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NUCLEAR REGULATORY COMMISSION
REGION II
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ATLANTA, GEORGIA 30323-0199

Report Nos. 50-269/93-23, 50-270/93-23, and 50-287/93-23

Licensee: Duke Power Company
422 South Church Street
Charlotte, NC 28242-0001

Docket Nos.: 50-269, 50-270, 50-287 and 72-4

License Nos.: DPR-38, DPR-47 DPR-55 and SNM-2503

Facility Name: Oconee Nuclear Station

Inspection Conducted: August 23 - 28, 1993

Lead Inspector: W. H. Miller Jr. 9/23/93
For P. Harmon, Senior Resident Inspector Date Signed

Inspectors: W. H. Miller Jr. 9/23/93
For G. MacDonald, Reactor Inspector Date Signed

W. H. Miller Jr. 9/23/93
For K. Poertner, Resident Inspector Date Signed

Approved by: 9/23/93
M. S. Lesser, Section Chief Date Signed
Projects Section 3A
Division of Reactor Projects

SUMMARY

Scope: This special inspection was performed to evaluate the circumstances surrounding the Unit 1 Reactor Trip on August 23, 1993 following loss of the 1DIA 125 Volt DC panelboard. The inspectors reviewed the sequence of events, plant response, operator response, maintenance and testing activities and the effectiveness of the licensee's Significant Event Investigation Team.

Results:

1. The cause of the loss of DC power and reactor trip was due to reversed power leads associated with the redundant diode power supply to panelboard 1DIA.

2. The Main Feedwater System did not respond properly following the trip due to an incorrect pump speed control circuit card which had previously been installed. This prevented the Main Feedwater pump from developing adequate pressure to feed the steam generator.

REPORT DETAILS

1. Persons Contacted

Licensee Employees

* H. Barron, Station Manager
  S. Benesole, Safety Review Manager
  D. Coyle, Systems Engineering Manager
* J. Davis, Safety Assurance Manager
  T. Coutu, Operations Support Manager
  B. Dolan, Manager, Mechanical/Nuclear Engineering
  W. Foster, Superintendent, Mechanical Maintenance
* J. Hampton, Vice President, Oconee Site
  D. Hubbard, Component Engineering Manager
  C. Little, Superintendent, Instrument and Electrical (I&E)
* M. Patrick, Regulatory Compliance Manager
  B. Peele, Engineering Manager
  S. Perry, Regulatory Compliance
* G. Rothenberger, Operations Superintendent
* R. Sweigart, Work Control Superintendent

Other licensee employees contacted included technicians, operators, mechanics, security force members, and staff engineers.

NRC Resident Inspectors

* P. Harmon
* W. Poertner
  L. Keller

NRC Personnel

* G. MacDonald
* M. Lesser

* Attended exit interview.

2. Introduction

a. Background

DC power at each Oconee unit is provided to the DC loads from four 125 vdc panelboards. Major loads from each panelboard include 125 vdc Control Power, and a 120 vac Static Invertor for vital instrument power. Each panelboard receives power through a dual set of isolating transfer diodes, referred to as Normal and Backup. Either set of diodes will provide full power to the panelboard. The diode set which provides power is automatically determined by the highest voltage present. The Normal supply for each of the Unit 1 panelboards is from the Unit 1 battery bus, and

the Backup is supplied from the Unit 2 battery bus. Each diode pair has an input and an output breaker provided for isolation and testing of the diodes.

On the day of the Unit 1 trip, all three Oconee Units were at 100 percent power with no major problems and no Technical Specification (TS) Limiting Conditions for Operations (LCOs) in effect. A scheduled surveillance test was underway to test the isolating transfer diodes' ability to transfer and provide power when the Normal diode pair's input breaker was manually opened. When the test was performed, the Backup diode pair did not provide power, and the 125 vdc panelboard was lost along with its attendant loads.

b. Event Summary

On August 23, at 11:17 a.m., Oconee Unit 1 tripped from 100 percent power. The trip was initiated during a maintenance surveillance of the Unit 1 DC panelboards' isolating diodes. When the 1DIA panelboard's supply was shifted to the backup source, the panelboard deenergized, causing a loss of the DC loads fed from 1DIA. The turbine electrohydraulic control system and several turbine supervisory instruments were deenergized, causing a turbine generator trip and a subsequent reactor trip. The control room operator's response to this trip was complicated by the loss of several related power supplies. The main feedwater pumps did not respond properly to the trip, and Emergency Feedwater was automatically initiated when steam generator levels decreased to the automatic initiation setpoint. Operators were able to stabilize the plant at hot shutdown with systems within normal parameters.

Several complications occurred due to the loss of DC control power from the 1DIA panel board. These included the loss of main feeder bus #1 and the Reactor Coolant Pump (RCP) supply bus 1TA not automatically transferring to the Startup Transformer CT1. The two RCPs on bus 1TA lost power and coasted down with their pump breakers remaining closed. Several minutes later, when power to the pump buses was restored, the RCPs attempted to restart. Additionally, numerous control room instruments and alarms were lost, adding additional confusion to the incident.

The event investigation found that a maintenance related error was the principal cause of the trip. The leads to the backup supply's isolating diodes for the 1DIA circuit had been inadvertently reversed during a breaker replacement evolution in May 1993. As a result, the diodes' input polarities were reversed, and the diodes did not conduct current. When the normal power supply was deenergized as part of the surveillance test, the backup supply did not provide power to the 1DIA panelboard.

The inability of the Main Feedwater Pumps (MFWP) to supply feedwater to the steam generators was also found to be maintenance related. A printed circuit card was replaced in the MFWP control circuit during the previous refueling outage. The new card was installed to replace a malfunctioning card in the circuit and was not properly modified by removing an integration limiter which is part of the basic card as a shelf item. As a result, MFWP speed did not increase to a high enough value to force water into the generators at the higher, shutdown pressures. As the water levels in the SGs decreased, the motor driven Emergency Feedwater pumps were automatically initiated when level dropped below 20 inches for 30 seconds and valves 1FDW-315 and 1FDW-316 automatically opened to supply emergency feedwater to the steam generators.

3. Sequence of Events on August 23, 1993

1100 I&E Technicians started performing surveillance test IP/0/A/3000/6, Peak Inverse Voltage Test, on the isolating diodes for the 1DIA 125 vdc Panelboard. (This 125 vdc panelboard receives normal supply from Unit 1 Battery Bus 1DCA via an isolating transfer diode. A backup supply, with its own isolating transfer diodes, is fed from Unit 2 Battery Bus 2DCA, with an auctioneering circuit which will select the highest potential from the two available diode pairs.)

1115 Technicians checked the availability of power from the backup source prior to opening the normal isolating diodes' input breaker. This check consisted of verifying the backup breaker position, and verifying no voltage drop across the breaker.

1117 Technicians opened the input breaker to the Unit 1 diodes. The following occurred:

- Power lost to 1DIA (feeds 1KVIA static invertor, D.C. control power for breaker control, and EHC control power among other loads).

- Power lost to static invertor 1KVIA (feeds Inadequate Core Cooling Monitor train A, RPS Channel A, ES channel A among others).

- Main Turbine trip due to loss of Electrohydraulic Control (EHC) power.

- Reactor trip due to turbine trip.

- Station auxiliary loads transferred from 1T (Auxiliary Transformer) to CT-1 (Startup Transformer).

- Reactor Coolant pump bus 1TA did not fast transfer to the Startup Transformer due to loss of DC control power. With

the Auxiliary transformer deenergized, the two RCPs (1A1 and 1B1) on bus 1TA coasted down and stopped.

- Power lost to the Radiation Monitor (RIA) monitor in the control room (no cause determined at time of this report).

1118 Operators responded to trip as follows:

- Verified that the Main Feedwater system was responding to the reactor trip and the Feedwater startup valves were opening to control Steam Generator (SG) level to the no-load setpoint of 25 inches. The Main Feedwater pump speed increased automatically to overcome the increased SG pressure, but did not provide enough speed and discharge pressure to overcome SG pressure. (This was later determined to be caused by installation of an incorrect printed circuit card which limited pump speed). Continued steaming of the SGs caused levels in the SGs levels to decrease further.

- Controlled Makeup Control Valve 1HP-26 to control RCS makeup.

- Started High Pressure Injection (HPI) Pump 1B and noted that the 1A HPI pump had no indicating light, but had normal running amps. HPI pump 1A could not be stopped.

- Noted the Condenser Circulating Water (CCW) gravity flow valves opening.

1124 I&E Technicians performing the surveillance reclosed the normal isolating diodes' input breaker, reenergizing 1DIA. This restoration of DC control power caused several additional events:

- RCP bus 1TA transferred to the startup transformer, restoring power to the 1A1 and 1B1 RCPs.

- RCPs 1A1 and 1B1 started to roll.

- High starting current on 1A1 and 1B1 RCPs was noted by the operator.

- High (long term) current tripped the RCP breakers approximately 7 seconds after trying to restart the RCPs. RCPs 1A1 and 1B1 stopped.

- 1KVIA power fuse blows, and the breaker to the 1KVIA Static Invertor opens.

1131 Steam Generator levels reached 20 inches, initiating the dryout protection feature and starting the motor driven emergency feedwater pumps. (The dryout protection feature is not a Technical

Specification required feature, but was available during this event).

1132 Emergency Feedwater (EFW) flow rates reached 500 gpm, operators took manual control of valves 1FDW-315 and 1FDW-316, the EFW level control valves, to raise SG levels slowly. Both valves go shut (Valves do not have a bumpless transfer feature). Operators reopened the valves in Manual mode of operation.

1133 Operators attempted to place the 1FDW 315/316 valves back in Automatic, but both valves shut. Operators regain Manual control (Operators did not realize that placing valves in manual reset the automatic level control associated with the SG dryout start feature). Operators concerned that Automatic control of 1FDW 315/316 was not working properly.

1135 SG levels returned to normal. Operators were controlling the plant within normal post-trip conditions. Forced circulation was in effect with two RCPs running. Trip review and event investigation begins.

4. Event Investigation and Findings

a. Trip Report and Significant Event Investigation Team (SEIT) Team Response

Shortly after the trip, licensee management decided to ask for an independent review of the event by their Significant Event Investigation Team (SEIT). A SEIT was formed and dispatched to the Oconee site. Individual team members began arriving at approximately 7:00 p.m. on August 23. The team conducted interviews and witnessed the licensee's trip review process. The SEIT team concurred in the plant staff's trip review and readiness for restart. The SEIT team's report contained items to be resolved prior to startup, recommendations which should be considered for subsequent corrective actions, and items to be reviewed without specific recommendations. Each of the team's issues to be resolved prior to restart were adequately addressed.

The inspectors observed the SEIT team's participation in the event review and trip review. The team's recommendations appeared to be reasonable and conservative, and included appropriate items for further review. Final disposition or resolution of the team's recommendations will be addressed by the Oconee staff in the Licensee Event Report (LER) covering this event. The resident inspectors will review resolution of these items during review of the LER.

The trip report identified the root cause of the trip, event and system anomalies, and ensured appropriate corrective actions were initiated. For the instances identified where maintenance errors had resulted in a loss of configuration control in the isolating

transfer devices and the feed pump control circuits, the licensee determined that the same devices on the other two units were properly configured.

b. Cause of the Trip

The trip was caused by a deenergized 125 vdc panelboard, and loss of loads associated with that panelboard. The electrohydraulic control circuitry powered from the panelboard deenergized and tripped the turbine. The reactor tripped as designed when the turbine tripped. The panelboard was deenergized during a surveillance test which required the backup power supply to function. A maintenance error had previously reversed the leads to blocking diodes supplying the panelboard. When the normal supply was deenergized as part of the test, the backup source did not automatically supply the panelboard. This item is discussed further in paragraph 6.

5. Plant and System Response

a. Feedwater System Response

Following a reactor trip, the Main Feedwater System (MFW) is designed to provide feedwater and bring SG levels to 25 inches. Due to installation of an incorrect printed circuit card in the MFW pump control circuit, pump speed did not increase to a point high enough to bring feedwater pressure above steam generator pressure. Steam pressure increases from approximately 850 psig at full power to approximately 1000 psig at hot shutdown. The feed pump circuit problem is discussed further in paragraph 6.b.

b. Emergency Feedwater (EFW) Response

The EFW system would not normally actuate to provide water to the SGs following a reactor trip. Since main feedwater did not respond properly and control levels at 25 inches, SG levels decreased below approximately 20 inches for 30 seconds, and the motor driven EFW pumps started. The start signal for the motor driven EFW pumps was a SG Dryout signal. This signal is not considered an emergency start signal, but is a backup to the "Both Feed Pumps Tripped" signal which is considered an emergency start. Since the MFW pumps did not trip in this instance, EFW operation was different than operators had experienced or trained for. Operators typically take Manual control of EFW control valves FDW 315 and FDW 316, throttle them to minimize the thermal transient on the SGs, and return the valves to Automatic when levels reach the control point, 30 inches. Since the Emergency start is sealed in by the MFW pumps being tripped, automatic control is still available and will control to the SG level setpoint. When the Dryout protection signal initiated the start of the motor-driven EFW pumps, the operators took manual control, and the valves immediately shut. Taking the valves to Manual resets the

actuation signal following a Dryout Protection start, and sends a zero position signal to the valves. Operators reopened the valves and fed the SGs to approximately 25 inches. The valves were then placed in Automatic, and the valves were reclosed. Since the operators were not aware of the different actuation and control circuitry for the valves in the "Dryout Protection" mode, they assumed the valves were malfunctioning. The valves were returned to Manual, and the operators maintained SG levels. In conclusion the EFW System responded properly although not as expected by operators.

c. Reactor Coolant Pump Response

When the reactor tripped, 125 vdc control power was not available to fast transfer the RCPs on bus 1TA to their alternate power supply. When power on the 1TA bus was lost, the pumps slowed down, but did not trip from the bus. The undervoltage protection scheme does not sense reduced voltage or hertz on the bus, but instead "anticipates" low voltage by monitoring breaker position of the normal and startup feeder breakers to the 1TA (1TB bus for pumps 1A2 and 1B2) pump supply bus. The undervoltage condition is sensed by both breakers being open for 2 seconds. Since DC power to the 2 second time delay circuit was lost, the undervoltage circuit did not actuate and open the RCP breakers. Consequently, the 1A1 and 1B1 RCPs remained connected to a dead bus. Approximately 7 minutes after the reactor trip and RCP coastdown, technicians restored power to the deenergized 1DIA panelboard. This also restored power to the 125 vdc control circuit. The 125 vdc control circuit then performed the fast transfer of the 1TA power supply to the startup transformer, reenergizing the two idle RCPs. The 1A1 and 1B1 RCPs began to roll, even though a normal pump start interlock had not been satisfied. The interlock, Oil Lift Pump running for at least 2 minutes and oil pressure normal, is only designed for preventing closure of the pump breakers. Due to the high starting current applied to start two pumps simultaneously, the RCPs tripped within approximately 7 seconds on overcurrent. Operators witnessed this series of events, and confirmed that high starting current and RCS flow indicated that the pumps had indeed started, but then tripped. Prior to restarting these pumps for the subsequent plant startup, the licensee conferred with the manufacturer, Westinghouse, on the possibility of pump damage due to starting without proper oil pressure from the oil lift pumps. Westinghouse recommended additional monitoring of pump vibration, but concluded that damage should not have occurred. The pumps were later started with no problems indicated.

d. Loss of Radiation Monitors (RIAs)

When the reactor tripped and station power transferred to the startup transformer, the process radiation monitors for the steam line and condenser air ejectors were lost. These monitors provide

crucial information relative to operators determining whether a SG tube rupture has occurred. The loss of the monitors was originally thought to be part of the instruments directly affected by the 1DIA panelboard power loss. Later investigation revealed that the RIAs should have been unaffected by the 125 vdc power loss. The RIAs for Unit 3 had also been lost during the previous Unit 3 trip on January 26, 1993. The licensee had initiated a Problem Investigation Process (PIP 93-375) on the Unit 3 event. Since the RIAs use the plant computer for signal processing, the licensee believes that the momentary power drop when the plant auxiliary power shifts to the startup transformer may cause a computer related problem in the RIAs. This is still under investigation by the licensee's corrective action program. After the Unit 1 trip resulted in the loss of RIAs, operators were notified of the possibility of RIA loss during future plant trips.

6. Review of Maintenance Activities

a. Maintenance/Surveillance On Isolating Transfer Diode Cabinet 1ADA

The inspectors reviewed the troubleshooting plans for the transfer of diode 1ADA. The licensee troubleshooting consisted of performing procedure IP/0/A/3000/006 to attempt to reproduce the failure. IP/0/A/3000/006 contained a check of the diode cabinet circuit breakers and diodes. Troubleshooting concentrated on the circuit breakers in the diode cabinets because of previous problems encountered with these breakers. The licensee did not have a written troubleshooting plan to systematically assess the diode cabinet power supply components and all diode cabinet components. The vendor manual/drawings were not initially present at the job site. The inspectors reviewed the vendor manual for the diode cabinets and noted that it contained a troubleshooting section. Once the licensee determined that the diode cabinet circuit breakers were acceptable, additional planning was required to develop testing to locate the problem. A comprehensive and systematic planning effort prior to beginning troubleshooting could have reduced the time to correct the problem and the time the unit was in an LCO for troubleshooting.

The inspectors witnessed the licensee's troubleshooting efforts on the diode cabinet. The licensee determined the cause of the failed diode cabinet power supply and completed the repairs within the time allowed by the plant technical specifications. Temporary modification TM1091 was implemented to reverse the DC power leads inside diode cabinet 1ADA and restore proper polarity to the unit 2 diode power supply. The inspectors witnessed the testing of diode cabinet 1ADA after the temporary modification was complete. The test results were satisfactory. The remaining diode cabinets were tested to verify that both power sources were operable. All power supplies to the diode cabinets were operable.

The licensee determined that the Unit 2 power supply circuit breaker leads had been reversed on the circuit breaker in DC Motor Control Center 2DCA Compartment 3A. During circuit breaker testing, the circuit breaker in 2DCA Compartment 3A was found to be cracked and was replaced under Work Order 9204935901 on May 18, 1992.

Licensee Maintenance Directive 4.4.13 original revision, "ONS I&E Configuration Control Work Practices" Step 5.3.1, requires that a "Component Out Of Normal Sheet" be completed when station I&E equipment is placed in an out of normal state. Lifting electrical leads was listed as an example requiring the use of the "Out Of Normal Sheet."

The inspectors reviewed Work Order 9204935901 and noted that the 2DCA Compartment 3A circuit breaker shunt trip leads were listed on the "Out Of Normal Sheet." The circuit breaker line and load side DC power cables were not listed on the "Out Of Normal Sheet." Step 10.3 of procedure IP/0/A/3011/013 required that the line and load side cables be marked and disconnected. A procedure step completion signoff was required by the performer for Step 10.3. Step 10.21 of IP/0/A/3011/013 required that the breaker cables be connected as marked in Step 10.3. Step 10.21 required a completion signoff by the performer and a verifier. From the review of the work package, it appeared that one individual marked and disconnected the breaker power cables and two different individuals reterminated the cables. The convention for marking leads could not be determined by the inspectors.

The post maintenance testing for Work Order 9204935901 consisted of performing circuit breaker overcurrent testing in accordance with IP/0/A/3011/013. The only control mechanism for maintaining configuration control was the marking of the breaker leads. The inspectors examined the circuit breaker power cables in 2DCA Compartment 3A and found no cable markings. The incorrect connection of 2DCA Compartment 3A circuit breaker rendered the Unit 2 DC supply to diode cabinet 1ADA inoperable.

Review of Work Order 9204935901 indicated that the 2DCA Compartment 3A circuit breaker power cables were not adequately controlled to ensure proper termination by a different individual. The "Out Of Normal Sheet" was not utilized to control the configuration of the circuit breaker power cables. This item is identified as an example of Violation 50-269,270,93-23-01: Failure to Follow Procedures to Maintain Configuration Control.

b. Maintenance/Surveillance on Unit 1 Main Feedwater Pump Speed Controls

On December 28, 1992, the main feedwater pump speed control proportional plus integral module failed its time specification during surveillance testing. The installed controller module was

a Bailey Meter Company Type 6620255A-9. Procedure IP/0/B/0325/003 calibration data sheet required a Type 6620255A-9 controller which did not have a speed limiter. Work Order 51316L installed a new Type 6620255A-10 controller which contained a speed limiter.

Licensee personnel obtained the spare module by referencing the MMIS number. The MMIS data indicated that part number 6620255A-10 was issued. It appeared that licensee personnel did not compare the part number of the old controller to the part number of the new controller. The part number on the calibration data sheet in IP/0/B/0325/003 was also not compared with the part number of the new module. The vendor manual clearly explained that the type 6620255A-9 module did not contain a speed limiter while the type 6620255A-10 contained a speed limiter. It appeared that the licensee relied solely on the MMIS data to identify the correct replacement module.

The inspectors reviewed the post installation calibration checks performed after the installation of the type 6620255A-10 module. The calibration checks did not input test values which could have detected the presence of a limiter card.

Subsequent to the trip the licensee verified that the feedwater speed controllers for Units 2 and 3 did not contain speed limiter cards in their proportional plus integral modules. The inspectors reviewed WR 93028973 for Unit 2 and WR 93028974 for Unit 3 which verified that the speed controllers for Units 2 and 3 did not have limiter cards.

There have been previous instances where incorrect Bailey modules were installed in the integrated control system. LER 287/90-01 Revision 2, reported that on January 19, 1990, an incorrect relay module was discovered in the Integrated Control System. The I&E procedures contained no requirements to compare or otherwise ensure exact replacements. On April 25, 1990, a memorandum was issued to all I&E Technicians, Supervisors, and General Supervisors in response to LER 287/90-01. The memorandum indicated that the MMIS number could not be relied on solely to ensure correct part replacements. The memorandum required that new and old part numbers should be compared and that the part numbers on the new part and the calibration data sheet should be compared. The licensee developed Maintenance Directive 4.4.13, "ONS I&E Configuration Control Work Practices", on February 25, 1993, to maintain I&E configuration control. Despite the memorandum, the procedure, and the management directive, licensee personnel still did not follow procedures and failed to maintain configuration control. This item is identified as another example of Violation 50-269,270,287/93-23-01: Failure to Follow Procedures to Maintain Configuration Control.

The inspectors observed that the licensee's MMIS database contained several different Bailey controller part numbers under

the same MMIS number (stock number). This represents a problem to personnel required to maintain configuration control of the ICS.

7. CONCLUSIONS

a. Root Cause of the Trip

The root cause of the event is considered to be maintenance errors during work activities conducted during the previous refueling outage for Unit 2. These errors resulted in the loss of configuration control of a power supply to safety related DC panelboard 1DIA. In addition to the maintenance errors, lack of a rigorous post-maintenance testing program prevented prompt identification of the errors at the time they were made. Instead, the errors went undetected until the failed device was challenged.

b. Maintenance-related errors

The maintenance practices detailed in this report indicate weaknesses in the Maintenance Program at Oconee. This event and several similar events precipitated by maintenance activities have unnecessarily challenged the safety systems and operators.

c. Post-maintenance testing inadequacies

Post-maintenance testing in the instances detailed was inadequate. The purpose of testing after a maintenance activity such as lifting and relanding leads should determine that the activity was properly performed. A lack of a rigorous approach to testing is indicated by this and several similar events at Oconee.

d. Evaluation of Operator Response

The Operations shift personnel performed well during the transient. They adequately verified the post-trip parameters, and maintained the plant at stable shutdown conditions. The complexity of a loss of 125 vdc panelboard concurrent with the trip introduced several anomalous indications and events the operators were not familiar with. Adherence to procedures and knowledge of the plant and systems were demonstrated during this event. A lack of adequate training and familiarity was indicated in the operation of the Emergency Feedwater System in the dryout protection mode.

8. Exit Interview

The inspection scope and findings were summarized on August 27, 1993, with those persons indicated in paragraph 1. The inspectors described the areas inspected and discussed in detail the inspection findings. The licensee did not identify as proprietary any of the material provided to or reviewed by the inspectors during this inspection.

Item Number	Description/Reference Paragraph
VIO 50-269,270/93-23-01	Failure to Follow Procedures to Maintain Configuration Control, two examples(paragraphs 6.a and 6.b).