AMP 203 ELECTRICAL INSULATION FOR INACCESSIBLE INSTRUMENTATION AND CONTROL AND LOW AND MEDIUM VOLTAGE POWER CABLES NOT SUBJECT TO ENVIRONMENTAL QUALIFICATION REQUIREMENTS (2021)

Programme Description

The purpose of the ageing management programme (AMP) described herein is to provide reasonable assurance that the intended functions of inaccessible cables[[1]](#footnote-2) that are not subject to environmental qualification requirements and are exposed to wetting or submergence and susceptible to age-related degradation are adequately age managed [1].

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 such as cables in buried or embedded raceway, cable trenches, cable troughs, duct banks, underground vaults, or directly buried in soil installations. When a cable is exposed to wet, submerged, or other environmental conditions for which it was not designed, age related degradation of the electrical insulation may occur resulting in a decrease in the dielectric strength of the conductor insulation. This insulation degradation can be caused by wetting or submergence or some other degradation mechanism, manufacturing defect, installation damage or a combination of these factors. This can potentially lead to failure of the cable’s insulation system [2-7].

In this AMP, periodic actions are recommended to prevent cables from being exposed to significant moisture. Significant moisture is defined as long term wetting or submergence over a continuous period that if left unmanaged, could have an adverse effect on operability, or potentially lead to failure of the cable insulation system. Cable wetting or submergence that occurs for a limited time as drainage by either automatic, manual or passive drains is not considered significant moisture for this AMP. Examples of periodic actions are inspecting for water accumulation in cable installations 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) low points in duct bank routing; (b) concrete cracking due to soil settling over a long period of time; (c) manhole covers not watertight; (d) routing locations subject to high water table (e.g., high seasonal cycles) and, (e) potential uncertainties exist with ageing mechanisms and effects including medium voltage power cable water tree formation even when duct banks are sloped with the intention to minimize water accumulation.

Therefore, in addition to periodic actions, in-scope cables exposed to significant moisture are tested to determine the condition of the electrical insulation. One or more tests may be required to determine age degradation of a cable based on its application, construction, and electrical insulation material. Cables designed for continuous wetting or submergence are also included in this AMP requiring a one-time inspection and test with additional periodic tests and inspections determined by the test/inspection results and industry and plant-specific operating experience.

While low voltage power, instrumentation and control cable ageing mechanisms and effects due to significant moisture are limited (e.g., lower instrument and control voltage levels do not support water or electrical tree formation), operating experience has shown that insulation degradation may occur if instrumentation and control cables are exposed to continuous wetting or submergence. Additionally, variances may exist in the ageing mechanisms and effects depending on electrical insulation material, manufacture, and application, therefore periodic actions are necessary to minimize the potential for insulation age degradation due to significant moisture.

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.

Inaccessible cables covered by this AMP are not subject to environmental qualification requirements, therefore this AMP is required to manage the ageing effects. This AMP provides reasonable assurance that the electrical insulation for electrical cables and connections will perform its intended function.

Evaluation and Technical Basis

1. *Scope of the ageing management programme based on understanding ageing:*

This AMP applies to inaccessible cables such as cables in buried or embedded raceway, cable trenches, cable troughs, duct banks, underground vaults, or directly buried in soil installations exposed to adverse environments, primarily significant moisture. Significant moisture is defined as long term wetting or submergence over a continuous period that if left unmanaged, could have an adverse effect on operability, or potentially lead to failure of the cable insulation system. Cable wetting or submergence that occurs for a limited time as drainage occurs by either automatic or passive drains is not considered significant moisture for this AMP. In‑scope cable splices subjected to wetting or submergence are also included within the scope of this programme.

Cables designed for continuous wetting or submergence are also included in this AMP as a one-time inspection and test with additional periodic tests and inspections determined by the test/inspection results and industry and plant-specific operating experience.

1. *Preventive actions to minimize and control ageing degradation:*

This is a condition monitoring programme. However, periodic actions are taken to prevent inaccessible cables from being exposed to significant moisture, such as identifying and visually inspecting in-scope accessible cable, cable splices, conduit ends, cable trenches, cable troughs, duct banks, underground vaults, or as applicable to embedded raceway or direct buried cable installations, conduit ends, penetrations, or other accessible access points for water accumulation. The water is drained as needed to minimize age degradation effects on cable insulation properties. Inspection frequencies are adjusted based on inspection results, (e.g., level indication, or direct visual) or plant specific operating experience.

Inspections for water accumulation are also performed after event driven occurrences, such as heavy rain, rapid thawing of ice and snow, or flooding. Plant-specific parameters are established for the initiation of an event driven inspection. Dewatering systems (e.g., sump pumps and passive drains) and associated alarms are inspected and their operation verified periodically. The periodic inspection includes documentation that either automatic, passive drainage systems, or manual pumping are effective in minimizing cable exposure to significant moisture.

For situations where the draining of accumulated water by manual, passive or automatic means to minimize water accumulation in the raceway is not effective in minimizing cable exposure to significant moisture, additional justification is provided (e.g., additional testing, visual inspection, plant specific and/or industry operating experience, applicable cable research) that demonstrates that cable subjected to continuous submergence (significant moisture) will continue to perform their intended function.

Cables are visually inspected where accessible (e.g. manholes, vaults, etc.) for direct indication that cables are not wetted or submerged, cable/splices are intact, and jackets are not showing signs of discoloration, loss of dielectric strength, or reduction of insulation resistance due to the ageing mechanism and effects of significant moisture.

1. *Detection of ageing effects:*

For inaccessible electrical cables exposed to significant moisture, test frequencies are adjusted based on test results (including trending of degradation where applicable) and operating experience. Testing of installed in-service cables may be comprised of mechanical, electrical, or chemical means such that in-scope cable electrical insulation degradation will be adequately age managed through the period of long term operation.

The condition of the cable insulation can be assessed with reasonable confidence using one or more of the following techniques:

* Test appropriate for medium voltage cables include dielectric loss (dissipation factor/power factor/tan delta testing/dielectric spectroscopy), alternating current (ac) or very low frequency (vlf) voltage withstand, partial discharge, time domain reflectometry(TDR), insulation resistance (IR), frequency domain reflectometry (FDR), or other testing that is state-of-the-art at the time the tests are performed [8-11].
* Test that may be appropriate for low voltage cable condition evaluation include dissipation factor, TDR, FDR, IR, polarization index (PI), or other testing that is state-of-the-art at the time the test are performed.
* One or more tests are used to assess cable age degradation and maintain cable intended function.

For low voltage power, instrumentation and control cable electrical insulation testing, a sampling methodology may be used.

The cable condition monitoring portion of the AMP utilizes sampling for electrical insulation testing of instrumentation & control, low voltage power electrical cable if applicable. The component sampling methodology utilizes a representative sample that also considers operational experience of electrical cable and connection electrical insulation types as permitted by national regulatory requirements.

A sample of 20 percent with a maximum sample of 25 constitutes a representative cable sample size. The sampling methodology utilizes a population that includes a representative sample of in-scope electrical cable factors (e.g., temperature[[2]](#footnote-3), voltage, circuit loading, and cable type and construction including the electrical insulation composition) regardless of whether or not the cable was included in a previous ageing management or maintenance programme. The basis for the methodology and sample used is documented.

More explanations and considerations related to testing methods to be used and the respective acceptance criteria can be found in Appendix 1 of AMP210.

1. *Monitoring and trending of ageing effects:*

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 may be used to provide additional information on the rate of cable insulation degradation.

1. *Mitigating ageing effects:*

This is a condition monitoring programme. However, preventive actions, where practicable, are taken to prevent or mitigate cables from being exposed to significant moisture. This programme has no specific operations, maintenance, repair or replacement mitigation aspects.

1. *Acceptance criteria:*

Any indication or relevant conditions of degradation may be evaluated for acceptance in accordance with the pertinent governing requirements or guidance documents. Examination results and flaws that exceed the acceptance criteria in the pertinent governing requirements or guidance documents may require repair or replacement activities, or further evaluation to demonstrate that the component will continue to perform its intended function.

Acceptance Criteria for Condition Monitoring Techniques**:** The acceptance criteria for each test are defined by the specific type of test performed and the specific cable tested.

Acceptance Criteria for Inspection: Acceptance criteria for inspections are defined by the observation that the cables are not submerged or immersed in standing water, if practicable, at the time of the inspection and dewatering/drainage systems are operable. Cable visual indications for cable jacket are free from unacceptable signs of discoloration, loss of dielectric strength, or a reduction of insulation resistance due to the ageing mechanism and effects of significant moisture. If the above indications are present, additional testing may be warranted to verify that the cable electric insulation is adequately managed.

1. *Corrective actions:*

An engineering evaluation is performed, and corrective actions are taken 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 inaccessible, in-scope 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 inspections, or replacement of the affected cable/section.

1. *Operating experience feedback and feedback of research and development results:*

This AMP addresses the industry-wide generic experience. Relevant plant-specific operating experience is considered in the development of the plant AMP to ensure the AMP is adequate for the plant. The plant implements a feedback process to periodically evaluate plant and industry-wide operating experience and research and development (R&D) results, and, as necessary, either modifies the plant AMP or takes additional actions (e.g. develop a new plant-specific AMP) to ensure the continued effectiveness of ageing management.

Operating experience has shown that many polymer cable insulations rated 2 kV or greater are susceptible to water tree formation. The formation and growth of water trees is dependent on the level of dielectric stress caused by the operating voltage. Ageing effects of reduced insulation resistance due to other ageing 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. Additionally, operating experience has associated cable insulation degradation of instrument and control and low voltage power cables <2 kV with exposure to wet or submerged conditions. Research results [11] have not identified any specific degradation mechanism such as water treeing at the levels of dielectric stress that these cables are operated. Nonetheless, if operating experience and subsequent forensic analysis identify an ageing related degradation mechanism and effect attributed to moisture or submergence, then those cable types are age managed.

Operating experience has shown that very low frequency tan delta testing and withstand testing, when applicable (typically performed in addition to the diagnostic tan delta testing for degraded insulations), has been effective in detecting insulation degradation for cables operated above 2000 volts. Guidance exists in IEEE [10] and EPRI research [11] that discuss how this test method can be applied and evaluated. EPRI has twice evaluated data obtained from various member states [12-13] and determined the efficacy of the test protocol in identifying insulation related degradation due to exposure to significant moisture.

Guidance has been developed on the use of condition monitoring to identify the presence and extent of ageing effects for cable ageing assessment [14-17]. Related to this AMP, the Electric Power Research Institute among others have on-going programmes [18] to align R&D results with industry guidance and to identify potential gaps in current or planned research projects. The plant monitors R&D activities and assesses the applicability to this AMP.

1. *Quality management:*

Site quality assurance procedures, review and approval processes, and administrative controls are implemented in accordance with the different national regulatory requirements [19].

References

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4. UNITED STATES NUCLEAR REGULATORY COMMISSION, Summary Report, Inaccessible or Underground Power Cable Failures that Disable Accident Mitigation Systems or Cause Plant Transients, NRC Generic Letter 2007-01, USNRC, November 12, 2008.
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[14] UNITED STATES NUCLEAR REGULATORY COMMISSION, NRC Regulatory Guide 1.218, Rev. 0, Condition Monitoring Techniques for Electric Cables Used in Nuclear Power Plants, USNRC, 2012.

[15] UNITED STATES NUCLEAR REGULATORY COMMISSION, NUREG/CR-7000, Essential Elements of an Electric Cable Condition Monitoring Program, USNRC, January 2010.

[16] INTERNATION ATOMIC ENERGY AGENCY, Assessing and Managing Cable Aging in Nuclear Power Plants, IAEA Nuclear Energy Series NP-T-3-6, IAEA, Vienna, May 2012.

[17] ELECTRIC POWER RESEARCH INSTITUTE, Long Term Operations Program: Assessment of Research and Development Supporting Aging Management Programs for Long Term Operation, EPRI, Palo Alto, CA: 2013. 3002000576.

[18] ELECTRIC POWER RESEARCH INSTITUTE, Medium Voltage Cable Aging Management Guide, Revision 1. EPRI, Palo Alto, CA: 2010. 1021070.

[19] UNITED STATES NUCLEAR REGULATORY COMMISSION, 10 CFR Part 50, Appendix B, Quality Assurance Criteria for Nuclear Power Plants, Office of the Federal Register, National Archives and Records Administration, USNRC, 2015.

1. Cables refer to all instrument and control, low and medium voltage power cables. [↑](#footnote-ref-2)
2. High ambient temperature values vary depending on cable insulation ratings. Typically, cables are rated for 40˚C and accelerated ageing can start as low as 50 ˚C (for neoprene or some PVC). [↑](#footnote-ref-3)