Up-Tower Electrical Testing

A comprehensive approach to maximizing generator and component lifespan, dependability, and performance through periodic electrical testing and fault analysis.

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At the heart of any wind power plant are the turbines themselves. There are many quality manufacturers of these graceful giants with nearly as many variations of drivetrain assemblies. While most in North America utilize the classic gearbox/generator design, there are also a number of direct-drive machines. Many generators are of the doubly-fed induction asynchronous type, but there are also traditional synchronous generators as well as induction generators that utilize full power conversion electronics.

Additionally, there are many permanent magnet style generators that are becoming popular due to reduced maintenance costs and more efficient performance. What are common among these configurations are the electrical windings where the power is actually generated, the insulating materials that maintain the electrical integrity and the mechanical aspects of the machinery – bearings, lubrication, alignment, vibration, etc. All of these parameters are carefully engineered to maximize the service life of the equipment, but properly structured and executed maintenance regimens are required to ensure dependable performance, component longevity and profitable operation.

This article is aimed at the electrical testing that should be done periodically on the generator and the ancillary components of the wind turbine. Unlike vibration analysis and other predictive testing, these electrical tests are not normally trended and are more like "snapshots" that indicate current conditions and highlight potential short term failure possibilities. However, collecting, normalizing and comparing these readings across a site could flag for inconsistencies and help identify potential problems. These tests therefore fall into two basic categories: standard periodic testing and fault analysis.

Up-tower periodic testing – safety first

Following safe work practices concerning electrical devices, whether in operation or under test, is paramount. All LOTO and arc flash requirements should be carefully followed, and only qualified electrical workers should undertake this testing. The International Electrical Testing Association (NETA) and National Fire Protection Association (especially NFPA 70E), as well as other organizations, have recommended guidelines for safely testing electrical components and should be consulted if there are any questions regarding safety. All electrical components also contribute to the arc flash hazards of the wind farm and should be, at the minimum, maintained for safety purposes. The NFPA 70B standard offers many guidelines on maintenance processes and intervals that help assure worker safety. Many IEEE standards and recommended practices are also available depending on the test and the testing environment.

Within the wind turbine, there are many electrical devices that

should be tested as required to maintain warranty and/or to assure reliability. The generator itself is, of course, the primary consideration, but ancillary components such as pitch and yaw motors, fans and other cooling equipment, as well as the internal cabling should also be tested and the results trended. Below are some of the common tests that should be considered as part of an effective reliability program.

Insulation Resistance

Insulation resistance testing (sometimes referred to as IR testing - not to be confused with infrared testing) is one of the oldest maintenance procedures developed for the electrical industry and is covered in detail in IEEE

ALSO IN THIS SECTION:

Recommended Practice 43-2000. It is fairly simple to perform and can provide information regarding the condition of the electrical insulation in the generator as well as identify the presence of contamination and moisture on the windings. This test is recommended before energizing a machine that has been out of service or where heating elements have failed to keep the winding temperature above the dew point, which might have resulted in condensation on the windings. Insulation resistance testing is also useful whenever there is doubt as to the integrity of the windings and before any over voltage testing is performed. An accurate IR test requires a correction factor for the winding temperature to create consistent readings. The methods and expected result data for this test are listed in the IEEE RP document. IR testing is also appropriate for pitch and yaw motors and any cooling or ventilation blower motors. Although not specifically described in the recommended practice, this general test method is also used to check collector ring assemblies, micro switches and other electrical components that might be contaminated or collect moisture.

It is critical that any heating elements mounted in the generator be tested and replaced if inoperable. Heaters are often used to maintain an internal temperature above the dew point and prevent condensation of moisture on the windings when the generator is below normal operating temperatures. If the generator is energized with high levels of moisture on the windings, there is an increased likelihood of a catastrophic failure, especially in the presence of carbon dust contamination or degraded insulation.

While the test results from IR testing are not normally trended, it is possible to do so in order to illustrate a gross degradation of the insulation system, but the damage would probably be severe before any significant changes would appear. It is, however, very important that the duration of the test, the temperature of the windings and the relative humidity be consistent or compensated.

Polarization Index

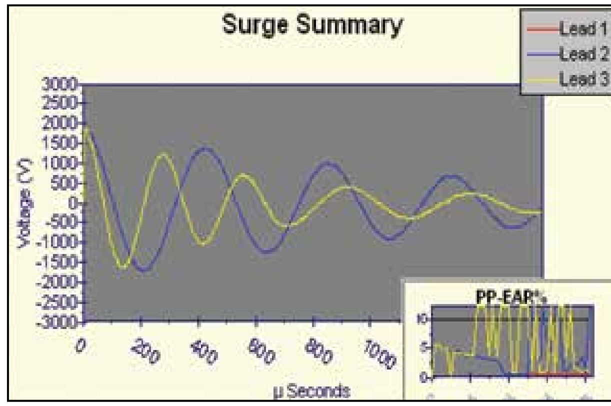
Another test described in IEEE RP 43-2000 is the polarization index (or PI) that is useful in some applications to identify contaminated and moist windings. In most modern machines, however, where the insulation resistance is above 5,000 megohms, the test might not prove meaningful. There has also been a consideration of collecting de-polarization data and analyzing the shape of the polarization curve. Refer to the standards document for additional applications and details.

Internal Tower Cable Testing

There are several methods to test the cables within the tower. Most of these power cables operate at 575 or 690VAC, but there are several machines that operate and higher voltages, up to 12,000VAC. For normal maintenance practices, an insulation resistance test is normally appropriate. If there are abnormal readings, inspections, especially of the connections and splices are the next step. If no obvious failure point is located, then more advanced testing is required which might include partial discharge, tan delta testing or high potential tests. These advanced tests are normally performed by a certified testing company.

What if the generator tests are inconclusive?

If the results gathered during a periodic testing cycle are inconclusive or out of the normal range, additional testing is recommended. Normally a generator/motor specialist, either internal or from a consulting service company, is engaged to perform these advanced tests as there are some possibilities of further damage the windings if the tests are not properly performed. Some electrical testing is by nature destructive and should only be performed for diagnostics reasons.



Coil Resistance

A coil resistance test looks for resistance imbalance between phases, discrepancies between measured resistance values, trends previous measurements and confirms nameplate values. If a problem is found the generator should be inspected for the cause of the discrepancies. Typical problems that may exist are 1) shorts to the stator or rotor core, 2) shorts between coils either within the same phase or between phases, 3) coils wound with the improper gauge wire, 4) loose or corroded connections. Until the resistance measurement is acceptable, further testing will not be useful. Normally, a standard volt/ohm meter is adequate for a simple check, but either a dedicated low-resistance meter or a Wheatstone bridge might be necessary depending on the configuration of the machine. However, this test only shows the static state of the windings and does not stress or analyze the condition of the insulation system.

Surge Comparison Testing

The normal advanced test for analyzing the insulation integrity is performed by electrically stressing the insulation above normal operating voltage levels and at very high pulse rate. The resulting wave forms are captured on a digital oscilloscope and any anomalies between phases of the circuit are compared. This surge comparison testing can be performed manually; however, automated test equipment with digital reporting is available and is highly recommended. This is not a trending test, nor does it answer all of the possible questions, but it provides a snapshot of the current condition that can support a decision to remove the generator or motor for repair or replacement.

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High Potential Testing

If testing is required to make an immediate decision regarding replacement of a generator, high voltage testing, normally DC high potential testing, is useful, but care should be taken as insulation weaknesses (cracking, contamination, carbon tracking, etc.) can be advanced to failure. Sometimes referred to as over-potential testing, the "hi-pot" test is designed to stress the electrical insulation beyond its normal operating voltages to expose potential failures at a convenient time. The DC test methods are described in IEEE Standard 95. Trending is possible with this test as it can often show current leakages before reaching an actual failure point, but it probably should be used sparingly and only if the site is prepared to replace the machine.

Step Over-Voltage Test

Using the same equipment as the high potential test, the step over-voltage test stresses the insulation at rising levels of voltage over a set time scale. This is a very useful trending test and can be used in periodic predictive maintenance testing. The same concerns exist as for high potential testing.

Conclusions

All good testing stratagems are designed to assure the profitability of the operation. Periodic electrical testing, vibration testing and alignment of the drive train are time consuming operations and are sometimes difficult to perform on a regular basis. However, the cost of unplanned outages including cranes, staffing and emergency generator repairs can also dramatically affect the bottom line. Good planning, proper testing and clear decisions regarding the condition of the equipment will always pay off with reduced overall maintenance costs.

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