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3-D Look-Up Table for Multi-Unit Accidents Assessment

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1. Introduction

In Korea, several nuclear power plants are located close in one site, so it is necessary to evaluate the multi-unit site risk. However, since different types of plants are constructed on one site, it is difficult to carry out the safety assessment of multi-unit site. The number of scenarios to be evaluated tends to increase sharply as the number of plants increases in performing probabilistic safety assessments of sites. This is because the source term category(STC) of each unit must be combined.

Therefore, the grouping methodology was used for multi-unit accident probability safety assessment. The grouping methodology is a method of reducing the number of scenarios that are ultimately evaluated by grouping STCs with similar characteristics and evaluating them[1].

Recently KAERI(Korea Atomic Energy Research Institute) has proposed the look-up table methodology for evaluating the safety of multi-unit site. This is a method of evaluating the health effect of an accident by converting the characteristics of the emitted radioactive material and the STC information of the power plant to be evaluated into a coefficient[2]. In this study, Look-up table was constructed to evaluate multiple simultaneous accidents of any site with four different reactors (R1, R2, R3, R4) with three different reactor types (M1, M2, M3).

2. Methods and Results

2.1 Look-Up Table

To evaluate the damage (health effect) of the public caused by the nuclear power plant accident, it is necessary to understand the characteristics of the source term. However, due to the variety of radioactive materials, the diversity of pathways, the complexity of the process and the behavior of radioactive materials, it is difficult to evaluate the characteristics of the source term. So KAERI made a look-up table for evaluating relative impact of each source term[3].

The Look-Up Table is a way to create a table of consequence of accident using quantified traits and to find an appropriate consequence when evaluating the multi-unit accident.

2.2 Assumption

In this study, Look-up table was constructed to evaluate multiple simultaneous accidents of any site with four different reactors (R1, R2, R3, R4) with three different reactor types (M1, M2, M3).

Table I: Reactor Types and Thermal Power of Each Reactor

Reactor	Reactor Type	Thermal Power (MW_{th})
R1	M1	1876
R2	M2	2900
R3	M3	2815
R4	M3	2815

Early health effects were assessed, and organs to represent the health effects of each period were selected as red bone marrow, respectively, with reference to the KAERI's report. The pathway of the exposure was considered cloud shine, ground shine, and acute inhalation. In case of DCF, FGR-13 selected as domestic regulatory standard was used. The nuclides considered 69 nuclides considered in the WinMACCS. Emergency response was not considered.

2.3 Calculation of Conversion Factor

According to the MACCS model description, the early health effects on the release of radioactive material were calculated as in equation (1). The health effects of each nuclide were assessed using doses from specific substances[4].

$$D_{acute} = DCF_{air} \times C_{air} + DCF_g \cdot C_g + DCF_{inhal} \cdot C_{inhal} \quad (1)$$

$$C_{air} = \frac{(1-\frac{1}{2}f)}{\sqrt{2\pi}\cdot\bar{\sigma_y}\cdot\bar{\sigma_z}\cdot\bar{u}} \quad (2)$$

$$C_g = \frac{f(\frac{\Delta T}{2}+\frac{1-e^{-\lambda_e(8hr-\Delta T)}}{\lambda_e}}{\sqrt{2\pi}\cdot\bar{\sigma_y}\cdot L_k} \quad (3)$$

$$C_{inhal} = V_{breath}\cdot\frac{\left(1-\frac{1}{2}f\right)}{\sqrt{2\pi}\cdot\bar{\sigma_y}\cdot\bar{\sigma_z}\cdot\bar{u}}\cdot\exp(-\frac{H^2}{2\sigma_z^2}) \quad (4)$$

Where f is deposition rate of radioactive material in cloud, $\bar{u}$ is average wind speed, $\bar{\sigma}$ is average dispersion parameter, ΔT is deposition time, and H is release altitude.

To reflect the difference in health effects according to the nuclides, the impact factor for health effects was calculated as follows. The early exposure dose of each nuclide is divided by the early exposure dose of the representative nuclide, so that the difference in the health effect is confirmed when the same pollution concentration is obtained. Representative nuclides were designated as Cs-137 and I-131. This is because the two nuclear species have the greatest influence on the early and late effects, respectively.

In this study, the multi-unit accidents with different reactor types were considered. If the reactor type is different, the core inventory varies according to each type. Therefore, it is necessary to select a standard type. The standard type was selected as M1. Equation (5) should be used to find the conversion factor for each reactor nuclide.

$$F = \sum \frac{D_{acute,n}}{D_{acute,s}} \times \frac{I_n}{I_s} \quad (5)$$

Where F is Equivalent Conversion Factor, n is nuclides to be evaluated, s is reference nuclide, and I is core inventory

Table II shows equivalent conversion factors of each nuclide group of R1.

Table II: Equivalent Conversion Factors of each group of R1

group name	Equivalent Conversion Factor	
	Cs-137	I-137
Xe	20.5	4.5
Cs	11.6	2.5
Ba	102.4	22.4
I	151.6	33.2
Te	18.3	4.0
Ru	24.7	5.4
Mo	46.3	10.1
Ce	89.5	19.6
La	131.7	28.9

2.4 3-Dimension Look-Up Table

Each axis in the Look-Up Table refers to the amount of radioactive material released in the early, intermediate, and late time. The standard of each time base was 24 hours and 48 hours, as the cumulative release amount of 72 hours was usually evaluated. This value is based on the criteria used to construct the 2-D look-up table in KAERI's report. MELCOR and MelMACCS can be used to obtain the emission fraction per hour for each accident scenario. The release fraction of plum segment at each time interval was calculated. The calculated emission fraction and the equivalent conversion factor of the nuclide group were multiplied to calculate the index of STC for each reactor. The STC index of R1 is shown in Table III.

Table III: Equivalent Conversion Factors of each group of R1

STC	Cs-137		
	early	intermediate	late
1	1.49×10^{-5}	0.00	3.39×10^{-5}
2	1.70×10^{-4}	0.00	1.56×10^{-4}
3	1.59×10^{-1}	3.89×10^{-2}	5.78×10^{-3}
4	0.00	0.00	6.28×10^{-2}
5	0.00	1.07×10^{-1}	8.53×10^{-3}
6	0.00	9.11×10^{-2}	2.12×10^{-3}
7	0.00	0.00	1.11×10^{-1}
8	0.00	0.00	1.47×10^{-1}
9	2.45×10^{-1}	2.94×10^{-2}	1.59×10^{-3}
10	9.63×10^{-2}	0.00	1.35×10^{-2}
11	1.98×10^{-1}	0.00	1.05×10^{-3}
12	1.00	9.86×10^{-3}	4.66×10^{-3}
13	4.15×10^{-3}	3.46×10^{-1}	0.00

2.5 Calculation of Consequence In Look-Up Table

If the indexes of the early, intermediate, and final periods for the STC of each power plant were obtained, you can obtain the coordinates of the types (early, intermediate, late) by adding the indexes of the reactors where the accident occurred. If the consequence corresponding to the coordinates in the look-up table is known, the effect of the public on the accident combination can be calculated.

There are two ways to determine the consequence of each point in the process of constructing the look-up table. The first method calculates all the accident scenarios matched to the point and selects the most appropriate one of them. The second method assumes one accident scenario that can represent the point and uses the result value. Although the accuracy of the first method is expected to be higher, it takes a long time to calculate all the accident scenarios, so the second method is used in this study.

Since the released radioactive material has different characteristics according to the accident scenarios, it is necessary to adjust the input values in an appropriate way to create representative scenarios for using second method. There are three ways to determine the input value: first, using the simple average of each scenario; second, using the heat output weighted average; and third, choosing the most conservative value. The consequence of the look-up table can be calculated using these three methods.

3. Conclusions

In this study, the look-up table methodology that can reduce time and man power in evaluating the health effect of multi-unit accident was studied. First, Look-Up Table was constructed to evaluate the early health effects of four reactors with different reactor types.

Using the look-up table, it is not necessary to simulate all the scenarios for each accident, and knowing the amount released in each time range has the advantage of predicting the health effects on it. In addition, this table can be used to identify the trends and changes in health effects depending on the amount of radioactive material released during the early, intermediate, late periods. However, due to the characteristic of the look-up table that selects and uses representative values for a single cell, uncertainty is high compared to evaluating all the accident scenarios and evaluating the consequence. Therefore, the user should pay attention to calculating and utilizing the consequence corresponding to each cell of the look-up table.

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