RENEWABLE ENERGY WORLD

Increasing Wind Turbine Reliability Through Blade Pitch Control Upgrades

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Wind power generation in the U.S. is enjoying favorable winds.

First, the cost of wind turbine installations has dropped by over one-third since 2010 as the capacity of turbines increased. Next, according to Lawrence Berkeley Labs, the average capacity of turbines installed is now 2.32MW, up more than 200% since the late 1990s. The upsizing is mainly due to a drop in the per unit cost of equipment that is of even more advanced technology.

Finally, capacity factors are also rising with an average of 42% reported over the period of 2014 to 2016, a significant increase of 31.5% reported over the period of 2004 to 2011. American Wind Energy Association (AWEA) data reports that there are now over 56,800 wind turbines representing 96,488 MW in service in the U.S., with 5,944MW installed in the fourth quarter of 2018 alone.

Repowering existing wind turbine sites with taller towers and longer blades is perhaps the most notable current industry trend. A repowered wind farm not only extends the life of the facility but leverages rising capacity factors found with modern technology along with more efficient power generation. One midwestern energy company, for example, has announced plans to spend upwards of $1 billion to repower 700 existing wind turbines with the promise of 19 to 28% more generation, depending on site. In fact, 15 repowering projects accounted for 2,136MW of the about 7,000 MW added to the grid in 2017, according to AWEA. The National Renewable Energy Laboratory (NREL), as reported by the EIA, has predicted that investment in repowering of existing wind turbine sites has the potential to grow to $25 billion by 2030.

Not all existing wind farm owners have the balance sheet or site factors that would encourage a full or partial repowering. Instead, those owners often pursue a more incremental approach to improving the reliability and capacity factor of their wind turbines. One approach is to consider an optimized blade replacement, typically at sites characterized by low wind speeds. Development of more reliable and efficient gearboxes has also been the desire of many wind farm owners and the Department of Energy has invested heavily in their development. NREL has also helped develop many new wind turbine components for increased turbine reliability. However, turbine blade pitch control valves, well known within the industry as having a limited life, continues to weigh down wind turbine reliability and capacity factor.

Controlling Blade Pitch

Blade pitch controlled is a critical function within the overall wind turbine control system. Wind turbines operate at constant rotational speed, usually about 15-20rpm for large turbines. The gearbox increases the shaft speed to about 1,000–1,800rpm to match the generator rotational speed requirements, typically producing 60-cycle AC electricity at about 700V. The turbine controller starts the turbine when the wind reaches a given speed, usually about 8-16mph. A yaw drive keeps the turbine pointed into the wind to maximize electricity production.

The pitch control system, located within the turbine hub, rotates the three variable-pitch turbine blades in unison to precisely control the generator speed based on a feedback signal from the generator. On hydraulically controlled units there is one pitch control proportional valve per blade on a turbine so, for example, there are three valves used on a three blade turbine. The pitch system also “stalls” the blades so that there is no lift generated by the rotating blades thus shutting the turbine down when the wind speed reaches about 55mph to protect the turbine from damage (Figure 1). A brake is usually engaged when the blades cease rotation.

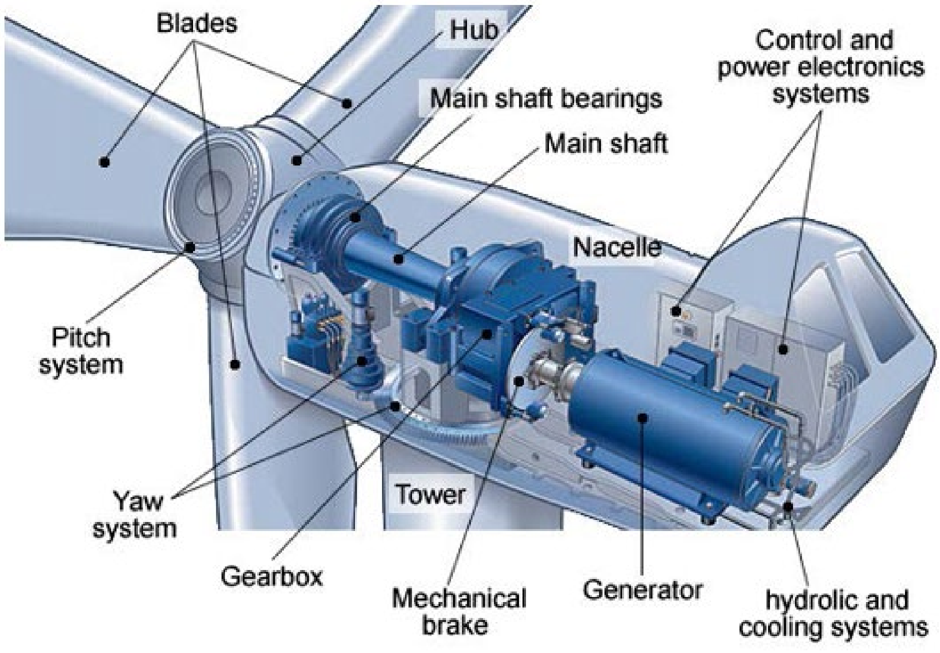

Figure 1. The anatomy of a typical wind turbine. *Source: Parker Hannifin*

The pitch control system operates in a very demanding environment and the proportional control valve, one per blade, is arguably the device exposed to the harshest operating environment. Failure of only one of the three valves will force the wind turbine out of service. Data from operators confirm this observation with many field reports of pitch control valve failure within weeks of its first operation, with an unexpectedly large number of failures occurring within six months of service. Upon failure, a maintenance technician must travel to the turbine site and replace the pitch control valve in the hub. Performing this service can take one or more days, depending on the site location, technician availability, and weather conditions. Often the cause of the failure has been traced to circuit board failure due to inadequate vibration protection or the circuit board enclosure design does not prevent dirt and moisture ingress. The cost of a replacement pitch control valve is secondary to the cost of maintenance replacement evolution and the loss of energy generation.

A pitch control valve must be designed to operate 24/7 in an extremely rugged environment. First, most pitch control valves are located in the turbine ub which rotates and thus exposed to heavy vibration, shock, and rotational forces (up to 50G on three axes). The valves are also subject to lightning strikes so the valve electronics must be electrically isolated from the turbine nacelle. Also, the pitch control valve must be capable of withstanding ambient temperatures, ranging from -40C (Minnesota in the winter) to 85C (West Texas in the summer) in which wind turbines are installed. Finally, it stands to reason that the pitch control valve should be designed to comply with IP65 standards for protection against dirt, grease, and moisture **(Figure 2**).

Figure 2. A well-designed pitch control valve will not only ensure stable turbine performance over its load range but will be designed to operate reliably in extreme cold and heat and will not allow dust or moisture intrusion, a known cause of valve failure. *Source: Parker Hannifin Corp.*

Up Your Turbine Game

One pitch control valve that has proven itself in multiple wind turbine applications is the Parker Hannifin D1FC (nominal size: NG06, 5gpm flow rate) and the D3FC (nominal size NG10, 16gpm flow rate) direct operated proportional DC valve with position feedback. The control valves receive an input signal (either 4-20ma or +/-10VDC) from the main turbine controller based on its monitoring of the generator output. Valve flow and performance specifications have been matched to the system requirements of the turbine so as to be compatible with the existing control parameters and co-exist with valves on the other axis.

In addition to IP65 designation, which inhibits moisture and dust infiltration, the D1FC and D3FC units are designed to meet IEC 68-2-6, -7 and -36 vibration standards so that sinus, random noise, and shock loads, respectively, are well accounted for in the design, unlike OEM pitch control valves The electronic driver card is installed with anti-shock mounting technology which minimize vibrational effects. Unlike other OEM valves, all fasteners are thread locked to guard against vibration as an additional measure of safety.

Field service reports often cite mating connectors as the root cause of a turbine forced outage. The connectors used on OEM pitch control valves do not have locking connectors so vibration can cause the connectors to disengage. The D1FC and D3FC valve assemblies use locking mating connectors much like those found in the automotive industry that is exceptionally vibration resistant. Other important design characteristics of the D1FC and D3FC pitch control valves are illustrated in **Figure 3**.

Figure 3. The Parker Hannifin pitch control valves are designed to meet the most demanding performance specifications and are configured to be “plug and play” when replacing OEM control valves. *Source: Parker Hannifin Corp.*

Exceptional Operating Report

It is not unusual for plant owners to inquire about the operating record of any new component proposed as an OEM replacement, particularly one that serves such a critical function as the pitch control valves. Potential suppliers expect those questions. A potential user should begin by investigating the track record of the supplier. Parker Hannifin is certainly recognized as a global provider of motion and control technologies, particularly hydraulic controls, for a century. Control of hydraulics has been its stock in trade for almost as long.

What about the track record of the proposed replacement components? Parker Hannifin pitch control valves have been in service in wind turbine applications since 2016, without a single failure attributed to the valve assembly. NextEra Energy Resources, for example, recently purchased D1FC valve assemblies as a replacement for problematic OEM pitch control valves that were the root cause of turbine forced outages. D1FC valves were selected because of its field track record but also because they are a direct replacement and required no tuning prior to use. Replacement of a valve by a technician requires only about 20 minutes.

There is a further advantage for cost-conscience owners: a single replacement D1FC valve may be used in conjunction with two existing OEM valves, thereby allowing an incremental replacement program. This approach may be preferable for those owners who would rather replace with upgraded components as repeated failures occur over time. Other owners may determine that changing all three valves may be most cost-effective solution when the technician labor cost for multiple repairs and lost generation costs are considered in the analysis.

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