# Distributed Wind Energy Monitoring Best Practices

Brent Summerville

*National Renewable Energy Laboratory*

**NREL is a national laboratory of the U.S. Department of Energy**
**Office of Energy Efficiency & Renewable Energy**
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**Technical Report**
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September 2024

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## NOTICE

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*Cover Photos by Dennis Schroeder: (clockwise, left to right) NREL 51934, NREL 45897, NREL 42160, NREL 45891, NREL 48097, NREL 46526.*

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Distributed wind monitoring working group members are included in the following table:

| Member | Organization |
|---|---|
| **Quentin Chopart** | Eocycle |
| **Liam Griggs** | Ryse Energy |
| **Chris Connor** | Northern Power Systems |
| **Rob Wills** | Intergrid |
| **Shawn Sheng** | National Renewable Energy Laboratory (NREL) |
| **Heather Rhoads** | eFormative Options |
| **Charles Newcomb** | mCloud/Hoss Consulting |
| **Padma Kasthurirangan** | Buffalo Renewables |
| **Remy Pengle** | REpowering Schools |
| **Lindsay Sheridan** | Pacific Northwest National Laboratory |
| **Suhas Pol** | Texas Tech University |
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| **Jason Endries** | Carolina Solar Services |

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# List of Acronyms

| | |
|---|---|
| DWEA | Distributed Wind Energy Association |
| IEC | International Electrotechnical Commission |
| IEEE | Institute of Electrical and Electronics Engineers |
| kW | kilowatt |
| LAN | local area network |
| NREL | National Renewable Energy Laboratory |
| OEM | original equipment manufacturer |
| PNNL | Pacific Northwest National Laboratory |
| PV | photovoltaic |
| SCADA | supervisory control and data acquisition |
| SIM | subscriber identity module |

# Executive Summary

Accessible performance and operational data have been identified as key enablers for distributed wind energy industry advancement. Although utility-scale wind farms benefit from reliable and continuous supervisory control and data acquisition-based monitoring platforms, monitoring of the U.S. fleet of distributed wind turbines has been more inconsistent, unreliable, and sometime difficult to access. Without fleet monitoring data, the industry will never understand and thus work to improve turbine underperformance and reliability issues. For the distributed wind industry to scale up, attract investors, and boost credibility, fleetwide monitoring must be robust and reliable, select data must be made accessible to stakeholders, and the data must be in a format helpful to users.

To help move the industry toward a more standardized, accessible stream of monitoring data, this distributed wind energy monitoring best practices report covers topics including key monitoring channels, hardware, communication strategies, and accessibility. Strategic engagement with distributed wind original equipment manufacturers, service providers, lab and university researchers, testing organizations, certification bodies, end users, and solar photovoltaic monitoring experts has enabled a better understanding of the current state of the art of monitoring and aided in articulating this set of best practices. This set of best practices will guide original equipment manufacturers toward harmonized monitoring strategies, aimed at a future goal of achieving accessible performance and operational data for the entire fleet of U.S. distributed wind turbines.

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# 1 Introduction

As the name implies, wind turbines used in distributed applications are installed where electricity is consumed at homes, farms, schools, businesses, and communities positioned across the United States. Unlike the process for more concentrated land-based, utility-scale wind farms, keeping track of the performance and condition of the fleet of distributed wind turbines can be challenging for turbine original equipment manufacturers (OEMs) and service providers because of the spatial diversity of the fleet. Furthermore, end users of distributed wind turbines have demonstrated a positive connection to their wind turbine(s) through local monitoring. End users want to know what the turbine is doing now and what it has been contributing; inaccessibility of these data results in frustration and concern. Other industry stakeholders, such as the U.S. Department of Energy and their network of national laboratories, are tasked with researching the performance of the fleet of U.S. distributed wind turbines. However, accessing field data can be arduous, and the data are often limited. This guide is intended to inform suppliers of distributed wind technology about monitoring best practices to help address these challenges in the distributed wind energy industry.

## 2 Benefits and Uses of Monitoring Data

Accessible data from the monitoring of distributed wind turbines in the field benefit end users, turbine manufacturers, service providers and technicians, and research bodies such as national laboratories and universities. These data can help end users monitor turbine performance, reliability, and costs/financing. As highlighted in a report from Bianchini et al. (2022), open data from distributed wind turbines are key enablers to addressing grand challenges in the global distributed wind industry, as shown in Figure 1. The report states that "sharing any available remote monitoring data is an opportunity for researchers and manufacturers to collaborate on a variety of potential research areas that could expand small wind markets while also helping reduce costs." Potential research activities include:

- Comparison of actual wind turbine performance with predicted performance to help understand the factors influencing real-world performance and working to improve the tools used to assess and estimate performance, including wind resource assessment tools. Bianchini et al. (2022) states that "the inability to predict performance consistently and accurately can negatively affect customer confidence in small wind and access to financing."
- Calculation of actual levelized cost of energy, a function of capital costs, operations and maintenance cost, and actual project performance
- Research into distributed wind energy's complementarity and interoperability with solar photovoltaic (PV)-based distributed energy resources and battery energy storage systems.

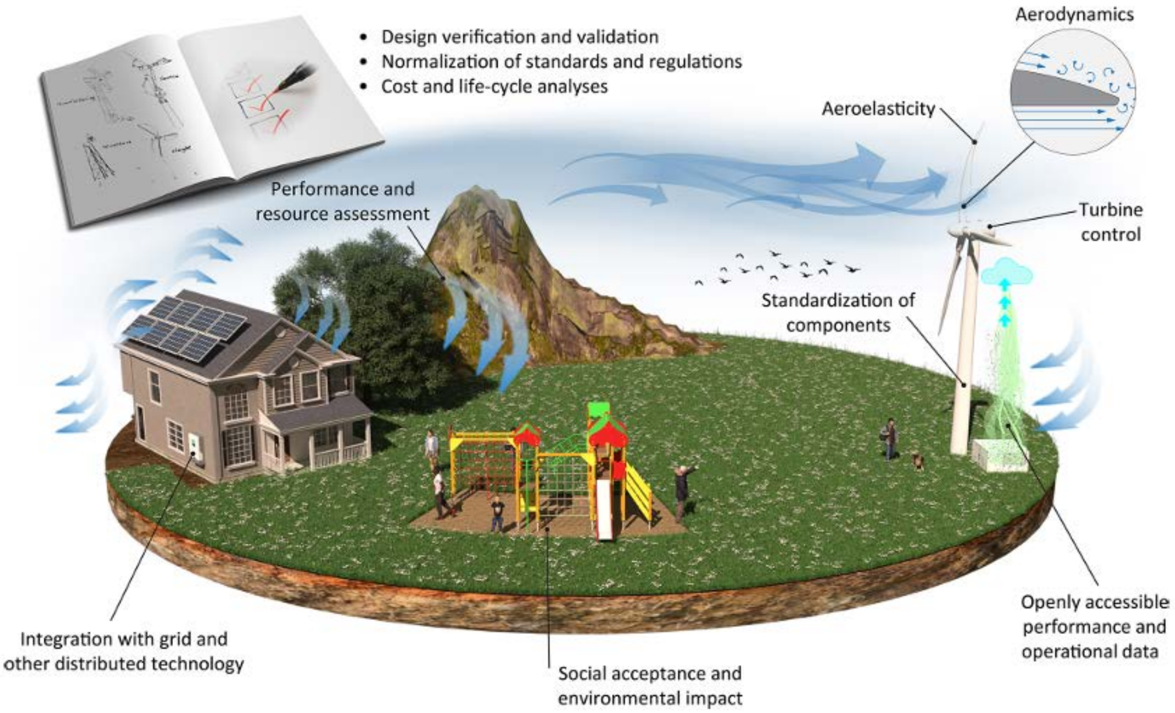

**Figure 1. Openly accessible data as a key enabler to address grand challenges for small wind turbine technology.** ***Image from Bianichini et al. (2022)***

Without robust monitoring, the reliability of distributed wind energy remains anecdotal. Field failures can cast doubt on the industry, but real data inform better decisions. Data on conditions during turbine issues experienced in the field inform work to improve turbine designs, to improve the standards and tools used to design turbines for long-term operation in real-world conditions, and to improve the operations and maintenance strategies by service providers.

The industry agrees on the many benefits of remote monitoring, but the cost of monitoring systems is a major consideration. The cost of monitoring systems is a function of turbine and project size. Consider the range of wind turbine functions and sizes in the following list:

- Micro wind turbines (less than 1 kilowatt [kW], as shown in Figure 2) typically use a simple, low-cost monitoring system for the purpose of end-user awareness. The system involves local digital or analog meters for electrical parameters such as voltage, amperage, and power or a Bluetooth-based performance monitoring application showing current turbine power output. Limited data from the micro wind turbine can help with remote technical assistance when issues arise.

**Figure 2. Micro wind turbine from Primus Windpower (now Ryse Energy) providing data for educational purposes at Appalachian State University.** ***Photo by Brent Summerville, National Renewable Energy Laboratory (NREL)***

- Small, residential wind turbines (1 kW to 20 kW, as shown in Figure 3) typically include web-based performance monitoring of power and accumulated energy and sometimes wind speed and direction. This basic information satisfies end users who are curious about the performance of their investment. The wind turbine manufacturer and service provider often have access to more data channels, such as rotor speed, voltages, amperages, and status signals to aid in troubleshooting and repair.

**Figure 3. Bergey Windpower Excel 10 on a farm in Oregon.** ***Photo by Small Acres Farm***

- Commercial wind turbines (20 kW to 1 megawatt) are a more sizeable investment and are equipped with remote monitoring of a more complete array of parameters, including power, energy, wind speed/direction rotational speed, statuses, yaw position, temperatures, voltages, frequencies, fault codes, and so on. The turbine manufacturer and service provider often have bidirectional communication with the turbine, allowing some turbine issues, such as minor faults, to be resolved remotely. Select data from the Northern Power Systems (NPS) turbine shown in Figure 4 are intercepted by the university and displayed on a web-based dashboard, shown in Figure 9.

**Figure 4. The 100-kW NPS 100B wind turbine at Appalachian State University.** ***Photo by Brent Summerville, NREL***

- Land-based, utility-scale turbines (multimegawatt) turbines, as shown in Figure 5, are typically equipped with sophisticated supervisory control and data acquisition (SCADA) systems, enabling both monitoring of turbine system data and issuing of commands to the turbine control system. Condition monitoring of turbine components enables sophisticated preventative maintenance strategies to maximize turbine availability. Developers and service providers keep a continuous eye on their fleet of multimegawatt turbines installed in distributed applications using solely the data from power output meters but turn to the more complex suite of monitoring channels as needed for maintenance and troubleshooting.

**Figure 5. Two 2.82-megawatt GE wind turbines powering a Dole Fresh Vegetables facility in Soledad, California.** ***Photo by Foundation Windpower, LLC***

# 3 Monitoring Discussions With the Distributed Wind Energy Industry

## 3.1 Monitoring Discussion at Distributed Wind 2022

In conjunction with Distributed Wind 2022, the Distributed Wind Energy Association's (DWEA's) annual conference in March 2022, Brent Summerville from NREL and Alice Orrell from the Pacific Northwest National Laboratory (PNNL) led an industry discussion on the topic of monitoring. The following topics were covered in an introductory presentation.

**Figure 6. The Pacific Northwest National Laboratory (PNNL) developed a monitoring package for option 1 using the eGauge power meter.** ***Photo by Alice Orrell, PNNL***

### *3.1.1 Potential Steps To Create Better Cost, Reliability, and Performance Data and Access Moving Forward*

Two options were discussed:

- Option 1: Develop systems to meter individual wind turbines. (see figure 6)
- Option 2: Monitor turbines through agreements with OEMs.

### *3.1.2 Metering Work Performed by the Pacific Northwest National Laboratory*

The metering work included the following:

- PNNL completed a pilot installation to demonstrate the feasibility of installing a preconfigured metering package with a Bergey Excel 10 at Small Acres Farm in Whatcom County, Washington.
    - A lab-supported program to monitor individual turbines (option 1) was found to be labor-intensive, perhaps good for a specific research need but not viable for overall distributed wind fleet monitoring.
- The following wind industry organizations shared a summary of OEM monitoring strategies:
    - Bergey Windpower

        - Optional on the Excel 10 using APRS World hardware[1] and web-based portal of power and energy
        - Standard on Excel 15 (in development).
    - Eocycle
        - Monitoring via the turbine controller on the S- and M-series.
    - Pecos Wind Power
        - Turbine in development, will have remote monitoring.
    - PowerGrid Partners (NPS)
        - In-house monitoring system captures data from 508 channels.
    - Primus Wind Power
        - Only via Bluetooth.
    - QED Wind Power
        - Transitioning to an updated monitoring platform.

### 3.1.3 Rationale for Reliable Monitoring and Access to the Data

The following were presented as benefits of reliable and accessible fleetwide monitoring data in terms of performance, reliability, cost, and compatibility.

#### Performance

- The inability to consistently and accurately predict performance can negatively impact customer confidence in distributed wind energy, as well as access to financing.
- Performance data help us understand why actual performance differs from predicted performance in real-world conditions.

#### Reliability

- Distributed wind reliability remains anecdotal.
- Failures can cast doubt on the industry; real data inform better decisions.
- Data inform work to improve design, siting, operations, and maintenance.
- Reliable turbine data help satisfy field inspection requirements per ANSI/ACP 101-1 (surveillance of 5 wind turbines for 3 years).

#### Cost

- Performance data validate advertised levelized cost of energy.
- Data help us to understand life cycle costs with inputs such as long-term wind turbine production, long-term turbine availability, turbine performance degradation, and increased impact of obstacles, such as vegetation growth.

#### Compatibility

- This information enables wind to complement/communicate with other distributed energy resources in the grid of the future.

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[1] https://www.aprsworld.com.

Participants in the industry discussion, listed in the appendix, were asked several questions; raw responses are in the following sections.

### 3.1.4 Additional Value of Monitoring

In addition to the values presented by Orrell and Summerville, the conference participants listed the following benefits of reliable, accessible monitoring. These raw responses are an encouraging and comprehensive list:

- QED stows turbine in response to weather events
- Credibility emerges from a data set larger than any one OEM
- Wind data may be needed for controller operation
- Low-cost IoT [internet of things] satellite comm [communication] will open the market
- Minimize climbing for everything
- There's generally reasonable wind data available locally, so it can be correlated to power production without an anemometer
- Risk mitigation
- Validation of models, turbulation
- Spotting maintenance issues
- For b-roll on nightly news/weather channel
- Increased security
- Great marketing tool
- Each DWT [distributed wind turbine] is a MET [meteorological] tower, meteorological value?
- Strengthen and build weight behind industry reports
- Public relations (PR)
- Save a truck roll, or at least come to site prepared
- Adds to wealth of public knowledge (if published) and helps understand future research/development needs
- Troubleshooting
- Model validation!!!
- Supports performance-based incentives
- Public confidence
- Turbine performance
- Warranty management
- Validation and improve energy production simulation models
- Proof
- Turbine health monitoring and forecasting can help prevent failures!
- Predictive maintenance opportunities for installers/decreased downtime
- Institute of Electrical and Electronics Engineers (IEEE) 2030.5 protocol is required for UL1741-SB—it can support wind monitoring as well
- Understanding rare extreme events and failures
- Maintenance management
- Predictive maintenance
- Customer/public engagement

- Service life consumption
- Performance feedback to manufacturers to improve products
- Consumer confidence.

### 3.1.5 Requirements for Making Distributed Wind Monitoring Reliable, Useful, and Accessible

Conference participants were asked, “What is needed to enable distributed wind monitoring to be made reliable, useful, and accessible?” The responses to this ranking poll indicate a need for standardization and reliable communications (Figure 7). We discuss how to achieve these in the next section.

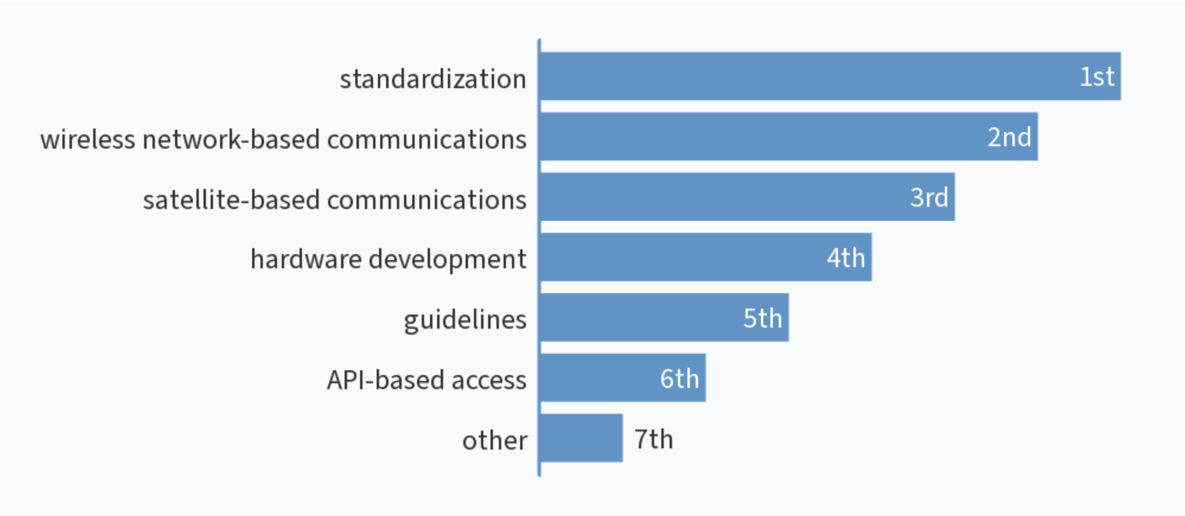


**Figure 7. Results from the question “What is needed to enable distributed wind monitoring to be made reliable, useful, and accessible?” from the DWEA 2022 session. The ranking function of Poll Everywhere was used to rank these options.**

Note: API = application programming interface.

### 3.1.6 Steps To Achieve the Top Enablers (Such as Standardization)

The conference participants answered the question, “How do we achieve the top enablers (e.g., standardization)?” The responses below are focused on the top enabler identified in section 3.1.5, standardization. We are made aware of an existing inverter communication standard, IEEE 2030.5, which may provide a baseline for standardization. An open-source platform is suggested while keeping an eye on cybersecurity. The participants’ raw responses follow (a few edits for clarity are included in brackets):

- Standardize communication with inverter = 3rd party collection and transmission OEMs don’t have to build/maintain
- Establish open-source primary protocols
- Maybe only monitor a statistical distribution of turbines for finance and reliability data from each OEM?
- Data applicability: customer, utility, OEM, commercial interests, etc. Need large set, multi consumers

- We need to distinguish between customer control and performance monitoring, aggregation control (e.g., storage export on utility request) and factory mods (setpoint updates, software updates)
- Collect real-time electricity price in parallel to measurements for cost-benefit studies, marketing, financing
- Security is a real issue—refer to INL [Idaho National Laboratory] work and the MIRACL [Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad] project
- UL1741-SB and IEEE 1547 allow 3 protocols: Sunspec, IEEE 2030.5 and DNP3; IEEE 2030.5 is preferred
- Rural Broadband would help—a lot of sites don't have internet
- Data should be open source
- IEC 18650 std and IEEE 2030.5
- Every system has pros
- Prioritize vendors [of hardware]
- Takes a standards making body for a consensus
- New industry codes
- Include it in the certification
- Does IEEE 2030.5 need a data set extension?
- Provide a hardware standard
- Have look at citizen science projects
- Cooperation between OEMs on hardware or at least data protocols
- SunSpec for wind. Standard data models from inverters
- Funding.

### 3.1.7 Accessible Data Needed To Assess Reliability, Performance, and Cost and To Provide Surveillance as Part of the Certification Process

Conference participants were asked, "What (accessible) data are needed to assess reliability, performance, cost and provide surveillance as part of the certification process? (e.g. power, average wind speed...)?" They were able to input a response and vote up/down for each of the responses. The following are the responses in rank order, with the response with the most votes listed first.

**Table 1. Polling Responses on Data Channels**

| Responses | Upvotes | Downvotes |
|---|---|---|
| Downtime | 7 | 0 |
| Wind speed and power | 6 | 0 |
| kWh [kilowatt-hour] | 6 | 0 |
| Power, wind speed, wind direction | 4 | 0 |
| Power output vs. rated capacity | 4 | 0 |
| 10-minute wind speed | 4 | 1 |
| Record braking and overspeed events | 3 | 0 |
| Revolutions per minute (RPM) | 3 | 0 |

| Responses | Upvotes | Downvotes |
|---|---|---|
| Day/month/year energy record | 2 | 0 |
| Small wind depending on wind gusts? So minute [1-minute] average? | 2 | 0 |
| Modeled vs. measured AEP [annual energy production] | 2 | 0 |
| Wind speed to energy production | 2 | 0 |
| Fault identification | 2 | 0 |
| Condition state | 2 | 0 |
| Maintenance hours and cost (somehow) | 1 | 0 |
| Adaptable time interval | 1 | 0 |
| Energy | 1 | 0 |
| AEP [annual energy production] | 1 | 0 |
| Tower height vs. time | 1 | 0 |
| 1-second data? Averages? If yes, which? Depending on data connection? | 1 | 0 |
| Noise | 1 | 0 |
| Availability/time | 1 | 0 |
| It would help if NREL or PNNL hosted a database with a standard API [application programming interface] — not difficult to implement | 1 | 0 |
| Vibration of tower | 1 | 1 |
| Machine state, region | 0 | 0 |
| Always in combination with local weather measurement? | 0 | 0 |
| Availability | 0 | 0 |
| Noise level (dB [decibels])? | 0 | 1 |
| Number of times the data has been accessed by a local user | 0 | 0 |
| Inverter settings (e.g., power curve configuration) | 0 | 0 |

Downtime was top ranked, followed by wind speed and power. One-minute averages were popular, but a 10-minute averaging interval received four upvotes and one downvote. Because downtime can be derived from wind/power data, primary data needs could be summarized as time-stamped power, wind speed, and accumulated energy, with secondary data as wind direction, faults (e.g., overspeed), and revolutions per minute (RPM).

### 3.1.8 Potential Issues With Making Data Available

Participants were asked, "What are some potential issues with making data available? (e.g., Where are the data stored? Who has access?)" They were able to input a response and vote up/down for each of the responses. Table 2 includes the responses in rank order, the response with the most votes listed first.

**Table 2. Polling Responses on Data Access Issues**

| Responses | Upvotes | Downvotes |
|---|---|---|
| Misinterpretation | 8 | 0 |
| Need quality metadata alongside it to make it useful (e.g., location, hub height) | 5 | 0 |
| Cybersecurity means firewall control from performance | 5 | 0 |
| Swarm module reports local GPS and time; real time clock is an issue | 2 | 0 |
| Uniform data content and structure | 2 | 0 |
| Manufacturer reputation | 2 | 0 |
| OEM privacy | 2 | 0 |
| Increased liability for manufacturers | 1 | 0 |
| Trust (how to prevent bad data casting doubt, digital signatures, etc.) | 1 | 0 |
| Comparison against fleet averages | 1 | 0 |
| Context | 1 | 0 |
| Black eyes | 1 | 0 |
| Compare data from different sources | 1 | 0 |
| Used as a sales tool. Good/bad | 1 | 0 |
| Security | 1 | 0 |
| Poor consumer reception | 1 | 0 |
| Cloud | 1 | 0 |
| Depends on the location of the measure | 1 | 0 |
| Privacy laws | 1 | 0 |
| None | 1 | 0 |
| There are none | 1 | 0 |
| Pay for your own data? | 0 | 0 |
| Look at the bad information from better generation (UK) in the past | 0 | 0 |
| No issues in just power and wind data | 0 | 0 |
| No data is bad data, only bad interpretation. Control levels of access. | 0 | 0 |
| Appropriate access for different levels of data provision | 0 | 0 |

| Responses | Upvotes | Downvotes |
|---|---|---|
| Lack of anonymous aggregation, where appropriate | **0** | **0** |

Misinterpretation of data was the top concern. It was reinforced in the discussions that the associated metadata for each site are critical in making the data useful. Cybersecurity was also a top concern. A concern for “uniform data content and structure” refers to the standardization discussion. Privacy, reputation, trust, and liability were concerns for OEMs. Overall, although the participants agree on a long list of values of accessible monitoring, there is some perceived risk in making the data public.

### 3.1.9 Additional Participant Input

This final poll question wrapped up the session: “Any other thoughts or questions on distributed wind monitoring and where we might go next?” Participants were able to input a response and vote up/down for each the responses. The following are the responses in rank order, the response with the most votes listed first. It is unclear what is meant by the first response, “Prepare for certification.” This may be in reference to the new field inspection requirement in ACP 101-1 for the surveillance of certified turbines. Participants recommended looking at the solar industry as well as new inverter communication requirements. The need to keep monitoring hardware costs down was expressed as was the question of who pays for the associated costs.

**Table 3. Polling Responses on Other Issues Regarding Monitoring**

| Responses | Upvotes | Downvotes |
|---|---|---|
| Prepare for certification! | **3** | **0** |
| Satellite IOT monitoring (e.g., Swarm.Space) will open low-cost worldwide wind monitoring—even at the South Pole (but the wind is marginal there—no diurnal driver :). Intergrid is a prime Swarm developer—despite their high cost to entry. | **2** | **0** |
| Solar energy performance has much lower visibility | **2** | **0** |
| Take advantage of the requirements for grid integration functions in inverter | **2** | **0** |
| What is solar doing? | **2** | **0** |
| Need to minimize cost of equipment while maximizing benefit to industry | **2** | **0** |
| An email if the data stream is broken | **1** | **0** |
| Lack of support for potential LCOE [levelized cost of energy] improvement | **1** | **0** |
| "Impact on LCOE unclear" | **1** | **0** |
| Nice to have an OTS [off-the-shelf] solution for certification | **1** | **0** |
| Who would pay for it? | **1** | **0** |
| Data can be anonymized to protect OEMs | **1** | **0** |
| Test center for weather stations | **1** | **0** |
| Monitoring/standardization will not occur unless the funding mechanism requires it. | **0** | **0** |
| Some differentiation on various turbine scales | **0** | **0** |
| Independent information on wind measuring instruments. | **0** | **0** |
| Do not follow solar's example of being tightly manufacturer bound (SMA, OutBack, etc.) | **0** | **0** |
| QR code on tower to allow user to get a "snapshot" of recent production | **0** | **0** |

## 3.2 Monitoring Discussion at Distributed Wind 2024

Industry discussions on distributed wind deployment and technology research and development needs were held on February 27, 2024, following Distributed Wind 2024, the annual DWEA conference, to discuss near-term and midterm prioritization of the U.S. Department of Energy's Wind Energy Technologies Office investments in distributed wind energy. Monitoring was a topic of discussion, with the following points captured from participants.

- Topic: Wind turbine technology, including reliability
    - To understand reliability, we need deployed turbines, monitoring, and time.

  - Data are needed to better understand reliability: maintenance logs (what has been replaced), downtime of individual turbines, monitoring data.
  - Sophisticated condition-based monitoring systems for large wind are too expensive for distributed wind; not many options exist for small systems.
  - Remote monitoring systems, potentially with some level of diagnostic/control, are needed.
  - Monitoring of turbines is a gap; [we] need power output and maintenance logs.
  - Monitoring is a gap: [we] need to publish downtime, require reporting.

# 4 Data Channels

The decision regarding which data channels will be monitored is made after considering operational issues and failures experienced in the field or identified as potential failures in a failure mode analysis; turbine size; and the type and the size of the project. If the temperature of a component is a critical factor, the OEM may choose to monitor the temperature of that component for preventative maintenance purposes. Smaller turbines and projects require a proportionally smaller investment; the cost of the monitoring system tends to follow this correlation, with larger investments receiving more costly and sophisticated monitoring systems.

## 4.1 Minimum Channels

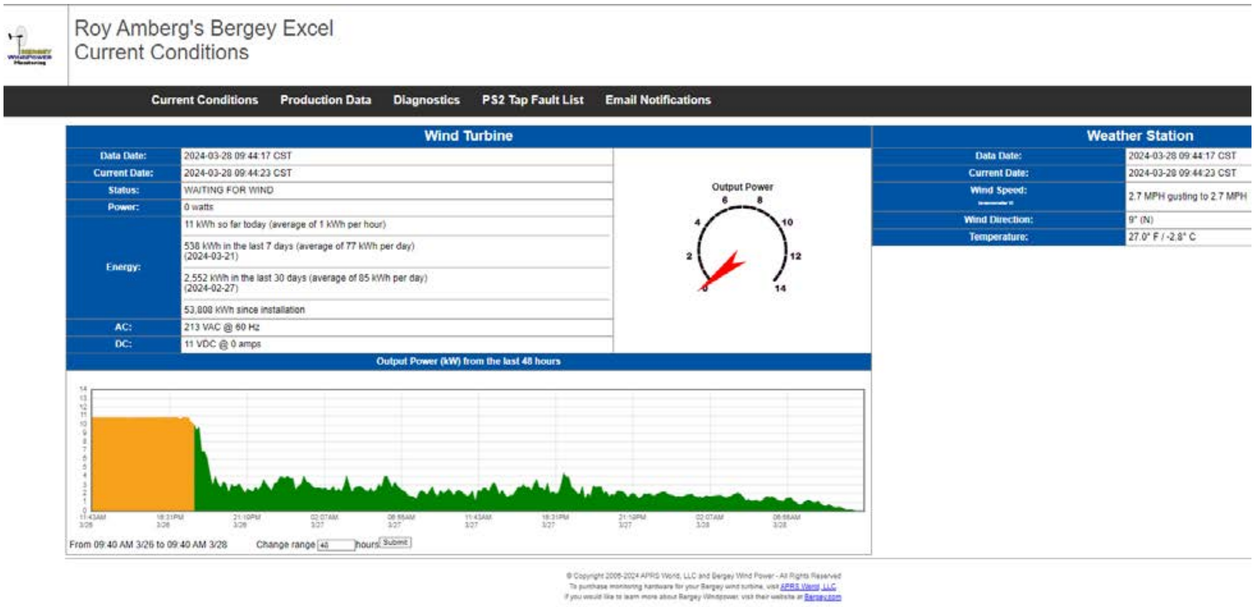
The following monitoring channels are sorted by priority. Power and energy represent the minimum data to remotely monitor and provide access to; subsequent channels add value but also add cost and complexity.

### *4.1.1 Power and Energy*

At a minimum, electrical power produced by the turbine should be reliably measured and remotely monitored for any project size. The single channel provides the opportunity to plot a time series of power output over time, telling a story of how the turbine has been performing over a specified period. The end user will use this data channel to satisfy this question: “What is my investment doing right now?” This single channel can alert a remote party that the turbine is experiencing downtime and requires attention. The power channel should include an accumulation of energy production over time, including the ability to calculate energy per day, per month, per year, and over the lifetime of the project. Figure 8 shows an example of simple web-based end user monitoring of a 10-kW Bergey Excel 10 installed on a farm in Minnesota. Figure 9 shows a web-based dashboard for Appalachian State University’s NPS 100B, 100-kW turbine. Despite many data channels being monitored by the turbine’s service provider, power and energy are the only channels needed for this end-user production monitoring.

### *4.1.2 Turbine System Status, Faults, Warnings*

You will also notice in Figure 8 that the status of the wind turbine is shown. This would typically be a signal from the inverter or turbine controller indicating a status of perhaps, RUNNING, or WAITING FOR WIND, or displaying a fault code corresponding to a known issue. Whether the status signal is simple or complex, indicating the status of various components including brakes, generators, inverters, and yaw systems, this information is invaluable for the turbine service provider when issues arise. The OEM and service provider should be alerted via email and/or text message when faults occur.



Roy Amberg's Bergey Excel
Current Conditions

**Wind Turbine**

| | |
|---|---|
| **Data Date:** | 2024-03-28 09:44:17 CST |
| **Current Date:** | 2024-03-28 09:44:23 CST |
| **Status:** | WAITING FOR WIND |
| **Power:** | 0 watts |
| **Energy:** | 11 kWh so far today (average of 1 kWh per hour)<br>538 kWh in the last 7 days (average of 77 kWh per day) (2024-03-21)<br>2,552 kWh in the last 30 days (average of 85 kWh per day) (2024-02-27)<br>53,808 kWh since installation |
| **AC:** | 213 VAC @ 60 Hz |
| **DC:** | 11 VDC @ 0 amps |

**Weather Station**

| | |
|---|---|
| **Data Date:** | 2024-03-28 09:44:17 CST |
| **Current Date:** | 2024-03-28 09:44:23 CST |
| **Wind Speed:** | 2.7 MPH gusting to 2.7 MPH |
| **Wind Direction:** | 9° (N) |
| **Temperature:** | 27.0° F / -2.8° C |

**Output Power (kW) from the last 48 hours**

From 09:40 AM 3/26 to 09:40 AM 3/28 Change range 48 hours

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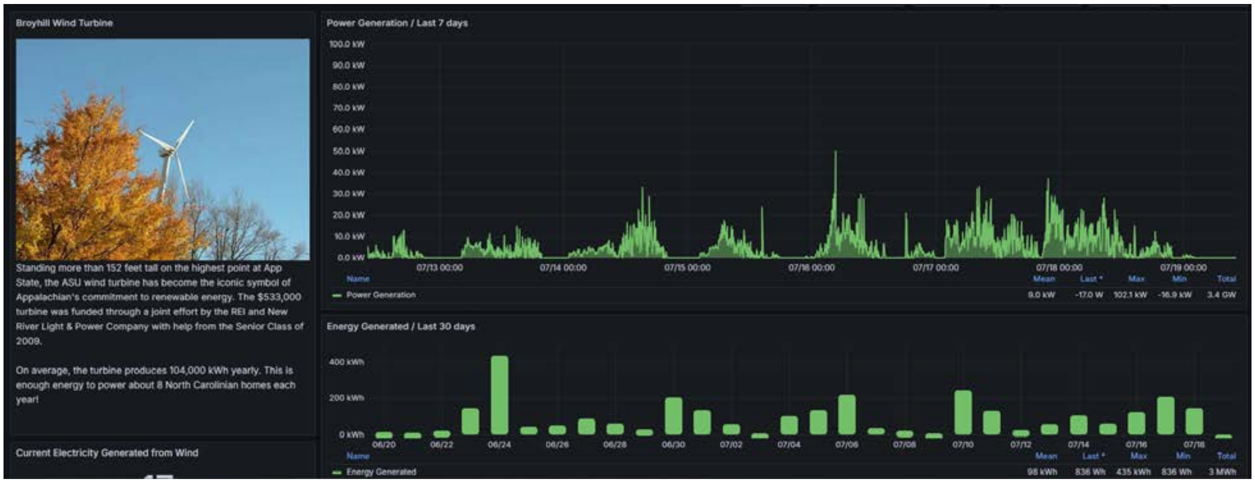
To purchase monitoring hardware for your Bergey wind turbine, visit APRS World, LLC
If you would like to learn more about Bergey Windpower, visit their website at Bergey.com

**Figure 8. Web-based monitoring of Roy Amberg's Bergey Excel 10 installed on his farm in Minnesota.** ***Image from APRS World, LLC (n.d.)***



Broyhill Wind Turbine

Standing more than 152 feet tall on the highest point at App State, the ASU wind turbine has become the iconic symbol of Appalachian's commitment to renewable energy. The $533,000 turbine was funded through a joint effort by the REI and New River Light & Power Company with help from the Senior Class of 2009.

On average, the turbine produces 104,000 kWh yearly. This is enough energy to power about 8 North Carolinian homes each year!

Current Electricity Generated from Wind

Power Generation / Last 7 days

| Name | Mean | Last * | Max | Min | Total |
|---|---|---|---|---|---|
| Power Generation | 9.0 kW | -17.0 W | 102.1 kW | -16.9 kW | 3.4 GW |

Energy Generated / Last 30 days

| Name | Mean | Last * | Max | Min | Total |
|---|---|---|---|---|---|
| Energy Generated | 98 kWh | 836 Wh | 435 kWh | 836 Wh | 3 MWh |

**Figure 9. Appalachian State University's web-based dashboard from their NPS 100B turbines.** ***Image from Appalachian State University Renewable Energy Initiative (n.d.)***

### 4.1.3 Communication Status

The condition of the monitoring system is an invaluable channel as well. If the system is not reporting, efforts can be deployed to troubleshoot and remedy the issue.

### 4.1.4 Maintenance Logs

Although not a data channel to be monitored remotely, it is important to maintain a log of wind turbine service and maintenance to track the turbine's service history. Logs can be a physical logbook or an electronic file and should include date of event/service, service provider, description of maintenance or services performed, and associated inspection photos. The turbine OEM will often supply an inspection/maintenance procedure and checklist.

### 4.1.5 Wind Speed and Direction

The example in Figure 8 also includes an optional weather station reporting wind speed and direction. These data, coupled with power/energy data, provide a more complete picture of conditions. For example, if power output is low or zero, yet the wind speed is high, a turbine issue would be suspected. If power output is low or zero and the wind is not blowing, normal operation could be assumed.

### 4.1.6 Temperatures

Ambient temperature can be an invaluable data channel to help understand the conditions at the site. Issues related to turbine operation and/or sensor operation (e.g., anemometers, wind vanes) can sometimes be attributed to icing events; ambient temperature data aid in troubleshooting. Component-level temperatures have proven useful for components that are not actively thermally managed. For example, temperature can provide a very early warning for bearing issues, primarily indicating deterioration of lubricants.

### 4.1.7 Data From Other Distributed Energy Resources

If the wind turbine is part of a microgrid, operating with other assets such as solar PV, battery energy storage systems, and backup generators, monitoring of these ancillary assets can provide status and performance of the whole system. For systems containing a battery energy storage system, battery state of charge, voltage, and other parameters can be invaluable. For wind and PV hybrid systems, performance monitoring can inform the contribution of both energy sources and enable wind and solar complementarity research.

## 4.2 Optional Channels

The following list of channels provide useful information but are considered optional.

- **Rotor Speed**

  When available, rotor speed measurements can provide an indication of normal/abnormal turbine behavior.

- **Live Video**

  Live video imagery of a monitored distributed wind turbine could prove invaluable for remotely viewing turbine status.

- **Vibration**

  Although sophisticated vibration-based condition monitoring systems are typically cost prohibitive, these systems can be used for prognostic health monitoring and monitoring potential resonant or dynamic issues. For example, if bearing failure is found to be a potential issue in a particular turbine model, a vibration analysis can be performed during regular inspection and compared to baseline vibrational data as a check into bearing health. As mentioned previously, component temperature can be a lower-cost alternative to vibration monitoring although it may provide a later warning than vibration analysis

- **Nacelle Direction**

  When available, nacelle direction can be useful in making comparisons to wind direction.

## 4.3 Data Labels, Sampling Rates, Averaging Period, Units

Data from remotely monitored channels is sampled frequently (e.g., every second) and stored in a database as averages (e.g., 1-, 5-, or 10-minute averages) with statistics including minimum, maximum, and standard deviation. Channels are labeled and units are included. Working to standardize these data-handling parameters is beyond the scope of this guidance document; however, we provide an overview of standards used in the land-based, utility-scale wind energy industry in the following list.

The International Electrotechnical Commission (IEC) 61400-25 suite of standards addresses the monitoring and control of wind energy assets through the following standard communication protocols:

- IEC 61400-25-1:2017 Communications for monitoring and control of wind power plants —Overall description of principles and models
- IEC 61400-25-2:2015 Communications for monitoring and control of wind power plants —Information models
- IEC 61400-25-3:2015 Communications for monitoring and control of wind power plants —Information exchange models
- IEC 61400-25-4:2016 Communications for monitoring and control of wind power plants —Mapping to communication profile
- IEC 61400-25-5:2017 Communications for monitoring and control of wind power plants —Compliance testing
- IEC 61400-25-6:2016 Communications for monitoring and control of wind power plants —Logical node classes and data classes for condition monitoring.

IEC 61400-26-1 is a standard developed to provide standardized metrics that can be used to create and organize methods for availability calculation and reporting.

IEC 61850 is an international standard defining communication protocols for intelligent electronic devices at electrical substations.

### *4.3.1 Snapshot of Monitoring Strategies in Utility-Scale Wind Energy*

Dedicated condition monitoring systems (e.g., vibration analysis) are often installed to get higher-frequency data and cover other failure modes that cannot reasonably be detected by using only the 1-second or averaged data as mentioned previously. Sometimes lubrication oil condition (e.g., cleanliness) monitoring or oil debris sensors are used in addition to vibration analysis because of the increased complexity of the monitored components (e.g., gearboxes). Note only permanently installed condition monitoring solutions are considered here, and periodic inspections (e.g., borescope inspections, oil sample or grease sample analysis) are not accounted for. There are various standards (e.g., International Organization for Standardization [ISO] 16079-2:2020) and recommended practices (e.g., AWEA Operations & Maintenance Recommended Practices[2]) or guidelines (e.g., DNV-SE-0439) can be referred to in terms of solution selection, sensor mounting locations, sampling rates, data interpretation, and fault severity evaluation (e.g., The Association of German Engineers [VDI] 3834 and ISO 10816), and

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[2] https://cleanpower.org/resources/awea-operations-maintenance-recommended-practices-second-edition/

so on. Typically, for vibration analysis-based solutions, they use accelerometers, which can be sampled at various rates (e.g., 10 kilohertz), depending on the sensor mounting locations and the monitored component expected rotational speeds. They are normally installed in the direction (e.g., radial) that produces maximum level of acceleration. A typical vibration system can monitor main shaft bearings, gearboxes, and generator bearings. A data acquisition system is often installed up tower (in the nacelle at the top of the tower), and it collects and transmits the data collected to either the control room nearby or the cloud. The solution typically comes with supporting analysis software, which can provide the end users with an intuitive overview of monitored turbines and components, access to raw data or snapshots of data, and further analysis if needed. Oil condition monitoring using cleanliness measurements is normally based on the optic sensing principle (detectable contamination size down to 4 microns and often expressed in three bins as recommended by ISO 4406[3]), whereas oil debris monitoring is based on magnetic field principle (detectable debris size down to, for example, 50 microns). Both can be installed either in the main filtration loop or a side stream of the gearbox filtration system. The data can be integrated into either a vibration-based condition monitoring system, the SCADA-based monitoring platform, or transmitted wirelessly to a remote server. For the scenario in which these data are a stand-alone stream, the end users are also typically offered a software platform, which can be used to visualize monitoring results and conduct deep analysis like the vibration analysis-based solutions. It is worth pointing out that oil condition is a good indication of lubrication oil properties and may not be effective for monitored component damage, for which oil debris monitoring normally works better.

## 4.4 Metadata

Metadata provide important information about the data being monitored at the wind turbine site. The following metadata should be provided for each monitoring site:

- Wind turbine make, model, and serial number
- Turbine location (address, latitude, and longitude)
- Customer information
- Turbine hub height
- Sensor information (anemometer, wind vane, temperature sensor)
- Layout and heights of sensors
- Time reference (time zone, daylight saving time, Greenwich Mean Time, Coordinated Universal Time)
- Description of monitoring system including communication configuration.

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[3] https://www.hyprofiltration.com/blog/bid/216397/iso-4406-what-do-those-numbers-mean-in-the-iso-cleanliness-codes.

# 5 Hardware

## 5.1 Power/Energy Meter

Many distributed wind turbines, particularly in the small to medium size range, are inverter-based resources. For inverter-based resources, turbine system power and energy data are made available by the inverter and can be added to the remotely monitored data channels. If power/energy cannot be obtained from the inverter or controller, a third-party meter, such as the eGauge[4] can be installed. Larger, utility-scale turbines will typically be equipped with a revenue-grade power/energy meter such as those offered by Trimark.[5]

## 5.2 Anemometers and Wind Vanes

Some distributed wind turbines employ nacelle-mounted anemometers and wind vanes to provide wind speed and direction inputs to the turbine controller, as shown in Figure 10. Turbines without on-board wind speed and direction sensors will require independent sensors for remote monitoring of ambient wind conditions. These sensors are typically installed on tower-mounted booms or occasionally on separate meteorological (met) towers. The ideal arrangement for estimating hub height wind speeds would be sensors installed on a met tower, following the requirements in the wind turbine power performance testing standard, IEC 61400-12-1. However, this level of accuracy is typically not required for the purposes of remote turbine monitoring but can provide guidance on mounting strategies that minimize the influence of obstacle wakes on the anemometer and wind vane. There are numerous suppliers of reliable wind sensors, including NRG systems,[6] R.M. Young,[7] and APRS World.[8]

## 5.3 Other Sensors

A variety of sensors are available for monitoring turbine-specific channels such as rotor speed, brake status, vibration, and temperature. The details of what is monitored and how it is monitored are specific to the turbine and are installed by the turbine OEM.

## 5.4 Accelerometer-Based Vibration Monitoring

Professor Patrick Lemieux, California Polytechnic University, is researching low-cost, vibration-based prognostic health monitoring systems using accelerometers for distributed wind turbine systems.[9]

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[4] https://store.egauge.net.

[5] https://trimarkassoc.com.

[6] http://www.nrgsystems.com.

[7] https://www.youngusa.com.

[8] http://www.aprsworld.com/

[9] https://www.me.calpoly.edu/faculty/plemieux.

## 5.5 Data Acquisition System (Datalogger, Modem)

All remotely monitored channels will feed into a data acquisition system that will sample and average the data and provide connectivity options, as discussed in Section 6.

**Figure 10. Nacelle-mounted anemometers and wind vanes provide input on inflow conditions to the turbine control system, such as on this NPS100 turbine.** ***Photo from Chris Connor, Northern Power Systems***

## 5.6 Calibration, Data Validation, Uncertainty

Sensors should be calibrated to ensure accuracy. When sensors are installed, end-to-end checks are necessary to validate the entire chain of connections from the sensor output to the data acquisition system input.

# 6 Communication Options

The reliability of remotely monitored data channels depends on the communication strategy employed at the turbine site. Several communication strategies are discussed in the following sections.

## 6.1 Bluetooth

Many distributed wind turbines include a local user interface that displays key turbine performance parameters such as power, energy, and status. A local Bluetooth-based application can be included, where these performance data are streamed to an application on the end user's smartphone device for basic on-site monitoring. As discussed in Section 2, this is a strategy most often found on microturbines, where remote monitoring is solely for the end user to monitor the performance and status of their turbine.

## 6.2 Local Area Network

A common strategy for accessing monitored data channels remotely is to connect to the end user's local area network (LAN) for connectivity via Wi-Fi or direct ethernet connection. For this strategy to provide a reliable data stream, the LAN connection must be robust. Direct ethernet connection would provide the most reliable connection. Wi-Fi-connected monitoring systems can be precarious: the local Wi-Fi signal can be weak at the turbine monitoring system because turbines can be installed far from the Wi-Fi source. Reliability can suffer, with outages in the end user's Wi-Fi system, or when Wi-Fi hardware is changed, or when passwords or network names are changed, thus requiring intervention to reestablish connectivity.

## 6.3 Cellular 4G/5G Network

When a local LAN connection is unavailable or unreliable, connectivity with the local 4G/5G cellular network can provide improved bandwidth and reliability. These connections require a cellular modem with a subscriber identity module (SIM) card and a monthly data plan with the cellular provider. Although this strategy is more costly than LAN-based connectivity, the improved reliability justifies the additional investment.

## 6.4 Satellite-Based Connectivity

For remote installation in which LAN and cellular connectivity is not an option, satellite-based connectivity can be a reliable option. As with cellular connectivity, a satellite-based system will require a modem and data plan with the provider.

## 6.5 Cybersecurity

Connectivity via cellular modems has become the trend as opposed to using the LAN, because of both reliability and cybersecurity concerns. Cybersecurity was a topic in the multilaboratory Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad project with cybersecurity efforts being led by the Idaho National Laboratory. Although cybersecurity remains an import issue, this guide does not attempt to address the details of this topic. Rather, we refer the readers to the publications from the Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad project.[10]

## 6.6 Cellphone or Email Alerts

Turbine OEMs and service providers should be actively monitoring their entire fleet of distributed wind turbines. To aid in responding to issues as they arise, the monitoring system should have the capability to alert the OEMs and service providers via cellphone text message alerts or email-based alerts.

## 6.7 Local Data Storage

Even if there is no live communications option, storing data locally remains useful for turbine troubleshooting and analysis of turbine performance and operations.

## 6.8 Grid-Interactive Inverter Communication Protocols

Distributed wind systems, if they use UL1741-SB certified inverters,[11] are required to have a capability to communicate, for utility control, using one of three standard protocols:

- IEEE Std 2030.5 (SEP2)
- IEEE Std 1815 (DNP3)
- Sunspec Modbus.

These systems (if the requirement is implemented) are required to respond whenever the turbine is operating and within 30 seconds of a request. In addition, California Rule 21 presently requires the implementation of a subset of the 2030.5 protocol (only) but may allow Sunspec in the future. These communication protocols could provide an opportunity for system monitoring by parties other than the electric utility; however, the utilities' communication to the inverter will have a strict layer of security, so a separate communication layer or path to the inverter may be needed for others to access the same data.

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[10] https://www.nrel.gov/wind/miracl.html.

[11] UL1741, Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources, ed. 3. Revised May 19, 2023.

# 7 Monitoring Demonstrations

The Distributed Wind Monitoring Working Group met on April 17, 2024. In this meeting, a sample of distributed wind OEMs (members of the working group) provided a demonstration of their current monitoring systems.

Eocycle America demonstrated the web-based SCADA system for their approximately 25-kW S-series wind turbine provided by their controller manufacturer, Mita-Teknik. Although the customer has access to a basic dashboard of performance parameters, the OEM and service providers/installers have access to the full suite of SCADA features, including the ability to stop/start and yaw the turbine as well as view detailed data such as turbine status. Their S-series turbines have nacelle-mounted anemometer, wind vane, and temperature sensors. A basic vibration trigger is part of the system for sensing large off-balance movements. Data are sampled and stored in 5-minute averages. Every morning, the system outputs a power curve to check turbine performance. Alarms are set for key parameters to alert the OEM/service provider of issues as they arise. Monthly energy production is checked against expected performance based on the wind speeds at the site for energy production comparisons. If needed, analysis can extend beyond power, energy, and wind speed and into other parameters, such as temperatures, for troubleshooting purposes. Eocycle is considering adding temperature sensors for the bearings. Availability is calculated in their monitoring system of a few major subsystems.

Ryse Energy demonstrated the web-based monitoring system for their G11 series (legacy Gaia turbine) called WindSync provided by Visualwind, a company based in the United Kingdom. End users pay a subscription fee, which enables access to the monitoring service. Ryse checks the fleet every morning and afternoon. The G11 turbine has a nacelle-mounted anemometer, which does have some rotor blockage. As with Eocycle, actual power curves are compared to tested power curves to assess performance. Some customers are connected via Wi-Fi, but Ryse has transitioned to installing SIM cards in every controller for cellular-based connectivity. Ryse is now building their own controller and has developed their own in-house monitoring system with similar features to WindSync. As with Eocycle, Ryse Energy's SCADA-based system enables remote curtailment and control (e.g., park) of their turbines if needed. Data are sampled at 10-second intervals and stored as 10-minute averages. Turbine status is now displayed as text (e.g., Waiting Wind, Generating, Parked, Brake On, Brake Off) instead of fault codes, which needed a translation.

Northern Power Systems demonstrated their SmartView SCADA system for their 100-kW, NPS 100 fleet. The NPS system was developed in-house and is based on utility-scale turbine monitoring but with fewer channels. Connectivity options include the LAN, cellular modem, and satellite. For improved reliability and cybersecurity, NPS has also transitioned to mostly cellular-based connectivity. Several hundred data channels are sampled at 1 Hz and stored as 1-minute and 10-minute averages. The 10-minute averages are pushed to a cloud-based repository for long-term storage. If the turbine faults, the OEM, field service team, and customer receive an email. The customer can access the turbine dashboard, showing a snapshot of turbine status and download historical data, as shown in Figure 11. Automated reports show actual power curves compared to tested curves.

1 min. Wind Speed 8.0 m/s
10 min. Wind Speed 7.7 m/s
Total Energy Produced 23905 kWh
Time Available 2660 Hr
Yaw Position -161.9 deg
Yaw Turns -0.4
Rotor Speed 43.7 RPM

**Wind Turbine Controls**
Enabled
Dispatch Enabled
Base Switch Run
Nacelle Run
Yaw OK

**Wind Turbine Status**
Turbine State: Running
Inverter State: Active
Warnings: No Warnings
Faults: No Faults

**Operating Conditions**
Wind Speed OK
Temperature OK
External Conditions OK
Grid OK

Ambient Temp 23 °C

Copyright (c) Northern Power Systems Srl

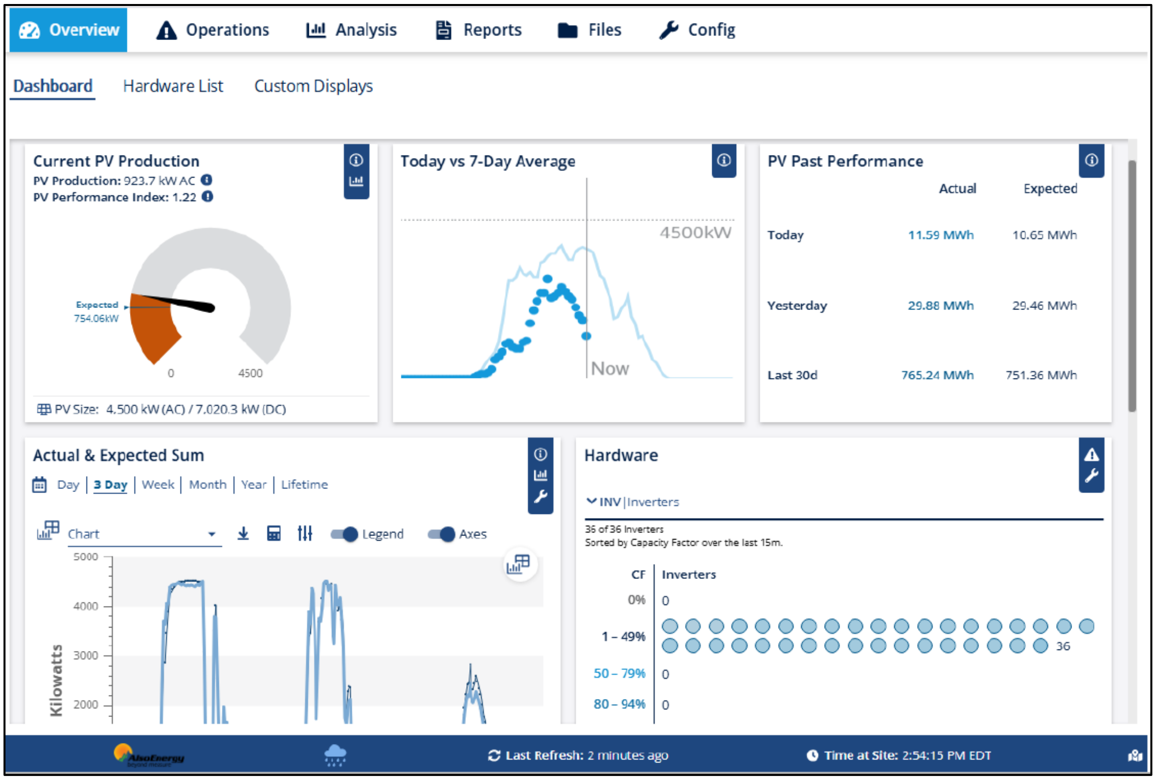
SmartView HMI 3.3.6 2024-04-17 14:30:22.11 Data OK

**Figure 11. NPS SmartView showing a snapshot of wind turbine status.** ***Image from Northern Power Systems***

Intergrid demonstrated their current work to develop a new monitoring system for the Bergey Excel 15 and other turbines using their 25-kW Intergrid inverter. As NPS reported, Intergrid is currently using an embedded personal computer, or low-cost next unit of computing, to run their monitoring software, which was developed in-house. The web-based platform shows a live array of parameters such as power, energy, voltages, currents, RPM, temperatures, and status codes. Daily power curves are saved for performance monitoring. As with the other OEMs, a fleetwide summary page shows a summary of the fleet with the ability to access the detailed data of individual turbines. Intergrid is experimenting with using local wind data as opposed to installing on-site anemometry, satellite connectivity, and LoRa (long range) radio communications.

To learn lessons from the solar PV monitoring industry, Carolina Solar Services, a PV plant operations and maintenance provider, demonstrated their monitoring systems. The PowerTrack platform from AlsoEnergy, shown in Figure 12, has a performance dashboard, on-site web-camera interfaces, the ability to remotely control trackers, and recloser controls. If the client is paying a sufficient subscription fee, raw data from numerous channels can be stored, which allows for detailed data analysis as needed.

Overall, these demonstrations highlight successes in monitoring strategies, an evolution of monitoring over time following lessons learned, and opportunities for improvement. Successes include reliable connectivity, early detection of problems, the ability to resolve issues remotely, and providing end users clear turbine performance data. Lessons include providing too much data and turbine control to end users and thus adjusting end user monitoring accordingly. Opportunities include working to lower the cost of monitoring systems and handling and interpreting large amounts of data streaming in from the fleet.



PV Production: 923.7 kW AC

PV Performance Index: 1.22

Expected 754.06kW

PV Size: 4,500 kW (AC) / 7,020.3 kW (DC)

PV Past Performance

| | Actual | Expected |
|---|---|---|
| Today | 11.59 MWh | 10.65 MWh |
| Yesterday | 29.88 MWh | 29.46 MWh |
| Last 30d | 765.24 MWh | 751.36 MWh |

36 of 36 Inverters

Sorted by Capacity Factor over the last 15m.

| CF | Inverters |
|---|---|
| 0% | 0 |
| 1 – 49% | 36 |
| 50 – 79% | 0 |
| 80 – 94% | 0 |

Last Refresh: 2 minutes ago

Time at Site: 2:54:15 PM EDT

Figure 12. Site summary for a Carolina Solar Services PV monitoring platform. *Image from Jason Endries, Carolina Solar Services*

# 8 Data Access

## 8.1 Data Repository

Monitoring data are stored on either a local server or a memory device or are transmitted to a cloud-based server. For locally stored or cloud-stored data, access is achieved through local software or dedicated application, or a connection is made to a web-based monitoring platform in which a dashboard is created for viewing and downloading the monitored data channels.

According to the U.S. Department of Energy's Atmosphere to Electrons site, a wind data hub has been established to provide "secure, timely, easy, and open access to all laboratory, field, and benchmark model data and offshore data produced by projects funded by WETO [U.S. Department of Energy's Wind Energy Technologies Office]." This data hub could prove to be an asset for monitoring of the fleet of distributed wind turbines.

Another idea brought forth by the distributed wind monitoring working group was to use a citizen-science network for providing access to remotely monitored turbine data. For example, Weather Underground[12] allows users to add their weather stations to their sensor network with public access.

## 8.2 Controlled Access

As shown in the monitoring demonstrations in Section 7, access to certain data channels and wind turbine controls is granted to various users, including the following:

- End user—access to basic monitoring of turbine performance (power, energy), can require a paid subscription
- Public—openly accessible basic monitoring of turbine performance (power, energy)
- OEM—full access to data and turbine control
- Service technicians—full access to data and turbine control
- Research labs—access to performance data (power, energy, wind speed, wind direction, downtime) and more for specific research purposes
- Universities/schools—access to performance data (power, energy, wind speed, wind direction, downtime) and more for specific research purposes.

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[12] https://www.wunderground.com.

# 9 Conclusion

Discussions with the distributed wind industry and the distributed wind monitoring working group have confirmed that reliable, accessible monitoring of the U.S. fleet of distributed wind turbines is an important, if not critical, endeavor. End users want to know what their wind turbine investment is doing and how it is performing. Research laboratories and universities value performance data, and other metrics, to understand fleet performance, turbine issues, factors that influence cost of energy, and other research topics. OEMs and service providers benefit greatly from a stream of data informing them on the health and condition of their fleet, receive alarms as issues arise, gather technical information remotely before needing to travel to distributed array of installations, and maintain a reliable fleet of well-performing distributed wind turbines. Even the most sophisticated monitoring system can be unreliable if a precarious connectivity option is incorporated. Currently, we see a trend of using the wireless network for connectivity when the LAN, especially local Wi-Fi, proves to be troublesome and to provide improved cybersecurity and bandwidth. As a research laboratory, we greatly appreciate the cooperation of distributed wind turbine manufacturers who have provided access to their fleetwide performance data, supporting our mission to help the U.S. distributed wind industry remain strong and competitive. We hope this guide will prove useful to the U.S. distributed wind industry and help move the industry toward a more standardized, accessible stream of monitoring data.

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# Appendix. Participants in Distributed Wind Energy Association's 2022 Industry Polling About Monitoring

The following is a list of participants in the Distributed Wind Energy Association's 2022 annual conference:

- Alex DeBroe
- Alice Orrell
- Brent Houchens
- Ben Anderson
- Benjamin Woodall
- Bethel Tarekegne
- Brent Summerville
- Bret Barker
- Chris Connor
- Dan Clunies
- Drew Gertz
- Ed Paparelli
- Enrico Menegetti
- Erika Boeing
- Fathalla Eldali
- Frits Ogg
- Heather Rhoads-Weaver
- Ian Baring-Gould
- Ian Brownstein
- Indrek Gregor
- James Truslow
- James Duffy
- John Mogensen
- Jonathan Miles
- Joseph Spossey
- Josh Groleau
- Kamila Kazimierczuk
- Ken Kotalik
- Ken Visser
- Kevin Wolf
- Liam Griggs
- Lindsay Sheridan
- Lisa Daniels
- Lucille Olszewski
- Michael Leitman
- Mike Bergey
- Paddy Jones

- Padma Kasthurirangan
- Patrick Gilman
- Paul Rowan
- Peter (Ryan)
- Richard Legault
- Robert Preus
- Robert Wills
- Ryan Storke
- Shawn Martin
- Steve Sherr
- Tonny Brink
- Vasu Primlani
- Will Hersey.