On-Line Shielded Cable Partial Discharge Locating — An Overview

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This is the second in a series of regular articles that focuses on electrical inspection methods and technologies that are performed while the electrical system remains energized. Although no-outage inspections can be very valuable tools, always remember to comply with proper safely guidelines when conducting the energized "On Line" inspections.

Introduction & Background

First and foremost, all shielded cables and their terminations or splices should be partial discharge free, just as the cable was when it was manufactured and tested at the cable manufacturer's plant. This is especially true for acceptance testing and as a basis for trending those existing service-aged facilities, which may have some partial discharge activity starting.

Partial discharge is the partial failure of medium- and high-voltage insulation. As the insulation fails, it produces signals that can be detected using advanced technologies. These signals are a symptom, or *Side Effect,* that is produced by the partial failure of the insulation. Therefore, the detection of partial discharge in cable and other insulation provides an early warning of eventual or impending failure. Partial discharge testing can be performed on-line without requiring an outage and can be economically applied on all facility equipment in a survey fashion. By doing so, failures will be reduced, and reliability will be greatly enhanced.

In addition to the obvious economic and convenience advantages of on-line partial discharge testing, research has indicated that on-line partial discharge measurements better represent the true condition of the insulation, since measurements are taken under actual operating conditions. This is due to a composite effect of several complex physical interactions within the operating cable system that are not present in its off-line state. The prime effects include service factors such as operating temperature and its effect on partial discharge via thermal expansion and contraction characteristics, material properties, mechanical loading influences, current-based power factor, and harmonic frequency effects. Additionally, long-term energization affects insulation characteristics, as the insulation may respond differently because it has been energized for a long contiguous time, as compared to initial short-term energization during an off-line test.

Partial Discharge in Cable Systems

When evaluating the integrity of a typical cable installation, it is important to consider all elements of the cable system – terminations, splices, and the cable itself. If any of these components fail, power is lost and service is interrupted until corrective actions can be carried out. Reliability statistics indicate that approximately 90 percent of cable system failures occur at splices and terminations. This is likely due to workmanship defects developed from the inability to create flawless insulation specimens in the field under varying conditions by craftsmen of varying skill levels as compared to the repeatability of producing cable insulation in a controlled manufacturing environment that utilizes laboratory partial discharge testing for quality assurance purposes.

Imperfections in cable system insulation can be caused by defects, contamination, poor workmanship, faulty installation, and many other problems. These imperfections create localized stresses in the electrical field which in turn create localized breakdowns that lead to eventual complete failure.

These localized breakdowns create high-frequency pulses that can be detected and evaluated with specialized sensors and instruments. This technology continues to advance, and presently a great deal of information can be gathered by processing these pulses including the discharge magnitude, discharge power, number of pulses per cycle, pulse phase angle, and specific information related to each individual pulse including pulse width, risetime, frequency and other detailed information. This information can then be filtered, sorted, and classified to determine the existence of partial discharge activity, the level of danger that the discharge represents, the type of discharge that is occurring, and the location of the discharge.

Locating Partial Discharge in Cable Systems

It is very valuable to the facility manager to know if partial discharge activity exists on a specific feeder cable and the threat level that this activity represents. Additionally, it is also important to know where the activity exists so that corrective actions can be planned (prior to a complete failure) and taken in a nonpanic emergency mode.

In order to effectively assess cable system integrity, partial discharge measurements are typically taken at locations where the cable shields are grounded. These locations usually exist at each termination and splice, but certain installation practices may not include shield grounding at the splice points. When shield grounding does occur at the splices, relative partial discharge location can be determined by the partial discharge pulse magnitude and frequency since pulse magnitude and frequency decrease as the distance from the partial discharge source increases. Therefore, locations along the cable system where the highest magnitude and highest frequency pulses are found indicate the most likely location of the partial discharge activity.

Different approaches must be taken to locate partial discharge in cable systems that do not have grounded splice shield points, and these approaches can also be applied to confirm partial discharge location in cable systems that do have grounded splice shield points. Depending on noise levels, partial discharge pulses can be detected a thousand feet or more away from the partial discharge source. By applying special noise reduction filters to the partial discharge measurement system, it is usually possible to detect partial discharge in the longest runs of cable just from the terminations. Even though the length of the cable run and the level of background noise may adversely influence the accuracy of the test results, it is still worth attempting the test since, at a minimum, termination flaws can be identified.

When partial discharge occurs in a cable system, two pulses of similar size and characteristics propagate away from the partial discharge site towards the terminations. Depending on the cable insulation type, shield construction, and other factors, the speed in which the pulses travel

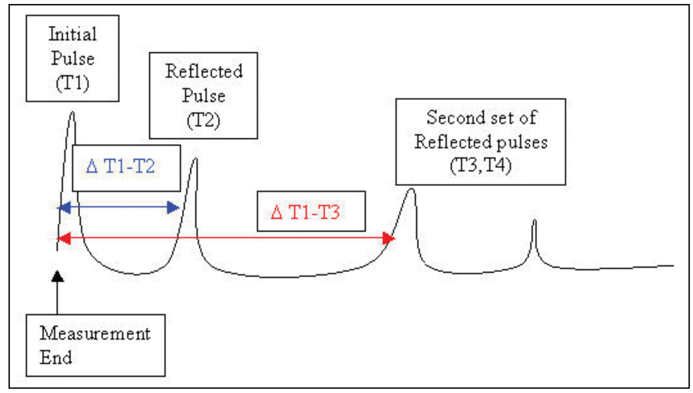

Figure 1 — Partial discharge pulse train seen from the measurement end of the cable system.

is relatively consistent. For instance, partial discharge pulses travel at a speed of approximately 468 feet per microsecond (142.65 meters / u-sec.) in XLPE insulation.

As can be seen in Figure 1, the time difference between the first two pulses (the initial pulse and the reflected pulse) is noted as delta T1-T2. The two pulses will continue to travel up and down the cable. These two pulses are reflected at exactly the cable return time (delta T1-T3) from the original pulse set, creating two sets of pulses, each spaced at the cable return time, delta T1-T3. Then the partial discharge location can be calculated from the following formula:

Location from Measurement End (in % Cable Length) = $100*(1- \Delta T1\text{-}T2/\Delta T1\text{-}T3)$

Under certain circumstances, such as an extremely long cable or noisy background conditions, the reflected pulse may fall below the noise threshold as it attenuates along the cable and may not be distinguishable at the measurement end. In those cases, it is possible to apply a remote pulse transponder to the far cable end. The transponder detects the reflected pulse as it reaches the far end and then injects a large pulse back on the cable shield that will easily be distinguished at the measurement end.

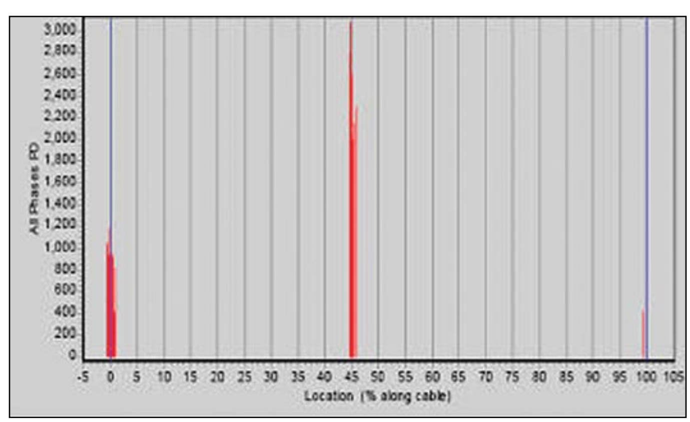

Figure 2 – On-line cable partial discharge mapping showing discharges from a splice located approximately 45% of the cable length from the measurement end and a secondary discharge occurring from the termination at the measurement end

In addition to performing hand calculations to determine partial discharge location, special software is available that calculates and plots partial discharge location as seen in Figure 2. This cable partial discharge mapping software can provide partial discharge location with more accuracy and more efficiently than hand calculations.

Conclusion

Partial discharge testing is a vital tool for determining the health of cable systems. This technology can be applied economically in an on-line survey fashion to provide excellent cable system condition assessments. This information can then be used to channel maintenance resources to the areas that require the most attention. Several advanced methods can be used to identify, quantify, and locate partial discharge, depending on the cable system construction and the partial discharge location accuracy requirements of the facility.

Mr. Genutis received his BSEE from Carnegie Mellon University. He was a NETA Certified Technician for 15 years and is a Certified Corona Technician. Don's technical training and education is complemented by nearly twenty-five years of practical field and laboratory electrical testing experience. He is presently serving as Vice President of the Group CBS Eastern U.S. Operations and acts as Technical Manager for their subsidiary, Circuit Breaker Sales & Service located in Central Florida.

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