Accident Sequence Analysis for PSA Update of OPR (Hanul 3&4): Results and Insights

Jin Hee Park, Dong-San Kim, Jae Hyun Cho, Joon-Eon Yang
1045 Daedeokdaero, YuseongGU, Daejeon, KOREA
**Corresponding author: jhpark6@kaeri.re.kr*

1. Introduction

After Fukushima accident, the full scope PSA (Probabilistic Safety Assessment) for OPR (Optimized Power Reactor) is performing for all types of risks from internal and external events and for all plant operational modes in Korea. For the purpose of this project, the internal full power PSA model, the basic PSA model for all types of risks from internal and external events, was updated. This updating process included all of PSA technical elements as follows.

- Re-identification of specific IEs(Initiating Events)
- Success criteria analysis for PSA support
- Accident sequence analysis and system analysis to respect as-built & as operated condition of target plants
- Adaption of standardized HRA methodology
- Domestic data gathering and specific reliability data estimation
- The third party independent review for a technical adequacy for updating PSA model

This paper summarizes the results and insights of the accident analysis of this PSA update process.

2. Accident sequences analysis

In this section, the main updating items for accident analysis are described. The accident sequences updating includes an addition of new specific IEs, updated accident sequence analysis, the third party independent review results, the final results and insights as follows.

2.1 An addition of New IE

The two IEs were identified through a systematic process and a detailed plant specific FMEA(Failure Mode & Effect Analysis) for target plants as follows.

- Total loss of CCW/ESW/ECW event
- Loss of 125V DC(division B)

And, SBO(Station Black-out) and the LSSB(Large Secondary Side Break) IEs were separated two IEs(SBO-S due to two emergency diesel generators fail to start & SBO-R due to two emergency diesel generators fail to running/LSSB in containment & out containment) respectively. The four event trees are added for the core damage frequencies quantification for updating the OPR PSA model.

2.2 The change of accident progression model

The various accident progression models were improved based on plant response according to each IEs, the detailed T/H(Thermal Hydraulic)analysis, specific design & operating condition, operator interview results, the EOP(Emergency Operation Procedure) & AOP(Abnormal Operation Procedure) and the other LWR PSA results. The main modeling changes are as follows.

- The success state (or end state)

In the former OPR PSA, the success state, to finalize the event tree development, applied long term cooling using shutdown cooling system(SCS) with component cooling system(CCW) and secondary cooling using auxiliary & main feed water system by condensate storage tank(CST) and back-up water tank on transient ET(Event Tree) during mission time. In this PSA updating project, the success state(using SCS) for the transient condition was eliminated based on realistic T/H analysis and the CST has enough inventory to carry and maintain the plant safe shutdown after transient.

-Consideration of the integrity of RCS

In the former OPR PSA, the challenge of RCS integrity caused by PSV(Pressurizer Safety Valve) open case due to over-pressurization of RCS caused by transient was not considered. In this PSA update, the integrity of RCS for special transient case is considered based on recent updated FSAR(Final Safety Analysis Report)and T/H analysis of target plants.

-Addition of RCP Seal LOCA Model

In the former OPR PSA, the possibility of RCP(Reactor Coolant Pump) seal LOCA(Loss of Coolant Accident) was not considered. In this project, RCP seal LOCA for special transient case is considered based on recent RCP Seal LOCA analysis results.

-Respect the as-built & as-operated condition

The several accident progression model changes are performed based on EOP & AOP as follows.

In the former OPR PSA, the aggressive cooldown by operator, to inject low pressure safety injection(LPSI) after high pressure injection(HPSI) system failed condition as a mitigation function, was considered. But, this mitigation function is not described definitely on EOP and the recirculation of coolant from sump to RCS by LPSI system for long-term cooling could not credit because the LPSI pump is stopped by RWT(Refueling Water Tank) low level signal. So, aggressive cooldown and LPSI recirculation function are eliminated from accident progression modeling.

In the former OPR PSA, the feed & bleed operation by operator using safety depressurization system(SDS) valve and HPSI system after secondary cooling system failed condition as a mitigation function also considered. But, there is a prerequisite process to perform the feed & bleed operation in EOP. The essential prerequisite is to check the PSV open condition by operator. According to the specific T/H analysis, the PSV is not challenged because of RCS inventory release to break point at some transient case such as steam generator tube rupture. For these case, the feed & bleed operation is not credit as a mitigation function in updating PSA model.

- Dependency model change

In this project, the detailed dependency analysis are performed and applied to PSA model update such as the 125V DC vital bus dependency, start-up feed pump dependency, room cooling dependency and so on.

- Independent Review

The third party independent review(two foreign experts with more than 20 years PSA experiences) based on ASME/ANS PRA Standard also performed. The review was performed to confirm the interim PSA model update and to find possible resolution, to improve the quality of final results. The review results are summarized in Tabel 1.

Table 1: Review Results

Capability Category Met	Number of SRs	Percentage of Total SRs	Percentage of Assessed SRs
Cat I	8	3.80%	3.90%
Cat I/II	10	4.70%	4.90%
Cat II	15	7.00%	7.30%
Cat II/III	13	6.10%	6.30%
Cat III	3	1.40%	1.50%
Cat I/II/III	100	46.90%	48.80%
Not Met	56	26.30%	27.30%
Not Applicable	8	3.80%	100.00%
Total	213	100.00%	

The internal PSA model is updated by integration of updating PSA technical elements independent review results

The quantification results are described with the former OPR PSA results respectively table 2 and figure 1.

Table 2: Quantification Results

IE	Former PSA	Update PSA
	%	
Large LOCA	11.5	0.2
Medium LOCA	8.1	11.0
Small LOCA	14.6	9.4
SGTR	9.0	4.9
ISLOCA	0.0	0.3
Rx Vessel rupture	4.9	1.1
Total LOCCW		30.1
LSSB	4.1	3.4
LOMF	9.0	0.4
Loss of CON. Vacum	0.2	0.8
Partial LOCCW	5.5	2.0
Loss of 4.16KV	0.0	2.0
Loss of 125V DC	7.2	7.2
LOOP	19.9	22.5
GTRN	3.6	4.9

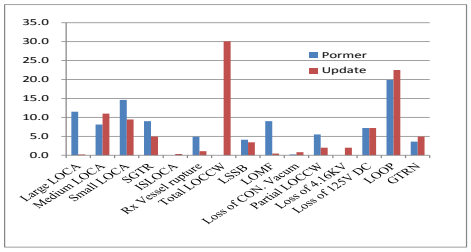

Fig. 1 Quantification Results

As shown in Table 2 and Figure 1, the risk profile including main contributor is different from the former PSA. The main contributor of updating PSA is caused by total loss of CCW/ESW(Essential Service Water)/ECW(Essential Chilled Water) accident that was not considered in former PSA.

3. Conclusions

The OPR PSA Updating, for all types of risks from internal and external events and for all plant operational modes, is performing after Fukushima accident. For this project, all of PSA technical elements are reviewed in detail and updated. The third party independent review to confirm the quality of final PSA model performed also. The internal PSA model is updated by improvement of various PSA elements and results of independent review. And new risk insights also are obtained such as different risk profile and main contributor compare to former PSA. This updating internal full power PSA Model would be a basic model for all types of risks from internal and external events

and for all plant operational modes. And the results of this updating PSA model would applied also to improve the plant safety such as procedure change and design changes.

ACKNOWLEDGMENTS

This work has been carried out under the nuclear long-term R&D Program sponsored by the Korea Ministry of Science and Future Planning

REFERENCES

[1] PSA for Ulchin Unit 3&4, 2004, KHNP.
[2] Sang Hoon Han, et. al.,"Improved Features in a PSA Software AIMS-PSA" Korean Nuclear Society Spring Meeting, Pyeongchang, Korea,2010..
[3] Dong-San Kim, Jin Hee Park, Jae-Hwan Kim, Independent Review of the at-Power Internal Event Level-1 PSA for Hanul Unit 3 & 4, KAERI/TR-5613/2014, 2014.
[4] The Final Safety Analysis Report for Ulchin 3&4, 2013, KHNP
[5] Dong-San Kim, et.al., Initiating Event Analysis for PSA Update of OPR (Hanul 3&4): Results and Insights, Korean Nuclear Society Autumn Meeting, 2015.
[6] Jae Hyun Cho, et.al., Success Criteria Analysis for PSA Update of OPR (Hanul 3&4): Results and Insights, Korean Nuclear Society Autumn, Korea,2015.