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A Comparative Study of the Standardized MPAS Level 2 PSA Model and the Operator Model

Hyun-bin Chang(Presenter), Gunhyo Jung, Jung Hyun Ryu, Jaebeol Hong

Introduction

Overview

☐ KINS developed the Multi-purpose Probabilistic Analysis of Safety (MPAS) Level 1 PSA model for risk-informed regulation in cooperation with KAERI from 2007 to 2018.

☐ The MPAS Level 1 PSA model cannot evaluate the integrity of containment buildings and radiation materials behavior. Therefore, Developing a Level 2 PSA model for risk-informed regulation required.

☐ A Standardized version of the MPAS Level 2 PSA model was presented after reviewing both domestic and foreign Level 2 PSA models in last year.

☐ The standardized MPAS Level 2 PSA model was developed by incorporating state-of-the-art research and considering the evaluation of portable equipment.

☐ The objective of the study is to compare the operator model and the standardized and identify the major differences between the two models. Also, the causes of the differences for each item will be explained, and sensitivity analysis will be conducted to demonstrate the validity and appropriateness of the standardized model.

Methodology

Methodology

☐ Quantification of Standardized Level 2 PSA model
⦿ PDSETs involve considering accident mitigation strategies and systems aimed at preventing containment failure as accident scenarios are expanded.
⦿ The development of the Containment Event Tree (CET) and Decomposition Event Trees (DETs) may vary based on the developer's engineering judgment, such as reflecting the latest research results or simplifying/detailing uncertain severe accident models.
⦿ This study aims to validate the standardized model by identifying major differences between the operator and standardized model.
⦿ To accomplish this, the study uses the operator model's PDSET and conducts Level 2 PSA quantification using the standardized model's Plant Damage State Logic Diagram (PDSLD), CET, DETs, and Source Term Category Logic Diagram (STCLD).

☐ Compare the Operator model's result and the Standardized model's result

☐ Identify the major differences and select sensitivity analysis items

☐ Establish sensitivity analysis method for each item

☐ Perform sensitivity analysis

Compare and Select Items

Select Sensitivity Items

☐ Compare of Quantification results

Failure Mode.	Operator	Standardized	Change Rate (%)
	Fraction (%)		
NOCF	86.8	85.7	-1.3
ECF	0.6	0.1	-83.3
LCF	1.5	0.4	-73.3
CFBRB	6.8	6.8	0.0
BMT	2.0	4.2	110.0
NOTISO	0.1	0.1	0.0
BYPASS	2.3	2.7	18.4
CFF	13.2	14.3	8.6

☐ Identify the major differences
⦿ The fraction of NOCF, CFBRB, NOTSIO are decreased slightly or not changed.
⦿ The fractions of ECF and LCF decreased significantly by 83.3% and 73.3%.
⦿ The fractions of BMT and BYPASS increased by 110% and 18.4%.
⦿ The increased fraction of BYPASS in the standardized model was attributed to the latest study on thermal-induced steam generator tube rupture, which considered the effect of loop seal clearing for steam generator tubes.
⦿ The significant differences in ECF, LCF, and BMT led to sensitivity analysis on the DETs related to these failure modes in the standardized model.

☐ Select sensitivity analysis items
⦿ ECF, LCF and BMT are selected as sensitivity items. Since the quantification results are differ greatly, the appropriateness of the cause should be identified.
⦿ BYPASS is not selected. Because the cause of the difference is identified.

Sensitivity Analysis

Establish Analysis Method

☐ ECF
⦿ The major difference between the operator model and the standardized model is that the operator model assumes a probability of 0.008 for Alpha-mode failure when the RCS pressure is low at the time of reactor vessel rupture, whereas the standardized model assumes a lower probability of 0.001 based on SERG-2.
⦿ To perform sensitivity analysis, the Alpha-mode failure probability in DCF DET will be changed to 0.01.

☐ LCF
⦿ The main difference between the operator model and the standardized model is that the operator model considers the possibility of containment failure during a reactor cavity dry and containment heat removal failure condition, while the standardized model assumes that LCF due to overpressure of the containment building will not occur even when containment heat removal fails with a dry Cavity.
⦿ To perform the sensitivity analysis, a probability of 0.2 for containment failure due to overpressure when the Cavity dry and containment heat removal fails was assumed in LCF DET like the operator model.

☐ BMT
⦿ The major difference between the operator model and the standardized model is the level of phenomena considered when BMT occurs.
⦿ To perform the sensitivity analysis, the BMT occurrence is assumed as below.

RCS Press. At Vessel Rupture	Cavity Condition	BMT	Probability
High	Not Flooded	No	0.5
		Yes	0.5
	Flooded	No	1.0
		Yes	0.0
Medium	Not Flooded	No	0.1
		Yes	0.9
	Flooded	No	0.9
		Yes	0.1
Low	Not Flooded	No	0.0
		Yes	1.0
	Flooded	No	0.9
		Yes	0.1

Sensitivity Results

☐ Sensitivity analysis results for each item

Failure Mode	ECF	LCF	BMT
		Fraction (%)	
NOCF	85.3	85.7	86.5
ECF	0.5	0.1	0.1
LCF	0.4	1.2	0.4
BMT	4.2	3.5	3.4
CFBRB	6.8	6.8	6.8
NOTISO	0.1	0.1	0.1
BYPASS	2.7	2.7	2.7

⦿ The analysis results for ECF, the fraction of ECF increased to 0.5%, which is similar to 0.6% of the Operator model.
⦿ The analysis results for LCF, the fraction of LCF increased to 1.2%, which is close to 1.5% of the Operator model.
⦿ The analysis results for BMT, the fraction of BMT decreased to 3.4%, which is somewhat different from the 2.0% of the Operator model.
⦿ However, the frequency of occurrence of LCF is significantly lower than that of the Operator model, and therefore, much of it is classified as BMT. . If sensitivity analysis is conducted by additionally reflecting the assumptions of SEN2, it is expected that the results will be closer to the results of the Operator model.

Conclusion

Conclusion and Insights

☐ The standardized MPAS Level 2 PSA model has been developed to support RIDM based on the APR1400 DC PSA model and considered the state-of-art studies and portable equipment application

☐ This study aimed to validate the standardized MPAS Level 2 PSA model by comparing it to the Level 2 PSA model of the OPR1000 operator. So, this study derived three sensitivity analysis items related to ECF, LCF, and BMT, which were different between the two models

☐ After evaluation it was found that the significant differences were addressed by incorporating state-of-the-art studies or minimizing the analyst's judgment during uncertain conditions. Additionally, similar results were obtained when the assumptions of the Operator model were reflected in the analysis. These findings suggest that the standardized MPAS Level 2 PSA model, which was developed for regulatory testing, is reasonable and appropriate