

# INNOVATION

Research & Development • Design & Engineering • Forecasting & Analysis  
• Consultancy • Certification & Standards • Efficiency • Emerging Technologies

## FULL-FIELD WIND MEASUREMENTS CAN MAKE WIND POWER MORE COMPETITIVE

*The historically difficult task of measuring a turbine's efficiency (due to a lack of wind field data) could be made easier by new technology*

By Dr. Fabio Bertolotti,  
SSB Wind Systems

At present, the efficiency of a wind turbine cannot be accurately measured because of inadequate data on the wind field across the swept area of the rotors. This poor correlation between energy generation and wind conditions conceals the true state of turbines and affects the accuracy of the 24 hours forecast of power output.

### INADEQUATE PERFORMANCE EVALUATION

Turbine performance is usually evaluated using power curves that express electricity generation as a function of wind speed.

The power curve is based on data from the nacelle-mounted anemometer and on the 15-second average power output. However, using the 15-second averaged figure means that the change in actual output cannot be clearly assigned to the measured wind speed (Figure 1). This ambiguity (output in relation to wind speed) can mainly be attributed to the inaccurate and incomplete nature of wind measurements being taken by the anemometer (which fails to take account of shear winds, wind direction, and changes in wind direction). This makes it impossible to determine the actual efficiency of the turbine. This disparity means that, even now, production losses of up to 10 percent cannot be identified with any degree of certainty.

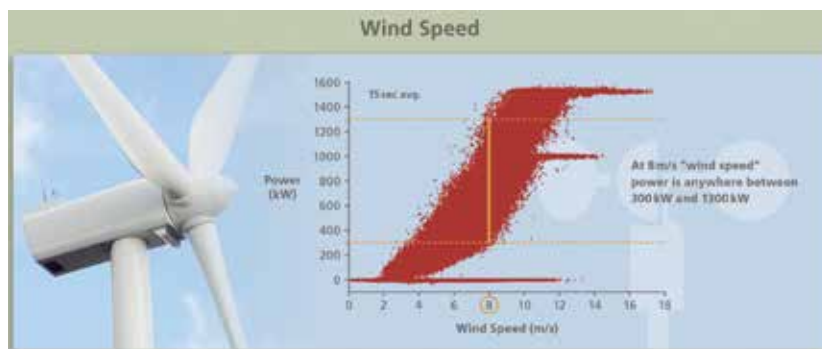


Figure 1: The data show that at an assumed wind speed of 8 m/s, a wind turbine generates somewhere between 300 kW and 1.3 MW of power. Averaging the data over a longer period is not the solution, for while the 10-minute average obviously reduces the variance this is still not adequate for more exact forecasting.

The reasons for the loss in efficiency therefore remain undetected, which in turn reduces the competitiveness of the turbine owner/operator.

### INDETERMINATE ENERGY YIELD

Energy yield presents another problem. There are many different reasons why losses occur when wind is converted into energy—one of these being a lack of precision when determining the actual wind direction.

Wind direction is established using a wind vane mounted on the nacelle. But the wind vane—like the anemometer—has a number of shortcomings. One aspect is that first, it is located behind the rotor blades in a turbulent airstream and therefore has to take measurements over a long period of time if it is to supply meaningful data. Moreover,

it only measures at one point in the flow field of the swept area, and consequently cannot record all the important data. The wind vane is also affected by the flow conditions prevailing at the nacelle itself and this in turn creates additional measurement errors (Figure 2).

### INADEQUATE TURBINE-OUTPUT FORECASTS

The use of 24-hour wind power forecasting is becoming increasingly popular as more and more wind power is traded on electricity markets.

The forecast consists of a weather report for the turbine site and a calculation of the power output under the forecasted conditions. The forecast for the following day is based on numerical simulations projected

# HEADLINES

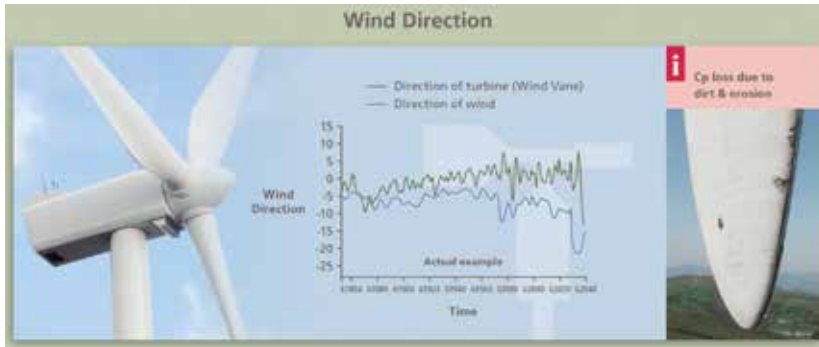


Figure 2: As the comparison between the signal from a turbine wind vane and that of a hub-mounted LIDAR shows, the wind vane does not always deliver accurate readings. These variances are not immediately recognisable because only the anemometer reading is available and the corresponding energy loss remains undetected.

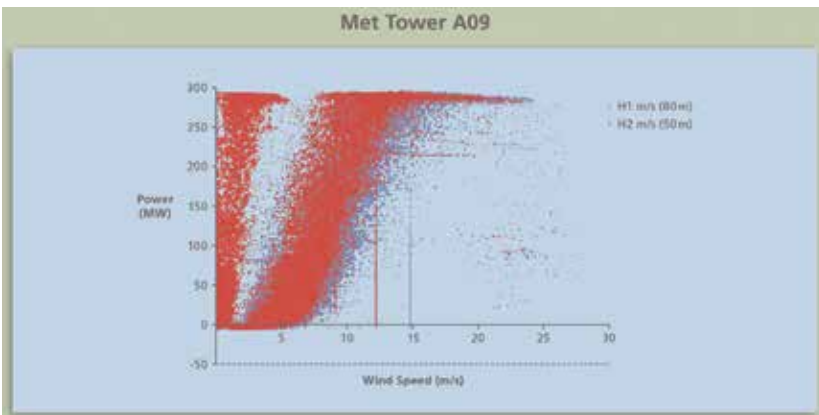


Figure 3: Wind farm yield in relation to the wind speed measured at a single point (weather station A09). Reproduced with the permission of NREL report NREL/CP-550-48146, June 2010

on to a grid, which nodal points are some three to eight kilometers apart. Seventy percent of all forecasting errors are connected with this process and relate to the difficulties that arise when trying to accurately predict weather front movements.

The remaining 30 percent of errors are caused by “downscaling,” the process whereby the predicted wind direction at the nodal points is assigned to the actual site of the turbine. To illustrate this, we have taken an NREL forecast (NREL/CP-550-48146) (Figure 3) that compares the yield from a wind farm with the actual air flow measured by a weather station set up in the park.

As the figure shows, the relationship between energy and wind speed

at the weather station presents a very fuzzy and ambiguous picture. In fact, when the wind speed is 10 m/s the power output varies between 100 MW and 300 MW. With more precise mapping (creating a link or correlation between the wind-field data at the respective nodal points and the corresponding wind turbine), not only in terms of wind speed but also for shear, turbulence, and changes in wind direction, the error rate associated with downscaling could be reduced.

## FULL-FIELD WIND MEASUREMENTS BASED ON BLADE DEFLECTION

The aforementioned problems could be tackled by taking full-field measurements with a wind sensor. The

## ACCIONA debuts medium-wind site turbine in Las Vegas

ACCIONA Windpower has upgraded its AW125/3000 wind turbine, with a new version specially designed for medium-wind sites (IEC IIb). This new design was highlighted at the WINDPOWER 2014. The upgraded design of the AW125/3000 allows for siting at locations with higher average wind conditions and lower turbulence intensity.

The AW125/3000 combines a 125-meter rotor with a three megawatt wind turbine generator and is available on multiple tower heights ranging from 87.5 meters to 140 meters. With the 87.5m tower, the AW125/3000 IEC IIb wind turbine—which has 61.2-meter blades—is uniquely positioned to deliver maximum Annual Energy Production while staying within a 150-meter tip-height threshold in sites with aviation permitting constraints.

The first Design Assessment for the AW125/3000 IEC IIb is expected by the end of 2014 and deliveries are available in early 2015.

## GE's Wind PowerUp reaches 1,000 installations

GE recently announced that its Wind PowerUp platform has secured more than 1,000 units under contract to date. PowerUp is a customized software-enabled platform that allows wind farm operators to increase annual energy production (AEP) on their turbines by up to 5 percent, taking into account environmental conditions. A 5 percent increase in energy output translates to up to a 20 percent increase in profit per turbine.

“The industry’s response to Wind PowerUp has been exciting to see over the past seven months,” said Anne McEntee, president and CEO of GE’s renewable energy business. “We have been working with our customers to develop customized solutions ideal for their fleet and working with them in new ways that helps them win.”

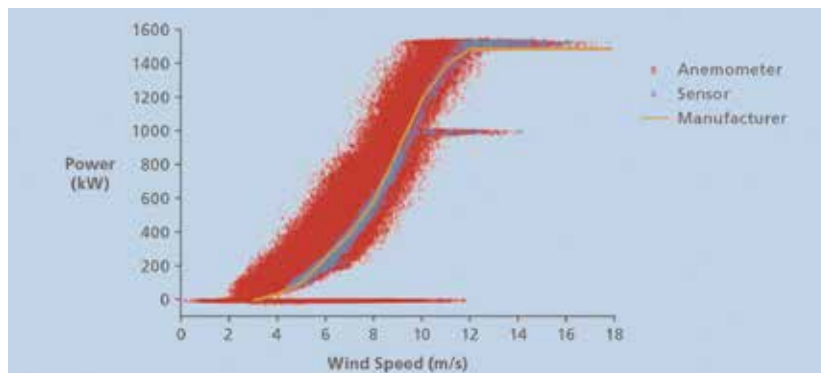
PowerUp adjust performance dials, including speed, torque, pitch, aerodynamics, and turbine controls with the goal of maximizing the power output of a wind farm.

underlying technology combines measurements of blade deformation with a highly advanced signal analysis and processing unit. Blade deformation is recorded by a digital camera, which tracks the displacement of reflectors embedded deep inside the rotor blades. As the “raw camera signals” are not very meaningful on their own, they are then relayed to a computer in the nacelle for real-time analysis and processing.

A one-year field trial compared flow speed, wind direction, shear wind components, changes in wind direction, and turbulence levels with the values recorded by a continuous-wave LIDAR system installed on the rotor hub. The LIDAR is equipped with a rotating prism that can pivot the laser beam so as to provide a comprehensive description of the prevailing wind field. The field trial found an excellent match between the blade-based wind sensor and the LIDAR. This consistency was based on 15-second mean data, whereby errors and discrepancies could be identified much more easily than with the 10-minute data. Moreover, during the test the wind vane was rotated manually through a precisely measured angle, whereupon the wind sensor was able to detect this deviation within 30 minutes to an accuracy of 0.3 degrees.

### MORE PRECISE POWER CURVES

The blade-sensor’s ability to provide a complete and instantaneous measurement of the wind field means that much more precise power curves can be obtained. By gaining immediate access to information about the complete wind-field conditions, it becomes possible to calculate the wind speed but also wind shear, turbulence levels, and wind shift at the moment of power generation. The measured power output can thus be broken down



**Figure 4:** Power curve (blue) for a precisely calculated wind field. The horizontal line at 1000 kW is due to night-time power restrictions. (All data are based on a 15-second average).

into “bins” (categories) according to wind shear, turbulence, and wind shift, which allows power curves to be generated for each categorized wind-field condition (Figure 4).

### DETERMINING ACTUAL EFFICIENCY

Having an accurate and clearly defined power curve, along with information about all prevailing wind-field conditions (bins), allows us to determine the actual efficiency of the turbine. Let us assume that the output of the turbine is below its specified rating. Is this because the installation itself is less efficient than it should be? To answer this question we need to look at the wind-field category (bin) that corresponds to the manufacturer’s power curve. If there is no divergence between the two then the turbine is operating at full efficiency. In such a case the reason has to be sought in the wind field, or more precisely in the bin in which the turbine is being operated most of the time. If there is a divergence here, the data from the wind sensor can be used to carry out a targeted root cause analysis.

### MORE ACCURATE MAPPING THROUGH “EXPERIENCE”

As stated above, errors in down-scaling can be greatly reduced if accurate information is available on the prevailing wind field. The data can be used to achieve much more

precise mapping between the values at the computational grid points and each individual turbine. This mapping would then build on the bin values used in the power curve and in practice continuously improve through “experience” (learning from errors between predicted and actual output).

### CONCLUSIONS AND OUTLOOK

Being able to make better assessments of turbine output is a top priority for turbine owners and operators. Wind speed, wind direction, wind shear, and turbulence in the wind field can now be measured with real accuracy and this makes for more exact power curves, increased energy production, better 24-hour forecasts, and more accurate blade condition monitoring. This new technology is both cost-effective and extremely reliable. Moreover, it can be used on every turbine and consequently offers significant potential for improving the competitiveness of the wind power industry. ✈

+49 5976 946 0

[www.emersonindustrial.com/en-us/ssbwindsystems](http://www.emersonindustrial.com/en-us/ssbwindsystems)

[/EmersonIndustrialAutomation](https://www.facebook.com/EmersonIndustrialAutomation)

## GE DEMONSTRATES BLADE EXTENSION TECHNOLOGY AT WINDPOWER 2014

### *Addition of seven-meter sections to turbine blades resulted in 20 percent output boost in prototypes*

At WINDPOWER 2014 in Las Vegas, GE demonstrated its new blade extension technology which takes GE wind turbines from a 77-meter rotor to a 91-meter rotor by adding a seven-meter extension to the turbine's blades. The extension increases the swept area of the rotor by 40 percent and increases the energy production by more than 20 percent.

The technology was implemented in two prototypes that have now been in operation for 10 months. The prototypes were completed with Noble Environmental Power at Noble's Clinton Wind Park in Clinton, New York.

The technology upgrades GE 1.5-77 turbines to GE 1.5-91 turbines utilizing the entire existing blade asset. The

program was developed by GE to help customers achieve significant increase in power output on their existing fleet while maintaining existing product life and acoustics. Throughout the development of the extensions, the GE team filed more than 16 patent applications and developed custom tooling for the extension installation.

"The blade extension program for GE is a great example of the magnitude of technology advancements GE is capable of developing," said Mark Johnson, engineering leader for GE's renewable energy business. "At GE, we take big swings to help our customers reach their goals and operate more successfully. Achieving production gains of more than 20 percent for

existing units is a challenging task, and with GE's expertise in engineering aerodynamics, material science, structural engineering and controls, we continue to be able to help our customers operate more profitably and efficiently."

Advanced technologies developed to make the project a reality include the unique, centrally located insert, improved methodologies and advanced controls for loads mitigation. The extended blades have undergone testing beyond IEC requirements, including static strength tests that are standard for all GE-engineered blades and fatigue tests totaling more than 6 million cycles. The model and process utilize the existing design margins of the 1.5-77 turbine in lower wind speed applications. In addition to the extended blades, modifications were made to controls and parts to adjust for the added loads on the turbine.

Videos be found at [www.youtube.com/user/GErenewables](http://www.youtube.com/user/GErenewables).

# TWR Lighting, Inc.

Enlightened Technology®

## ALL IN ONE SOLUTION

Preferred & Specified By Most OEMs and Developers  
Orga's new generation of LED FAA obstruction lights for the wind industry

Global leader with over 35,000 systems installed onshore & offshore worldwide

FAA/U.S. Fish and Wildlife Avian Protection Compliant

Radar System(VWS) Interface Compatible with all manufacturers

5 year complete system warranty

# Solution

Met tower lighting system for 60-100 meter tower complete with solar system

Integrated Photocell/GPS/Flasher/Monitoring

orga Aviation

Office 713 973 6905 | [sales@twrlighting.com](mailto:sales@twrlighting.com) | [www.twrlighting.com](http://www.twrlighting.com)

Scan to learn more





## VESTAS INSTALLS NEXT GENERATION LOW-WIND PROTOTYPE

Vestas has installed the first V110-2.0 MW prototype turbine at a test site in Høvsøre, Denmark. The turbine has produced its first kilowatt hour of electricity and will undergo an extensive test and verification program to ensure reliability before full-scale production commences. Initial availability of the V110-2.0 MW is expected by year's end.

The V110-2.0 MW is built on the proven technology of Vestas' 2 MW platform and features a larger rotor using 55-meter blades. The turbine is optimized for production on low-wind sites, and increases annual energy production by up to 13.6 percent when compared to the V100-1.8 MW on low wind sites.

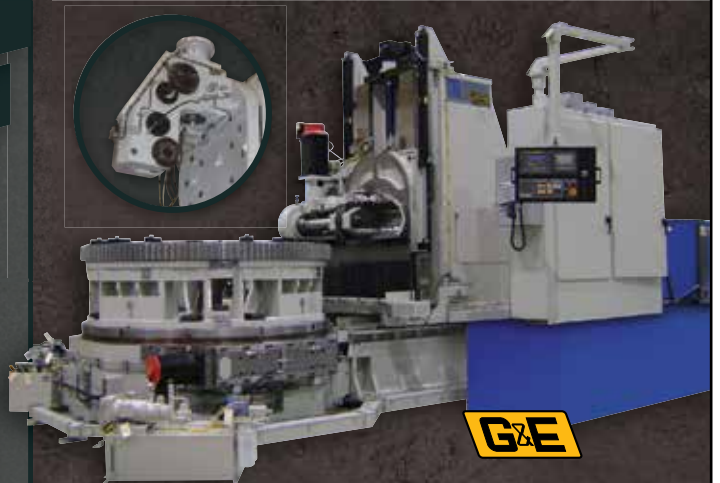
"Vestas' product development strategy is to optimize our products and services to continue to lower the cost of energy for customers," said CTO Anders Vedel. "The V110-2.0 MW is an extremely competitive product for maximizing energy production at low wind speeds, and over 400 turbines sold demonstrate customers are responding positively to Vestas' strategy."

In addition to the larger rotor, the V110-2.0 MW has a strengthened gearbox when compared to previous 2 MW turbines, to withstand the increased force from the wind on the larger rotor. Furthermore, new control features have enabled strengthening of the hub and other parts of the structure without increasing the overall weight.

## Your #1 Source for Gear Machinery

Gould & Eberhardt is a pioneer in high-speed gear gashing with large diameter carbide-inserted cutters. Our new line of machines has a rigid design and heads engineered with state of the art gear gashing cutter technology. Gear gashing technology has opened many gear cutting applications in wind energy, mining, off-highway construction and other coarse pitch gearing.

Our gasher/hobbers are equipped with the new G&E interchangeable cutter head design. This design provides the option for both internal and external heads on a single column machine with capacities up to 5.5 meters.



704.872.8888

**RP MACHINE**  
ENTERPRISES, INC.

860 Connor St • Statesville, NC 28677  
F: 704.872.5777 • [www.rpmachine.com](http://www.rpmachine.com)  
[sales@rpmachine.com](mailto:sales@rpmachine.com)