Customised Filtration Solutions Help Maintain Wind Turbine Gearboxes

Clean, Green Wind Machine

By Eric Rud, Global Hydraulic Filtration Product Manager, Eaton, USA

As one of the fastest-growing renewable energy resources globally, wind energy is free, sustainable and inexhaustible. At the same time, manufacturers strive to build bigger, safer, more efficient, and powerful turbines to provide the world with more affordable electricity. However, due to their continuous energy production and often remote locations, both onshore and offshore, gear-driven wind turbines are a very demanding application that requires extreme reliability and durability. For optimal reliability, uptime and service life, the health of the gear oil is critical. Oil contamination can cause gear failure and lead to breakdowns, potentially resulting in high repair costs, lost energy production or even damage to the wind turbine's structure. Therefore, the continuous monitoring and filtration of gear oil is essential to maximise uptime. This article focuses on the wind turbine's gearbox and lubrication system and the key aspects to consider when selecting the filtration system.

Figure 1. Eaton's TWF Twinfil filter systems are especially designed for gear lubrication systems in wind turbines

Gear-driven wind turbines are the epitome of sustainable, green energy generation. To maximise efficiency and reduce costs, engineers strive to build bigger, safer and more powerful turbines. To lessen the structural load on the nacelle, designers must reduce the size and weight of the gearbox and filtration system.

Demanding Wind Power Generation

The nacelle at the top of the wind turbine's tower houses all the generating components, such as the generator, gearbox, drive-train, and brake assembly. For gear-driven wind turbines, the gearbox is a critical system. It steps up the relatively slow rotational speed of the blades, or extruders, to a higher speed, roughly 60 times more, which is needed to generate electricity. Generally, turbines start producing energy at wind speeds above 5 to 7mph (2 to 3m/s). The turbine is not generating electricity at speeds below this threshold, and the rotor just idles. On top of the nacelle are wind instruments, such as an anemometer and wind vane. The data from these instruments is used to calculate the correct position of the rotor to point it into the wind and the pitch angle of the blades. For optimal turbine performance in any wind condition, the pitch of each of the three blades is controlled independently by a gearbox.

Optimising Safety

Pitch control is essential, especially in very windy conditions, to prevent overloading of the gearbox and to avoid imbalance. The gearbox rotates each extruder blade to optimise power generation depending on the wind's direction and strength. There is usually a vibration sensor inside the nacelle to measure vibration, which increases with wind speed. If the vibration reaches a specific limit, the turbine goes into a safe 'pause' mode until the wind dies down. However, large moments and forces are applied by the turbine rotor to the drive-train. To prevent stress points and failures, designers adjust the gearbox to support the loads and stress. Seals and lubrication systems must operate consistently, even in wide temperature variations, otherwise dirt and moisture may accumulate inside the gearbox. Therefore, gear oil maintenance, monitoring and filtration are essential parts of a preventive maintenance programme.

Weight and Corrosion Issues

The need to continuously optimise the power-to-weight ratio and energy yield of wind power gearboxes while simultaneously reducing the cost of producing wind energy led a manufacturer to reach out to Eaton for a customised solution. The company has installed thousands of gearboxes with a total capacity greater than 50,000MW. The original filter system was made from carbon steel and cast iron, which was butadiynyl (C4H) painted to protect it from corrosion. This system was incredibly heavy, which puts a tremendous strain on the structural load of the nacelle. In addition, although the paint coating is supposed to last for several years, any paint damage during transit or installation would result in severe corrosion

– a particular problem for wind turbine installations where maintenance and replacement costs are incredibly high. Therefore, the primary objectives were to reduce the weight of the filter system and reduce the number of components and interfaces needed, while providing full filtration quality and corrosion protection.

A Lighter, More Robust Filtration System

Made from anodised aluminium, Eaton's TWF Twinfil filter system minimised the corrosion risk (Figure 1). Also, with a density of 168lb/ft³ (2,699kg/m³), anodised aluminium in place of carbon steel and cast iron, with a density of 491lb/ft³ (7,873kg/m³), reduced the weight of the filter system by at least 882lb (400kg), depending on its size. With the filter system's lower weight, the nacelle's overall weight, a key design parameter in this project, was reduced significantly. The result was a new generation of gear lubricant filtration systems that reliably met the weight and performance specifications required by the gearbox manufacturer.

Improved Serviceability

Serviceability and low initial investment were equally important factors for the gearbox manufacturer. The custom-designed TWF Twinfil filter system combines the filter's four mounting blocks into a single connection, virtually eliminating misalignment issues. The simplified mounting design also uses fewer sealed connections to reduce the risk of leaks. In addition, the new design integrates all valves into the system and connects the mounting plate to the manifold block. The new bayonet closure replaces the flange cover, enabling rapid filter element changes and improving serviceability, as well as minimising maintenance and operating costs.

Reliable Filter Elements

The TWF Twinfil filter system uses glass fibre fleece 01.NR 1000 return-line filter elements and a 2-stage Twinfil filter element (Figure 2). The latter combines a fine 10µm glass fibre fleece filter with a coarse stainless steel wire mesh with a nominal fineness of 25µm. A bypass valve separates these two parts, allowing an opening pressure of 51psi (3.5bar), protecting the fine filter from damage due to high viscosity at low temperatures or providing permanent filtration by the fine filter when closed. Up to three different levels of fineness are possible, depending on the selected filter elements, and the system is suitable for working pressures up to 263psi (25bar).

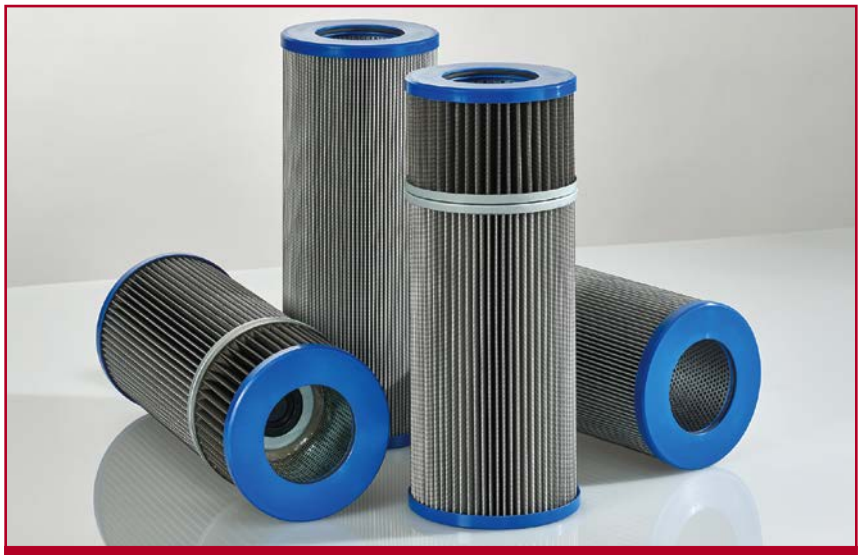

Figure 2. Eaton's 01.NR 1000 return-line filter elements and 2-stage Twinfil filter elements meet the demanding challenges in lubrication oil filtration in wind power gearboxes

In-Field Performance

The custom-designed TWF Twinfil filter system fulfilled the requirements of the gearbox manufacturer. The result was a new-generation gear lubricant filtration system that reliably met performance specifications. In the field, the system effectively removes particles from oils down to 6µm reliably and consistently throughout the filter's life at a maximum flow rate of 66gal/min (250l/min). The flow dividing valve reliably controls the flow rate to the cooler or directly back to the gearbox. All system components work properly from a cold start to the +158°F (+70°C) maximum operating temperature without affecting the overall gear oil supply.

Result – Maintaining Filtration Quality While Reducing Weight

Eaton's compact TWF Twinfil filter systems provide reliability, durability and efficiency to the wind turbine gearbox and lubrication system. In this pilot project, Eaton provided more than 80 units of TWF Twinfil 4000 and 6000 filter systems for a variety of different wind turbines. Essential was the success in reducing the weight of the filter systems by 78%, which was key to reducing the gearbox's overall weight. The Twinfil filter element is designed specifically for wind power applications to ensure that the gearbox is never lubricated with unfiltered fluid. Since installation, both filtration systems have proven to remove particulate contamination and deaerate oil under all operating conditions, enhancing the reliability and efficiency of the gearbox and its lubrication system. An additional benefit for the gearbox manufacturer is that the TWF Twinfil filter system meets all the relevant safety certifications for both on- and offshore wind turbine applications worldwide. ■

Eric Rud is Global Hydraulic Filtration Product Manager for Eaton. He started his career with Eaton in 1997 and has held various roles in hydraulics during that time. Eric holds an MS degree in operations management from the University of Wisconsin-Stout.

Contact Details
Eaton, Filtration Division
Eric M. Rud, Global Product Manager
Chanhassen, MN, USA
ericmrud@eaton.com
Eaton.com/filtration