Non-Intrusive Oil-Filled Cable Leak Location: Use of Perfluorocarbon Tracers increases infrastructure lifetime, saves money, protects the environment

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Self-contained, fluid-filled cable systems are mature, robust and reliable HV technology that has been deployed in most major cities and towns around the world for many years. In recent times the deployment and installation of oil-filled cable has declined, with the majority of new installations now using XLPE solid insulated cables. However, due the high capital replacement cost, and with limited access to roads and streets in our major towns, it is anticipated that fluid-filled technology will continue to be in service for many years to come.

High voltage underground cables are typically filled with dielectric fluid to provide electrical insulation, suppress corona and arcing, and in some cases to serve as a coolant. The dielectric fluid is pressurized to prevent gases from forming inside the cable, which can cause catastrophic failure. When leaks occur, they are difficult to locate and expensive to repair, usually requiring major excavations and power outages. Problems can occur with buried cables due to ground movement, deterioration, and third party strikes, which result in the leakage and loss of the insulating fluid. This leakage is often difficult to locate and repair when circuits need to be removed from service for the work to be done and can result in long outage periods. Leaks can range from a few litres per day to many litres an hour, having an effect on the local environment, causing breeches in national and local environmental legislation and exposing utilities to financial penalties and possible loss of reputation.

Perfluorocarbon tracer (PFT) leak location technology offers a benign and environmentally acceptable method of pinpointing leaks, even very small leaks that cannot be detected using traditional 'freezing' techniques. The leak location is carried out by tagging the cable fluid with a liquid tracer so personnel can then detect leaks using above-ground test equipment while the cable remains in service, thus reducing outage time, cost of excavation and speeding up the repair process. Leaks can be detected to within one meter depending on ground conditions and the local environment.

HISTORY

PFT is a non-CFC Freon liquid that is used for a multitude of applications in the medical and environmental fields. In the early 1990s, a technique was developed by the Energy Products Research Institute (EPRI) to apply PFT for use as a liquid tracer in high-pressure, fluid-filled cable systems. The original project was the result of a partnership between Consolidated Edison of New York (ConEd) and Brookhaven National Lab (BNL) to carry out leak location in the cable systems, which at the time resulted in large volumes of oil being lost as the fluid in these cables can circulate up to 300 gallons per minute.

It was demonstrated that a presence of less than 10ppm of PFT within the cable fluid could be detected at ground level when a leak occurred. This very low level was proven safe to the cable, joints and seals of the cable system and has no foreseen long-term potential effects. At these extremely low levels there is no effect on the characteristics of the dielectric fluid. There is also no environmental or emission issues using PFCs in this application. This differs from other tracer experiments tried using SF6, helium or hydrogen, where tracer concentration must be near 100% and injected in gaseous form.

As a result of requiring such a low level of tracer for detection, very sensitive instrumentation was developed to accommodate low detection levels. The instrument must be able to see individual PFCs at the part per quadrillion range (ppq) or equivalent to 1 second in 37 million years.

The PFT tracer is dissolved in cable oil and injected into a cable circuit. Under normal operating conditions, the tracer remains in solution with dielectric properties well-matched to cable oil. On escaping from the cable through a leak, accompanied by a local change in pressure, the PFT tracer becomes a gas and escapes to ground level. As it reaches ground level the minute plume of PFT vapour can be detected using PFTtech's specialized instrumentation that is either vehicle-mounted or handheld. The oil leak can be accurately located, with the cable in service and without the need for major excavation and the subsequent disruption to road traffic. Using PFT technology, an oil leak can be located to within one meter in less than 24 hours.

The outcome of the project was so successful that Coned has pre-tagged all 1000km of their cable system, accounting for more than 27 million litres of tagged dielectric fluid. In addition they invested in a number of vehicle- mounted test instruments to provide a 24-hour response when system leaks developed. This has been the utility's primary method of leak location since 1997.

NATIONAL GRID AND PFT TECHNOLOGY

National Grid is an international electricity and gas company and one of the largest investor-owned energy companies in the world. The utility plays a vital role in delivering gas and electricity to millions of people across Great Britain and the northeastern United States.

National Grid's policy of reducing the impact of cable oil leaks into the environment as well as its goal to minimize disruption caused by cable repair is of central and critical performance in its mission for serving its customers.

Oil leak location is, however, technically challenging, time consuming and for most methods can only be carried out under outage conditions. During the period of the leak, a cable will remain under pressure and continue to leak oil, whether it is in or out of service. In fact, it is quite common for leaks to seal up when the cable cools down as a result of being taken out of service and cools down, making location impossible.

The traditional 'Freeze and Dig' technique is proving obsolete in a modern utility system. Limited application, tighter outage schedules, intolerance to road closures, damage to the sheath and a limited success rate make the older process very costly in terms of time, money and public disturbance.

The implementation of a more proactive, non-intrusive leak location system to minimize fluid loss and reduce circuit outages was vital to National Grid in ensuring high system reliability for all underground fluid-filled cables.

NATIONAL GRID R & D PROJECT

In 2005, National Grid partnered with PFT Technology (PFTtech), a global, full service leak-locating company with locations in New York and London, to develop a comprehensive leak reduction program. PFT Technology had been formed by former ConEd managers and technicians, and the company's staff had developed advanced detection equipment to complement PFT tracers.

PHASE 1

The first phase of National Grid's project focused on 132kV cables, using a problematic cable with previously detected leaks in London that was scheduled to be de-commissioned as it seemed to have reached the end of its useful life.

Applying PFTs in a closed circuit system (SCOFF) proved challenging. There can be no dissolved gases in the system. Since the cable is at only 0.5 - 4 bar, the tracer gases can precipitate out of the cable fluid much more easily. HPFF feeders operate at pressures of up to 250 + PSI where all gases

tend to remain dissolved and no degassing precautions need to be taken. The oil in a LPFF, however, is at low pressure, does not circulate and is static. Consequently, degassing is much more of a concern for the long-term health of the cable.

Very specific injection apparatus had to be developed to insure proper introduction of PFT without compromising the integrity of the cable. There are two methods to inject a cable--flushing and topping off. The first entails calculating the core duct volume of the cable and flushing the cable with the approved and proven concentration of tracer fluid. The latter is a process where a higher concentration of PFT tracer is injected into the reservoir tanks and the leak rate carries the tagged fluid to the leak site. The flushing method is the safest and most effective method. Topping off is used in very limited circumstances, for example, where cables are very short or it is known that a leak is very close to the injection point. Beyond that, topping off becomes a much more expensive and time consuming leak detection process.

Once a cable is tagged, any current or future leaks can be accurately located with field instrumentation that can sample ambient air for a rise in the background PFT levels. Taking soil gas samples to further pinpoint the leak location to a few meters then follows up an elevated ambient signal. Multiple tracers are used to eliminate older leaks on the same cable or parallel runs of cables.

By utilizing the PFT technology, National Grid was able to identify and fix five leaks on 3 sections of cable in London.

PHASE 2

After the success with the 132kV cable, the second phase of the project was to step up the voltage level (275kV) and try the technology on a problematic cable with longer hydraulic sections and an overall route length of 10km across seven hydraulic sections that run over open country as well as under major roads and city streets. The cross-country cable could only be accessed on foot, which led to PFTtech's development of a hand-held air-sampling device.

The project delivered far more than anticipated, locating several leaks, each with the accuracy of two meters over hydraulic sections that ran as long as 2.5km. 'Bar holing' through the road surface enabled air samples to be taken from below tarmac road, allowing accurate location, which has the added benefit of being able to identify leaks on buried oil pipe work and buried tanks, resulting in only a partial excavation of the joint bay.

Following this success, National Grid embarked on a project to 'tag' the twenty cables with the worst historic oil loss, with the long-term intention to tag all of its major transmission circuits over a three-year period.

In that time, the PFT technology was able to have a major impact on both the environmental and financial concerns of National Grid: the gross fluid loss was reduced significantly, by more than 50 percent; at the same time, cost to the utility was reduced dramatically in that the outage time to make the repairs was reduced by two-thirds. There was also significant reduction of direct costs because annual excavation costs declined and oil pumping costs fell dramatically as leaks were systematically found and repaired.

National Grid embarked on further development with PFTtech to refine the process, enabling the technique to be deployed on self contained oil-filled cables with a very high success rate, and it is now the main tool used for the detection of all cable oil leaks on the network. Additionally, a third phase has been initiated to develop the tagging process to enable tagged fluid to be injected into the cable with the circuit live. This project is still ongoing and is due to be completed later in the year.

Conclusions

PFT technology has allowed National Grid to reduce fluid loss into the environment; reduce outage times; and realized a positive return on investment due to a reduction in maintenance costs. As a result, the utility expanded its original parameters so that all leaking sections throughout the entire system were targeted for injection. A decision was also made to preventatively tag all available sections that had no current leaks. Now, more than 400 km of cables from 132kV to 400kv are now injected with the proper levels of PFT tracer, totaling more than 500,000 liters of tagged dielectric fluid.

All leaks that were being maintained at the start of the project have been located and repaired. All new leaks are now located on 'routine' leak searches. No outages are required for injection since almost the entire system has been preventatively tagged. Once new leaks are pinpointed, outages with specific time frames are scheduled for repairs and re-tagged prior to energization if required. As a direct result of implementing PFT technology, National Grid does not have any active leaks that have not been located and scheduled for repair.

Using PFT technology on an occasional basis will prove productive and help locate difficult leaks, but for National Grid to meet the goals and high standards it has imposed on its organization, an aggressive systemic approach was required. This approach proved to be not only an environmental success, but it also a good economic decision.

Taking a systemic proactive approach to leak management has provided long-term benefits across the National Grid transmission system: reduced outage times, reduction in public disturbance, overall cost reduction and, most important of all, a reduction of fluid loss to the environment.