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2005 OCT 11 AM 7: 52

September 30, 2005

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8/01/05
70FR44127
(6)

Chief, Rules and Directives Branch
Division of Administrative Services
Office of Administration
Mail Stop T6-D59
U. S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Comments Concerning Proposed Generic Communication, "Inaccessible or Underground Cable Failures That Disable Accident Mitigation Systems," (70FR44127, dated August 1, 2005)

This letter is being submitted in response to the Nuclear Regulatory Commission (NRC) request for comments concerning the proposed generic communication, "Inaccessible or Underground Cable Failures That Disable Accident Mitigation Systems," published in the Federal Register (i.e., 70FR44127, dated August 1, 2005). Exelon Generation Company, LLC (Exelon) and AmerGen Energy Company, LLC (AmerGen) appreciate the opportunity to comment on this proposed GL.

The NRC is proposing to issue a Generic Letter (GL) that would alert licensees to the potential susceptibility of certain cables to affect the operability of multiple accident-mitigation systems. This proposed GL would request addressees to provide information regarding the monitoring of inaccessible or underground electrical cables. The NRC believes that adequate monitoring will ensure that cables will not fail abruptly and cause plant transients, or disable accident mitigation systems when they are needed.

The results of a Nuclear Energy Institute (NEI) industry survey have determined that failures of MV cable installed below ground are isolated to a limited number of facilities and cable types. Although water and age play a part in the degradation of buried cables, most of the failures can be attributed to manufacturing or installation issues. The NEI survey data demonstrates that the majority of cable failures occur early in the cable's life, and that the failure rate is actually declining.

Therefore, Exelon/AmerGen recommends that the NRC reconsider issuance of the GL, and that the NRC work with NEI and the industry's MV Underground Cable Task Force in order to develop recommendations that could be evaluated and implemented, as necessary, by the industry in order to satisfactorily address and resolve this issue.

SISP Review Complete
Template – ADM-013

E-RIDS= ADM-03
Add= Tom Koshy (TXK)
A. Markley (AWM)

Exelon/AmerGen fully supports NEI's position and comments concerning this Proposed GL. In addition, Exelon/AmerGen offer the attached comments for consideration by the NRC.

If you have any questions or require additional information, please do not hesitate to contact us.

Sincerely,

D. P. Helker

David P. Helker
Manager - Licensing
Exelon Generation Company, LLC
AmerGen Energy Company, LLC

Attachment

Exelon Generation Company, LLC
AmerGen Energy Company, LLC

Comments Concerning NRC Proposed Generic Letter,
"Inaccessible or Underground Cable Failures That Disable Accident Mitigation Systems"
(70FR44127, Dated August 1, 2005)

Comments Concerning Proposed Generic Communication

Exelon Generation Company, LLC (Exelon) and AmerGen Energy Company, LLC (AmerGen) offer the following specific comments concerning the NRC's proposed generic communication, "Inaccessible or Underground Cable Failures That Disable Accident Mitigation Systems," for consideration by the NRC.

Testing

The proposed Generic Letter (GL) attempts to establish a regulatory basis for diagnostic cable testing. When used throughout this document, the term diagnostic testing refers to the Type 2 Field Tests described in Institute of Electrical and Electronics Engineers (IEEE)-400, "Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems," as it relates to providing indications that the insulation system has deteriorated. None of the regulations identified in the *Applicable Regulatory Requirements* section of the proposed GL specify that testing needs to be diagnostic. Periodic testing of the electrical power systems, to include functional testing of the cables, is already included in guidance provided under Regulatory Guide (RG) 1.118, "Periodic Testing of Electrical Power and Protective Systems."

RG 1.118 states that conformance with the requirements of IEEE Standard 338-1987, "IEEE Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems," provides a method acceptable to the NRC for satisfying the regulations with respect to periodic testing of electric power and protection systems, subject to a few exceptions that are not relevant to cable testing. IEEE Standard 338-1987, Section 6.1, "General Considerations," states, "*The periodic surveillance testing program for the safety system shall include, as applicable, functional tests (including channel functional tests), instrument channel checks, verification of proper calibration, and response time tests. It shall also establish the extent and frequency of the testing required commensurate with plant safety concerns.*" Some of the stated program objectives are 1) Identify high failure rates, 2) Provide tests that simulate, as much as practicable, the actual operating conditions during which the system under test would be required to operate, 3) Provide for alteration of the test interval, and 4) Derive the periodic surveillance testing program from considerations such as component failure modes, applicable reliability and availability analysis, and other historical data.

The nuclear power industry is adhering to the guidance specified in RG 1.118 and IEEE Standard 338-1987 with regard to testing of Medium Voltage (MV) and Low Voltage (LV) cables.

- MV and LV cables are functionally tested every time a connected load is functionally tested.
- The extent and frequency of the functional testing of MV and LV cables is in excess of that calculated commensurate with plant safety concerns and the failure history of MV and LV cables.
- Failure rates of cables can be determined from the functional tests.

- Functional tests are identical to those required under actual operating conditions.
- Industry experience has shown that utilities experiencing cable failures have adjusted their testing intervals and practices commensurate with their corrective action programs.
- The industry failure data has shown a declining trend in cable failures, which is confirmation of the effectiveness of the existing surveillance test program.

The following specific comments on the proposed GL pertain to the topic of testing.

1. The Applicable Regulatory Requirements section, last paragraph, third sentence, states: "*The cable failures that could disable risk-significant equipment are expected to have monitoring programs to demonstrate that the cables can perform their safety function when called on.*" Cables associated with risk significant systems are functionally tested during the surveillance tests of the risk significant systems. The cable functional testing is no different from functional testing of motors during the corresponding surveillance test. The capability of cables to perform their intended safety function is demonstrated during surveillance testing of the system.

2. The *Discussion* section, first example, second sentence, states: "*The incipient failures of these cables can go undetected because these cables generally remain de-energized when the plant is generating power.*" This paragraph is discussing power cables that connect the offsite power to the safety buses. Power cables used for offsite power, or in-plant distribution, are continuously energized and any failure would be immediately detected. Cables that are normally de-energized are feeds to Emergency Core Cooling System (ECCS) pumps. These cables are functionally tested during the surveillance testing of the connected loads.

3. The *Discussion* section, second example, states: "*The failure of the power cables from an emergency diesel generator (EDG) to the respective safety bus (where the EDGs are located in separate buildings) would prevent recovery of standby power from the respective EDG and result in the unavailability of a full train of accident mitigation systems during a loss-of-offsite-power event (LOOP).*" Power cables from the Emergency Diesel Generators (EDGs) are functionally tested, typically once per month, during the EDG surveillance runs.

4. The *Discussion* section, third example, states: "*The failure of the power cables to an emergency service water (ESW) or component cooling water pump can disable one train of emergency core cooling systems for long-term service unless the headers can be cross-connected and the redundant pump(s) can be lined up to supply sufficient cooling for both trains. If the EDGs are cooled from ESW or service water, the cable failure could disable the EDG and lose one train of standby power.*" Power cables supplying Emergency Service Water (ESW) pumps are functionally tested during surveillance testing of the ESW pumps. It is not uncommon for all ESW pumps to run coincident with the start of an EDG. Some plants perform this evolution weekly, but no less frequent than monthly.

5. The Discussion section states, "*Those degraded cables that are normally energized may fail to reveal their degraded condition, and the potential failure of the de-energized safety systems might only be revealed during a demand for the mitigation capability.*" Normally energized cables are continuously monitored and any cable degradation that would render the load inoperable would be immediately identified. De-energized cables are functionally tested during the surveillance testing of the connected loads.

The following comments relate to the need for testing.

6. In the *Applicable Regulatory Requirements* section: the NRC references General Design Criteria (GDC) -18, "Inspection and testing of electrical power systems." The excerpt provided in the proposed GL is quoted out of context. The full text of GDC-18 reads as follows (please note, the underlined words were omitted from the proposed GL): *"Electric power systems important to safety shall be designed to permit appropriate periodic inspection and testing of important areas and features, such as wiring, insulation, connections, and switchboards, to assess the continuity of the systems and the condition of their components. The systems shall be designed with a capability to test periodically (1) the operability and functional performance of the components of the systems, such as onsite power sources, relays, switches, and buses, and (2) the operability of the systems as a whole and, under conditions as close to design as practical, the full operation sequence that brings the systems into operation, including operation of applicable portions of the protection system, and the transfer of power among the nuclear power unit, the offsite power system, and the onsite power system."* This GDC requires that the capability for functional testing be provided within the design of the system. All of the testing indicated within the GDC is accomplished by surveillance testing, or by having the MV cables continuously energized, possibly carrying full load current. There is no requirement within the GDC for diagnostic testing.

7. The *Applicable Regulatory Requirements* section also references 10 CFR 50.65, "Requirements for monitoring the effectiveness of maintenance at nuclear power plants," paragraph (a)(1). The excerpt provided in the proposed GL is quoted out of context. The full requirement reads as follows (please note, the underlined words were omitted from the proposed GL): *"Each holder of a license to operate a nuclear power plant under §§ 50.21(b) or 50.22 shall monitor the performance or condition of structures, systems, or components, against licensee-established goals, in a manner sufficient to provide reasonable assurance that such structures, systems, and components, as defined in paragraph (b), are capable of fulfilling*

their intended functions." The subsequent paragraph of the regulation states that monitoring is not required *"where it has been demonstrated that the performance or condition of a structure, system, or component is being effectively controlled through the performance of appropriate preventive maintenance, such that the structure, system, or component remains capable of performing its intended function."* Functional testing of cables demonstrates that the system or component is capable of performing its intended function. A significant portion of the industry has not experienced any cable failures; therefore, no supplemental monitoring requirements should be imposed under this regulation.

8. The *Applicable Regulatory Requirements* section of the proposed GL cites 10 CFR 50, Appendix. B, Criteria XI, *"Test Control."* The excerpt provided in this proposed GL is taken out of context. The full text reads as follows (please note, the underlined words were omitted from proposed GL): *"A test program shall be established to assure that all testing required to demonstrate that structures, systems, and components will perform satisfactorily in service is identified and performed in accordance with written test procedures which incorporate the requirements and acceptance limits contained in applicable design documents."* The focus of the criteria is that testing is done in accordance with written procedures. MV Cable testing, as required for compliance with Appendix B, Criteria XI is performed either by being continuously energized or under the surveillance program.

Consensus

The Insulated Conductors Committee of the IEEE Power Engineering Society is recognized as the industry consensus group for cables. Members of that committee represent both the distribution and the nuclear industries. As the International Code Council (ICC) is the industry group on MV cables, any design, installation, or testing practices identified in ICC standards and codes should be the basis for this issue. Any design, installation, or testing practices not endorsed by ICC standards and guides should be viewed as in development, or receive increased scrutiny.

The following comments relate to statements in the proposed GL that are inconsistent with ICC standards and guides.

9. The *Summary* section of the proposed GL states: *"Adequate monitoring will ensure that cables will not fail abruptly and cause plant transients or disable accident mitigation systems when they are needed."* This same assertion also appears in the *Purpose* section. IEEE-400-2001, *"Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems,"* Association of Edison Illuminating Companies (AEIC) G7-90, states: *"There are no field tests available that will provide an exact measurement of remaining service life in an operating cable system."* There is no "adequate monitoring" that will ensure cables will not fail abruptly. The best that presently can be achieved by monitoring is consistent with that achieved by other system surveillances (i.e., demonstration that the system was functional over the past surveillance interval along with reasonable assurance that it will perform its function in the future).

10. The _Discussion_ section of the proposed GL states: *"Potential cable failures can be detected through state-of-the-art techniques for measuring and trending the condition of cable insulation."* Potential cable failures cannot be detected. Changes in the insulation properties of MV shielded cables can be tested and trended; however, the results of these tests are subject to many variables such that an accurate correlation cannot be made for just-in-time cable replacements. Time Domain Reflectometry is a troubleshooting tool that can be used to determine the approximate location of a failure; it is not a diagnostic cable test. IEEE-400 does not include a discussion on Broadband Impedance Spectroscopy (BBIS). The only references found regarding BBIS are in the NRC Nuclear Reactor Regulations (NRR) Weekly Information Report, dated September 10, 2004, an abstract prepared by Boeing / Rockwell Scientific on BBIS research on aircraft wiring, and a presentation by the same authors at an American Nuclear Society (ANS) Meeting dated November 16, 2004, entitled *"Application of the Broadband Impedance Diagnostic / Prognostic Technique to Nuclear Power Plant Cables."*

The Weekly Information Report indicates that the research was being performed on LV instrumentation and control cables used in aircraft. The abstract indicates that the testing can identify differences in characteristics between new and stressed cables; however, it appears that significant work needs to be done to gather data indicating life remaining in the cables. The abstract indicates that knowledge of specific properties of the cable materials is required to interpret the results. The testing was also performed in laboratories, but the technology needs to be demonstrated in the field. Additionally, experience has to be gained in the field with any of these emerging technologies such that test data can be correlated precisely to the condition of the cables. The paper on nuclear plant cables presented at the ANS meeting is not readily available and it is doubtful that answers to the concerns raised have been addressed in the few months between the abstract and the presentation.

11. In addition, the _Discussion_ section states: *"A diagnostic cable test program provides reasonable confidence that the cable will perform its intended function. The frequency of the test should be commensurate with the observed cable test results. To avoid unplanned outages and unanticipated failures, certain licensees have adopted a baseline frequency of 5 years for new cables or more frequent testing when insulation degradation is observed."* IEEE-400, Section 4.4, "Need for Testing," states: *"The decision to employ maintenance testing must be evaluated by the individual user, taking into account the costs of a service failure, including intangibles, the cost of testing, and the possibility of damage to the system."* Utilizing functional testing until there is some indication that there is an issue with the population of cables represents a valid approach. The MV cables in use at most plants are similar for safety-related and non-safety related applications. The non-safety related cables are typically subjected to similar environmental conditions as the safety-related cables, and the non-safety related cables are typically exposed to greater electrical stresses. They are continuously energized, operated at a voltage closer to the cable's rating, and not necessarily de-rated as conservatively as safety-related cables. If there is an increasing failure

trend on the non-safety cables, this serves as an alert for action on the safety-related cables. After the failure mode of the non-safety cables is determined, the relevance can be applied to determine the need to act on the safety-related cables. There is significant cost associated with cable diagnostic testing. The equipment must be de-energized and de-terminated, resulting in increased equipment unavailability and a potential for causing errors in re-connecting. The Nuclear Energy Institute (NEI) survey indicates that the majority of cable failures have occurred in a limited type of cable construction at a limited number of sites. Given no site specific and cable-type failure history, it could be concluded that maintenance testing is not warranted.

Unsupported Assertions

The proposed GL provides many conclusions that are not coupled with supporting arguments or documentation. Without the supporting documentation or information, it is difficult to accept the conclusions discussed prima fascie.

12. The *Purpose* section, page 2, Item (1), states: *"Alert the licensees on the potential susceptibility of certain cables to affect the operability of multiple accident-mitigation systems."* There is no supporting evidence provided within the document, or obtained during the NEI MV Cable Survey, that identifies a common mode failure mechanism for underground cables.

13. The *Background* section, fourth paragraph, second sentence, states: *"When the staff observed that some of the cables qualified for 40 years through the equipment qualification program were also failing at several nuclear stations, a detailed review was conducted."* The paragraph continues, *"These reported events are believed to be only a very small fraction of the failures since not all cable failures are reportable. In most of the reported cases...."* A conclusion should not be developed based upon beliefs and use of the term *most*. NEI has surveyed the nuclear industry regarding failure history of MV cables subjected to wet environments. The results of this survey should be used as the basis for the conclusions.

14. The *Background* section, first paragraph, states: *"Cable failures have a variety of causes: Manufacturing defects, damage caused by shipping and installation, and exposure to electrical transients or abnormal operating conditions during operation. Most of these defects worsen over time as insulation degradation leads to cable failure."* The logic connecting these two statements needs to be developed. The first statement includes many generalities that are not indicative of both MV and LV cables. The concluding statement uses lumped generalities to build its case. For instance, there have been some identified manufacturing defects in MV cables (i.e., contaminants in cross-linked polyethylene (XLPE) early extrusions) that do worsen over time. There does not appear to be an issue with manufacturing defects in LV cables worsening over time. There is minimal nuclear industry experience with electrical transients causing LV or HV cable failures. There is

experience where lightning surges have caused failures of HV cables; however, cables installed in nuclear power plants are not subjected to surges of this magnitude. There has been experience where excessive high temperatures, both external and internal, have caused premature failure of MV and LV cables; however, the proposed GL is not addressing this particular issue. Damage that occurs during shipping or installation is typically identified during post installation testing, and may or may not worsen with age. Refer to Comment 29 below regarding the cause of cable failures.

15. The _Applicable Regulatory Requirements_ section, last paragraph, states: *"However, the recent industry cable failure data indicates a trend in unanticipated failures of underground/inaccessible cables that are important to safety."* The proposed GL has not provided any data to support an increasing trend in cable failures. NEI/EPRI analysis of MV underground cables has shown just the opposite trend, in that there is a decreasing trend in cable failures as the cable population becomes older.

16. The _Discussion_ section, first sentence, states: *"Although nuclear plant systems are designed against single failures, undetected degradation of cables due to pre-existing manufacturing defects or wetted environments of buried or inaccessible cables could result in multiple equipment failures."* The proposed GL has not provided any data to support common mode failure of cables. Industry experience is contrary to this supposition in that cable failures have been shown to be random and time related. None of the examples cited are common mode failures, nor could the causes identified in this section result in the failure of more than one cable.

17. In addition, the _Discussion_ section highlights events concerning Davis-Besse. The Davis-Besse cable failure is not an example of a cascading failure. The failure of one non-safety related power cable to a non-safety related distribution center resulted in the loss of downstream, non-safety related connected loads. There was no over-tripping (i.e., loads tripping erroneously as a result of fault current) associated with this event. The major cause of failure of MV cables is due to over-voltage stresses in that sustained over-current will result in the generation of heat, which may take life out of cables, but will not result in immediate failure unless the cable fuses. Available fault current is not sufficient to cause cable fusing in the brief time it takes for a breaker to operate. Lack of breaker coordination is not a cable failure issue. If a cable failure results in fault currents several orders of magnitude over the normal current, the only voltage transient is a reduction in nominal voltage. Reduced voltage transients do not stress cables and cause cable failures.

18. The _Discussion_ section, of the proposed GL states: *"While a single failure may be manageable, multiple failures of this kind would pose undue challenges for the plant operators."* Though this sentence may be true, a common mode failure path that would affect multiple cables has not been demonstrated.

19. The _Summary_ section, second paragraph, second sentence, states: "*Adequate monitoring will ensure that cables will not fail abruptly and cause plant transients or disable accident mitigation systems when they are needed.*" Although there is nothing inherently incorrect with this statement on a philosophical level, there is no supporting evidence provided within the document, or obtained during the NEI MV Cable Survey, that identifies an abrupt failure mechanism for underground cables.

Erroneous Statements

The following comments discuss statements made in the proposed GL that Exelon/AmerGen considers to be incorrect.

20. The _Background_ section, last paragraph, last sentence, states: "*In most of the reported cases, the failed cables were in service for 10 years or more and none of these cables were identified as designed or qualified for long-term wetting or submergence.*" The MV cables used in nuclear power plants are typical of cables used in the underground residential distribution circuits of most of the utility distribution systems in the country. The XLPE cables in use in the nuclear power plants were specified to National Electrical Manufacturers Association (NEMA) WC-7 (ICEA S-6-524), which states, "*3.1 Material ... This insulation is suitable for use on power cables in wet or dry locations....*" The ethylene propylene rubber (EPR) cables in use in nuclear power plants were specified to NEMA WC-8 (ICEA S-68-516) which states: "*Material ... This insulation is suitable for use on cables in wet or dry locations....*" The rubber insulated cables in use in nuclear power plants were specified to NEMA WC-3 (ICEA S-19-81). Table 3-1 of that standard provides the suitability for wet and dry locations for the various grades of rubber. The specific grade of rubber insulation needs to be identified in order to determine its suitability. The majority of the MV cables in use in the nuclear industry are XLPE or EPR. These cables are suitable for use in wet locations.

21. Regarding GDC-4, the _Applicable Regulatory Requirements_ section states: "*Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation.*" As discussed previously, MV cables used in nuclear power plants are designed such that they are suitable for use in wet environments.

22. Regarding GDC-17, the excerpt provided in the _Applicable Regulatory Requirements_ section is quoted out of context. The following provides the full text from GDC-17 (please note, the underlined text was missing from the proposed GL): "*Provisions shall be included to minimize the probability of losing electric power from any of the remaining supplies _as a result of, or coincident with, the loss of power generated by the nuclear power unit, the loss of power_ from the transmission network, or the loss of power from the onsite electric power supplies.*"

The intent of this complete sentence is related to system stability. The design of the plant electrical systems should be such that the loss of the unit, transmission system or onsite supplies do not cause the remaining supplies to be lost. The statement is subsequently used in support of the argument related to cascading failures. The proposed GL has not made a valid argument related to cascading failures.

23. The _Applicable Regulatory Requirements_ section, last paragraph, first sentence, states: *"These design criteria require that cables which are routed underground be capable of performing their function when subjected to anticipated environmental conditions such as moisture or flooding."* Although this statement may be accurate, it implies that cables are not qualified for use in wet locations. The cables are designed/specified as acceptable for their operating environment, including moisture and flooding.

24. The _Discussion_ section, second paragraph following examples, first sentence, states: *"As cables that are not qualified for wet environments are exposed to wet environments, they will continue to degrade with an increasing possibility that more than one cable will fail on demand from a cable or switching fault."* Cables used in nuclear power plants are designed/specified for use in wet environments. Although the first sentence in this paragraph may be accurate, it is irrelevant to MV cables in nuclear power plants. Cable faults (i.e., over-currents) do not cause MV cable failures. During routine surveillance testing, normally de-energized cables are subjected to switching transients that are typical of those expected during accident demands.

25. The _Requested Information_ section, Item (1): Responding to this item will take in excess of the 40 hours, contrary to the statement identified in _Reasons for Requested Information_ section. NEI has already collected this information for MV cables installed below grade, which appears to be the population of cables discussed predominantly throughout the proposed GL.

Scope Definition

Earlier versions of the proposed GL (i.e., February 2004) raised concerns with MV underground/below grade cables. The majority of the discussion provided within this version of the proposed GL is relevant to MV cables; however, the _Requested Information_ section asks for all failures to "inaccessible or underground" cables, "for all voltage levels."

26. The early discussions focus on water intrusion as the major contributor to failure, yet the actions are associated with inaccessible cables. The definition of inaccessible could include all cables within conduits (above and below grade), and all cables within containment.

27. Failure mechanisms such as "treeing" are discussed, which are associated with MV cables.

28. The testing methodologies identified are only effective for shielded MV cables. The 23 Licensee Event Reports (LERs) represent both MV and LV cables. Since the causes of failure for MV and LV cables are different, the monitoring plans for these cables should be addressed separately.

The following comments are not directed at specific sections of the proposed GL, but at concepts found throughout the document.

29. MV cables used in nuclear power plants are expected to have very long lives - at least the 40 years of the initial licensed period. However, the cable manufacturers and non-nuclear power users of MV cables have since recognized that cables manufactured during the 1970s did not always meet expectations. By the mid-1980s, the industry identified a number of improvements, including insulation reformulation, improved cleanliness to reduce impurities, tighter quality controls, and improved manufacturing methods that were incorporated into cables manufactured later. Fortunately for the nuclear industry, even though problems existed with cable design and manufacturing in some cases, the voltage stresses in nuclear applications are relatively low. Most power cables have a basic impulse insulation level (BIL) capability that is comparable to other electrical equipment with similar voltage ratings. Cable insulation must be able to withstand brief voltage spikes from switching inductive loads, such as motors, without breakdown or inception of partial discharging. Cables are designed and manufactured to have a high BIL throughout their operating life.

    The majority of early nuclear plant cables were constructed with XLPE, black EPR, or gray EPR, although a few plants have natural or butyl rubber insulated cables. In dry applications, these cables have very long lives. However, if both energized and continuously wet, especially with the presence of significant manufacturing flaws, lives of less than 40 years can be expected for some cables. Cables are now produced with higher quality extrusion practices, with high cleanliness and better materials, thereby reducing the probability of contaminants and voids, while leading to longer service lives. Contaminants and voids are a significant problem in wetted extruded cable insulations because they disturb the potential gradient within the insulation and increase the potential across the remaining good insulation, thereby increasing the effects of water-enhanced degradation. For XLPE, the water-enhanced degradation takes the form of water treeing in which the potential gradient gradually forces the water to create small channels in the polymer that look like "trees" under magnification. The exact mechanism of water-enhanced degradation of EPR is less understood and more difficult to observe due to the opacity of the material. Different types of EPR are in use and EPR sub-types have different susceptibilities to water-enhanced degradation. Pink (red) EPR, which is now used in most EPR MV cable designs, is hydrophobic and less prone to water-enhanced degradation than black EPR. Gray EPR cables were purposely designed to have small leakage currents through the insulation that prevent charge buildup. This design prevents charge buildup to the point where water-enhanced degradation can occur. The NEI survey has identified a failure-free history for brown EPR.

The water-enhanced degradation does not cause direct breakdown of the XLPE or EPR, but rather reduces the dielectric strength of the insulation, eventually weakening the material to the point where it is susceptible to voltage surges that can initiate partial discharging. Partial discharging causes relatively rapid electrical degradation, leading to an electric tree and a faulted condition in weeks to months following inception. Instantaneous failure in the weakened condition would only be expected under severe lightning surge conditions. However, nuclear plant MV circuits are not directly exposed to lightning strike conditions, given that the cables are either inside buildings or underground and not terminated to equipment exposed to lightning.

Additionally, cables must be energized in order for partial discharging to occur. If the cables are not energized, there are no electrical stresses, and there is no electrical degradation of the insulation. The presence of water, by itself, does not cause premature degradation of the cables.

30. Current "state-of-the-art" cable testing technology is not as impressive as implied within the proposed GL. The recognized methodologies (i.e., partial discharge and tan-delta) require that the cable be shielded in order to provide meaningful results. LV cables do not have shields, and more than 20% of the industry does not have shielded 4 kilovolt (kV) cables. The recognized methodologies do not have established acceptance criteria. External factors such as temperature and humidity have a significant impact on the results. Absent quantitative acceptance criteria, the qualitative results could provide some ranking of similar cables; however, none of the tests can accurately predict remaining cable life.

    The recognized MV cable testing methodologies require that the cables be disconnected from their sources and loads. This requires reworking all of the connections since most designs do not utilize means for quick disconnects. Reworking the connections introduces the likelihood of errors or damage.