U.S.NUCLEAR REGULATORY COMMISSION
REGION I

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| Report Nos. | 50-317/94-05<br>50-318/94-05 |
| License Nos. | DPR-53<br>DPR-69 |
| Licensee: | Baltimore Gas and Electric Company<br>Post Office Box 1475<br>Baltimore, Maryland 21203 |
| Facility: | Calvert Cliffs Nuclear Power Plant, Units 1 and 2 |
| Location: | Lusby, Maryland |
| Inspection conducted: | January 19, 1994, through January 21, 1994 |
| Inspectors: | Peter R. Wilson, Senior Resident Inspector<br>Carl F. Lyon, Resident Inspector<br>Henry K. Lathrop, Resident Inspector<br>Richard A. Skokowski, Reactor Engineer, DRS |

Approved by: _____ 2/16/94
Larry E. Nicholson, Chief — Date
Reactor Projects Section No. 1A
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**Inspection Summary:**

This inspection report documents the special inspection of the January 12, 1994, Unit 2 reactor trip and partial loss of offsite power. This report includes a detailed description of the event and BG&E's response. The report also describes the causes of the event and its safety significance.

**Results:**

See Executive Summary.

## EXECUTIVE SUMMARY

### Calvert Cliffs Nuclear Power Plant, Units 1 and 2

### Inspection Report Nos. 50-317/94-05 and 50-318/94-05

A breakdown in communications, inattention to detail and inadequate design instructions resulted in the installation of a modification to both units that was incomplete, not fully tested and inadequately evaluated. Despite several meetings between site groups involved with the modification, BG&E did not achieve a clear and common understanding of what work was going to be performed and how the operating units would be protected from that work. This was safety significant because this condition caused the January 12, 1994, Unit 2 reactor trip and partial loss of offsite power. Since the same condition existed on Unit 1 with regard to the modification, the potential existed for a complete loss of offsite power. The failure to implement adequate design controls was a violation of NRC requirements.

Operators responded promptly and according to procedures following the trip. The plant responded to the transient as designed. BG&E's troubleshooting and initial corrective actions were appropriate. The control and methodology used by the technicians during the troubleshooting were noteworthy.

## TABLE OF CONTENTS


PAGE

1.0 PURPOSE . . . . . 1

2.0 BACKGROUND SUMMARY . . . . . 1
2.1 Event Description . . . . . 1
2.2 Modification Description . . . . . 2

3.0 TROUBLESHOOTING/TEMPORARY ALTERATION/ROOT CAUSE . . . . . 3
3.1 Troubleshooting . . . . . 3
3.2 Temporary Alteration . . . . . 4
3.3 Bench Testing . . . . . 4

4.0 INSPECTION FINDINGS . . . . . 4
4.1 Operator and Plant Response . . . . . 4
4.2 Troubleshooting . . . . . 5
4.3 Design Package Inconsistencies . . . . . 5
4.4 Communication Problems . . . . . 6
4.5 Attention to Detail . . . . . 8
4.6 Safety Evaluation . . . . . 8
4.7 Design Engineering Review of Work Packages . . . . . 8
4.8 Safety Significance . . . . . 9
4.9 Recent Similar Events . . . . . 9

5.0 SHORT TERM CORRECTIVE ACTIONS . . . . . 9

6.0 MODIFICATIONS INCORPORATING SOLID-STATE RELAYS . . . . . 9

7.0 CONCLUSIONS . . . . . 10

8.0 EXIT MEETING . . . . . 10

## DETAILS

### 1.0 PURPOSE

The purpose of this inspection was to review the January 12, 1994, Unit 2 reactor trip and partial loss of offsite power. The event occurred after BG&E had connected electrical breaker trip circuitry associated with a modification to the 13 kV electrical system. The NRC reviewed this event to determine the safety significance and the root causes, and to evaluate BG&E's corrective actions.

The NRC review included evaluation of plant and operator response to the event; work and design controls associated with the 13 kV modification; selected controlled work procedures and design documents; and plant logs, sequence of events printout, and other plant transient information. The inspectors also interviewed personnel involved including supervisors and managers.

### 2.0 BACKGROUND SUMMARY

#### 2.1 Event Description

Unit 2 tripped on January 12 following loss of 4 kV transformer U-4000-22, due to the trip of its feeder breaker from 13 kV bus 21. The transformer loss caused the loss of 4 kV buses 22, 23, and 24. Loss of buses 22 and 23 caused a loss of power to the control element drive motor generator sets and subsequent undervoltage condition on the reactor trip bus. The undervoltage condition caused a main turbine trip, subsequent loss of load signal to the reactor protection system, and automatic reactor trip.

The 21 emergency diesel generator auto-started and loaded onto safety-related 4 kV bus 24 as designed. Auxiliary feedwater actuated and operated as designed, and unit equipment responded as expected.

About 25 minutes after the U-4000-22 feeder breaker opened, the 13 kV bus 21 feeder breakers to 4 kV transformers U-4000-21 and 23 also tripped. This caused the loss of power to 4 kV buses 25, 26, and Unit 1 safety-related bus 14. The 12 EDG auto-started as designed, but operators reenergized bus 14 from its alternate Unit 1 feeder. Operators then isolated 13 kV bus 21. Operators reenergized Unit 2 bus loads from Unit 1.

Inspectors monitored post-trip actions in the control room, BG&E's preliminary investigation, and actions to remove the fault pressure trip circuit and the voltage regulator modification from the electrical system. Preliminary investigation revealed that U-4000-22 deenergized due to the actuation of the fault pressure trip signal from new voltage regulators that were under construction for the 13 kV system. While the new voltage regulators had not been tied into the 13 kV system and were not in service, the fault pressure trip protective circuit had been activated.

Following initial evaluation and discussion with the NRC, BG&E divorced the voltage regulator modification and its protective circuit from 13 kV bus 21. Bus 21 was reenergized and reloaded. Unit 1 13 kV bus 11 loads were then shifted to Unit 2 and the modification was divorced from Unit 1. Operators subsequently restored electrical lineup to normal.

BG&E promptly formed a Significant Incident Finding Team (SIFT) to investigate the sequence of events leading to the loss of the three transformers and evaluate the voltage regulator modification that activated the fault pressure protective circuit. The SIFT review of the event was still in progress at the end of the inspection.

## 2.2 Modification Description

The voltage regulators and fault pressure trip protective circuits described in the section above were being incorporated into the plant under Field Change Request (FCR) 88-0094. This modification allowed for the connection of a new offsite transmission line to the Calvert Cliffs switchyard to improve grid stability during peak demand. Included in the modification was the installation of one voltage regulator and associated transfer switch and trip circuitry for each of the six U-4000 transformers at Calvert Cliffs.

### Voltage Regulators

When installed, the voltage regulators will give BG&E the capability of automatically regulating the auxiliary distribution power. The primary side of the voltage regulator is provided from 13.8 kV service buses through bypass switches. The secondary side of the voltage regulator provides regulated voltage to the 4.16 kV service transformers through the transfer switch.

### Transfer Switches

As designed, the transfer switches will provide a means to bypass and isolate the voltage regulators and associated trip circuitry from the remainder of the system. At the time of the event, all six transfer switches were in the normal (open) position.

### Trip Circuitry

Each voltage regulator has two parallel trip circuits, that were available for tripping the down-stream 13.8 kV feeder breaker to the U-4000 transformers. These circuits were associated with the fault pressure (also known as sudden pressure) sensed in the main voltage regulator oil tank and in the load-tap changer oil tank for each regulator. The circuitry associated with these devices was connected to 125 Vdc control power on January 7, 1994, for 13 kV Bus 11, and January 11, 1994, for 13 kV Bus 21, by contracted Bechtel technicians.

## 3.0 TROUBLESHOOTING/TEMPORARY ALTERATION/ROOT CAUSE

### 3.1 Troubleshooting

The inspectors interviewed the BG&E technicians involved with troubleshooting the January 12, 1994, event. According to the technicians, after the loss of transformer U-4000-22, there was indication that the feeder breaker lockout device (86 device) had actuated. However, there was no indication that any of the existing protective circuits had caused the feeder breaker to trip. The technicians found similar indications following the trips of the feeder breakers for transformers U-4000-21 and 23. Further investigation by the technicians identified indications that the recently installed sudden pressure trip circuits had actuated for all three Unit 2 U-4000 transformer feeder breakers.

The inspectors reviewed BG&E's troubleshooting plan. The plan was in accordance with Calvert Cliffs Instruction (CCI)-117, and addressed the following for each transformer feeder breaker that had tripped:

- Verifying that the sudden pressure trip was the only protective device to have actuated for each circuit breaker;

- Measuring various locations within the sudden pressure trip circuitry for possible grounds;

- Removing the fuses that isolated the entire protection circuit for each feeder breaker, and disconnect the sudden pressure trip circuitry from dc control power; and

- Replacing the fuses, that returned the remaining feeder breaker protection circuits to a functional status.

During the performance of this troubleshooting plan, the technicians verified that the sudden pressure trip was the only cause of the feeder breaker trips. Furthermore, they identified a ground on the positive side of the dc control power. The ground disappeared when the 2102 voltage regulator transfer switch (serving U-4000-21) was placed in the bypass position. The ground path was through two adjacent terminals found physically touching on the 2102 transfer switch auxiliary position switches. One terminal was connected to the dc power and the second terminal was connected to a lifted lead, that was touching the door of the metal cabinet housing the transfer switch. The lead found touching the cabinet door had been lifted as part of Maintenance Order 09302110, that had connected temporary power for space heaters required to maintain the voltage regulators in a storage status until completion of the modification.

BG&E was concerned that the sudden pressure trip installed in Unit 1 may also be susceptible to inadvertent actuation. Therefore, they performed similar troubleshooting on the Unit 1 voltage regulators. Since Unit 1 was at 100% power, BG&E took the precaution

of transferring the loads from each bus, prior to performing any troubleshooting. The inspectors observed part of the troubleshooting for Unit 1. They found that the technicians performed the work safely, with appropriate supervisory oversite and attention to detail.

During the troubleshooting, BG&E found that the sudden pressure sensors for two of the three Unit 2 voltage regulators were physically disconnected from their seal-in circuits. The sensors for the third voltage regulator were connected to the seal-in circuits; however, broken pins within the connectors created a break in the circuit. Additionally, BG&E learned that work was in progress in the area of the voltage regulator transfer switches, at the time of both trips. The troubleshooting was thorough and performed professionally.

### 3.2 Temporary Alteration

The inspectors reviewed Temporary Alterations (TAs) 2-94-0003 and 1-94-0008, that disconnected the Unit 2 and Unit 1 sudden pressure trip circuitry from the dc control power. The TAs had adequate detail and appropriate review and approval. The control of the installation of the TAs was good.

### 3.3 Bench Testing

The licensee removed the seal-in circuit card from the 2101 voltage regulator for bench testing. Initially, BG&E was unable to reproduce the actuation of the relay during this bench testing. However, after further review, they modified the test setup to more closely simulate the plant configuration. This configuration included simulating Calvert Cliffs dc ground detection system and the as-found conditions of the sensors, (i.e., the sensors were not connected to the seal-in circuits.) With this configuration, the licensee was able to recreate the actuation of the sudden pressure trip by rapidly inducing a ground on the positive dc supply.

## 4.0 INSPECTION FINDINGS

### 4.1 Operator and Plant Response

Operators responded promptly and properly to the event. They performed the appropriate steps of the applicable emergency operating procedures. The operators restored power to the affected Unit 2 U-4000 transformers only after ensuring that no faults existed on the affected buses. Unit 2 responded as designed during the event. The No. 12 EDG and the auxiliary feedwater system actuated and operated as expected. BG&E made all required 10 CFR 50.72 notifications.

4.2 Troubleshooting

The inspectors found BG&E's troubleshooting and initial corrective actions, as described in Section 3.0 of this report, to be appropriate. The control and methodology used by the technicians during the troubleshooting was noteworthy.

4.3 Design Package Inconsistencies

The inspectors reviewed FCR 88-0094 and identified inconsistencies regarding the use of the transfer switch to maintain the newly installed voltage regulator equipment separated from the existing electrical system. The FCR described how positioning the transfer switch in bypass would disable the sudden pressure trip function. However, the FCR was unclear regarding maintaining the transfer switch in the bypass position. This was evident by the following examples:

- Design Input Record (various sections) implied that the transfer switch would not be placed in the bypass position until after the completion of FCR 88-0094, Supplement 3;

- Design Input Record (Section 15, Operational Requirements Under Various Conditions) implied that the transfer switch would be in the bypass position during the interim between all interconnections and a future FCR supplement that would evaluate the operability of the regulator;

- Design Instructions stated the transfer switch would be placed in the bypass position during Step 2 of FCR 88-0094 Supplement 3; and

- The Safety Significance Screen states that, "the 13.8 kV power to the U-4000 transfers will be supplied via the transfer switches in the bypass position. The transfer switches will remain locked in bypass position until system analysis is performed."

The inspectors also reviewed the safety evaluation associated with FCR 88-0094. The evaluation stated that the design instructions provided instructions to lock the transfer switches in the bypass mode, and that this would disable the sudden pressure trip signal. Furthermore, the evaluation determined that no unreviewed safety questions existed based on the concept that "maintaining the transfer switches in the bypass mode this activity [the modification] will not adversely affect any SSC [system, structure, or component] function necessary for operation of equipment important to safety."

The design instructions were used to develop the work package that controlled the physical completion of the modification. The design instructions for FCR 88-0094 Step 1, "Installation of Misc. Steel Material and Top Hats," Item e, states, "During this step of construction to install one (1) 2-pole 30 Amp fuse block with 10 Amp fuse in each 13.8 kV

Switchgear Breaker (No. 252-1101, 1102 and 1103 for Unit 1 and 252-2101, 2102, and 2103 for Unit 2). Locate fuse blocks adjacent to existing control fuses, and install associated dc circuits." The only dc circuits associated with this modification were the voltage regulator annunciator panel, which was isolated and protected by a fuse, and the sudden pressure trip circuits.

However, the design instructions did not discuss the need to ensure that the transfer switches were kept in the bypass position until Step 2. Discussions with the lead design engineer regarding the FCR indicated that he intended the trip circuit to be connected during Step 2 of the design instructions, after the transfer switches were placed in the bypass position. However, there were no explicit written instructions showing that the trip circuit should be connected in Step 2, nor were there any explicit written instructions to show that the trip circuit should not be connected in Step 1 with the other dc circuits.

The integration of the design instructions into the work package allowed for the connection of the regulator sudden pressure trip circuit to the existing system prior to placing of the transfer switch in the bypass mode. Review showed that the work was performed according to the work package. Through discussions with the Bechtel task manager, the inspectors ascertained that the required continuity and ground checks for the dc circuitry were performed, and that there were no indications of the ground at that time.

4.4 Communication Problems

Circuit Isolation

The inspectors found that breakdowns in communications were a root cause for the event. BG&E operations, design engineering, system engineering, and project management held several meetings to discuss the work to be performed under FCR 88-0094, Supplement 3. During these meetings the connection of the voltage regulator sudden pressure relays to the 125 Vdc system was presented. However, participants in these meetings did not have a common understanding on how the sudden pressure relays would be disabled.

Through interviews of personnel involved, the inspectors found the following. The task manager intended to connect the relays and had approved drawings to connect the relays. He stated that he had clearly communicated his intention to connect the relays during the Supplement 3, step 1, of the project. The BG&E project manager responsible for the modification mistakenly believed that the relays would be disabled by removing fuses. This was also the understanding of the General Supervisor for Nuclear Plant Operations. The system engineer thought that the relays would be disabled by locking the transfer switches in the bypass position. However, the work performed under the FCR Supplement 3 Step 1 required manipulation of the transfer switches.

As described above, the BG&E lead design engineer intended for the trip circuitry to be connected during a later phase of the modification when the transfer switches would be

locked in the bypass position. He stated that he knew that the transfer switch would be manipulated during Step 1 of the work. However he did not realize that the manipulation of the transfer switch would enable the circuit.

On November 8, 1993, design engineers presented FCR 88-0094, Supplement 3, and its associated safety evaluation to the Plant Operation and Safety Review Committee (POSRC). The engineers assured the POSRC during their presentation that isolation of the voltage regulator project from the operating units would be accomplished by locking the transfer switches in the bypass position. The POSRC subsequently recommended approval of the supplement.

In summary, despite several meetings between site groups involved with the modification, BG&E did not achieve a clear and common understanding of what work was going to be performed and how the operating units would be protected from that work. The incorrect assertions made to the POSRC represented a missed opportunity to prevent the event.

Receipt Inspection of the Sudden Pressure Relay Sensors

The inspectors reviewed the details regarding the relay sensors connections. BG&E found that had the sensors for the sudden pressure relays been connected properly, the trip circuitry would not have been susceptible to inadvertent actuation due to control power grounds. A memorandum dated January 11, 1994, regarding the December 17 - 30, 1993, receipt inspection and acceptance tests for the voltage regulators described several discrepancies. Of these discrepancies, two were related to the sudden pressure relay sensors. First, the wrong type connectors were delivered with the sudden pressure relay sensors, (a four-pin connector was delivered, which conflicted with the standard three-pin connector specified.) Second, pins within one sensor connector were sheared off. Additionally, this memorandum stated that all the sudden pressure relays needed to be tested after associated discrepancies were corrected.

Solid-state Controlled Seal-in Circuit

Specification SP-643 for the 13.8 kV voltage regulators specified the sudden pressure relay to be a Qualitrol type 900 series. Each relay was to be provided with an auxiliary seal-in 125 Vdc circuit. No additional details were specified regarding the seal-in circuit. The seal-in circuit delivered was a 900 series solid-state controlled circuit. Discussions with BG&E revealed that some initial engineering reviews of this modification were not provided with the information that would have showed that the seal-in relay was solid-state controlled.

During these initial reviews, BG&E assumed that seal-in circuit being delivered was an electro-mechanically controlled seal-in circuit, that had been used in other applications throughout BG&E facilities. Subsequent engineering reviews identified that the seal-in circuits were solid-state controlled, but this was not questioned. The combination of the solid-state controlled seal-in circuit and the unconnected relay sensors allowed the sudden

pressure trip circuit to actuate in response to the ground, since the solid-state circuit was much more sensitive to voltage transients.

4.5 Attention to Detail

The inspectors found that several opportunities existed where the responsible design engineers should have recognized that the sudden pressure trip relay circuitry would be energized during Step 1 of the work. This was evident by the following:

- The design instructions associated with the FCR did not explicitly describe the connection of the trip circuitry. The only reference in the design instructions to dc circuits was contained in Step 1 as described above. The design engineers prepared the design instructions;

- Design engineers attended several meetings where the connection of the trip circuitry during Step 1 was discussed. Design engineers were aware that the work proposed in Step 1 required the manipulation of the transfer switch but failed to recognize the vulnerability created;

- On December 30, 1993, design engineering section at the request of the task manager, approved Drawing Change Notices (DCNs) 1340616-1001A and 83614-1001A that clearly showed the connection of the trip circuitry to the 125 Vdc system.

The inspectors concluded that the failure to recognize that the sudden pressure trip relay circuitry would be enabled before the design engineers intended was due to inattention to detail.

4.6 Safety Evaluation

Due to design engineering section's inattention to detail, the engineers who prepared the 10 CFR 50.59 safety evaluation for Supplement 3 of the FCR were not aware that the trip circuitry would be connected while the transfer switches were open. The inspectors determined that the modification as performed in the field represented a potential unreviewed safety question. The modification was incomplete and not fully tested when connected to both operating units. This increased the probability of a loss of offsite power, an accident described in the safety analysis report (SAR).

4.7 Design Engineering Review of Work Packages

The inspectors noted that the responsible design engineers did not review the construction work package prior to the commencement of work. Additionally, there were no programmatic requirements that engineering review construction work packages.

4.8 Safety Significance

The installation of an incomplete and not fully tested modification to the electrical systems of both operating units was safety significant. BG&E had not fully evaluated the modification as installed. The modification, together with an electrical ground caused a reactor trip and engineered safety features actuation. Since the same modification was installed on Unit 1, a potential existed for a loss of offsite power. There were no safety consequences because of the event.

4.9 Recent Similar Events

The inspectors did not identify any recent similar events.

## 5.0 SHORT TERM CORRECTIVE ACTIONS

As result of the event, BG&E stopped all work associated with the voltage regulator modification. Before reinitiating work, the licensee developed a Voltage Regulator Project Work Scope Plan and presented it to PORSC for review and to the plant general manager for approval. This plan stated that the modification was isolated from the plant systems by the removal of voltage regulator annunciator control power fuses, and by the lifted leads in the voltage regulator sudden pressure trip circuit. Additionally, BG&E tagged the voltage regulator transfer switches in the bypass position. The inspectors reviewed the scope of the work to be restarted and found no concerns. This plan also described initiatives to strengthen work controls, communications and work processes. The inspectors found these initiatives to be appropriate. However, other actions are expected based on the completion licensee's SIFT investigation.

The inspectors observed some of the SIFT investigation and found it to be thorough and methodical. At the completion of this NRC inspection, the SIFT had yet to issue their report regarding the event. After the completion of the SIFT investigation, the NRC intends to review the SIFT results and document this review in an upcoming inspection report.

## 6.0 MODIFICATIONS INCORPORATING SOLID-STATE RELAYS

During the initial engineering reviews of this modification, the licensee was unaware that the seal-in circuits were solid-state controlled. As a result, the circuit susceptibility to system transients was not adequately evaluated. However, as part of the SIFT investigation, the technical information associated with the solid-state controlled seal-in circuit was evaluated and found adequate to withstand the system transients if the sensors had been properly connected. Nevertheless, BG&E intended to replace the solid-state controlled seal-in circuits with the more commonly used electro-mechanically controlled seal-in circuits.

Since solid-state relays could be more susceptible to system transients and electromagnetic interference than electro-mechanical relays, inspectors evaluated BG&E's approach to

replacing electro-mechanical relays with solid-state-relays. Discussions with BG&E indicated that all modifications were required to undergo a cross discipline impact screening, which would identify if electrical or instrumentation and controls unit reviews were needed. Also, the equivalency procedure required the replacement components perform their function in a similar manner as the components being replaced. Therefore the replacement of an electro-mechanical relay with a solid-state relay would be required to go through the modification review process. Furthermore, BG&E had performed few upgrades from electro-mechanical to solid-state relays.

BG&E was aware of the different specifications requirements of solid-state relays as compared to electro-mechanical relays. Additionally, BG&E was actively involved in the development of industry-wide standards regarding the incorporation of digital-based equipment into the plants. BG&E was considering the need to develop administrative guidelines for modifications containing solid-state and digital equipment.

## 7.0 CONCLUSIONS

Operators responded promptly and in according to procedures following the trip. The plant responded to the transient as designed. BG&E's troubleshooting and initial corrective actions were appropriate. The control and methodology used by the technicians during the troubleshooting were noteworthy.

However, a breakdown in communications, inattention to detail and inadequate design instructions resulted in the installation of a modification to both units that were incomplete, not fully tested and inadequately evaluated. This was safety significant in that this condition resulted in a Unit 2 reactor trip and partial loss of offsite power. Since the same condition existed on Unit 1 with regard to the modification, the potential existed for a complete loss of offsite power.

10 CFR 50 Appendix B, Criterion III requires in part that design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews or by the performance of a suitable test program. Therefore, the failure to adequately control the design of FCR 88-0094, Supplement 3 is a Violation (50-317 and 318/94-05-01).

## 8.0 EXIT MEETING

The inspectors met with the licensee's personnel denoted in Attachment 1 of this report at the conclusion of the inspection on January 21, 1943. The scope of the inspection and inspection results were summarized. During this meeting, the licensee acknowledged the inspection findings as detailed in this report and had no additional comments regarding the inspection results.

ATTACHMENT 1

## PERSONS CONTACTED

**Baltimore Gas and Electric Company**

M. Carr; Operating Experience Review Unit
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* Indicates those attending the exit meeting