UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION II
101 MARIETTA STREET, N.W., SUITE 2900
ATLANTA, GEORGIA 30323-0199

Report Nos.: 50-327/94-02 and 50-328/94-02

Licensee: Tennessee Valley Authority
6N 38A Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

Docket Nos.: 50-327 and 50-328 License Nos.: DPR-77 and DPR-79

Facility Name: Sequoyah 1 and 2

Inspection Conducted: January 10-14, 1993

Inspector: MB Shymlock for Feb 10, '94
G. MacDonald Date Signed

Approved by: MB Shymlock Feb 10, '94
M. Shymlock, Chief Date Signed
Plant Systems Section
Engineering Branch
Division of Reactor Safety

SUMMARY

Scope:

This special, announced inspection was conducted in the area of Electrical Maintenance. The maintenance and testing activities associated with the Unit 2 main generator voltage regulator and exciter were reviewed. Problem evaluation report SQPER940015 regarding blown fuses in vital inverter 2-III was also reviewed.

Results:

The licensee would not reasonably have been expected to discover and correct the problems with the Unit 2 main generator exciter prior to the Unit 2 restart in October, 1993. Required insulating material boards were not installed between the field pole windings and the pole pieces. This defect was due to inadequate repair during a previous vendor exciter overhaul.

The licensee performed five problem identification and repair attempts on the voltage regulator before the root cause was discovered and corrected. The licensee utilized a comprehensive approach evaluating all voltage regulator interfaces on the final repair effort. Considering the number of repetitive unsuccessful voltage regulator troubleshooting attempts, the full scope problem identification approach could have been adopted earlier.

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Lessons learned from Unit 2 will be applied to Unit 1.

The licensee was not trending the results of the insulation resistance testing of the main generator.

Licensee resolution of problem evaluation report SQPER940015 was adequate.

In the areas inspected, violations or deviations were not identified.

REPORT DETAILS

1.0 Persons Contacted

Licensee Employees

*M. Burzynski, Engineering Manager
S. Collier, Electrical Maintenance Supervisor
*M. Cooper, Maintenance Manager, Acting
*F. Cuzzort, Technical Support Lead Engineer, Instrumentation Controls and Electrical
*R. Driscoll, Site Quality Manager
*R. Fenech, Vice President Sequoyah
*T. Flippo, Site Support Manager
*J. Gates, Outage Manager
*R. Gladney, Technical Support Supervisor, Instrumentation Controls and Electrical
*O. Hayes, Operations Manager, Acting
D. Lundy, Technical Support Manager
*K. Meade, Licensing Engineer
K. Powers, Plant Manager
*R. Proffitt, Licensing Engineer
R. Shell, Site Licensing Manager
*R. Thompson, Compliance Licensing Manager
*J. Ward, Manager, Engineering and Modifications
*D. Willis, Technical Support System Engineer, Instrumentation Controls and Electrical

Other licensee employees contacted during this inspection included engineers, technicians, and administrative personnel.

Other Organizations

*S. Chichka, Westinghouse Balance of Plant Site Advisor

Other NRC Employees

*B. Holland, Senior Resident Inspector
*R. Starkey, Resident Inspector

2.0 Review of Unit 2 Main Generator Voltage Regulator and Exciter Repair Activities (IP-62705)

2.1 Description of Repair Activities

On March 1, 1993, a steam pipe ruptured near the Unit 2 main generator voltage regulator. Unit 2 main generator output voltage which is normally 24 kV went to 28 kV. The licensee contacted the vendor for assistance in evaluating the impact of the overvoltage.

Westinghouse Generator Engineering Department reviewed the transient and made the following recommendations:

1. The main generator rotor should be megger tested to check for grounds.

2. A thorough crawl through inspection should be performed at the next scheduled refueling outage.

3. Generator vibration levels should be monitored closely during unit startup.

The inspector reviewed the licensee actions taken on the vendor recommendations. The licensee performed megger testing of the rotor and no grounds were identified. The generator vibration levels were checked during startup and were considered acceptable. The inspector confirmed that a crawl through inspection was scheduled for the Unit 2 cycle 6 outage Work Request (WR)C128711.

The Westinghouse Generator Engineering Department evaluated the exciter field windings insulation and determined that the overvoltage transient should not have significantly stressed the exciter field insulation. The vendor's evaluation assumed the field pole insulation to be adequate during this evaluation.

The licensee considered sending the Unit 2 voltage regulator electrical equipment drawers to the vendor for overhaul. However, the time required for the voltage regulator overhaul did not fit the current outage schedule. Thus, the licensee obtained vendor field support and dried, cleaned and tested the Unit 2 and Unit 1 voltage regulators.

Testing of the Unit 2 voltage regulator verified proper regulator operation. This testing was performed at 60 hz in accordance with vendor recommendations. The excitation system normally operates at 420 hz. When the Unit 2 forced outage schedule expanded, voltage regulator overhaul was again considered. Voltage regulator testing demonstrated proper operation and the management review committee decided not to perform vendor overhaul of the Unit 2 voltage regulator.

Unit 2 main generator was connected to the grid on October 21, 1993. On October 27, 1993, unstable operation was noted with the regulator in automatic mode. The generator output voltage and reactive power were oscillating. On October 30, 1993, Unit 2 generator was shutdown for troubleshooting and repairs to the voltage regulator.

From October 30, 1993 to December 3, 1993, the Unit 2 voltage regulator operation was unreliable with alarms and unstable operation noted. The Unit 2 generator was again shutdown and voltage regulator troubleshooting and repairs were performed on November 8, 1993, and November 18, 1993. During each troubleshooting activity defective components were replaced. Subsequent post maintenance testing

demonstrated proper regulator operation and Unit 2 main generator was returned to service.

On December 3, 1993, a turbine trip followed by a reactor trip occurred. The licensee determined that more thorough root cause evaluation was required for the voltage regulator. The licensee developed a plan utilizing a freebody analysis to evaluate all voltage regulator interfaces. A Kepner Tregoe problem solving analysis was performed as part of the root cause evaluation process.

On December 8, 1993, the licensee conducted a visual inspection of the Unit 2 exciter and discovered multiple potential grounds in the exciter field winding. One location indicated evidence of arcing. Grounds were noted in three field poles. Megger testing was performed which confirmed the grounds.

The Unit 2 exciter was sent to the vendor for repair. The Unit 1 voltage regulator electrical equipment drawers were also sent to the vendor for overhaul. The Unit 1 exciter was installed on Unit 2. During the vendors disassembly of the failed exciter, a defect was noted in the exciter field pole insulation system. The required micarta insulator boards were not installed between the field poles and the windings. These insulator boards were part of the field pole winding insulation system. The inadequate insulation occurred during a previous vendor exciter overhaul. The licensee has not performed maintenance on the exciter requiring disassembly of the field poles.

After installation of the Unit 1 exciter onto the Unit 2 main generator, the licensee performed comprehensive post maintenance testing of the voltage regulator and exciter to verify that all problems had been identified and repaired.

2.2 Evaluation of the Repair Activities

The vendor design organizations evaluated the impact of the overvoltage event of March 1, 1993 and made recommendations for testing the main generator. The licensee implemented the vendor recommendations. Additional details of this event are contained in NRC Inspection Report 50-327,328/93-10. The defective exciter field insulation system was not known nor would reasonably have been suspected.

The licensee was testing the exciter field insulation resistance at each scheduled refueling outage in accordance with vendor manual recommendations. The inspector reviewed the main generator vendor manual, SQN-VTM-W120-4100 and the licensee's procedure, O-MI-ETG-057-135.0, Disassembly, Reassembly, and Testing of Main Generator. The inspector verified that the testing was being performed in accordance with the recommendations of the vendor manual. The inspector examined the Unit 2 main generator insulation resistance test results. The results did not show a trend of decreasing insulation resistance.

The last insulation resistance test data, performed during the Unit 2 cycle 5 outage, indicated that the exciter field insulation resistance was 60 Megohms utilizing 500 VDC. The inspector determined that the vendor manual acceptance criteria for the exciter insulation resistance was ≥ 2 megohms. Previous test data indicated that the reduced exciter field winding insulation system, without the micarta boards, was still exceeding the minimum acceptance criteria.

On the basis of previous test data, vendor design organization recommendations, and an unknown field pole insulation system defect, it was not reasonable to expect the licensee to discover, and repair the exciter field grounds prior to Unit 2 startup in October 1993.

In retrospect, the overvoltage transient in March, 1993 most probably overstressed the defective Unit 2 exciter field insulation system and contributed to the development of several grounds. Intermittent additional grounds could cause regulator instability and abnormal system voltages and currents which could have caused failure of components in the voltage regulator.

The licensee submitted failed voltage regulator circuit cards to the vendor for evaluation. The vendor confirmed that the cards were failed and indicated that the transformer card failures could be age related. Some circuit card failures could have been caused by the original moisture event and not been detected during testing.

The inspector reviewed the work requests which documented the troubleshooting and repair activities performed on the Unit 2 voltage regulator and exciter. Thorough post maintenance testing of the voltage regulator and exciter were completed following the Unit 1 exciter installation on Unit 2 main generator prior to the Unit returning to service.

The licensee took steps to improve their problem solving capabilities. First they began testing at 420 hz after the October 30, 1993 generator shutdown. The licensee utilized formal freebody diagram and Kepner Tregoe problem solving after the December 3, 1993 turbine trip. Considering the number of repetitive troubleshooting efforts required to correct the problem, the formal root cause analysis techniques could have been adopted earlier.

Additional details on the December 3, 1993 turbine trip event and the voltage regulator repair efforts are included in NRC Inspection Report 50-327,328/93-54. The licensee initiated incident investigation SQ930775 to track this issue. The inspector verified that the lessons learned on Unit 2 will be applied to Unit 1.

The inspector reviewed previous Unit 2 generator insulation resistance testing and determined that neither the maintenance or system engineering organizations were trending the insulation resistance test data. Normalizing the insulation resistance data and trending the results may indicate degradation of the insulation system.

3.0 Review of Vital Inverter 2-III (IP-62705)

During routine testing of the Unit 2 vital inverters, the AC rectifier input fuses in vital inverter 2-III blew. Testing was stopped and the licensee declared the inverter inoperable and entered the action statement of the Technical Specifications. Problem Evaluation Report (PER) SQPER940015 was initiated.

The inspector reviewed the PER. The testing was performed using procedure PI-731, revision 0, "120 VAC Vital Inverter Functional Test". Step 5.11 of the procedure closes the inverter AC supply breaker restoring the AC source. Step 5.12 opens the DC supply breaker to verify that the AC source will function to carry the inverter load and maintain voltage and frequency. When the DC supply breaker was opened the AC rectifier input fuses blew resulting in no output from the inverter. The associated vital instrument power board was momentarily without power until the auxiliary unit operator reclosed the DC supply breaker which restored the inverter output.

Work Request WR205873 was prepared for troubleshooting vital inverter 2-III. The inspector reviewed the work request. The licensee tested the fuses and verified that they had blown. The licensee tested the AC rectifier diodes and silicon controlled rectifiers (SCRs) to determine if they had sustained damage. The testing indicated that the components were not affected. However, the licensee replaced the SCRs and also the fuses.

The licensee determined that the operator had not allowed sufficient time for the AC source to reach full voltage before opening the DC supply breaker. If the DC output breaker was opened with low AC source voltages an increased current would result. Additionally, the AC source charge a capacitor bank which would also increase the current. The inspector evaluated the current which could occur with low AC source voltage and reviewed the fuse curve. The AC rectifier input fuses are Gould Shawmut Amp Trap Form 101 A25X Semiconductor Fuses. The inspector determined that the potential circuit current under low AC source voltage conditions might cause the fuses to clear.

The licensee's engineering organization evaluated the issue and discussed the condition with the vendor. The vendor indicated that opening the DC supply breaker with the AC source voltage less than DC source voltage could cause a momentary shutdown of the AC source rectifier. A momentary shutdown of the AC source rectifier could cause noise in the inverter SCR circuits which could generate spurious conduction of the inverter SCRs creating a short circuit and high current.

After completing troubleshooting activities and replacement of the fuses and SCRs, the licensee performed a retest of vital inverter 2-III per PI-731. The inspector witnessed the retest of vital inverter 2-III and the test of vital inverter 2-IV. The test demonstrated satisfactory performance. Both the AC and DC sources provided power and maintained

inverter output voltage and frequency within required specifications. The licensee personnel allowed time for the AC source to reach normal voltage prior to opening the DC input breaker. The licensee added a note to step 5.11 of procedure PI-731 to require the operator to allow enough time for the rectifier to build up full voltage before continuing. The inspector concluded that the licensee's evaluation and corrective actions for PER SQPER940015 were acceptable.

The inspector reviewed the vendor manual for the inverters, SQN-VTM-S250-0010, Vendor Technical Manual Model SV12200/AC34R Inverters. The manual listed a recommended parts replacement schedule. The licensee was in the process of revising preventive maintenance for the inverters as part of the Reliability Centered Maintenance Program.

4.0 Exit Meeting

The inspection scope and findings were summarized on January 14, 1994, with those persons indicated in paragraph 1. Proprietary information is not included in the report. There were no dissenting comments received from the licensee.

5.0 Abbreviations and Acronyms

AC	Alternating Current
DC	Direct Current
KV	Kilovolts Alternating Current
NRC	Nuclear Regulatory Commission
PER	Problem Evaluation Report
SCR	Silicon Controlled Rectifier
VAC	Volts Alternating Current
VDC	Volts Direct Current
WR	Work Request