Overall Vibration Values for Reliable Wind Turbines

The New VDI 3834 and the New ISO 10816-21 Guideline Close a Gap - Less Vibration is Better

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Condition-based maintenance on wind turbines not only involves maintenance, but also encompasses servicing, inspection, measurement and evaluation of the condition of the unit. The current condition can be evaluated on the basis of machine-specific overall vibration values. Until now, overall vibration values had not been defined for wind turbines. In fact, ISO 10816-3 explicitly excludes wind power plants. The new VDI 3834 closes this gap shown in Sheet 1: Vibration values for wind turbines up to 3 MW. In addition to the new VDI 3834 is the ISO 10816-21 in preparation. The author of the article Dr. Edwin Becker is the nominated expert for Germany.

1. Introduce

Wind power is an industry undergoing turbulent growth, both with regard to its volume and its energy generation capacity. System vendors have had little opportunity to test the wind turbines as their power output has grown, and this has had a negative impact on system availability. Particularly because of the frequent occurrence of gearbox damage in 2002/2003, system insurers introduced a so-called revision clause and cancelled almost all old contracts. The revision clause stipulates that "all roller bearings in the drive train must be replaced after 5 years or 40,000 operating hours at the latest, unless a suitable condition monitoring system(CMS) has been installed". These types of CMS can be used for function diagnosis and/or for fault diagnosis.

Function diagnosis refers to the measurement of functional and operating parameters and overall vibration values. That knowledge is required for the proper functioning and long-term operation of rotating machinery. Fault diagnosis is the determination of damage conditions on machinery and machine components.

The use of CMS has made it clear that wind turbines are highly complex machines for which the overall vibration values must be systematically determined and made available. The following points had to be taken into consideration in creating the new guideline:

- The functional and structural design of wind turbines and their components.
- The interaction between the individual machine train components(modules) being tested.
- Information and experience regarding the possible faults and damage occuring in the

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individual modules during operation and their economical impact.

· Knowledge of operation-related and machine-related vibration influences, the diagnosis procedures that can be applied, and the diagnosis conditions that need to be adhered to and their limits.

VDI 3834 was released in March 2009 and takes into account the special requirements of wind turbines. The guideline is the first of its kind and is available as Sheet 1 for wind turbines with gears up to 3 MW.

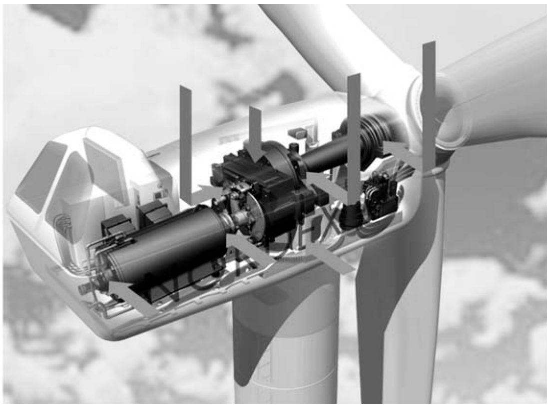

Fig. 1 Typical drive train concept and some measuring locations on a wind turbine

2. Measurement Technology and Characteristic Values

Piezoelectric accelerometers can be used to measure both low frequency vibrations beginning with 0.1 Hz and high frequency vibrations up to 6 kHz, as defined by VDI 3834. In chapters 2 and 3 of the VDI 3834, clear specifications are given for the installation location of these types of accelerometers. Acceptance measurements should be made in the following typical measurement directions: radial vertical, radial horizontal and axial. A minimum load of 20 % is required. Because of the natural fluctuations in wind load, the VDI 3834 specifies longer measurement times ranging from 1 to 10 minutes and even requires a root mean square to obtain stable and meaningful vibration values for slowly rotating components.

3. Characteristic Values for Drive Train Components

The VDI guideline divides the drive train components into their main components and assigns

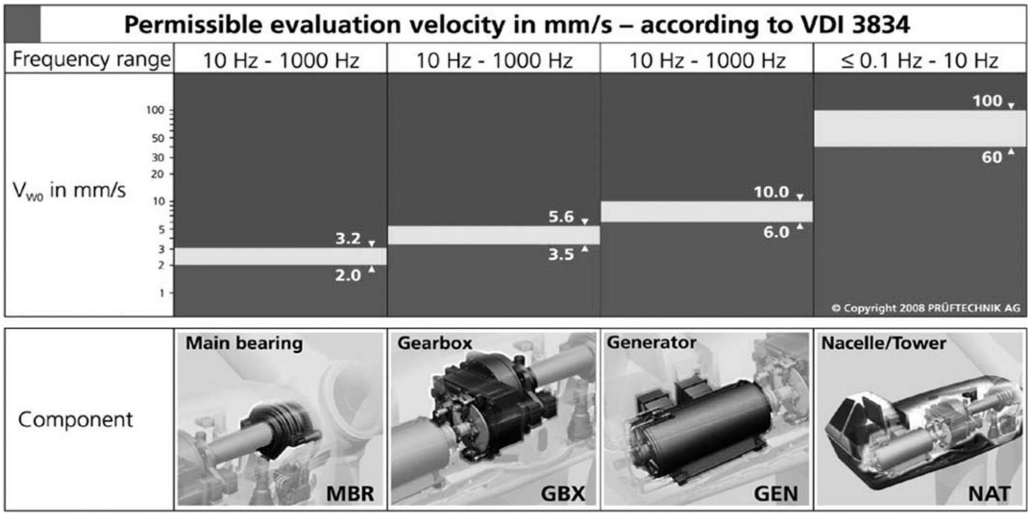

Fig. 2 Guide values: permissible evaluation velocities

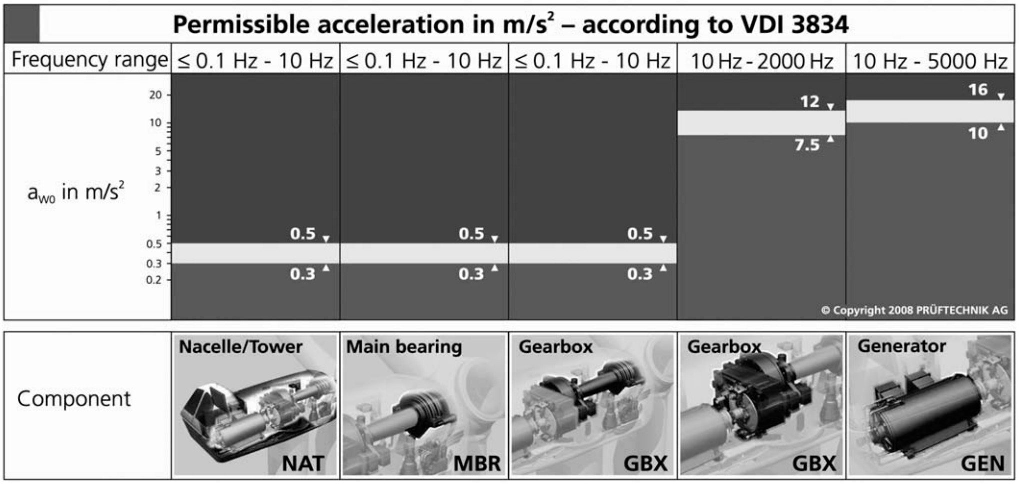

Fig. 3 Permissible evaluation accelerations

overall vibration values to the most important of these. In this way, component-specific vibrations can be classified and wind turbines and their components showing unfavorable behavior with respect to their vibrations can be identified. The VDI 3834 is based on a statistical analysis of vibration measurement results on more than 450 wind turbines and defines threshold values in terms of vibration velocity in mm/s and vibration acceleration in m/s^2 for the drive train components(generator, gear and main bearing) and for the nacelle/tower. The threshold values were defined as component-specific frequency bands. The VDI 3834 also gives recommendations for warning and alarm thresholds. Figure 2 shows the acceptable levels for overall vibration velocity and Fig. 3 shows them for overall acceleration.

In Level 1 monitoring, we differentiate between the remote monitoring of these overall vibration values and the remote monitoring of characteristic diagnosis values. But these methods are not new. In machines and industrial plants, the vibration values of the ISO-10816-3 are used to monitor the general vibration condition and, increasingly, detailed monitoring uses frequency-based or order-based characteristic trending values.

4. Assessing the Vibration Level and Reducing Vibrations

Based on the overall vibration values, it is now possible to assess the vibration levels of wind turbines and to compare these. After all, the experience made during service is that "less vibration means a longer machine life" must also apply to wind turbines. The early detection and reduction of elevated vibration levels therefore extends wind turbine service life.

5. Identifying Corrective Measures

The required measures can be identified by means of a condition diagnosis. Diagnosis specialists use amplitude spectra, envelope spectra, time signals and/or cepstra to detect unusual vibration signals, to identify dominant excitations and to evaluate frequency specific trends using the water fall display function[2]. A few examples of how the availability of systems can be increased using vibration results are presented below:

- **Detecting additional vibrations resulting from a generator fault:** Figure 4 shows the trend of a

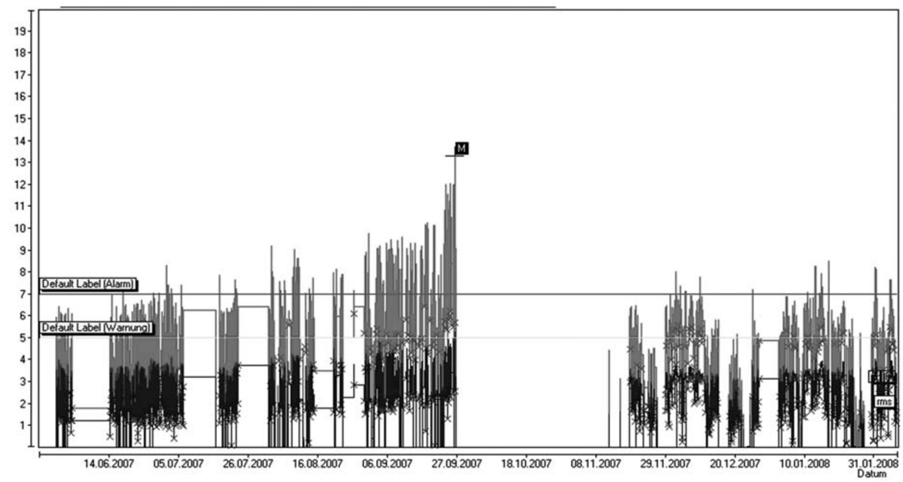

Fig. 4 Detecting generator faults early on. Machine damage can result in vibration increases

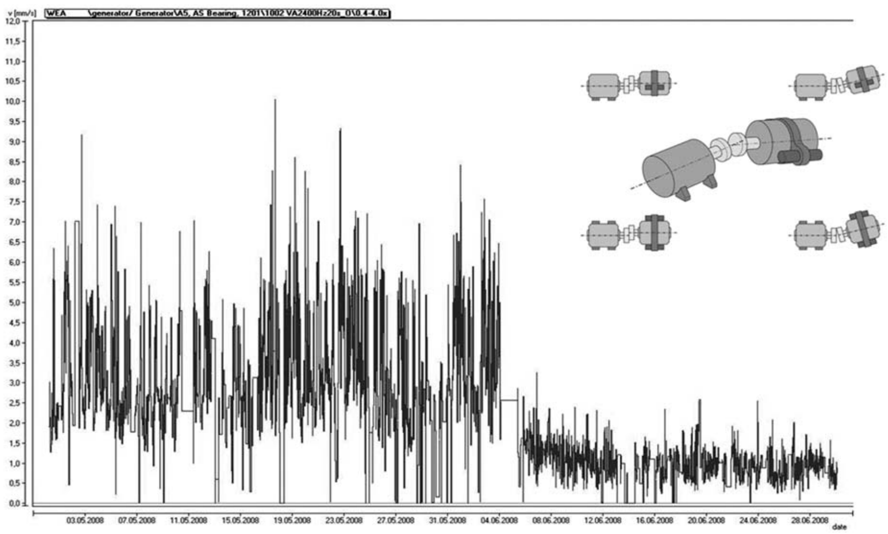

Fig. 5 Reducing vibrations. Alignment with alignment targets reduces generator vibrations

wind turbine generator in which an increase in vibration amplitudes indicated an impending machine fault several weeks in advance. After the generator was replaced, the overall vibration values returned to normal. It should be pointed out that such vibration changes only arise if the affected drive train component is dominant in the frequency band. Overall vibration values do not rise when the damage is not dominant in the amplitude spectra.

- **Identifying deviations in the machine alignment:** During telemonitoring of a wind turbine, elevated overall vibration values were detected. The frequency analyses showed additional vibrations due to poor machine alignment. The machine was then aligned according to siutable alignment targets[3]. The overall vibration values became significantly lower, as seen in Fig. 5.
- **Reducing rotor blade imbalances:** Rotor blade

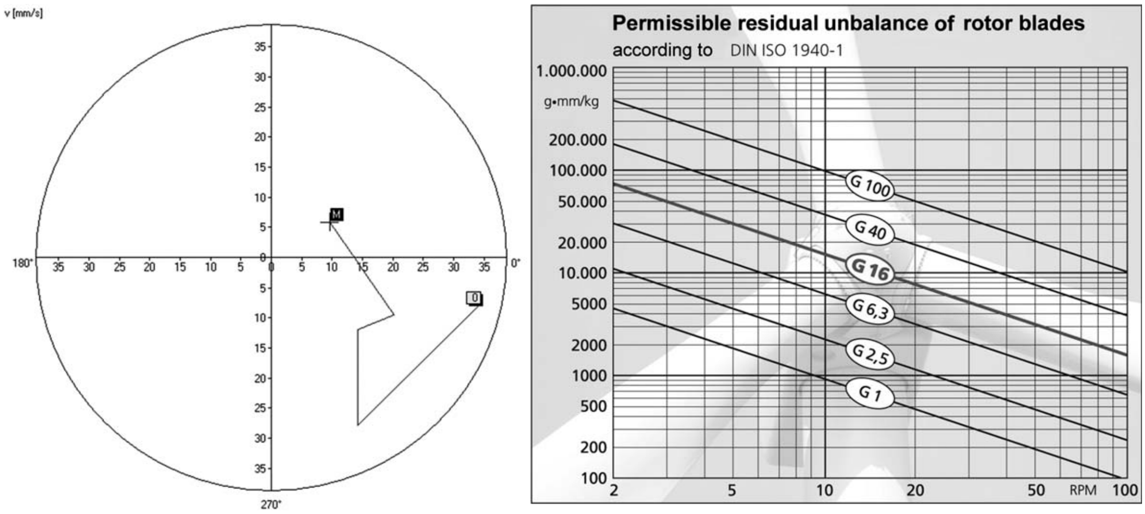

Fig. 6 Field balancing reduces nacelle and main bearing vibrations

imbalances lead to rotational excitations and e.g. increased loads on bearings and components. While they are of very low frequency in wind turbines, they can result in vibration amplitudes of 100 mm/s. Measurements must be taken with linear vibration sensors and longer measuring times, as prescribed by VDI 3834. Figure 6 shows the effect of field balancing on vibrations, applying the recommended G16 balancing grade for rotor blades(2). In this particular case, the additional vibrations, caused by imbalance, were actually reduced to the point where the difference was noticeable in the nacelle.

6. Outlook

These examples alone illustrate that the targeted use of measuring and testing techniques make it possible to reduce vibrations in already installed wind turbines. The VDI 3834 enables manufacturers and operators to assess the vibration condition of wind turbines and reduce them by implementing specific corrective measures in order to reach state of the art threshold levels. KSNVE

References

[1] VDI 3834 Sheet 1, Measurement and Evaluation of the Mechanical Vibration of Wind Energy Turbines and Their Components - Onshore Wind Energy Turbines with Gears.

[2] www.telediagnose.com, issue 12.

[3] Becker, E., Holstein, O., Determining Alignment Targets for Drive Trains in Wind Turbines. Erneuerbare Energien 10/2007.