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A Demonstration of Level-2 Risk Uncertainty Decreasing Efforts for a Phenomenological Accident Progression Prediction

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1. Introduction

An uncertainty decrease is an very important issue for enhancing risk-informed (RI) activities worldwide. Especially, a relatively large uncertainty in a level-2 (L2) PSA risk compared with level-1 internal PSA risk has been a bottleneck problem in the RI application to the extent of a severe accident management. According to the ASME PRA standard [1] in which sources of an uncertainty to capture a category-II RI (= Option 2) capability are listed, an uncertainty analysis which identifies the key sources of an uncertainty and includes sensitivity studies for dominant contributors to LERF (Large Early Release Frequency) needs to be provided. To solve these problems, USNRC have developed the 'SPAR-LERF' [2] model related to the L2 RI application and 'L2 uncertainty assessment and improvement' work is being taken as a main PSA2 topic of the SARNET (Severe Accident Research Network of Excellence) program in Europe by OECD/NEA. Domestically, a mid/long-term R&D [3] is being started this year to choose the fields for L2 uncertainty decrease. As an effort, an uncertainty improvement process is demonstrated for a phenomenological accident progression prediction in this paper. A representative deterministic severe accident (SA) analysis code, MELCOR [4], is used as an analysis tool and the Korean standard NPP, OPR-1000, as a target plant.

2. Accident Progression Analysis

2.1 Approaching Steps

1. As a hypothetical conservative accident, a Station Black-Out (SBO) scenario with no power recovery and no operator action is selected for the analysis of phenomenological accident progression prediction.
2. In order to compare the uncertainties, baseline data is necessary and the results of another commercial deterministic SA code, MAAP4 [6], from the Ulchin 3&4 L2 PSA project [5], are used as a verified basis.
3. As the old data before adjustment, MELCOR-KSNP results [7] are used. User input data including the nodalization scheme, plant data, model options, etc. are adjusted in the new OPR-1000 data. For the changes of input data which show large differences in the progress timing, a sensitivity analysis is made.
4. A comparison is made between the old and new results with the baseline data for the final results and supplementary insights are drawn.

2.2 Input Adjustment

Major adjustment is made for the following factors:

- Core(axial & radial) nodalization scheme and power distribution (see Tab.1)
- Vessel / Primary system (see Fig.1) / SG (see Fig.2) nodalization with the same node size and volume
- Control volume thermodynamics model option

	X축	1	2	3	4	5	6	7	계
Y축	면적 FA	1,09667	1,065	1,1	1,04714	1,0975	1,06	0,66125	7,12756
	면적 송	1,1739	1,1453	1,1829	1,1261	1,1802	1,1399	0,7111	7,6648
	반경	0,6127	0,8602	1,0566	1,2145	1,3604	1,4878	**1,5620**	
	면적 CORRii01	1,1755	1,1416	1,1791	1,1224	1,1764	1,1362	0,7088	7,64
	반경	0,61	0,86	1,05	1,21	1,36	1,49	**1,56**	
	표면적	1,46	2,06	2,53	2,90	3,25	3,56	3,73	19,49
MAAP / MEL	FPR FPA	0,051	0,09	0,136	0,158	0,181	0,203	0,181	1,0
	CORRii03 CORZjj03	0,357	0,63	0,952	1,106	1,267	1,421	1,267	7,0
	Normalize	0,051	0,09	0,136	0,158	0,181	0,203	0,181	1
13 / 14	0 / 0	0	0	0	0	0	0	0	0
	0,736	[illegible]						0,133	0,736

Tab.1 MELCOR/MAAP core nodalization

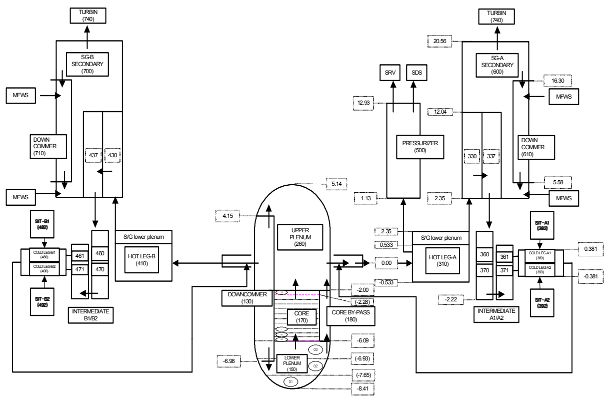

Fig.1 MELCOR RCS nodalization

MELCOR				MAAP		
Vol.			H	H+2.35 [m]	H_{base} [m]	Vol. [m³]
610	600	sum				
	0.0	0.0	2.35	2.35	0.0	0.0
0.0	24.63	24.63	5.58	(5.58)		(24.61)
(9.36)	36.6	45.96	8.71	8.714	6.3642	48.493
				11.253	8.9032	74.281
19.8	73.6	(93.4)	12.2	(12.2)		(93.3)
(nominal water level : Collapsed)				14.201	11.851	133.48
40.8	131.5	(172.3)	16.3	(16.3)		(172.23)
				19.05	16.7	223.0
	196.8		20.6			
(40.8)	207.67	(248.47)	21.69	21.689	19.339	248.466

Fig.2 MELCOR SG nodalization

2.3 Sensitivity Analysis

Sensitivity analysis is made for the following factors and the accident progression is compared in Tab.2.

- Case KSNP: Before adjustment
- Case1: Core(axial & radial) nodalization scheme is changed from 4x10 to 7x10
- Case 2: Primary volume is decreased by 25%
- Case 3: Thermodynamic option is changed from equilibrium to non-equilibrium (except Pressurizer)
- Case OPR: After final adjustment including reactor trip coverage and FP core release models and irradiation history, etc.
- Case MAAP4: MAAP baseline data

Case	Accident Progression Timing [sec]		
	Core uncovery	Core depletion	Reactor Vessel failure
KSNP	8,971	9,900	14,027
1	9,152	10,092	13,581
2	8,287	9,162	12,558
3	5,541	9,747	16,799
OPR	6,861	9,007	11,855
MAAP4	7,126	9,459	12,900

Tab.2 Accident Progression Comparison

2.4 Results

Figures 3 and 4 indicate the time-dependent water mass in the secondary and primary sides, respectively. The mass change with the temperature and pressure changes (which are not shown here) appears to be more consistent in the case of OPR (after adjustment) than in the case of KSNP (before adjustment) when compared with the MAAP4 baseline data. The steam generator behavior shows almost the same decreasing trend (until Mass<10 Ton) meaning the consistent total integral mass of gas out of the MSSVs (Main Steam Safety Valves). According to the RCS water mass behavior, the mass inventory decrease is very similar until a core uncovery (= t<7K sec) but the RCS inventory is depleted a little faster in MELCOR after core uncovery. RCS water is almost depleted before RV failure (but >10% inventory remains in MAAP). The accident progression timing which provides the basis for the risk-informed L2 application shows a good normalization.

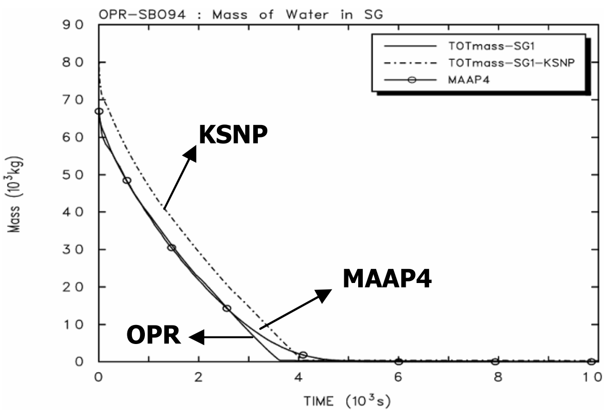

Fig.3 S/G water mass

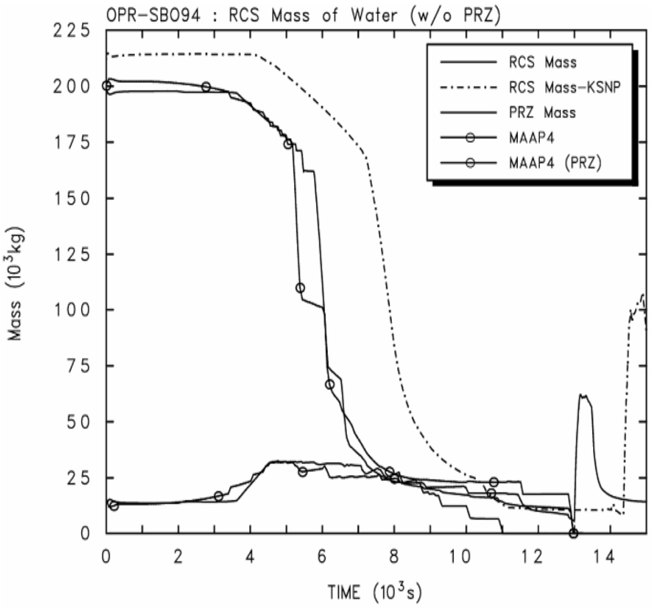

Fig.4 RCS water mass

3. Conclusion

The sensitivity study is made for a SBO accident in OPR-1000 plants using MELCOR and MAAP codes. This is to demonstrate the possibility of an uncertainty decrease through a peer review when the deterministic results need to provide the accident progression information for the level 2 risk assessment. The phenomenological accident progression until a reactor vessel failure becomes more consistent through the verification and adjustment processes which shows the importance of these processes.

ACKNOWLEDGMENTS

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