



Does your WTG have
a solid standing?

SHM.Tower® and SHM.Foundation®

Intelligent Systems for the Early Detection of Tower and Foundation
Damages and for an Optimized Lifetime Extension

The logo for Wölfel, featuring a green curved line above the word "Wölfel" in a bold, teal, sans-serif font.



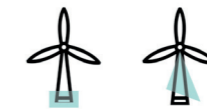
Actively Prevent Serious Damage and Long Downtimes

If you want to generate green energy safely, continuously and efficiently, you need a solid base. In the case of wind turbines (WTG), this is the tower and foundation. The two supporting structures are responsible for the stability. Damage is therefore naturally primarily a major risk for the people in the immediate vicinity of the plant. However, if it is not detected early enough, serious and cost-intensive consequential damage, extensive repairs and long downtimes are also a risk.

To prevent this, we have developed our Structural Health Monitoring Systems SHM.Tower and SHM.Foundation. By means of changes in the structural properties (e.g. natural frequencies or compensated inclination values), they can detect damage at an early stage and continuously monitor it. Repairs and service interventions can thus be planned. In addition, the systems provide information on the lifetime consumed. Thus, they fulfill two essential requirements at once: The operator always has an up-to-date overview of the entire wind farm and a basis for the decision about lifetime extension.

The Functions of SHM.Tower and SHM.Foundation at a Glance

The symbol next to the headline shows you in which system the described function is integrated:



SHM.Foundation SHM.Tower

Vibration monitoring enables proactive optimization



Depending on the location and mode of operation of a wind turbine, the vibration stress – especially on the tower – varies greatly. SHM.Tower and SHM.Foundation record these stresses using an integrated 3D acceleration sensor. The averaged acceleration data (RMS-values) recorded as daily, monthly or yearly time histories allow for exact analyses as well as for a comparison with applicable standards (e.g. VDI 3834, ISO 10816-21). Special events such as strong winds and their effects can be identified and precisely examined in time histories and frequency spectra. The optional acquisition of operational and environmental data such as wind speed, rotational speed, power, pitch or azimuth angle

allows for an assessment and optimization of the WTG operation against the background of these plant data.

Significant extension of WTG lifetime



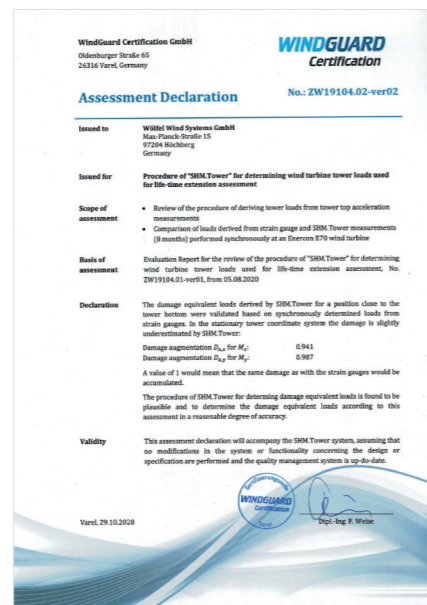
Wind turbines are usually designed for a service life of 20 years. However, at the end of this design lifetime there is often a large potential for a lifetime extension. The decision on this is made within the scope of a lifetime extension report. So far, these are usually based on historical operating and wind data as well as turbulence reports or historical yield data. However, due to conservative load assumptions and insufficient consideration of the wind direction – and thus the distribution of the lifetime consumption over the whole tower



cross-section – the entire potential for the longest possible lifetime extension is often underestimated.

By recording vibration profiles, SHM.Tower and SHM.Foundation can easily and accurately determine the actual fatigue loads distributed over the tower cross-section. The integrated evaluation algorithms use a calculation model that is adapted to your plant in advance and provides insight into the loads on the entire tower structure.

With this load reconstruction methodology, the exact lifetime consumption of a wind turbine can therefore be calculated. Even critical extreme conditions are directly recorded. Thus, the lifetime prognosis is no longer based on assumptions alone. The lifetime extension can be maximized and the entire yield potential can be tapped.



Certificate of assessment for the calculation methodology for load determination on wind turbine towers

SHM.Tower was already certified as a Condition Monitoring System by WindGuard Certification GmbH in 2019. In 2020, the implemented load reconstruction methodology was also successfully assessed. It was proven that SHM.Tower enables load detection with a very high accuracy and is therefore very well suited for use in the context of lifetime extension reports:

“Now that it was shown that the vibration profiles recorded with SHM.Tower are a very good representation of the system dynamics relevant for fatigue, there are indeed valuable possibilities for assessing the lifetime extension of modern WTGs. On the one hand, the DELs derived from vibrations can be used to validate and optimize the dynamic calculation model in order to minimize conservative safety factors. On the other hand, the measured load distribution in the tower cross section can be used to reduce the determined damage to the foundation and tower. In real terms, this results in a significant lifetime extension beyond the usual service life horizon without any loss of forecasting reliability. We have proven this in the assessment procedure.”

Frank Weise,
Managing Director of WindGuard Certification GmbH

Reducing and optimizing visual inspections



Without a suitable monitoring system, damage can only be detected and monitored with regular visual inspections. They are usually complex and expensive. The monitoring of e.g. displacements, inclinations, component stresses or frequencies is therefore unanimously recommended. In numerous projects, however, the monitoring of only ten percent of all turbines has been, to date, set as common practice.



Since each wind turbine has individual characteristics as well as damages, we take a more comprehensive approach and recommend that all turbines in a wind farm be equipped with a system for monitoring the tower and foundation structure. In offshore wind farms, we generally equip ten percent of the turbines with the comprehensive SHM.Foundation individual system and 90 percent of the turbines with the cost-effective standard SHM.Foundation system. This combination makes it possible to switch from the time-based inspections that have been common up to now to condition-based inspection concepts.

Identification of black sheep



The continuous comparison of the current RMS values with the applicable standards – e.g. ISO 10816-21 and VDI 3834 – makes it possible to immediately identify problematic wind turbines under extreme load. The operator is alerted and can initiate appropriate countermeasures. Consistently exceeded limit values indicate a faulty condition or faulty operation of the wind turbine.

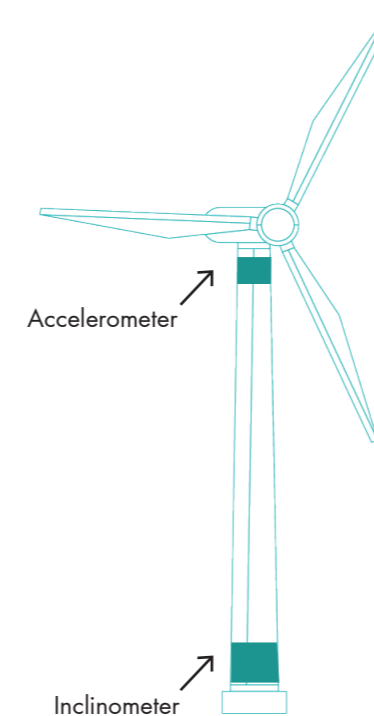
Monitoring of foundation damage



Although damage to foundations accounts for only about ten percent of all registered damage, it is particularly cost-intensive. Whether faulty foundation structures, a decoupling of foundation and tower or a loosened foundation component – early detection and continuous monitoring with SHM.Foundation ensures that no serious consequential damage and long downtimes occur. In addition, the system enables object-related damage analyses and a continuous evaluation of the damage progress (e.g. according to FGW TR 7 Rubrik B3).

Easy installation – even as a retrofit

For monitoring, we only need a few, low-cost sensors in the easily accessible tower area (Offshore: TP area). Our Virtual Sensor concept based on a Digital Twin still provides you with information about the entire support structure. In the case of SHM.Foundation, for example, an acceleration sensor in the tower records the dynamic movement of the tower structure, while an inclination sensor at the base of the tower detects and monitors the global quasi-static inclination of the tower due to a damaged foundation.



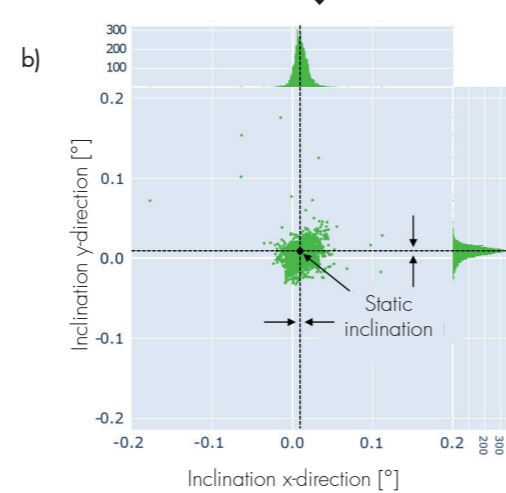
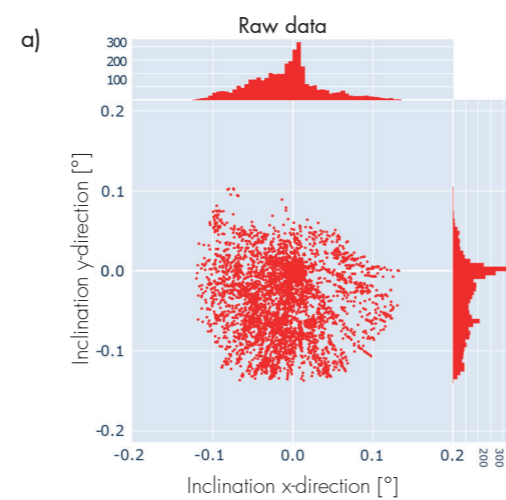
Reliable solution for tower and foundation monitoring

Of course, some functions – especially the calculation of the lifetime consumption – unfold their full effect best if the system is used from the very beginning. This is because then the operating status and the lifetime consumption are precisely recorded throughout all phases of use – thanks to the energy-autonomous mode even during construction and in the event of power failures. However, SHM.Tower and SHM.Foundation can also be retrofitted. Although the vibrations of the first years of operation are not available, significantly improved lifetime extension assessments are achieved compared to conventional methods. Extrapolations in combination with historical wind data allow for the assessment over the entire lifetime. After the first lifetime extension report, you can optimally accompany the remaining lifetime of your WTG by continuously monitoring the vibration levels and loads.

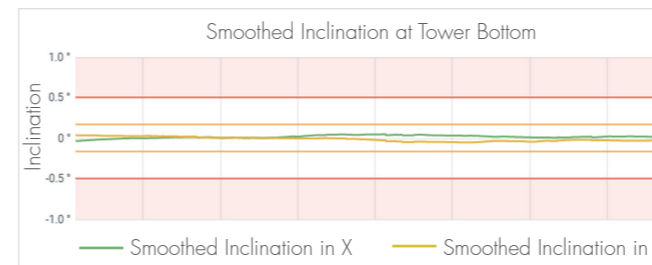


Artificial Intelligence (AI) enables even more precise results

In the basic version, the influence of temperature on the inclination is compensated for with an integrated temperature sensor. If the EOC/SCADA data is also recorded, the dependence of the damage indicator (the compensated inclination value) on the operating conditions can be detected. By an optional function extension, the influence of the EOC-/SCADA data can be compensated for with the help of AI methods, thus further increasing the accuracy.



Structural inclination without and with compensation of temperature and operating conditions



Smoothed, resulting inclination at the tower base (damage indicator allows for warning)

Monitoring Intelligence Center: Turning data into knowledge

The data collected by SHM.Tower and SHM.Foundation are evaluated or visualized together with the optional operational and EOC data directly in our Monitoring Intelligence Centers MIC.Tower and MIC.Foundation. All important indicators are extracted from this flood of data and made available to the user at any time in a clearly arranged form. You can see at a glance whether limit values are being complied with, whether and where a problem is occurring, what the cause may be and what measures need to be taken to rectify the error or prevent the damage from progressing.

Event-triggered notifications and alarms can be configured individually. In addition, automated reporting (optionally with expert assessment) can be generated, which also meets regulatory requirements.

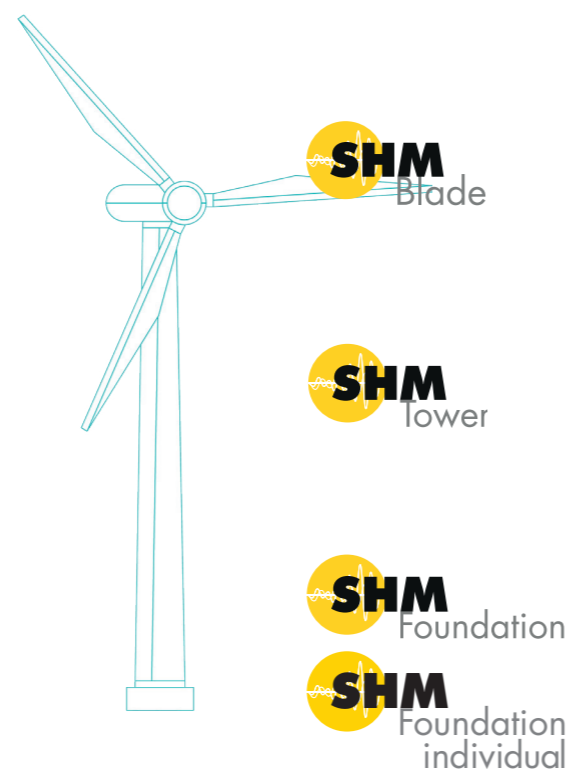
The security of the sensitive measurement data is always in the foreground. A data center in Germany, a secure Internet connection and a three-level user management system ensure that only authorized persons can view data and results and edit settings. If a data connection is still not desired or not possible, all monitoring and data backup functions can also be outsourced to a central wind farm server.



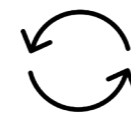
Holistic Approach: From the Bottom to the Tower to the Top

Regardless of location, a sustainable reduction of operating costs while simultaneously increasing yields is becoming increasingly important. In order to fully develop the potential of a wind farm and to ensure long-term efficiency, it is therefore advisable to monitor the turbines holistically. Contact us for more information about our global Structural Health Monitoring concept and our products for condition monitoring of blades.

With the SHM.Foundation individual monitoring system, the structural behavior of your wind turbines and substations can also be recorded, tracked and evaluated in compliance with the guidelines. The focus here is on the detailed analysis of maximum and fatigue loads, the acting wind and wave loads, the structural condition and the resulting residual lifetime, as well as the detection of corrosion and scouring. Both the necessary hardware as well as the software for data analysis are configured individually according to your project requirements.



The advantages of SHM.Tower and SHM.Foundation at a glance



With our methodology for load reconstruction, which has been successfully assessed by WindGuard Certification GmbH, the assessment for the lifetime extension of the turbine is based on the loads that actually occur and are distributed over the tower cross section. Thus, the exact lifetime consumption can be calculated and the WTG lifetime can be extended.



With SHM.Foundation and SHM.Tower, you can detect and monitor tower and foundation damage safely and efficiently, thus preserving the asset value.



Problematic WTGs under extreme load are identified safely and efficiently with the help of comprehensive wind farm monitoring. Countermeasures can be initiated before damage occurs.



Permanent monitoring enables continuous and proactive optimization of turbine settings and operation. The data collected also forms the basis for a sound asset valuation.



SHM.Foundation makes it possible to switch from the previously common time-based inspections to condition-based inspection concepts.



What moves Wölfel?

Vibrations, structural mechanics and acoustics – this is the Wölfel world. Here we are experts, this world is our home. More than 120 employees daily do their best for complete satisfaction of our customers. For more than four decades we support our customers with engineering services and products for the analysis, prognosis and solution of tasks in the fields of vibrations and noise.

Are vibrations really everywhere? Yes! That's why we need a wide variety of solutions! Whether it is engineering services, products or software – there is a specific Wölfel solution to every vibration or noise problem, for example

- simulation-based seismic design of plants and power stations
- measurement of acoustic emissions of wind turbines
- universal measuring systems for sound and vibrations
- expert reports on noise immission control and air pollution forecasts
- dynamic occupant simulations for the automotive and aviation industry
- and many other industry-specific Wölfel solutions ...

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