AeroTorque – Torque Monitoring & Control Case Study

BETA 1 TEST SITE

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Introduction

In May, 2011, AeroTorque partnered with a wind farm in the western U.S. to study transient load events in their NEG Micon NM48 750 kW wind turbines using AeroTorque's new torque monitoring system, the WindTM™. Phase I focused on understanding the magnitude and frequency of torque reversals in the drive system. These reversals are known to be damaging to 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 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 3 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 WindTC™ equipped turbine, the first negative torque was controlled to a maximum level of 40% of nominal turbine rating. The turbine without the WindTC™ recorded torque reversals as high as 80% of nominal turbine rating and typically several additional torque reversals followed the first in each event. Surprisingly, the slight amount 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%.

The WindTC™ also provided torque protection in the forward direction. During phase II, some up-shifting events on the unprotected turbine resulted in 200% forward torque overloads. The turbine with the WindTC™ during the same event had forward torque overloads effectively limited to 150% 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. Life expectancy is projected to be at least 5 years and perhaps 10 without rebuilding.

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.

Phase I

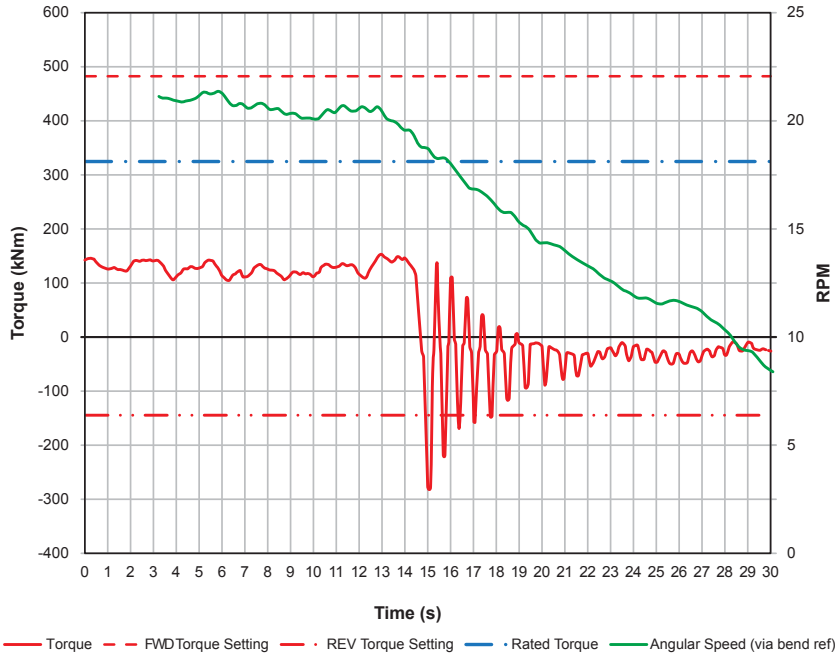
***WindTM*™ Torque Monitoring Installation:** AeroTorque, with its testing partner JR Dynamics, developed a set of test gear, called WindTM™, a torque monitoring device, which allows for real-time continuous torque measurement in a wind turbine drivetrain.

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.

Looking for transient event data with continuous measurements can be like looking for a needle in a haystack. The ***WindTM*™**, was designed to only store 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™, puts a marker the 8 seconds prior to the event and continues recording for a total of 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
- Dashed blue line is nominal torque.
- Dashed red lines are standard torque limiter settings

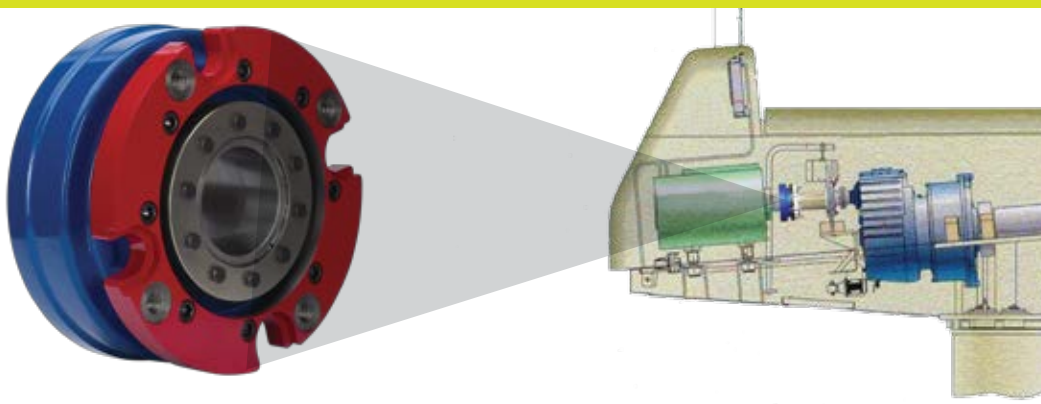
When the brake engages, the torque (solid red line) spikes in the negative direction, causing the system to wind up and unwind back and forth in the reverse and forward directions. Each time the torque crosses the black zero line, the load zone on every bearing in the gearbox shifts approximately 180°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

Many plots similar to the one shown were recorded, in all types of wind conditions. 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 in the same events.

The ***WindTC™*** is the first torque limiter with independent settings for forward and reverse torques in a drivetrain. Standard torque limiters used in some wind turbines have one setting, usually 150% to 180% 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 edge loading of the rollers and damage to the rollers and races (to see this data, request a copy of the Gear Solutions Magazine article, "Troubleshooting Wind Gearbox Problems"). The high reverse loading during torque reversals can cause of bearing deterioration and gearbox damage. The ***WindTC™*** is designed to limit the reverse loads to 40% of rated turbine torque and to dampen the torsional vibration.

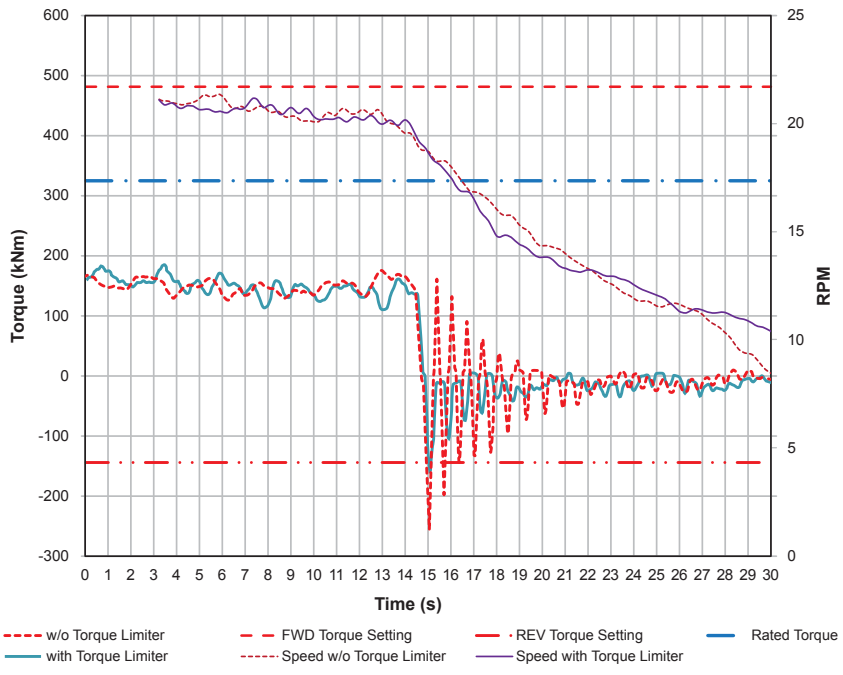


Reverse Slip Events

These data plots are representative samples collected over several months, comparing the 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.

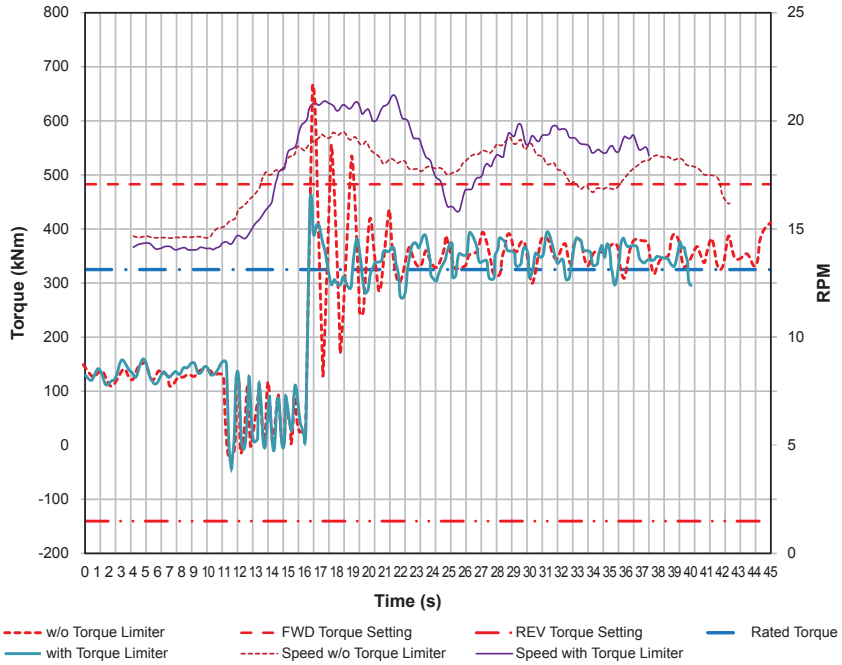
Without the WindTC™ (dotted red), there is a large uncontrolled torque reversal at 75% of nominal turbine rating followed by a series of torque reversals back and forth over the zero torque line. The turbine equipped with a ***WindTC™*** from AeroTorque (solid blue line), shows the initial reverse torque spike being absorbed at 40% 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 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.

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



Conclusion:

*The Phase I testing showed that transient torsional events occur in wind turbine drivetrains and occur much more often than expected. It also proved the feasibility of recording and monitoring these events in the field with a usable data output format and methodology. 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 Phase III program to retrofit their NEG Micon NM48 750kW wind turbines with the **WindTC™**. Further examination of the results of that reduction in torsional loading will be examined in the future to show further evidence of the methodology of reducing loads to increase gearbox life.*

For additional information or to set up a site visit by AeroTorque, please contact AeroTorque at info@areotorque.com or 330-239-4933.