Performance Monitoring Program for the Vermont State-sponsored Small Wind Turbine Network

Phase 1 Report

Prepared for the
Vermont Department of Public Service

By

Vermont Environmental Research Associates, Inc.

December 20, 2004

Introduction and Scope

The Vermont Department of Public Service (VDPS) is assisting educational institutions and agricultural sites in the installation of small wind turbine systems. Four 10-kilowatt turbines have already been erected, with at least five more awaiting final approvals. The wind turbine generators are "net-metered" to feed power directly into the electric grid. They also serve as educational examples for teachers, students, and local communities, on subjects which include wind energy technology, physics, statistics and global climate change.

In October 2004, VDPS contracted with Vermont Environmental Research Associates (VERA) to initiate and oversee a performance monitoring program for the network of small wind turbine systems. The purpose of the program is to allow operating data to be available in a consistent format to schools, the VDPS, and the general public in a timely manner initially proposed for the next three years. The standardized data will provide for a broader understanding of the wind resource across the state, and the performance data will demonstrate the effectiveness of this technology in Vermont's climate.

This "Phase 1 Report", as outlined in the agreement, reports on the inventory of equipment present at each turbine location necessary for recording, storing, and monitoring wind resource and power production data. The report also specifies what additional equipment must be procured to automate the turbine system network for recording, storage and collection of data to a remote, centralized location as outlined in the project proposal.

A VERA representative has visited each of the existing wind turbine systems, and met with on-site personnel. Contact information for both existing and proposed systems is included in Appendix I. Figure 1 shows the locations of existing and proposed turbines receiving funding from VDPS. Four systems are installed, with at least five more installations planned for 2005. The installation status of the various systems is summarized in Table 1.

Figure 1: Installed and proposed turbine sites

Table 1: Location and installation dates of installed and planned turbine systems

TOWN	OWNER/HOST	INSTALLATION DATE[1]
Danville	Danville School	July 2003 (9/22/04)
Concord	Private residence	August 2003 (11/24/04)
Randolph	Vermont Technical College	September 2003 (9/22/04)
Mount Holly	Mount Holly School	March 2004 (9/20/04)
Addison	Addison Central School	*Early Winter 2004*
Dover	Dover School	*Spring 2005*
Marlboro	Marlboro School	
Burlington	University of Vermont	
Middlebury	Middlebury College	

[1] Defined as the month in which the wind turbine generator was raised. Dates in parentheses represent date of VERA site visit. Italics represent expected installation dates.

As of mid-December 2004, all installed turbine systems are in service and producing power, which is being "net metered" and fed into the electric grid. None of the four systems have components in place to record energy production in a consistent and efficient manner, nor the capability to log wind resource data as it corresponds to energy production. Cumulative energy output is being recorded manually from an analog watt meter at some sites periodically, and at other sites not at all.

In order to monitor wind resource and performance at each location in accordance to the standards in this monitoring program, it is necessary to install additional equipment with the capability to collect, store and transmit data to a remote, centralized location. Once the equipment is installed and operational, on-site maintenance and the impact on existing operations is expected to be minimal. Among the four systems in operation, there is some variation in installed instrumentation essential for the monitoring program. In general, every turbine system installation needs to be modified to achieve the program objectives diagrammed in Figure 2.

As Figure 2 indicates, there are two largely-separate systems that will be in place when additional work is complete. The 'energy production' system is already in place at the four operating turbines. The 'data collection' system is scheduled for installation in late-2004/early-2005.

The **Symphonie Logger**, the industry-standard data collection system, records 10-minute averages of instantaneous scans of the following sensors at 2 second intervals:

- Wind speed and wind direction from an **anemometer** and **wind vane** mounted on the wind turbine tower
- Temperature from a **temperature sensor** mounted outdoors in the vicinity of the wind turbine
- Revolutions-per-minute (RPMs) of the rotor, via signal fed from a small **transformer** connected to the power leads at the turbine generator

Figure 2: Configuration of a small wind turbine system for automated energy production monitoring and data collection to a remote location

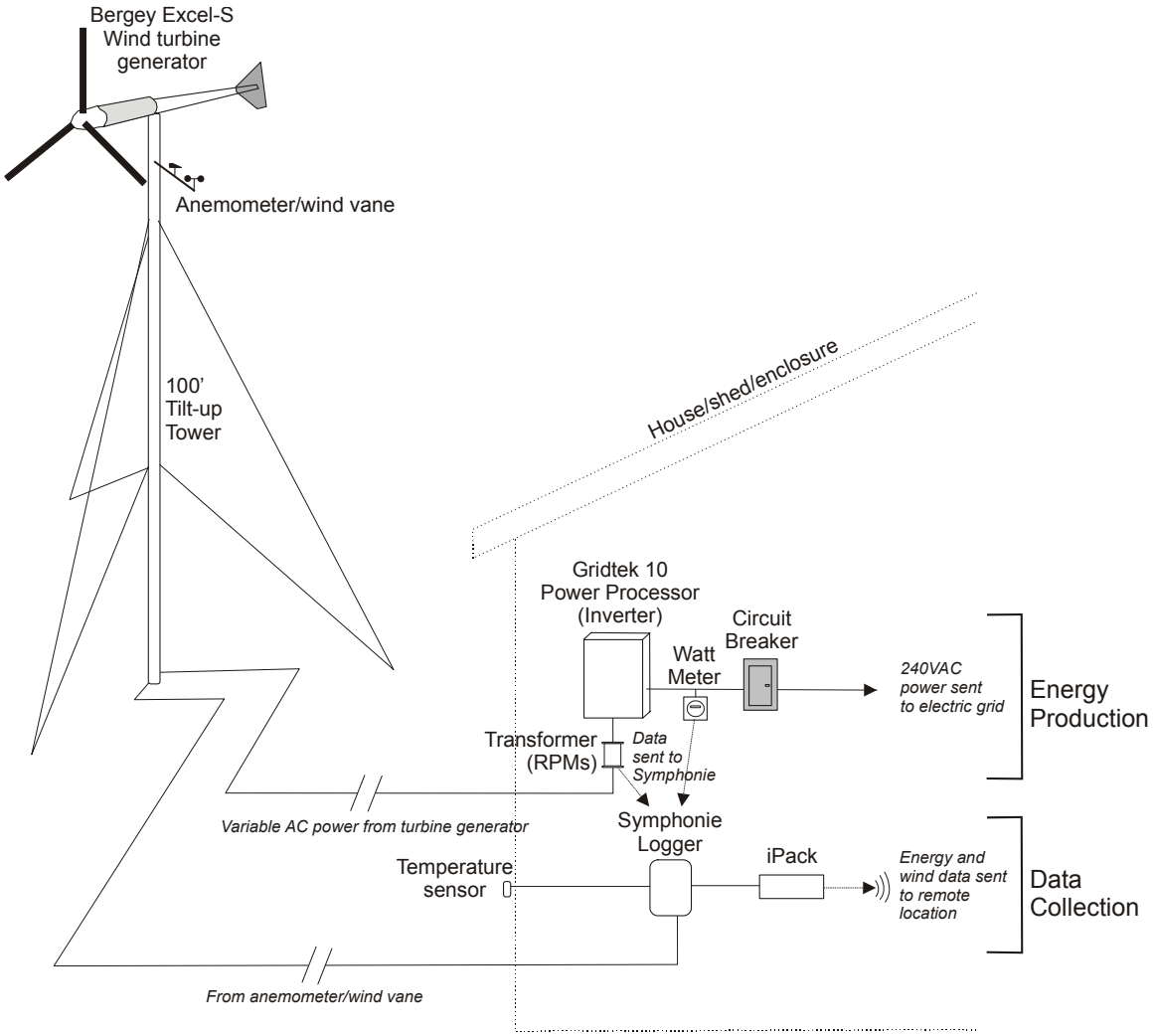

Diagram not to scale

The Symphonie Logger also records average power output of the 2-second scans for each 10-minute period from a **Watt Meter** installed near the **Gridtek 10 Power Processor (Inverter)**. The data is stored on a non-volatile 16MB Flashcard inside the Symphonie Logger, and transmitted to a remote location daily.

Collection of data is achieved via an **iPack**, a communication device that uses either a telephone line ("iPack for dialup") or a cellular phone service ("AMPS iPack") to dial a remote location. Data from the Symphonie Logger is sent through the iPack and arrives as an email attachment, for storage and analysis.

INSTALLED TURBINE SYSTEMS

Background information specific to the equipment configuration at each of the four locations is outlined below, along with recommendations and specifications for additional equipment purchases and cost estimates for them. Note that estimates for labor related to installation of new equipment are not included in this report.

Danville School, Danville

School buses park near the Danville School turbine during school hours

Background

The wind turbine system at Danville School was installed in July 2003, and began generating electricity in October 2003. The 10kW Bergey turbine is sited approximately 200' southwest from the school (elevation 1250' Above Mean Sea Level [AMSL]).

Configuration

At present, there is no wind data collected at this site. Energy production totals are recorded manually in a semi-consistent schedule from a cumulative watt meter located in the shed approximately 30' south of the turbine location. The power inverter is also housed in this shed. A one-inch conduit from the turbine to the shed encloses the electric line and wind measurement cables. Currently the leads to the anemometer and wind vane cables terminate in the shed. A transformer has been installed in the shed to correct the voltage drop that was occurring between the power source at the school and the inverter.

An equipment shed near the turbine houses inverter and transformer

Additional equipment necessary

In order to automate data collection, the Danville turbine system will require a Symphonie Logger, Watt Meter, temperature sensor, and iPack to collect data. A telephone line will be fed through the existing conduit between school and shed, and the iPack will be configured to utilize an existing phone line at the school. This is the least-cost option. If feeding a telephone line between shed and school proves to be too difficult, it will be necessary to utilize an AMPS iPack and purchase a cell service plan.

NRG will donate a Symphonie Logger and a Symphonie iPack for dialup to Danville School for this project. Alternatively, if it is determined that installation of the iPack for dialup is not feasible, NRG will donate an AMPS iPack and accessories.

A cost estimate for the purchase of new equipment at this location is provided below.

New data collection equipment recommended for Danville School

INSTRUMENT	COST
Symphonie Logger	*To be donated*
iPack	*To be donated**
Temperature sensor	$220
Watt Meter	$400
Transformer (RPMs)	$50
TOTAL	$770

* If it is determined that an iPack for dialup is not feasible at this site, NRG will supply an AMPS iPack and accessories instead.

Private residence, Concord

Background

The wind turbine system in Concord is the only state-funded 10kW system on private land. It is located on a thinly wooded hill at 1570' AMSL. Livestock, especially sheep, are free to graze in the vicinity of the turbine tower and supporting guy wires.

Configuration

The turbine is visible atop a hill to much of the surrounding agricultural landscape

Power generated from the turbine is fed through a buried conduit approximately 200 yards to the basement of the residence. Cable feeds from the anemometer and wind vane mounted on a tower boom are also sent through this conduit. In the basement, the turbine output is converted to 240 VAC power through the GridTek 10 Power Processor inverter, while the anemometer and wind vane send continuous data to a Symphonie Logger. The wind data is being recorded on a 16MB Flashcard, but is not analyzed or reviewed consistently. Cumulative power production is recorded in the analog Watt Meter mounted near the inverter, and copied to a kitchen calendar periodically by the landowner. An iPack for dialup is connected to the Symphonie Logger, but is not sending data. There is a telephone line nearby, but the iPack is not connected to it at this time.

Additional equipment necessary

To record energy production and meteorological data, the turbine system will require a Symphonie-compatible Watt Meter and temperature sensor, installed in the vicinity of the basement. The landowner has indicated a preference for installing the temperature sensor on an exterior basement wall, which would require minimal additional wiring. An additional transformer is needed to record rotor RPMs. This transformer would be installed next to the inverter. In order to transmit data to a remote location, the iPack needs to be connected to the existing phone line.

A buried conduit connects turbine generator and wind equipment (behind photographer) to the basement of the white house at center

A cost estimate for the purchase of new equipment at this location is provided below.

New data collection equipment recommended for private residence, Concord

INSTRUMENT	COST
Temperature sensor	$220
Watt Meter	$400
Transformer (RPMs)	$50
TOTAL	$670

Vermont Technical College (VTC), Randolph

Background

The 10kW Bergey turbine is located atop a cleared knoll west of VTC, at 1430' AMSL. The site is a few hundred feet from the top of VTC's ropetow and ski slope. Installation of the turbine began in September 2003, and was completed in October 2003. VTC's working farm with classrooms is situated approximately 150 yards away to the north-northeast. The turbine is visible from Interstate 89, especially during periods when the leaves are off.

The VTC turbine is visible in the far distance in a field up the hill from the VTC farm

Configuration

Power generated from the turbine is fed to the Bergey GridTek 10 inverter through a buried line running across the field to a weather-proof electronics enclosure near the main building of the farm. An anemometer and wind vane are mounted on the tower as well, and have leads that terminate in this enclosure.

A weatherproof enclosure (opened for the photograph) houses inverter and cable leads from anemometer and wind vane

Access to an existing VTC farm building phone line depends on the presence of a conduit between the building and the enclosure. Energy production totals are recorded manually in a semi-consistent schedule off of a cumulative Watt Meter housed in the weatherproof enclosure as well. There is no wind data being recorded. A Symphonie Logger has been furnished as part of this system, but as of December 2004 has not been connected.

Additional equipment necessary

To record energy production and meteorological data, the VTC turbine system requires a Symphonie-compatible Watt Meter and temperature sensor, which should be installed in the vicinity of the weatherproof enclosure. An additional transformer would be installed to record rotor RPMs. In order to transmit performance data to a remote location, an iPack must be purchased and installed. A telephone line will be fed through the conduit between the enclosure and the farm building, and the iPack will be configured to utilize an existing phone line. This is the least-cost option for data transfer. If installing a telephone line between enclosure and building proves to be too difficult, it will be necessary to purchase an AMPS iPack and a cell service plan.

A cost estimate for the purchase of new equipment at this location is provided below.

New data collection equipment recommended for Vermont Technical College

INSTRUMENT	COST
iPack	$950 ($1230)*
Temperature sensor	$220
Watt Meter	$400
Transformer (RPMs)	$50
TOTAL	$1620 ($1900)

* If it is determined that an iPack for dialup is not feasible at this site, an AMPS iPack will need to be purchased instead (cost in parentheses).

Mount Holly School, Mount Holly

Background

The 10kW Bergey wind turbine at Mount Holly School was installed in March 2004. It is situated approximately 300' from the school building, on the high land in a relatively flat, broad plain (elevation 1040' AMSL). The turbine is sited on a 100' tower in the corner of a baseball/soccer field behind the school. It is clearly visible from Route 103, the predominant road through the area.

The Mount Holly turbine stands near a playing field behind the school

Configuration

The instruments related to turbine system operations are conveniently housed inside the school building. An underground conduit runs from the turbine location to a storage room attached to the staff kitchen. The Bergey GridTek 10 inverter and a Symphonie Logger are located here. The Logger is configured to record wind speed and direction data from the anemometer and wind vane mounted on the tower. There is no energy production data being recorded, and therefore no indicator of turbine performance in various wind speeds and wind directions.

Additional equipment necessary

In order to record energy production data, the Mount Holly School turbine system requires a Watt Meter and temperature sensor, installed in the vicinity of the storage room. The purchase and installation of an iPack is required to transmit data to a remote location. There is no cellular phone service in Mount Holly, and therefore data will have to be transferred by a land-based phoneline. The hub for all telephone

State Route 103 to the north affords a good view of the turbine

lines in the school is located inside a utility closet near the storage closet. The hub will accept an iPack feed. In order to configure the iPack in this manner, a telephone line will run from the storage room to the utility closet. Based on initial observations, this process should require minimal alterations to the wall between the two rooms.

A cost estimate for the purchase of new equipment at this location is provided below.

New data collection equipment recommended for Mount Holly School

INSTRUMENT	COST
iPack for Dialup	$950
Temperature sensor	$220
Watt Meter	$400
Transformer (RPMs)	$50
TOTAL	$1620

PLANNED TURBINE SYSTEMS

In addition to the four state-funded wind turbine systems already installed, several projects have been proposed to the VDPS and are in various stages of development. Furthest along is the wind turbine at Addison Central School in Addison. This turbine is expected to be installed and producing power by the end of 2004. The next system, at Dover Elementary School, is expected to be installed in the spring of 2005.

As additional turbine systems come online, VERA will include these site areas in future report. An updated spreadsheet similar to Appendix I will also be included.

APPENDIX I
Comprehensive listing of components and equipment at existing and proposed turbine sites

Site name	Address (site contact)	Location/elevation	Installation date	Turbine	Inverter	Anemometer/vane	Symphonie logger	iPack	Temp sensor	Watt meter	RPM transformer	Est. cost *
Danville School	Peacham Rd, Danville, 05828 (John Rapoza, 684-3651)	N44°24'36" W72°08'43"/ 1250'	July 2003	Bergey XL-S 10kW	GridTek 10	Installed; not logging	To be provided (NRG	--	--	--	--	$770
Private residence	1120 High Ridge Road, Concord, 05824 (Nancy Lapotin, 695-1430)	N44°22'30" W71°51'55"/ 1570'	August 2003	Bergey XL-S 10kW	GridTek 10	Installed; logging	Installed	Installed	--	--	--	$670
Vermont Technical College	Randolph Center, Randolph, 05061 (Prof. John Kidder, 728-1783)	N43°56'30" W72°36'50"/ 1430'	September 2003	Bergey XL-S 10kW	GridTek 10	Installed; not logging	on-site	--	--	--	--	$1,620 ($1,900)
Mount Holly School	150 School St, Mount Holly, 05758 (Pncpl. Craig Hutt Vater, 259-2392)	N44°26'46" W72°49'18"/ 1040'	March 2004	Bergey XL-S 10kW	GridTek 10	Installed; logging	Installed	--	--	--	--	$1,620
Addison Central School	121 VT Route 17W, Addison, 05491 (Pncpl. Wayne Howe, 759-2131)	N44°05'30" W73°18'50"/ 150'	*Early Winter 2004*	Bergey XL-S 10kW	--	--	--	--	--	--	--	N/A
Dover Elementary School	9 Schoolhouse Rd, East Dover, 05341 (Pncpl. Susan Mach, 464-5386)		*Spring 2005*	Bergey XL-S 10kW	--	--	--	--	--	--	--	N/A
Marlboro Elementary School	PO Box D/Route 9, Marlboro, 05301			Bergey XL-S 10kW	--	--	--	--	--	--	--	N/A
University of Vermont	Burlington, 05401			--	--	--	--	--	--	--	--	N/A
Middlebury College	Middlebury, 05753			--	--	--	--	--	--	--	--	N/A

* Estimated cost for all recommended equipment for performance data recording and transmission, as listed in Phase 1 Report
List is current to: 12/20/04