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Director of Nuclear Reactor Regulation
Attention: Mr. G.W. Knighton, Chief
Licensing Branch No. 3
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

SUBJECT: Waterford SES Unit 3
Docket No. 50-382
Generic Letter 83-28, Item 4.5.3
Reactor Trip System Reliability

REFERENCE: W3P84-3381 dated December 7, 1984

Dear Sir:

Attached please find our response to Item 4.5.3 of Generic Letter 83-28. As committed to in the referenced letter, LP&L is providing a review of the existing Technical Specification intervals for on-line functional testing of the Reactor Protection System (RPS). This report is compiled from a CE Owners Group study on this subject as it applies to Waterford 3.

With this submittal we consider our action on this item complete. We trust that you will find sufficient information in this evaluation to conclude that present RPS functional testing intervals are consistent with the goal of maintaining high RPS availability. Should you have any questions or comments on this matter please contact R.J. Murillo at (504) 595-2838.

Yours very truly,

for

K.W. Cook
Nuclear Support & Licensing Manager

KWC/KNC/pcl
Attachment
cc: E.L. Blake, W.M. Stevenson, R.D. Martin, D.M. Crutchfield, J. Wilson,
G.L. Constable, T. Alexion

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Attachment

WATERFORD SES UNIT NO. 3
REACTOR PROTECTION SYSTEM
TEST INTERVAL EVALUATION

I. Summary

The objective of the completed study was to evaluate the availability of the C-E supplied NSSS reactor trip system at Waterford 3 based on the current tech spec testing intervals and to compare this resultant availability with the goal implied by the NRC in their evalaution of the proposed ATWS rule [1].

As part of a C-E Owner Group commissioned study [2], a fault free model for the postulated fault, "failure to trip the reactor", was constructed for the type RPS design implemented at Waterford 3. This model explicitly addressed four of the five concerns of subject item 4.5.3 (GL 83-28), which are the effects on RTS availability by 1) random component failures, 2) common cause failures, 3) out-of-service time for testing and 4) operator errors. The fifth concern is not considered a factor for GE AK-2-25 trip breakers used at Waterford 3 [3].

The results of this analysis for the RPS design supplied for Waterford 3 is that the median probability that the RPS will fail to trip the reactor is less than 4.91×10^{-6} per demand with a 95th percentile confidence limit probability of 2.20×10^{-5} per demand. This compares favorably to the NRC derived point estimate value of 2×10^{-5} per demand as the probability that the RPS would fail to trip the reactor for plants supplied with C-E supplied NSSS. Based on this we conclude that the current RPS test intervals are consistent with maintaining the high degree of availability expected of the RPS.

II. Fault Tree Model

A fault tree was constructed to model the Reactor Protection System (RPS) for failure to generate a full trip. The base case fault tree considers one protective trip parameter, pressurizer pressure, input to four trip unit bistables. These in turn interface with six logic matrix blocks to form all possible 2 out of 4 coincident signals from the four protective channels A, B, C and D, respectively. Each RPS trip path consists of a trip circuit K-relay in series with six logic matrix relays (one from each logic matric block). Each K-relay provides a trip signal to its associated trip circuit breakers via two sets of contacts. Each set includes a normally open (NO) contact in series with the reactor trip breaker undervoltage device and a normally closed (NC) contact in series with the breaker shunt trip device. Manual trip buttons perform the same function as K-relays in the automatic trip path. They open NO contacts to de-energize undervoltage devices causing reactor trip breakers to open and close NC contacts to energize shunt trip coils which also act to open the reactor trip breakers. There are a total of eight reactor trip breakers in the Waterford RPS which open to interrupt holding power to the CEDMs, causing CEAs to drop into the reactor core. High local power density trip from the core protector calculators (CPCs) is incorporated into the model as a diverse trip parameter. Its failure probability was evaluated separately. Though failure of CEDM power supplies have the same effect as a trip signal they are excluded from the analysis.

Using nominal failure rates for all components in the model, the fault tree was used to determine base system reliability. Next a sensitivity analysis was done to determine how system reliability was affected by variations in component failure rates, common mode failure rates and operator error rates. For each selected component or condition, the failure rate was varied .01% to 1000% of its nominal value, while holding constant all other contributing failure rates to the RPS fault tree. If the system failure rate changed little over the range of individual failure rates applied, then the system was considered insensitive to that particular component or mode of failure. However if system reliability fluctuated widely over the variance applied then the system was considered sensitive to that particular component or failure mode. The results are shown on Table 1 and are discussed further in the next section. Table 2 shows which cutsets dominate the RPS Class 3 (Waterford 3 design) fault tree. A cutset is the combination of component failures, operator errors, etc. that will result in the fault tree top event (i.e. failure to trip reactor).

III. Failure Analysis

A. Data Analysis

NPRDS failure reports and LERs (from 1972 through 1983) with C-E supplied NSSS comprised the data base for this report. Failures which did not impact RPS availability or occurred during fault isolation testing were eliminated from this base. Failure events were then divided into two categories, independent RPS component failures and dependent (or common mode) RPS failures.

To account for uncertainties in the data collected, prior distributions were updated through the Bayesian method to adjust the plant specific data. The Bayesian approach treated failure parameters as random variables themselves and used prior distributions from WASH-1400 [4] and IEEE-500 [5] to derive the density functions which govern the failure parameters.

B. Component Failure Rates

Table 3 presents the RPS component failure posterior distributions as updated from prior distributions by the Bayesian method. RPS component unavailabilities are lognormally distributed in terms of 5th, 50th (median) and 95th percentile confidence limits. As can be seen from Table 1 and 2, individual component failure rates have very little impact on RPS system reliability. The most dominant individual component failures are mechanical failure of reactor trip breaker to open and failure of pressure sensors.

C. Common Mode Failure Rates

Table 4 represents the common cause failures that were incorporated into the RPS Class 3 fault tree. The Marshall-Olkin method was used to estimate common cause failure rates for fault tree component types with two or more unit failures in the past. The Beta-Factor method was used to estimate the common mode failure rates of RPS components which had not experienced multiple failures (diesel generators excepted). As can be expected, common mode failures are the biggest contributors to RPS unreliability. Table 2 shows that common cause mechanical failure of reactor trip breakers to open is the most dominant cutset of RPS failure to trip the reactor and accounts for 76.2% of the RPS system unavailability.

D. RPS Testing

Testing affected the RPS fault tree in two ways. First, test frequency partially determined the number of demands individual RPS components received per operating cycle and hence affected their failure rates. Second, testing contributed to unavailability of RPS trip paths. Since only one channel of the RPS can be in bypass at any given time, unavailability contributions were included for Channel D and for Logic Matrix AC of the fault tree model. Test intervals for this study were based on current Tech Spec requirements and were not varied in determining contributions to component failure rate and system unavailability.

E. Operator Error

The two types of operator error modeled in the RPS fault tree were:

1. Miscalibration of the RPS bistables (2.5×10^{-3} per demand) and
2. Failure to manually scram the reactor (5×10^{-2} per demand).

Quantifications of these errors was accomplished using methods developed by Swain and Guttran [6], whose median failure rates are shown in parentheses above. As shown in Table 1, after common cause mechanical failure of the reactor trip breaks, the RPS system is most sensitive to these two failure modes. These operator errors contribute to 21% of the RPS system failure rate. Tables 1 and 2 emphasize the importance of operator input into maintaining RPS system reliability.

IV. Conclusion

Results of the fault tree analysis for RPS reliability of the Waterford 3 RPS NSSS design is as follows:

Probability of Failure to Trip on Demand

5% Lower Bound	Median	95% Upper Bound
2.16×10^{-6}/d	4.91×10^{-6}/d	2.20×10^{-5}/d

These results are comparable to failure probabilities used by the NRC in determining the cost/benefit value of requiring diverse scram and ATWS mitigation systems for C-E NSSS supplied plants. Based on this it is concluded that current Technical Specification required test intervals are consistent with maintaining the high degree of reliability expected of the RPS.

V. References

1. SECY-83-293, "Amendments to 10CFR50 Related to Anticipated Transients without Scram (ATWS) Events"; U.S. Nuclear Regulatory Commission; July 19, 1983.

2. CE NPSD-277, Reactor Protection System Test Internal Evaluation, C-E Owners Group Task 486; December, 1984.

3. Letter W3P84-3344, "Reactor Trip Breaker Life Cycle Testing"; K.W. Cook (LP&L) to G.W. Knighton (NRC); November 30, 1984.

4. WASH 1400 (NUREG-75/014), Reactor Safety Study, An Assessment of Accident Risk in U.S. Commercial Nuclear Power Plants; October 1975.

5. IEEE-STD500-1977, IEEE Guide to the Collections and Presentation of Electrical, Electronic, and Sensing Component Reliability for Nuclear Power Generating Stations.

6. NUREG/CR-1278, Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Operations; A.D. Swain and H.E. Guttman; October, 1980.

TABLE 1

SENSITIVITY ANALYSIS RESULTS
FOR
PLANT CLASS 3

COMPONENT FAILURE MODE	NORMALIZED SYSTEM UNAVAILABILITY*, GIVEN COMPONENT FAILURE RATE CHANGES BY A FACTOR OF:				
	.0001	.1	.9	1.1	10.0
Common Cause Mechanical Failure of the Trip Circuit Breakers to Open	.24	.32	.92	1.08	7.84
Operator Fails to Initiate Manual Reactor Trip	.76	.79	.98	1.02	3.13
Operator Sets Bistable Setpoints Incorrectly	.82	.84	.98	1.02	2.63
Common Cause Failure of Pressure Sensors	.97	.97	1.00	1.00	1.25
Mechanical Failure to Trip Circuit Breaker to Open	1.00	1.00	1.00	1.00	1.22
Common Cause Failure of Sensor Power Supplies	.99	.99	1.00	1.00	1.10
Common Cause Failure of Bistable Relays to De-Energize	.99	.99	1.00	1.00	1.07
Failure of Pressure Sensors	1.00	1.00	1.00	1.00	1.04
Common Cause Failure of K-Relays to De-Energize	1.00	1.00	1.00	1.00	1.04

*Normalized System Unavailability = System Availability calculated with changed component failure rate divided by median system unavailability

TABLE 1 (Cont.)

SENSITIVITY ANALYSIS RESULTS
FOR
PLANT CLASS 3

COMPONENT FAILURE MODE	NORMALIZED SYSTEM UNAVAILABILITY*, GIVEN COMPONENT FAILURE RATE CHANGES BY A FACTOR OF:				
	.0001	.1	.9	1.1	10.0
Common Cause Failure of the Bistable Trip Units	1.00	1.00	1.00	1.00	1.03
Common Cause Failure of Shunt Trip Device to Actuate	1.00	1.00	1.00	1.00	1.03
Common Cause Failure of Undervoltage Device to Actuate	1.00	1.00	1.00	1.00	1.01

*Normalized System Unavailability = System Availability calculated with changed component failure rate divided by median system unavailability

TABLE 2

DOMINANT CUTSETS
FOR
RPS CLASS 3

CUTSET NUMBER	CUTSET MEMBERS	PERCENT OF TOTAL UNRELIABILITY
1	Common Cause Mechanical Failure of Trip Circuit Breakers	76.2%
2	Operator Sets Bistable Setpoints Incorrectly Failure of Diverse Trip Parameter, Operator Fails to Initiate Manual Trip	18.2%
3	Common Cause Failure of Pressure Sensors, Failure of Diverse Trip Parameter, Operator Fails to Initiate Manual Trip	2.8%

TABLE 3

RPS COMPONENT FAILURE
POSTERIOR DISTRIBUTIONS

RPS COMPONENT	OPERATING EXPERIENCES			POSTERIOR DISTRIBUTIONS		
	NO. OF FAILURES(1)	NO. OF DEMANDS	NO. OF OPER. HRS.	5th	50th MEDIAN	95th
Trip Circuit Breakers	1*	58576		2.0×10^{-5}	4.5×10^{-5}	9.0×10^{-5}
Undervoltage Trip Devices	57	32202		1.4×10^{-3}	1.7×10^{-2}	2.1×10^{-3}
Shunt Trip Devices	5	42993		6.3×10^{-5}	1.2×10^{-4}	2.1×10^{-4}
K-Relays	1*	97890		1.1×10^{-6}	6.2×10^{-6}	2.3×10^{-5}
Logic Matrix Relays	24	58092		2.5×10^{-4}	2.7×10^{-4}	5.1×10^{-4}
Bistable Relays	2	215196		1.9×10^{-6}	6.9×10^{-6}	1.9×10^{-5}
Bistables	105		14,637,950	4.3×10^{-7}	2.7×10^{-6}	1.1×10^{-5}
Instru. Loop Power Supplies	36		15,472,346	3.4×10^{-7}	1.5×10^{-6}	5.7×10^{-6}
Sensor/High Pressure	9		2,359,944	2.4×10^{-6}	4.1×10^{-6}	6.6×10^{-6}
RCS Temperature Detectors	20		10,210,656	1.3×10^{-6}	1.9×10^{-6}	2.7×10^{-6}

1. * Means No Failure was Reported; However, One Failure was Assumed in Order to Estimate the Posterior Distribution

TABLE 3 (Cont.)

RPS COMPONENT FAILURE POSTERIOR DISTRIBUTIONS

RPS	OPERATING EXPERIENCES			POSTERIOR DISTRIBUTIONS		
COMPONENT	NO. OF FAILURES(1)	NO. OF DEMANDS	NO. OF OPER. HRS.	5th	50th MEDIAN	95th
Excore Detectors	12		2,819,318	7.6×10^{-6}	9.5×10^{-6}	1.2×10^{-5}
Axial Offset Calculators	21		1,409,659	5.9×10^{-6}	8.8×10^{-6}	1.3×10^{-5}
Power Calculators	11		1,409,659	2.7×10^{-6}	4.5×10^{-6}	7.0×10^{-6}
Trip Comparators	36		2,919,318	7.7×10^{-6}	1×10^{-5}	1.4×10^{-5}
Core Protection Calculators	13		144,364	7.6×10^{-6}	1.4×10^{-5}	2.5×10^{-5}
CEA Calculators	19		72,182	2×10^{-5}	3.6×10^{-5}	6.2×10^{-5}
Manual Push Button	1	3392		5.1×10^{-6}	1.5×10^{-5}	4.4×10^{-5}
Batteries	11		1,648,106	3.4×10^{-6}	5.8×10^{-6}	9.1×10^{-6}
Battery Chargers	4		2,542,152	5.7×10^{-7}	1.4×10^{-6}	2.9×10^{-6}
Diesel Generators	67	1997		2.7×10^{-2}	3.3×10^{-2}	4×10^{-2}

TABLE 4

RPS COMPONENT COMMON CAUSE FAILURE RATES

RPS COMPONENT	NO. OF REDUNDANT COMPONENT	MIN. NO. OF COMP. CONSTITUTING SYS. FAILURE	NO. OF EVENTS WITH 2 FAILURES	NO. OF FAILED COMPONENTS IN NO. OF EVENTS	BETA FACTOR	COMMON CAUSE FAILURE RATE
Trip Circuit Breakers	8	2	0	0	0.1	1.3×10^{-5}/D
Shunt Trip Devices	8	2	1	4	N/A	2.3×10^{-5}/D
Undervoltage Trip Devices	8	2	14	46	N/A	4.3×10^{-4}/D
K-Relays	4	2	0	0	0.1	6.7×10^{-7}/D
Logic Matrix Relays (All)	24	12	1	3	N/A	1.1×10^{-11}/D
Logic Matrix Relays (One Channel Bypassed)	12	6	1	3	N/A	4.3×10^{-6}/D
Bistables	4	3	8	18	N/A	1.2×10^{-7}/Hr.
Bistable Relays (All)	12	6	0	0	0.1	6.9×10^{-7}/D
Bistable Relays (One Channel Bypassed)	6	3	0	0	0.1	6.9×10^{-7}/D
Push Buttons	4	3	0	0	0.1	1.5×10^{-6}/D

TABLE 4 (Cont.)

RPS COMPONENT
COMMON CAUSE FAILURE RATES

RPS COMPONENT	NO. OF REDUNDANT COMPONENT	MIN. NO. OF COMP. CONSTITUTING SYS. FAILURE	NO. OF EVENTS WITH 2 FAILURES	NO. OF FAILED COMPONENTS IN NO. OF EVENTS	BETA FACTOR	COMMON CAUSE FAILURE RATE
Sensor/High Pressure	4	3	2	4	N/A	3.6×10^{-7}/Hr.
Instru. Loop Power Supplies	4	3	0	0	0.1	1.5×10^{-7}/Hr.
RCS Temp. Detectors	8	6	7	18		2.0×10^{-9}/Hr.
Excore Detectors	4	3	2	4	N/A	3.0×10^{-7}/Hr.
Axial Offset Calculators	4	3	0	0	0.1	8.8×10^{-7}/Hr.
Power Calculators	4	3	0	0	0.1	4.5×10^{-7}/Hr.
Trip Comparators	4	3	1	2	N/A	2.5×10^{-7}/Hr.
Core Protection Calculators	4	3	1	4	N/A	6.9×10^{-6}/Hr.
CEA Calculators	2	1	0	0	0.1	3.6x10-6/Hr.

TABLE 4 (Cont.)

RPS COMPONENT
COMMON CAUSE FAILURE RATES

RPS COMPONENT	NO. OF REDUNDANT COMPONENT	MIN. NO. OF COMP. CONSTITUTING SYS. FAILURE	NO. OF EVENTS WITH 2 FAILURES	NO. OF FAILED COMPONENTS IN NO. OF EVENTS	BETA FACTOR	COMMON CAUSE FAILURE RATE
Batteries	4	2	1	2	N/A	6.1×10^{-7}/Hr.
Battery Chargers	4	2	0	0	0.1	1.4×10^{-7}/Hr.
Diesel Generators	2	1	1	2	0.03	1.0×10^{-3}/D