How Turbine Control Sensors Can Improve Turbine Performance

With the focus on optimizing turbine performance, operators are constantly seeking ways to deliver more power more reliably.

BY LAURA GOODFELLOW

For wind farm operators, maximizing return on their existing assets is the name of the game. Whether they are managing new wind farms with state-of-the-art machines or older plants with machines coming off warranty, operators are constantly seeking ways to deliver more power more reliably.

At the same time, turbine manufacturers are improving the efficiency and durability of their machines by finding ways to produce power at lower wind speeds and in complex environments, which is particularly important because many of the prime wind sites in the U.S. have been built out. Utilities, developers, manufacturers and operators are all demanding the same thing: lower cost and higher-performing machines.

While optimizing turbine performance has always been a priority, today's market conditions in the U.S. make it a necessity. The American Wind Energy Association reported that over $40 billion in assets are coming off of warranty this year. At the same time, new installed capacity of wind dropped from 10 GW in 2009 to 5.1 GW in 2010 and is expected to remain flat. For turbine manufacturers, this means fewer sales of new turbines in the U.S. On the other hand, there is an opportunity to provide customers with new products and services that maximize the performance of existing assets.

All mid- to large-scale turbines have turbine control sensors and would fail to operate without them. The control sensors sit atop the nacelle, behind the blades, and send signals that communicate wind speed and direction to the controller. As the blades pass by the hub, they disturb the flow of air and create high levels of turbulence. All sensors are designed to operate in this harsh environment.

The data from the sensors is used to regulate yaw, cut-in, cut-out and blade pitch. When there is no signal or if there is a problem with the signal, a fault condition in the controller is triggered. The operator can then check the sensor and controller to evaluate the situation and may use other operational metrics, such as rotor speed, turbine output and meteorological data, to identify the root cause.

In some cases, the turbine will automatically respond to the discrepancy and clear the fault condition. In other cases, a field technician may be needed to fix the problem. Turbine control sensors are also used in power performance verification to ensure actual power output is aligned with expected output. By knowing the wind speed and direction atop the nacelle, operators are able to check this data against past turbine performance and troubleshoot possible failures.

There are two main types of technology on the market today: mechanical sensors with rotating parts, such as anemometers and wind vanes, and ultrasonic sensors that measure wind speed and direction using ultrasonic acoustic waves. There are also heated versions of both technologies, which are used to ensure operation during icing events. Both ultrasonic and mechanical sensors play a role in the industry.

Ultrasonics provide real-time data and are not vulnerable to inertia, which occurs during the short lag time it takes a mechanical sensor to start and stop moving. As a result, they are able to recognize quick gusts or changes in the wind. It is important to note, however, that real-time recognition does not necessarily lead to rapid response of the turbine. Depending upon the sensor's output signal configuration and the turbine's controller, there may be a lag between wind changes and turbine response. Another benefit of ultrasonics is their low thresholds, meaning they are able to send signals to their controllers in very low wind speeds. This is helpful for operators who are trying to eke more power from their machines at low wind speeds.

Which technology is more accurate? That depends upon the definition.

The downsides of ultrasonics are poor performance in rain and snow (the acoustic waves can bounce off water droplets), vulnerability to insects or birds that may nest in them, and, with certain models, fragility of the sensors during installation and transport.

Mechanical sensors have been in use for many years and are considered to be a familiar technology. They work well in rain and are available fully heated or with heated bearings. The design of the sensor is generally more rugged, allowing for easier installation and handling. They are also priced lower than ultrasonics.

On the other hand, mechanical sensors have higher thresholds than ultrasonics and are less effective at very low wind speeds, such as below 2 meters per second. They are also subject to inertia and, therefore, recognize changes in wind speed or direction more slowly than ultrasonics.

Understanding and improving accuracy

Which technology is more accurate? It depends on the technical definition of accuracy and what error measurements are rolled into that definition. Looking at manufacturers' stated specifications is a start, but comparing accuracy measures can be like comparing apples and oranges because of differences in the underlying technology.

All sensor types and technologies have their weaknesses, and all are susceptible to different forms of error. For example, the bearings in mechanical sensors can wear or become damaged, changing the response of the sensors. Ultrasonics are more susceptible to environmental error because of rain and ice buildup. In short, there is no universal definition of accuracy. When comparing technologies, it is most important to understand what underlies manufacturers' accuracy statements and dig a little deeper if the information is not immediately apparent.

Anemometer accuracy, including inertia and bearing friction, can affect the threshold level in addition to cut-out and blade pitch. Vane accuracy and alignment, on the other hand, affects yaw and, ultimately, how much power is captured from the wind. If the vane operates a few degrees off center or shows a consistent bias, the nacelle could be pointed off center, leading to lower power output and excessive wear.

Proper alignment ensures that the zero point for all vanes is perfectly lined up with the front of the nacelle and faced directly into the wind. With most turbine models today, this alignment is achieved during production. Some turbine manufacturers mount sensors on posts in the factory and then affix these posts to the top of the nacelle during construction using pre-measured configurations.

Other manufacturers align vanes during construction with lasers, strings or other methods. After establishing proper alignment, operators must also maintain alignment throughout the life of the turbine. When vanes are calibrated to have the same zero point, technicians can easily change out damaged sensors. When this is not the case, the use of lasers and other more expensive techniques is necessary. Regardless of the method used, proper alignment is critical to ensuring optimal performance of the turbine.

Vane accuracy, defined as how well the vane tracks with the wind, is based on several factors, including the performance of the bearings, physical design of the sensor mounting configuration, interaction between the sensor and the controller, and ice-free performance.

Improving vane accuracy is a complex task with many opportunities for fine-tuning. For example, reducing friction and inertia can be achieved by better protecting bearings from dirt and dust, while mechanical design changes can improve the response to off-axis winds and performance in icing conditions.

Control sensors evolving

Given these market trends and technological improvements, where is the industry headed? Will it begin to favor one technology over another? Likely not.

The redundancy of sensors and pairing of ultrasonics with mechanicals is a trend that is likely to continue. It ensures reliable operation of the turbine in case one set fails and allows the operator to take advantage of each technology's unique benefits. Given the importance of maximizing the performance of wind turbines, redundant sensors mounted on the nacelle are critical to minimizing sensor fault conditions.

In the coming years, there may be a growing role for remote sensing in both turbine control and power performance verification. For example, using turbine-mounted light detection and ranging, an operator could see changes in the wind one quarter-mile out and make the necessary adjustments, such as pitching the blades on the turbine, earlier.

The possibility of seeing wind events that have not yet occurred presents a new frontier for maximizing power output and extending turbine life. The impact at the individual turbine or wind farm scale could be profound, as could the impact on the industry overall.

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