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ANALYSIS OF SHUTDOWN TECHNICAL SPECIFICATIONS USING THE LOW POWER AND SHUTDOWN RISK MODEL FOR THE SURRY NUCLEAR POWER PLANT*

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ABSTRACT

This paper describes a risk-based screening analysis that was performed on the Surry nuclear power station to evaluate the adequacy of technical specifications (TS) for PWRs during shutdown periods. Of particular concern was the risk sensitivity to allowable TS configurations while at reduced reactor coolant system inventory conditions since incidents have occurred in plants over recent years during this time. A typical refueling outage was analyzed to determine the plant configurations created due to surveillance testing and maintenance activities. The impact from single and multiple component outages were identified so their risk influence on the plant configuration could be assessed. From these results, generic insights into the efficiency of existing TS to control high risk configurations were obtained as well as the applicability and ability of the risk-based methodology employed to make that determination.

1. INTRODUCTION

Commercial nuclear power plant technical specifications were written with the assumption that risk during shutdown is acceptably small. Therefore, no need was perceived for TS control of equipment outages due to surveillance testing and maintenance activities during these periods. However, over recent years, incidents have occurred in plants during shutdown that have raised concerns about the risk associated with shutdown operations and prompted a preliminary risk analysis to evaluate Low Power and Shutdown (LP & SD) Accident Frequencies of the operating nuclear power plants. Under a USNRC program, low power and shutdown probabilistic risk assessment (PRA) models are being developed for the Surry and the Grand Gulf Nuclear Power Stations.

With the availability of this LP & SD PRA model,[1] a corollary program was initiated to perform risk-based evaluations on the adequacy of existing TS requirements and the need for implementing additional requirements for effective control of risk during these modes of operation. Objectives of this study were to evaluate the risk significance of the TS requirements during shutdown using the Surry model as an example for PWRs and to determine possible improvements to these requirements, as appropriate, using risk analyses. This involved identification of the TS requirements during shutdown, evaluation of risk impacts from equipment outages, and evaluation of risk contributions associated with surveillance requirements as well as determination of how the benefit of surveillance testing can be maximized while incurring minimal risk due to the performance of the test. Insights gained from this work will be the focus of this paper.

2. ISSUES IN SHUTDOWN TS EVALUATIONS

There are three major aspects common to all TSs. One of these is the operational mode of the plant which defines the plant characteristics in terms such as power generation, reactivity in the core, and pressure/temperature of the reactor coolant system (RCS). The second is the Limiting Condition of

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Operation (LCO) and the respective Allowed Outage Time (AOT) for plant equipment. This aspect of the TSs determines the minimum equipment required to keep the plant in a safe state by providing mitigation capability for potential accident situations. The third aspect of TSs is surveillance testing. This aspect of the TSs is meant to assure that both standby or operating equipment required to perform a function during an accident situation would be available to do so. Within this framework, a number of issues associated with TSs for shutdown situations arise.

First is the issue of the adequacy of the existing requirements. Due to the large amount of testing and maintenance that takes place during shutdowns, off-normal and sometimes unique plant configurations are likely during these periods. TS requirements need to assure that plants do not get into configurations that may result in high risk levels. A significant portion of the activity during shutdown periods relates to either known repair or preventative maintenance work to preclude failure of components during power operation. For risk-important components, the impact of having them unavailable during shutdown periods may be significant. There may be a need to define specific AOTs for these components. However, the AOT must also take into account adequate time to complete necessary maintenance.

Substantial number of surveillance tests are also performed during shutdown. The purpose of performing these tests is to identify or prevent equipment problems before they become risk relevant. Some of the surveillance testing done on many components can only be performed when the plant is shut down. This is because many of these tests require changes to the plant configuration that are only possible during shutdown and are usually associated with long test downtimes. Although many of these surveillances are required to assure safe power operation or the safe shutdown of the plant, the risk benefit (i.e., risk reduction) during power operation of the plant is sufficient to warrant the risk incurred due to the performance of the test during shutdown.

There is also the issue of whether a need exists to define additional modes of operation in the TSs to cover certain shutdown configurations. Currently, there are six modes used to define all possible plant operational states. For PWRs, a unique configuration, known as "mid-loop" exists, which may warrant definition of an additional TS mode of operation. This configuration only exists during cold shutdown and occurs when access to the primary side of the steam generators is required. In this configuration a loss of decay heat removal (DHR) can quickly lead to boiling in the RCS with subsequent core damage if not mitigated. In this configuration the steam generators are isolated, so the only means of removing decay heat is via the RHR system. Increased importance is therefore placed on certain plant support systems during this time. Two of these systems are the intermediate (CCW) and the primary (SW) heat removal paths for the RHR system to the ultimate heat sink.

Interestingly, since Surry is a multi-unit site and does have shared support systems, the TSs for one unit may be satisfied by using shared equipment from the other unit. This may result in risk implications for both units over the time periods involved. In some situations, such sharing may be the only available means to perform necessary work on these systems. Based on risk, appropriate guidelines for such actions may be warranted.

3. RISK-BASED SCREENING ANALYSES OF SHUTDOWN TS REQUIREMENTS

Table I shows the Surry specific requirements for selected equipment with the generic TS requirements proposed in the draft Westinghouse Owners Group Standard Technical Specifications (WOG STS). Review of Table I shows that the Surry TSs are geared toward operational configurations and primarily concerned with bringing the plant from full-power operation to a shutdown state. Surry requirements for cold shutdown (CSD) are predominantly a restatement of those for power operation.

Since Surry is a multi-unit station with shared facilities, the TS requirements rely heavily on system crosstie capability and reflect configuration impacts dependent on the other units' operational state. Further review of Surry specific documentation did show awareness of shutdown configuration control. This was reflected in their Abnormal Procedures (APs), Operating Procedures (OPs), and minimum equipment lists (MELs). Surry has also established a Critical Parameters Assessment (CPA) system to provide monitoring capability during shutdown. A review of this system shows that, along with TS-controlled systems, it also contains the status of other relevant parameters important to shutdown risk such as switchyard work status and reduced inventory requirement status.

To identify the types of plant configurations possible during shutdown, a review of the 1992 refueling outage for Unit 1 was performed, which included the mid-loop configuration. From this review a time-line diagram including unavailable equipment and important events was developed and is shown in Figure I.

Qualitative analysis of this figure shows that the time in mid-loop is small (29 hrs.) but the time the steam generators are isolated is relatively long (813 hrs.). Surry is one of 16 Power units that has RCS loop isolation capability. This capability is very important to mid-loop risk. After taking the RCS to a mid-loop level to drain the primary side of the steam generators for access purposes, the loop isolation valves are closed. Once closed, the RCS level can be raised to a higher level (usually just below the reactor flange). Air intrusion into the RHR system, which is a dominant cause of RHR loss, would be virtually precluded. Installation of nozzle dams requires more time than closing the valves ar[illegible]v have only about a 50psi pressure retaining capability. Both these factors would result in extendin[illegible] the t[illegible]me in mid-loop. The figure shows also that much of the work on critical equipment is performe[illegible] [illegible]le the core is offloaded. Interestingly, during this period, the entire decay heat load of the core and spent fuel pool, which is common to both units, is being handled by one train of the CCW system. Another interesting item is that the safety related instrument air systems were unavailable for a substantial period due to work being done on the branch of the service water system that supplies bearing cooling to the compressors and cooling to the air dryers. Work on EDG#1 was partitioned into 2 outage times due to TS constraints. If the outage time exceeded 7 days, LCO requirements would not be met and the other unit which was operating would have to be brought to CSD.

Using the figure as a basis, a number of repair and surveillance activities were selected and their risk impact during mid-loop operation (designated POS 6) and in some cases, during a post refuelling cold shutdown condition (designated POS 12) were evaluated. These designations were assigned in the LP & SD PRA[1] and represent Plant Operating States during shutdown.

Table II and III show the risk-based anlaysis of single and multiple component outages respectively. Both represent the increase in core damage frequency levels and the core damage probability impact of the component outage durations for POSs 6 and 12. The CDF impacts were assessed using dominant sequences resulting from loss of RHR and loss of offsite power initiating events. Assessing the results from the single component cases, the CDF impact for the motor driven AFW pump is small during POS 6 because the steam generators are isolated and therefore unavailable for decay heat removal. Loss of the LPI pump is more significant because it represents a loss of redundant injection capability. Having one of the 3 EDG's down for repair results in a relatively small increase in CDF compared to that for an electrical bus. This is due to the bus outage disabling an entire train of systems, whereas the EDG outage only represents a loss of redundancy to a bus, but does not guarantee the loss of an entire train of systems. For the multiple component outage cases, the CDF impact for the first two cases is small for the same reason given in the single component case for the AFW pump. Even in the second case were an LPI pump is removed from service, the CDF impact remains small. Only in the third case, with the addition of an EDG being removed from service does the CDF impact increase.

Table IV contains the risk contribution associated with the test downtimes for shutdown surveillance testing. Three aspects of this contribution, the conditional CDF during the shutdown operating state, the impact considering the duration of the test, and the normalized contribution considering the test intervals are presented. As shown in this figure, the normalized contributions are small, but the impact due to the unavailability of the components affected can be larger. This is because of the relative importance ranking of particular components involved in the test activity. For example, the logic testing of a vital bus may require disabling an entire train of systems, as was shown in the single component case.

Table V contains the risk benefit or risk reduction to be achieved during power operation due to the performance of the test during plant shutdown. The risk reduction is measured by the product of the unavailability of the component tested and the change in CDF due to the failure of the component. In some situations, both the terms contributing to the determination of the risk benefit may need to be considered in deciding the need for the surveillance requirements. The examples in the table show that in general, risk benefits of the surveillances are small. A reason for this is the low failure rates of the components being tested. However, the conditional CDF in case of component failure can be large. For example, the testing of the check valve in the RWST discharge line has small risk benefit, but its failures can cause a large increase in CDF during power operation due to the unavailability of a water source for RCS injection.

4. SUMMARY OF RESULTS AND INSIGHTS

Based on the results of the qualitative and quantitative risk-based analyses performed, some valuable insights into aspects of both shutdown TS and shutdown risk were gained.

Results from the TS review showed that shutdown requirements are sparse. At Surry, the TS are written such that emphasis is placed on bringing the plant to a shutdown state, they do not reflect requirements of the plant during shutdown. Review of the generic documentation showed that this is not unique to Surry. Although not in the TS, review of the reference outage schedule showed that operating personnel are cognizant of mid-loop risk potential. Much of the outage work performed on equipment essential to both minimize and mitigate a loss of RHR event was scheduled during non mid-loop shutdown periods. It also showed that multiple equipment outages due to surveillance testing and maintenance needs produce different and somewhat unique plant configurations, some of which with high risk potential.

Risk calculations performed show that there is a need for improved TS control during shutdown periods. Due to its unique configuration, an additional TS plant operating mode for mid-loop may be warranted. Results from the evaluation of single and multiple component outages show that the risk during shutdowns can be reduced by controlling the plant configurations during shutdown. This may imply control of durations for maintenance and testing of selected important equipment and delineation of shutdown periods when particular test and maintenance can be performed.

The risk-based methodology presented in this paper and its use to analyze risk impacts from testing and maintenance can systematically address shutdown TS requirements for nuclear power plants. It can be used to determine any allowed outage time for certain vital equipment, and optimize the risk-benefit of surveillance testing. It can also define the allowable plant configurations from a risk perspective, and thus define an outage planning process that balances the need to minimize the time in shutdown and the risk during these periods.

Table I. Surry-Specific TS and WOG STS Requirements During Cold Shutdown

System	Surry Specific TS	Surry AOT	WOG STS	WOG AOT	Comments
CCW	2 trains operable when other Unit is operating.	None.	2 trains operable. 1 train inoperable.	 Restore within 72 hrs.	This system is common to both Units at Surry. Commonality is reflected in Surry TSs.
RHR	2 trains operable during power operation. No requirement during CSD.	None.	2 trains operable. 1 train inoperable.	 2 hrs.	Surry TSs deal with power operation. WOG STSs apply to refueling only (Mode 6).
AFW	2 motor driven pumps and crosstie flow path operable when other Unit operating.	None.	2 trains operable. 1 train inoperable.	 Restore within 72 hrs.	Surry specific TS relies heavily on crosstie. Could have 1 pump from each unit operable with crosstie and TS is met.
EDGs	Swing EDG and 1 other available when 1 Unit operating.	Restore affected EDG within 7 days or bring operating Unit to CSD.	None.	None.	WOG STSs deal with vital bus power, not specifically EDGs.
HPI	1 train operable.[1]	None.	None.	None.	1 train operable per GL 88-17 response.
LPI	1 train operable.[1]	None.	None.	None.	1 train operable per GL 88-17 response.

Table I. Surry-Specific TS and WOG STS Requirements During Cold Shutdown (Cont'd)

System	Surry Specific TS	Surry AOT	WOG STS	WOG AOT	Comments
CPC	1 train operating.	None.	N/A	N/A	Charging Pump Cooling (CPC) system is a supporting system at Surry.

CCW: Component Cooling Water
RHR: Residual Heat Removal
AFW: Axillary Feedwater
EDG: Emergency Diesel Generator
HPI: High Pressure Injection
LIP: Low Pressure Injection
CPC: Charging Pump Cooling*

* At Surry, the High Pressure Injection pumps are also the charging pumps.

[1] 1 of 2 LPI and 1 of 3 HPI per GL 88-17

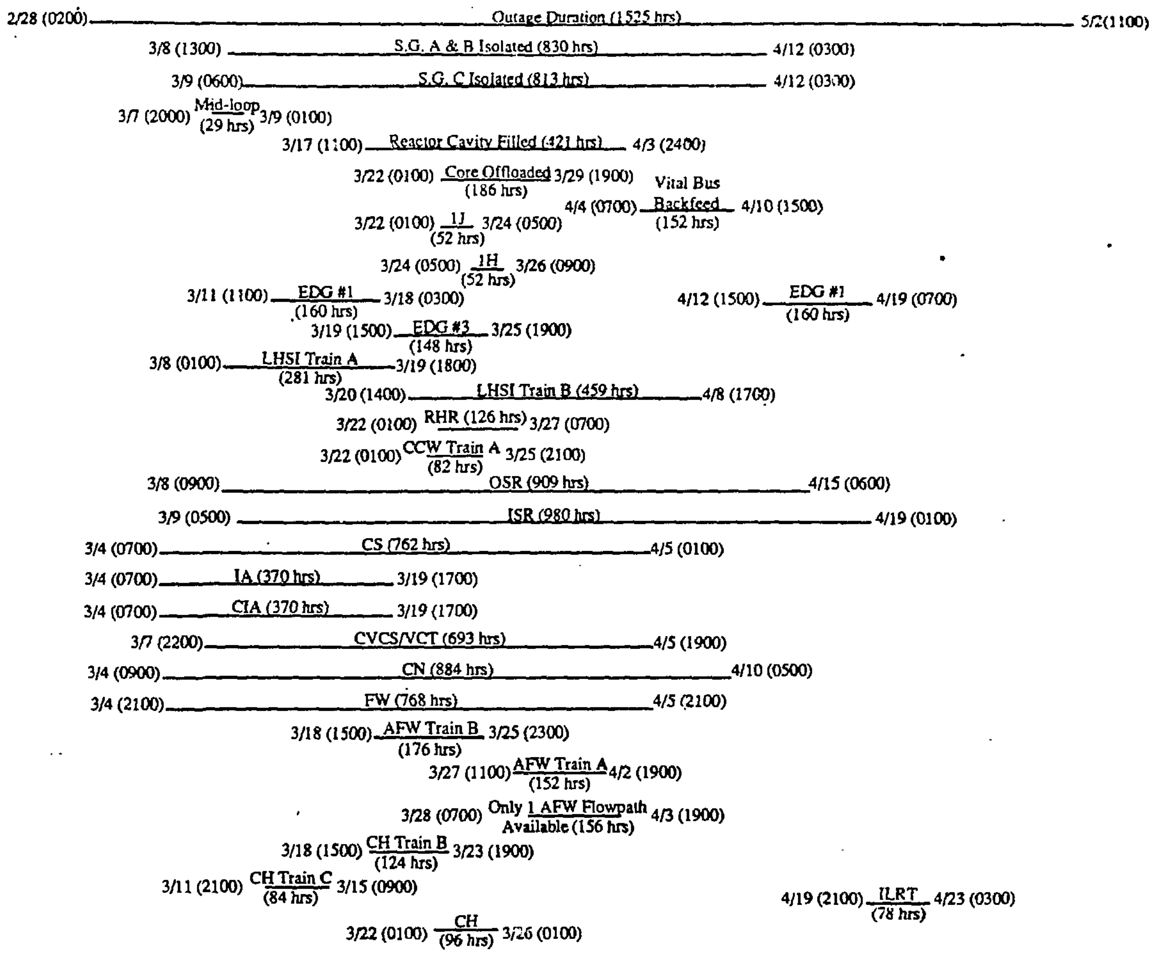

Figure I. Important events and equipment outages during a shutdown period

Table II. Risk Impact of Single Component Outage

Component	Surry CSD TS AOT	Proposed Mid-loop AOT/ (Outage Time)	ΔCDF		AOT or Outage Time Impact	
			POS 6	POS 12	POS 6	POS 12
AFW-MDP	None	72 hrs.[1] (176 hrs.)	S	M	M	L
LPI-MDP	None*	None (230 hrs.)	S	M	M	L
HPI-MDP	None*	None (124 hrs.)	N	N	N	N
EDG	7 days	7 days (148 hrs.)	S	M	S	S
CCW-MDP1B	None	72 hrs.[1] (82 hrs.)	N	N	N	N

1 WOG STS
* 1 of 2 LPI and 1 of 3 HPI per GL 88-17

L: Large
M: Medium
S: Small
N: Negligible

Table III. Risk Impact of Multiple Component Outages

Multiple Outage Configuration	Surry TS AOT	Duration of I & R	Factor Increase in CDF	
			POS 6	POS 12
AFW-MDP 3A AFW-MDP 3B	None	~144-168 hrs.	S	M
AFW-MDP 3A AFW-MDP 3B LPI-MDP 1B	None	~144-232 hrs.	S	M
AFW-MDP 3A AFW-MDP 3B EDG #3 LPI-MDP 1B	168 hrs.	~116-288 hrs.	M	M

Table IV. Risk Impact of Surveillance Requirements (Test Downtime Impact)

Equipment Tested	Type of Test	Frequency	Test Duration	R(1)	R_I	R_n
AFW MOV (151 A,C,&E)	Stroke and Leakage	R	72 hrs.	S	S	S
CV Hot Leg SI (CV 228 & 229)	Hydro and Leakage	R	2 hrs.	M	S	S
Cold Leg SI (CV 79,82,85)	Leakage and Hydro	R	3 hrs.	S	S	S
CV in RWST (CV 410,25)	Leakage and Hydro	R	32 hrs.	M	M	S
Bus 1J	Logic	R	12 hrs.	L	M	S

R(1) = Conditioned CDF given the components are down for test
R_I = CDF impact = R(1) x Test Duration
R_n = Normalized CDF = R_I/Test Interval

Table V. Risk Benefit of Surveillance Requirements (Risk Reduction During Power Operation)

Equipment Tested	Unavailability (q)	Change in Conditional CDF (R(1) - R(0))	Risk Benefit q(R(1) -R(0))
SI Hot Leg Injection (CV 228 & 229)	2.0E-4	L	S
RWST to SI Flowpath (CV 410 & 25)	2.0E-4	L	S
Bus 1J	4.0E-5	M	S

R(1): CDF given the components are down for test
R(0): CDF given the components are up following test

REFERENCES

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2. U.S. Nuclear Regulatory Commission, "Standard Technical Specifications - Westinghouse Plants," NUREG-1431, Draft Report for Comments, January 1991.

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