NETA WORLD

The Official Publication of the InterNational Electrical Testing Association

Winter 2001-2002

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NETA Tribute – September 11, 2001

Annual Technical Conference

Communications and Metering

Using Partial Discharge Surveys to Increase Electrical Reliability

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Today's facilities demand high levels of electrical reliability. Traditional high-reliability operations, such as health care and continuous manufacturing, have been joined by a whole new wave of industries demanding even greater reliability. The growth of the Internet and an increase of e-commerce have spawned a new explosion of mission-critical facility construction. High reliability web hosts often require reliability levels of 99.9999 percent or higher. This equates to an average annual service interruption time of just 32 seconds. Downtime losses for these 24/7 facilities can exceed millions of dollars per hour. EPRI indicates that losses from outages at high-tech firms in California's Silicon Valley can be up to one million dollars per minute.

After a facility is operating, implementation of a strong preventive maintenance program is necessary to realize the reliability expectations of the design. Using a new predictive maintenance technology can enhance reliability even further. Any facility manager utilizing medium-voltage equipment that wishes to reduce downtime should perform regular partial discharge surveys to reduce component failures and increase reliability.

This article outlines the statistical increase in electrical reliability expected by performing regular partial discharge surveys along with examples of how these surveys are being used to reduce facility downtime.

Partial Discharges

Partial discharge is defined as an electrical discharge that bridges a portion of the insulation between energized conductors in a dielectric. It need not occur at either of the conducting bodies but may be anywhere between where the electric field strength exceeds the breakdown strength of that portion of the dielectric material. This occurrence is due to imperfections, voids, contaminants, cracks, and other irregularities in the dielectric. Partial discharges typically occur at 2000 volts or greater and are measured in units of charge called picoCoulombs (pC). These discharges will increase in magnitude and quantity over time, leading ultimately to electrical failure.

Partial discharge measurements have been performed for many years in laboratories on medium- and high-voltage components for quality assurance purposes. This technology has more recently been successfully applied as a diagnostic tool for field use to detect impending insulation failure and is now a recognized method to increase electrical reliability for aging and new electrical installations.

The virtues of partial discharge field measurements are:

- It is truly a predictive test, indicating specific symptoms in advance of the failure.
- It is a nonintrusive test, requiring no interruption of service and is performed under normal operating voltage.
- It is a nondestructive test; it does not test to failure or adversely affect the equipment under test.
- It need not use any overvoltages, thereby not exposing the tested equipment to higher voltage stresses than those encountered under normal operating conditions.
- Trending can be accomplished by storing results to allow comparison with future tests.
- In many instances the site of the partial discharge occurrence can be located within the test object so the localized problem can be repaired.
- The cost to perform a partial discharge survey is relatively inexpensive, allowing annual surveys to be performed economically at most facilities.

Examples of equipment that can be tested include:

- Cables, terminations and splices
- Instrument transformers: potential, current, capacitive coupled potential devices
- Power transformers and bushings
- Motors and generators
- Switchgear
- Surge arrestors
- Capacitors

Partial discharges create small impulses in the nanosecond range. The impulses are detected in the field by using capacitive and inductive sensors. These analog signals are then collected and further processed through a network of noise filters, amplifiers, and analog-to-digital converters. Custom software allows the captured data to be displayed in graphic form (Figure 1) where it can be analyzed and saved for future tracking.

Most electrical equipment such as transformers, switchgear, and cables are partial-discharge free when they leave the factory floor. Cables, for instance, are required by IEEE standards to produce less than five pC.

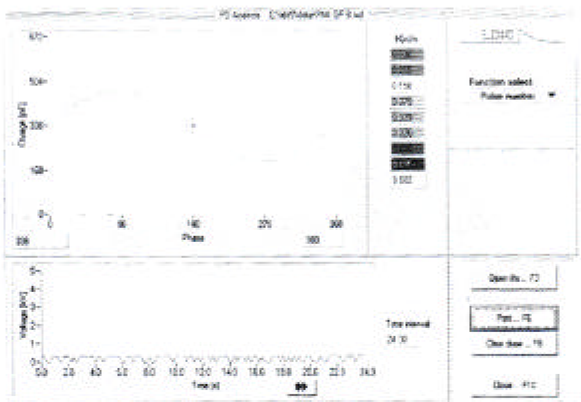
It is not uncommon for field insulation surveys of existing facilities to produce very little or no partial discharges, in which case the insulation system can be classified as being in good condition. A survey in one year would be recommended.

For apparatus that has moderate magnitudes and quantities of partial discharge, the partial discharge is trended to determine insulation deterioration rates so that future corrective actions can be implemented when necessary.

Should critical levels of partial discharge activity be discovered, immediate corrective actions must be taken. The top priority of performing a partial discharge survey at a facility for the first time is to identify dangerous conditions.

Partial discharge surveys should not be substituted for traditional preventive maintenance activities but should be used to enhance reliability. If a facility performs annual preventive maintenance outages during Christmas, it would be of great benefit to perform annual partial discharge surveys during the summer, for instance.

Partial discharge analysis works very well for all types of medium- or high-voltage equipment but is an extremely important condition assessment tool for cables. Cables are often ignored in preventive maintenance programs partly due to the inability of any convenient field test to produce meaningful results and partly due to the facility manager's fear of damaging the cables. Since partial discharge testing does



Partial discharge pattern measured at a 25 kV cable termination. Results are indicative of a dangerous internal flow.

not require an outage, is performed during normal working hours, and reliably assesses cable insulation condition, this test is well suited for predicting cable failure.

Reliability

According to NFPA 70B, insulation breakdown is the number one cause of electrical system failures. The *IEEE Gold Book* statistics indicate that electrical insulation deterioration causes up to 95 percent of electrical failures of certain high-voltage equipment. Using these IEEE statistics as a basis, the equipment failure table found in the *Gold Book* can be modified to estimate the impact of performing regular partial discharge surveys. These statistics can then be applied to specific electrical system configurations, such as the simple radial system For this system, IEEE reliability statistics indicate that a total of 1.71 annual hours of nonutility-related downtime will occur before implementation of a partial discharge survey program. By preventing high-voltage electrical insulation failures, the nonutility-related downtime can be reduced to 0.52 hours or an improvement of 69 percent. These remarkable improvements in electrical system reliability clearly justify the necessity to implement an annual partial discharge survey program at all facilities utilizing medium- or high-voltage equipment.

Case Studies

Case Study One

A partial discharge survey program was instituted on a municipality's aging 25 kV class cable system.

Immediately upon program initiation, several problems were discovered, including thirteen cable terminations, two splices, and one cable circuit with critical levels of partial discharge. These items were successfully repaired, thus avoiding emergency outages. Several other components found with moderate levels of partial discharge activity are being monitored to develop deterioration trends.

Case Study Two

A thirty-year-old hospital experienced failures of three of their 4160 volt dry-type transformers over a three-year period. After consulting with the manufacturer, the hospital was advised that the transformers were reaching their life expectancy and that continued unexpected failures were likely. Lacking the significant financial resources to replace all of the transformers, a partial discharge testing program was implemented to prioritize replacement. Two transformers were found with critical partial discharge levels and were identified for immediate replacement. Three additional transformers were found with moderate partial discharge levels and are being trended for insulation deterioration. The remaining twelve transformers were found to be in good condition, and replacement of these units is being deferred, pending future partial discharge survey results.

Case Study Three

Extremely high partial discharge activity was discovered on a 12.47 kV load interrupter switch at a chemical plant being surveyed for the first time. Facility directors were advised to immediately remove the circuit from service but could not due to production schedules. The switch insulator failed within a week. However, the early warning allowed repair materials to be brought on-site before the failure occurred, saving several critical hours of downtime.

Conclusion

Field partial discharge surveys of medium- and high-voltage electrical systems have become a valuable tool to evaluate insulation condition. The surveys do not require power interruption and do not damage the insulation. Failures can be predicted by trending survey results, and the implementation of a regular partial discharge survey program can significantly enhance electrical reliability.

Don A. Genutis acquired the former Westinghouse East Pittsburgh electrical insulation testing laboratory in 1983 and operated the facility for several years before concentrating on field testing. Don is presently Managing Director of Hampton Tedder Technical Services, a NETA full member company with offices in Southern California, Las Vegas, and Phoenix. An additional office will open in northern California early next year.