DOE/Golden Field Office • NREL • National Wind Technology Center

Field Verification Program for Small Wind Turbines

September 2001

QUARTERLY REPORT

January-March 2001
1st Quarter, Issue #4

Windward Engineering Profile

Last quarter, Windward Engineering added some data processing capabilities to their LabView data acquisition system (DAS) to determine extreme loading events on the Whisper H40 furling wind turbine (Figure 1). The new data processing includes six new calculated outputs: maximum instantaneous rotor speed, maximum instantaneous wind speed, maximum yaw rate, time of maximum yaw rate event, maximum furl rate, and time of maximum furl rate event. This quarter, ending March 31, 2001, was the first full quarter where these values were monitored.

Windward Engineering staff included within their quarterly report some of the extreme event data collected during the quarter. Figures 2, 3, and 4 show the turbine response during a maximum instantaneous rotor speed event. Windward Engineering provided some observations from these data. Maximum rotor speed is caused by a strong gust where the peak wind speed was ~15.5 m/s. This gust initially caught the turbine unfurled.

Figure 1. Furling Whisper H40 in Spanish Fork, Utah.

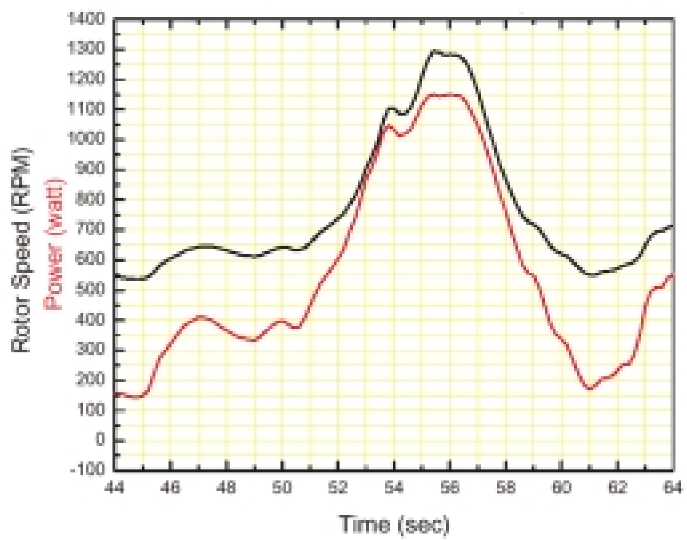


Figure 2. Rotor Speed and Power Plot for Highest Recorded Rotor Speed

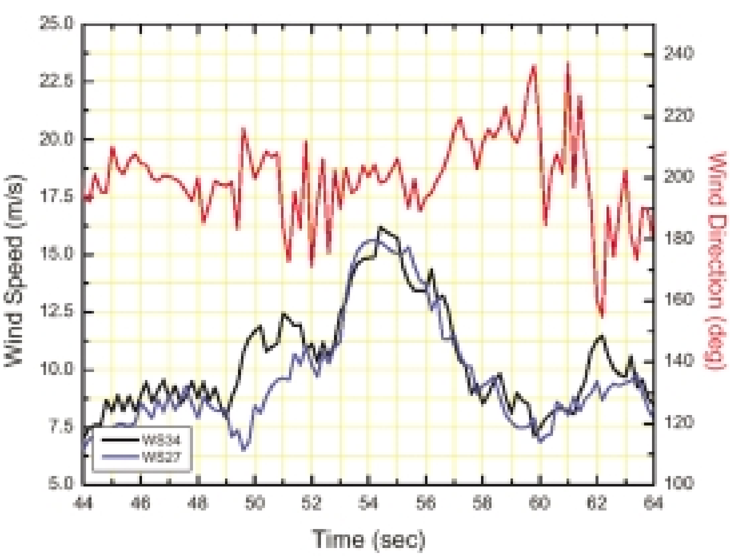


Figure 3. Wind Speed and Wind Direction Plot for Highest Recorded Rotor Speed

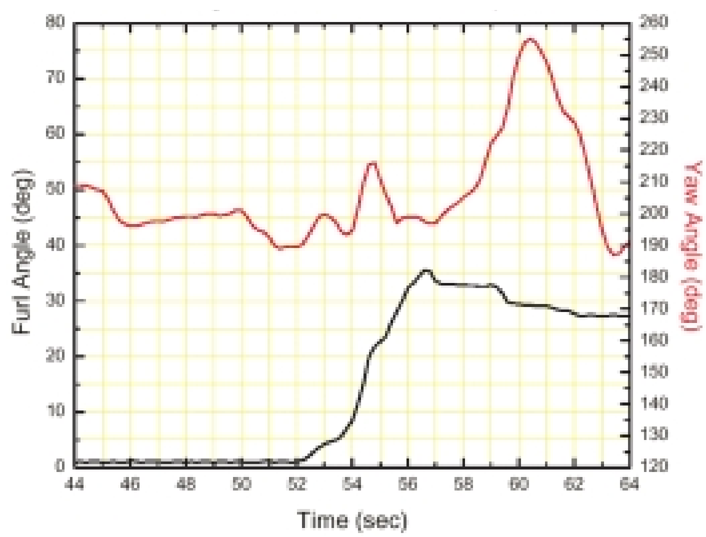


Figure 4. Furl Angle and Yaw Angle Plot for Highest Recorded Rotor Speed

Continued on page 2.

Windward Engineering Profile (Continued)

Figures 5, 6, and 7 show data during a maximum furl rate event. The maximum furl rate (Figure 5) is 62 degrees per second when calculated over a 200-ms time period. This furl rate appears to be associated with the rapid yaw rate of 71 degrees per second when calculated over a 200-ms time span.

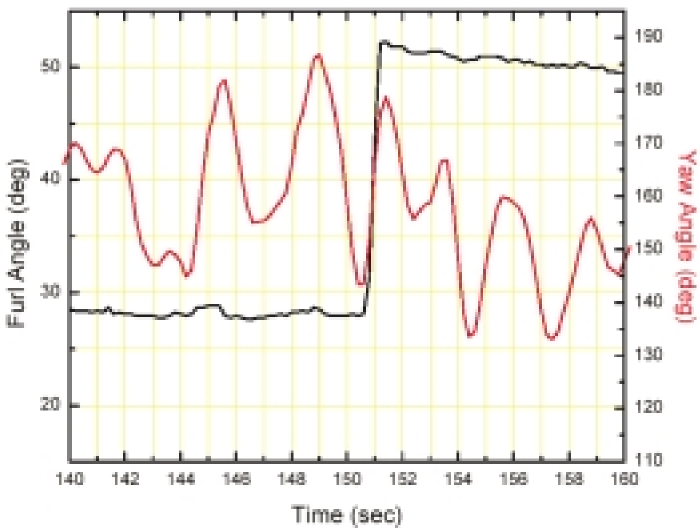


Figure 5. Furl Angle and Yaw Angle Plot for Highest Recorded Furl Rate

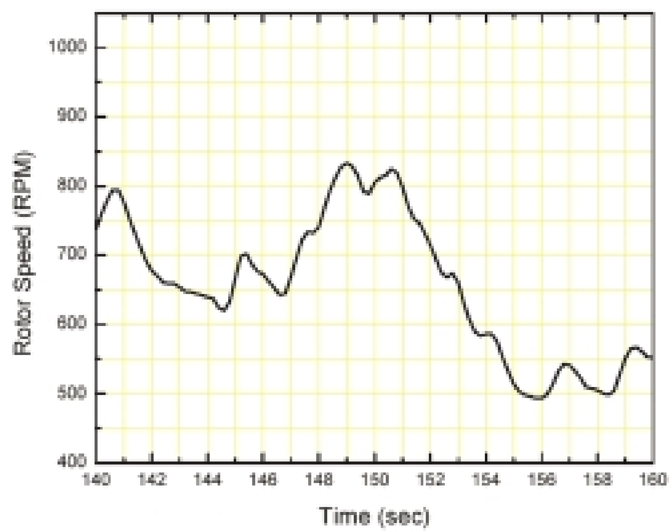


Figure 6. Rotor Speed Plot for Highest Recorded Furl Rate

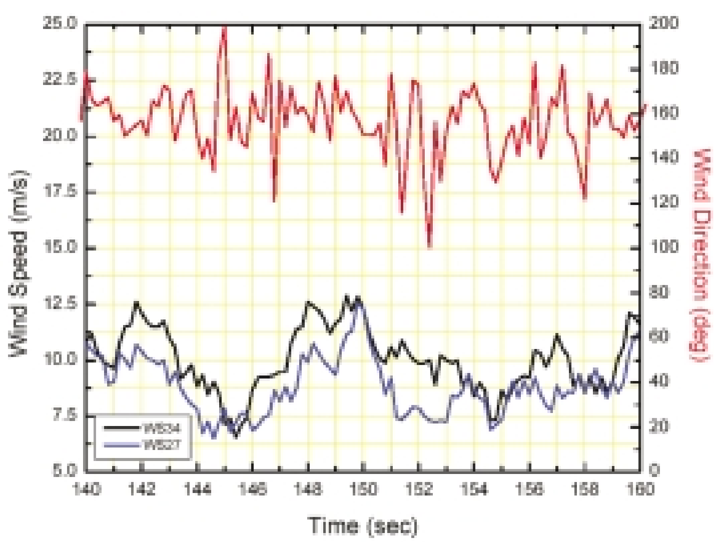


Figure 7. Wind Speed and Wind Direction Plot for Highest Recorded Furl Rate

Host Sites

The five recipient organizations manage 13 sites. Figure 8 and Table 1 show the names of the organizations and contacts, locations, turbine types, and applications.

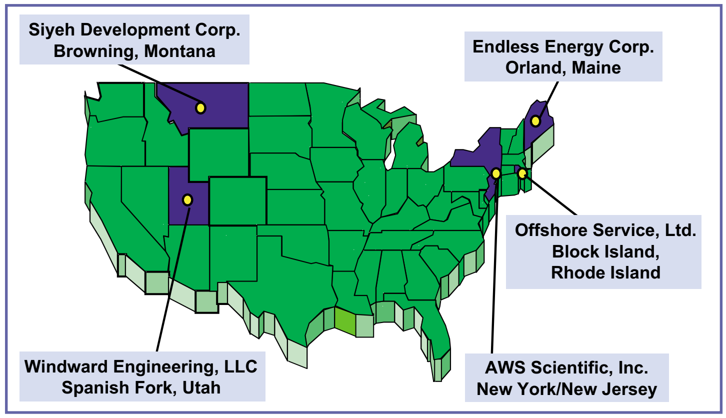


Figure 8. DOE Field Verification Program turbine locations

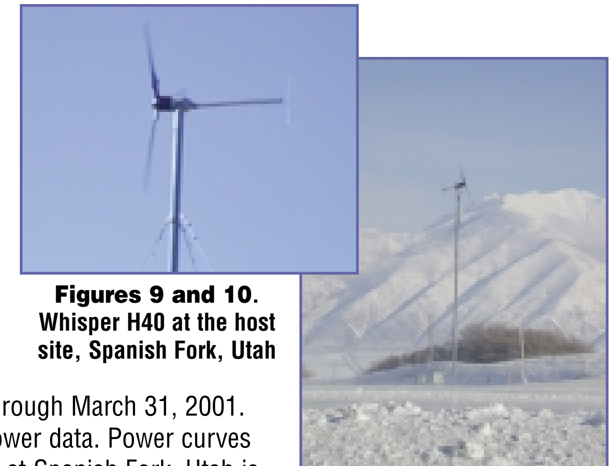
Table 1. Field Verification Program Locations and Participating Organizations

Organization/Contact	SWT #	Turbine Location	Quantity/Type of Turbine	Application
Windward Engineering 4661 Holly Lane Salt Lake City, UT 84117 Contact: Craid Hansen/Dean Davis	Turbine #1	Spanish Fork, Utah	One Whisper H40 (previously named Whisper 900)	Grid Connected
Endless Energy Corporation 57 Ryder Road Yarmouth, ME 04096 Contact: Harley C. Lee/Michael Boice	Turbine #1	Allen Blueberry Plant, Orland, Maine	One AOC 15/50	Grid Connected
	Turbine #2	Monhegan Island, Rockland, Maine	One AOC 15/50	Grid Connected
Siyeh Development Corporation P.O. Box 1989 Browning, MT 59417 Contact: Dennis Fitzpatrick	Turbines #1–4	Waste Water Treatment Facility, Browning, Montana	Four Bergey Excel—S/E 10 kW	Pumping and Purification
Offshore Service, Ltd. P.O. Box 457 Block Island, RI 02807 Contact: Henry G. duPont	Turbine #1	Block Island Goose and Garden Greenhouse, Block Island, Rhode Island	One Bergey Excel/R 7.5 kW	Residential Consumption
	Turbine #2	TBD	One Bergey Excel—S/E 10 kW	Residential Consumption
	Turbine #3	TBD	One Bergey Excel—S/E 10 kW	Residential Consumption
	Turbine #4	TBD	One Bergey Excel—S/E 10 kW	Residential Consumption
	Turbine #5	Jonathan & Jo-An Evans Residence Block Island, Rhode Island	One Bergey Excel—S/E 10 kW	Residential Consumption
AWS Scientific, Inc. 251 Fuller Road Albany, NY 12203-3656 Contact: Bob Putnam/Dan Bernadett	Turbine #1	Webster, New York	One Bergey Excel—S/E 10 kW	Distributed Generation
	Turbine #2	Liberty Science Center Jersey City, New Jersey	One Bergey Excel—S/E 10 kW	Distributed Generation
	Turbine #3	Southhampton College Long Island, New York	One Bergey Excel—S/E 10 kW	Distributed Generation
	Turbine #4	Peconic Land Trust's North Fork Stewardship Center Long Island, New York	One Bergey Excel—S/E 10 kW	Distributed Generation

First Quarter Status and Statistics Summary

Windward Engineering, LLC

Windward Engineering staff are testing a grid-connected Whisper H40 at an existing wind energy test site (Figures 9 and 10) in Spanish Fork, Utah. Since the turbine was commissioned in February 2000, it has produced a total of 1,543 kWh, and 77% of the energy produced has been sold to the grid. Another Whisper H40 has been tested at the NWTC since February 2000.



Figures 9 and 10. Whisper H40 at the host site, Spanish Fork, Utah

Spanish Fork, Utah

For the quarter ending March 31, 2001, the Whisper H40 turbine in Spanish Fork, Utah, ran normally with complete data acquisition systems operational. It produced 294 kWh under an average quarterly wind speed of 4.74 m/s.

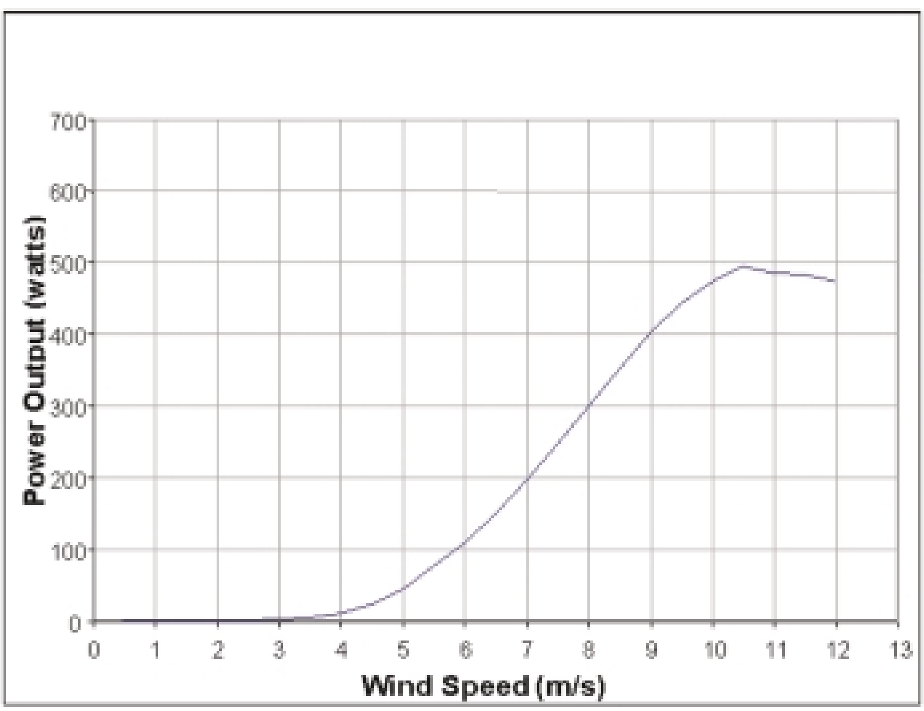
The following tables and figures contain the test results of the Whisper H40 at the site in Spanish Fork, Utah. Table 2 shows the quarterly project summary through March 31, 2001. Note that the Windward Engineering tables and figures report the measured power data. Power curves are not corrected to sea-level air density unless otherwise noted. The elevation at Spanish Fork, Utah is 4,800 ft. All wind speeds reported are the average of the two values measured by the primary anemometer (at hub height plus the rotor radius) and the secondary anemometer (at hub height minus the rotor radius).

The turbine operated with 100% turbine availability and 100% system availability.

Table 2. Project Summary

kWh Total	kWh/m^2	Capacity Factor*	Unavailable Hours	Turbine Availability	Max kW**	Concurrent Wind Speed*** (m/s)	Ave. Wind Speed at Hub Height (m/s)
294	82.2	15%	0.0	100%	672.5	11.9	4.74

* Rated output is 900 watts
** Maximum power is the peak 10-minute-average output
*** The concurrent wind speed is a 10-minute-average wind speed



Wind Speed (m/s)	Power (watts)
0.5	2
1.0	2
1.5	2
2.0	2
2.5	2
3.0	3
3.5	5
4.0	12
4.5	24
5.0	45
5.5	78
6.0	110
6.5	150
7.0	198
7.5	248
8.0	300
8.5	354
9.0	404
9.5	445
10.0	473
10.5	494
11.0	486
11.5	483
12.0	474

The test results indicate that the H40 wind turbine power curve reached a maximum power of 494 watts at a wind speed of 10.5 m/s and then decreased to 474 watts at 12.0 m/s (Figure 11). The H40 showed its furling capabilities at high wind speeds.

Figure 11. Whisper H40 Wind Turbine Power Curve

Windward Engineering, LLC

Figure 12 shows the wind speed distribution at the Spanish Fork, Utah, test site for this quarter. The most productive wind speeds range from 5 -13 m/s. There was little energy produced for wind speeds above 14 m/s or below 4 m/s.

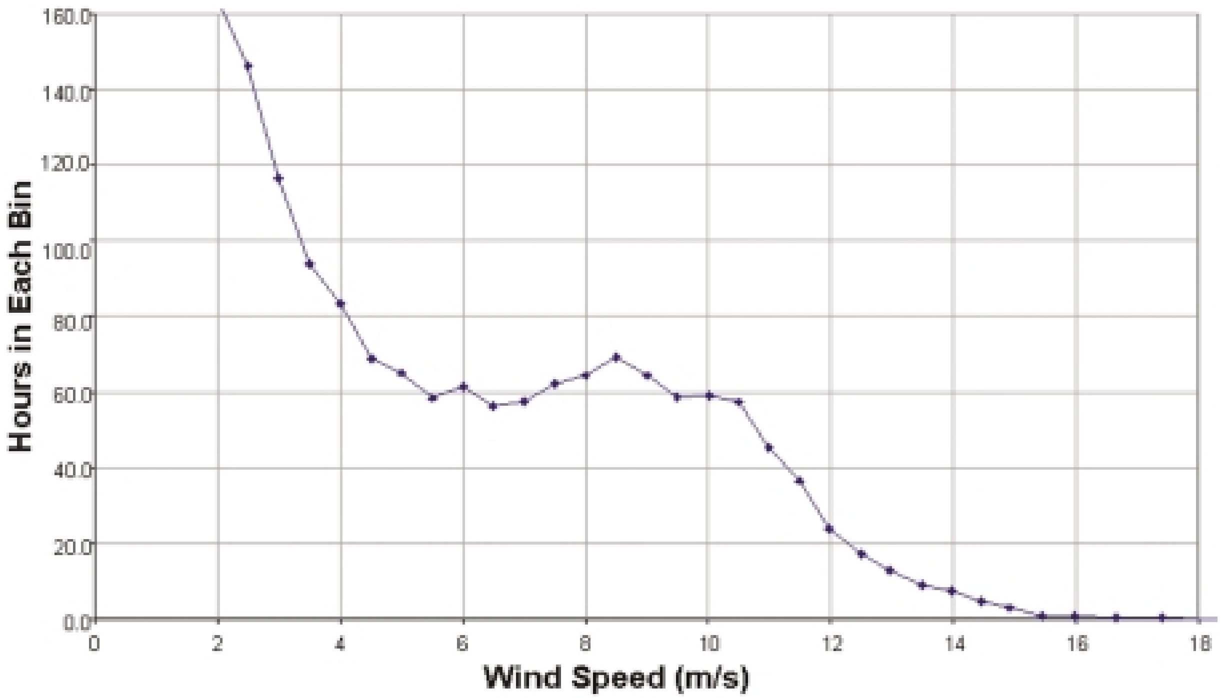


Figure 12. Wind Speed Distribution Curve

Figure 13 shows that only 13 days of this quarter (out of 90) produced daily energy below 0.25 kWh. The site's steady diurnal wind patterns make the wind turbine productive 86% of the time.

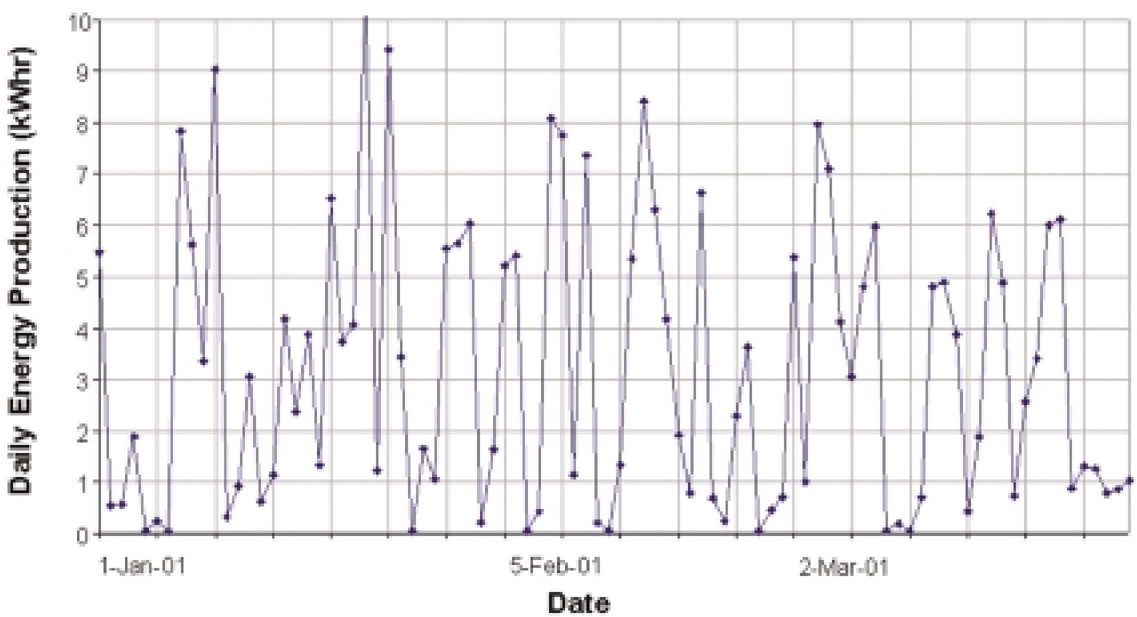


Figure 13. Daily Energy Production

Endless Energy Corporation

Endless Energy Corporation (EEC) will install two AOC 15/50 turbines along the windy Maine coast for several commercial power customers. The goals of the project are to verify the performance of the turbine under harsh coastal conditions and to create a model for commercially competitive wind power installations in small, distributed settings. The project will benefit from the convergence of essential factors for successful wind-powered generation: windy, buildable locations; the use of well-engineered wind turbines; and the existence of the necessary regulatory scheme and power markets for financial success.

Allen Blueberry Plant, Orland, Maine

The issues addressed this quarter focused on connecting the system to the grid. Previously it was agreed that two protective relay units would be added to address Central Maine Power's (CMP) concern about the level of grid-monitoring, relay-protection equipment. Before the turbine (Figure 14) could be connected to the grid, utility staff needed EEC to simulate a fault, without disturbing relay wiring, to verify the protective relays would disconnect the turbine from the grid and the protective relay operation would translate through the program logic controller to the instrumentation relays and to the main contactor. EEC added a three-pole, double-throw switch to the control circuitry to prepare to simulate a fault. EEC scheduled the fault simulation and turbine commissioning at the same time. Staff from Atlantic Orient Corporation, EEC, G.M. Allan & Son, and CMP were present. During the fault simulation, the turbine successfully disconnected from the grid when the protective relay inputs were switched. The utility representative gave verbal authorization to connect to the grid and left before the commissioning. Later that day, January 15, 2001, the utility representative provided written authorization after returning to his office. During the commissioning, a wiring problem was discovered with one of the factory-wired connectors on the rotary transformer cable connection to the blade tip brakes. Commissioning was halted, but within a week a corrective patch cable was assembled at the factory and delivered to the site.

Figure 14. AOC 15/50 wind turbine at the Allen Blueberry Plant in Orland, Maine.

Commissioning commenced on January 23, 2001, with only EEC and the factory on the telephone. The turbine failed to connect automatically with the grid and a tip brake deployed due to an overspeed condition. Commissioning was halted. On January 25, 2001, adjustments had been made to the frequency-to-voltage converters in the speed sensor circuit of the control system, but commissioning was postponed for two weeks due to calm wind conditions. February 7, 2001, the turbine generated power but suffered repeated automatic shutdowns that were traced to a three-phase wiring problem involving the power transducer module within the control system. This problem was corrected by February 14, 2001, and the turbine operated normally and has not required any further corrective actions. After commissioning and through March 30, 2001, the turbine produced 370 kWh of energy. AOC installed a software modification as part of their effort to verify the performance characteristics of the wind turbine per the purchase and sale agreement. These data have not yet been analyzed. Future tasks still include making the DAS operational, confirming the performance of the wind turbine (power output versus wind speed), and installing fencing and signage at the site.

Regarding the Net Energy Billing discussed last quarter, CMP objected to providing G.M. Allen & Son a net energy billing contract. CMP says that the turbine is owned by EEC rather than by G.M. Allen & Son. EEC has retained a lawyer familiar with electric utility issues to represent EEC and G.M. Allen & Son. EEC tried to get the differences resolved with an informal conference call between CMP's lawyer, EEC's lawyer, and Public Utilities Commission (PUC) staff, but CMP's lawyer was unavailable. The matter has been formally filed and is a docketed item on the PUC agenda awaiting a formal response and Commission decision. EEC is optimistic about the PUC outcome, but the dispute strikes at the heart of the business and financial mechanisms that make this wind turbine installation possible.

Monhegan Island, Rockland, Maine

Negotiations for a second wind turbine installation have been proceeding but no action has been taken while the net energy billing dispute of the Allen Blueberry Plant is before the PUC. EEC will analyze its costs to date, estimate the costs for a second turbine, and provide those costs to DOE for review.

Siyeh Development Corporation

Siyeh Development Corporation (of the Blackfeet Indian tribe) in conjunction with the Town of Browning, Montana; Bergey Windpower; the Indian Health Service; the Blackfeet Indian Housing Authority; and Glacier Electric Cooperative will partner to install four Bergey turbines at Browning's Waste Water Treatment Facility. These project partners represent a broad base of experience and interests ranging from local government and utility functions to state-of-the-art wind turbine systems engineering. It is believed that the project will assist in the improvement of the community waste water treatment system and promote a cohesive and integrated experience base for future wind power development.

Waste Water Treatment Facility, Browning, Montana

Siyeh continued to work with Trace Technologies and NREL on the retrofit of the inverters. The inverter for turbine #1 was removed from the facility and delivered to Trace for diagnosis and repair. The inverter for turbine #3 is not operating. Trace will be installing parts that are on order. With the assistance of NREL, there were equipment changes made to the project, specifically, four new transducers were installed.

Siyeh will continue to work with Trace on the ongoing retrofit of the inverters, and the furling mechanism of turbine #4 still needs to be repaired. Performance data continued to be collected from the remaining two turbines. Siyeh is making adjustment to the collection software as needed in order to properly analyze the wind speed and electrical generation information.

No valid or reliable data were available to report this quarter.

Offshore Services, Ltd.

Offshore Services will install five Bergey Excel wind turbines on Block Island, Rhode Island, to evaluate the effectiveness of wind power in a harsh marine environment at five different locations with different types of ownership structures. In addition, Block Island Power Company has a number of circuits that experience low voltage at the ends of the distribution system during peak demand periods. Some of these turbines will be placed at the end of the distribution system to measure the effect of adding distributed power sources.

Block Island Goose and Garden Greenhouse, Block Island, Rhode Island

The turbine has been operating normally and providing excellent power availability; the site has not used its 6.5-kW backup generator. The turbine has been producing more power on many occasions than the facility can use, which results in the system battery voltage regulator limiting the charge current from the wind turbine to prevent overcharging the battery. This results in lower power output than expected in periods of higher winds. Under these conditions, the wind turbine, operating partially or mostly unloaded, has a higher rotor speed and produces a different and slightly louder sound. This can be instantly corrected by loading the turbine by plugging in a 1.5-kW (or larger) electric heater or the site's Ford Ranger electric vehicle (Figure 15) for a charging cycle. The current-limiting phenomenon shows up in the power curve data in higher winds with a wide spread of possible power output depending on the battery state of charge.

Figure 15. A Bergey 7.5 kW/R wind turbine charges the site's electric Ford Ranger pickup.

Offshore staff plan to automate the "harvesting" of excess power by installing a relay that will turn on a 2.5-kW water heating coil in the site's wood/coal hot water furnace to keep the turbine loaded under all wind and battery conditions. The relay will close at 28.2 volts and open at 27.5 volts and will automatically dump excess power to the heating coil in the furnace during windy periods. Staff will separately meter that portion of the power used by the facility to determine the amount of available power that would be lost under normal circumstances. The only area of concern, besides the thunderstorm issues discussed in earlier quarterly reports, is the 4:1 transformer between the turbine and the AC-DC rectifier. This device, which steps down the 125-volt AC from the wind turbine to the 32 volts AC for the rectifier, is running quite hot and has, during periods of high wind, produced a burning smell. Staff have talked to Bergey Windpower about this problem in the hopes that they will use a transformer with slightly greater current capacity in the future.

Data results are on the following page.

Offshore Services, Ltd.

Block Island Goose and Garden Greenhouse, Block Island, Rhode Island

The following tables and figures show the project summary (Table 3), distribution of monthly average wind speed (Figure 16), and wind speed distribution curve (Figure 17) for the quarter ending March 31, 2001, for the Goose and Garden Greenhouse.

Table 3. Project Summary

kWh Total	kWh/m^2	Capacity Factor	Max kW*	Concurrent Wind Speed** (mph)	Ave. Wind Speed at Hub Height (mph)
2,886.1	72.9	22%	5.7	14.1	15.5

* Maximum power is the peak hourly average wind speed
** The concurrent wind speed is an hourly average wind speed

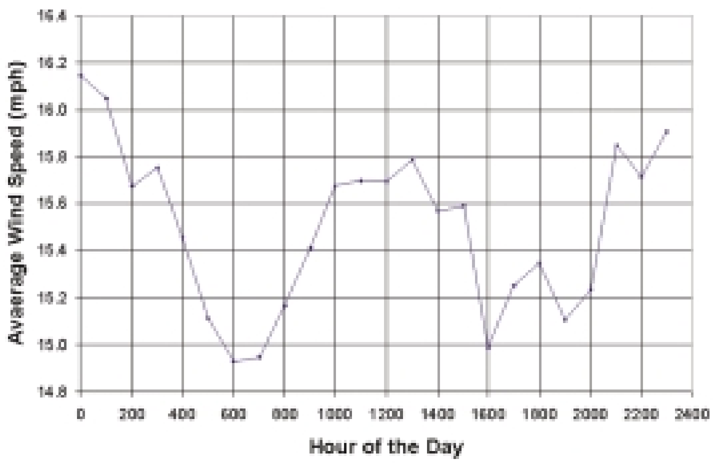


Figure 16. Distribution of Monthly Average Wind Speed

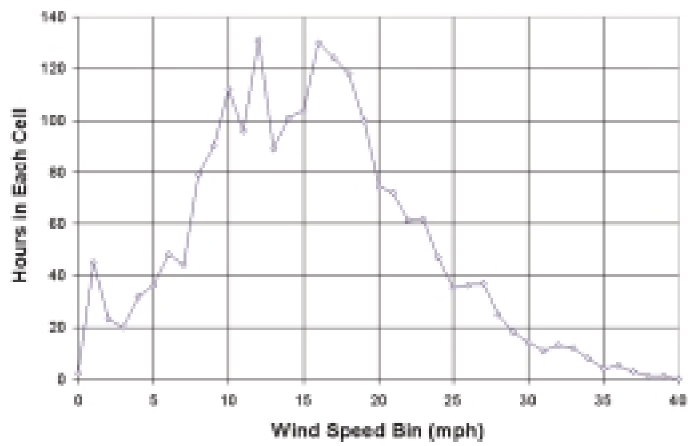


Figure 17. Wind Speed Distribution Curve

Jonathan & Jo-An Evans Residence, Block Island, Rhode Island

In Issue #2, Offshore reported that the power transducer equipment was producing noise. Staff thought that perhaps it was due to electromagnetic interference from the proximity of the Trace inverter. Staff moved the Ohio Semitronics (OSI) current transformer and transducer away from the inverter. The noise was only lessened, rather than eliminated. Staff will try an alternate OSI and/or a Second Wind "Nomad" Data Logger. In addition, last quarter, the turbine's guy wire to the tower failed and the turbine fell (Figures 18 and 19). The guy wire was repaired this quarter. Before the turbine could be reraised, a neighbor appealed the repair permit and put a temporary stop on the work. (Note: In the Field Verification Program Quarterly Report, Issue #2, Offshore reported problems the Block Island community was having with wind turbine installations. Block Island was in the process of adding new zoning and noise ordinances, which would allow neighbor input before permitting. To date, there is a wind turbine building moratorium in effect until May 28, 2001, in order for the Town to reexamine the provisions in the present wind turbine ordinance.) The town held a public hearing on February 26, 2001. The host site owner and the town building official testified that the repair permit was issued in accordance with the town ordinances. The Zoning Board decided that the building official was correct and the appeal was denied. The turbine would have been immediately erected except, in the interim, the insurance carrier that paid for the turbine's repair declined to provide coverage in the future. A new insurance carrier is being sought. The turbine did not operate this quarter and no operating data are provided.

Figure 18. A guy wire failed on the Evans Residence Bergey Excel-S/E 10 kW.

Figure 19. The Evans Residence turbine fell after a guy wire failed. Here you see the tail crushed with embedded rocks and soil. Next to it lay the blades.

Offshore Services, Ltd.

Alternate Site 1, Block Island, Rhode Island

Offshore has a hotel owner interested in having his property be a host site, but further evaluation of the site and the emerging new zoning ordinances led Offshore to look elsewhere. Offshore has located a 3-acre private island named North Dumpling Island, which is located north of Fishers Island, New York, and south of Groton Long Point, Connecticut. This island, which is 23 miles west of Block Island, already has a Bergey 10-kW wind turbine that was installed in 1987 and is presently inoperable due to a tail boom failure and excessive wear to the original turbine. The owner of North Dumpling Island is interested in hosting a turbine and participating in the program. The site offers no neighbors within a mile, a grid-connected load, and a location (within 20 feet of Fishers Island Sound) that will certainly test the ability of this machine to operate in a severe marine environment. Negotiations with the owner are in their final stages.

Alternate Site 2, New Shoreham, Rhode Island

A wind-turbine-friendly neighborhood group has asked if their property can act as a host site. The group consists of five neighbors who own 23 contiguous acres. Offshore is working with this group and the owner of the lot where the wind turbine would be placed to get an agreement. The turbine would be used in an off-grid application.

Alternate Site 3, New Shoreham, Rhode Island

Offshore is negotiating with the Rhode Island State Airport Corporation, which is interested in hosting a turbine on the 370-acre Block Island Airport site. This turbine would generate approximately 40% of the power used in the airport terminal facility.

AWS Scientific, Inc.

AWS Scientific will install, operate, maintain, and monitor the performance of one Bergey Excel at each of its four sites. These four sites are geographically diverse and are characterized by challenging weather extremes. These projects will demonstrate the use of wind for distributed power needs for grid-connected generation under diverse ownership scenarios.

Webster, New York

The new foundation is delayed until May 2001 due to weather and ground conditions. AWS expects to install the turbine two weeks after the foundation work is completed. AWS continues to wait for the results of the UL (Underwriters Laboratories) testing of the GridTek inverter to determine if it will meet the additional New York State Standard Interconnection Requirement.

Liberty Science Center, Jersey City, New Jersey

The foundation was installed January 22-26, 2001. Turbine installation is planned to begin April 17, 2001.

Alternate Site 1, Southampton College, Long Island, New York

AWS signed a Professional and Technical Services Agreement with the Long Island Power Authority (LIPA) to support the turbine installation at Southampton College. The Environmental Checklist and site map for Southampton College was submitted to DOE in March. AWS is working with LIPA and Inter-Science Research Associates, Inc., an environmental planning and development consulting firm working on behalf of Southampton College, to expedite the local zoning and planning application and approval process for the proposed site. All of the parties hope to have the turbine installed by early fall 2001 in order to integrate performance evaluation into the semester's curriculum.

Peconic Land Trust's North Fork Stewardship Center, Long Island, New York

AWS continues to work to put a professional and technical services agreement in place and to address any permitting and approval issues.

Testing at the NWTC

Whisper H40

NREL is continuing to test the Whisper H40. During 12 months of testing that concluded in March 2001, this turbine operated 2,646 hours and produced 1,871 kWh of electricity with an operational time fraction of 100%. Note that operational time fraction is a carefully defined interpretation of availability as specified in the draft standard, IEC 61400-2. Operational time fraction is not reduced due to interruptions from testing activities or grid outages. The turbine exhibited a minor problem in March when its furling mechanism caused it to remain furled inappropriately in light winds. NREL staff removed some metal from the nacelle casting that appeared to be causing some binding. NREL researchers expect that this corrective action will resolve the problem.

AOC 15/50

NREL has been testing the AOC 15/50 at its NWTC site since October 1994. However, the turbine has undergone several important upgrades and changes since it was first installed. The most recent change was to adjust its pitch setting from that which would be used at the almost 2,000-meter elevation of the NWTC to the standard setting for a European (50 Hz) turbine installed at sea level. This change reduces the power considerably from what would be expected if the pitch was set appropriately for a 60-hertz turbine at the NWTC elevation. A second significant change to the turbine was the temporary replacement of the rotary transformer with modified slip rings to enable NREL to obtain blade and shaft loads data for turbine certification. These slip rings proved to be significantly less reliable than the standard rotary transformer. To account for this change, NREL did not reduce operational time fraction (key variable for duration test) when outages were caused by slip ring problems.

Bergey Excel 10 kW

Duration tests began on March 14, 2001. Although the Excel turbine was installed at the NWTC in November 1999, teething problems with the new turbine controller/inverter delayed valid testing until March 2001. NREL anticipates completion of this test by the end of 2001 if no additional failures are encountered.

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