Quality of the Current Low Power and Shutdown PSA Practice

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1. Introduction

A probabilistic safety assessment (PSA) for the low-power and shutdown (LPSD) modes in a Korea standard nuclear power plant (KSNP) has been performed for the purpose of estimating the LPSD risk and identifying the vulnerabilities of LPSD operations. Both the operational experience and PSA results indicate that the risks from LPSD operations could be comparable with those from power operations. However, the application of the LPSD risk insights to risk-informed decision making has been slow to be adopted in practice. It is largely due to the question of whether the current LPSD PSA practice is appropriate for application to risk-informed decision making or not. Such a question has to do with the quality of the current LPSD PSA practice. In this paper, we have performed self-assessment of the KSNP LPSD PSA quality based on the ANS Standard (draft as of 13 Sep. 2002)[1]. The aims of the work are to find the LPSD PSA technical areas insufficient for application to risk-informed decision making and to efficiently allocate the limited research resources to improve the LPSD PSA model quality. Many useful findings regarding the current LPSD PSA quality are presented in this paper.

2. Overview of the LPSD PSA Model for KSNP

The LPSD risk model for KSNP (Yonggwang Units 5&6) [2] was selected for the self-assessment of the quility, since it was the first LPSD PSA in Korea and has played an important role as the technical basis for other KSNP LPSD PSAs. The Korea Atomic Energy Research Institute (KAERI) has performed it for an operation license during the period of 1994-2001, reflecting the plant-specific LPSD operating experience and information from the three operating KSNPs at that time. The characteristics of this model are summarized as follows:

- It typically covers refueling outages only.
- It has been developed as a traditional time-averaged PSA model, similar in structure to the full-power PSA model.
- Several success criteria and operator grace times at the LPSD conditions were determined based on the plant-specific LPSD thermal-hydraulic analyses using a best estimate code (e.g., RELAP)
- 17 plant operating states (POS) and 21 initiating events were defined, reflecting five refueling outage experiences of the operating KSNPs.
- The LPSD specific fault trees for 20 systems were developed by the modification of the full-power system models.
- Generic component reliability data was used.

As a result of an accident sequence quantification, the total core damage frequency (CDF) indicates a point estimate of 5.05×10^{-6}/yr under the assumption that the PSV popping test at POS 2 will be improved.

3. Self-Assessment of the LPSD PSA Quality

Based on the ANS Draft Standard as of 13 Sep. 2002[1], a self-assessment of the quality of the KSNP LPSD PSA model has been accomplished in two steps, (i) internal review and (ii) independent review. Some experts with experiences in LPSD PSA have independently reviewed the results of the internal self-assessment to ensure their objectivity. Among the 10 technical areas covered in the ANS Draft Standard, two areas - internal flooding (IF) and the large early release frequency (LFRF) analysis – were not included in the scope of the self-assessment, because there was no requirement for the LERF area in the standard and the internal flooding analysis was out of the scope of the KSNP LPSD risk model. Thus, 8 technical areas, 37 high level requirements (HLR), and 218 supporting requirements (SR) of the ANS Draft Standard have been applied.

Table 1. Results of the self-assessment by technical areas

Technical Areas (Code)	# of HLR	# of SR	Result of Assessment (Category)				
			<I	I	II	III	N/A
Plant Operating State Analysis (PS)	4	15	0	7	8	0	0
Initiating Events Analysis (IE)	4	30	0	15	15	0	0
Accident Sequence Analysis (AS)	3	21	0	5	16	0	0
Success Criteria (SC)	3	16	0	7	9	0	0
System Analysis (SY)	3	42	0	14	26	1	1
Human Reliability Analysis (HR)	9	34	8	17	8	1	0
Data Analysis (DA)	5	29	0	19	10	0	0
Quantification (QU)	6	31	4	11	14	2	0
SUM	**37**	**218**	**12**	**95**	**106**	**4**	**1**

The overall results of the self-assessment is shown in Table 1 and Figure 1. Of a total of 218 SRs, 107 SRs (about 49%) were classified into Category 1 and below, 106 SRs (48%) into Category 2, and only 4 SRs (2%) into Category 3. Only one SR (SY-A12: 'dependency in the support-state approach') was not applicable for the current LPSD risk model.

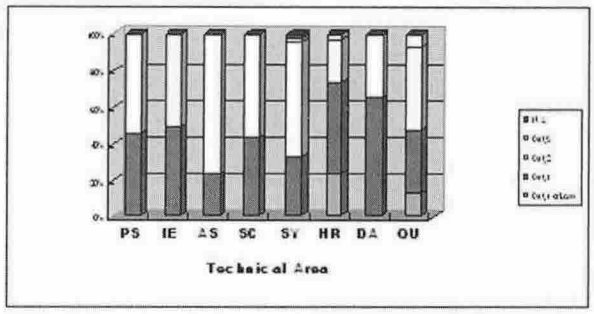

Figure 1. Results of the self-assessment

Table 2. Limitations of the current LPSD PSA practice for applications to risk-informed decision making

Technical Areas	Limitations
Common	-Inappropriateness of documentation -No level 2/3 risk analysis -No internal fire/flooding analysis
Plant Operating State	-Incompleteness of POS analysis for other outage type -No update based on the recent plant-specific O/H information
Initiating Event Analysis	-Insufficient plant-specific experience data -No guidence of a systematic grouping and screening process of initiating events -Exclusion of some initiating events (e.g., spent fuel misloading, heavy load drop, human-induced IE's, etc.)
Accident Sequence Analysis	-Poor understanding of the LPSD-specific accident progression (e.g., LTOP, fast-acting reactivity insertion, gravity feed, reflex cooling, mid-loop operation, etc.)
Success Criteria	-Insufficient impact analysis of input paramenters on the results of the T/H analyses at LPSD conditions
System Analysis	-No systematic method and guidance for modifying full-power system models. -No detailed failure cause and mode analysis -Inadequacy in treatment of intra- and inter-system dependency
Human Reliability Analysis	-Inadequacy in application of full-power HRA method to LPSD conditions (including recovery models) -Insufficiency of plant walk-through or operator interview, -Overall weakness in pre-accident HRA
Data Analysis	-Inadequacy in application of full-power failure data to LPSD conditions -No use of plant-specific component failure data
Quantification	-No uncertainty analysis - Insufficient traceability for review of the results

The overall quality of the KSNP LPSD PSA model is estimated to be between Category 1 and Category 2. First, the technical area with the lowest quality turned out to be the human reliability analysis (HRA) in the KSNP LPSD risk model. Of the 34 SRs in this area, 25 SRs (about 74%) belong to Category 1 and below. Second, the data analysis (DA) was identified as the technical area with the next lowest quality. SRs with Category 1 and below in the DA area are estimated to be about 66%. In the other technical areas, the percentages of the SRs with Category 1 and below range from 24% to 50%. The inappropriateness of the documentation was also one of the largest contributors to the poor quality of the current LPSD PSA practice, since 22 of a total of the 27 documentation-related SRs in all the technical areas corresponded to Category 1.
Finally, the limitations of the current KSNP LPSD PSA model for risk-informed applications are summarized in Table 2. It shows the technical areas which we must investigate for improving the current LPSD PSA practice to the high level appropriate for the application to risk-informed decision making.

4. Conclusion

Many findings related to the current LPSD PSA practice have been discussed from the results of the self-assessment of the KSNP LPSD PSA quality. In particular, we identified the technical areas of which the current LPSD PSA practice should be improved for application to risk-informed decision making in Korea (See Table 2.) However, the use of the ANS Draft Standard may cause some limitations for the final findings and discussions due to some difficulties in the process of the self-assessment such as the interpretation of the technical requirements.

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[1] ANS, Low-Power and Shutdown PRA Methodology Standard, draft of 13 Sep. 2002.
[2] KEPRI, Peobabilistic Safety Assessment for Yonggwang Units 5&6: Low Power and Shutdown PSA, 2000.