UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION II
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MEMORANDUM TO: Aby S. Mohseni, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

FROM: Terrence Reis, Director
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SUBJECT: REQUEST FOR TECHNICAL ASSISTANCE REGARDING OCONEE NUCLEAR STATION DESIGN ANALYSIS FOR SINGLE FAILURE AND THE INTEGRATION OF CLASS 1E[1] DIRECT CURRENT CONTROL CABLING IN RACEWAYS WITH HIGH ENERGY POWER CABLING (TIA 2014-05)

On June 27, 2014, Region II documented the results of a component design basis inspection at Oconee Nuclear Station (ONS) Units 1, 2, and 3 in inspection report 05000269/2014007; 05000270/2014007; 05000287/2014007 (ADAMS Accession Number ML14178A535). In that report, the inspection team identified an unresolved item involving cable configurations in certain underground cable raceways, which may not comply with the ONS licensing basis, design basis, and NRC regulations and requirements. In certain underground raceways, ONS staff has installed Class 1E[1] and associated non-Class 1E direct current protection and control circuits adjacent to high energy medium voltage power cables. The inspectors were concerned that the proximity of these cables to one another may not meet the single-failure design criteria of the ONS engineered safeguards protection system.

Through this task interface agreement, Region II requests the Office of Nuclear Reactor Regulation to provide technical support in the evaluation of whether the cable configuration in certain underground raceways meets the existing ONS licensing basis, design basis, and NRC regulations and requirements.

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[1] Class 1E - The safety classification of the electric equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or are otherwise essential in preventing significant release of radioactive material to the environment

Introduction

On June 27, 2014, Region II documented the results of a component design basis inspection (CDBI) at Oconee Nuclear Station (ONS) Units 1, 2, and 3 in inspection report 05000269/2014007; 05000270/2014007; 05000287/2014007 (ADAMS Accession Number ML14178A535). In that report, the inspection team identified an unresolved item (URI) involving cable configuration in certain underground cable raceways, which may not comply with the ONS licensing basis, design basis, and NRC regulations and requirements. In certain underground raceways, ONS staff has installed Class 1E and associated non-Class 1E direct current (DC) protection and control circuits adjacent to high energy medium voltage alternating current (AC) power cables. The inspectors were concerned that the proximity of these cables to one another may not meet the single-failure design criteria of the ONS Engineered Safeguards Protection System (ESPS).

Through this task interface agreement, Region II requests the Office of Nuclear Reactor Regulation (NRR) to provide technical support in the evaluation of whether the cable configuration in certain underground raceways meets the existing ONS licensing basis, design basis, and NRC regulations and requirements. Specifically, Region II requests a definitive description of the requirements for analyzing electrical failure vulnerabilities (single failure or otherwise) between medium voltage AC power and low voltage DC circuits in order to determine whether the as-installed designs at ONS are in compliance with regulatory requirements. The circuits in question are coupled with and interrelated with the emergency power, protected service water (PSW), ESPS, Reactor Protection (RPS), and the Keowee Hydro Unit generators (KHUs) supervisory control systems. This TIA will inform Region II in determining whether the licensee (Duke Energy Corporation) had appropriately considered all electrical system design requirements for such vulnerabilities as single failures, consequential failures, common cause failures, and protection from short circuits and ground faults when ONS staff implemented plant modifications to their onsite power system. The TIA response will be used as part of the effort to address URI 05000269/2014007-05, 05000270/2014007-05, 05000287/2014007-05.

Background

The CDBI team reviewed the electrical cable configurations (including power, protection, and control circuits) between the 87.5 million volt-amp (MVA) KHUs and the ONS emergency power transformer CT-4, between the KHUs and the PSW switchgear, and between the ~12MVA 100 kilo-volts alternating current (kVac) alternate power system (APS) switchyard and the PSW switchgear. The team observed that there is one ~4000' raceway between the Keowee Hydro Station (KHS) and transformer CT-4 at ONS (identified as trench 3), and a newer raceway addition (PSW raceway) that extends another ~2000' past CT-4 and around the ONS site to the new PSW building, thus connecting each system through underground interconnected raceways. The team identified that these raceways contained 13.8kVac power cabling, 4.16kVac power cabling, Class 1E 125 volts direct current (Vdc), and associated non-Class 1E 125Vdc cabling adjacent to one another (in close proximity) along the entire route of raceways.

The team identified that the KHU 13.8kVac power system was high impedance grounded, which limited ground fault currents to ~17.5 amps. However, the commercial 13.8kVac power feeders (the Fant line) between the APS switchyard and the PSW switchgear, located in the PSW raceway, were not high impedance grounded, therefore the Fant line power feeders were not protected against potentially catastrophic ground faults. The team identified that most of the Class 1E and associated non-Class 1E 125Vdc cabling was connected directly or indirectly to the Class 1E DC busses at ONS and at Keowee. The DC system protective devices did not appear to be designed to mitigate the effects from medium voltage AC power short-circuiting to the 125Vdc circuits. Specifically in trench 3, the team identified in close proximity to one another the following components:

- The ESPS Class 1E DC protection and control circuits;
- The KHU DC supervisory control circuits that appear to be connected directly to the ONS Class 1E DC buses and the Keowee KHU start panels;
- The PSW DC control circuits that appear to be connected between the Keowee KHU start panels and the PSW system;
- 13.8kVac Class 1E emergency power cables connected from the KHUs to the ONS emergency power transformer CT-4;
- 13.8kVac QA-1 power cables connected from the KHUs to the PSW switchgear; and
- 4.16kVac Class 1E power cables connected from the ONS 1TC switchgear to the Keowee auxiliary power transformer.

Specifically in the PSW raceway extension, the team identified in close proximity to one another the following components:

- The ESPS Class 1E DC protection and control circuits;
- The KHU DC supervisory control circuits that appear to be connected directly to the ONS Class 1E DC buses and the Keowee KHU start panels;
- The PSW DC control circuits that appear to be connected between the Keowee KHU start panels and the PSW system;
- 13.8kVac QA-1 power feeder cables connected from the KHUs to the PSW switchgear; and
- 13.8kVac commercial Fant Line power cables connected from the APS switchyard to the PSW switchgear.

The team could not verify the adequacy of this design, relative to regulatory requirements and the ONS licensing basis. The team's specific concern was that given a multi-phase power cable short circuit, or a phase to ground power cable fault in the case of the Fant line power feeders, one or more of the following could occur:

- A release of energy sufficient to damage or destroy adjacent cables could be released in the affected raceway
- An electrical signal of sufficient voltage to damage or destroy Class 1E components and systems at both ONS and KHU could be transmitted through Class 1E and non-Class 1E 125Vdc cables in the affected raceway
- Cable forces and resulting motion could result in consequential damage to adjacent cables in the affected raceway, and possible consequential short circuits and circuit interconnections

To address the team's concerns, ONS staff wrote three problem investigation program (PIP) documents (O-14-02965, O-14-03190, and O-14-05125) and performed prompt determinations of operability (PDOs) for each PIP. In addition, on March 23, 2014, the licensee reported these conditions to the NRC under 10 CFR 50.72(b)(3)(ii) in Licensee Event Report (LER) 269/2014-01, Rev. 0.

Licensee Position

The licensee's current position is that electrical failures addressed as single failures cannot occur at any time but must only occur explicitly at the mechanical actuation of a device to provide its safety function. Additionally, ONS staff has stated that short circuits on shielded power cables are not credible events and thus do not have to be postulated. The licensee stated that they have properly routed the Class 1E and associated non-Class 1E DC protection and control circuits with the high-energy 13.8kVac cables and that this configuration does not compromise the single-failure-proof design of the emergency power system or the Class 1E protection system. Also, the licensee has concluded that offsite commercial grade electrical protective equipment (relays, circuit breakers, lightning arrestors, etc…) is adequate to assure the protection of the adjacent Class 1E and associated non-Class 1E DC protection and control circuits. The licensee's position, as the team understands it, includes the following:

- A review of their licensing basis applicable to electrical single failures was conducted circa 1992 and was documented in an ONS internal memo to file. (The memo was presented to the team as the ONS licensing basis.) The memo stated, in part:
  - *"This review indicates that nothing within the Oconee licensing basis specifically requires consideration of single failures at times other than "immediately on demand" vs T = 0, or coincident with the event";*
  - *"It is clear that there is no requirement within the Oconee licensing basis to analyze for "smart" single failures";*
  - *"A final conclusion that can be reached is that we are not required to identify the worst time when the worst case single failure will occur";*
  - *"This conclusion is simply based on the fact that had the analyses considered single failures occurring at any time other than immediately on demand, the results would have been unacceptable";*
  - *"SECY 77-439, "Single Failure Criterion"*
    The staff states that a single failure evaluation "··· proceeds on the proposition that single failures can occur at any time." The Oconee position is in direct contradiction to this portion of the guidance. However, the SECY paper concludes that "the single failure criterion has served well in its use as a licensing review tool to assure reliable systems as one element of the defense in depth approach to reactor safety."; and
  - *"10 CFR 50, Appendix A, the General Design Criteria* (GDCs)*, is interpreted by the NRC staff in SECY 77-439 to require that there be no distinction between active and passive failures for electrical equipment. The GDCs are not part of the Oconee licensing basis. Therefore, for Oconee, a distinction can be made between active and passive failures."*

- Per the design basis specification OSS-0254.00-00-4013, "Oconee Single Failure Criterion", Rev. 4 (the single failure design basis document "DBD"):
  - Section 3.2.1.3, "Single Failure Licensing Basis for Electrical Systems" referenced the "single failure memo to file" as the definitive document outlining the ONS licensing basis for single failure timing. The DBD, stated, in part:
    - *"Per Reference 4.3.1.1, single failures in electrical systems shall only be postulated to occur on initial demand (i.e. failure is coincident with the time the component is initially required to perform its design function in response to an event)"; and*
    - *"10CFR50 Appendix A are not part of Oconee's licensing basis, and a distinction between active and passive failures is made for Oconee electrical systems (see Reference 4.3.1.1)."*

- Section 3.3.6.1, "Cabling" references cable testing that was performed by the licensee in 1977 and was documented in MCM-1354.00-0029.001, which determined that cable faults in armored multi-conductor cabling could not propagate to adjacent cabling. The DBD stated:
  - *"Armored electrical cabling will not be subject to a single failure in one cable propagating to another cable"; and*
  - *"This exception is only applicable to armored cables."*

- The PDO documented in PIP O-14-02965 concluded that the electromagnetic cable whip induced by short circuits will not damage the "Unistrut" cable support hardware, the power cables, or the Class 1E DC cables. Additionally, the 13.8kVac and 4.16kVac power cables were described as armored.

- The PDO documented in PIP O-14-03190 concluded that a single electrical failure cannot occur until after the grid is removed from the emergency power system. (The KHUs are designed to periodically generate to the grid for commercial purposes and during monthly surveillance testing) In addition, it concluded that short circuits between shielded or armored power cables were not credible and that the single failure criterion only requires the analysis of credible single failures. The PDO stated, in part:
  - *"The subject 13.8 kV power cables were procured with bronze armor tape with a primary function of providing a grounded metallic shield and a secondary function of providing mechanical protection to the cable";*
  - *"Therefore a fault at the terminals of transformer CT-4 would not be considered until after the underground KHS Air Circuit Breaker (ACB) has closed after a load rejection";*
  - *"The worst-case credible single failure of high-energy power cables occurs at the ends of the cables only. For the emergency power system, this occurs at the bolted connection at Transformer CT-4";*
  - *"The Keowee KHUs are high impedance grounded prohibiting catastrophic ground faults";*
  - *"The steel armor on the DC control cables are grounded; therefore short-circuited high-energy power cables cannot secondarily short circuit to the DC control cables and affect the Class 1E DC control system"; and*
  - As part of this PDO the licensee engaged United Research Services (URS) Corporation to determine if the two layers of 10mil bronze tape employed in the cable design in question was equivalent to armored cables designed in accordance with the requirements of industry standard NEMA WC 7 4/ICEA S-93-639-2012, *"5-46kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy."* The study stated, in part, that *"It is concluded that the characteristics and application of the bronze tape on the 13.8 kV power cables in Trench 3 are equivalent to the requirements of bronze armor tape in ANSI/NEMA WC 74/ICEA S-93-639"*
  - The licensee asserted that NUREG-6850, "Fire PRA Methodology for Nuclear Power Facilities," supported their position, stating, in part:
    - *"…multiconductor-multiconductor hot shorts are not plausible given the intervening grounded barrier…"*
    - *"If the cable design can be verified as one that employs a rugged grounded metallic shield (e.g., armor, braid, etc.), then the analysis need only consider the effects of shorting between the conductors within the shield and shorting of the conductor to ground…"*
    - *"…the use of grounded, metallic, armored cable…are considered in most cases to preclude external hot shorts from further consideration…"*

- The PDO documented in PIP O-14-05125 concluded that offsite commercial grade protective equipment could assure the protection of the adjacent Class 1E components. In subsequent discussions with the licensee (i.e. a telephone call on 06/02/2014), the licensee indicated that it was their position that any failure of a commercial component would be regarded as "the single failure" per the ONS licensing basis, thus precluding any further failures of commercial or Class 1E components. The PDO stated*:*
  - *"The PSW substation protective relaying and breaker will detect and clear phase-ground and three-phase on the Fant power path before additional cable damage occurs"; and*
  - *"Previous evaluations of fault induced cable movement on other SSCs bound the fault evaluated by this PDO. "*

Regulatory and Technical Issues

Licensing Basis Concerns: The CDBI team observed that the WO Parker letter[2] to the NRC required the onsite AC and DC systems meet Section 4.2 of Institute of Electrical and Electronic Engineers (IEEE) Standard 279 -1971, "Criteria for Protection systems for Nuclear Power Generating Stations." The scope of IEEE 279-1971 appeared to be limited to "the electrical and mechanical devices and circuitry (from sensors to actuation device input terminals) involved in generating those signals associated with the protective function." It was unclear to the team how to apply IEEE 279-1971 to the medium voltage emergency power cables affecting the Class 1E and associated non-Class 1E DC protection and control circuits. Of the standards and NRC reports the licensee evaluated in the PDOs, IEEE 279 was the only licensing basis document evaluated for electrical single-failure-proof design but the licensee did not appear to consider the example in the note of IEEE 279, Section 4.2 describing the shorting of electrical power cables as a single failure as applicable.

The team noted that even though the Updated Final Safety Analysis Report (UFSAR) Chapter 3 listed multiple GDCs for Nuclear Power Plant Construction Permits proposed by the Atomic Energy Commission (AEC) in a proposed rule-making published for 10CFR Part 50 in the Federal Register of July 11, 1967 as applicable to the ONS licensing basis for electrical design (i.e. Criterion 19, 20, 21, 22, 23, 24, 31, and 39) only Criterion 24 and 39 were cited in the PDOs.

Additionally, the team noted that the UFSAR Section 8.3.1.2 "Analysis" for onsite AC Power Systems stated that *"the basic design criterion for the electrical portion of the emergency electric power system of a nuclear unit, including the generating sources, distribution system, and controls is that a single failure of any component, passive or active, will not preclude the system from supplying emergency power when required."*

Given that the team could not verify that the cable configurations were acceptable where commercial and QA-1 medium voltage power cables were installed in close proximity with Class 1E and associated non-Class 1E protection and control circuits and the team could not verify that the power cables bronze tape could be considered equivalent to the steel interlocked armor

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[2] Letter from WO Parker (Duke) to BC Rusche (NRC), dated 5/13/1976, states, in part, that "The design of the Oconee onsite emergency AC and DC power systems conforms to the single failure requirements of IEEE-279-1971."

described in the single failure DBD test report MCM-1354.00-0029.001, the team was concerned that the licensee's analyses appeared to be non-conservative. The analyses appeared to inappropriately establish the timing of electrical failures to instants that could limit the magnitude of potential damages. The team could not verify that the licensee met the following requirements to ensure that electrical single failure proof design was maintained in the design of the underground cabling systems between ONS, Keowee hydro-station, and the PSW building:

- Technical specification (TS) for 3.8.1 "Electrical Power Systems: Emergency AC Sources – Operating," TS 3.3.21 "Emergency Power Switching Logic (EPSL) Keowee Emergency Start Function";
- GDCs 19, 20, 21, 22, 23, 24, 31, and 39;
- 10 CFR 50.55a.(h).(2) "Protection and Safety Systems";
- 10 CFR 50.59.(c) "Changes, tests and experiments"; and
- 10 CFR 50, Appendix B, Criterion III "Design Control."

<u>Design Basis Concerns</u>: The CDBI team identified several concerns with the licensee's use of the single failure memo to file and the single failure DBD to define the licensing basis for single-failure-proof design criteria. These two documents were previously described in the Licensee Position section of this TIA:

- <u>January 12, 1992, single failure memo to file</u>: The CDBI team could not verify that the positions outlined in the memo accurately reflected the ONS licensing basis for single-failure-proof design. The team could not identify any portions of the ONS licensing basis (TS, GDCs, or IEEE 279) that allowed the licensee to establish the timing of electrical failures, which could artificially limit the magnitude and potential damages that could occur from electrical failures or make distinctions between passive and active electrical failures. The team could not find the term "smart" single failures as described in the single failure memo to file in any part of the ONS licensing basis. The team identified that ONS GDC 39 specified active component failures, one in each of the onsite and offsite power systems concurrently, but IEEE 279 specified single failures and did not distinguish between active or passive components.

- <u>Single failure DBD, OSS-0254.00-00-4013</u>: The CDBI team was concerned that the DBD referenced the single failure memo to file to justify the limited evaluations of single failures based on specific timing and distinguishes between active and passive failures as previously discussed. The team had a concern that the licensee's design philosophy for plant modifications appeared to incorporate the "single failure memo to file" into plant design specifications and procedures. In addition, the team could not verify that the referenced cable test report, MCM-1354.00-0029.001, supported the claim that "*armored electrical cabling will not be subject to a single failure in one cable propagating to another cable.*" The team noted that ONS staff was using this test report to envelope the configuration of the 13.8kVac power cables. The licensee asserted that two wraps of 10mil bronze shielding tape was equivalent to the armor described in the test report. The team's specific concern was that the testing did not envelope the cable designs in the underground raceways. The test report indicated that the testing was limited to 6.9kVac power cables that used steel interlocked armor that had been drilled and vented and that only 2-phases were shorted instead of 3-phases, which limited the energy released from the cables. For AC, 3-phase short circuits provide the maximum energy released in arc flashes and the maximum electromagnetic forces. The team noted that a high impedance ground scheme, such as the one on the KHUs, was not simulated during these tests. A high impedance grounded system would contribute to the magnitude of energy release during AC arc flashes. The team could not verify from the review of the test report that two layers of 10mil bronze tape could be equivalent to steel interlocked armor subjected to the test conditions. In addition, the team could not verify that the tests could support a conclusion that armored cables (steel interlocked or otherwise) would prevent the propagation of electrical failures between cables.

In summary, the CDBI team could not verify that, from the standpoint of the ONS licensing basis, the proximity of the 13.8kVac and 4.16kVac power cables to the Class 1E and associated non-Class 1E 125Vdc protection and control circuits in the ONS design of the underground cable raceways was adequate to prevent a credible power feeder short circuit from damaging the adjacent Class 1E and associated non-Class 1E protection and control circuits and components such that the safety systems would be prevented from performing their safety functions at the system level when called upon. This is based on:

- The licensee's determination that if power cables are shielded or armored they cannot develop multi-phase short-circuits. This does not appear to correspond with electrical engineering standards or recent operating experience;
- The licensee's limiting the timing of a short circuits to manage the worst-case faulted current and voltage to a lower significance;
- The licensee distinguishing between active and passive electrical failures;
- The licensee's conclusion that the high impedance ground on the KHU power system prevents catastrophic faults of any kind whether the faults are ground faults or multi-phase short circuits. The team could not verify that this type of grounding scheme would mitigate these types of faults and, in addition, the team noted that high impedance grounded systems increase the energy released during arc flashes;
- The licensee's conclusion that faulted currents and voltages resulting from cable failures would be dissipated or redirected by grounding, which is averse to the high impedance grounding scheme implemented for the KHUs; and
- The licensee's conclusion that offsite commercial equipment (i.e. power cables and protective devices) can assure the adequacy of design for the adjacent Class 1E and associated non-Class 1E protection and control circuits and systems.

Technical Concerns with the PDOs: The CDBI team could not verify the licensee's determination that the cabling systems in the underground raceways were adequately designed. The following PDOs documented the licensee's justification for why they believe they are in compliance with the current licensing basis. The PDOs did not adequately resolve the team's concerns with cable proximity, fault timing, short circuit characterization, the potential results of inadequate modeling, cable and raceway installation issues, and operational considerations.

1. PDO O-14-02965: The team could not verify that the PDO adequately examined the effects from short circuits on the ends of the cables (i.e., a short at the terminals of CT-4) and the magnetic forces it would produce along the length of the cable in the raceways. The licensee determined that the damage would be limited to breaking the cable bracing (i.e. cable ties) and bending the steel end retaining plate of the cable support system, which would allow the power cables to whip around the raceways. The PDO concluded that no secondary cable damage would occur as a result of the cable whip, which the team could not verify. The PDO's analysis of the cable impact on other components in the raceways did not account for the multidirectional forces that could damage the cables' Unistrut support mounting, potentially displacing it and the cables from the sidewalls.

The team identified quality issues not evaluated by the PDO that were associated with the raceways configuration that could make secondary cable damage more likely, and consequently secondary cable short circuits more likely, Specifically:

- The team identified in cable installation drawings a section of trench 3, the "cable switchover area," where the KHU power feeders for CT-4, the PSW switchgear, and for the Keowee 4.16kVac Aux power transformer were intertwined around each other only separated by a layer of licensee's "welders cloth" (touching); this was confirmed by historical pictures of the installations. Cable whip in this area could cause these cables and support hardware to become damaged from jerking motions around the cables.

- The team identified (and it was confirmed by the licensee) that the cable bracing was inadequate to restrain the cables against the forces from short circuits. With failed bracing, the cables could whip around the raceways, potentially impacting the steel cable support hardware and anything else that is in the raceways, which could cut into the cable insulation causing secondary short circuits.

- The multidirectional forces produced by a short circuit could impart forces on the Unistrut cable supports that they do not appear to be designed to withstand. The PDO only evaluated vertical "downward" forces. The commercial design of the steel Unistrut cable supports base plate was only secured by a single spring nut and bolt combo clamp from the top of the plate, allowing an upward cantilevered moment to bend the base plates and supports up. Since both the base plate and end retaining plate were of the same material design, the team could not verify that the base plate would not bend in the same way as the PDO determined the ¼" steel end retaining plate would. The team was concerned that the bending moment would damage the cable supports in such a manner that it could also damage the cables.

2. PDO O-14-03190: The team could not verify that the PDO adequately addressed the team's concerns about inter-cable short circuits in the raceways and the potential effects from such a short circuit. The PDO argued that the timing of electrical failures could artificially limit the magnitude of potential damages, as previously identified in the single failure memo to file, was acceptable and concluded that inter-cable short circuits on shielded power cables were not credible. The team considered inter-cable and intra-cable short circuits credible and well understood phenomena by electrical engineering design standards, including IEEE 279-1971.

   The PDO cited some portions of SECY 77- 439, "Single Failure Criterion," but excluded Section 2.A paragraph 3 in which the staff specifies that short circuits between electrical cables are credible single failures and must be analyzed for. The PDO cited portions of IEEE 379-2000 and IEEE 352-1987 that seemed to explicitly characterize short circuits as common cause failures which is an inaccurate characterization and the licensee later recanted this. The PDO cited portions of NUREG/CR-6850, mostly from Chapter 9, which evaluates consequential damage to electrical cables from "low intensity fire." This is not the only failure mechanism discussed in single failure design standards. The team observed that NUREG/CR-6850 is not a single failure design criteria standard or report. The team examined the standards and the NRC reports cited by the licensee and could not verify that the licensee accurately characterized the technical conclusions in these documents.

In addition, the team's questions about the bronze shielding tape resulted in the licensee performing an equivalency analysis of the bronze tape and industry standards for cable armoring. This was documented in a URS engineering study dated 04/08/2014. The team's review of this analysis and the associated industry standard could not verify the conclusions made by URS since the bronze shield tape did not match the standard's specifications for any type of armor. Thus the team could not validate the URS claim that the characteristics and application of the two wraps of 10mil bronze tape was equivalent to the requirements of bronze armor tape as the URS study concluded.

3. PDO O-14-05125: The team could not verify the PDO adequately addressed the team's concerns with installing commercial 13.8kVac power cabling in raceways adjacent to Class 1E and non-Class 1E 125Vdc cabling. The PDO concluded that offsite commercial power cables and protective devices, that were neither quality related nor under the direct quality control of ONS, were sufficient to ensure the safety of the adjacent 125Vdc Class 1E and associated non-Class 1E protection and control circuits. The team noted that the overload settings on the protective relays appeared to allow ~2000 amps to flow through the cables for more than 15 seconds and ~3000 amps for more than 6 seconds, which could exceed the cable thermal design specifications. The commercial 13.8kVac power feeders were continuously powered and while QA-1 procured cable was spliced in place where the cables passed though the PSW raceway, none of these components are maintained under a QA program. In addition, the team identified PIPs O-11-03333, O-12-01399, O-12-01340, and O-12-01551 that indicated that the pulling tensions and bend radii parameters for the cables in the PSW raceway may have been exceeded during installation. The team could not verify how commercial components could be credited toward ensuring the safety of the Class 1E and associated non-Class 1E protection and control circuits because, as the team understands it, all commercial components are considered to fail in the most limiting way.

Potential Results of Inadequate Modeling and Resulting Damage to Class 1E Control Systems: The team postulated that, upon a worst case single failure (13.8kVac or 4.16kVac 3-phase power cable fault or a single line to ground fault on the 13.8kVac Fant line), the Class 1E and associated non-Class 1E DC protection and control cables could transmit the medium voltages throughout the control systems and damage connected components and equipment. The team reviewed the ONS single line power feeder diagrams, control wiring interconnection diagrams, and control system elemental diagrams and observed that clear electrical pathways appeared to exist that could transmit the voltages from the above mentioned failures to the three ONS 125Vdc safety systems, to the Keowee 125Vdc safety systems, and to the PSW 125Vdc systems. The team was concerned that this damage and the resulting consequences could impact much, if not most, of the systems connected to the 125Vdc DC Instrumentation & Control Power Panel Boards 1DIA, 1DIB, 2DIA, 2DIB, 3DIA, and 3DIB including the associated batteries. These power panel boards contain, among other things: the controls and lockouts for the alternate emergency power source (CT-5 transformer), the digital reactor protection system (reactor trip and engineered safeguards control), plant isolation from all offsite power, connections to the control room operator panel boards, boron dilution controls, excore nuclear instrumentation, and component cooling water controls. Any exposure of faulted medium voltage AC to the digital protection and control systems direct or indirect could conceivably, permanently disable them. In addition, the team noted that abnormal operating procedure AP/0/A/2000/002, "Keowee Hydro Station - Emergency Start" revision 15, step 5.15, directs the operators to realign the KHU from the overhead to the underground path if at any time the KHU aligned to the underground path experiences a trip. The team was concerned that this procedure step could cause further damage to any undamaged components from a short circuit in the underground raceways.

Finally, the team postulated electrical failure vulnerabilities where DC to DC electrical interactions could disable the emergency power system because of how both KHUs are interconnected between themselves and the three ONS units. The three ONS units consolidated their ESPS emergency power start wiring into two ESPS start trains (A and B). Each ESPS train must be able to start both KHUs, and the supervisory controls for each KHU must enable and operate the same KHU start circuits, governors, and field controls as the ESPS trains. All of these aforementioned circuits are interconnected at Keowee and between Keowee and ONS.

Requested Actions

Region II requests NRR to provide technical support in the evaluation of whether the cable configuration in certain underground raceways meets the existing ONS licensing basis, design basis, and NRC regulations and requirements, with emphasis on the following:

1. What are the ONS licensing basis, design basis, and NRC regulations and requirements for analyzing electrical failure vulnerabilities (single failure or otherwise) between medium voltage AC power and low voltage DC circuits as presented in this TIA?

2. Within Oconee's licensing basis:
    a. Are medium voltage power cables that are intended to provide emergency power to the RPS/ESPS equipment as well as provide the motive force to the actuated ESPS equipment during a chapter 15 event within the scope of IEEE-279-1971?
        - Must such power cables be considered under Section 3 “Design Basis” item 7 for transient conditions?
        - Must potential multiphase short circuits or ground faults from such power cables be considered under Section 3, “Design Basis” item 8 for unusual events, etc…?
    b. Does 3-phase medium voltage power cables, intended to provide Class 1E emergency power to the RPS/ESPS equipment, represent "interconnecting signal or power cables," as discussed in 4.2 of IEEE-279?
    c. Can the timing of electrical failures assumed in analyses, be limited to reduce the consequential damage as described in the “single failure memo to file?”
        - How is single failure timing applied to the commercial Fant power feeders and the QA-1 power feeders from the KHUs to the PSW different than the Class 1E power feeders to the CT-4 transformer?
    d. Can ONS staff make any distinctions between passive and active electrical single failures as described in the “single failure memo to file”?
    e. Is the ONS staff required to analyze for combinations of multi-phase short circuits as well as ground faults within trench 3 in order to be compliant with the regulations and/or the current licensing basis for ONS?
    f. Is the licensee required to analyze for consequential damage from electrical failures to the adjacent Class 1E safety systems?
        - Is the licensee required to assume that AC circuits could short to DC circuits?
        - If so, are the installed ONS 125Vdc protective devices sufficient to mitigate the effects of AC voltages ranging from 2.5kVac to 13.8kVac to prevent these voltages from propagating throughout the DC systems?
    g. Are all commercial, non-quality related (i.e. not QA-1 or QA-5) electrical components assumed to fail in the most limiting way possible?
        - Does the failure of one of these commercial components represent a “single failure,” in the context of the ONS licensing basis?

h. Can unrestrained cable whip in trench 3 be assumed to cause cable damage leading to secondary short circuits that could cause damage to the DC systems and should these effects of cable whip be analyzed?
i. Are overload currents as well as short circuit currents required to be evaluated to determine the most limiting results from electrical faults and component failures?
   - Do the results of such an analysis influence the required component separation to meet regulatory requirements and the ONS licensing basis?
j. Can cable shielding or armor prevent short circuits or limit faulted currents and voltages?
   - Can the two wraps of bronze shielding tape in the licensee's current power cable configuration be considered equivalent to the steel interlocked armored cable as described in the test report MCM-1354.00-0029.001?
   - Are the results of test report MCM-1354.00-0029.001 sufficient to demonstrate that electrical faults cannot propagate from one cable to another as described in the single failure DBD, Section 3.3.6.1?
k. Does the interconnected nature of the Class 1E DC systems in the ONS KHU start panels and the Keowee hydro-station KHU start panels present vulnerabilities where DC to DC interactions could disable the Keowee emergency power systems?

Coordination

This request was discussed between Theodore Fanelli (RII/DRS/EB1), Gurcharan Matharu (NRR/DE/EEEB), and others. The TIA was accepted by NRR with an agreed-upon draft response date of six months from the date of this TIA request.

Regulatory Requirements

Technical Specifications

3.8.1 Electrical Power Systems: Emergency AC Sources -Operating
LCO 3.8.1(a): The following AC electrical power sources shall be OPERABLE:

1. Two offsite sources on separate towers connected to the 230 kV switchyard to a unit startup transformer and capable of automatically supplying power to one main feeder bus; and
2. Two Keowee Hydro Units (KHUs) with one capable of automatically providing power through the underground emergency power path to both main feeder buses and the other capable of automatically providing power through the overhead emergency power path to both main feeder buses.

Tech Spec Bases 3.8.1 AC Sources – Operating

Background: The AC Power system consists of the offsite power sources (preferred power) and the onsite standby power sources, Keowee Hydro Units (KHU). This system is designed to supply the required Engineered Safeguards (ES) loads of one unit and safe shutdown loads of the other two units and is so arranged that no single failure can disable enough loads to jeopardize plant safety.

3.3.21 Emergency Power Switching Logic (EPSL) Keowee Emergency Start Function
LCO 3.3.21 Two channels of the EPSL Keowee Emergency Start Function shall be OPERABLE.

10 CFR 50.55a(h)(2) “Protection Systems”, states, “For nuclear power plants with construction permits issued after January 1, 1971, but before May 13, 1999, protection systems must meet the requirements stated in either IEEE Std. 279, "Criteria for Protection Systems for Nuclear Power Generating Stations," or in IEEE Std. 603-1991, "Criteria for Safety Systems for Nuclear Power Generating Stations," and the correction sheet dated January 30, 1995. For nuclear power plants with construction permits issued before January 1, 1971, protection systems must be consistent with their licensing basis or may meet the requirements of IEEE Std. 603-1991 and the correction sheet dated January 30, 1995.”

Letter from WO Parker (Duke) to BC Rusche (NRC), dated 5/13/1976, states, in part, that “The design of the Oconee onsite emergency AC and DC power systems conforms to the single failure requirements of IEEE-279-1971.”

IEEE 279-1971, Section 4.2, “Single Failure Criterion,” states, in part, that “Any single failure within the protection system shall not prevent proper protective action at the system level when required.” and “Note: “Single Failure” includes such events as the shorting or open-circuiting of interconnecting signal or power cables.”

General Design Criteria
USFAR, Section 3.1, Conformance with NRC General Design Criteria;
- Section 3.1.19, Criterion 19 - Protection Systems Reliability (Category B);
- Section 3.1.20, Criterion 20 - Protection Systems Redundancy and Independence (Category B);
- Section 3.1.21, Criterion 21 - Single Failure Definition (Category B);
- Section 3.1.22, Criterion 22 - Separation of Protection and Control Instrumentation Systems (Category B);
- Section 3.1.23, Criterion 23 - Protection against Multiple Disability for Protection Systems (Category B);
- Section 3.1.24, Criterion 24 - Emergency Power for Protection Systems (Category B); and
- Section 3.1.39, Criterion 39 - Emergency Power for Engineered Safety Features (Category A).

UFSAR Chapter 8
Section 8.3.1.2 “Analysis”
- “The basic design criterion for the electrical portion of the emergency electric power system of a nuclear unit, including the generating sources, distribution system, and controls is that a single failure of any component, passive or active, will not preclude the system from supplying emergency power when required.”
  Section 8.3.1.4.6.2, “Cable Separation”
- “Control, instrumentation, and power cables are applied and routed to minimize their vulnerability to damage from any source.”
- “Power and control cables for redundant auxiliaries or services are run by different routes to reduce any probability of an accident disabling more than one piece of redundant equipment.”

Section 8.3.2.2, “Analysis”
- “The 125 Volt DC Instrumentation and Control Power System and the 125 Volt AC Vital Power System are designed such that upon loss of power supplies no interactions exist between Reactor Protection Systems, Engineered Safeguards Protection Systems, and control systems that would preclude these systems from performing their respective functions.”

Section 8.3.2.2.2 “Single Failure Analyses of the 125 Volt DC Keowee Station Power System”

- “The 125 Volt DC Keowee Station Power System is arranged such that a single fault within either unit's system does not preclude the other unit from performing its intended function of supplying emergency power.”

References

Miscellaneous

Memo to File, Oconee Nuclear Station Single Failure Timing Licensing Basis, dated 01/12/1992
ONS UFSAR Section 8.3.1.4.6.2, dated 12/31/2012
SECY-77-439, Single Failure Criterion, dated 08/17/1977
OPS Guide 13-19, Restrictions on Keowee Unit Aligned to Underground, Rev. 2
SEL-351S-7, Relay Setting Scheme for the Oconee PSW Substation (LT RMAG CB SEL-351S-7 50-51TL Relay, Setting Version 8), dated 4/22/2013.
MCM-1354.00-0029.001, Report of Power and Control Cable Overload and Short Circuit Tests Performed for McGuire Nuclear Station, dated 11/08/1977

Corrective Action Documents

PIP/PDO O-14-02965, Questions were raised during review of calculation OSC-11061 Rev. 1 (Civil Evaluation of Dynamic Loads from Cable Faults)
PIP/PDO O-14-03190, Questions raised concerning single failure criteria associated with Keowee underground cable (Trench 3)
PIP/PDO O-14-05125, Cable faults on the PSW 13.8 kV Fant power path
PIP O-13-08748, Bracing of the cabling between the Keowee buss and the KPF-9 and KPF-10 switchgear.

Engineering Changes

NSM ON-53065, Keowee Underground Path Replacement, dated 02/04/2002
EC 91874, Scope Description Rev. 4, 13.8 kV Feed to PSW System from 100 kV APS, Rev. 4

Oconee Specifications

OSS-0254.00-00-4013, Design Basis Specification for the Oconee Single Failure Criterion, Rev. 4
OSS-0254.00-00-2005, Design Basis Specification for the Keowee Emergency Power, Rev. 22
OSS-0139.00-00-0010, Keowee Underground Replacement Medium Voltage Single Conductor Cable, Rev. 1

Calculations

OSC-11013, Unit 1,2,3 Short Circuit Currents on Keowee Underground Path, Rev. 0
OSC-11061, Civil Evaluation of Dynamic Loads From Cable Faults, Rev. 1
OSC-11062, Cable Electromagnetic Forces on Keowee and Protected Service Water 13.8 kV & 4.16 kV Single Conductor Power Cables during Fault Conditions, Rev. 0
ONS-17-05-100-001, URS Engineering Study, dated 04/08/2014

Drawings

2616OL1, Online relay Instrumentation & Control, Rev. 1
2616E Sheet 10 of 14, Elementary Circuits Bank 1 L.T. CB-21 Relay (RMAG), dated 12/04/07
261STO2, Structure 100 to 13.8kV Newry, S.C., Rev. 1
O-705, One Line Diagram 120AC & 125 VDC Station Aux. Circuits Instrumentation Vital Buses, Rev. 98

OEE-120, Elementary Diagram Channel ‘A’ Keowee Emergency Start, Rev. 17
OEE-120-A, Elementary Diagram Channel ‘A’ Keowee Emergency Start Contact Development, Rev. 10
OEE-120-1, Elementary Diagram Channel ‘B’ Keowee Emergency Start, Rev. 17
OEE-120-1-A, Elementary Diagram Channel ‘B’ Keowee Emergency Start Contact Development, Rev. 10
KEE-117, KHU 1 Elementary Diagram Remote Controls, Rev. 6
KEE-217, KHU 2 Elementary Diagram Remote Controls, Rev. 8
CS-16939, Okonite 750 MCM Cable Cross Section Detail Drawing Revision Date 3/13/14

<u>Standards and NUREGs</u>

IEEE 279-1971 - Criteria for Protection Systems dated, 06/03/1971
IEEE 379-2000 - IEEE Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems, dated 07/21/2000
IEEE 383-1974 IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections, dated 02/28/1974
IEEE 308-1974 IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations, dated 04/14/1975
IEEE 352-1987 IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems, dated 06/13/1985
IEEE 100, The Authoritative Dictionary of IEEE Standard Terms, Seventh Edition
IEC 61914 Edition 1.0 2009-01, Cable Cleats for Electrical Installations
NUREG/CR-6850 EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities Volume 2: Detailed Methodology, dated 07/2005
NUREG/CR-6850 Supplement 1, Fire Probabilistic Risk Assessment Methods Enhancements, dated 09/2010
NUREG/CR-6794 Evaluation of Aging and Environmental Qualification Practices for Power Cables Used in Nuclear Power Plants ML030130268, dated 01/2003
ICEA S-93-639-2012 / ANSI/NEMA WC74, 5-46kV Shielded power cable for use in the Transmission and Distribution of Electric Energy, dated 12/08/2012
ANSI/ICEA T-27-581 & NEMA WC 53-2008, Standard Test Methods for Extruded Dielectric Power, Control, Instrumentation, and Portable Cables for Test, dated 06/27/2008
ANSI/ICEA P-32-382-2007, Short Circuit Characteristics of Insulated Cables, dated 06/04/2007
ICEA P-45-482-2013 Short Circuit Performance of Metallic Shields and Sheaths on Insulated Cable, dated 02/27/2013
NEMA WC 50-76/ICEA P-53-426, Ampacities Including Effect of Shield Losses for Single-Conductor Solid-Dielectric Power Cable, 15kV through 69kV (Copper and Aluminum Conductors), dated 05/17/1976

October 16, 2014

MEMORANDUM TO: Aby S. Mohseni, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

FROM: Terrence Reis, Director
Division of Reactor Safety ***/RA/***

SUBJECT: REQUEST FOR TECHNICAL ASSISTANCE REGARDING OCONEE NUCLEAR STATION DESIGN ANALYSIS FOR SINGLE FAILURE AND THE INTEGRATION OF CLASS 1E DIRECT CURRENT CONTROL CABLING IN RACEWAYS WITH HIGH ENERGY POWER CABLING (TIA 2014-05)

On June 27, 2014, Region II documented the results of a component design basis inspection at Oconee Nuclear Station (ONS) Units 1, 2, and 3 in inspection report 05000269/2014007; 05000270/2014007; 05000287/2014007 (ADAMS Accession Number ML14178A535). In that report, the inspection team identified an unresolved item involving cable configurations in certain underground cable raceways, which may not comply with the ONS licensing basis, design basis, and NRC regulations and requirements. In certain underground raceways, ONS staff has installed Class 1E[1] and associated non-Class 1E direct current protection and control circuits adjacent to high energy medium voltage power cables. The inspectors were concerned that the proximity of these cables to one another may not meet the single-failure design criteria of the ONS engineered safeguards protection system.

Through this task interface agreement, Region II requests the Office of Nuclear Reactor Regulation to provide technical support in the evaluation of whether the cable configuration in certain underground raceways meets the existing ONS licensing basis, design basis, and NRC regulations and requirements.

CONTACT: T. Fanelli, DRS
404-997-4433

(*) – SEE PREVIOUS PAGE FOR CONCURRENCE

☐ PUBLICLY AVAILABLE X☐ NON-PUBLICLY AVAILABLE ☐ SENSITIVE X☐ NON-SENSITIVE

ADAMS:X ☐ Yes ACCESSION NUMBER:_ML14290A136________ X☐ SUNSI REVIEW COMPLETE ☐ FORM 665 ATTACHED

OFFICE	RII:DRS	RII:DRS	RII::DRS	RII:DRS	RII:DRS		
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NAME	TFANELLI	JEARGLE	RNEASE	MMILLER	TREIS		
DATE	10/10/2014	10/10/2014	10/15/2014	10/15/2014	10/16/2014	10/ /2014	10/ /2014
E-MAIL COPY?	YES NO	YES NO	YES NO	YES NO	YES NO	YES NO	YES NO

OFFICIAL RECORD COPY DOCUMENT NAME: S:\DRS\ENG BRANCH 1\OCO CABLE ISSUE\TIA\OCO SINGLE FAILURE TIA 10 08 2014.DOCX