Hot on the trail

Ice detection systems for the rotor blades of wind turbines are gaining traction. They are designed to prevent equipment running with thick sheets of ice and unbalanced blades or endangering people and the environment with flying chunks of ice.

Winter arrives every year. The wind industry does well to heed this truism. When rotors are at risk of icing up, turbines have to be shut down until a sensor gives the green light for an ice-free turbine restart. Requirements for prevention of flying ice are in place in Austria, Germany, Switzerland and Scandinavia. Usually, the underlying reason is the turbine’s proximity to residential areas, roads or railway lines. Such regulations aim to protect both people from falling chunks of ice, as well as protecting the wind turbines themselves, which without ice detection would simply continue running dangerously off kilter.

This has driven growth in the market for such solutions. To avoid long downtimes, the art is detecting the actual degree of icing and the ice-free state of the blades as reliably as possible using sensors on the one hand, and on the other hand, the layers of ice have to be melted quickly with heating systems laminated into the blades. This is especially important for operators in areas with strong icing, because otherwise the machines are encased for weeks or months at a time in a thick layer of ice and provide no income. Picturesque though this may be, such idyllic winter scenes lead to liquidity problems. In a perfect world, operators would have reliable sensors on the rotor blades and heaters that melt ice while the turbines are in operation.

Tinkerers are hot on the case

The developer scene is closing in on this perfect state. A number of suppliers want to take advantage of the obligation for ice detection and use sensors for the complete monitoring of the structural health of rotor blades. Like CMS for the drivetrain, these sensors can detect even nascent damage and ice on rotor blades in a single stroke. “The next step is blade monitoring. Sensors measure shifts in the resonance frequencies of the rotors. The expertise is clearly in the evaluation of the signals, which makes it possible to detect ice build-up reliably and also to avoid inspection costs from recurring checks. Such systems are gaining in importance because the benefits outweigh the
Wind resources in cold climate areas are typically good and combining these resources with typically low population densities makes cold climate areas attractive for wind development.

Photo: dpa

costs,” says Karl Steingröver of the Industrial Services department at Germanischer Lloyd.

The testing institute has so far certified the suitability of the ice detection systems from four providers. These include Bosch Rexroth monitoring systems and recently also Eologix from Austria, as well as fos4x and Wölfel Consulting Engineers from Germany. Wölfel’s IDD Blade has a sensor that responds to changes in the natural frequency of the blades and can detect additional masses of as little as 10 to 20 kg per blade. The system is first trained on the turbine to determine the reference values for each blade. These values are functions of stiffness, mass and the tolerances of the blades to one another. Once a change is detected, the system warns the operations manager by switching on a light or automatically shutting down the turbine based on parameters pre-set in the controller. The equipment is designed to perform at wind speeds as low as 2 m/s. “We can even perform measurements during shutdowns or in trundle mode because, even then, wind excitation is sufficient. In addition, the IDD is capable of detecting cracks of cm and larger, as changes in the structure affect the rigidity of the blade and thus the frequencies,” says Bernd Wölfel of project management. Afterward, the system also logs the ice-free state of the blades and gets the go-ahead for an automatic restart of the turbine. The supplier has an exclusive contract with Nordex until the end of 2015, but then it is free to enter the competitive market.

Along the same lines is the system made by fos4x, which at wind speeds of 3 m/s can detect whether or not ice has formed on the blades. Two
fibre optic sensors for measuring the acceleration and expansion in each blade form the basis for fos4Blade BID ice detection system. They require no electrical energy because the signals are transmitted via fibre optic cable and glass fibres. This fibre optic sensor technology is the core business of the company, which was founded in 2010. Because the measuring technique is always the same, ice detection will be increased. “We want to log blade loads and developing damage and enable real-time adjustment of the individual blades,” says Stefan Eichhorn of fos4X. With those aims in mind, tests are already underway with several manufacturers.

The benefit for operators is partly the fact that such systems offer a CMS for rotor blades. On the other hand, they can also use it to meet regulatory requirements and avoid prolonged shutdowns. The cost should eventually pay for itself, especially in areas with frequent icing. To enable automatic restart, the sensor has to detect with the utmost certainty that the blades have been cleared of ice. “The information is transmitted to the controller via interfaces,” says John Reimers from Bosch Rexroth. The company has already sold BLADEcontrol-1000 systems and supplies companies like Vestas. However, operators complain that the systems do not always work smoothly and that turbines sometimes shut down due to ice accumulation, even in above-zero temperatures. “If the systems are not reliable or ice warnings are ignored by the controller, then it is not at the interfaces, but the manufacturers,” says Reimers.

**Combined ice detection and blade heating**

The Finnish manufacturer Labkotec also has expertise in this segment. It supplies all of the leading manufacturers with a sensor that is suitable for temperatures up to -40°C. The system is based on ultrasound and a probe wire. If ice forms on the wire, the ultrasonic signal is reduced, and the sensor sends a signal to the controller. The sensor is mounted on the nacelle near the rotor and against the wind. “Manufacturers often combine our technology with other systems. In 2016, we will also bring a second sensor to the market capable of directly detecting ice accumulation on the rotor blades,” says Pasi Hautamäki of Labkotec.

And this is precisely the solution operators require. After all, it is possible for ice to form on the tip of a 60 m long blade, and that the sensor on the nacelle still reports the blade free of ice. Furthermore, the question arises of which solutions manufacturers ultimately provide to their customers. For instance, ice detection at Vestas, Enercon and Senvion is performed via power curve analysis. Although this method works reliably by showing a drop in yield, it does not work when a system is idle. “In addition, the authorities decide in the end which technology is used and they demand a second ice detection system to supplement power curve measurements,” says Hautamäki.

This is exactly the approach Enercon takes by combining the power curve method with the nacelle-mounted system from Labkotec. For blade de-icing, Enercon uses a convection method which blows warm air all the way to the tip of the blade using a fan installed at the blade root. At low-risk sites the system is capable of automatic activation of the blade de-icing system during operation. Thin layers of ice are thus melted off at an early stage. If, in extreme weather conditions the ice continues to build up, the turbine is shut down. After a predetermined defrosting time, based on the outside temperature, a restart is initiated. Should the location require it, the automatic restart can be deactivated. A technical validation of the system by Deutsche Windguard Consulting determined that over a period of five winter months the Enercon system resulted in a difference in yield of 870 MWh when compared with two E-82 turbines at the same location.

**Too warm for ice**

In addition to ice detection systems, blade heating plays a crucial role in minimising losses caused by shutdowns. These always depend on the meteorological icing conditions and are site-specific. Meanwhile, all major manufacturers have standard or retrofit systems as solutions in their portfolios. The art lies in preventing ice accumulation even while
the turbine is in operation through the interplay of sensors. After all, these systems are of little help if there is already ice on the blade and the turbine has to stand still for several hours for defrosting.

Vestas offers its in-house VDS de-icing system for the V112-3.3 MW. It is an active de-icing solution consisting of a power-curve-based ice detection system and a hot air flow unit within the blades. The VDS is fully SCADA integrated and can be triggered automatically or manually. The VDS de-ices the full rotor simultaneously by heating up the blades internally with a flow of hot air. It de-ices the outer 1/3 of the blade full chord and the outer 2/3 of the leading edge towards the tip end. Each blade contains its own VDS that works simultaneously to capture, heat and propel air through a specially designed outlet within the blade. All mechanical parts are serviceable from the hub and inside of the blade at the root end. According to Vestas, the system is designed for the lifetime of the turbine, with no impact on overall turbine performance. It may not have any influence on the blade profile and there is no impact on noise performance.

On behalf of a Scandinavian energy supplier, Nordex deployed its anti-icing system to the field in the winter of 2010. In an N100/2500 wind farm, the manufacturer tested different prototypes and compared the results with a turbine on the same site without an anti-icing system. The result is the system, which Nordex now offers for the N100 and N117. The system results in 8 % greater yield over the space of a year. In the frosty months the yield was as much as 25 % greater. The system consists of an ice sensor and heating elements on parts of the leading edge of each rotor blade. The sensor continuously determines the external environmental conditions and reports the status to the operational management of the wind turbine. If the external conditions are favourable for ice formation, the heating system switches on. At a standstill, the system detects ice formation, initiates the defrost cycle and starts up again. And during operation, the anti-icing system removes existing ice from the leading edge of the blade.

Siemens may have the most experience with de-icing. As early as 1994, the company presented its first de-icing system, and the first such system was installed in Sweden in 2011. Over 50 % of all the Siemens turbines installed in Sweden are equipped with the system. Siemens uses an electrical method with built-in carbon heating mats on the leading edge. The system includes power connections at the root end and heating elements integrated into the blade surface at factory. Depending on the ambient temperature and wind speed, a blade can be de-iced in less than one hour.

Despite all the market-ready solutions, there is still a long way to go to creating reliable solutions for the wind industry in cold climates from each of these individual applications. “One question, for example, is at what ice thickness sensors should begin to respond. A good deal of clarification is still needed with regard to the parameters,” says Andreas Krenn of the Austrian Energiewerkstatt. He is also a member of the expert group for the International Energy Agency’s (IEA) Task 19 for wind energy in cold climates. This is just one of the intensively discussed questions in the group. The group published its last document for the implementation of wind energy projects in cold climates in 2012. In the coming months, a state of the art report is set to be released that sums up all of the sensors, ice-detection and sheet heating systems on the market.

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