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Research of Current Issues & Preliminary Sensitivity Analysis of Level 3 PSA

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1. Introduction

The technique of assessing an off-site radiation effect quantitatively is required because the interest in off-site consequence analysis has been increased after the Fukushima accident.

Therefore, in order to use Level 3 PSA(L3 PSA) in Korea, methods of calculating MACCS(MELCOR Accident Consequence Code System) code to be adequate for domestic circumstances in Korea were investigated.

2. Methods and Results

In this study, solutions to current issues that are expected from using MACCS code in Korea were researched. Furthermore, the preliminary sensitivity analyses of the major issues were carried out.

2.1 Selection of current issues

To select current issues for L3 PSA, focusing on MACCS code which has been used for the offsite consequence analysis of severe reactor accidents in Korea, limitations of using this code and the propriety of input parameters were reviewed.

The U.S. Nuclear Regulatory Commission (NRC) conducted the State-of-the-Art Reactor Consequence Analyses (SOARCA) project for the Peach bottom atomic power station and the Surry power station. The SOARCA project researched best practices and key modeling improvements for MACCS code.

Key current issues were selected by comparing input parameters of SOARCA project and Sample Problem A provided with MACCS2 v1.12 and by reviewing previous studies related to both L3 PSA and MACCS code.

The key issues selected in this study are similar with issues which were suggested from the SOARCA(State-of-the-Art Reactor Consequence Analysis) project.[1]

2.2 Solutions to current issues

Current issues investigated in this study are as follows. Dispersion parameters, mixing height, plume rise effect, surface roughness, deposition model, source term, dose conversion factors, health effects, protective actions, and shielding factors were selected as the main current issues.

Issues of dispersion parameters, mixing height, plume rise effect, surface roughness, and deposition model are related to the atmospheric dispersion model of MACCS code.

In general, the Gaussian plume model has been used to model atmospheric dispersions in reactor accident risk assessments. The size of a Gaussian plume in the vertical and crosswind directions is determined by dispersion parameters. The vertical dispersion parameter is corrected by surface roughness, while the crosswind dispersion parameter is corrected by lateral meander. Additionally, these two dispersion parameters are corrected by downwind effect [2]. Thus, these dispersion parameters can be calculated by applying surface roughness, lateral meander and downwind effect, reflecting domestic circumstances in Korea. A surface roughness of 10 cm has been used in the U.S. [1]. Unlike the U.S., most of nuclear power plant sites in Korea are covered with forests and buildings. Thus, if the topographical characteristics of Korea are considered in MACCS, the higher value than 10 cm should be applied.

Mixing heights for atmospheric dispersion model is the top of the well-mixed atmospheric layer. Unlike the case of sample problem A which used seasonal afternoon mixing data, the SOARCA project used diurnal (morning and afternoon) seasonal mixing heights. Diurnal mixing height variation should be considered in order to improve the reliability of analysis because morning and afternoon mixing heights are quite different. The seasonal morning(minimum) and afternoon(maximum) mixing heights are described in the FSAR(Final Safety Analysis Report) in Korea. Thus, these values of mixing heights in the FSAR of target plant can be used in MACCS code.

Meanwhile, to solve issues of deposition model and plume rise effect, input parameters related to these issues should be obtained by using other code programs. The MELMACCS which provides an interface utility between MELCOR and MACCS is used to determine the particle size distribution data for dry deposition velocity. In order to estimate the plume rise effect based on the mass rate of release and the density of the plume, radioactive release should be calculated by using MELCOR code. Also, MELCOR results should be converted into MACCS input values by using MELMACCS program [3].

Information about source term should be also obtained from the results of MELCOR or MAAP [4, 5]. Core inventory is usually calculated by ORIGEN, core release fraction is calculated by MELCOR or MAAP. As described above, the MELMACCS converting MELCOR results into MACCS input values should be used.

Issues of dose conversion factors (DCFs) and health effects can be solved by considering using the recent data. The SOARCA project used DCFs described in FGR-13, based on ICRP 60 [1]. Meanwhile, cancer risk factors based on BEIR V were used in the SOARCA project. In 2009, the NRC released the BEIR VII [1]. Therefore, it is needed to investigate the possibility of application of the recent BEIR VII report.

Issues of protective actions and shielding factors can be solved by applying factors reflecting domestic circumstances in Korea. The network evacuation model used in SOARCA can be applied to MACCS calculation by using road networks and evacuation pathways described in radiation emergency plan in Korea.

Shielding factors are determined by building types, residential distribution, the proportion of time spent on indoors and outdoors and so on. Therefore, shielding factors set by reflecting circumstances of the U.S. are not appropriate for MACCS calculation in Korea. It is needed to set shielding factors by utilizing statistical data of residential distribution and the fraction of time the public spends in Korea.

2.3 Preliminary Sensitivity Analysis

The preliminary sensitivity analyses of the surface roughness, shielding factors, and deposition model were performed with changing input parameters related to these issues. MACCS2 v1.12 code was applied to the analysis by using input files of sample problem A. Results of the analyses are shown in Table I.

In case of surface roughness, considering the topographical characteristics of Korea, the higher value than 10 cm which is the default value should be applied to MACCS calculation in Korea. Thus, the sensitivity analysis of the surface roughness was performed by using the value of 100 cm. As a result of applying surface roughness multiplied by ten times, the number of fatalities was decreased regardless of distance from the nuclear power plants (NPPs). Especially, the number of early fatalities for source term 1 within a 16.1 km radius of the NPPs was greatly decreased about 47%. Because the result of calculation is different according to surface roughness, the surface roughness should be set appropriately.

Secondary, the sensitivity analysis of the deposition model was performed. Because the particle size distribution data for dry deposition velocity cannot be identified, the parameters only for wet deposition were changed to those of SOARCA. As a result, the change of wet deposition parameters made little difference to the result since there was a little change in wet deposition parameters

Lastly, the change in shielding factors made quite an influence on the results because shielding factors are used as multipliers on the doses. It is important to set shielding factors properly since these factors are directly proportional to the doses.

3. Conclusions

If L3 PSA is performed in Korea, it will be possible to raise many issues. Thus, in this study, key current issues came from research on previous studies related to L3 PSA.

L3 PSA has been carried out by using MACCS code in Korea on a trial basis. Since MACCS code is based on the U.S., input parameters and the scope of analysis were set by considering circumstances of the U.S. For this reason, by focusing on solutions to current issues, the method for reflecting circumstances of Korea in L3 PSA was investigated. It is also required to find out methods for decreasing uncertainty of L3 PSA in Korea.

REFERENCES

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Table I: The result of preliminary sensitivity analysis

	Distance from NPPs	Health effect cases	Sample Problem A	Surface roughness		Wet deposition		Shielding factors	
				100 cm	Rate of change (%)	SOARCA	Rate of change (%)	SOARCA	Rate of change (%)
Source term 1	0-80.5	Cancer fatalities	1.72E+03	1.64E+03	-4.65	1.73E+03	0.58	1.67E+03	-2.91
	0-16.1	Early fatalities	1.34E+01	7.10E+00	-47.01	1.33E+01	-0.75	1.24E+01	-7.46
	0-16.1	Cancer fatalities	3.87E+02	3.22E+02	-16.80	3.86E+02	-0.26	3.83E+02	-1.03

	Distance from NPPs	Health effect cases	Sample Problem A	Surface roughness		Wet deposition		Shielding factors	
				100 cm	Rate of change (%)	SOARCA	Rate of change (%)	SOARCA	Rate of change (%)
Source term 2	0-80.5	Cancer fatalities	4.68E+02	4.67E+02	-0.21	4.72E+02	0.85	4.31E+02	-7.91
	0-16.1	Early fatalities	4.54E-03	3.92E-03	-13.66	4.32E-03	-3.85	2.86E-03	-37.00
	0-16.1	Cancer fatalities	7.22E+01	6.33E+01	-12.33	7.16E+01	-0.83	7.08E+01	-1.94