Status and Review Results of PSA for Operating Nuclear Power Plants

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1. Introduction

In August 2001, the Ministry of Science and Technology (MOST) issued the "Policy on Severe Accidents of Nuclear Power Plants" [1]. It required the licensee to take measures to minimize the possibility of severe accident and to minimize the risk of radiation exposure to the public even if a severe accident occurs. The major elements included in the Policy are: the establishment of the safety goal, performing PSAs for all operating NPPs, provisions for severe accidents prevention and mitigation capability, and the establishment of severe accident management program (SAMP). The objectives of the Policy regarding PSA implementation are to identify plant-specific vulnerabilities to severe accidents and to find out the safety enhancement items considering cost-benefit. In response thereto, Korea Hydro and Nuclear Power (KHNP) company set up its own PSA implementation plan, which was approved by the MOST [2]. On the other hand, according to request by the MOST, Korea Institute of Nuclear Safety (KINS) developed safety review guidelines for PSA, SAMP and severe accident prevention and mitigation capability. Using the guideline for PSA [3], KINS has been reviewing PSA results submitted by the licensee.

2. Implementation Status of PSA

The licensee conducted PSAs for all operating NPPs as required by the Policy on Severe Accident. Table 1 shows the status of PSA implementation in Korea. PSAs for the older plants of Kori-1, Kori-2, Ulchin-1&2 and Wolsong-1 were carried out for the first time as shown in the table.

Table 1. Status of PSA implementation

Plant	Level of Analysis	Scope of Analysis	Completion Date	
			Initial	Update
Kori-1	Level-1,2	Full Power	'03.11	'07.5
Kori-2	Level-1,2	Full Power	'03.12	'07.6
Kori-3&4	Level-1,2	Full Power	'92.8*	'03.6
YGN-1&2	Level-1,2	Full Power	'92.8*	'03.12
YGN-3&4	Level-1,2	Full Power	'94.2	'04.12
YGN-5&6	Level-1,2	LP/SD ** included	'00.12	'05.12
UCN-1&2	Level-1,2	Full Power	'05.12	-
UCN-3&4	Level-1,2	Full Power	'97.10	'04.12
UCN-5&6	Level-1,2	LP/SD ** included	'02.6	'06.6
W-1	Level-1,2	Full Power	'03.12	Under way
W-2,3,4	Level-1,2	Full Power	'97.10	'06.12

* Level-1 only ** LP/SD : Lowe Power/Shutdown mode

PSA up to level 2 with both internal and external initiators was performed as required in the Policy. External event analyses were performed mainly by probabilistic approach. Seismic, internal fire and internal flooding were taken into account as external initiators. In case of seismic analysis, the methodology of seismic margin analysis (SMA) was applied for some older plants of Kori-1, Kori-2, Ulchin-1&2 and Wolsong-1.

Table 2 shows the risk results of CDF and LERF. It should be noted that the scope of analyses for Kori 3&4 and Yonggwang 1&2 performed first in 1992 did not include level 2 resulting in no risk value of LERF, and external initiators were not dealt with in the update analyses for Yonggwang 5&6 and Ulchin 5&6. Results from initial analysis for Kori 1 showed relatively high CDF, and PSA update was done to reflect the plant improvement for safety enhancement. The effect of safety enhancement was such that the CDF level was reduced about an order of magnitude, *i.e.*, from 1E-04 to 1E-05, as shown in the Table 2.

Table 2. Results of CDF and LERF

Plant	Type of Analysis	CDF		LERF	
		Internal initiators	Total	Internal initiators	Total
Kori-1	Update	1.62E-05	8.36E-05	9.54E-07	3.49E-06
	Initial	1.19E-04	9.05E-04	3.7E-06	2.04E-05
Kori-2	Update	1.89E-05	1.06E-04	2.20E-06	6.23E-06
	Initial	3.77E-05	1.74E-04	2.15E-06	9.16E-06
Kori-3&4	Update	8.38E-06	9.34E-05	1.05E-06	3.09E-05
	Initial	8.03E-05	1.83E-04	-	-
YGN-1&2	Update	7.25E-06	5.68E-05	7.59E-07	1.38E-05
	Initial	7.24E-05	1.56E-04	-	-
YGN-3&4	Update	4.74E-06	5.60E-05	5.03E-07	4.42E-06
	Initial	8.35E-06	3.94E-05	8.41E-07	1.66E-06
YGN-5&6	Update	5.46E-06	-	5.97E-07	-
	Initial	7.43E-06	1.67E-05	7.25E-07	1.00E-06
UCN-1&2	Initial	7.96E-06	6.0E-05 5.4E-05	1.24E-06	7.06E-06
UCN-3&4	Update	5.44E-06	3.96E-05	6.42E-07	3.28E-06
	Initial	8.25E-06	2.73E-05	1.25E-07	1.73E-06
UCN-5&6	Update	5.65E-06	-	5.96E-07	-
	Initial	7.27E-06	1.51E-05	1.12E-06	1.44E-06
W-1	Initial	3.29E-05	1.34E-04	8.27E-07	9.40E-07
W-2,3,4	Update	2.02E-06	9.80E-05	1.05E-08	6.38E-07
	Initial	8.02E-05	3.77E-04	3.04E-07	1.24E-05

The licensee identified several plant improvements to address perceived weaknesses in design or operation of the plant. Those improvements are classified as procedural changes or hardware changes, but many improvements involve hardware change. For example, the contribution of station blackout (SBO) initiator to CDF is relatively high for most PWRs without alternative alternating current (AAC) power. Thus, the most significant safety improvement is to install AAC diesel generator in addition to emergency diesel generators for some older plants. The risk level for some newer plants is low enough with the order of 1.0E-

06 and the design is comparatively well balanced not to make any single accident sequence dominate the total risk level, resulting in no notable plant improvement derived.

3. Regulatory Review Results

Totally 11 analyses results covering 20 operating plants were submitted for the regulatory review, as shown in Table 1. Reviews of 7 submittals among them are completed up to now, and reviews of the remaining ones are under way. The review is expected to be completed by the end of the year 2008. The objectives of regulatory review of PSA are to confirm if a NPP achieves a reasonable safety level and if the methodology and data used in PSA are technically acceptable. Insights and implication of the collective results will be evaluated after the review is completed. As a whole, the results up to now show that the risk level from PSAs maintains at reasonable level and the methods and data are appropriate to use for satisfying the objectives of the Policy although the following specific issues were raised during the review process.

PSA for operational mode of low power/shutdown was not made for operating plants. However, it was revealed from the results of LP/SD PSA for some newer plants that the risk level for LP/SD was comparable to that for full power operational mode. Thus, it was requested for the licensee to perform LP/SD PSAs for operating plants. With regards to seismic analysis, the licensee used two kinds of methodology. One is the seismic PSA and the other is seismic margin analysis. Seismic margin analysis was used for some older plants such as Kori-1 and Kori-2. Quantitative results such as CDF and LERF couldn't be obtained from seismic margin analysis while there was a more concern about the risk level for those older plants. Thus, it was also requested for the licensee to perform seismic PSA rather than seismic margin analysis to compare risk levels among operating plants and get some insights from the analysis.

In terms of the PSA methods and data, there are some arguments between KINS and the licensee for the following specifics. The component failure data were collected for the period of full power operation only. However, for instance, some of the in-service valve test did not include full stroke test for full power operation. The full stroke test was made in cold shutdown mode, and thus the accurate component failure data should be collected with considering all modes of operation. It is requested not to limit the data collection period to full power operation only.

For KSNP type reactors, there are two issues to be addressed in common. One is the unfavorable exposure time (UET) which means the fraction of time the plant has an unfavorable moderator temperature coefficient in anticipated transient without scram (ATWS), and the other is aggressive cooldown model for small break loss of coolant accident (LOCA) and steam generator tube rupture (SGTR). Regarding UET, the generic data of 0.01 obtained from CE System 80+ analysis was used for KSNP-type reactors. But the specific analysis of ATWS for Ulchin 5&6 initial core showed the UET result of 0.37 which is 37 times higher than the generic data [17]. Since this data is directly related to the core damage sequence resulting from ATWS, the use of generic data can lead to an optimistic result of CDF. Thus, it is necessary that the plant-specific UET data should be used for KSNP-type reactors. The licensee indicates that the specific analysis of reload core for KSNP-type reactors is in progress. In case of small break LOCA or SGTR, the aggressive cooldown by depressurizing primary system for the actuation of low pressure safety injection system is needed to prevent core damage when high pressure safety injection is not available. The success criteria of aggressive cooldown is that the operator must open at least one atmospheric dump valve on each steam line with its maximum heat removal rate within 30 minutes after initiation of the accident. However, there is no explicit expression in emergency operating procedure (EOP) and the operator is not aware of it though the operator action is crucial for the mission. The licensee submits its plan to revise the EOP remedying the inconsistency, which results in PSA model as designed and as operated.

The final risk results for the operating plants in Korea showed 2.02E-06 ~ 3.29E-05 for CDF and 1.05E-08 ~ 2.20E-06 for LERF with considering the internal initiators only. The results were regarded as relatively good and meet the performance goal of 1.0E-04 of CDF which is accepted internationally for operating plants as a whole although the Korean specific performance goal is not established yet.

4. Conclusions

PSAs for all operating NPPs in Korea were carried out and submitted for review according to the Policy on Severe Accidents. KINS has been reviewing PSA results to determine if the submittal meet the intent of the Policy on Severe Accident. Several plant improvements were identified by the licensee and some improvements to PSA were derived through the regulatory review. The review results up to now show that the risk level from PSAs maintains at reasonable level and the methods and data are appropriate to use for satisfying the objectives of the Policy.

REFERENCES

[1] The Ministry of Science and Technology, Policy on Severe Accident of Nuclear Power Plants, August 2001.
[2] The Ministry of Science and Technology, Notice of the Review Result on the Implementation Plan for the Policy on Severe Accident, January 2002.
[3] Korea Nuclear Power Co., Ltd., Analysis Report of ATWS Event of Ulchin Units 5&6, KOPEC/NED/TR/2003-008, May 2003.