Transmission & Distribution World®

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A PRIMEDIA Publication

January 2004

www.tdworld.com

The Big Picture In T&D

As a new year begins, we take an in-depth look at the future of T&D utilities and the impact of customer choice.

Assuring a Reliable Underground Feeder System

By Michael J. Smalley, We Energies

We Energies uses partial-discharge detection techniques to locate installation problems and minimize incipient cable failures.

With an increasing emphasis on reliability, We Energies began searching for a better way to more effectively test medium-voltage underground cable systems. The utility needed to find a way to test cable circuits so that it could detect, correct and ultimately eliminate the problems encountered in new installations that lead to the incipient failures on new cable systems. We Energies (Milwaukee, Wisconsin, U.S.) has been unable to detect problems associated with poor installation procedures with traditional high-potential-withstand testing; this is not acceptable. We Energies wants to be able to walk away from a construction project with confidence that circuits will provide trouble-free operation.

Electrical testing technicians (from left to right) Mike Wood, Gary McDermott and Randy Miller

> **"We Energies wants to be able to walk away from a construction project with confidence that circuits will provide trouble free operation."**

Market Review

We Energies undertook a review of existing cable testing products and services. The utility decided to focus on several promising technologies and embarked on a series of field trials. Upon completion of these trials, We Energies decided to purchase a 60-Hz resonant test set capable of detecting and locating partial discharges (PD) in the utilityís cable system. Although the acquisition of a generator and resonant test set added significant cost to the testing, the utility decided that using a voltage source similar to that used during factory testing would provide the best opportunity for evaluating cable systems.

Implementing a Change

Prior to receipt of the equipment, We Energiesí electrical testing technicians received training from the equipment vendor. Training included a general overview of cable engineering theory and details of the testing technology. This training and subsequent field training on the We Energies system has allowed the utility to perform all testing in-house.

We Energies purchased the test equipment to perform

Operation of the System

We Energies is using technology based on the detection and location of a partial discharge (PD), a localized electrical discharge restricted to a portion of dielectric material that does not bridge the cable between conductor and shield. The brawn of the test equipment is a combination of a motor generator set and a variable reactor capable of producing test voltages up to 45 kV (60 Hz). In series mode, the reactor inductance is tuned to the capacitance of the cable under test, minimizing the size of the motor generator set. For short segments of cable, the reactor is wired in parallel mode as an autotransformer, eliminating the need for tuning. The brain behind the test is a sophisticated microprocessor (estimator), which captures waveforms induced in the cable during the test.

The test process starts when a test clearance is granted. The grounds are lifted and the time domain reflectometry equipment is connected to “map” the cable. A low-voltage pulse is sent down the cable to determine the length of the cable and the distance of any cable joints from the test equipment. When the map is complete, the sensitivity of the system is determined and calibration of the measuring instrument is performed. Then the cable is energized with a steadily increasing voltage up to the maximum test voltage. During this process, the tester is monitoring the “estimator” display for any signs of PD. If PD is observed, the test voltage is held constant for a short time while data is recorded. The voltage is then lowered to zero so that the location and source of the PD can be determined before any higher excitation voltage is used. To determine the origin of the PD, the tester enters the analysis mode of the software. One important step of this process is to program the digital filter to eliminate high-magnitude noise signals (normally AM radio stations). This can improve the quality of the data tremendously in some cases. Depending on the source of the PD, the cable may be re-energized to attain the maximum test voltage or the test may be terminated.

“We Energies uses contract crews to install approximately two-thirds of its new primary direct-buried cable systems.”

acceptance tests on new feeders and to diagnose aged cable. The utility first focused on the new feeders, as these situations tended to be less complicated and allowed the technicians to gain experience and confidence with the test set and testing procedures. However, since new cables are often spliced onto aged cable, the technicians found that tests on newly upgraded feeders can be quite challenging. When new solid dielectric cables are tested, the maximum test voltage is normally set at three times the rated phase to ground operating voltage. In tests of hybrid installations, technicians limit the test voltage to a lower value. In either case, partial discharge detection and location (PDDL) is now the utilityís preferred acceptance test for extruded dielectric cables.

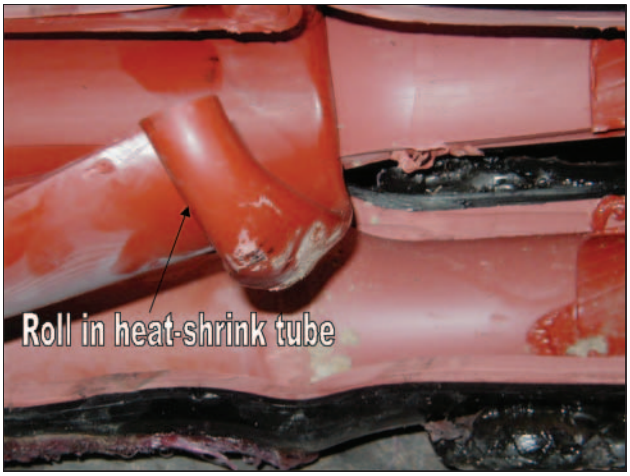
We Energies uses contract crews to install approximately two-thirds of its new primary direct-buried cable systems. To ensure there is no miscommunication on the meaning of test results, We Energies revised its contract specifications to incorporate limits on PD extinction voltage for cable systems. The limits originated from industry standard cable specifications, IEEE standard 404 for cable joints, IEEE standard 48 for cable terminations and IEEE standard 386 for separable connector systems.

Promising Results

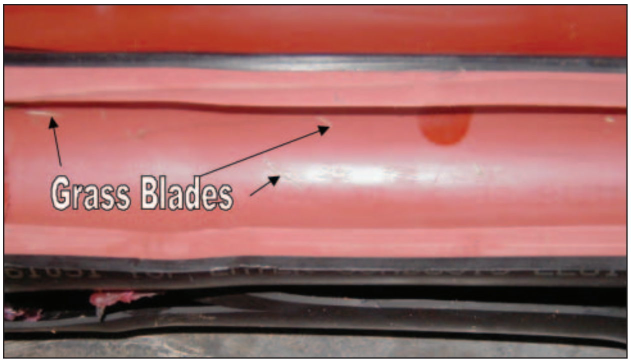
Since We Energies began using this technology on new feeder cable systems, it has found several problems with cable accessories that would have resulted in failures and, therefore, customer outages. For example, prior to launching its PD test program, the utility ran into problems with a 35-kV heat-shrink joint installed on a feeder exiting the new Apple Hills Substation. Within a year, We Energies found that one joint had failed. After making repairs, the utility went back and performed PD testing on all the new feeders exiting this substation and found two additional joints with PD levels above those specified in IEEE 404 requirements.

During ìsplice-opsies,î We Energies found one joint that was poorly constructed, with a stress relief layer folded over on itself. In another joint, the utility found several blades of grass stuck between stress relief tubes. The contractor picked up the expenses incurred in replacing these joints.

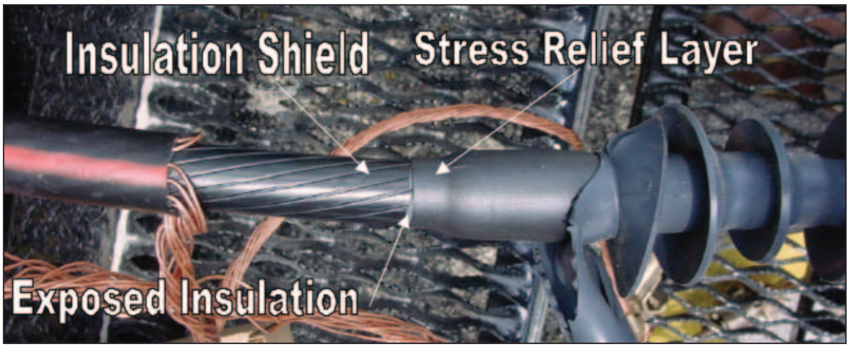
Another case involved a polymeric riser termination



Heat-shrink joint improperly installed.



Heat-shrink joint with blades of grass between stress layers.



Stress relief portion of polymeric termination not overlapping onto cable insulation shield.

that exhibited partial discharge below the IEEE 48 voltage level. Dissection revealed that the termination was installed too high on the cable. This resulted in a situation where the stress relief layer of the termination did not overlap onto the insulation shield. Again, the cost of the repair was born by the contractor.

Aging Systems

The age of the We Energies underground system is increasing, which could potentially affect reliability. The utility is constantly searching for ways to maximize the value received from its capital expenditures while looking for ways to maintain or improve reliability. We Energies recognizes that replacing cable systems at or before their estimated end of life is not always an option. Thus, the utility is committed to leveraging systems like the PDDL technology to better understand the condition of its aged cable system. Aged underground cables likely contain water trees. The PD detection technology (a localized test) can locate only those water trees associated with electrical trees emitting PD. For this reason, We Energies is planning to use dissipation factor testing (a global test) to complement PDDL on aged cable systems. In 2004, the utility will receive this loss-factor equipment, which will enable us to more thoroughly evaluate the condition of the underground residential system.

We Energiesí selection criterion for testing aged cable systems considers the overall performance of the system. It also addresses specific concerns with accessories used on the system. For aged extruded dielectric cables, the utility has set the maximum test voltage to two-and-half times the rated phase-to-ground operating voltage for cables rated 28 kV and below. If paper-insulated lead cable is being tested, the maximum test voltage is reduced to two times rated voltage.

When new or aged cables are spliced to cables of a different size, reflections occur because of the characteristic impedance difference between the cables. This poses a practical problem since much of the energy of the signal from a PD can be lost or reflected back into the cable at these transitions. The same phenomenon occurs at reducing joints. In particular, this situation is most prominent when solid dielectric cable with concentric neutral wires is spliced to lead sheathed solid dielectric cable and then to PILC, resulting in data that can be quite tough to analyze.

Rest in Peace

The high-potential-withstand tests method We Energies used previously prevented technicians from seeing problem situations within the cable system. Now, because the technicians can read PD signals on a monitor, they have the opportunity to correlate these signals to existing system problems, which the utility believes to be a significant improvement in cable testing and inspection technology. With an established cable testing program and a trained workforce in its back pocket, We Energies, its customers and its cables are afforded a better opportunity to rest in peace. ■

Mike Smalley received the BSEET degree from the Milwaukee School of Engineering in 1991 and the MSE degree from the University of Wisconsin–Milwaukee in 2000. He began his career as a student engineer with We Energies (formerly Wisconsin Electric Power Co.) in 1990, and has held engineering positions in the nuclear power department and the transmission and substation group. He is currently a senior engineer in the distribution standards and materials group. Smalley is a registered professional engineer in the state of Wisconsin.