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Preventing Bearing Failure At An Oregon Wind Farm

A bearing protection ring can divert up to 120 amps of continuous high-frequency shaft current at frequencies as high as 13.5 MHz and discharges of up to 3,000 volts.

BY WILLIAM OH

Encouraging results from recent up-tower testing at a wind farm in Oregon indicate that a conductive-microfiber bearing protection ring designed to protect wind turbine motor bearings has solved a chronic bearing failure problem of wind turbines.

The generator bearings installed in one of the wind farm's turbines first failed in May 2006, 11 months after the turbine was brought online. The company that owns and operates the wind farm replaced the bearings and slip rings, but the new bearings failed after five months. Once again, new bearings and slip rings were installed.

The third bearing failure came 11 months later, in September 2007. This time, in addition to replacing the insulated bearings and slip rings on both ends of the generator, the project owner decided to try a conductive-microfiber bearing protection ring and a shaft collar with a highly conductive surface on the drive end. All components were installed in September 2007. The generator's two standard carbon block, spring-loaded brushes, which rub on the slip ring at the non-drive end, also were replaced.

In December 2007, measurements were taken with a probe and oscilloscope of shaft voltage on the generator with and without the bearing protection ring and collar engaged. All measurements were taken on the same circuit. Wind speed ranged from 10.2 to 13.4 miles per hour (mph). Real-time data from these field tests show that the conductive-microfiber bearing protection ring and collar were reducing shaft voltage by an average of 84.5%.

The first measurement, taken during full-power operation with a wind speed of 12.1 mph, established a baseline voltage (the system's ground noise level) of 2.60 volts (peak-to-peak) from the 5.824-inch shaft of the tower's doubly fed, asynchronous generator. The oscilloscope settings were 10 volts per division and 400 milliseconds per division.

Eight more measurements were conducted in two series. The Series 1 readings measured the shaft voltage with all components engaged. The bearing protection ring and collar were on the drive end of the shaft, and the standard carbon block brushes were on the non-drive end. For the Series 2 readings, the bearing protection ring was disengaged and the shaft collar was removed, leaving the non-drive-end carbon block brushes as the only shaft-current mitigation.

Results of the Series 1 tests of the turbine with the bearing protection ring installed showed an average shaft voltage of 6.41 volts (peak-to-peak). Results of the Series 2 tests for which only the spring-loaded carbon block brushes were used showed an average shaft voltage of 41.35 volts (peak-to-peak).

The difference between these figures, 34.94 volts, indicates that the bearing protection ring and collar divert approximately 84.5% of the damaging current that remains on the tower's generator shaft when the only bearing protection is from the carbon block brushes at the non-drive end. Furthermore, the voltage wave form with the ring and collar engaged was a smooth wave with no detectable discharge to the bearings, while the wave form without the ring and collar showed a bearing-current-discharge pattern with voltage peaks an average of 6.5 times higher.

These measurements show that the bearing protection ring lowers shaft voltages and mitigates the destructive impacts of shaft current discharges to bearings in wind turbine generators.

High-frequency currents induced on the shafts of wind turbine generators through parasitic capacitive coupling can reach levels of 60 amps and 1,200 volts or greater. If not diverted, these currents discharge through the generator's bearings, causing pitting and fluting that result in premature bearing failure and turbine failure. The conductive-microfiber bearing protection ring technology steers these harmful currents away from the bearings and channels them safely to ground.

The ring surrounds the generator shaft with millions of conductive microfibers of a very small diameter (less than 10 microns). Strong and stiff, yet flexible, these fibers provide a high density of contact points – parallel paths of least resistance from the motor shaft to ground. Capable of conducting currents of many tens of amperes and discharging from tens to thousands of volts with frequencies in the MHz range, the fibers significantly reduce voltage buildup on the generator shaft. The ring is especially suitable for use at high frequencies because its fibers tend to compensate for variations in the roughness of the shaft surface and/or microscopic misalignment of the ring and shaft.

When the microfibers lose mechanical contact with the rotating shaft, electric contact is quickly re-established at a point along the ring, due to local field emission. A gap between the shaft and the fibers of 5 microns or greater is accomplished through the phenomenon known as a gaseous or electric breakdown – a cascading effect of secondary electrons obtained by collisions and impact ionization of the gas ions accelerating across the gap.

With a smaller gap of between 5 nanometers and 5 microns, field emission is a form of quantum tunneling, known as Fowler-Nordheim tunneling, a process in which electrons tunnel through a barrier in the presence of an electric field. Thus, the ring functions without direct frictional wear or hot-spotting/thermal wear. Because multiple microfibers dissipate heat better than single-conductor devices, the ring can tolerate higher current densities. Furthermore, the microfibers are not adversely affected by oil, grease, dust, moisture or other contaminants.

More specifically, the bearing protection ring is engineered to safely divert up to 120 amps of continuous high-frequency shaft current at frequencies as high as 13.5 MHz and discharges of up to 3,000 volts (peak).

Damaged bearings can cause generator failures, which lead to costly repairs and unplanned downtime. In fact, a failed 1.5 MW generator can account for over $48,000 of lost revenue if down for a month, and repair costs can add up to as much as $50,000. Consequently, the return on investment for preventing such failure by installing bearing protection rings at the factory or in the field as part of a preventive maintenance program can be quite high. NAWP

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