NRC FORM 366 (5-92) U.S. NUCLEAR REGULATORY COMMISSION

APPROVED BY OMB NO. 3150-0104
EXPIRES 5/31/95

ESTIMATED BURDEN PER RESPONSE TO COMPLY WITH THIS INFORMATION COLLECTION REQUEST: 50.0 HRS. FORWARD COMMENTS REGARDING BURDEN ESTIMATE TO THE INFORMATION AND RECORDS MANAGEMENT BRANCH (MNBB 7714), U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, DC 20555-0001, AND TO THE PAPERWORK REDUCTION PROJECT (3150-0104), OFFICE OF MANAGEMENT AND BUDGET, WASHINGTON, DC 20503.

# LICENSEE EVENT REPORT (LER)

| FACILITY NAME (1) | DOCKET NUMBER (2) | PAGE (3) |
|---|---|---|
| Arkansas Nuclear One, Unit Two | 05000368 | 1 OF 6 |

TITLE (4) HUMAN ERROR IN THE DESIGN OF A PLANT MODIFICATION CREATED THE POTENTIAL FOR FAILURE OF ONE DC ELECTRICAL BUS TO HAVE CAUSED CONSEQUENTIAL FAILURE OF THE OPPOSITE TRAIN OF EMERGENCY FEEDWATER

| EVENT DATE (5) | | | LER NUMBER (6) | | | REPORT DATE (7) | | | OTHER FACILITIES INVOLVED (8) | |
|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | DAY | YEAR | YEAR | SEQUENTIAL NUMBER | REVISION NUMBER | MONTH | DAY | YEAR | FACILITY NAME | DOCKET NUMBER |
| 07 | 19 | 95 | 95 | 001 | 00 | 08 | 18 | 95 | FACILITY NAME | DOCKET NUMBER |

| OPERATING MODE (9) | 1 | THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR: (Check one or more) (11) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 20.402(b) | | 20.405(c) | | 50.73(a)(2)(iv) | | 73.71(b) |
| POWER LEVEL (10) | 98 | | 20.405(a)(1)(i) | | 50.36(c)(1) | X | 50.73(a)(2)(v) | | 73.71(c) |
| | | | 20.405(a)(1)(ii) | | 50.36(c)(2) | | 50.73(a)(2)(vii) | | OTHER |
| | | | 20.405(a)(1)(iii) | X | 50.73(a)(2)(i) | | 50.73(a)(2)(viii)(A) | | Specify in Abstract Below and in Text |
| | | | 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 (Include Area Code) |
|---|---|
| Thomas F. Scott, Nuclear Safety and Licensing Specialist | 501-858-4623 |

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

| CAUSE | SYSTEM | COMPONENT | MANUFACTURER | REPORTABLE TO NPRDS | | CAUSE | SYSTEM | COMPONENT | MANUFACTURER | REPORTABLE TO NPRDS |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| | | | | | | | | | | |

| SUPPLEMENTAL REPORT EXPECTED (14) | | | | EXPECTED SUBMISSION DATE (15) | MONTH | DAY | YEAR |
|---|---|---|---|---|---|---|---|
| | YES (If yes, complete EXPECTED SUBMISSION DATE.) | X | NO | | | | |


ABSTRACT (Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines) (16)

During validation of procedures on the plant simulator, a condition was discovered where failure of one DC electrical bus could potentially render the opposite train of the Emergency Feedwater (EFW) system inoperable. Consistent with system design, a failure of the green train DC bus would cause a loss of control power to the normally closed green train EFW injection valves and trip of the main turbine generator. This same loss of power could cause the two normally open green powered injection valves in series with the two red powered valves for the motor-driven EFW pump to close enough to restrict flow, contrary to intended system design, during a series of events involving loss of control power to the main turbine generator with its subsequent coast down. The green powered injection valves that closed during the event would not re-open until AC power was manually transferred to Startup Transformer #3 and an open command was present. Upon confirmation of the validity of the condition, the motor-driven EFW pump was declared to be inoperable and a 72 hour Technical Specification action statement was entered until the bus providing power to the normally open green powered valves could be transferred to Startup Transformer #3. The root cause of this condition was determined to be human error during the design of a plant modification installed in the mid-1980s to replace the electro-hydraulic EFW injection valves with motor-operated valves. A modification was completed on July 27, 1995, to correct the condition.

A. Plant Status

At the time this condition was discovered, Arkansas Nuclear One Unit 2 (ANO-2) was operating at approximately 98 percent power in normal steady-state conditions.

B. Event Description

On July 19, 1995, ANO-2 discovered a condition in which failure of one DC electrical bus [EJ] could render the opposite train of the Emergency Feedwater system (EFW) [BA] inoperable.

At ANO-2, the EFW system has two trains. One train (green) contains a turbine-driven pump (2P-7A) and the other train (red) contains a motor-driven pump (2P-7B). Both pumps are capable of feeding both steam generators. Pump 2P-7A feeds both steam generators through four DC motor-operated valves, two valves for each generator, with two normally closed green-powered valves closer to the pump and two normally open red-powered valves closer to the steam generators. The 2P-7A governor and the common steam line isolation valves receive green DC power. Pump 2P-7B feeds both steam generators through four AC motor-operated valves, two for each generator, with two normally closed red-powered valves closer to the pump and two normally open green-powered valves closer to the steam generators. The normally open valves in the red train have a normally energized green-powered DC control relay. The main function of the relay is for normal open and close operation of the valves. It also provides functions associated with closing the valves for a Main Steam Isolation Signal (MSIS) [JE] and for Engineered Safety Features Actuation System (ESFAS) [JE] override capability. AC buses 2A2 and 2A4, Emergency Diesel Generator (EDG) "B", main turbine Electro-Hydraulic Control (EHC) [TG] controls, and main generator excitation field breaker are dependent upon green DC for control power.

During a validation of Abnormal Operating Procedures on the simulator, a loss of green train DC voltage was initiated from a normal operating configuration. The main turbine tripped in approximately three seconds due to a loss of DC power to the EHC system. Closing the turbine valves tripped the generator and its output breakers, but the generator field breaker did not trip since control power was not available to the trip coil. The main generator remained tied to AC bus 2A2 via the Unit Auxiliary Transformer (UAT). Generator voltage decayed in approximately 30 seconds. The DC control relays for green train valves in the motor-driven EFW pump (2P-7B) discharge were de-energized which initiated closure of those valves. Green AC needed to close those valves was available from the coasting main generator. The simulator model resulted in a coast-down of sufficient duration for these two valves to close. Approximately 30 seconds after initiation of the event, steam generator levels dropped due to shrink and boil-off causing an Emergency Feedwater Actuation Signal (EFAS). EFAS applied open signals to all

eight EFW discharge valves and start signals to both EFW pumps. Depending upon the particular scenario in which the DC power loss was initiated in different tests, 2P-7A either did not start or started and tripped. 2P-7B received a start signal. The two AC green-powered valves in the red train (2P-7B discharge) had closed (or partially closed) and could not open because the generator had coasted down and AC power was not available (no fast transfer to Startup Transformer #3 occurred and EDG "B" was inoperable). These valves would not re-open until power was restored to the AC bus and an open command was present. This was an unanticipated effect of green DC bus failure on operability of the red EFW train.

There is no conclusive evidence that actual plant response to this condition would have resulted in a generator coast down of sufficient duration to allow the green train valves to close completely and block all EFW flow. A review of plant design documentation indicated that it is more likely that the generator voltage would decay in approximately 10 seconds and result in a throttling condition allowing some EFW flow, but less than required for operability as defined in Technical Specifications. After confirming that the simulator response reflected possible plant response, the EFW red train was declared to be inoperable at 2010 hours on July 19, 1995, and a 72-hour action statement of Technical Specification 3.7.1.2 was entered. The condition, operability of the EFW red train potentially affected by a green train DC bus failure, was determined not to cause the green EFW train to be declared inoperable since the green train vulnerability to this failure is a basis for designing redundant trains. At 1210 hours on July 20, 1995, AC electrical bus 2A2 that provides power to the green train AC valves was transferred from being supplied by the Unit Auxiliary Transformer to Startup Transformer #3. In this configuration, the green-powered AC valves in the red train would still close following the postulated failure of the green train DC bus, but they would re-open with actuation of an EFAS. The Technical Specification action statement was exited at 1224 hours on July 20, 1995.

## C. Root Cause

The root cause of this condition was determined to have been human error in the design of a plant modification installed in 1984 that replaced electro-hydraulic discharge valves in the EFW system with motor-operated valves. During this modification, red and green power was mixed within each EFW flow path to provide single failure protection for the conflicting fail states associated with the dual functions of opening to supply EFW and closing to isolate the steam generators for MSIS. The human error was an assumption by the design engineer that the normally open green-powered valves in the red train would fail "as-is" upon loss of power. This obscure error was not detected during the review process for that modification or during the numerous subsequent reviews of the EFW system that have occurred since then.

The design process attempts to determine the effects of various failure modes; however, the depth of the analysis of each potential fault event is a matter of engineering judgment. At some point in the design phase, assumptions are made which terminate each postulated fault branch. While the specific depth of analysis is not documented for this modification, it was concluded that loss of green DC power in the red EFW train was acceptable based on the assumptions that the valves would normally be open and that there would be no AC power available to close the green AC valves after the turbine tripped. This specific design error was determined to be unique, non-recurring, and not indicative of a programmatic flaw with the modification design process. The modification process has also undergone significant changes since this particular design change was implemented that serve as additional barriers to prevent a similar condition from occurring. A comprehensive program was implemented to improve the quality, depth, and documentation of reviews for plant design changes. The relocation of Design Engineering to the site in 1990 allows for increased involvement during the construction, testing and close-out of design change packages. For these reasons, no corrective actions associated with the modifications program are required for this condition.

D. Corrective Actions

An evaluation of the potential generic implications of this condition was conducted. The unique combination and depth of red and green power interrelations in the EFW system appear to be isolated to this modification. The other train of EFW, other ESFAS actuations, and other ANO-2 systems were examined and found not to have similar problems. The condition was not applicable to ANO-1 which uses modulating EFW discharge valves due to the different design of their steam generators.

On July 27, 1995, a modification to the control relays of the green-powered valves in the red EFW train was completed to correct the potential consequential failure of the red EFW train. Following successful post-modification testing, AC electrical bus 2A2 was transferred from Startup Transformer #3 to the Unit Auxiliary Transformer at 1800 hours.

A "lessons learned" module concerning this condition will be provided to applicable ANO Engineering departments by October 20, 1995.

E. Safety Significance

The EFW system performs the safety function of removing residual heat from the Reactor Coolant System (RCS) [AB] following a reactor trip. It was designed to meet the requirements of General Design Criterion (GDC) 34, which requires that the system have sufficient redundancy to assure that its function can be accomplished assuming a single failure. The potential inability of the red train to supply EFW with a failure of the green train DC bus violates GDC 34 since the safety system function may not be accomplished assuming a single failure. Therefore, this condition represents a potentially significant safety issue.

As described above, a review of design documents indicated that the more likely plant response to the green train DC bus failure would have resulted in the valves in the red train not reaching their fully closed position. Having some amount of EFW flow, even less than required by Technical Specifications for operability, would mitigate the consequences of this accident. Other factors acting to reduce the safety significance are availability of the Station Blackout diesel generator as a backup power supply and the Auxiliary Feedwater system capable of adding feedwater to the steam generators, both of which require operator action. Since these systems were not available for the full period over which this condition existed, credit was not taken for them in evaluating Core Damage Frequency (CDF).

The safety significance of this condition is also mitigated by the expected rapid response of Operations personnel to the postulated inability to supply EFW. Operator response is directed by a "Loss of Feedwater" procedure that verifies the discharge valves are open or directs manually opening them. This recovery is anticipated to occur well before the steam generators dry out and core damage is postulated to occur. Restoration of EFW from the red train to either steam generator will restore the required safety function. Other operator actions to restore electrical power to AC and DC buses that were de-energized will also assist in terminating the event.

From a Probabilistic Safety Analysis (PSA) perspective, this condition is safety significant. When the dependence of the red EFW train on the green DC bus is accounted for in the ANO-2 PSA model, the CDF is estimated to become 6.49E-5/rx-yr. This is a significant increase in the ANO-2 CDF from its estimated value of 3.29E-5/rx-yr, as reported in the ANO-2 Individual Plant Evaluation (IPE). However, the revised CDF value is still well below the NRC safety goal of 1E-4/rx-yr (SECY-91-270). Therefore, this condition is not considered to have represented an undue risk to the public health and safety.

F. Basis for Reportability

Section 15.1.31.2 of the ANO-2 Safety Analysis Report, an analysis of the consequences of the loss of one DC system, states, "The remaining DC system will allow a safe shutdown of the plant during emergency conditions." The consequential failure of the red EFW train could have prevented a safe shutdown during emergency conditions and was therefore determined to be outside the design basis of the plant. This condition was reported to the NRC Operations Center at 2039 hours on July 19, 1995, in accordance with 10CFR50.72(b)(1)(ii)(B). This report is submitted in accordance with 10CFR50.73(a)(2)(ii)(B). Since it also represents a condition that alone could have prevented fulfilling a required safety function, it is reportable in accordance with 10CFR50.73(a)(2)(v).

With one EFW train inoperable longer than allowed by Technical Specification 3.7.1.2, an operation prohibited by Technical Specifications existed that is reportable in accordance with 10CFR50.73(a)(2)(i)(B).

G. Additional Information

There have been no previous similar events reported by Arkansas Nuclear One as Licensee Event Reports.

Energy Industry Identification System (EIIS) codes are identified in the text as [xx].