PRÜFTECHNIK

Machinery Service

Reducing vibration by balancing rotor blades

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A technician taking measurements on a wind turbine.
The VIBXPERT balancing display (above).

Imbalance: A danger to components

Balancing of rotor blades to reduce vibration

Wind turbines are systems that are capable of vibration. To prolong the service life of wind turbine components, vibration should be kept as low as possible. Imbalance of rotor blades increases vibration levels unnecessarily. Therefore, after working on rotor blades and in new wind turbines, the balancing grade should be checked and, if necessary, improved.

Balancing machines and systems

According to DIN ISO 1940-1:2004, balancing is a "procedure by which the mass distribution of a rotor is checked and, if necessary, corrected to ensure that the residual imbalance or the rotational vibrations of the bearing journals and/or the bearing forces at operating speeds are restricted to within specific limits". [1] Imbalance differentiates between the 'gravity axis' and the rotating axis of the rotor.

Balancing of rotors, machines, propellers, fans, etc., is standard procedure in the general machine and plant industry. Balancing machines can be used, and/or the balancing procedure is performed in the machine or plant itself. On-site balancing is generally referred to as field balancing and is often the only method of achieving a favorable balancing grade in large machines. The required balancing grades for many different machine types are defined in DIN-ISO 1940. It is also common practice to simply use the permissible vibration velocities as per ISO 10816-3 as a measure of the required grade.

PRÜFTECHNIK has been working with the mobile hand-held measuring devices needed for field balancing since the nineties and offers balancing services in the various sectors. [2]

Balancing of wind turbines

Generators, gearboxes, couplings and brake discs are balanced in a manner similar to the method used in the general machine industry. For rotor blades in wind turbines, a balancing grade has not yet been defined and field balancing is not yet widespread. Service technicians make due with static weighing and trimming of the rotor blades and use carefully selected three-blade sets in wind turbines. However, information is accumulating that indicates that some 20% of wind turbines have an imbalance and run with raised rotational vibration and/or resonance excitation.[3] Other indicators of imbalance are when wind turbines are difficult to start up or when they switch off frequently. Possible causes of mass imbalance are fluid inclusions or damper damage. Also, it should be clear to everyone that repairs to a rotor blade change the mass conditions and thus invariably result in imbalance. Because re-weighing after a repair is extremely time intensive, it is rarely performed. Moreover, the replacement of individual rotor blades is no longer avoidable due to today's availability demands. For these reasons, it can be assumed that a mass imbalance will occur at some point.

Figure 1 lists further causes of imbalance in wind turbine rotors and rotor blades. In addition to mass imbalance, aerodynamic imbalance also plays an important role in wind turbine rotor blades. It can be reduced, for example, by correcting the blade angle. This article will not discuss aerodynamic imbalance.

Field balancing should take place at comparable speeds and under constant vibration conditions. This means that the necessary options and authorizations for 'running' the wind turbine must be available for field balancing. Wind speeds should not be too high.

Field balancing requires highly precise rotational speed measurements on the main rotor and a sufficiently long measurement period of the amplitudes and phase of very low frequency rotor vibrations. This places great demands on the sensor equipment, particularly for multi-megawatt units at low speeds. PRÜFTECHNIK has developed sensors that can handle this task. The variable that should be measured when field balancing is the vibration velocity, as in other sectors of industry as well. If the mobile measurement device is equipped with an automatic measurement signal processing system, the current balancing condition can be quickly assessed and the balancing weights suggested by the measuring device can be mounted and adjusted.

PRÜFTECHNIK integrated a special function in VIBXPERT designed specifically for wind turbines that enables the user to call up a polar diagram of the vectors during trim runs and to eliminate resonance influences.

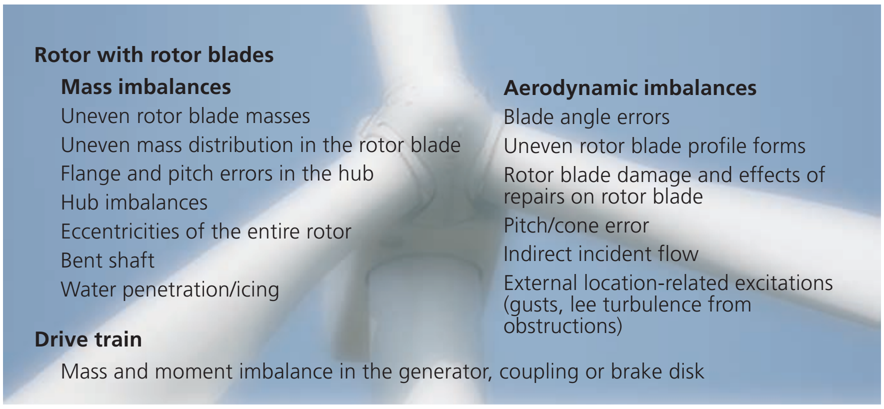

Fig. 1: Imbalance in the wind turbine can have many causes and results in premature wear.

What is the required balancing grade?

When the wind turbine is well-balanced, this can be felt in the nacelle. On the other hand, it is also possible to use characteristic overall vibration values as a reference. These values are defined in the new VDI 3834 in the frequency range of 0.1 Hz to 10 Hz (for the nacelle see Fig. 2a). The permissible residual imbalance can be derived from the nomogram shown in Figure 2b as a function of the rotor speed. This nomogram is based on DIN ISO 1940-1 [1] and the balancing grades G 1 to G 100 were extrapolated in this view from 20 rpm to 2 rpm. Balancing grade G 16 is shown in bold in Figure 2b. It also applies to propellers, and PRÜFTECHNIK has had good experience with this balancing grade in wind turbine service calls.

This nomogram can also be used to assess whether vibrations can be influenced at all by applying additional weights close to

Fig. 2a: Overall vibration values (nacelle)

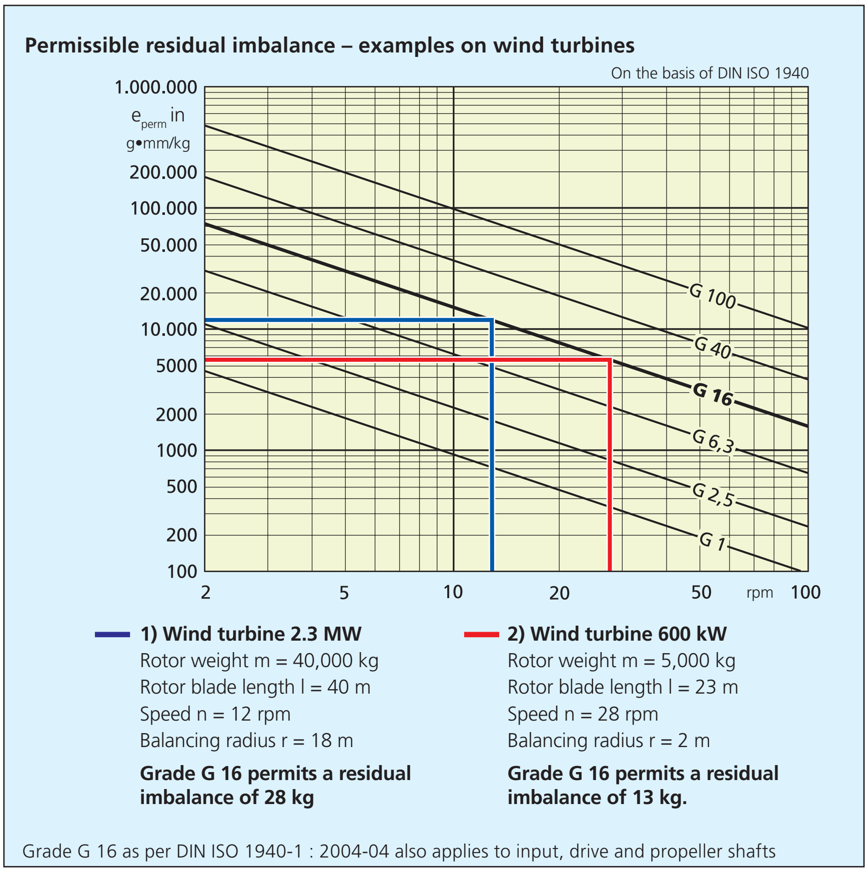

Fig. 2b: Permissible specific residual imbalance as a function of the balancing grade G and the operating speed n.

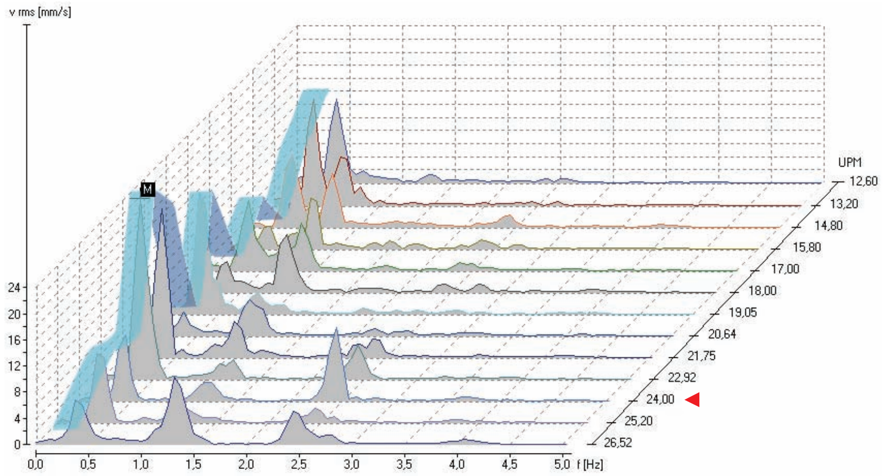

Fig. 3: Coast-down spectra of a gearless wind turbine

the rotor hub, or whether it would be better to apply additional weights to the rotor blades from the start. Two sample calculations are included with Figure 2b.

These assessments show that to be able to balance multi-megawatt units, additional means should be provided inside the rotor blades that make it possible to securely mount and remove weights. These facilities should be provided by the manufacturer and should be independent of the (closed) balancing chambers.

Measuring equipment and procedure

The two photos at the beginning of the article show a small wind turbine being balanced and the VIBXPERT screen during the balancing run. The first step is to apply a reflective mark to the main rotor shaft. The RPM sensor is directed onto the reflective mark, and an accelerometer that can take linear measurements beginning at 0.1 Hz is mounted on the main bearing, preferably in the horizontal measurement direction. Then a diagnosis measurement is performed to check whether the rotor blade rotational frequency is in fact dominant in the frequency spectrum. If so, balancing can begin. If not, a measurement point with significant amplitudes is searched out.

If the vibration behavior of the wind turbine is unknown, coast-down spectra of the vibration velocity should be measured over the operating speed range. To do this, the wind turbine is gradually slowed down from the rated speed while low frequency spectra of the vibration velocity are measured with VIBXPERT. The respective rotational speeds (UPM) are shown in the waterfall spectrum in Figure 3. Now it is relatively easy to quickly assess the speeds at which the wind turbine can be balanced without disturbing influences. In the example shown here, field balancing is readily possible above 24 rpm. Speeds of 23 rpm, for example, should be avoided since resonance peaks occur here. If these measurement results are available for the turbine the next time the rotor is balanced, the correct rotational speed can be used from the start. However, the initial vibration condition should always be documented by taking a diagnosis measurement prior to balancing.

Fig. 4: Mounting balancing weights

In the next step, the balancing menu is started in VIBXPERT. The setting for single-plane balancing is used because the rotor with the rotor blades approximates a disc. The rotor mass, balancing radii and the desired balancing grade are entered in the associated machine manager.

Field balancing in four steps

The field balancing procedure itself can now begin. Single-plane balancing consists of the following four steps:

Determining the imbalance

Initial imbalance is the imbalance present in the entire rotor prior to balancing. The measurement is started using the joystick navigation feature of VIBXPERT.

Determining the trial mass and measuring its effect

The required trial mass is determined by VIBXPERT and defined by taking into account the three rotor blades (as a fixed position correction). Applying (or reducing) the trial mass can also be used to "become familiar with the balancing system". In smaller wind turbines, the trial masses can be mounted with a tie-down strap and additional weights. [2] Alternatively, as shown in Figure 4, additional weights can be mounted in the hub area.

The trial mass should cause a significant change of the vibration pointer in the

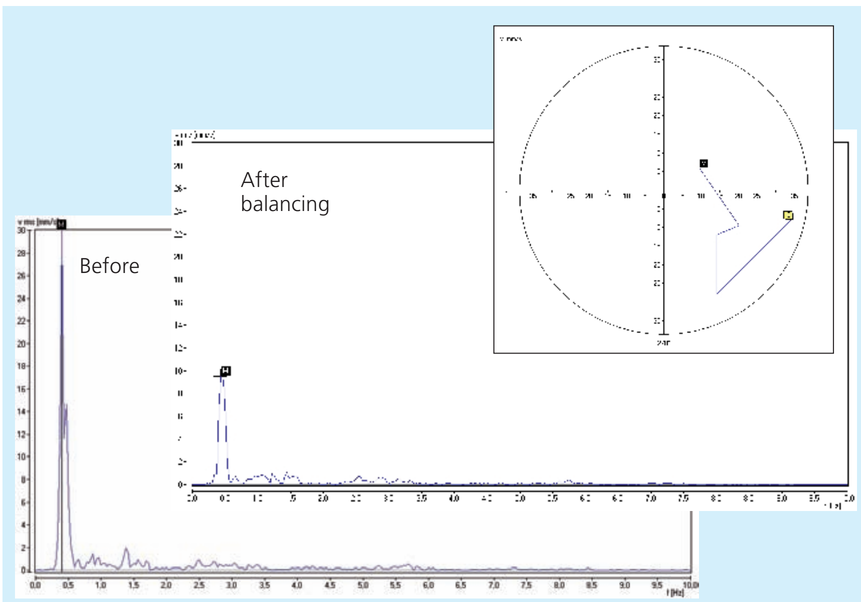

Fig. 5: Frequency spectra before/after balancing, and balancing diagram

VIBXPERT display since it serves as a basis for the calculation of the balancing mass. VIBXPERT suggests balancing masses, and the weights actually used are entered.

Applying balancing masses and performing trial and trim runs

The VIBXPERT balancing software is also used for the subsequent trial and trim runs. The suggested balancing weights are mounted and the trim run is repeated.

As is the case when balancing industrial machines, two to four runs are needed to find suitable balancing masses. In the end, a certain residual imbalance will remain: PRÜFTECHNIK has found that G 16 is a reasonable grade to strive for.

Repeating the diagnosis measurement

After the balancing runs are completed, the diagnosis measurement is repeated and compared with the initial condition. If the rotational excitations are now lower, the balancing procedure was successful. Often, natural frequency exitations will be lower as well.

Outlook

The wind sector is not yet obligated to present proof of the balancing grade since rotor and wind turbine manufacturers have up to now been required to use statically balanced three-blade sets. Also, it is not yet possible to easily attach balance weights in a reversible manner in the neutral plane of the rotor blade. It is likely only a matter of time before rotor blades will be kept at a certain balancing grade by means of balancing pumps, for example. [5]

Ultimately, measures such as these will improve wind turbine performance and reduce premature wear in roller bearings and in the gearboxes of the classical drive train design with a three-point mount system.

Bibliography

[1] DIN ISO 1940-1, Edition 2004: “Mechanische Schwingungen- Anforderungen an die Auswuchtgüte von Rotoren in konstantem Zustand, Teil 1: Festlegung und Nachprüfung der Unwuchttoleranz”.

[2] www.telediagnose.com, Issue 11 and Issue 12

[3] VDI 3834, April 2009 “Messung und Beurteilung der mechanischen Schwingungen von Windenergieanlagen und deren Komponenten – Onshore-Windenergieanlagen mit Getrieben”

[4] A. Grunwald, M. Melstein, C. Heilmann, J. Liersch “Unwuchtbestimmung mit Ampelfunktion”, Erneuerbare Energien 08/2007.

[5] DE 102008023109 A1 2009.03.19

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