UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION II
245 PEACHTREE CENTER AVENUE NE, SUITE 1200
ATLANTA, GEORGIA 30303-1257

February 25, 2016

Mr. Scott Batson
Site Vice President
Duke Energy Carolinas, LLC
Oconee Nuclear Station
7800 Rochester Highway
Seneca, SC 29672

SUBJECT: OCONEE NUCLEAR STATION - NRC SPECIAL INSPECTION REPORT 05000269/2016008 AND 05000287/2016008

Dear Mr. Batson:

On December 22, 2015, the U.S. Nuclear Regulatory Commission (NRC) completed its initial assessment of the circumstances surrounding the power cable failures/degradation on the Units 1 and 3 startup transformers at the Oconee Nuclear Station. The failures/degradation were identified during operator rounds on December 7 (Unit 3) and during licensee extent of condition review on December 15, 2015 (Unit 1). Based on this initial assessment, the NRC sent an inspection team to your site on January 5, 2016.

On January 8, 2016, the NRC completed the onsite portion of the special inspection and on January 14, 2016, the NRC discussed the results of this inspection with you and other members of your staff. The inspection team documented the results of this inspection in the enclosed inspection report.

No findings were identified during this inspection.

In accordance with Title 10 of the Code of Federal Regulations 2.390, “Public Inspections, Exemptions, Requests for Withholding,” of the “Rules of Practice,” a copy of this letter, its enclosure, and your response (if any) will be available electronically for public inspection in the

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Sincerely,

/RA/

Frank Ehrhardt, Chief
Reactor Projects Branch 1
Division of Reactor Projects

Docket Nos.: 50-269, 50-287
License No.: DRP-38, DPR-55

Enclosure:
Special Inspection Report 05000269/2016008
and 05000287/2016008 w/Attachment:
Supplementary Information

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Letter to Scott Batson from Frank Ehrhardt dated February 25, 2016

SUBJECT: OCONEE NUCLEAR STATION - NRC SPECIAL INSPECTION REPORT 05000269/2016008 AND 05000287/2016008

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U. S. NUCLEAR REGULATORY COMMISSION

REGION II

Docket No.:	50-269, 50-287
License No.:	DRP-38, DPR-55
Report No.:	05000269/2015008, 05000287/2015008
Licensee:	Duke Energy Carolinas, LLC
Facility:	Oconee Nuclear Station, Units 1 and 3
Location:	Seneca, SC 29672
Dates:	January 5, 2016 through January 14, 2016
Inspectors:	Eddy Crowe, Senior Resident Inspector (Lead) Marcus Riley, Reactor Inspector Brendan Collins, Reactor Inspector
Approved by:	Frank Ehrhardt, Chief Reactor Projects Branch 1 Division of Reactor Projects

Enclosure

SUMMARY

IR 05000269/2015008, 05000287/2015008; 01/05/2016 - 01/14/2016; Oconee Nuclear Station, Units 1 and 3; Special Inspection.

This report documents special inspection activities performed onsite and in the Region II office by one senior resident inspector and two reactor inspectors to review the circumstances surrounding the power cable failures/degradation on the Units 1 and 3 startup transformers at the Oconee Nuclear Station identified during operator rounds on December 7 (Unit 3) and during extent of condition review on December 15, 2015 (Unit 1). The NRC's program for overseeing the safe operation of commercial nuclear power reactors is described in NUREG-1649, "Reactor Oversight Process," Revision 5.

REPORT DETAILS

Summary of the Degraded Condition

During operator rounds on December 7, 2015, an auxiliary operator discovered the Oconee Unit 3 startup transformer (CT-3) with one of its phases disconnected at the phase bushing. After isolation and repairs, the connector (wire clamp) and wire were sent to McGuire Nuclear Plant laboratory for analysis. The licensee subsequently performed extent-of-condition reviews and discovered broken power feed cable strands on all three phases of the Unit 1 startup transformer (CT-1). The licensee repaired the degraded connections by cutting off the degraded cabling and re-clamping the cables. The number of strands that were broken on each of the cables varied.

Special Inspection Charter

Based on the deterministic and conditional risk criteria specified in Management Directive 8.3, “NRC Incident Investigation Program,” a special inspection was initiated in accordance with NRC Inspection Procedure 93812, “Special Inspection Team.” The inspection focus areas included the following special inspection charter items:

1. Develop a detailed sequence of events from the time of discovery of the CT-3 power cable failure until the licensee completed assessing extent of condition. Include any recent work/maintenance completed on CT-3 and CT-1.

2. Review and evaluate the licensee’s causal evaluation related to this event, including the cause of the material failures as well as any programmatic contributors (e.g., lack of cable replacement, cyclic fatigue, corrosion, etc.)

3. Review and evaluate the licensee’s actions to detect and prevent open phase conditions in offsite power system in view of industry operating experience identified in NRC Information Notice IN 2012-03 and Bulletin 2012-01 are in accordance with the licensee’s response dated February 3, 2014 (ADAM Accession No. ML14035A453.)

4. Review the laboratory report associated with the analysis of the failure mechanism from CT-3 and CT-1. Include information from analysis of intact CT-2 cables.

5. Review and assess the licensee’s testing and maintenance practices related to the maintenance/inspection of wires/cables in the startup transformers and other transformers onsite.

6. Review and evaluate the licensee’s compliance with vendor recommendations regarding maintenance and testing of transformer cables at the site.

7. Review and verify the licensee’s reportability determination was in accordance with the reportability criteria in 10 CFR 50.72 and NUREG-1022.

8. Review and evaluate the licensee's immediate corrective actions taken related to the issue and the extent of condition completed for the other startup transformers, CT-5, and the Keowee step-up transformer. Verify acceptability of the completed temporary modifications.

9. Review and evaluate the licensee's operability and past operability determinations of CT-3 and CT-1, to include:

    a. How many strands of wire are necessary to carry 80 amps and 35MWe which is the engineered safeguard features (ESF) loading criteria?
    b. Exact times that the emergency AC power paths were out of service over the required operability times from the last time it was proven that these startup transformers would have carried full load.
    c. Review available Duke test data of the intact core of CT-2 cable which was removed to verify it would carry 100 amps for applicability to conditions discovered on CT-3.

10. Assess the licensee's actions resulting from NRC generic communications, vendor technical bulletins, and industry operating experience related to similar events.

11. Collect data necessary to support completion of the significance determination process, if applicable.

12. Identify any potential generic safety issues and make recommendations for appropriate follow-up action (e.g., Information Notices, Generic Letters, and Bulletins.)

4. OTHER ACTIVITIES

4OA5 Other Activities – Special Inspection (IP 93812)

.1 Develop a detailed sequence of events from the time of discovery of the CT-3 power cable failure until the licensee completed assessing extent of condition. Include any recent work/maintenance completed on CT-3 and CT-1.

On December 7, 2015 at 8:20 AM, during auxiliary operator (AO) rounds, the AO identified that a power cable, which connects the incoming power feed from the 230KV switchyard to the Unit 3 startup transformer "Y" phase bushing, was completely disconnected. The AO reported this condition to the work control senior reactor operator (SRO). The SRO responded to the scene and evaluated the condition. The SRO was unable to positively identify the effect of the broken cable upon the startup transformer and requested support from the engineering staff. The engineering assessment resulted in the recommendation to declare the Unit 3 startup transformer inoperable. The Unit 3 control room supervisor declared the startup transformer inoperable at 8:47 AM and entered Technical Specification (TS) 3.8.1 Condition A.

During the inspector's review of station logs, the inspectors noted that the emergency AC underground power path from Keowee Hydro had been declared inoperable at 5:00 AM on December 7, 2015 for planned maintenance. The scope of the work included racking out the standby feed to main feeder bus breaker (S1) which receives power from the emergency AC power path transformer (CT-4). Operations personnel were hanging tags to isolate the standby feed to the main feeder bus breaker (S1) for planned maintenance on the feeder breaker relays. The operators discovered existing tags on associated components and were evaluating a solution with Unit 3 control room and work control staff. This tagging activity occurred at the same time as evaluation of the degraded condition of the Unit 3 startup transformer. The staff involved in resolving the tagging issue decided to restore the underground emergency AC path from Keowee Hydro to the main feeder buses at 8:41 AM on December 7, 2015, as documented in the station logs.

The inspectors noted the overlap of time during which both emergency AC power paths were inoperable and interviewed station personnel to determine why the applicable technical specifications for this condition was not logged in the station logs. During these interviews, the inspectors learned that staff involved with the discovery of the tagging activity had acted independently of the staff involved with the evaluation of the degraded startup transformer. The inspectors did not discover any communications between the two groups during these evaluations. The inspectors determined that TS 3.8.1 Condition I applied as both emergency AC power paths required by station technical specifications were inoperable. This condition existed for 21 minutes.

Technical Specification 3.8.1 Condition A requires operators to align the emergency startup bus to share another unit's startup transformer within 12 hours of the declaration of an inoperable unit startup transformer. The licensee cross-connected the Unit 3 startup transformer (CT-3) load side to the Unit 2 startup transformer (CT-2) at 4:50 PM on December 7, 2015. The licensee electrically isolated the Unit 3 startup transformer and performed repairs, which included cutting the damaged ends from the disconnected power cable and re-installing the power cable into its connections. The licensee completed the repairs and returned the Unit 3 startup transformer to an operable status at 7:57 AM on December 8, 2015.

On December 8, 2015, the licensee completed extent of condition actions on the transformers listed below. These actions included unaided visual inspection for failed connectors, frayed wires, and other indications of degraded cables and connections. The licensee did not identify any adverse conditions during the performance of the below inspections.

- Unit 1 startup transformer (CT-1)
- Unit 2 startup transformer (CT-2)
- Keowee Hydro underground emergency AC power path stepdown transformer (CT-4)
- Keowee Hydro overhead emergency AC power path stepup transformer
- Lee/Central Substation transformers (CT-7C and CT-8C)
- 100KV/13.8 stepdown transformer which powers the protected service water electrical buses

The licensee determined additional extent of condition actions were warranted and generated work orders to perform detailed inspections of the transformers listed above. At 9:21 AM on December 15, 2015, maintenance personnel using an optical aid, discovered broken strands on the incoming power feed from the 230KV switchyard to the Unit 1 startup transformer “X” phase bushing. The licensee declared the Unit 1 startup transformer (CT-1) inoperable and entered TS 3.8.1 Condition A. At 1:50 PM the licensee cross-connected the load side of the Unit 1 startup transformer (CT-1) to the Unit 2 startup transformer (CT-2) as required by TS 3.8.1 Condition A. The licensee subsequently isolated the power side of CT-1 for repairs. The licensee determined that all six of the aluminum strands of the power feed cable were broken at the connection point on the “X” phase bushing. The iron center core strand was intact at this connection point. The licensee also discovered two of the six aluminum strands of the “X” phase power feed cable broken at the connection point to the overhead line carrying power from the 230KV switchyard to the insulator at the plant turbine building. Additionally, maintenance personnel discovered five of the six aluminum strands broken at the connection point to the “Y” phase bushing and one of the six aluminum strands broken at the connection point to the “Z” phase bushing. The iron core was intact on both of the connection points of the “Y” and “Z” phase bushings. Maintenance personnel removed the degraded portion from each power cable by cutting the damaged ends from the power cables. These cable sections were retained for further testing. The licensee reconnected the remaining portions of the power cables and returned the Unit 1 startup transformer to service at 1:55 AM on December 16, 2015.

Following the discovery of degraded cables on the Unit 1 startup transformer (CT-1), the licensee decided to perform additional inspections of other large oil filled stationary transformers by electrically isolating those transformers to allow close-up inspection. These inspections involved visual inspection for failed connectors, frayed wires, and other indications of degraded cables and connections.

The licensee inspected the transformers listed below. The licensee did not identify any degradation/physical damage to any of the components that were inspected.

- Unit 2 startup transformer (CT-2)
- Lee/Central Alternate Power System and Lee/Central Alternate Power stepdown transformer (LCT) (CT-5)
- Keowee main stepup transformer

Additionally, on December 21, 2015, engineering provided written instructions to operations department for performing weekly visual inspections of the startup and main stepup transformers cable connections. These inspections are conducted from ground level using optical aids. The licensee plans to continue these inspections until all planned modifications to the startup transformers are complete.

On January 7, 2016, the licensee received metallurgical test results for the ends of the severed power cable from the Unit 3 startup transformer from the Nuclear Generation

Metallurgy and Welding Services laboratory at the McGuire Nuclear Station. In addition to this metallurgic evaluation, the licensee performed ampacity testing at the Oconee Maintenance Training Facility laboratory and at Georgia Technical National Electric Energy Testing, Research and Applications Center.

.2 Review and evaluate the licensee's causal evaluation related to this event, including the cause of the material failures as well as any programmatic contributors (e.g., lack of cable replacement, cyclic fatigue, corrosion, etc).

a. Inspection Scope

At the time of the NRC SIT inspection, the licensee had begun their evaluation process but had not completed their apparent cause evaluation. The inspectors reviewed information available at the time of the inspection, including the report generated by the Nuclear Generation Metallurgy and Welding Services laboratory. The licensee sectioned portions of the "Y" phase cable from the Unit 3 startup transformer and sent them to the laboratory where they were mechanically tested, as described in Section 4OA5.4 of this report. The laboratory report did not provide any conclusions but merely reported on the metallurgical conditions discovered at the time of the evaluation. Additionally, the inspectors reviewed laboratory reports for ampacity testing performed on the cables for all three transformers as described in Section 4OA5.9 of this report. The inspectors discussed the ampacity testing performed on the iron core of the CT-2 power cable at the Oconee Maintenance Training laboratory with engineering. The inspectors reviewed the licensee's fault table, which was constructed as part of their initial failure investigation process (FIP). The inspectors also reviewed procedures related to periodic maintenance and required surveillance testing to determine the type and periodicity of these activities. The inspectors reviewed the licensee's draft charter for their cause determination. Since the licensee's causal evaluation team was just forming, the NRC inspectors were not able to review the licensee's completed apparent cause evaluation.

b. Findings and Observations

The licensee's FIP concluded that excessive flexing of the conductors was the likely cause of the failure. The licensee's FIP concluded that it was indeterminate as to whether or not excessive vibration, contamination, or manufacturing defects contributed to the failure. The licensee also stated that the visual inspection of the break in the cable leads to a preliminary conclusion that it broke due to fatigue and that on occasion Oconee personnel had observed these cables moving back and forth.

Because the licensee's final causal evaluation was not completed at the time of the inspection, the inspectors did not identify any findings or observations. NRC inspectors will review and evaluate the licensee's final causal evaluation when completed. These reviews will contribute to determining whether a performance deficiency (PD) exists as part of unresolved item (URI) 05000269, 287/2016008-01, described below in Section 4OA5.5.b.

.3 Review and evaluate the licensee's actions to detect and prevent open phase conditions in offsite power system in view of industry operating experience identified in NRC Information Notice IN 2012-03 and Bulletin 2012-01 are in accordance with the licensee's response dated February 3, 2014 (ADAM Accession No. ML14035A453).

a. Inspection Scope

The inspectors reviewed Duke Energy's response to IN 2012-03 and NRC Bulletin 2012-01 to assess the ability of Oconee Nuclear Station, Units 1, 2, and 3, to detect and automatically respond to a single-phase open circuit condition or high impedance ground fault condition on a credited offsite emergency power source. The inspectors also reviewed the licensee's interim corrective actions in response to a request for additional information (RAI) to verify that the licensee was implementing corrective actions and that the corrective actions were adequate to promptly diagnose and respond to open phase conditions on the offsite power circuits for Class 1E vital buses until permanent corrective actions are implemented.

b. Findings and Observations

The NRC issued Information Notice 2012-03, "Design Vulnerability in Electric Power System," dated March 1, 2012, to all holders of an operating license to inform them of recent operating experience at other plants involving the loss of one of the three phases of the offsite power circuit. The NRC issued Bulletin 2012-01, "Design Vulnerability in Electric Power Systems," dated July 27, 2012, to all power reactor licensees and holders of combined licenses for nuclear power reactors for the same issue. Duke Energy provided their response to this bulletin in a letter dated October 23, 2012 (ADAMS ML12300A426). On December 20, 2013, the NRC issued an RAI requesting Duke Energy to (1) provide a summary of all interim corrective actions that have been taken since the January 30, 2012 event at Byron Station Unit 2, to ensure that plant operators can promptly diagnose and respond to open phase conditions on the offsite power circuits for Class-1E vital buses until permanent corrective actions are completed and (2) provide a status and schedule for completion of plant design changes and modifications to resolve issues with an open phase of electric power. Duke Energy provided their response to this RAI in a letter dated February 3, 2014 (ADAMS ML14035A453).

In response to Bulletin 2012-01, Duke Energy described two relay protection schemes that separate the ESF buses due to a loss of voltage or a sustained degraded voltage condition. The first scheme monitors the 230kV yellow bus and isolates the switchyard upon detection of at least two out of the three phases on the yellow bus being degraded when an engineered safeguards (ES) signal is present. The second scheme monitors the 4160V buses and disconnects the 4160V buses from the offsite power source on a loss of offsite power using two out of three logic.

The licensee stated in their response that annunciators and computer points would actuate in the control room for an under voltage condition on the open phase, but no automatic trip would be initiated, and that control room operators would respond per the appropriate alarm response guide. The alarm response guide provides manual actions for the operators to determine which phase is experiencing the under voltage or open phase condition and directs operators to refer to technical specifications for applicability. The inspectors noted that in certain cases, specifically during normal plant operations when the ESF buses are normally aligned to the unit auxiliary transformer as occurred when the licensee found disconnected/degraded cables on CT-3 and CT-1, the licensee would not be able to automatically detect an open phase condition. This is because there is not enough current for installed relays to detect a single open phase when the startup transformers are unloaded.

As part of the RAI, the licensee implemented interim actions to complete a review of their preventative maintenance procedures and to perform daily and monthly walkdowns of the switchyard. These walkdowns included steps to monitor insulators, cables, and connections for degradation or damage. The inspectors noted that preventative maintenance procedures IP/0/A/2007/001, “Transformer Inspection and Maintenance”, Rev. 34, and IP/0/A/2400/002, “Substation Insulators, Lightning Arrestors, CCVT, Transformer Drop Down Line, Bus Inspection, and Maintenance”, Rev. 7, contained steps to perform unaided visual inspections of the transformers. Procedure IP/0/A/2400/002 required inspections of all connections for cracks and fraying as part of transformer drop down line maintenance. Procedure IP/0/A/2007/001 required inspections of the transformer bushings and line connections for breaks, cracks, or corrosion. The inspectors performed a visual inspection of the startup transformers from ground level and determined that while the Procedure IP/0/A/2007/001 did have steps to verify equipment had not degraded, an unaided visual inspection from ground level would not be adequate to detect smaller cracks and frays on the cables and connections. In addition, the inspectors noted that the weekly surveillance procedures performed to verify the operability of the offsite power sources could not detect an open circuit condition from the offsite power source during unloaded conditions.

In addition, per the RAI, the licensee performed thermal imaging of the startup transformers, the Keowee main step up transformer, and transformer CT-5 under normal loaded conditions on at least a semi-annual frequency to detect potential equipment problems. However, no evidence was provided by the licensee that thermal imaging was performed on the startup transformers during loaded conditions. The inspectors determined that failing to fully load the transformer could mask degradation of the cables and connectors. The licensee also completed a corrective action for operators to complete a read and sign package and classroom training related to NRC Bulletin 2012-01 and IN 2012-03.

The inspectors determined that the licensee had completed all interim actions in response to IN 2012-03 and NRC Bulletin 2012-01. The inspectors concluded that the licensee’s actions regarding preventative maintenance and testing lacked the necessary rigor to detect slow degradation of cables or other equipment, which could lead to an open circuit condition. The inspectors opened an URI to determine if a performance deficiency exists related to the adequacy of the licensee’s maintenance and testing program as it relates to this issue. The URI is discussed further in Section 4OA5.5.

.4 <u>Review the laboratory report associated with the analysis of the failure mechanism from CT-3 and CT-1. Include information from analysis of intact CT-2 cables.</u>

a. <u>Inspection Scope</u>

The inspectors reviewed the laboratory analysis of the power cables from all three phases of the CT-3 startup transformer performed by the Nuclear Generation Metallurgy and Welding Services Laboratory. The inspectors also reviewed the results of electrical testing that was conducted on the CT-2 power cables to establish the viability of a proposed testing technique for the CT-1 cables. The licensee subsequently sent samples of the CT-1 cables to Georgia Tech National Electric Energy Testing, Research and Applications Center for electrical testing. This testing was used to evaluate past operability of the CT-1 transformer rather than to evaluate the failure mechanism, and as such, it is described in Section 4OA5.9.

b. <u>Findings and Observations</u>

The test data that was available at the time of the inspection is described below.

Transformer CT-3:

The licensee performed an evaluation of the failed portions of each power cable from the CT-3 transformer at the Nuclear Generation Metallurgy and Welding Services Laboratory located at the McGuire Nuclear Station. The laboratory performed visual inspections utilizing the naked eye, optical microscope, and scanning electron microscope (SEM) with energy-dispersive spectroscopy (EDS) capability.

On the “Y” phase cable, which had completely separated (all six aluminum strands and steel core strand), the laboratory noted that the steel core exhibited a flat surface on approximately 63 percent of the failure surface. This flat feature was oriented perpendicular to the strand axis, and had very faint beach marks, indicative of a fatigue mechanism. The other 37 percent of the failure surface was oblique to the strand axis, and exhibited features consistent with sudden tensile failure. The laboratory noted light rust on the failure surface of the steel strand, but none on the outer surface, as would be expected for the construction of the steel strand (galvanized/coated steel). The laboratory noted that no distinct features were evident on the failed ends of the aluminum strands due to apparent rubbing. The failure surface of the steel strand contained a thin, smeared layer of aluminum oxide, leading the licensee to conclude that the aluminum strands had rubbed against the steel strand as well as against each other. Most of the aluminum strands appeared to have a cup-and-cone appearance, indicative of a slow tensile failure.

At the bushing end, the laboratory noted that two of the aluminum strands that had failed in the freespan portion of the cable were also broken near the bushing connector. These two failures exhibited a more “blocky” shape than the cup-and-cone appearance of the other aluminum failures. At these two failure locations, the laboratory observed mechanical damage on the outer surface of the aluminum strands, consistent with a clamping motion (as opposed to rubbing). There was also evidence of rubbing in various areas along the length of all the aluminum strands, including some near these failure locations. The laboratory made no definitive conclusions about the source of the mechanical damage or rubbing.

On the “X” and “Z” phase cables, the steel strands were both intact, and no features were noted which provided more information than what was gleaned from the “Y” phase steel strand. The laboratory performed mechanical testing on portions of the steel strands of all three phases, determined that the strength met design requirements, and concluded that no other cracks existed in these steel strands. The laboratory also performed mechanical testing on aluminum strands from all three phases. The results were not definitive, but the laboratory noted that there appeared to be some work hardening on two of the “Y” phase aluminum strands that may have led to a greater loss of strength than what was observed on the “X” or “Z” aluminum strands. The laboratory concluded that this was likely the result of the “Y” phase cable having a greater freedom of motion as it progressed through the failure sequence, but did not rule out the possibility that the work hardening may have contributed to the failure rather than being a result of the failure.

As stated in Section 4OA5.2, these efforts represented only the beginning efforts of the licensee’s causal evaluation, and the licensee had not established a definitive conclusion at the time the inspectors conducted the exit meeting. The inspectors reviewed the available data and determined that no conclusion could be established. The licensee’s additional efforts will be reviewed when closing the URI 05000269, 287/2016008-01, described below in Section 4OA5.5.b.

Transformer CT-2:

No damage was noted on any of the strands of any of the three phases of the CT-2 transformer power cables, as stated in Section 4OA5.1. Therefore, the licensee did not perform mechanical testing on these cables. However, the licensee took small sections from these cables and performed electrical testing to establish the viability of a proposed testing technique for the CT-1 cables. This electrical testing was performed at the Oconee Maintenance Training facility, and is described in Section 4OA5.9.

Transformer CT-1:

When the licensee discovered the broken cable on CT-3, they performed visual examinations (naked eye) to evaluate the extent of condition on CT-1 and CT-2, as described in Section 4OA5.1. The steel strands of all three phases of CT-1 cables were found to be intact, but several aluminum strands of each of the three CT-1 cables were found to be broken (6 on “X” phase, 5 on “Y” phase and 1 on “Z” phase). No further mechanical evaluation was done on the CT-1 cables. After completing the suitability testing described above for CT-2, the licensee sent samples of the CT-1 cables to Georgia Tech National Electric Energy Testing, Research and Applications Center for electrical testing. This testing was used to evaluate past operability of the CT-1 and CT-3 transformers rather than to evaluate the failure mechanism, and is described in Section 4OA5.9.

The inspectors determined that no definitive conclusions could be made about the cause of the event based on the testing the licensee had completed at the time. However, because the licensee has not completed the final cause evaluation, the NRC will review the final cause evaluation under URI 05000269, 287/2016008-01, described below in Section 4OA5.5.b.

.5 Review and assess the licensee's testing and maintenance practices related to the maintenance/inspection of wires/cables in the startup transformers and other transformers onsite.

a. Inspection Scope

The inspectors reviewed the licensee's surveillance activities required by technical specifications to verify the correct breaker alignment and power availability for each required offsite source of electrical power. The inspectors also reviewed the licensee's preventative maintenance program to determine the licensee's ability to detect early degradation of power cables and their connections. The inspectors specifically focused upon inspections of bushings, surge arrestors, cable connections, T-connections, and cables on the station's large oil filled stationary transformers. The inspectors reviewed associated station procedures to determine if the licensee was inspecting for failed connectors, frayed wires, and other indications of degraded cables and connections. The inspectors also conducted interviews with licensee personnel pertaining to preventative maintenance and testing activities. Additionally, the inspectors reviewed station documents to determine if the licensee's planned maintenance program included verification of potential age-related degradation of components. The specifics of these reviews are described in Section 4OA5.3 above.

b. Findings and Observations

Introduction

An URI was identified to determine if a performance deficiency exists regarding the adequacy of the licensee's maintenance program to detect substantial degradation of cables and their connections used on the station's large oil filled stationary transformers.

Description

The inspectors developed an issue of concern related to the adequacy of the licensee's maintenance program to detect substantial degradation of cables and their connections used on the station's large oil filled stationary transformers. The inspectors noted that all inspections required by the licensee's surveillance and preventative maintenance programs used unaided visual inspections of bushings, surge arrestors, cable connections, T-connections, and cables on the station's large oil filled stationary transformers. The inspectors noted that the licensee's metallurgical report associated with the failed power cable from the Unit 3 startup transformer identified degradation which likely occurred over a lengthy period of time. The inspectors determined that the following inspection activities should be pursued to determine if a performance deficiency exists:

- Review of the licensee's completed cause determination
- Review of any additional testing and metallurgical reports
- Review of any license event report submitted by the licensee
- Review of requirements associated with emergency AC power paths and associated transformers

This issue is identified as URI 05000269, 287/2016008-01, "Potential lack of adequacy of the licensee's maintenance program to detect substantial degradation of cables and their connections used on Oconee large oil filled stationary transformers."

.6 Review and evaluate the licensee's compliance with vendor recommendations regarding maintenance and testing of transformer cables at the site.

a. Inspection Scope

Southwire manufactured the cables that supply power to the startup transformers CT-1, CT-2, and CT-3; the Keowee main stepup transformer; and LCT (CT-5). These are Aluminum Conductor Steel Reinforced Bare (ACSR) cables. The inspectors reviewed the cable vendor manual, as well as the transformer vendor manuals, to determine if any guidance was provided in regards to maintenance and testing of the incoming cables to the transformer connections.

b. Findings and Observations

The inspectors noted that the Southwire cable vendor manual did not provide recommendations for testing and maintenance of the cables. Additionally, the inspectors noted that the transformer vendor manuals did not provide recommendations for testing and maintaining incoming cables to the transformer. Therefore, there were no vendor recommendations pertaining to the maintenance and testing of the transformer cables for the inspectors to review.

.7 Review and verify the licensee's reportability determination was in accordance with the reportability criteria in 10 CFR 50.72 and NUREG-1022.

a. Inspection Scope

The inspectors reviewed 10 CFR 50.72 and NUREG-1022 to determine the likely reporting criteria associated with the degraded Unit 1 and Unit 3 startup transformer power cables. The inspectors interviewed station regulatory affairs personnel and station senior management to determine their logic for their decision making process. The inspectors also interviewed licensee personnel regarding the time of discovery of the degraded condition on the Unit 3 startup transformer. Additionally, the inspectors performed walkdowns of potentially affected equipment and evaluated the licensee's corrective actions related to extent of condition.

b. Findings and Observations

The inspectors determined that it is the licensee's responsibility to evaluate plant conditions and determine the appropriate reporting criteria associated with those conditions. The inspectors evaluated the reportability criteria in 10 CFR 50.72 and determined the most appropriate criteria for the degraded conditions were: operation or condition prohibited by technical specifications; event or condition that could have prevented fulfillment of a safety function; and degraded or unanalyzed condition. The inspectors concentrated their additional efforts on these three criteria with respect to evaluating the licensee's decision making process.

The licensee identified the time of discovery as 8:47 AM on December 7, 2015. The inspectors discovered evidence that station personnel knew of the degraded condition at 8:20 AM on December 7, 2015. This discrepancy between the NRC inspectors' perceived point of discovery and the licensee's time of discovery was further evaluated through interviews with station personnel. The inspectors noted that existence of parallel independent activities related to restoration of the underground emergency AC power path and the evaluation of the degraded startup transformer contributed to this discrepancy. The inspectors noted that corporate and station personnel relied upon existing station protocol of establishing the time of discovery as the point when the Unit 3 startup transformer was declared inoperable. This occurred at 8:47 AM on December 7, 2015. The inspectors noted that this was six minutes after station personnel had restored technical specification operability of the underground emergency AC power path and had exited TS 3.8.1 Condition D. The corporate and station personnel included in their decision the fact that the underground emergency AC power path would have been able to power both main feeder buses through a backfeed that is part of the design of the station's power distribution system. These two factors, ability to backfeed and time of discovery, led to the licensee's decision that the safety function of providing emergency AC power to station safety related buses was met.

The inspectors reviewed test results and metallurgical reports to evaluate potential past operability concerns. The licensee performed testing onsite in their maintenance training facility and at the Georgia Tech National Electric Energy Testing, Research and Applications Center. The purpose of these tests was to demonstrate the ability of the steel core of the power cables to carry the necessary current required by UFSAR Chapter 15 accident analysis for station blackouts and loss of offsite power. Tests were conducted at 100 and 150 amps. The temperature of the steel core increase to a maximum of 204.6 degrees Fahrenheit. However, the licensee did not establish how these tests correlated to potential adverse conditions included in the design basis and beyond design basis accident analyses. Therefore, the inspectors concluded that additional inspection would be necessary to properly evaluate past operability of the degraded conditions discovered on the Unit 1 and Unit 3 startup transformers. This inspection activity is documented in the URI discussed in Section 4OA5.5.

.8 Review and evaluate the licensee's immediate corrective actions taken related to the issue and the extent of condition completed for the other startup transformers, CT-5, and the Keowee stepup transformer. Verify acceptability of the completed temporary modifications.

a. Inspection Scope

The inspectors reviewed station documents and interviewed station personnel to determine the immediate corrective actions taken by the licensee after discovery of the broken power cable on the Unit 3 startup transformer (CT-3). The inspectors also reviewed station documents and interviewed station personnel related to the additional corrective actions taken following the discovery of the broken strands on the Unit 1 startup transformer (CT-1) power cables. The inspectors reviewed these corrective actions to determine if they were permanent or constituted a temporary modification to a station component. The inspectors performed walkdowns of the station's large oil filled stationary transformers to verify their operability and to evaluate the existence of temporary modifications.

b. Findings and Observations

The inspectors determined the licensee had made permanent repairs to transformers CT-1 and CT-3 and did not perform any temporary modifications. The licensee made repairs by removing the damaged portions of cables from the existing power cables. The licensee cut approximately six inches from the power cables at the connection point to the phase bushings on the Unit 1 and Unit 3 startup transformers. Additionally, the licensee cut approximately six inches from the cable connected to the lightening arrestor on the "X" phase of the Unit 1 startup transformer. The licensee remade all connections and performed resistance readings of all connections on the Unit 1 and Unit 3 startup transformers in accordance with their procedure.

The licensee's initial response to the disconnected power cable on the Unit 3 startup transformer was to declare the transformer inoperable, apply technical specifications, accomplish the repairs listed above, and perform a visual inspection of the other station large oil filled stationary transformers. The inspections were performed on December 8, 2015, and consisted of unaided visual inspections performed from ground level. The licensee implemented additional corrective actions consisting of detailed visual inspections at each cable connection and subsequently discovered damage to the Unit 1 startup transformer power cables.

After the discovery of the degraded condition of the Unit 1 startup transformer, the licensee performed visual inspections at all connection points associated with power cables of each on transformers listed below. The inspections did not reveal any degraded power cables or connections.

- Unit 2 startup transformer (CT-2)
- Lee/Central Alternate Power System and Lee/Central Alternate Power stepdown transformer (LCT) (CT-5)
- Keowee main stepup transformer

The licensee removed approximately six inches from the "Y" phase cable of the Unit 2 startup transformer, at the phase bushing connections, for future evaluation. The licensee reconnected the power cable and performed resistance readings of the connections. Following repairs/inspections, the licensee performed thermographic scans of the Unit 1, 2, and 3 startup transformers.

The licensee performed laboratory analysis of the ends of the Unit 3 startup transformer "Y" phase power cable as described in Section 4OA5.4. The license also performed ampacity testing of the ends removed from CT-1 and CT-2 startup transformer power cables.

.9 Review and evaluate the licensee's operability and past operability determinations of CT-3 and CT-1, to include:

i. How many strands of wire are necessary to carry 80 amps and 35MWe which is the ESF loading criteria?
ii. Exact times that the emergency AC power paths were out of service over the required operability times from the last time it was proven that these startup transformers would have carried full load.
iii. Review available Duke test data of the intact core of CT-2 cable which was removed to verify it would carry 100 amps for applicability to conditions discovered on CT-3.

a. Inspection Scope

The inspectors reviewed the results of the tests that were performed by the licensee to determine if the damaged CT-1 cable could provide the necessary ESF loads without reaching temperatures which could damage the cable. The inspectors also reviewed the results of the test that the licensee performed to evaluate past operability of the CT-3 transformer. The inspectors gathered data from the station logs dating back to September 1, 2015 in an attempt to bound any potential past inoperability that may be determined by future testing and evaluation.

b. Findings and Observations

The inspectors determined that the licensee discovered Unit 3 startup transformer CT-3 inoperable at 8:20 AM on December 7, 2015. The inspectors noted that auxiliary operators perform inspections of the station's startup transformers every 24 hours during routine rounds. The inspectors determined the previous 24 hours prior to the discovery of the disconnected cable would bound the past operability of the Unit 3 startup transformer. The inspectors reviewed station logs and discovered that the Keowee underground emergency AC had been declared inoperable at 5:00 AM on December 7, 2015 for planned maintenance. The inspectors did not discover any additional periods of inoperability of the emergency AC power paths during this 24 hour period.

The inspectors evaluated conditions related to the Unit 1 startup transformer CT-1 and tests that were completed on samples removed from the power cables. The inspectors noted that testing performed by the licensee showed that the cables would carry the required 80 amps of electrical load under the test conditions. Because of the limited data available during the inspection period, the inspectors determined that future inspection would be necessary to fully evaluate past operability after the cause of the cable degradation is determined by the licensee. However, the inspectors gathered data covering the period of time from December 7, 2015 back to September 1, 2015 related to operability of the underground emergency AC power path. This information will be provided to inspectors performing additional inspection activities related to the URI identified in Section 4OA5.5. Additionally, the inspectors interviewed station personnel regarding to the surveillance practices associated with fully loading the station's startup transformers to their required capacities. The licensee does not perform surveillance activities related to loading the transformer, but does load these transformers during plant shutdown activities or a unit trip. This is accomplished using Enclosure 4.7, "Transfer of Unit Auxiliaries from Auxiliary Transformer to Startup Transformer" in the licensee's unit specific procedure OP/1/A/1702/002, "Normal Power."

The licensee tested the ends of the CT-2 startup transformer cable on site to determine if the cable could provide the necessary ESF loads. This test was conducted on the steel core with different levels of current passing through the cable for five minutes. The test was performed with currents up to and including 100 amps. The licensee completed additional testing at the Georgia Tech National Electric Energy Testing, Research and Applications Center (NEETRAC). The licensee completed two sets of tests at NEETRAC using cables from the CT-1 transformer, which are of the same type as the CT-2 and CT-3 transformer, to verify that the cable could provide the necessary power to ESF loads.

In the first NEETRAC test, the inspectors noted that the results showed that with one strand of steel wire intact, the cable could provide up to 150A at a stable cable temperature. The second test was done to evaluate the past operability of the CT-3 transformer, which exhibited a flat surface on approximately 63 percent of the failure surface on the "Y" phase cable. In the second test, the steel strand was reduced to 37 percent of the original cross-sectional area, and the inspectors noted that the cable could provide 150A at a stable cable temperature. Based on the second test, the inspectors determined that the licensee had shown that there was a reasonable expectation that the CT-3 cable would have been capable of carrying 100A. However, the inspectors identified that further review would be required to determine how the above testing corresponds to conditions assumed in the UFSAR accident analysis. This further review will require evaluation of the licensee's cause determination and any potential additional testing of the power cable samples. This review is included in the URI actions listed in Section 4OA5.5.b above.

.10 Assess the licensee's actions resulting from NRC generic communications, vendor technical bulletins, and industry operating experience related to similar events.

a. Inspection Scope

As discussed in Section 4OA4.3, the inspectors reviewed the licensee's response to NRC generic communications contained in IN 2012-03 and NRC Bulletin 2012-01 to determine if the licensee had taken appropriate interim actions to detect open phase conditions until permanent corrective actions are completed. The inspectors also reviewed the following licensee event reports (LERs) to determine if the licensee had established any preventative or corrective measures in response to these events.

- Monticello Nuclear Generating Plant Unit 1 LER 87-014-00 (ADAMS Accession Number 8708190145) – Substation Transformer Design Deficiency Causes Phase Fault and Reactor Scram
- Nine Mile Unit 1 LER 90-023-00 (ADAMS Accession Number 9012190161) – Loss of Offsite Power Due to Equipment Failure
- Comanche Peak Unit 1 LER 92-016-00 (ADAMS Accession Number 9207280106) – High Winds Damage Transformer Causing an Engineered Safety Feature Actuation
- Beaver Valley Power Station Unit 1 LER 2007-002-00, "Undetected Loss of 138 kV 'A' Phase to System Station Service Transformer Leads to Condition Prohibited by Plant Technical Specification"

b. Findings and Observations

The inspectors' assessment of the licensee's actions in response to NRC generic communications are discussed above in Section 4OA5.3 above. The inspectors noted that the licensee took steps to enhance the ability to detect an open phase condition. However, the inspectors determined the licensee's actions regarding preventative maintenance and testing in response to NRC generic communications and industry operating experience lacked the necessary rigor to detect the slow degradation of cables and connecting equipment. The inspectors determined this lack of rigor could lead to an open circuit condition which would not be immediately recognized. The inspectors were not provided any evidence which showed that the licensee had established any preventative or corrective measures to detect open phase conditions in response to the reviewed LERs, which were issued before Bulletin 2012-01 and IN 2012-03. The inspectors noted that the licensee's long term corrective actions were to follow Nuclear Energy Institute (NEI) industry guidance for detecting open phase conditions and these actions are currently planned for implementation by the end of 2018. As discussed in Section 4OA5.5, the inspectors have opened an URI to determine if a performance deficiency exists with regards to the adequacy of the licensee's maintenance and testing program.

.11 Collect data necessary to support completion of the significance determination process, if applicable.

The inspectors did not identify any performance deficiencies during this inspection. However, the inspectors did identify an URI to determine if a performance deficiency exists as discussed in Section 4O5.5.

.12 Identify any potential generic safety issues and make recommendations for appropriate follow-up action (e.g., Information Notices, Generic Letters, and Bulletins).

a. Inspection Scope

The inspectors reviewed information provided by the licensee to evaluate the potential for any generic safety issues associated with the failure of the CT-3 transformer cable. The inspectors reviewed the Nuclear Generation Metallurgy and Welding Services Laboratory report, described in detail in Section 4OA5.2.a. and discussed it with station personnel to identify any generic safety issues. Additionally, the inspectors reviewed industry information on similar events to evaluate if this occurrence was new or a repeat of other events. The inspectors also reviewed documents related to license renewal to evaluate whether this event might be a previously unidentified aging management issue.

b. Findings and Observations

As stated in Section 4OA5.2.a, the results described in the laboratory report are only the beginning of the licensee's causal evaluation, and did not produce enough evidence to allow the licensee to establish a definitive conclusion. The inspectors concurred that no conclusion could be drawn as yet, and determined that the potential exists that an aging mechanism could have been involved in the failure. The inspectors discussed this with staff in NRR Division of License Renewal and concluded that more evaluation would be required before any generic issue associated with license renewal can be positively identified. This further supported the need for the inspectors to review the conclusions of the causal evaluation when the licensee's efforts are complete, consistent with statements made previously in Section 4OA5.2.b.

4OA6 Meetings, Including Exit

On January 14, 2016, the inspection team presented the inspection results to Mr. Scott Batson, Site Vice President, and other members of the licensee's staff. The inspection team confirmed that no proprietary information was provided and examined during the inspection period.

ATTACHMENT: SUPPLEMENTARY INFORMATION

SUPPLEMENTARY INFORMATION

KEY POINTS OF CONTACT

Licensee personnel:
S. Adams, Senior Nuclear Engineer
S. Batson, Site Vice President
V. Bowman, Engineering Design Basis Manager
E. Burchfield, Engineering Manager
K. Caldwell, Nuclear Switchyard SPOC
M. Carroll, Senior Reactor Operator
K. Comeaux, Organization Effectiveness Manager
C. Dunton, Nuclear Site Support Director
M. Dunton, Maintenance Manager
L. Duvall, Switchyard Supervisor
P. Fisk, Operations Manager
S. Holcombe, Work Management PM Coordinator
S. Jennings, Engineering Power Systems Manager
B. McDaniel, Switchyard Coordinator
B. Meixell, Senior Nuclear Licensing Specialist
M. Mullinax, System Engineer
T. Patterson, Director of Organization Effectiveness
J. Ratliff, Engineering Director, Electrical and Reactor Systems Engineering
T. Ray, Plant Manager
J. Smith, Regulatory Affairs Technical Specialist
R. Treadway, Regulatory Affairs CFAM
C. Wasik, Regulatory Affairs Manager

NRC personnel:
C. Doutt, Senior Electrical Engineer, Aging Management of Structures, Electrical and Systems Branch, NRR
R. Hall, Project Manager, NRR
C. Nolan, General Engineer, NRR
J. Rivera-Ortiz, Senior Reactor Engineer, Electrical Branch 3, Region II
M. Sadollah, Electrical Engineer, Aging Management of Structures, Electrical and Systems Branch, NRR
B. Wittick, Branch Chief, Aging Management of Structures, Electrical and Systems Branch, NRR

LIST OF ITEMS OPENED AND CLOSED

<u>OPENED</u>

05000269/287/2016008-01	URI	Potential lack of adequacy of the licensee’s maintenance program to detect substantial degradation of cables and their connections used on Oconee large oil filled stationary transformers. (Section 4OA5.5)

<u>CLOSED</u>

None

LIST OF DOCUMENTS REVIEWED

Documents

Draft document – CT-3 Broken Drop Line Reportability Determination

Duke Energy Nuclear Generation Metallurgy and Welding Services report titled, “ONS – Broken Y-Phase Conductor on CT-3,” dated January 4, 2016

Duke Energy Nuclear Generation Metallurgy and Welding Services report titled, “ONS – Broken Y-Phase Conductor on CT-3,” dated January 7, 2016 (revision 1)

eSOMS Log Data Search for T.S. 3.8.1 Condition D, “Underground Emergency AC Power Path”

Georgia Tech National Electric Energy Testing, Research and Applications Center, “Emergency Heat Rise Testing – Failed Sample Run Project Number: 15-212 dated January, 2016

Georgia Tech National Electric Energy Testing, Research and Applications Center, “Emergency Heat Rise Testing – Steel Reduction Run Project Number: 15-212 dated January, 2016

Inspection Manual Chapter 0326, “Operability Determinations & Functionality Assessments for Conditions Adverse to Quality or Safety”, issued 12/03/15

LER 05000220 – 90-023-00, “Loss of Offsite Power Due to Equipment Failure” ML 9012190161

LER 05000263 – 87-014-00, “Substation Transformer Design Deficiency Causes Phase Fault and Results in Reactor Scram” ML 8708190145

LER 0500334/2007-002. “Undetected Loss of 138 kV ‘A’ Phase to System Station Service Transformer Leads to Condition Prohibited by Plant Technical Specifications”

LER 05000445 – 92-016-00, “High Winds Damage Transformer Causing an Engineered Safety Feature Actuation” ML 920728016

Maintenance rule function scoping database for KOH+1, provide emergency 4160 volt AC power to Oconee auxiliary from and Keowee unit, through the 230KV switchyard yellow bus to all three Oconee unit main feeder bused through the respective CT-1, CT-2, CT-3 startup transformers

Maintenance rule function scoping database for KOH+1, provide power at adequate voltage to connected safety-related loads and non-safety related loads

NUREG-2191, Volume 1, “Generic Aging Lessons Learned for Subsequent License Renewal (GALL) Report, published December, 2015

NRC RIS 2005-20, Revision to NRC Inspection Manual Part 9900 Technical Guidance, “Operability Determinations & Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety”, dated June 5, 2015

Oconee Nuclear Station Technical Specification 3.8.1, AC Sources – Operating and the respective bases documents, Amendment # 372, 374, 373

Oconee Surveillance Frequency Control Program SF List (portion applicable to TS SR 3.8.1.1, 3.8.1.2, 3.8.1.3, 3.8.1.4, 3.8.1.5, 3.8.1.6, 3.8.1.7, 3.8.1.8, 3.8.1.9, 3.8.1.10, 3.8.1.11, 3.8.1.12,

Southwire Company specification sheet for aluminum conductor, steel reinforced, bare wire, dated April 19, 2012

Drawings

O-707-A, Rev 7

O-709, Rev 27

Nuclear Condition Reports (NCRs)

01984302; 01988523

Procedures

IP/0/A/2007/001, “Transformer Inspection and Maintenance”, Rev. 34
IP/0/A/2400/002, “Substation Insulators, Lightning Arrestors, CCVT, Transformer Drop Down Line, Bus Inspection, and Maintenance”, Rev. 7
OP/0/A/6100/004, Alarm Response Guide SA-4, Rev 7
OP/0/A/6100/005, Alarm Response Guide SA-5, Rev 7
OP/2/A/1102/020 D, SSF and Outside Rounds, Rev 78
PT/0/A/0610/026, Electrical System Weekly Surveillance (Common), Rev 14
PT/1/A/0610/025, Electrical System Weekly Surveillance (Unit 1), Rev 23
PT/2/A/0610/025, Electrical System Weekly Surveillance (Unit 2), Rev 25
PT/3/A/0610/025, Electrical System Weekly Surveillance (Unit 3), Rev 23

Work Orders/Work Requests

01632920; 02024070; 02078728; 02106331; 1644752; 1992217; 1992595; 20040721; 20041308; 20041310; 20041315; 20041627; 20043385; 20044503; 20044504; 20044505; 2140010; 2186586; 2185844