ARE TRANSIENT EVENTS DAMAGING YOUR TURBINE'S DRIVETRAIN?

Searching for the root causes of White Etch Area damage and other failure modes.

By Doug Herr and Dave Heidenreich

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INTRODUCTION

Wind turbine bearings and gearbox life issues have long plagued the wind industry. Since 2007, NREL has focused on industry solutions with their Gearbox Reliability Collaborative (GRC). They have used the NEG Micon 750 KW NM48 wind turbine as their study model. Recent meetings at the GRC have highlighted WEA damage as a common denominator in wind gearbox problems and impact loading as a potential root cause. But where are these impact loads coming from?

In May, 2011, AeroTorque (then known as PT Tech Windproducts) partnered with a wind farm in the United States to study transient load events in their NEG Micon NM48 750kW wind turbines using AeroTorque's new torque monitoring system, the WindTM.™ Phase I focused on understanding the magnitude and frequency of transient torque reversals in the drive system. These reversals are known to cause concentrated loading on skewed bearing rollers, which could potentially initiate White Etch Area (WEA) damage in bearing races. These damaging reverse loads impact bearings and gears in the gearbox and are suspected of shortening the life of all drive system components, including blades and generators. Generally, the greater the

reverse loads and the more often they occur, the shorter the life of any highly stressed component. If significant torque reversals were measured, Phase II would evaluate a new type of asymmetrical torque control device, the WindTC,™ capable of reducing both the magnitude and the frequency of the torsional reversals. If the WindTC effectively damped the reverse vibrations, Phase III would be to begin retrofitting these turbines with the WindTC.

RESULTS SUMMARY

Phase I: One of the wind turbines was shut down for three hours to install the WindTM, monitor. Data was collected for several months, with the WindTM, recording numerous transient torque reversal events. More importantly, each event resulted in several actual reversals, as the mass of the rotor and the mass of the generator wound up against each other and unwound back and forth in a classic torsional ringing action. Enough evidence was collected to proceed to phase II.

Phase II: The first turbine with the WindTM, was retrofitted with a prototype WindTC Torque Control, and a second nearby turbine was equipped with an additional WindTM, to evaluate the two turbines operating during the same events. Again, numerous transient torque reversal events were recorded on both turbines. In every torque reversal event on the asymmetric torque limiter equipped turbine, the first negative torque was controlled to a maximum level of 40 percent of nominal turbine rating. The turbine without the WindTC recorded torque reversals as high as 80 percent of nominal turbine rating and typically several additional torque reversals followed the first in each event. Surprisingly, the slight amount

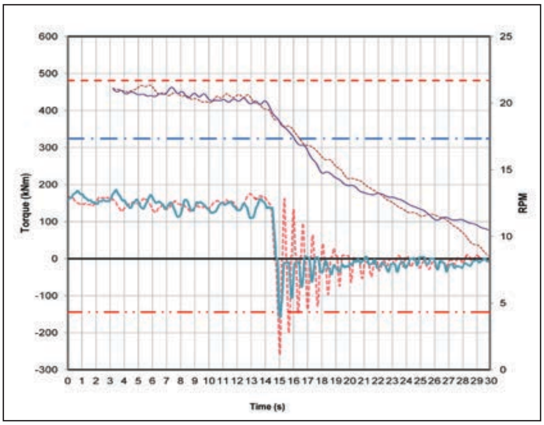


Figure 1

of slippage in the WindTC during the first reversal so effectively damped the torsional vibration that no additional torque reversals were recorded. The maximum torque reversal magnitude was cut in half, and the total number of torque reversals was reduced by more than 80 percent.

The WindTC also provided torque protection in the forward direction. During Phase II, some up-shifting events on the unprotected turbine resulted in 200 percent forward torque overloads. The turbine with the WindTC during the same event had forward torque overloads effectively limited to 150 percent of rated turbine torque.

After several months of flawless operation, the WindTC was replaced with a second prototype unit. The first prototype was returned for a thorough disassembly and inspection. It was found to be in

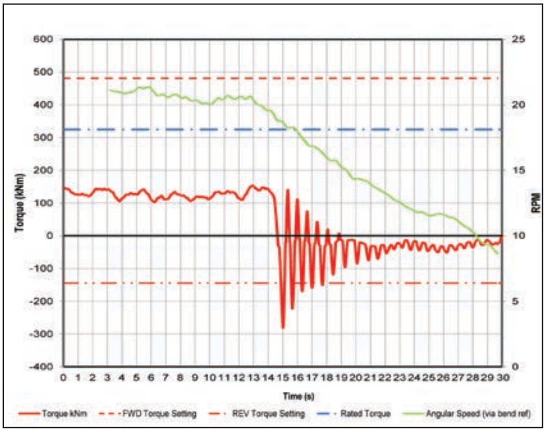
excellent condition, with no measurable wear in either forward or reverse slip components. Wear life is projected to be 10–20 years with minimal maintenance.

As a result of the data collected in Phase I and Phase II, the wind farm has begun Phase III, the process of retrofitting their turbines with the WindTC. Future reports on this case study will include data on the effectiveness in reducing damage to bearings and gears, and reducing O&M costs of all drive components.

A DETAILED LOOK AT PHASE I

WindTM Torque Monitoring Installation: AeroTorque partnered with JR Dynamics, to develop the WindTM, a torque monitoring device, which allows for real-time torque measurement in a wind turbine drivetrain.

The WindTM monitor was magnetically mounted to the main shaft of the turbine, allowing for quick installation and removal. The on-shaft unit communicated to a transceiver that allowed remote access to the data accumulated via cellular network. Strain gauges on the main shaft measured both torsion and bending. The cycling rate of the bending load in the shaft provided a measurement of the speed. The monitoring unit continuously fed the data into a buffer.



Looking for transient event data with continuous measurements can be like looking for a needle in a haystack. The WindTM was designed to only record the worst 100 forward torque events and worst 100 reverse torque events over any monitoring period. It does this by continuously feeding the data into a buffer. When a significant torque transient occurs, the WindTM records the eight seconds prior to the event and continues recording for 45 seconds. It discards all the data in between the significant 200 events. The events are also time-stamped to allow for syncing with SCADA and other data sources.

Phase 1 Monitoring: Numerous torque reversal events were recorded during Phase I, occurring almost daily.

This plot shows the results of a normal braking event on this turbine. The aero-tips have deployed while the turbine is operating under partial power.

Note:

- Black line is zero torque
- Red line is actual torque
- Dashed blue line is nominal torque.
- Dashed red lines are standard torque limiter settings

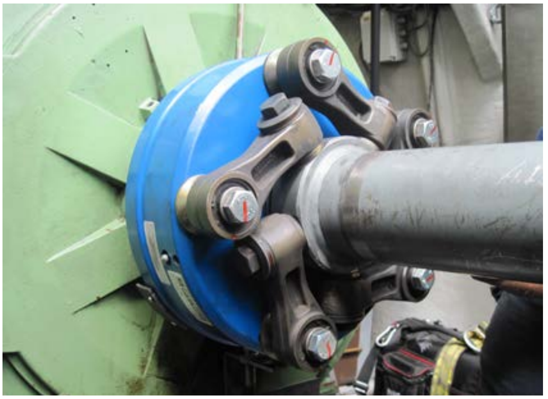
When the aero brake engages, the torque spikes in the negative direction, causing the system to wind up and unwind back and forth in the reverse and forward directions. Each time the torque crosses the black zero line, the load zone on every bearing in the gearbox shifts approximately 180 degrees in the opposite direction. In this instance, it occurs 11 times.

Many plots similar to the one you see here were recorded, in all types of wind conditions. Surprisingly, even when the turbine power was minimal at the time of the aero braking event, similar transient reverse torque loads were experienced by the gearbox and drive system.

PHASE II

WindTC Installation: After seven months of monitoring, the new WindTC was installed on the test turbine. In addition, a nearby turbine was installed with a second WindTM torque monitoring device. This allowed for direct comparison testing of turbine drivetrain loads during the same events.

The WindTC is the first torque limiter with asymmetric, independent settings for forward and reverse torques in a drivetrain. Standard torque limiters used in some wind turbines have one setting, usually 150–180 percent of nominal turbine torque. This limits only very large transient torque spikes in both directions. Drivetrains are designed to handle these loads in the forward direction. JR Dynamics has instrumented the rollers in gearbox bearings on other wind turbines and found that during torque reversals the rollers in the bearings are skewed when these reversals occur. This causes concentrated loading of the rollers and damage to the rollers and races (to see



this data, request a copy of the Gear Solutions article, “Troubleshooting Wind Gearbox Problems” February 2010). The concentrated impact loading during torque reversals may be a root cause of White Etch Area (WEA) damage to the bearings that is known to dramatically shorten bearing and gearbox life in wind turbines. The WindTC is designed to limit the reverse loads to 40 percent of forward torque setting (approximately 25 percent of nominal) and to dampen the overall torsional vibration.

Reverse Slip Events

This data plot (Figure 2) is a representative sample of many collected over several months, comparing the

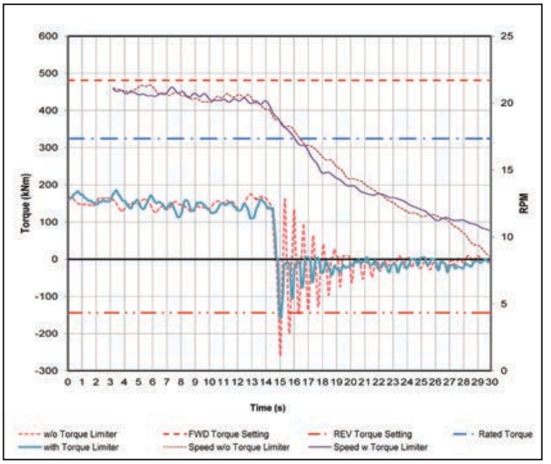


Figure 2

actual torque loads in the turbine drive systems with and without the WindTC.

This plot shows the results of a normal braking event on two turbines, one with the WindTC (blue solid line) and one without (red dotted line). The aero-tips have deployed while the turbines are operating under partial power.

Note:

- Black line is zero torque
- Solid blue line is the torque with the WindTC

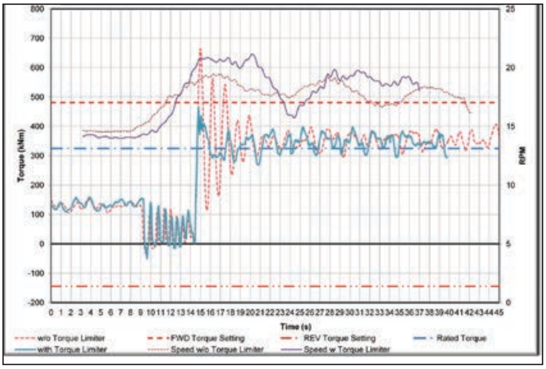


Figure 3

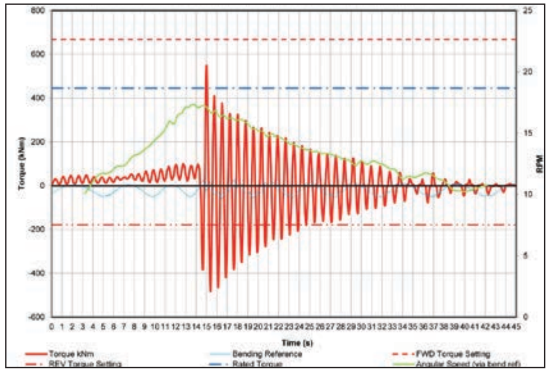


Figure 4: Nordex N54 – 1 MW Braking event

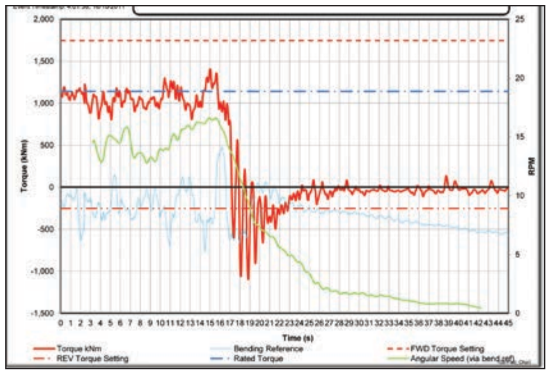


Figure 5: Gamesa G87 – 2 MW High Wind Shutdown

- Red dotted line is torque without the WindTC
- Dashed blue line is nominal torque
- Dashed red lines are standard torque limiter settings
- Dashed maroon and purple lines show low-speed shaft speed

Without the WindTC, (dotted red), there is a large uncontrolled torque reversal at 75 percent of nominal turbine rating followed by a series of torque reversals back and forth over the zero torque line. The turbine equipped with a WindTC, from PT Tech (solid blue line), shows the initial reverse torque spike being absorbed at 40 percent of the nominal turbine rating. More importantly, the slight reverse torque slippage in the WindTC dampens the torsional vibration so effectively that no additional reversals are recorded.

Forward Slip Torque Event: The NEG Micon NM 48 is a two-speed turbine that is not equipped with any torque limiting device. This plot (Figure 3) shows the comparison during an upshift event of the two turbines. The generators are operating at low speed. As wind speed increases, the low speed generators are disengaged, and the wind turbine speeds up as the high speed generators contactors engage.

Note:

- Black line is zero torque
- Solid blue line is the torque with the WindTC
- Red dotted line is torque without the WindTC
- Dashed blue line is nominal torque
- Dashed red lines are standard torque limiter settings
- Dashed maroon and purple lines show low-speed shaft

The turbine without the WindTC protection sees a torque spike of 200 percent when changing from one set of contactors to another. The turbine with the WindTC is protected from this spike at its 150 percent setting and also prevents significant additional oscillations that are potentially damaging, even though they don't cross the zero torque line.

CONCLUSION

The Phase II testing proved the effectiveness of the WindTC's ability to reduce the magnitude of both positive and negative transient torque spikes in the drive system. It also proved its effectiveness at dampening any additional torsional reversals after the initial slip event. As a result of these findings, the wind farm has initiated a program to retrofit their NEG Micon NM48 750kW wind turbines with the WindTC. Additional testing on other turbines has shown that torque reversals are not unique to the NEG Micon or to fixed pitch two-speed turbines.

Larger, more current generation wind turbines up to 2MW have been monitored in the field with the same methods and have shown dramatic torsional reversals during transient events (Figures 4 and 5). Blade pitch systems reduce braking shock load events but damage still occurs with sudden curtailments and e-stops. These events are much less common but they are significantly larger in impact due to the increased size of the turbine's rotor and generator.

AeroTorque will be releasing more data this fall on their work with larger turbines, as they have a full summer of new installations and monitoring. To control the life of your gearbox, you must control the loads that goes through it. An asymmetrical approach to reducing these loads in the highly dynamic drivetrain of a wind turbine is an important way to do just that.