Avoiding Unnecessary Cable Replacement in Nuclear Power Plants

C. Kiger,[a] C. Sexton,[a] H. Hashemian,[a] T. Toll,[a] L. Dormann,[b] W. Wasfy[b]

[a]*Analysis and Measurement Services Corporation, 9119 Cross Park Drive, Knoxville, Tennessee 37923*
chad@ams-corp.com, casey@ams-corp.com, hash@ams-corp.com, trevor@ams-corp.com
[b]*Oyster Creek Nuclear Generating Station, Exelon Generation Company, Lanoka Harbor, New Jersey 08734*
Leo.Dormann@exeloncorp.com, walid.wasfy@exeloncorp.com

ABSTRACT

This paper reports the results of in-situ cable testing performed at the Oyster Creek Nuclear Generating Station in September 2016 to assess the aging condition of a number of cables as installed in the plant. Despite having been in service for over 40 years, our results found that a majority of these cables still met their qualification criteria, were in good working condition, and could continue to serve the plant for the foreseeable future. Some degradation in the cable insulation was noted, but not as much as one would expect after more than 40 years of service in a nuclear power plant. Specifically, test results revealed that 10 percent of cables exhibited a noticeable degree of degradation, 30 percent were only slightly degraded, and the remaining 60 percent were essentially unaffected by aging. In the case of jacketed cables, which were assessed using walk-downs performed by the plant's personnel, almost all aging and degradation was limited to the jacket material while the underlying cable insulation was largely unaffected. This is consistent with laboratory test results which have shown that jacket material, especially Neoprene and Hypalon, degrade much faster than XLPE and other materials that are used for primary cable insulation.

INTRODUCTION

A number of in-situ cable testing techniques have been developed and validated through years of research and development (R&D) efforts, funded by the U.S. Department of Energy (DOE), to provide new technologies for cable condition monitoring, aging management, and remaining useful life estimations. Carried out at Analysis and Measurement Services Corporation (AMS), these R&D efforts have resulted in new equipment and techniques that can identify problems along cable conductors, in connectors, and cable insulation material. In particular, reflectometry methods such as Time Domain Reflectometry (TDR) and Frequency Domain Reflectometry (FDR) can identify and locate degradation of polymers such cross-linked polyethylene (XLPE) and ethylene propylene rubber (EPR) and other materials used for insulation of nuclear plant cables. These methods were implemented at the Oyster Creek Nuclear Generating Station to assess the aging condition of a number of cables as installed in the plant. These cables have been in service in the plant since it began operation over 40 years ago. The in-situ tests revealed that most of the cables tested were in good working condition and could remain in service with no adverse safety implications.

BACKGROUND

Oyster Creek Nuclear Generating Station, a Boiling Water Reactor in New Jersey, had experienced a number of low voltage cable degradation issues, some of which had significant plant impact. In response, a strategy was developed to address aging of low voltage cables in adverse environments throughout the plant.

The original plan was to perform extensive visual inspections of the identified cables and replace them as needed. This approach would have required scaffolding to be built and multiple contingency conduit/cable runs to be installed prior to the refueling outage. However, during weekly team meetings it was determined that visual inspections could be significantly reduced by supplementing or replacing them with a new approach to electrical cable testing. The electrical tests provided a means to use industry-standard laboratory measurements to develop acceptance criteria for non-intrusive field application. For each cable type, correlations were developed in the laboratory between the Elongation at Break (EAB) test, which is the industry standard for measurement of ductility (i.e., age) of polymers, and electrical measurements that can be performed non-intrusively and remotely (in-situ testing). These correlations were then used to convert in-situ test data to equivalent EAB data from which the condition of a cable could be estimated.

IN-PLANT TESTING AT OYSTER CREEK NUCLEAR POWER STATION

A suite of electrical tests were performed by AMS at Oyster Creek including TDR, FDR, IR, and Impedance measurements consisting of Inductance (L), Capacitance (C), and Resistance (R) tests or LCR. These are non-destructive, in-situ tests which, when used together, can identify, locate, and quantify impedance changes in a cable circuit. The results of these tests were used with the acceptance criteria that AMS developed as described below to segregate the good cables from the degraded cables at Oyster Creek.

AGING ACCEPTANCE CRITERIA

EAB is the percent of specimen tensile elongation at the point of fracture. Cable insulation polymers are malleable/ductile when new and become more brittle/stiff as they age. Therefore, cable insulation aging results in a reduction in EAB values.

It is generally concluded that 50% EAB represents the end of a cable's useful life. This is based on conservatisms that consider maintenance-related manipulations and the cables' viability during accident scenarios. As such, the electrical test methodology for in-plant tests implemented acceptance criteria that correlates the 50% EAB value to a specimen that is 100% aged.

The correlations between the FDR test results and EAB criteria were developed through extensive laboratory testing, which included accelerated thermal aging of different polymer materials. It was found that test results trended with the increase in cable degradation as measured by EAB (Fig. 1). With this correlation for each polymer type, one can perform in-situ FDR testing on a cable as installed in a plant and convert the result to an equivalent EAB measurement from which the cable qualification status may be determined. Four categories of acceptance criteria were developed for field application as shown in Table I and used to interpret the results of tests at Oyster Creek Nuclear Plant.

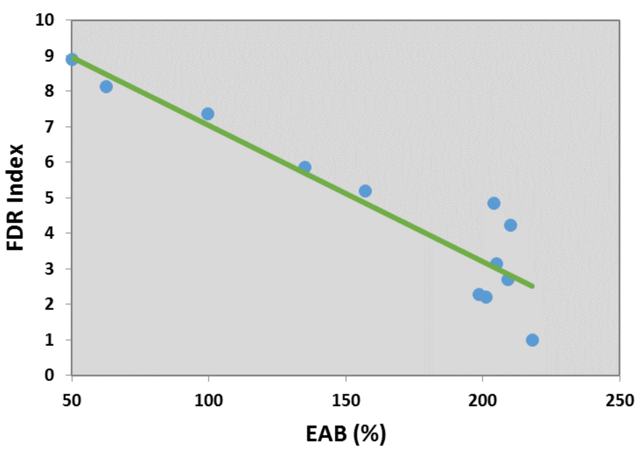

Fig. 1. FDR correlation with EAB.

TABLE I. Acceptance Criteria for Field Application

Category	%Aged	Comments
1	0 – 33	Little to no indication of age-related degradation
2	33 – 66	Initial indication that age-related degradation has occurred
3	66 – 99	Cable insulation has significant aging but is expected to function normally
4	>99	Cable insulation is at or near its end-of-life condition as defined by 50% EAB

These categories were established based primarily on the results of FDR testing which has been shown to be the most sensitive in-situ cable testing technique for identifying cable insulation age. The other testing techniques (TDR, impedance, and insulation resistance) were used to confirm the cables' operational status.

COST SAVINGS

Cost and time savings were vital during development of the low voltage cable aging management strategy for Oyster Creek Nuclear Plant. The original approach involved construction of approximately $2.5 million in scaffolding in the condenser bay to support extensive visual inspections. Contingency cable installations netted another $1.5 million in potential costs. Implementation of the electrical test methods resulted in a significant reduction in the scaffolding required and in pre-outage contingency conduit/cable installations. Precursory tests were implemented prior to the outage that gave insight on the health of similar cables and reduced the risk/cost of installing new conduit/cable prior to the outage. Overall, the reduction in outage costs, through implementation of the new test methodology was on the order of $3.7 million.

CONCLUSION

New electrical testing technology was successfully implemented for in-situ cable condition monitoring at the Oyster Creek Nuclear Generating Station. The results established the condition of the cables and saved the plant from replacing healthy cables.