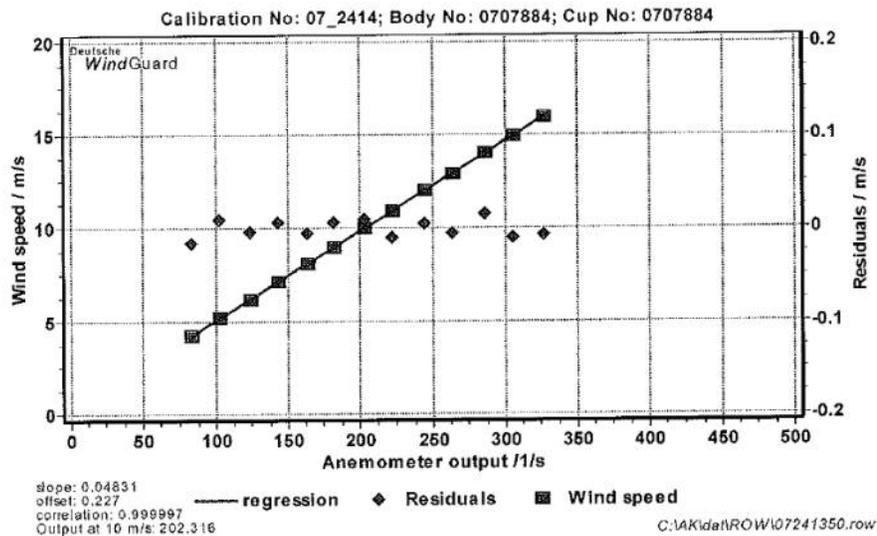
DKD calibration no. 07_2414
 Body no. 0707884
 Cup no. 0707884
 Date 24.07.2007
 Air temperature 23.1 deg
 Air pressure 995.6 hPa
 Humidity 56.6 %



Linear regression analysis

Slope 0.04831 (m/s)/(1/s) ±0.00004 (m/s)/(1/s)
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 Correlation coefficient 0.999997

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) and Physikalisch Technische Bundesanstalt – PTB (Federal Office for Physics and Technique). Registration: DKD – K – 36801

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



Figure A.2. Primary anemometer pre-test calibration; 2nd instrument; installed 24Feb10, removed 23Jul10



CERTIFICATE FOR CALIBRATION OF CUP ANEMOMETER

Certificate number: 09.02.3146 **Date of issue:** June 15, 2009
Type: Thies 4.3351.10.000 **Serial number:** 0609010
Manufacturer: ADOLF THIES GmbH & Co.KG, Hauptstrasse 76, 37083 Göttingen, Germany
Client: Sky Power Int'l LLC, 250 Sawdust Road, 29657-8521 Liberty SC, USA

Anemometer received: June 11, 2009 **Anemometer calibrated:** June 12, 2009
Calibrated by: mh **Calibration procedure:** IEC 61400-12-1, MEASNET
Certificate prepared and approved by: Calibration engineer, soh *Svend Ole Hansen*

Calibration equation obtained: $v \text{ [m/s]} = 0.04639 \cdot f \text{ [Hz]} + 0.22041$
Standard uncertainty, slope: 0.00125 **Standard uncertainty, offset:** 0.05885
Covariance: -0.0000007 (m/s)²/Hz **Coefficient of correlation:** $\rho = 0.999991$
Absolute maximum deviation: -0.032 m/s at 3.986 m/s

Succession	Velocity pressure, q, [Pa]	Temperature in wind tunnel [°C]	Temperature in control room [°C]	Wind velocity, v, [m/s]	Frequency, f, [Hz]	Deviation, d, [m/s]	Uncertainty u_c (k=2) [m/s]
2	9.07	31.9	23.8	3.986	81.8715	-0.032	0.029
4	13.98	31.7	23.7	4.947	102.0168	-0.006	0.033
6	20.26	31.6	23.7	5.954	123.6056	0.000	0.038
8	27.44	31.5	23.7	6.929	144.1422	0.022	0.044
10	35.72	31.4	23.7	7.904	165.2496	0.018	0.049
12	45.28	31.4	23.7	8.899	187.0774	0.000	0.055
13-last	56.04	31.3	23.7	9.898	208.3476	0.013	0.061
11	67.93	31.4	23.7	10.900	230.0186	0.010	0.067
9	80.35	31.5	23.7	11.855	250.6971	0.006	0.073
7	94.30	31.6	23.7	12.846	272.2475	-0.004	0.080
5	109.47	31.7	23.7	13.843	293.8560	-0.009	0.086
3	125.82	31.8	23.7	14.844	315.8145	-0.027	0.092
1-first	143.41	32.0	23.8	15.855	336.8582	0.008	0.099

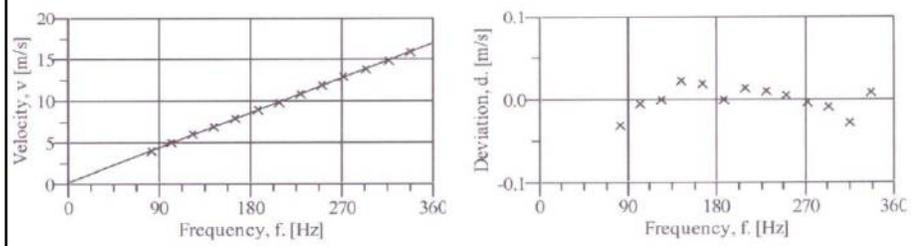


Figure A.3. Primary anemometer pre-test calibration; 3rd instrument; installed 23Jul10, used until end of test

Branch #: 5000

NREL METROLOGY LABORATORY

Test Report

Test Instrument: Multifunction Transducer

DOE #: 03574C

Model # : DMT-1040E

S/N : 07070473

Calibration Date: 08/26/2008

Due Date: 08/26/2010

A. Set-Up for Total Power Calibration:

A.1. Voltage is applied to Lines 1, 2, & 3 = 277.128 V @ 60 Hz.

A.2. Current is applied to n = 1-TURN through three current transformers that are connected to Lines 1, 2, & 3 .

A.3. Analog Output-1 is measured across precision resistor = 250 Ω .

A.4. Full Scale setting = -124.71KW to 124.71KW.

Input Current (AAC)	Input Power (KW)	Analog Output-1 (VDC)
150	124.71	5.022
105	87.30	3.517
60	49.88	2.009
0	0	0.001
-60	-49.88	-2.007
-105	-87.30	-3.515
-150	-124.71	-5.019

B. Set-Up for Power Factor Calibration:

B.1. Voltage & Current are applied as A.1 & A.2.

B.2. Analog Output-2 is measured across precision resistor = 250 Ω .

Power (KW)	Power Factor	Analog Output-2 (VDC)
49.88	1.0	5.001
"	0.8	3.999
"	0.6	3.000
"	0.4	1.998

Figure A.4. Power transducer calibration sheet; installed 25Feb09, removed 8Feb10

Branch #: 5000

NREL METROLOGY LABORATORY

Test Report

Test Instrument: Multifunction Transducer

DOE #: 03574C

Model # : DMT-1040E

S/N : 07070473

Calibration Date: 02/09/2010

Due Date: 02/09/2012

A. Set-Up for Total Power Calibration:

A.1. Voltage is applied to Lines 1, 2, & 3 = 277.128 V @ 60 Hz.

A.2. Current is applied to n = 1-TURN through three current transformers that are connected to Lines 1, 2, & 3 .

A.3. Analog Output-1 is measured across precision resistor = 250 Ω .

A.4. Full Scale setting = -124.71KW to 124.71KW.

Input Current (AAC)	Input Power (KW)	Analog Output-1 (VDC)
150	124.71	5.018
105	87.30	3.513
60	49.88	2.006
0	0	0.001
-60	-49.88	-2.005
-105	-87.30	-3.514
-150	-124.71	-5.018

B. Set-Up for Power Factor Calibration:

B.1. Voltage & Current are applied as A.1 & A.2.

B.2. Analog Output-2 is measured across precision resistor = 250 Ω .

Power (KW)	Power Factor	Analog Output-2 (VDC)
49.88	1.0	4.998
"	0.8	3.999
"	0.6	2.997
"	0.4	1.996

Figure A.5. Power transducer calibration sheet; recalibrated and reinstalled on 19Feb10, used until end of test

Wind Vane Calibration Report

Calibration Laboratory:
 National Wind Technology Center - Cert. Team
 National Renewable Energy Laboratory
 1617 Cole Boulevard
 Golden, Colorado 80401

Customer:
 National Wind Technology Center - Certification Team
 National Renewable Energy Laboratory
 1617 Cole Boulevard
 Golden, Colorado 80401

Calibration Location:
 National Wind Technology Center
 Room 101, Building 256

Calibration Date: 13-Sep-07

Report Number: U1477-070913

Procedure:
 NWTC-CT: GI24-000613, Wind Vane Calibration

Page: 1 of 1

Deviations from procedure: Calibrated on 5V range
 Calibrated in Volts (not mV)

Item Calibrated:
Manufacturer: Met One Instruments, Inc
Model: 020C
Serial Number: U1477
Vane Material: Aluminum
Condition: Refurbished

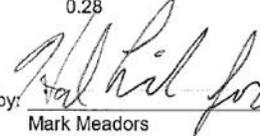
Results:
Slope: 71.87 deg/V
Offset to boom: 86.96 deg
Max error: 0.38 deg

Estimated Uncertainty:

Inclinometer Uncertainty (deg)	Total Uncertainty (deg)
0.10	0.28

Traceability:

Mfg & Model	Serial Number	Cal Date
Inclinometer: Spi-Tronic	31-038-3	22-Mar-07
Voltmeter: Fluke743B	6965608	10-May-07

Calibration by: 
 Mark Meadors

13-Sep-07
 Date

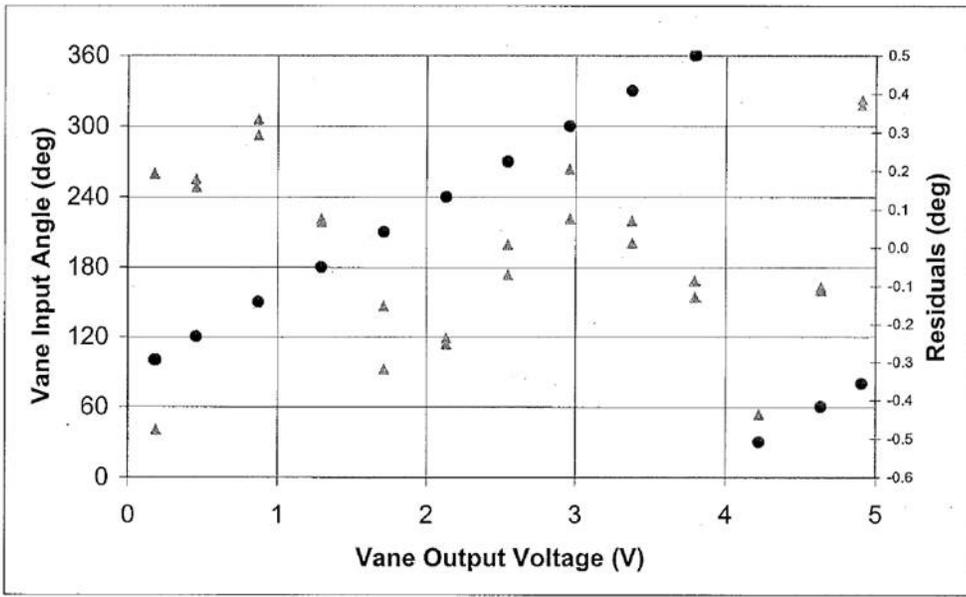


Figure A.6. Wind vane calibration sheet; 1st instrument; installed 25Feb09, removed 24Feb10

Wind Vane Calibration Report

Calibration Laboratory:
National Wind Technology Center - Cert. Team
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

Customer:
National Wind Technology Center - Certification Team
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

Calibration Location:
National Wind Technology Center
Room 101, NWTC Bldg 256

Calibration Date: **5-Feb-10**

Report Number: W1494-100205

Procedure:
NWTC-CT: C104 Calibrate Wind Vane_091209.pdf

Page: 1 of 1

Deviations from procedure: Calibrated on 5V Range
Calibrated in Volts (not mV)

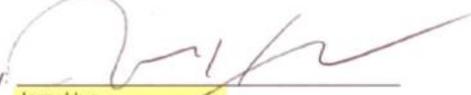
Item Calibrated:
Manufacturer Met One Instruments, Inc
Model 020C
Serial Number **W1494**
Vane Material Aluminum
Condition Refurbished

Results:
Slope: 71.3304 deg/V
Offset to boom: 97.2 deg
Max error: 1.0 deg

Estimated Uncertainty:
Inclinometer
Uncertainty (deg) 0.10
Total
Uncertainty (deg) 0.53

Traceability:

	Mfg & Model	Serial Number	Cal Date
Inclinometer:	SPI-Tronic	31-038-3	19-May-09
Voltmeter:	HP 3458A	2823A05145	5-May-09

Calibration by: 
Jerry Hur
Date: 5 FEB 10

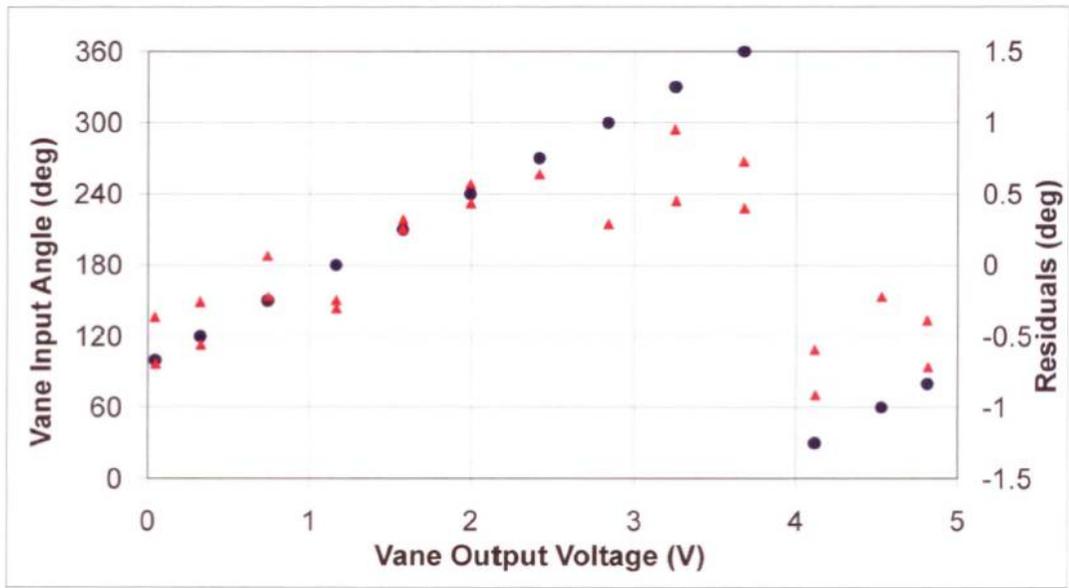


Figure A.7. Wind vane calibration sheet; 2nd instrument; installed 24Feb10, used until end of test

Board Information:

Serial Number: I3DEC38
NI Part Number: 192580G-02L
Description: NI 9229

Certificate Information:

Certificate Number: 1222096
Date Printed: 31-MAR-09

Calibration Date: 10-NOV-08
Recommended Calibration Due Date: 10-NOV-09*

Ambient Temperature: 23 °C
Relative Humidity: 36 %

National Instruments certifies that at the time of manufacture, the above product was calibrated in accordance with applicable National Instruments procedures. These procedures are in compliance with relevant clauses of ISO 9001 and are designed to assure that the product listed above meets or exceeds National Instruments specifications.

National Instruments further certifies that the measurements standards and instruments used during the calibration of this product are traceable to National and/or International Standards administered by NIST or Euromet members or are derived from accepted values of natural physical constants.

The environment in which this product was calibrated is maintained within the operating specifications of the instrument and the standards.

The information shown on this certificate applies only to the instrument identified above and the certificate may not be reproduced, except in full, without prior written consent by National Instruments.

For questions or comments, please contact National Instruments Technical Support.

NI Hungary Software és
Hardware Gyártó Kft.
4031 Debrecen, Határ út
1/A.
HUNGARY

Signed,



Andrew Krupp
Vice President, Quality and
Continuous Improvement

* Recommended calibration due date is based on a combination of calibration interval and, when applicable, calibration shelf life. This date may vary depending on your application requirements.

Figure A.8. NI 9229 data acquisition module calibration; 1st module; installed 25Feb09, removed 3Feb10 (calibration pasted due)

Board Information:

Serial Number: 13E3D05
NI Part Number: 193299F-01
Description: NI-9205

Certificate Information:

Certificate Number: 1224953
Date Printed: 31-MAR-09

Calibration Date: 12-NOV-08
Recommended Calibration Due Date: 12-NOV-09*

Ambient Temperature: 22 °C
Relative Humidity: 37 %

National Instruments certifies that at the time of manufacture, the above product was calibrated in accordance with applicable National Instruments procedures. These procedures are in compliance with relevant clauses of ISO 9001 and are designed to assure that the product listed above meets or exceeds National Instruments specifications.

National Instruments further certifies that the measurements standards and instruments used during the calibration of this product are traceable to National and/or International Standards administered by NIST or Euromet members or are derived from accepted values of natural physical constants.

The environment in which this product was calibrated is maintained within the operating specifications of the instrument and the standards.

The information shown on this certificate applies only to the instrument identified above and the certificate may not be reproduced, except in full, without prior written consent by National Instruments.

For questions or comments, please contact National Instruments Technical Support.

NI Hungary Software és
Hardware Gyártó Kft.
4031 Debrecen, Határ út
1/A.
HUNGARY

Signed,



Andrew Krupp
Vice President, Quality and
Continuous Improvement

* Recommended calibration due date is based on a combination of calibration interval and, when applicable, calibration shelf life. This date may vary depending on your application requirements.

Figure A.9. NI 9205 data acquisition module calibration; 1st module; installed 25Feb09, removed 3Feb10 (calibration pasted due)

Instrument Identification

Company ID: 120205
 NREL
 BEV KAY
 16253 DENVER WEST PARKWAY
 GOLDEN, CO, 80401

PO Number: CC- TBA

Instrument ID: **04037C**

Model Number: NI 9229

Manufacturer: NATIONAL INSTRUMENTS

Serial Number: 13DEC38

Description: 4-CHANNEL, ± 60 V, 24-BIT SIMULTANEOUS ANALOG INPUT

Accuracy: Mfr Specifications

Certificate Information

Reason For Service: CALIBRATION

Technician: WAYNE GETCHELL

Type of Cal: ACCREDITED 17025 WITH UNCERTAINTIES

Cal Date 22Feb2010

As Found Condition: IN TOLERANCE

Cal Due Date: 22Feb2011

As Left Condition: LEFT AS FOUND

Interval: 12 MONTHS

Procedure: NATIONAL INSTRUMENTS 3.4 CAL EXECUTIVE REV 3.4

Temperature: 23.0 C

Humidity: 39.0 %

Remarks: *Reference attached Calibration Data w/uncertainties.*

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2008 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/ISO/IEC 17025-1:2005, ISO 10012:2003, 10 CFR 50 AppB, and 10 CFR 21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited.

All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: WAYNE GETCHELL
 Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
3768091	15-0048	MULTIFUNCTION CALIBRATOR	5700A	29Dec2009	29Mar2010

Figure A.10. NI 9229 data acquisition module post-test calibration; 1st module



Certificate of Calibration

3930692

Certificate Page 1 of 1

Instrument Identification

Company ID: 120205
NREL
BEV KAY
16253 DENVER WEST PARKWAY
GOLDEN, CO, 80401

PO Number: CC- TBA

Instrument ID: **04035C** Model Number: NI 9205
Manufacturer: NATIONAL INSTRUMENTS Serial Number: 13E3D05
Description: 32-CH ± 200 MV TO ± 10 V, 16-BIT, 250 KS/S ANALOG INPUT MODULE

Accuracy: Mfr Specifications

Certificate Information

Reason For Service: CALIBRATION	Technician: WAYNE GETCHELL
Type of Cal: ACCREDITED 17025 WITH UNCERTAINTIES	Cal Date: 22Feb2010
As Found Condition: IN TOLERANCE	Cal Due Date: 22Feb2011
As Left Condition: LEFT AS FOUND	Interval: 12 MONTHS
Procedure: NATIONAL INSTRUMENTS 3.4 CAL EXECUTIVE REV 3.4	Temperature: 23.0 C
	Humidity: 39.0 %
Remarks: Reference attached Calibration Data w/uncertainties.	

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2008 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994, ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025:2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited.

All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: GALEN WASHBURN
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
3768091	15-0048	MULTIFUNCTION CALIBRATOR	5700A	29Dec2009	29Mar2010

Davis Calibration • 2324 Ridgepoint Drive, Suite D • Austin, TX 78754 • Phone: 800-365-0147 • Fax: 512-926-8450

Figure A.11. NI 9205 data acquisition module post-test calibration; 1st module



Dynamic Technology, Inc.

Certificate of Calibration

Certificate #: 1551670002 F



Calibration Laboratory
Certificate #: 2516.01

Acct #: 101320
Customer: National Renewable Energy Laboratory
Shipper #:
Address: 16253 Denver West Parkway
 Golden, CO, 80401
Contact: NI RMA
PO #:

Manufacturer: National Instruments
Model: 9229
Description: 4 Channel Analog Input Module
Serial Number: 12CBC7A
Asset Number: 12CBC7A
Barcode:

As Received	As Returned	Action Taken	Cal Date:	01/18/2010
In Tolerance X	In Tolerance X	Full Calibration X	Due Date:	01/18/2011
Out of Tolerance	Out of Tolerance	Special Calibration	Temperature:	73.04 deg. F
Malfunctioning	Malfunctioning	Oper. Verification	Humidity:	49.00 %
Operational	Operational	Adjusted	Baro. Press.:	
Damaged	N/A	Repaired	Procedure:	DCN 07648
N/A		Charted	Reference:	manufacturer's manual
		Returned As Is		

Incoming Remarks:

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
1524190005	Fluke	5700A	Multifunction Calibrator	12/04/2009	03/04/2010

The above identified unit was calibrated in our laboratory at the address shown below.

This report applies only to the item(s) identified above and shall not be reproduced, except in full, without the written approval of Dynamic Technology, Inc. This unit has been calibrated utilizing standards with a Test Uncertainty Ratio (TUR) of greater than 4:1 at 95% confidence level with a coverage factor of k=2 unless otherwise stated above. The calibration was performed using references traceable to the SI through NIST or other recognized national laboratory, accepted fundamental or natural physical constants, ratio type of calibration, or by comparison to consensus standards. Dynamic Technology's calibration program is in compliance with ANSI/NCSL Z-540-1, MILSTD 45662A, ISO 17025, QD-4000

Dynamic Technology warrants all material and labor performed for ninety (90) days unless covered under a separate policy.

* Any number of factors may cause the calibrated item to drift out of calibration before the interval has expired.

Technician Name/Date: Gary Schmidt, 01/18/2010

Signatory:

QA Approved:

3201 West Royal Lane, Suite 150, Irving, TX 75063 (214) 723-5600 FAX (214) 723-5601

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Figure A.12. NI 9229 data acquisition module calibration; 2nd module; installed 3Feb10, used until end of test



Dynamic Technology, Inc.

Certificate of Calibration

Certificate #: 1551670001 F



Acct #: 101320	Manufacturer: National Instruments
Customer: National Renewable Energy Laboratory	Model: 9205
Shipper #:	Description: 32 Channel Analog Input Module
Address: 16253 Denver West Parkway	Serial Number: 12ECB77
Golden, CO, 80401	Asset Number: 12ECB77
Contact: NI RMA	Barcode:
PO #:	

As Received	As Returned	Action Taken	Cal Date:	01/18/2010
In Tolerance <input checked="" type="checkbox"/>	In Tolerance <input checked="" type="checkbox"/>	Full Calibration <input checked="" type="checkbox"/>	Due Date:	01/18/2011
Out of Tolerance	Out of Tolerance	Special Calibration	Temperature:	73.04 deg. F
Malfunctioning	Malfunctioning	Oper. Verification	Humidity:	49.00 %
Operational	Operational	Adjusted <input checked="" type="checkbox"/>	Baro. Press.:	
Damaged	N/A	Repaired	Procedure:	DCN 09381
N/A		Charted	Reference:	manufacturer's manual
		Returned As Is		

Incoming Remarks:

Technical Remarks:

Calibration Standards Utilized					
Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
1524190005	Fluke	5700A	Multifunction Calibrator	12/04/2009	03/04/2010

The above identified unit was calibrated in our laboratory at the address shown below.

This report applies only to the item(s) identified above and shall not be reproduced, except in full, without the written approval of Dynamic Technology, Inc. This unit has been calibrated utilizing standards with a Test Uncertainty Ratio (TUR) of greater than 4:1 at 95% confidence level with a coverage factor of k=2 unless otherwise stated above. The calibration was performed using references traceable to the SI through NIST or other recognized national laboratory, accepted fundamental or natural physical constants, ratio type of calibration, or by comparison to consensus standards. Dynamic Technology's calibration program is in compliance with ANSI/NCSL Z-540-1, MIL-STD 45662A, ISO 17025, QD-4000.

Dynamic Technology warrants all material and labor performed for ninety (90) days unless covered under a separate policy.

* Any number of factors may cause the calibrated item to drift out of calibration before the interval has expired.

Technician Name/Date: Gary Schmidt, 01/18/2010

Signatory: *[Signature]*

QA Approved:

3201 West Royal Lane, Suite 150, Irving, TX 75063 (214) 723-5600 FAX (214) 723-5601

Figure A.13. NI 9205 data acquisition module calibration; 2nd instrument; installed 3Feb10, used until end of test