NRC Form 366 (9-83)

U.S. NUCLEAR REGULATORY COMMISSION
APPROVED OMB NO 3150-0104
EXPIRES 8/31/85

LICENSEE EVENT REPORT (LER)

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE (3)
Virgil C. Summer Nuclear Station	0 5 0 0 0	1 OF 0 9

TITLE (4): Potential Inadvertent Operation of Safety-Related Solenoids Due to Grounds on DC System

EVENT DATE (5) MONTH	DAY	YEAR	LER NUMBER (6) YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	REPORT DATE (7) MONTH	DAY	YEAR	OTHER FACILITIES INVOLVED (8) FACILITY NAMES	DOCKET NUMBER(S)
1 2	0 2	8 8	8 8	- 0 1 2 -	0 1	0 3	3 0	8 9		0 5 0 0 0
										0 5 0 0 0

OPERATING MODE (9): 5
POWER LEVEL (10): 0 0 0

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more of the following) (11)

20.402(b)	20.405(c)	50.73(a)(2)(iv)	73.71(b)
20.405(a)(1)(i)	50.36(c)(1)	50.73(a)(2)(v)	73.71(c)
20.405(a)(1)(ii)	50.36(c)(2)	50.73(a)(2)(vii)	OTHER (Specify in Abstract below and in Text, NRC Form 366A)
20.405(a)(1)(iii)	50.73(a)(2)(i)	50.73(a)(2)(viii)(A)	
20.405(a)(1)(iv)	X 50.73(a)(2)(ii)	50.73(a)(2)(viii)(B)	
20.405(a)(1)(v)	50.73(a)(2)(iii)	50.73(a)(2)(x)	

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER
W. R. Higgins, Supervisor, Regulatory Compliance	AREA CODE 8 0 3 3 4 5 - 4 0 4 2

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFAC TURER	REPORTABLE TO NPRDS	CAUSE	SYSTEM	COMPONENT	MANUFAC TURER	REPORTABLE TO NPRDS
				N					

SUPPLEMENTAL REPORT EXPECTED (14)

YES (If yes, complete EXPECTED SUBMISSION DATE) — X NO

EXPECTED SUBMISSION DATE (15): MONTH DAY YEAR

ABSTRACT (Limit to 1400 spaces, i.e., approximately fifteen single-space typewritten lines) (16)

On December 2, 1988 at approximately 1550 hours, South Carolina Electric & Gas Company (SCE&G) identified a design deficiency with the Class 1E 125V DC distribution (ungrounded) system at the Virgil C. Summer Nuclear Station (VCSNS). System reviews initiated by recent NRC questions and NRC Information Notice No. 88-36, "Operating with Multiple Grounds in Direct Current Distribution Systems," led SCE&G to conclude that a potential existed for spurious operation of solenoid valves due to possible multiple ground paths occurring in a harsh environment.

The review of affected solenoid valves at VCSNS considered those components which go to their deenergized failure position on Engineered Safety Features (ESF) actuations. Circuit design with unsealed terminations for limit switches, terminal blocks and solenoid coils had previously been considered acceptable. Failures that were postulated to occur were considered to result in the deenergization of the solenoid coils, thereby placing the components in their desired design basis accident response state.

Corrective actions completed on December 9, 1988 involved design modifications for installation of hermetic seals or to provide isolation contacts to prevent the possibility of spurious actuations and ensure deenergization. SCE&G completed an analysis on March 22, 1989 to determine impact on the Design Basis for the plant during past operation. This analysis concluded that the installed configuration for these components would not have resulted in the plant being outside of design basis.

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TEXT (If more space is required, use additional NRC Form 366A's) (17)

PLANT IDENTIFICATION:

Westinghouse - Pressurized Water Reactor

EQUIPMENT IDENTIFICATION:

DC Power System - EIIS-EJ

IDENTIFICATION OF EVENT:

At approximately 1550 hours on December 2, 1988, Engineering personnel at the Virgil C. Summer Nuclear Station (VCSNS) determined that at least six (6) components (Feedwater Isolation Valves and Main Steam Isolation Valves) would be susceptible to spurious actuations in the event of a high energy line break accident. The Engineering analysis determined that during such an event, multiple ground faults on the ungrounded direct current (DC) distribution system could potentially reenergize or continue to energize solenoid valves (SOV) whose operation was required to mitigate an accident. This determination was derived following a review of recent NRC questions and NRC Information Notice No. 88-86, "Operating with Multiple Grounds in Direct Current Distribution Systems." On confirmation that field design configurations could potentially cause spurious operations of valves, South Carolina Electric & Gas Company (SCE&G) initiated notifications per the requirements of 10 CFR 50.72(b)(2)(iii).

EVENT DATE:

December 2, 1988

REPORT DATE: December 30, 1988

This report was initiated by Off-Normal Occurrence Number 88-086.

PREVIOUS SIMILAR EVENTS:

None

CONDITIONS PRIOR TO EVENT:

Mode 5 - Refueling Outage No. 4

DESCRIPTION OF EVENT:

SCE&G initiated an investigation on November 18, 1988, to determine if the ground detection criteria at Virgil C. Summer Nuclear Station was adequate. This investigation was initiated by NRC questions concerning the criteria used to determine whether a ground was significant enough to take action to remove.

The initial concern centered around an electrical maintenance procedure that required maintenance to search for and remove a ground when the voltage from either side of the bus to ground was 5 VDC or less. During the review of this criteria, Engineering determined that it was possible for a ground to occur on the positive side of a device, such as a solenoid valve, which would potentially prevent deenergization due to the ground impedence of the ground detector system. The ground detector provided a balanced 1500 ohm ground path which was a low enough impedance that another ground could potentially cause spurious control problems. With 5 VDC on the positive to negative side, there is effectively 80 ohms of resistance from positive to ground. With a second ground postulated on the solenoid, there could be a low enough impedance short to pick up the solenoid. Informal tests have shown that ASCO solenoid valves will pick-up at about 40 VDC and drop out at about 20 VDC. With the postulated ground path, approximately 35.5 VDC could be maintained across a coil, preventing drop out. This condition is considered unacceptable for a device which must deenergize to perform its safety function. Problems of this nature are described in recently issued Information Notice 88-86.

Despite this problem, the ground detector did perform its function of indicating unbalanced voltage on the DC system due to grounds. Grounds have always been considered unacceptable, and operations and maintenance initiated a search for grounds anytime an imbalance was indicated on the ground detection system. If the voltage degraded to 5 VDC or less from ground to either side of the DC bus, the electrical maintenance procedure required removal of the ground through breaker and fuse isolations.

The ground detector alone does not create a problem since another strategically placed ground is required to create a possibly unacceptable condition. If the strategically placed ground did occur and was of the proper impedance that the 5 VDC criteria was met, the ground could exist until safeguards testing identified improper equipment function. The probability of this becoming a common mode problem is remote. However, a steam line break could provide a common mode failure for solenoids exposed to the break since valves could stay energized or reenergize.

The problem with a solenoid remaining energized is mitigated by test results that indicated that failure of the solenoid occurred two days into testing. However, in the Intermediate Building a case was found in which non sealed, non nuclear safety related (NNSR) associated circuits on the safety related A & B batteries could be exposed to the same steam break as solenoids on the Main Steam and Feedwater isolation valves. This could cause the solenoids on both trains to reenergize.

For the above identified phenomena, it is necessary for the following events to occur:

1. A leakage resistance from battery positive to ground must be established.

2. A simultaneous leakage path must be established between the plant ground and the positive side of a normally deenergized safety related solenoid valve.

3. The series combination of leakage resistances resulting from 1 and 2 above must be low enough to allow current flow equal to the minimum current required to actuate a solenoid.

4. Leakage paths from the battery negative to ground caused by the same environmental conditions remain relatively high so as not to reduce the positive potential on the ground grid and trip a breaker or blow a fuse.

A harsh environment in the area of these devices could result in steam intrusion and subsequently may cause insulation resistance to decrease to a value producing leakage paths between the positive side of various components in these circuits (terminal blocks, limit switches, solenoid valves) and the plant ground.

CAUSE OF EVENT:

The cause of the event is considered to be a design deficiency. It was not realized during the design process of the ungrounded DC distribution system that the failure mode of components could result in spurious actuations from multiple grounds potentially occurring during design basis accidents.

ANALYSIS OF EVENT:

The installed ground detector did perform its design function to indicate unbalanced voltage conditions resulting from ground on the DC distribution system; however, the system design placed a low impedance ground path onto a system designed to be ungrounded. The ground detector alone does not create a problem. Spurious actuations of plant components would still require an additional strategically placed ground. Grounds have always been considered to be unacceptable and VCSNS maintenance procedures were designed to initiate a search for grounds anytime voltage degraded to 5 VDC or less from either side of the DC bus to ground. The timely isolation of grounds mitigates the potential of adverse consequences which could occur during normal operational modes.

The potential consequences resulting from a harsh environment, however, can be varied. The major concern is that the plant ground may assume a positive potential. A review of typical Class 1E 125 VDC solenoid valve circuit configurations indicates that in general, the plant ground will assume a minimal positive potential. Typically, the negative side of the battery connects directly to the solenoid coils and limit switches in the field for position indicating lights. The positive side of the coils are normally interrupted by the control switch and other control related contacts (e.g., from relays). With this configuration, there are always more field terminations, on a per circuit basis, tied directly to the negative battery lead than there are positive terminations. Therefore, leakage from the negative termination will tend to short the devices and deenergize them.

SCE&G Design Engineering, with the supportive efforts of the Architect Engineer and NSSS supplier, has completed a detailed consequence evaluation associated with steam line break and LOCA postulated type events and their interaction with the potentially affected equipment identified during the initial analysis. Future operability of affected components has been assured by modifications made during the fourth refueling outage.

The summary of the method, results, and conclusions for each subtask performed to accomplish the consequence evaluation are described below:

1. Testing to Determine Validity of the Problem

   Testing was performed at the V. C. Summer Nuclear Station, and at Wyle Labs to assess the magnitude of leakage current between a solenoid's lead wires and case and if sufficient leakage current could develop to cause actuation of a solenoid.

   a. Site Testing

      To simulate a worst case condition, aged coils were installed in SOV's which were then placed in a boiling reactor building spray solution.

      For the first test, the solenoid did not energize during its 125 minute test duration. For the second test, the solenoid energized 59 minutes after test initiation.

      These tests supported the probabilistic model used in the consequence evaluation. The tests also showed that if a SOV should energize, it would take considerable time for it to occur.

   b. Wyle Lab Tests

      Six preaged solenoids and two new solenoids were placed in a LOCA test chamber with simulated harsh environment peaks of 340°F and 51 psig. A chemical spray with a pH of 9.5 was made for 2 hours.

All solenoids but one remained in their deenergized state. Post-testing investigation of the solenoid (#1) that energized showed there was a faulty coil lead wire in the test specimen condulet. The wire went to ground causing energization of the solenoid. The solenoid did not energize due to leakage currents from the SOV leads to case or lead to lead. One preaged solenoid (#6) had a shorted coil (fuse blew) due to moisture impregnation. This failure caused the solenoid to remain deenergized in its normal post accident state.

The tests showed that the energization of a solenoid due to leakage current paths is highly improbable. In addition, the tests provide further support that the probabilistic model used in the consequence evaluation as well as the evaluation's results are correct.

2. Identification of the Solenoid Valves of Concern

The V. C. Summer Nuclear Station environmental qualification (EQ) data base was searched for Class 1E 125V dc SOV's.

Each of the 102 SOV's for 60 parent valves identified as being of concern had their control circuit routing checked for possible unsealed terminations in a harsh environment due to limit switches and terminal blocks. The number of possible leakage current paths for each solenoid was then determined.

As a result of this subtask, computer sorts of valves by system, location, and circuit configuration was made to permit the evaluation of the consequences of spurious operation of the 102 SOV's in the Failure Modes and Effects Analysis (FMEA) and Probabilistic Risk Assessment (PRA) subtasks.

3. Failure Modes and Effects Analysis (FMEA)

A functional analysis was performed on the 102 SOV's of concern. This analysis identified 14 SOV's as not being affected by leakage currents on their solenoid circuits because they will not be required to perform their safety function when exposed to a harsh environment.

A Failure Mode and Effects Analysis (FMEA) was performed on the remaining 88 solenoid operated valves to determine what would have happened had the solenoids energized due to leakage currents that may result from a harsh environment.

The result of this analysis for each parent component has revealed that in order to lose its parent component's protective function:

a. A backup component would have to fail (if applicable).

b. An additional component either safety related or non-safety related in the same process stream would have to fail.

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c. Piping in either the safety or non-safety portion of the system would have to fail.

However, the simultaneous failures of multiple components or piping is considered very unlikely.

Therefore, from the FMEA standpoint, the failure of solenoid operated valves of concern would not have jeopardized the safety of the plant nor the public health. The FMEA was used as a design input for the probability risk assessment.

4. Model of Inadvertent Operation of Class 1E Solenoids

In order to determine the probability of inadvertent operation of a solenoid due to leakage current paths that may result due to a harsh environment, a solenoid probabilistic circuit model has been developed.

The circuit model and its component values were used in the probability calculations for inadvertent SOV operation.

5. Probability of Inadvertent Operation of Class 1E Solenoid Operated Valves in a Harsh Environment.

A Monte Carlo Simulation program was used to perform the probability evaluations based on the circuit model and the determined voltage and resistance value ranges for the circuit components.

The probability evaluation for inadvertent operation of solenoid operated valves in a harsh environment was done in two calculation steps.

a. Probability Evaluation of Inadvertent Energization of One Solenoid

This result was interpreted as the probability of a solenoid failure in a harsh environment.

b. Probability Evaluation of Inadvertent Operation of a Parent Valve

The calculated probabilities of inadvertent valve operations in a harsh environment is used as input data to the Probabilistic Risk Evaluation.

6. Development of the Probabilistic Risk Evaluation

The purpose of this Probabilistic Risk Evaluation (PRE) is to quantify the increase of the risk to the V. C. Summer Nuclear Station due to inadvertent operation of unsealed Class 1E solenoid operated valves.

The overall results of the PRE evaluation showed that the incremental increase in the probability of radioactive releases was less than 8×10^{-10} per reactor year. Therefore it is concluded that the increased risk associated with a harsh environment common mode failure is well within the safety goal of less than 10^{-6} per reactor year.

In addition, a comparison was also made with the Zion PRA's most significant contributors to the risk. At Zion, the most significant contributor is a major seismic event (90% of the total risk) with a mean annual frequency of 5.6×10^{-6}. Other significant contributors at Zion are Interfacing System Large LOCA (1.1×10^{-7}) and Loss of All dc Power and Auxiliary Feedwater (2.0×10^{-7}). As can be seen, the increased risk (8×10^{-10}) was insignificant when compared to the Zion PRA study.

The conclusion from the Probabilistic Risk Evaluation was that there was negligible risk to V. C. Summer Nuclear Station due to unsealed safety related solenoids exposed to a harsh environment from initial commercial operation to the Refuel IV Outage, or over the last six years of operation.

7. Containment Response Consequence Evaluation

A review of the FMEA demonstrated that none of the safety systems that would mitigate any postulated transient would have been affected by the inadvertent operation of SOV's.

Based on the FMEA performed, there were only 3 solenoid valve failures which could cause an increased mass/energy release to the containment. The solenoid valves in question were those used to open/close the pressurizer power operated relief valves (PORV). Therefore the worst case scenario selected was the assumed failure of all 3 PORV's following a postulated double ended main steam line break.

The test data, as previously described, confirmed that at least 59 minutes were required before the SOV's might possibly energize. It was conservatively assumed that the PORV's opened 10 minutes following the postulated double ended rupture of a main steam line at 102% power.

Opening of the PORV's will not cause an increase in containment pressure over that provided in the licensing basis LOCA and MSLB for the plant.

In conclusion, scenarios were evaluated that would potentially lead to increased containment pressures. The results of this evaluation demonstrate that the licensing basis containment analyses documented in FSAR Section 6.2.1 remain the bounding analyses.

8. Radiological Release Consequence Evaluation

Scenarios were developed in order to assure that any potential offsite doses were within 10CFR100 limits and were bounded by the licensing basis analyses presented in FSAR Chapter 15. Scenarios inside and outside containment were addressed.

From the FMEA it was shown that most containment isolation valves located inside containment are backed up by redundant isolation valves outside containment. It can be concluded that leakage through penetrations for harsh environment initiating events would remain within the leak rate criteria of the Tech. Specs. and the leakage rates used for the accident analyses presented in the FSAR are bounding.

Therefore, the environmental consequence analysis for the LOCA presented in FSAR Chapter 15 remains the bounding analysis for offsite release.

CORRECTIVE ACTION:

The ground detector installed on the Class 1E DC distribution system was disabled until a replacement system with a high impedance to ground can be obtained and installed. Since the potential exists for grounds to occur on the system in the future, SCE&G has established an alternate method of detecting significant grounds. The procedural controls established on December 9, 1988, require that the system be checked daily for grounds. Significant grounds will be isolated under programmatic controls previously established by SCE&G.

On determination that the configuration of field components could result in spurious actuations of solenoid valves exposed to a harsh environment, SCE&G initiated a review of Class 1E valves required to deenergize during an ESF actuation. Valves with hermetic connectors already installed were then eliminated from consideration since the connectors are considered to be an appropriate seal to prevent moisture intrusion.

Modifications to the DC system, such as grounding the negative leg, appear to be the ultimate resolution to this design problem. However, due to the time involved in analysis and implementation of such a major design basis change, SCE&G elected to either hermetically seal solenoids or provide isolation contacts on both sides of the device. Isolation of certain components was necessary since the solenoid type was not compatible with hermetic connectors. This isolation of both polarities was made by means of a control relay which is located in a mild environment (Control Building). Modifications were completed by December 9, 1988.

SCE&G
A SCANA Company

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Ollie S. Bradham
Vice President
Nuclear Operations

March 30, 1989

Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: Virgil C. Summer Nuclear Station
Docket No. 50/395
Operating License No. NPF-12
LER 88-012, Revision 1

Gentlemen:

Attached is Revision 1 to Licensee Event Report No. 88-012 which was initially submitted on December 30, 1988 pursuant to the requirements of 10CFR50.73(a)(2)(ii) for the Virgil C. Summer Nuclear Station. This report provides a more detailed Engineering assessment of actual and potential safety consequences resulting from this event.

Should there be any questions, please call us at your convenience.

Very truly yours,

O. S. Bradham

CJM/OSB:lcd
Attachment

c: D. A. Nauman/O. W. Dixon, Jr./T. C. Nichols, Jr.
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