XI.E3 INACCESSIBLE POWER CABLES NOT SUBJECT TO 10 CFR 50.49 ENVIRONMENTAL QUALIFICATION REQUIREMENTS

Program Description

The purpose of the aging management program (AMP) described herein is to provide reasonable assurance that the intended functions of inaccessible or underground power cables that are not subject to the environmental qualification requirements of 10 CFR 50.49 and are exposed to wetting or submergence are maintained consistent with the current licensing basis through the period of extended operation.

Most electrical cables in nuclear power plants are located in dry environments. However, some cables may be exposed to wetting or submergence, and are inaccessible or underground, such as cables in conduits, cable trenches, cable troughs, duct banks, underground vaults, or directly buried in soil installations. When a power cable (greater than or equal to 400 volts) is exposed to wet, submerged, or other adverse environmental conditions for which it was not designed, an aging effect of reduced insulation resistance may result, causing a decrease in the dielectric strength of the conductor insulation. This insulation degradation can be caused by wetting or submergence. This can potentially lead to failure of the cable's insulation system.

In this AMP, periodic actions are taken to prevent cables from being exposed to significant moisture, defined as periodic exposures to moisture that last more than a few days (e.g., cable wetting or submergence in water. Examples of periodic actions are inspecting for water collection in cable manholes and conduits and draining water, as needed. However, the above actions are not sufficient to ensure that water is not trapped elsewhere in the raceways. For example, (a) if a duct bank conduit has low points in the routing, there could be potential for long-term submergence at these low points; (b) concrete raceways may crack due to soil settling over a long period of time; (c) manhole covers may not be watertight; (d) in certain areas, the water table is high in seasonal cycles, so the raceways may get refilled soon after purging; and (e) potential uncertainties exist with water trees even when duct banks are sloped with the intention to minimize water accumulation.

Experience has shown that insulation degradation may occur if the cables are exposed to 100 percent relative humidity. The above periodic actions are necessary to minimize the potential for insulation degradation. In addition to above periodic actions, in-scope power cables exposed to significant moisture are tested to indicate the condition of the conductor insulation. The specific type of test performed is determined prior to the initial test, and is to be a proven test for detecting deterioration of the insulation system due to wetting or submergence, such as Dielectric Loss (Dissipation Factor/Power Factor), AC Voltage Withstand, Partial Discharge, Step Voltage, Time Domain Reflectometry, Insulation Resistance and Polarization Index, Line Resonance Analysis, or other testing that is state-of-the-art at the time the tests are performed. One or more tests are used to determine the condition of the cables so they will continue to meet their intended function during the period of extended operation.

As stated in NUREG/CR-5643, "the major concern is that failures of deteriorated cable systems (cables, connections, and penetrations) might be induced during accident conditions." Because the cables are not subject to the environmental qualification requirements of 10 CFR 50.49, an AMP is required to manage the aging effects. This AMP provides reasonable assurance the insulation material for electrical cables will perform its intended function for the period of extended operation.

Evaluation and Technical Basis

1. ***Scope of Program:*** This AMP applies to all inaccessible or underground (e.g., in conduit, duct bank, or direct buried) power cables (greater than or equal to 400 volts) within the scope of license renewal exposed to adverse environments, primarily significant moisture. Significant moisture is defined as periodic exposures to moisture that last more than a few days (e.g., cable wetting or submergence in water). Submarine or other cables designed for continuous wetting or submergence are not included in this AMP.

2. ***Preventive Actions:*** This is a condition monitoring program. However, periodic actions are taken to prevent inaccessible cables from being exposed to significant moisture, such as identifying and inspecting in-scope accessible cable conduit ends and cable manholes for water collection, and draining the water, as needed.

   The inspection frequency for water collection is established and performed based on plant-specific operating experience with cable wetting or submergence in manholes (i.e., the inspection is performed periodically based on water accumulation over time and event driven occurrences, such as heavy rain or flooding). The periodic inspection should occur at least annually. The inspection should include direct observation that cables are not wetted or submerged, that cables/splices and cable support structures are intact, and that dewatering/drainage systems (i.e., sump pumps) and associated alarms operate properly. In addition, operation of dewatering devices should be inspected and operation verified prior to any known or predicted heavy rain or flooding events. If water is found during inspection (i.e., cable exposed to significant moisture), corrective actions are taken to keep the cable dry and to assess cable degradation. The first inspection for license renewal is completed prior to the period of extended operation.

3. ***Parameters Monitored/Inspected:*** Inspection for water collection is performed based on plant-specific operating experience with water accumulation in the manhole. Inaccessible or underground power (greater than or equal to 400 volts) cables within the scope of license renewal exposed to significant moisture are tested to provide an indication of the condition of the conductor insulation. The specific type of test to be used should be capable of detecting reduced insulation resistance of the cable's insulation system due to wetting or submergence.

4. ***Detection of Aging Effects:*** For power cables exposed to significant moisture, test frequencies are adjusted based on test results (including trending of degradation where applicable) and operating experience. Cable testing should occur at least once every 6 years. A 6-year interval provides multiple data points during a 20-year period, which can be used to characterize the degradation rate. This is an adequate period to monitor performance of the cable and take appropriate corrective actions since experience has shown that although a slow process, aging degradation could be significant.. The first tests for license renewal are to be completed prior to the period of extended operation with subsequent tests performed at least every 6 years thereafter. The applicant can assess the condition of the cable insulation with reasonable confidence using one or more of the following techniques: Dielectric Loss (Dissipation Factor/Power Factor), AC Voltage Withstand, Partial Discharge, Step Voltage, Time Domain Reflectometry, Insulation Resistance and Polarization Index, Line Resonance Analysis, or other testing that is state-of-the-art at the time the tests are performed. One or more tests are used to determine the condition of the cables so they will continue to meet their intended function during the period of extended operation.

5. ***Monitoring and Trending:*** Trending actions are included as part of this AMP, although the ability to trend results is dependent on the specific type of test(s) or inspection chosen. Results that are trendable provide additional information on the rate of cable insulation degradation.

6. ***Acceptance Criteria:*** The acceptance criteria for each test are defined by the specific type of test performed and the specific cable tested. Acceptance criteria for inspections of manholes are defined by the observation that the cables and support structures are not submerged or immersed in standing water at the time of the inspection.

7. ***Corrective Actions:*** Corrective actions are taken and an engineering evaluation is performed when the test or inspection acceptance criteria are not met. Such an evaluation considers the significance of the test or inspection results, the operability of the component, the reportability of the event, the extent of the concern, the potential root causes for not meeting the test or inspection acceptance criteria, the corrective actions required, and the likelihood of recurrence. When an unacceptable condition or situation is identified, a determination is made as to whether the same condition or situation is applicable to other accessible or inaccessible, in-scope power cables. Corrective actions may include, but are not limited to, installation of permanent drainage systems, installation of sump pumps and alarms, more frequent cable testing or manhole inspections, or replacement of the affected cable. As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the corrective actions.

8. ***Confirmation Process:*** As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the confirmation process.

9. ***Administrative Controls:*** The administrative controls for this AMP provide for a formal review and approval process. As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the administrative controls.

10. ***Operating Experience:*** Operating experience has shown that insulation materials are susceptible to water tree formation. The formation and growth of water trees varies directly with operating voltage. Aging effects of reduced insulation resistance due to other mechanisms may also result in a decrease in the dielectric strength of the conductor insulation. Minimizing exposure to moisture mitigates the potential for the development of reduced insulation resistance.

    Recent incidents involving early failures of electric cables and cable failures leading to multiple equipment failures, are cited in NRC IN 2002-12, “Submerged Safety-Related Cables,” and NRC GL 2007-01, “Inaccessible or Underground Power Cable Failures That Disable Accident Mitigation Systems or Cause Plant Transients.”

    The NRC issued GL 2007-001 on inaccessible or underground cables to (a) inform licensees that the failure of certain power cables can affect the functionality of multiple accident mitigation systems or cause plant transients and (b) gather information from licensees on the monitoring of inaccessible or underground power cable failures for all cables that are within the scope of the Maintenance Rule. Based on the review of licensees’ responses, the NRC staff has identified 269 cable failures for 104 reactor units. The data obtained from the GL responses show an increasing trend of cable failures. The NRC staff

has noted that the predominant factor contributing to cable failures at nuclear power plants was due to moisture/submergence. The staff also noted that the GL failure data show that the majority of the reported failures occurred at the 4160-volt, 480 volt, and 600-volt service voltage levels for both energized and de-energized cables. These cables are failing within the plants' 40-year licensing period.

The NRC inspectors also have continued to identify safety-related cables which are submerged. The staff noted that licensees had not demonstrated that the subject safety-related cables were designed for wetted or submerged service for the current license period.

This AMP considers the technical information and generic communication guidance provided in NUREG/CR-5643; IEEE Std. 1205-2000; SAND96-0344; EPRI 109619; EPRI 103834-P1-2; NRC IN 2002-12; NRC GL 2007-01; NRC GL 2007-01 Summary Report; NRC Inspection Procedure, Attachment 71111.06, Flood Protection Measures; NRC Inspection Procedure, Attachment 71111.01, Adverse Weather Protection; RG 1.211 Rev 0; DG-1240; and NUREG/CR-7000.

References

10 CFR Part 50, Appendix B, *Quality Assurance Criteria for Nuclear Power Plants*, Office of the Federal Register, National Archives and Records Administration, 2009.

DG-1240, *Condition Monitoring Program for Electric Cables Used In Nuclear Power Plants*, June 2010.

EPRI TR-103834-P1-2, *Effects of Moisture on the Life of Power Plant Cables,* Electric Power Research Institute, Palo Alto, CA, August 1994.

EPRI TR-109619, *Guideline for the Management of Adverse Localized Equipment Environments,* Electric Power Research Institute, Palo Alto, CA, June 1999.

IEEE Std. 1205-2000, *IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations.*

NRC Inspection Procedure, Attachment 71111.06, *Flood Protection Measures*, June 25, 2009.

NRC Inspection Procedure, Attachment 71111.01, *Adverse Weather Protection*, April 8, 2009.

NRC Information Notice 2002-12, *Submerged Safety-Related Electrical Cables*, March 21, 2002.

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SAND96-0344, *Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Cable and Terminations,* prepared by Sandia National Laboratories for the U.S. Department of Energy, September 1996.

RG 1.211 Rev 0, *Qualification of Safety-Related Cables and Field Splices for Nuclear Power Plants*, April 2009.

NUREG/CR-7000, *Essential Elements of an Electric Cable Condition Monitoring Program*, January 2010.