AGING CABLE INFRASTRUCTURE

Managing lifecycle performance of T&D cable systems

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The 2014 Annual Energy Outlook Report compiled by the US Energy Information Administration (EIA) forecasts that total electricity demand will grow by 29 percent (0.9 percent per year) by 2040. While growth has slowed in every decade since the 1950s, due in part to efficiency gains in appliance standards and investment in energy efficient equipment, a need exists to increase capacity while maintaining the current infrastructure to meet this future demand.

Transmission and distribution cable systems installed prior to the 1990s are nearing the end of their designed life and aging infrastructure is often cited by electric utilities as a basis for unplanned power outages. However, utilities also cite construction activities during the commissioning of new systems also as a factor affecting reliability.

Cable and accessory manufacturers believe—for a long time—that the catalyst of cable system failure is a phenomenon associated with partial discharge (PD). Consequently, manufacturers, have quality control tested newly manufactured components for PD activity as a standard operating procedure since the 1960s. However, for many years, electric utilities could not assess aged underground residential distribution (URD) and transmission cable systems to these exacting manufacturers' standards in the field.

Manufacturers perform highly sensitive partial discharge measurements in multi-million dollar shielded laboratories, but replicating these test conditions with limited noise levels and high sensitivity has proven impossible or impractical in a field-testing environment. In 1995, IMCORP developed an innovative cable assessment technology to field test and assess newly commissioned and aged cable systems. The goals of this technology were to deliver results analogous to manufacturers' standards on-site as well as to save electric utilities money in lost revenue and maintenance costs.

In an attempt to offset expenses further, a recent U.S. Federal Energy Regulatory Commission (FERC) ruling now allows utilities to capitalize funding related to underground electric cable assessment programs that use this specific technology as part of a rehabilitation program to help prolong useful life. This ruling has helped bolster the already sound business case for assessing and extending the life of underground cable systems, rather than replacing them in a wholesale fashion.

> **The silent killer of the U.S. critical infrastructure is age**

THE CURRENT SITUATION

The silent killer of the U.S. critical infrastructure is age. The country is pushing their century old bridges, sewer systems, and energy networks far beyond designed limits and well past their designed life. The capacity to sustain this infrastructure into the 21st century far exceeds the time, cost, and labor required to rebuild or replace it; let alone meet greater future demands. Innovation is the key to move forward and remain competitive by repurposing and reinventing methods to improve the status quo.

Electric utilities in North America are experiencing aging-related reliability challenges within their transmission and distribution cable infrastructure, constructed prior to 1990, to meet future energy demand requirements. Fortunately, most of this cable still currently functions well, and more satisfactorily, may continue functioning to manufacturers' specifications for years to come. The challenge is identifying which cables still function correctly as well as require repair or replacement. Monitoring the traditional metrics of failure rate, age, and vintage has proved unreliable in predicting power failure.

Wholesale replacement of these cable systems based on these metrics have proven too cost prohibitive, but public opinion and strict regulatory demands often set uptime as the utmost priority, while keeping consumer pricing stable. Operations and maintenance budgets are usually the first to lose funding as a measure to maintain profitability. Management expects fewer personnel to work fewer hours to operate and maintain more systems at lower costs. Concurrently, management expects workers to deliver higher efficiency, higher availability, and higher profits with the company's aging assets.

Utility asset managers and cable manufacturers understand that cable systems fail due to an insulation erosion process, associated with partial discharge activity that can originate during manufacturing, shipping, construction, accessory installation, and aging. Consequently, testing for partial discharge activity at the production stage, commissioning stage and at regular operating intervals is prudent when assessing cable system viability.

Cable and accessory manufacturers have tested their products for many years to standards that meet electrical power cable standards set by the Insulated Cable Engineers Association (ICEA) for electrical power cable and as well as standards for separable connectors, joints, and terminations set forth in Table 1 by the Institute of Electrical and Electronics Engineers (IEEE).

Cable manufacturers are able to quality control (QC) test to the aforementioned standards at the manufacturing stage in electromagnetically shielded rooms; however, an order of complexity exists in testing to these same standards once the cable is installed underground in the field, during the commissioning and operating stage of the cable lifecycle. Up until recently, the testing procedures available for cable system assessment fell well short of meeting the IEEE and ICEA standards and were, at best, guidelines to system integrity, or in some cases, classified as destructive by design and intended to fail cable at a weak point.

While each available test method may have merit in some way with respect to cable system integrity, only one field test is currently available that can match the requirements set forth by the standards writing organizations such as IEEE, IEC, and ICEA.

THE NEED FOR EFFECTIVE ASSESSMENT TESTS

While age plays a part in cable system reliability, it is insulation damage in the presence of voltage transients that leads to partial discharge, erosion, electrical treeing (that is, pre-breakdown in insulation), and eventually, complete dielectric failure. If the worker does not test the cable system to the manufacturers' specifications, then the risk of cable system defects going unnoticed increase, thus leading to unplanned outages. The vast majority of cable system failures are associated with partial discharge activity.

An innovative cable diagnostic system developed by Dr. Matt Mashikian of IMCORP has revolutionized cable testing practices, making defect specific assessment of cable and accessory systems to manufacturers' standards available for field testing purposes. This testing method can pinpoint the exact location of a defect, allowing the opportunity to repair, resulting in over 70 percent in savings over complete system replacement.

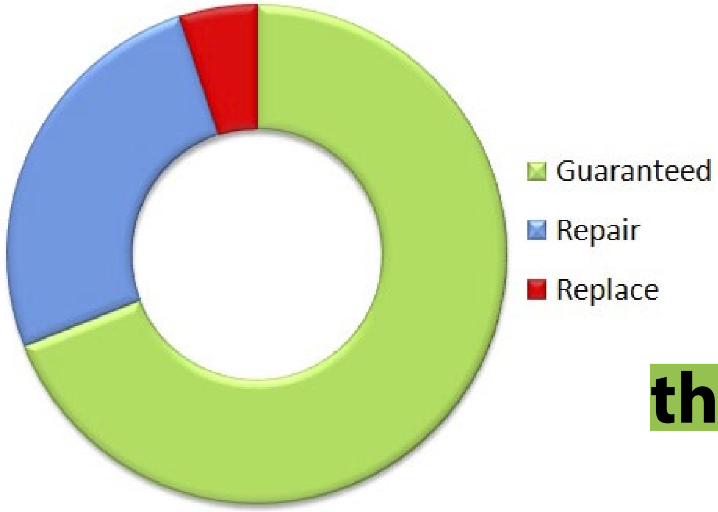
Mashikian's test method has assessed more than 100 million feet of cable to date and catalogued detailed information from each test in a central database. Taking a sample of thousands of assessments performed on aged utility cable (~4,000 conductor miles), less than six percent of the population has needed wholesale replacement.

To date, these results have saved consumers from countless power outages and resulting lost production, while saving electric utilities over $100 million in replacement costs. The test, an offline 50 to 60 hertz (Hz) partial discharge assessment with better than

Table 1: Field testing cable systems to the manufacturers' test is not a simple matter

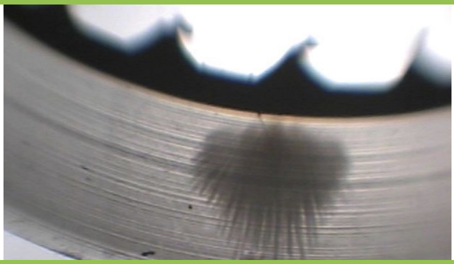
MANUFACTURER'S STANDARDS			
Component Standard	**Testing Frequency (Hertz)**	**Thresholds***	
		Sensitivity (Picocoulomb)	**Voltage (Phase to Earth)**
Terminations IEEE 48: *"Standard for Test Procedures and Requirements for Alternating-Current Cable Terminations Used on Shielded Cables Having Laminated Insulation Rated 2.5 kV through 765 kV or Extruded Insulation Rated 2.5 kV through 500 kV"*	50/60 Hz	5pC	≤1.5 Uo
Joints IEEE 404: *"Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2.5 kV to 500 kV"*	50/60 Hz	5pC	≤1.5 Uo
Separable Connectors IEEE 386: *"Standard for Separable Insulated Connector Systems for Power Distribution Systems above 600 V"*	50/60 Hz	3pC	≤1.3 Uo
Medium-Voltage Extruded Cable ICEA S-94-649: *"Standard for Concentric Neutral Cables Rated 5-46 kV"* ICEA S-97-682: *"Standard for Utility Shielded Power Cable Rated 5-46 kV"*	50/60 Hz	5pC	≤4.0 Uo^
High-Voltage/Extra-High-Voltage Extruded Cable ICEA S-108-720: *"Standard For Extruded Insulation Power Cables Rated Above 46 Through 345 kV"*	50/60 Hz	5pC	≤2.0 Uo

** No partial discharge should be observable above the sensitivity threshold up to the voltage threshold*
^200 volts per mil
Uo = Operating voltage
Sources: IEEE Standards Association, Insulated Cable Engineers Association



Utility cable assessment sample for thousands of cables

TYPES OF CABLE SYSTEM DEFECTS



Aged cable defect was pinpointed by a field partial discharge (PD) test matching factory test standards in Table 1 test but not visible with an online test

New installation defect: New cable defect passed a very low frequency PD test and was pinpointed by field PD test matching factory test standards

Critical facility defect: Power plant termination installation error pinpointed with a field PD test matching factory test standards test but missed by a tangent delta and very low frequency test

five picocoulomb (pC) sensitivity, can measure defect-specific information across an entire cable system and components—even when the cable is buried underground.

In addition, FERC directly endorses this defect specific assessment test for capital expense when added to a cable life extension program. If an aged cable system performs to the same specifications as a brand new system or can be repaired and brought back to manufacturers' standards, then only the cost of testing, or testing and repairing is incurred.

This condition-based information presents a tremendous opportunity to electric utilities who face enormous replacement backlogs and capacity restraints when dealing with cable assets that are nearing or have surpassed their designed life. The opportunity now exists to verify that all installed cable systems will continue to function and meet new component quality standards.

Testing cable systems using this assessment approach provides identification of all components within the cable system and provides a full assessment of the condition of each; including terminations, joints, separable connectors and the cable itself. In addition, this assessment approach provides detailed feedback so that maintenance personnel can take corrective action. Currently, many electric utilities globally as well as facilities with critical operations such as hospitals, data centers, and sport venues are using this procedure to assess cable system integrity. Furthermore, utilities and regulators are commissioning new installations at renewable and traditional energy plants using this assessment approach.

FAMOUS LAST WORDS

When the power industry considers the massive undertaking required in order to upgrade North America's aging infrastructure to meet operational and designed standards, implementation requires innovative methods to move forward with greater effectiveness and efficiency. News stories emerge daily that discuss the effects of aging infrastructure failures, with many citing power cable failure as the result of power outages.

Each year, underground power cable system failures affect millions of people and thousands of businesses. Efficient rehabilitation of these systems, through measurement of cable system integrity, will ultimately save electric utilities billions of dollars in replacement costs, help reduce power outages, offset price increases, and ultimately benefit electric power consumers. ET