How can you hear ice grow?

IDD.Blade® and SHM.Blade® – Monitoring of rotor blades
for the efficient detection of icing and structural damage

Wölfel

Icing and structural damage

Authorities demand that a wind turbine (WT) is stopped in case of icing to protect the surrounding area against ice shedding. However, increased loads caused by unbalances due to icing also have a significant impact on the lifetime of the WT. Rotor blades of wind turbines are exposed to extreme environmental conditions and high dynamic stresses. Their condition has a decisive influence on the energy yield and thus on the economic efficiency of a WT. Incipient damage must be detected at the earliest stage possible in order to take repair measures in due time. In the worst case, unnoticed damage can mean that complete rotor blades have to be replaced, which leads to extended and unnecessary downtimes for the complete WT or the entire wind farm.

In summary:

- Ice detection by measurement of the vibration behavior of the rotor blade
  – has proven to be a safe and effective method,
  – allows ice detection also during downtimes of the WT, below cut-in wind speed,
  – allows automatic start and stop of the WT in case of icing.
- It has been proven that if systems without automatic restart are used, up to 40 % of WT downtimes are unnecessary![1]
- High sensitivity of ice and damage detection is indispensable for a profitable operation. This can be ensured by location-specific settings.
- Periodic inspections are not sufficient for an early detection of damage or icing. Continuous monitoring ensures a higher level of safety.

[1] Source:
T. Jung et al.: Economic feasibility study of ice detection systems on wind turbines, Weilburg 2015

The solution – SHM.Blade® and IDD.Blade®

SHM.Blade is a tried and tested condition monitoring system for rotor blades, which can detect structural damage and – with the option IDD.Blade – icing. If the rotor blade is at risk of incipient damage or if there is ice on the rotor blades, the system sends a warning or an alarm. This can be the basis for a shutdown or for taking inspection and repair measures. SHM.Blade and IDD.Blade are based on the measurement and interpretation of the global vibration behavior. Vibrations change when the structural stiffness is reduced due to damage or when the mass changes due to icing. By means of sensors and complex data evaluation algorithms the condition of the rotor blade can thus be determined. The evaluation is based on a patented procedure where structural-dynamic characteristics of the rotor blade are determined by means of output-only modal analysis through system identification directly from the sensor data.

A key advantage of our blade monitoring systems is that the structural properties can be directly and objectively detected by the sensors in the rotor blades. The following table shows the resulting advantages and compares them with the characteristics of ice detection systems based on other physical principles.

Ice detection systems			
Meteorological	Visual	Power curve	Rotor blade monitoring
• No direct ice detection at the rotor blade possible • Not approved for automatic restart	• Not fully operational due to weather conditions • Not approved for automatic restart	• No direct ice detection at the rotor blade possible • Not approved for automatic restart	• Direct ice detection at the rotor blade possible • Certified for automatic restart

Ice and damage detection

Damage detection: SHM.Blade®

SHM.Blade detects structural changes in relation to a certain reference condition. This reference condition is determined fully automatically without any help from outside and individually for every single rotor blade immediately after the activation of SHM.Blade. Such a blade-specific learning phase ensures high sensitivity to damage – despite the mass and stiffness tolerances caused during production. After completion of the learning phase, the system continuously calculates condition indicators, which provide information on the current condition of the blade at all times. By means of a two-level warning and alarm concept the system control can react and subsequent damage can be prevented. More detailed information is available via the web monitoring portal MIC.Windenergy.

Prevention of serious damage with SHM.Blade

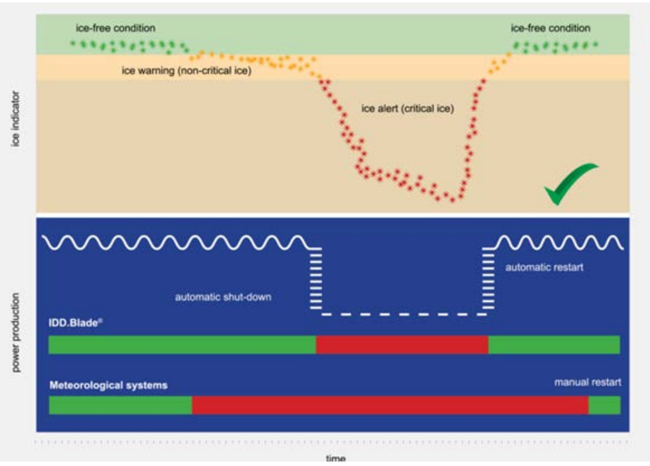
Ice detection: IDD.Blade®

IDD.Blade detects ice on rotor blades. As the sensors in the rotor blades directly record the actual icing condition, the results are much more reliable than an assessment based on meteorological parameters. However, the main economic advantage is that wind turbines which have been shut down due to icing are automatically released for further operation after thawing of the ice. Comprehensive and expensive service inspections with subjective results are not necessary. As a special feature, the warning and alarm concept is freely configurable in coordination with the operator and in accordance with the regulations imposed by the authorities. Thus, depending on the location, the energy yield can be optimized according to the priorities, i.e. with the main focus either on personal safety or on the protection of the wind turbine against excessive stress. IDD.Blade can also be used as independent module without SHM.Blade.

On the safe and most economical side

SHM.Blade® and IDD.Blade®

- Early damage detection leads to increased safety and significantly lower costs because service work can be planned
- Automatic restart after ice detection prevents unnecessary downtimes

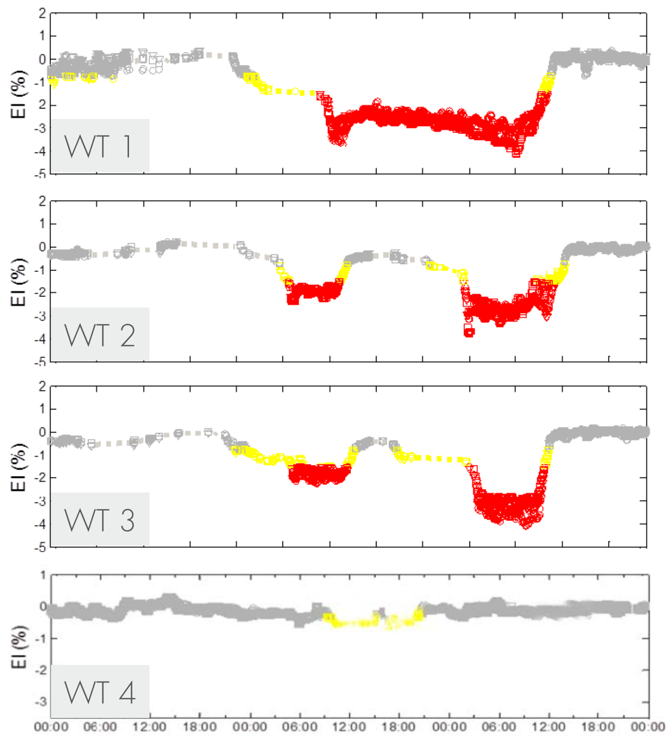


Advantage of automatic restart: Higher energy yield due to later shutdown and earlier automatic restart

- Several hundred systems have been used successfully in the field for many years with high customer satisfaction
- TÜV NORD certificate (type-specific proof of reliable operation based on risk assessment)
- Tested lightning and surge protection according to the requirements of Lightning Protection Level I in compliance with IEC 61400-24
- Customer-specific configuration and simple retrofitting; experienced service personnel available
- Optional provision of detailed information about the vibration behavior of the rotor blades (comparison of the blades of one WT; comparison of the blades of several WTs) through the web monitoring portal MIC.Windenergy for the detection of “abnormal blades” and for the detection of unusual vibration behavior.
- GL Type Certificate SHM.Blade: damage detection, IDD.Blade: ice detection, Type Certificate TC-GL-015A-2013

Cost-optimized monitoring with IDD.Blade®

IDD.Blade reduces shutdown times to the times of actual icing and allows automatic restart of the wind turbine when the rotor blades are ice-free. The diagrams below show examples of the icing of 4 wind turbines of a German wind farm. Only at the times that are marked red a shutdown of the wind turbine is required due to icing. It can be seen that icing can also vary considerably within a wind farm and IDD.Blade minimizes the shutdown times of each individual WT to the actual icing periods.



Shutdown in critical ice conditions

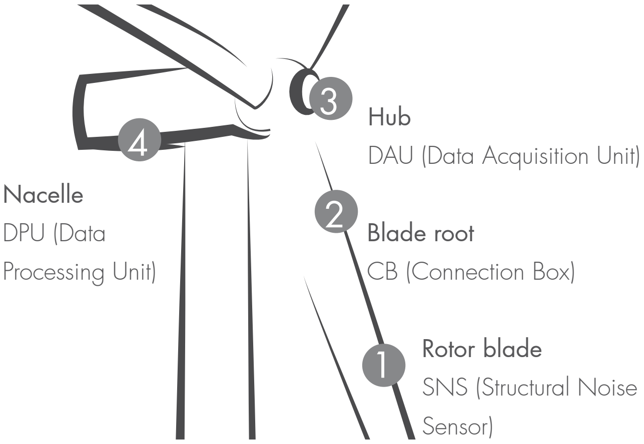
Continuous power generation in non-critical ice conditions

Location: Region in Hesse

Period: 13–14 February 2015

The hardware – successfully used in numerous wind turbines

Vibrations and sound are measured by SHM.Blade and IDD.Blade in each rotor blade with structural noise sensors (SNS). These sensors detect accelerations as well as the temperature and have an excellent signal-to-noise ratio.
The high signal resolution is essential for successful operation. The sensors are protected against overvoltage and the effects of lightning strikes in the rotor blades according to the requirements of Lightning Protection Level I (IEC 61400-24).



Components of SHM.Blade and IDD.Blade

For IDD.Blade and SHM.Blade Basic, one sensor per rotor blade is sufficient. In case of higher requirements in terms of precision and redundancy, SHM.Blade Standard can be used with two sensors on each rotor blade.

At each rotor blade root, a connection box (CB) with a robust plug-in connection ensures that the sensors can be connected with the system. The analog sensor signals are digitized by the data acquisition unit (DAU) in the hub, stored temporarily and then the signals are transferred through a TCP/IP connection to the data processing unit (DPU) in the nacelle, where they are processed further. Data are continuously recorded so that information about the current condition of the rotor blade can be provided at any time. In the DPU, the condition indicators for damage and ice detection (with option IDD.Blade) are calculated. The measuring data are evaluated fully automatically. For this purpose, the WT control system has to provide the current operating data like e.g. wind speed, electrical power, generator or rotor speed and pitch angle. At the same time, the communication with the turbine control and the data connection with the external monitoring center (MIC.Windenergy) are realized from the DPU. Real-time monitoring and remote access to the system is possible via a web interface. By means of several self-diagnosis procedures, individual plausibility checks and continuous monitoring of the cyclical program flow, SHM.Blade reports any unexpected system conditions to the turbine control system and the monitoring center.

The core competence of Wölfel – extracting useful information from masses of measuring data

Signal analysis and damage identification

SHM.Blade successfully masters the challenge of extracting exactly that type of data from the masses of measurement data and masking environmental influences that provide information about the technical condition of the rotor blade.

An SHM system has to sensitively detect critical changes of the rotor blade that impair the blade's bearing capacity; on the other hand it must not trigger false alarms. So there are a few challenges:

- How does SHM.Blade know which condition is good or bad?
- How are thresholds set to define a bad condition for alarm?
- How can production-related deviations of blade stiffness, mass and its distribution, which make each rotor blade an individual, be brought in line with thresholds?
- How is it possible to distinguish between influences on the vibration behavior caused by changes in environmental or operating conditions and influences caused by icing or structural damage?

Dynamic properties depending on

- temperature
- rotational speed
- pitch angle
- electrical power

↓

Compensated dynamic properties

↓

Final condition indicators

- ice
- damage

Compensation of influences from operation and environment

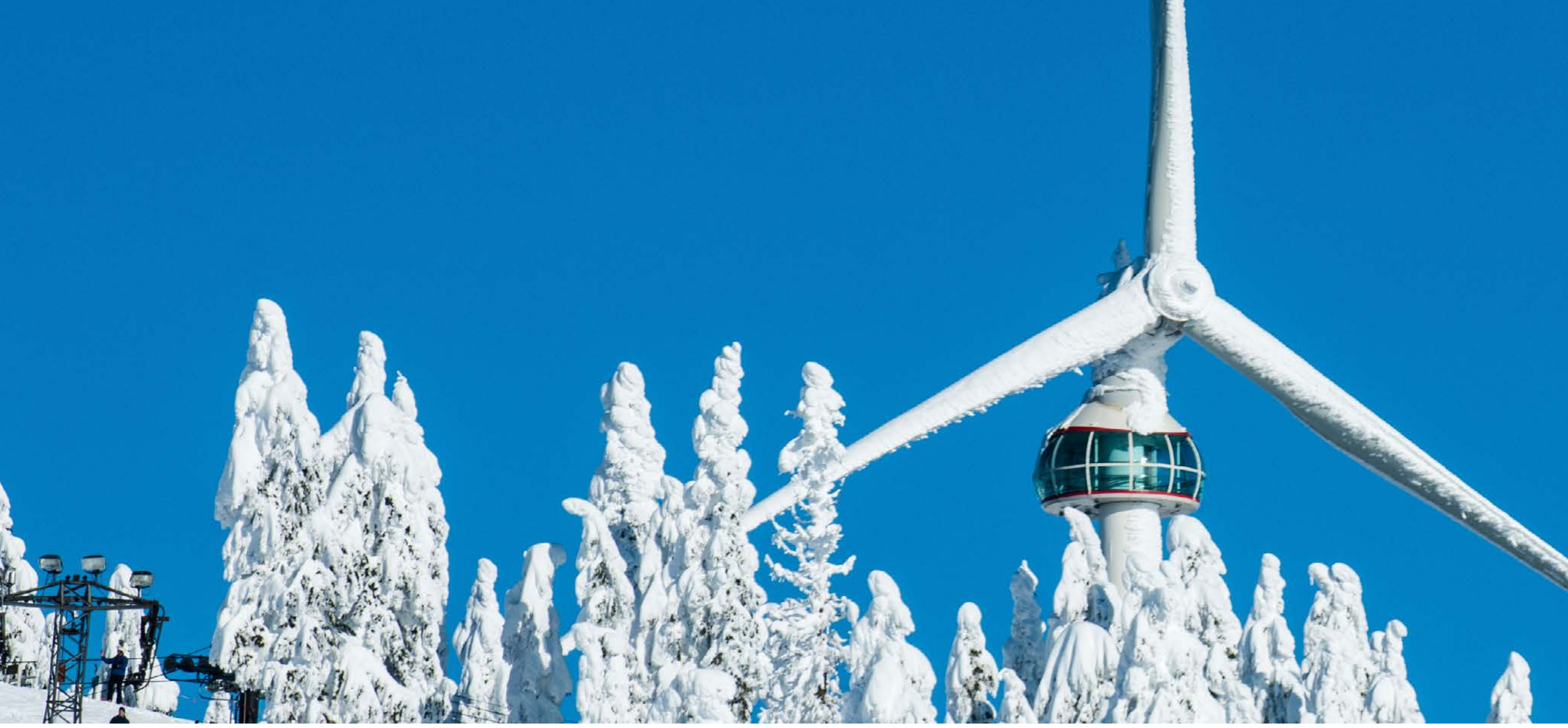
The issues raised can only be answered if the „basic settings“ are defined for a rotor blade type in a configuration phase. Thus, a learning phase of SHM. Blade follows after commissioning of the wind turbine. During this period, the so-called individual blade-specific referencing is carried out. This is necessary in order to obtain a high system sensitivity despite production-related rotor blade variations that affect the structural dynamic behavior.

Referencing is done depending on the operating conditions, so that even when commissioning is realized in the winter months, statements about the icing conditions can be made within a short period of time. Data analysis is realized in the time domain by identification of the state-space models, which describe the structural dynamic behavior. Existing identification methods based on the methods that are referred to as output-only modal analysis in literature (time domain system identification) were expanded and adapted to take specific conditions into account. With the above-mentioned methods it is possible to obtain results faster and with higher accuracy than e.g. with spectral analysis by Fourier transform.

During the analysis, particular attention is given to the distinction between structural resonances and harmonic excitation shares. Moreover, the constantly changing operating conditions have to be taken into account. In particular, variable operating and environmental conditions affect the measuring data often more than effects caused by icing or structural damage. Here, statistical methods for classification are used successfully.

„With these methods, which have been developed over many years and tested successfully in the field, SHM.Blade reaches its exceptionally high sensitivity. Thus, SHM.Blade improves the safety and availability of wind turbines.“

Dr.-Ing. Carsten Ebert
Engineering Director Wind Energy at Wölfel



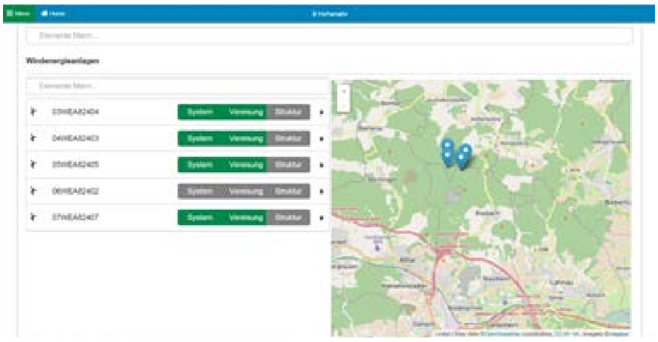
Monitoring Intelligence Center

MIC.Windenergy

SHM.Blade was developed for fully automatic and independent operation on wind turbines. Thanks to the direct communication with the turbine control system, this system can react immediately in case of icing or structural damage. Furthermore, we also offer the option to connect our blade monitoring system with our web monitoring portal MIC.Windenergy, where detailed information about the system and the rotor blade are available. For efficient operation, such remote control of key components is common standard today.

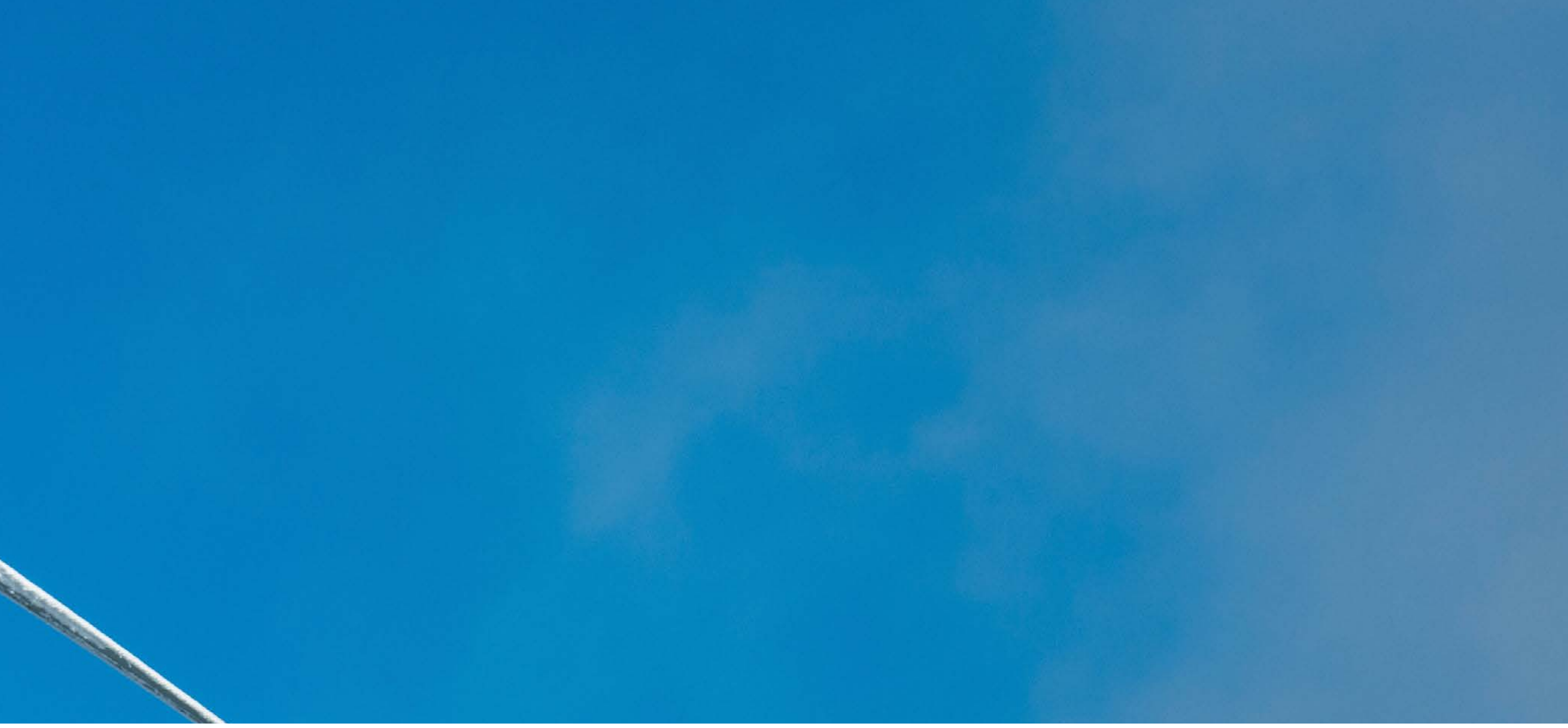
Upon request, all relevant data are transferred via the Internet and saved. Via the web interface of the Wölfel monitoring center MIC.Windenergy all important indicators are available for the operator as graphical presentations.

Event-triggered messages and automatic reporting ensure current information at any time. If a data connection is not desired for safety reasons or not available on site, all monitoring and data backup functions can also be outsourced to a central wind farm server.



MIC.Windenergy

MIC.Windenergy



Further products for structural health monitoring

SHM.Tower

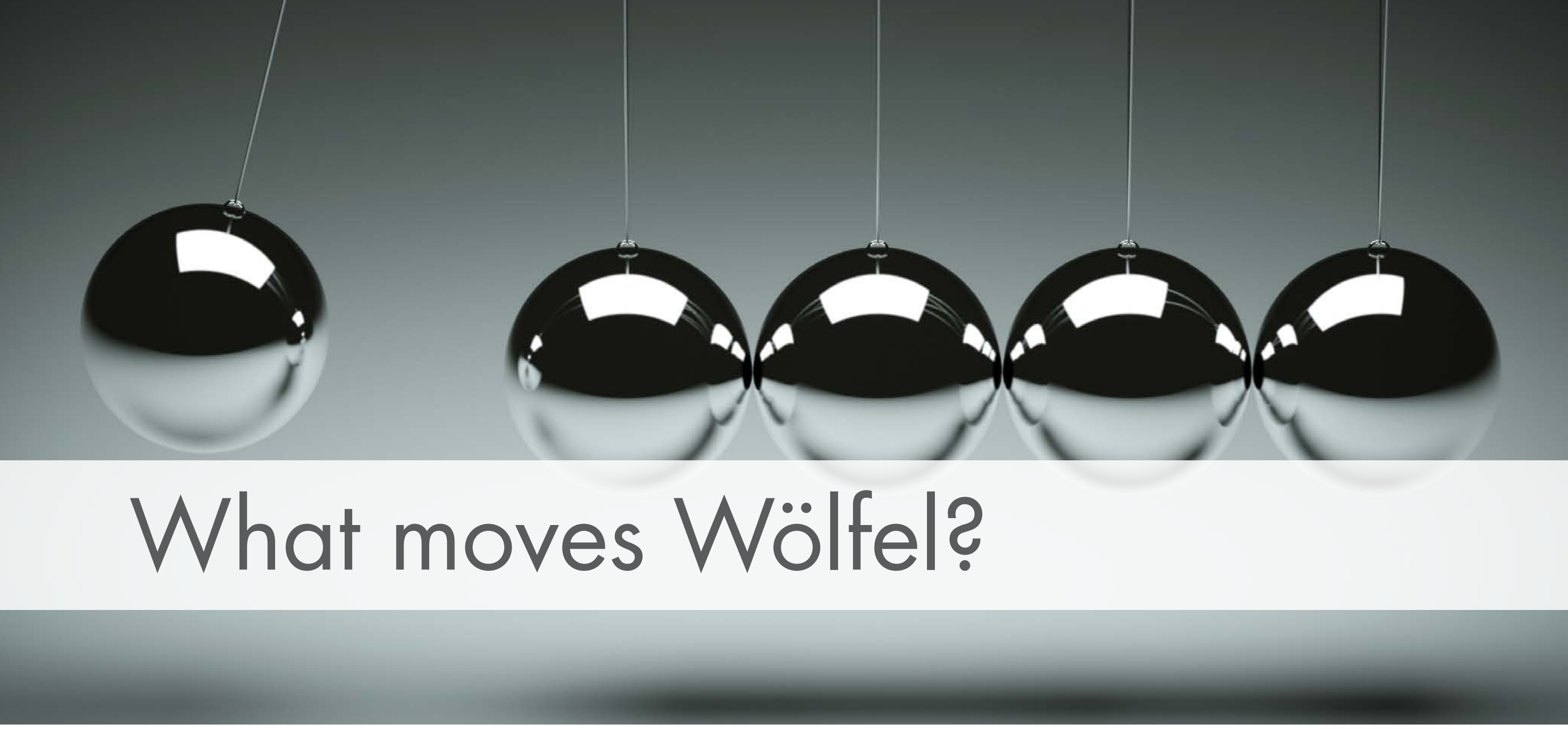
Tubular steel towers can be exposed to considerable vibrations, which affect the service life significantly. As there are no monitoring systems, high fatigue loads are not recognized – especially when no power is available due to power failure.

Our product SHM.Tower detects the tower vibrations with an acceleration sensor and documents the fatigue loads and the life consumption, for up to 6 months even without power supply. SHM.Tower can easily be retrofitted, so that a lifetime evaluation is even possible towards the end of the service life of the wind turbine. For a lifetime extension, important information is thus available.

SHM.Foundation

In offshore wind farms it is often required that at least every tenth foundation structure is monitored by a monitoring system. Wölfel has comprehensive expertise in this field and advises on the optimal configuration based on individual customer and project requirements. Our monitoring systems are equipped with robust electronic components according to industrial standard. The installation of surge protection modules and a CE marking is standard.

The systems are installed by our teams that are well-trained for offshore work. Our core competence is the data analysis. It is not helpful for the park operator, just to obtain measurement data. We extract the essential information, compare the detected loads with design assumptions, calculate the lifetime consumption and create reports for licensing authorities. By comparing the behavior of several wind turbines in a wind farm, suboptimal modes of operation can be detected and inspection measures can be planned.



What moves Wölfel?

Vibrations, structural mechanics and acoustics – this is the Wölfel world. Here we are experts, this world is our home. More than 90 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 ...

IDD Blade   SHM Blade   MIC Windenergy   SHM Foundation   SHM Tower

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