VIBRATION ANALYSIS OF ROTOR BLADES AND BALANCING OF ROTORS ON WIND TURBINES

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Summary

Vibration excitations at wind power plants are caused by different reasons. Unbalance of a rotor influences the excitation of vibration specially. These unbalances have to be balanced definitely, to ensure a non-vibration and reliable operation of wind turbines. The balancing in operation can be used for balancing of wind turbines.

1. Introduction

Wind tubines are built on a slim and high tower. The rigidity of the tower of the most plants is very slight. So it comes very fast to vibration excitations in cause of the heavily nacelle and the big rotor. Mass unbalances are the main cause of vibration excitations in transverse direction to the rotor shaft. Often wind turbines are laid out so, that the natural frequency of the tower is in the range of the operation revolutions. This range of revolution must be drive through fast, to exclude vibration excitations of the tower.

2. Reasons for unbalances at wind turbines

Unbalances caused by different masses of the rotor blades at wind turbines have different reasons:

- False or unsatisfied balancing by the rotor blade manufacturer
- Material fault (e.g. varied mass distribution, varied material thickness)
- Operational faults (e.g. water inside the blade tip, ice sticking to the blade surface,
- Mass changes by extensive repairs of the rotor blades

These reasons for unbalances must be eliminated for a non-failure and reliable operation of wind turbines.

3. Aim and purpose of balancing

It is necessary to avoid the rotor unbalance, about keep the vibrations of the nacelle and the tower on a low level. The highest unbalances at wind turbines arise from high mass moment of inertia. If such an unbalance is detected, the rotor blades should be balanced with a balancing device.

By balancing the bearing loads and the excitations of nacelle and tower vibrations could get on a bearable level. The operational reliability of the wind turbine increases and a continuous operation is guaranteed. The influences to the operational reliability play a big financial roll for the wind turbine operator.

4. Physical backgrounds for mass unbalances

The centre of gravity S will move with the amount e out of the rotation axis, if an unbalance mass u is attached to a disc with the mass m at the radius r. So the mass symmetric of the rotor or the disc is disturbed respectively. At the rotating unbalanced rotor work centrifugal forces caused by the unbalance mass. These centrifugal forces with the unbalance cause a device to vibrations with the rotational frequency. The dimension of the vibrations depends on the dynamic behaviour of the device; it especially depends on the dynamic stiffness. Wind turbines have mostly little stiffness because of the high and softly laid out tower. That's why little unbalances, especially unbalances at the rotational frequency near the natural frequency of the tower lead to high vibration amplitudes.

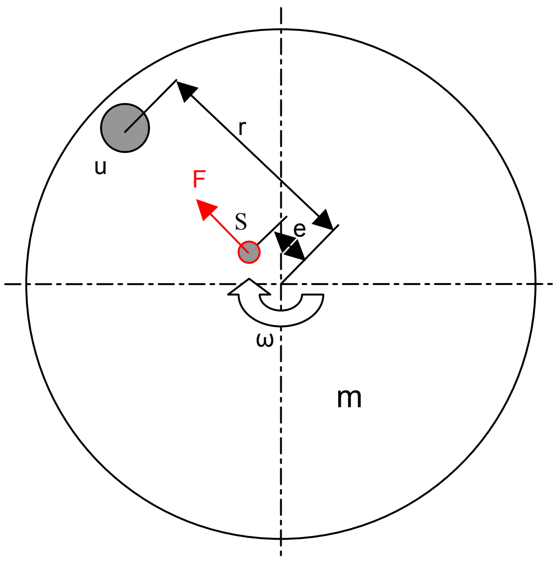

Fig. 1: Rotational disk with an eccentric centre of gravity

Mass unbalances at wind turbines can be compensated by static operation balancing. Balancing means that the free centrifugal forces at the rotor decrease the effect on the bearing and the bearing isn't strained by periodic forces and forces with rotational frequency. The effect of the free centrifugal forces is influenced by the mass distribution of a rotor. At a balanced rotor the central axis of inertia corresponds with the shaft axis. The rotor has to be in a dynamic balance that means, all forces which attack the rotor are balanced.

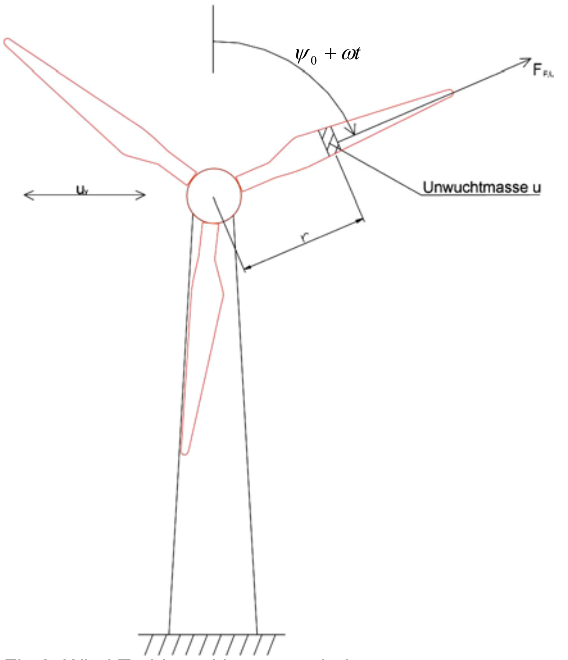

Fig 2: Wind Turbine with mass unbalance

The balancing belongs at first determining of the main balancing corrections then the balancing with masses for correction and finally the control of the reached balancing quality.

Figure 3 shows a vibration spectrum of a wind turbine without unbalance. Otherwise figure 4 shows a spectrum with a huge unbalance.

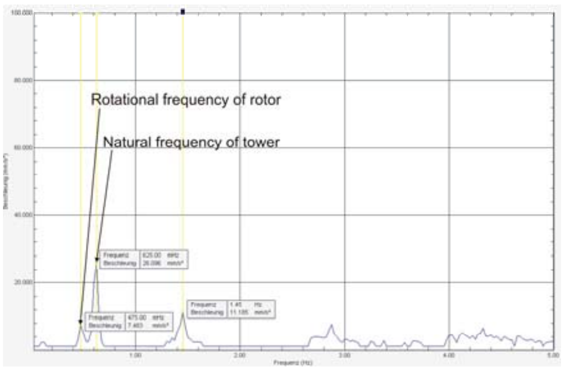

Fig. 3: Vibration spectrum of wind turbine without mass unbalance

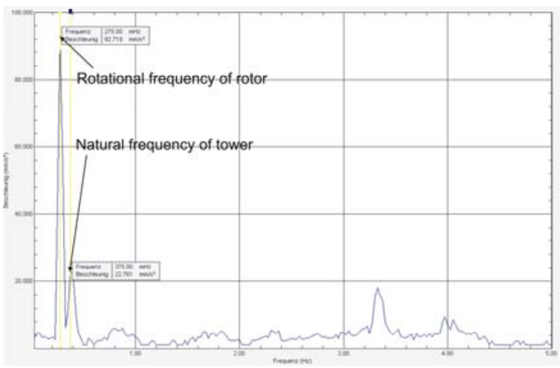

Fig. 4: Vibration spectrum of a wind turbine with a huge mass unbalance

5. Balancing in operation of wind turbines

For balancing wind turbines we use a compact and mobile measuring device (Brüel&Kjær). With this measuring device we want to carry on the static operation balancing.

The balancing in operation based on the following principle:

The measured vibration vectors are calibrated and adjusted with attached test masses, whose mass is known. With the measured values the real unbalance can be determined and removed.

Criterions of the balancing:

- the reasons for the high vibrations are known; or after the analysis of the vibration behaviour it was find out, that unbalancing is a ensured and practicable handling
- the unbalancing should be carried out, if the rotational vibrations a significant part of the system vibration of the wind turbine
- the vibration vector which was find out during the normal operational conditions through balancing should be static and reproducible

5.1 Measurements for Balancing

The mass unbalance of the rotor is indirectly determined by the resulting unbalance vibrations which force the main bearing. The absolute bearing vibrations are detected with a piezoelectric accelerometer which measures in a low frequency level from 0,1 Hz upwards. For the application of the static operational balancing at wind turbines it is sufficient to measure the vibration in only one measuring plane. The measuring plane should be near to the balance plane. The balance plane corresponds to the rotation plane and the measuring plane should correspond to the main bearing. The main bearing can be chosen only in the case of no determined aerodynamic unbalance at the wind turbine.

A trigger sensor measures the relative angle coordination to the place of the detected unbalance. The vector of the detected unbalance is saved in the measuring device. Than a test mass with a determined weight is installed at any place at the rotor. While the 2. Measurement the device measures by the vector of the detected unbalance and the vector caused by the test mass the real necessary balance weight with the according place for the balancing. After attaching the balance weight a next control measurement is necessary to determine the rest unbalance. If the effect of the balance weight isn't reduced enough the measuring device suggest an additional balance weight. This step will repeated until the unbalance vibrations are reduced to an acceptable level.

The balancing of wind turbines have to carry out at a permanent operational rotation speed similar to conventional turbines. That's why the syncronisation of the measuring signal with the rotational frequency of the rotor by an optoelectronic trigger. The measured system frequency is related to rotational frequency of the rotor and the sinus vibration caused by the unbalance filtered. This handling is called frequency-selected measuring. Anyway the unbalance effects depend on the rotational speed, because by increasing of rotational speed the unbalance increases too. In this case wind turbines with fixed speed have no problem, but they should balance at the highest gear level to eliminate the high vibration amplitudes. At wind turbines with variable speed the unit control has to be adjusted to a fixed speed. Anyway, at balancing you should keep attention that the rotational speed doesn't work to the resonance range of the turbine to avoid rough measuring fault.

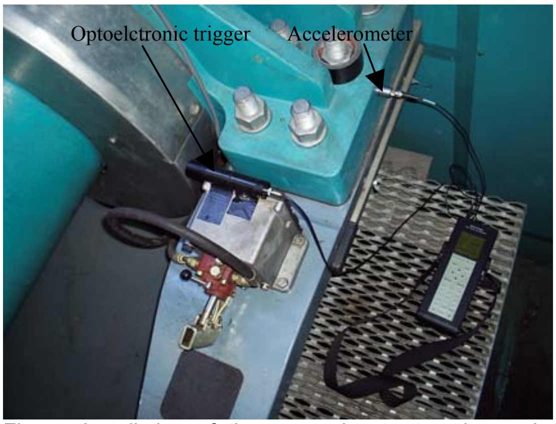

Fig. 5: Installation of the measuring system in a wind turbine

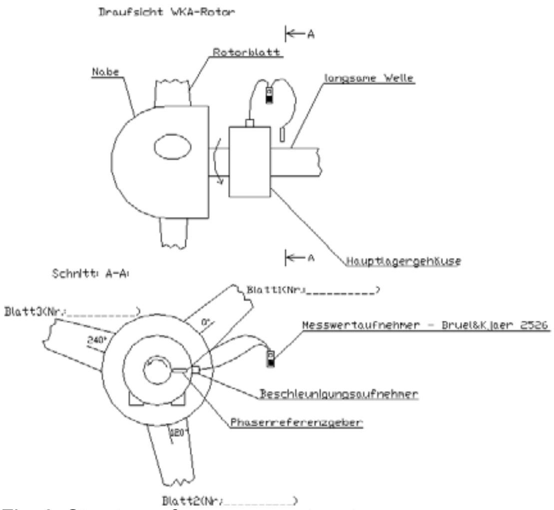

Fig. 6: Structure of measurement system

5.2 Selection and attachment of test weight

For operating balance must be attached a test weight at the rotor, to determinate the connection between unbalance and vibration. The used test weights should be practicable in handling and should be installed fast at a rotor blade. As test weights are suitable leads used in diving sport. These are attached with clamping belts at the blade root at a radius of 3-5 m.

Fig. 7: Attachment of test weights at the blade root

The mass of the test weights must cause an alteration of the unbalance vector, which is clearly measurable. It is necessary to try out, which masses cause a sufficient vector alteration at the respective rotor. For the accuracy of the computed balancing masses it is needed especially the quantity of the vector alteration. The relative error is substantially higher, when the vector alteration is too small. This error affects to the computed balancing masses.

To attach the test weights at a larger radius of the rotor, it's possible to install the weights inside the blades. It is necessary to install the test weights in a special construction. Some blades have threaded rods at a large radius, to attach balancing weights. These could be used for attachment of the test weights, too.

Fig. 8: Threaded rods for balancing weights in a rotor blade

6. Conclusion

The big rotor regards as a disc and is the balance level. Such big rotors could have a substantial unbalance, which can reach an order of magnitude of several 100 kgm. Rotor blades can be balanced at an installed condition. With the static operation balancing with vibration measuring technique could be reached a high balancing quality. Possible early disconnections or retarded starts can be prevented by balancing of rotor blades. In addition it can be ensured a non-vibration operation of wind turbines.