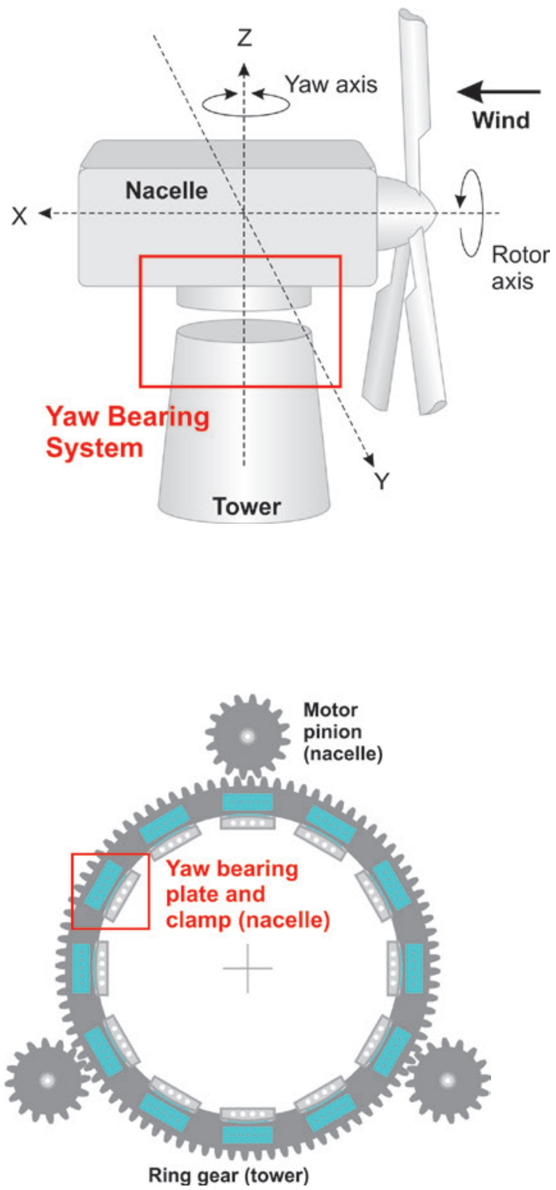
CASE STUDY

YAW BEARING SYSTEM FAULT DETECTED

Two case studies demonstrate how an effective remote condition monitoring strategy avoids uneconomical operation, costly downtime and consequential damage of wind turbines

After remotely monitoring several thousand wind turbines over the past 10 years, most of the wind turbine faults detected and diagnosed by the Brüel & Kjær Vibro Surveillance Centres have been related to the drive train. In this article, we give two case stories where the faults were detected and diagnosed in an entirely different but important component; the yaw bearing system. It is this system that bears the enormous static and dynamic loads of the nacelle and blades, and allows the nacelle to align itself into the wind.

The root cause in both case stories is the same but the fault manifested itself differently in each case, although the wind turbines were similar.



YAW BEARING SYSTEM

Located between the nacelle and tower (Figure 1, top), this system allows the nacelle to rotate on the tower to align the blades in the direction of the wind. If the blades are not perpendicular to the wind, the wind turbine will not be producing the maximum potential power and will be losing revenue. The yaw bearing system is also designed to bear the static weight of the nacelle, as well as resist the enormous dynamic loads that occur due the rotating drive train and blades.

The system consists of a toothed ring gear that is fixed to the tower (Figure 1, bottom). Yaw motors turn several pinion gears on the ring gear to rotate the nacelle. The load bearing components consist of axial and radial glide bearing pad segments that sit on the ring gear, as shown in Figure 1 (bottom). The bearing pad normally includes a pre-tensioning system, which consists of a spring and an adjustment screw, as shown in Figure 2. This ensures that there is no looseness between the glide bearing segments and the ring gear, and that there is even wear on all the guide bearings. If the glide bearings are not properly pre-tensioned, this can damage the glide bearings and adversely affect the ability of the nacelle to turn.

Figure 1. *The yaw bearing system on a wind turbine (top) aligns the blades to the wind. It consists of the ring gear, yaw motor and the yaw bearing clamp assemblies (bottom, looking down from the nacelle).*

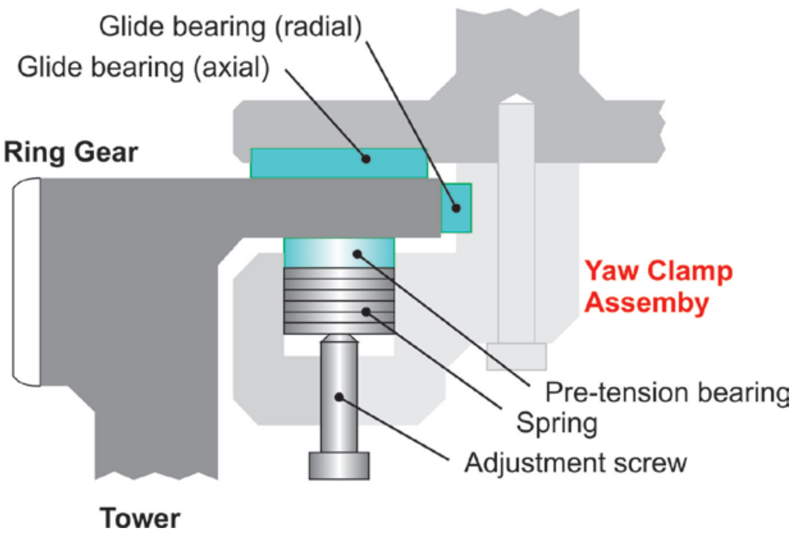


Figure 2. *Cross-section of the yaw clamp assembly on the ring gear.*

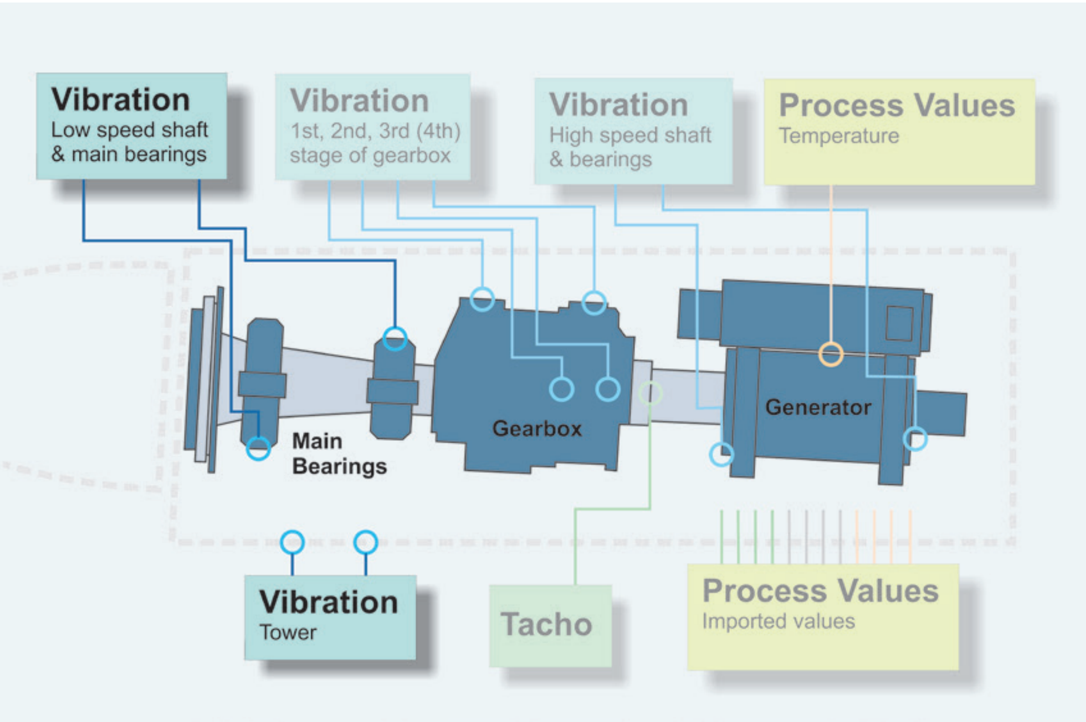
OBSERVATIONS

The Brüel & Kjær Vibro Surveillance Centres have been remotely monitoring many different kinds of faults, but these two cases were unique. The monitoring system configuration for detecting the faults is shown in Figure 3.

Case 1: The vibration descriptors of the signal from the accelerometers located on the main bearing (not shown) and on the tower (Figure 4, top) for a wind turbine exceeded the alert limits in February 2013. The overall RMS vibration signal, not shown, remained within acceptable limits. There were no faults found in the main bearing or blades, so the spring packs on the yaw clamp assemblies were replaced and the wind turbine put back into operation in May 2013, where the vibration levels returned to normal. The vibration increased again more dramatically in September 2013.

Case 2: The tower accelerometers for a wind turbine at another wind park showed an immediate and abrupt change as indicated on the bottom in Figure 4, exceeding the danger alarm limits. Monitoring focus was subsequently placed on the blade/main rotor assembly, the main bearing, and the yaw bearing system.

Figure 3. *Typical monitoring strategy for a wind turbine like the one in this case story. The accelerometers located on the tower and the main bearing detected the yaw bearing system fault.*



INTERPRETATION

The fault detected appeared to be unique. The time signals for both wind turbines proved to be ideal for the initial analysis.

Case 1: At both times, in February 2013 and September 2013, there appeared to be a random impact seen in the time signal from the accelerometers on the tower (Figure 5, top) and main bearing (not shown). Because of the randomness of the impacts, it was initially difficult to pinpoint the exact cause, as the problem could be related to the blades, main bearing or the yaw bearing system. No problems were found in either the blades or the main bearing, so the yaw bearing system was suspect. The spring packs for the yaw bearing clamp assemblies were replaced in May 2013 and the high vibrations disappeared. The high vibrations returned again in September 2013 unexpectedly. Again the yaw bearing system is suspect.

Case 2: The time signal shown in Figure 5 (bottom) indicated a periodic impact that corresponded to two times the main rotor running speed. This periodic impact was assumed to be related to the blades and/or the yaw bearing system.

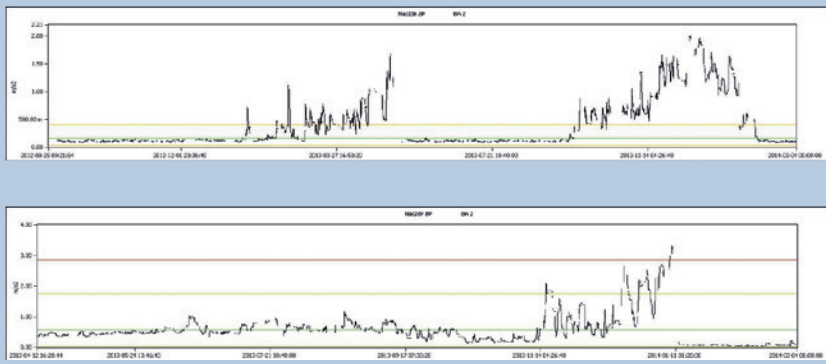


Figure 4. *Case 1 (top, before and after repair) and Case 2 (bottom, before and after repair): Bandpass acceleration vibration descriptors from the tower accelerometers.*

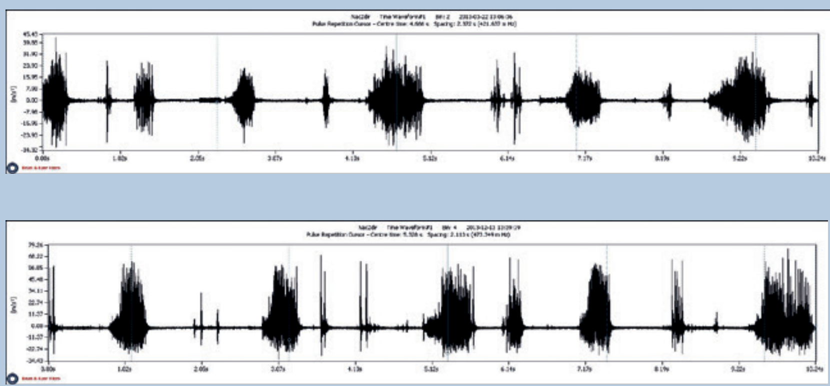


Figure 5. *Case 1 (top) and Case 2 (bottom): A vibration impact signal is visible in both plots. For Case 1 (top) it appears random while for Case 2 it occurs twice every rotation.*

ADVICE/ACTION

The severity level of the faults and the recommended service action time were different for the two wind turbines.

Case 1: Both faults were a unique occurrence for the wind park. A medium severity level was initially assigned to the first fault because it was present for some time and it never exceeded the danger limits. A higher severity was assigned to the second occurrence of the fault, partly because it was more dramatic, and because it was the second time the same fault symptoms occurred. In both cases the fault development was carefully followed.

Case 2: A high severity was assigned to this fault because of the very rapid vibration level increase combined with the fact that the danger alarm limits were violated. This was also partly based on the experience and feedback gained from Case 1. Recommended service time was 4 weeks.

FEEDBACK AFTER SERVICE

Case 1: When the wind turbine was shut down for the first time, the main bearing and blades were checked and found to be OK, so attention was given to the yaw bearing system. It was decided to change all the pre-tensioning spring packs in the system. When the wind turbine was re-started, the vibration levels returned to normal (Figure 4, top). However after only three and a half months operation, the same fault symptoms occurred again, but more dramatically. The yaw bearing system was disassembled again, and this time it was observed that many of the axial gliding bearing plates were damaged. These were re-machined, the spring packs changed a second time and the wind turbine was put back into normal operation. It is believed that the yaw plates were damaged due to a rocking motion of the nacelle on the tower, caused by the loose yaw bearings. The random motion of the rocking is believed to be due to the variable wind conditions and loading. There was no imbalance in the blades that would "tie in" the rocking motion of the nacelle to the rotation of the blades (as what occurred in Case 2). Over an extended period of time with loose bearings, the bearing plates were damaged by the continuous impacts to a point where the new pre-tensioning springs weren't capable of compensating for this.

Case 2: Both the blades and the yaw bearing system were inspected. The blades were found to be out of balance, and around 60% of the yaw clamp assemblies had loose pre-tensioning screws. The combined effect of this resulted in a rocking motion of the nacelle on the yaw bearing system. This created the impact signature seen in the time signal (Figure 5, bottom), as one of the specific blades reached the 12 and 6 o'clock positions (2 vibration impacts for each rotation). After re-balancing the blades and tightening the pre-tensioning screws, the wind turbine vibration signature returned to normal. As a result of the unique occurrence of this yaw bearing system fault in Case 1, the detection and diagnosis techniques were quickly optimized by the time Case 2 occurred.

CONCLUSION

Both of these case stories demonstrate that there are critical components in the wind turbine other than the drive train that needs to be effectively monitored, like the yaw bearing system. Case 1 demonstrates that there can be more than one problem occurring at the same time. If the loose yaw plate bearings were not monitored and serviced in time, a catastrophic failure could occur that would render the yaw system non-functional, thus requiring a complete shutdown or operating at only partial power for a period of time.

ACKNOWLEDGEMENT

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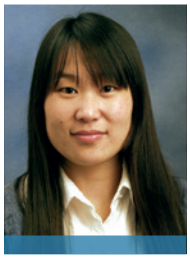


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