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Measurements for Climate Protection

High-precision inertial sensors detect even the slightest vibrations on wind turbines

Many wind turbines (WT) do not achieve optimum yield because imbalances on the rotor blades reduce their efficiency. The Kiel-based engineering service provider, eta DYNAMICS GmbH, intends to change all this: In the future, damage to wind turbines will be recorded by means of state-of-the-art measurement technology at the initial stage. High-precision accelerometers from ASC play a key role in this, as well as ensuring enhanced dependability.

All wind turbines outwardly look the same. Even specialists can only recognize changes in the material or structure through in-depth investigations. Since many wind farms are hard to reach, inspections are often only carried out once or twice a year for cost reasons. In the time between inspections, the turbines are often left unattended for months on end. As a result, minor damage can spread unnoticed and become a safety risk for the installation. In addition, anomalies can also have a negative impact on the yield of a WT. A 2-megawatt wind turbine can record annual losses of around €20,000 due to imbalances, for example.

Both aerodynamic and mass-related imbalances, or a combination of both, can affect WT rotors. The causes are manifold: Mass-related imbalances can arise, for example, due to ice formation, water absorption, or in the production itself of the rotor blades. Aerodynamic imbalances result, among other things, from incorrect blade angle adjustment, errors in the profile of the blades or blade erosion.

WT monitoring is often still inadequate

Some wind turbines are now monitored by a specialized monitoring center in order to be able to detect changes early. The Kiel-based engineering service provider, eta DYNAMICS, offers this service worldwide for WT operators and has decades of experience in the field. According to its CEO, Roman Wolff, these are still very early days in the industry for the condition monitoring of wind turbines, as part of an overarching health monitoring concept: "Even many energy suppliers are culpable in neglecting the topic, and are only slowly coming around to truly professional WT operation."

Energy transition cannot be achieved without thorough monitoring

It is not only in economic terms that the wind energy expert finds this problematic: "Without thorough WT monitoring, we will not be able to achieve energy transition either," says Roman Wolff, with conviction. He has seen lots of damage to wind turbines during his career and knows that much of this damage could have been avoided when designing the wind turbines. Dictating against this,

however, is the enormous cost pressure that the manufacturers are under. "They save on material and use very thin structures." According to Mr. Wolff, due to ever more lightweight WT design, the design reserves are also continuously being reduced, in other words, the tolerances that are factored in as a safety buffer in the development of the installations. These are intended to ensure that the wind turbines can also withstand occasional overloads without any problems.

"Since the design tolerances have become steadily reduced in recent years, permanent monitoring of the installations has become all the more important," says Mr. Wolff, in describing the challenge. Even the slightest deviations in the blade angle can cause considerable aerodynamic imbalances. If, for example, defects occur when the rotor blades are being hardened in production, deformations can develop. As a result, the wind flow strikes the rotor blades differently than calculated and there are completely different moments of force at play on the nacelle and the tower of the WT, which can extend right down to the foundation.

High-precision accelerometers can detect the slightest changes

When monitoring wind turbines, Roman Wolff and his colleagues also rely on sensors: "For condition monitoring we use particle counters and oil quality sensors, among other things, but also simple accelerometers."

With conventional measurement technology, however, it is far from all the processes at play that can be measured on the wind turbine, because this kind of technology is exclusively installed on the drive train between rotor bearings, transmission and generator. "However, a lot happens on the rotor with the individual rotor blades as well as on the steel tube tower, concrete tower or hybrid steel tube-concrete tower and the foundation," says Wolff.

In order to be able to thoroughly monitor this area in the future, eta DYNAMICS has tested highly accurate accelerometers from ASC GmbH. Roman Wolff had been made aware of the company through a specialist magazine, finding out that it offers a wide range of highly accurate inertial sensors for demanding test and measurement applications. The engineer contacted the sensor specialists from Pfaffenhofen and quickly realized that he would find what he was looking for there: "ASC is one of the very few manufacturers on the market that produce accelerometers precise enough to meet our needs. The sensors tie in perfectly with our metrological concept."

ASC sensors were ideal for the test measurements

Roman Wolff was won over above all by the excellent signal-to-noise ratio of the ASC 5511LN and ASC 5515 LN capacitive triaxial accelerometers, a prerequisite for the high-precision measurements on the wind turbines. The low-noise sensors offer a low noise density of 7 to 400 µg/√Hz according to measuring range and have a frequency range from DC to 2000 Hz (±5%). Only the capacitive measurement principle of sensors based on high-quality micro-electro-mechanical systems (MEMS) can reliably detect the low rotor rotational frequencies of wind turbines (<0.5 Hz). With signal and

amplitude resolutions of <20 µg (<0.2 mm/s ²), the ASC 5511LN and ASC 5515 LN are not only ideally suited to detecting aerodynamic and mass-related imbalances on wind turbines but can also be used in many other applications.

Vibrations are measured on the machine carrier
Roman Wolff and his colleagues fitted an ASC 5511LN sensor and an ASC 5515LN sensor on a test WT, in the machine carrier in the nacelle. The engineers had chosen this installation location because the oscillations and vibrations induced here by the rotor blades affect the entire wind turbine. "The forces induced by the wind in the rotors and thus also in the nacelle and the tower are enormous," Wolff explains.

The high-precision triaxial accelerometers from ASC were attached to the machine carrier using a mounting plate and aligned to the axes. Here they recorded the entire tower-nacelle dynamic over a period of eight weeks. The measured values flowed bidirectionally to a data acquisition unit in the switch cabinet of the nacelle, and from there via a VPN connection to a data center where they were recorded.

The tests delivered a wide range of measurement data
"During the investigations, we wanted to know how the turbine reacts to the different wind flow conditions," says Wolff in describing the project objective.
Therefore, a wind turbine was selected for the test that received a partially unimpeded wind flow in one main wind direction sector but was also partly downwind of other WTs. If one WT is behind other WTs, there are completely different wind flow conditions at play than with turbines receiving an unimpeded wind flow.

Since the tests were carried out in the summer, the conditions were ideal. There were also thunderstorms with strong changes in wind direction and gusts. In this way, all critical operating loads that occur during the life cycle of a WT could be recorded.

Sensors will be used in regular operation in the future
The Kiel engineers are very satisfied with the results of the investigations: "We have seen that we were able to measure even the slightest changes to the WT using the sensors from ASC," says a delighted Roman Wolff. Smaller adjustments are now being made to the sensors so that they can be smoothly integrated in the measurement concept of eta DYNAMICS. For ASC, this is a matter of course: The sensor specialist not only produces highly accurate measurement technology but also offers individualized service. All sensors are modified in close cooperation with customers so that they optimally meet the requirements of each application.

In the future, the capacitive accelerometers from ASC will therefore be monitoring wind farms in regular operation. In this way they are making an important contribution to increasing wind turbine efficiency and, by the same token, contributing to climate protection.

Image overview

Fig. 1 - ASC-eta-DYNAMICS-Beschleunigungssensoren.jpg:
The high-precision accelerometers from ASC were installed on the machine carrier in the wind turbine nacelle
Image: eta DYNAMICS GmbH

Fig. 2 - ASC-Sensor-Position-Gondel.jpg:
The ASC sensors were installed for test purposes at this position in the nacelle of a wind turbine
Image: alecicco telli/AdobeStock, ASC GmbH product

Fig. 3 - ASC-Windenergieanlagen.jpg:
By means of thorough monitoring, the yield of wind turbines can be significantly increased
Image: engel.ac/AdobeStock

Fig. 4 - ASC-Beschleunigungssensoren-5511LN.jpg:
The ASC 5511LN capacitive triaxial accelerometer is ideal for detecting the slightest oscillation amplitudes
Image: ASC GmbH

Fig. 5 - ASC-Beschleunigungssenosren-5515LN.jpg:
Offering a very good signal-to-noise ratio: The ASC 5515LN capacitive triaxial accelerometer
Image: ASC