PROJECTS & DEVELOPMENT

What Are Transient Loads, and How Do I Reduce the Effect On My Turbines?

By Doug Herr

In the wind industry today, there is more discussion than ever on loads in the drivetrain of turbines. A significant amount of work has been done over the past few years to show that transient loads, particularly transient torque reversal loads, are occurring more often than expected. NREL's Gearbox Reliability Collaborative has discussed transients and developed test cells to better understand the dynamics within the drivetrain. A major drivetrain modeling company recognized the value of field torque monitoring and has introduced their own system. Bearing companies are now addressing the effects of transient and impact loads in their presentations at conferences. Why is this happening? What exactly is a transient torque load? And, most importantly, why should it concern a farm owner or operator?

Transient loads are sudden changes in the magnitude and/or the direction of a torque load, and they have been widely misunderstood and underemphasized within the wind industry. Obviously, loads analyses are performed at the time of design by highly qualified and competent engineers at wind turbine OEMs. Unfortunately, many of the most critical and costly wind turbine drivetrain components are still requiring repairs or replacements long before reaching their targeted 20-year or 25-year life. Despite significant improvements to gearbox design standards, modeling, manufacturing, and load management by the turbine control systems, major components continue to fail. Why do these issues persist? One answer lies in these dynamic transient torque loads that occur as a result of changing wind loads or other commonly occurring events.

To understand the scope of the problem, there needs to be a better understanding of several factors. One major factor is the effect of this "real world" loading in the drivetrain during a transient event. Modeling tools are useful and are highly complex, but they often cannot capture the full dynamic impact of transient torque loads. Field recordings of torsional loading in drive systems of many different turbine models show that the worst torsional vibrations and the worst torque reversals generally occur during transient events, such as emergency stops and other hard tripping faults or stops. Many other types of equipment experience transient loads, but wind turbines are unique in their variety and severity of transient loads, as well as their inherent flexibility that causes significant torsional "windup" in the entire drivetrain.

Figure 1 shows how aerodynamic braking on a modern wind turbine can cause this torsional windup in the drivetrain. As the blades pitch, the system sees rapid deceleration of the rotor, continuing through the gearbox to decelerate the generator as well. As seen in Figure 1, the red torque trace shows that torsional reversals can be as high as 75 percent of rated torque (in the negative direction). This can cause significant excitement of vibrational energy as well. Each spike on the curve is a torsional reversal whose energy must be dissipated, causing impact loads on bearings throughout the turbine.

In harder and more critical stops, the caliper disc brake engages as well. As seen in Figure 2, the braking begins as aero-only braking in the negative direction and then becomes positive as the mechanical brake engages. This causes extreme oscillation of the torque loads. These load swings can be highly damaging as the bearings are loaded significantly in forward and reverse in an alternating fashion. Even worse for the turbine is when the turbine stops since there is a consistant final reversal to the system. This is a high-magnitude torque spike occurring on these stationary components. These torsional and impact loads can cause potentially significant damage to the surfaces of all the bearings, from main shaft to gearbox and even in the generator.

It is not just stopping or tripping modes that can cause these events. Field measurements have captured

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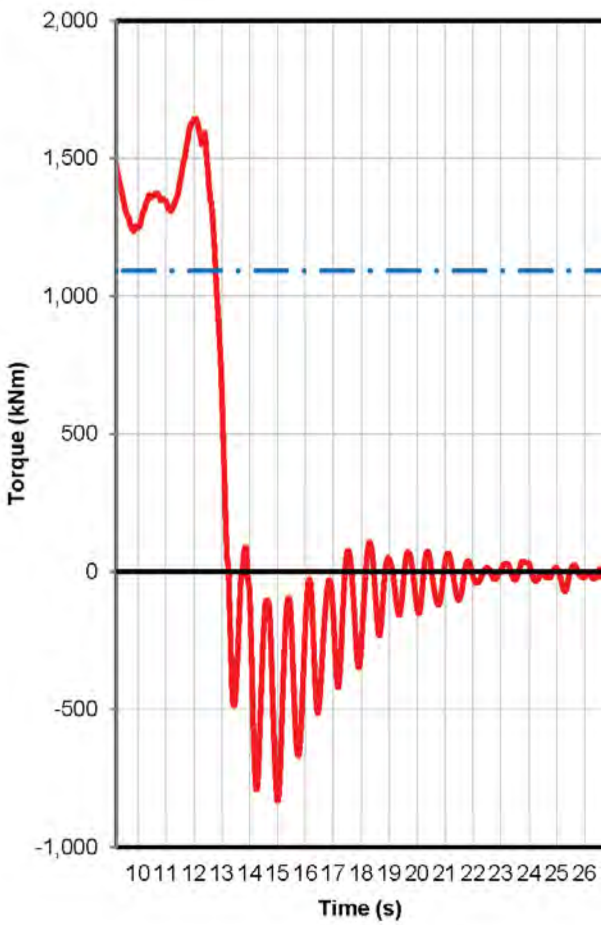

Figure 1: Aero braking only on 1.65-MW turbine, as recorded by AeroTorque's WindTM

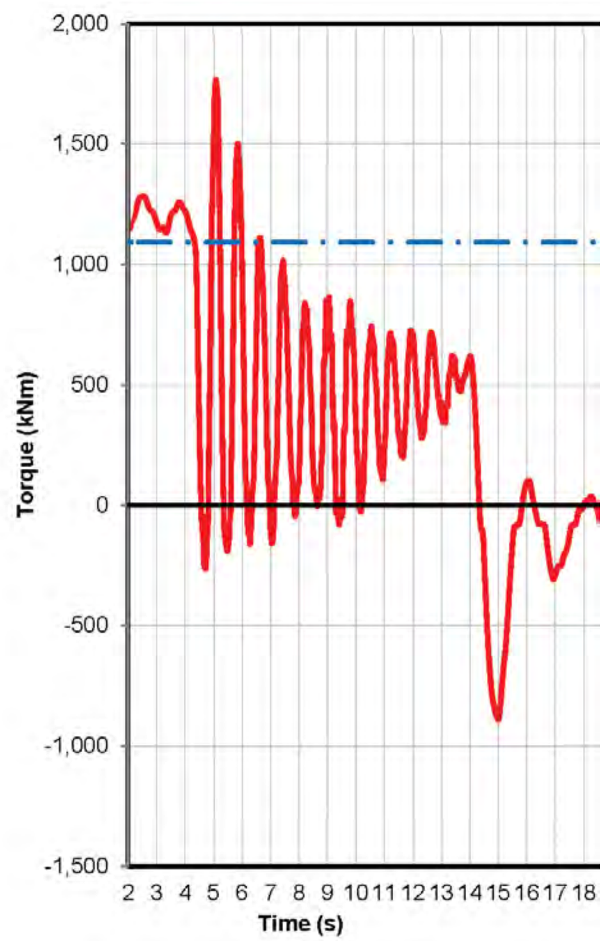

Figure 2: Hard stop on 1.65-MW turbine, as recorded by AeroTorque's WindTM

events that were never recorded by SCADA systems. The torque reversal in Figure 3 was captured by field monitoring of a wind turbine, but SCADA never recorded the anomaly caused by wind variation. The turbine continued to operate without a fault code being recorded, despite the fact a significant negative torque spike had occurred in all of the components throughout the system. This shows how easy it is to underestimate the number of transient events impacting wind turbines.

We now have a better understanding of how a transient load event affects the wind turbine, but how often do these events occur? Analysis of SCADA data at multiple wind farms have shown that many sites underestimate their stopping events significantly. To understand how often these transient loads are occurring, you need to understand how your turbine is responding to each fault, which means reviewing as many as 200 fault codes. In most systems, multiple fault codes will result in the same type of "hard" stop by the mechanical systems. These codes are set up to be recorded in SCADA by turbine manufacturers to help diagnose the event that caused the stop to occur. For the most damaging loading, there may be as many as 25 different codes that initiate as few as four specific hard stop reactions or protocols. The turbines must initiate the hard stop in order to prevent a more damaging situation from occurring.

By data mining turbine SCADA data from multiple wind farms, AeroTorque has found that there are significantly more hard stops than owners have previously believed. At one farm, it was found that over a 4-year period, 29 percent of their overall stops during periods of production were hard stops. This is a significant number of transient loads, not counting any wind-related events that were not captured by SCADA. Additional analysis can show which turbines at your farm are seeing these heavy loads. In a different region of the country, a wind farm found that the worst turbines in their farm saw up to three times more hard stops when compared to lower loaded turbines. Sometimes, turbines that see the worst transient loads are the top producers in a farm as they likely see the most wind of any of the turbines. That means that they are potentially getting the worst, most damaging loads and the most damage. So, your star turbine may also be the first in line for major repairs, leading to significant lost production on top of the repair costs.

A last area in understanding why transient loading is more damaging than expected is related to how the majority of load calculations are performed by designers. IEC61400-1 Edition 3 is the current standard that new wind turbine designs need to conform to in order to be certified. This standard can be considered as a de facto design guideline. Most manufacturers utilize it as a minimum requirement in the development of system loads to which they design. Each edition of the standards is used as a key step in the development of the next generation of commercial wind turbines. There is a growing consensus that more dynamic loading events need to be included to ensure that the turbine component's design life is achieved. The bulk of the turbines currently in the field were designed under the Edition 2 standard, which may have not fully accounted for the potential damages caused by transient loads due to aggressive braking and environmental issues.

Because fatigue loads are the driver in most standards, transient loads can be underestimated and are commonly believed to be captured by safety factors and load spectrums. Load cases primarily view loads as single entities, torque loads at a time slice, and not dynamically changing. While additional work is done on "peak-to-peak" loading, that may not capture the speed of the transitions completely. It is in these rapid transitions that transient loads are most damaging and the safety factors may not be enough. In the wind industry, it is generally believed that many of these safety factor ratings have become tighter over the years. Gearboxes' nameplates no longer show the high degrees of safety margins as earlier wind turbine gearboxes. It could be that other considerations, such as weight, have forced a reduction in the safety factors of the rating and have shown an increased reliance on the significant improvements in controls assisting in reducing any loads outside the standard operating parameters. While improved controls have made significant strides, they cannot reduce the loads that are caused by their own

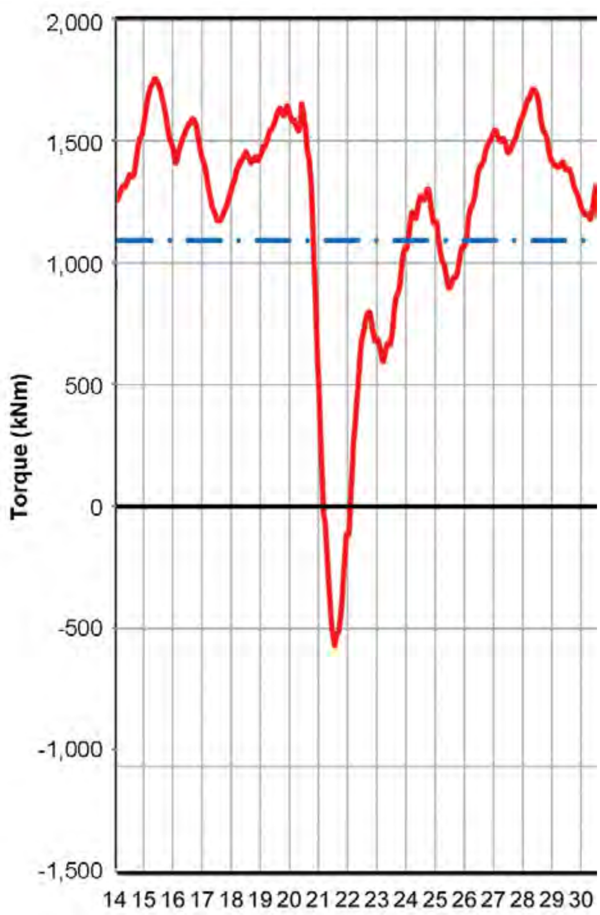

Figure 3: Wind related torsional reversal that was never recorded by SCADA, but captured by WindTM field monitor.

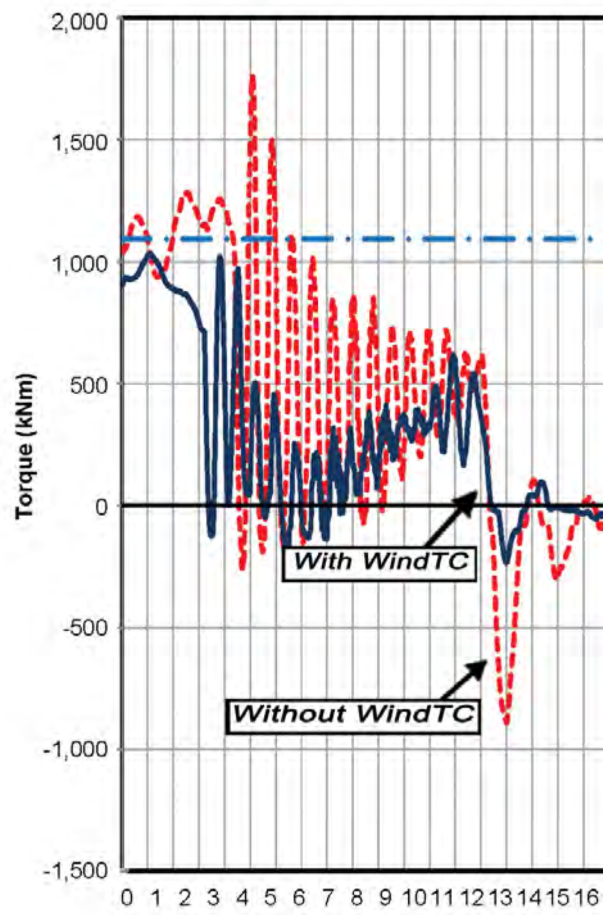

Figure 4: The reduction in peak loads seen by the gearbox with utilization of a WindTC. Peak loading is reduced up to 70 percent.

necessary reactions. In reality, it may be more likely that the improved standards have shown that the earlier safety factors did not adequately show the true safety factor, given the dynamic loading. Regardless, these "real world" loads have proven to be far more damaging than the standards have predicted, leading to reduced life in everything from main bearings to gearboxes, couplings, and generators.

Improvements in standards will help future turbines but will not help the ones currently in service. To understand how these transient loads are affecting your turbines and to achieve the desired life for your turbines, you must understand what is going on at your farm. Analysis should be done at the farm or corporate level to better understand which turbines are seeing a higher number of faults and determine what is causing these faults. By reviewing your SCADA history, you can begin to understand which turbines are seeing greater than expected loads. What events occur most often and on which turbines? Your analysis should include a review of which SCADA events produce rapid braking, by the blades, the mechanical brakes, or both at the same time. Operations manuals usually contain this translation key to the events that trigger these reactions. Additionally, your turbine OEM or your ISP may have this information for you. Remember that these events are caused by conditions, not by your turbine, so it is in everyone's interests to work together on this. This important review is the first step to reducing your O&M costs.

Additionally, you can begin to protect your turbine by introducing better components into the areas that show the most damage. Bearing manufacturers are offering improvements to the original bearings to help them see extended life. AeroTorque's WindTC reduces the transient loads by damping the torque oscillations to a more manageable level (up to 70-percent reduction), as shown in Figure 4. Modeling companies have introduced modeling of turbines based on all of these improvements to the systems, helping to plan your maintenance schedule in a way to reduce downtime. De-rating has even been used on some farms or on certain turbines within farms to reduce damaging loads and increase uptime. Lower power that is produced more often can be a better option than no power being produced during quality winds due to damaged turbines.

These solutions are tools that a farm can use to improve performance. Performance must be viewed as more than just power output as farms must consider the tradeoff between power production and long-term uptime. A reactive approach will lead to disappointment down the line.

It will take proactive solutions to move from chronically damaged components to a more managed approach to O&M costs. O&M costs have often been looked at as standard costs of operation and have been historically underestimated. This is true of bearing replacements in gearboxes and other repairs that are costly but are becoming expected. If you can control the damage to the bearings or other components, you will control the life of your turbine. It is critical to gain a better understanding of these cost drivers and act accordingly to manage them. Wind farms cannot control the winds, but you can improve your approach to help limit costly damage to their turbines. If you can reduce your O&M costs, you will drive profits directly to your bottom line.

HOW TO IMPROVE UPTIME BY REDUCING THE EFFECTS OF TRANSIENT LOADS:

1. Do a SCADA history study to determine the events that are affecting the life of your turbines and how often they are occurring. Consider torque monitoring to understand local loading.
2. Introduce improved components or proactive solutions to mitigate the damage that does occur.
3. Review the production tradeoff between high production and high maintenance costs to determine if de-rating is recommended for your fleet or for single turbines within your fleet. Improved components, such as a WindTC and improved bearings, may eliminate the need for this option.

Parts of this article are excerpted from an upcoming white paper, "The Mitigation Value of Reverse Torsional Damping of Transient Torsional Events in Wind Turbines, Using a Failure Modes and Effects Analysis Approach," written by Scott Eatherton, Emil Moroz, Dustin Sadler, and David Heidenreich.