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Various Spatial Grid Settings for Effective Offsite Consequence Analysis

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1. Introduction

The speed of analysis is very important because a huge amount of calculations is required to deal with all the scenarios for a single-unit or multi-unit Level 3 PSA. Therefore, the speed of analysis is highly emphasized.

Some factors such as spatial grids, plume segments, and particle size distribution have flexible input formats and users can control both the number and value of parameters, while others related to washout coefficient or scaling factor for dispersion have a rigid format and fixed number of parameters. This flexibility may affect the accuracy of the results and speed of analysis depending on how they are set.

Korea Atomic Energy Research Institute is conducting research on optimizing the analysis model to perform efficient offsite consequence analysis. As part of this, a plume segmentation optimization methodology was developed to reduce analysis time by as much as 55% while maintaining the accuracy of analysis results [1, 2]. Furthermore, research is continuously being conducted to evaluate the impact of other input factors, such as particle size distribution setting [3, 4] and spatial grid setting, on analysis results and speed.

Fine setting by splitting spatial grids is expected to enhance the accuracy of analysis, whereas it can take a long running time for each analysis. Spatial grid setting is a way to represent spatial grid data of polar coordinates by dividing it into various radii.

In this study, various divisions of spatial grids are defined and the strategy of sensitivity analysis is established.

2. Spatial Grid Settings

2.1 Spatial Grid

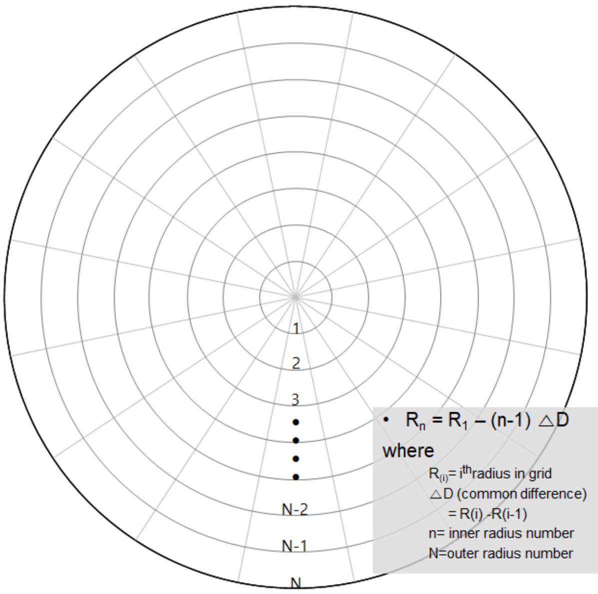
In the event of an offsite accident at a nuclear power plant, the most rapid environmental transport pathway of radioactive material that can affect many residents over a wide area is diffusion and deposition in the atmosphere. The accident source in the offsite consequence analysis becomes the reference point for atmospheric diffusion and deposition, and it is necessary to establish a spatial grid to calculate diffusion and deposition based on this point.

In this study, the MACCS code [5] was used for offsite consequence analysis. MACCS uses a polar coordinate spatial grid system to represent the region surrounded by the nuclear power plants. The plant is located at the center point of the polar coordinate system (r=0). The polar coordinates of MACCS allow up to 35 radial rings and 64 compass sectors, but in this study, 30 radii and 16 directional sectors were set as the base case.

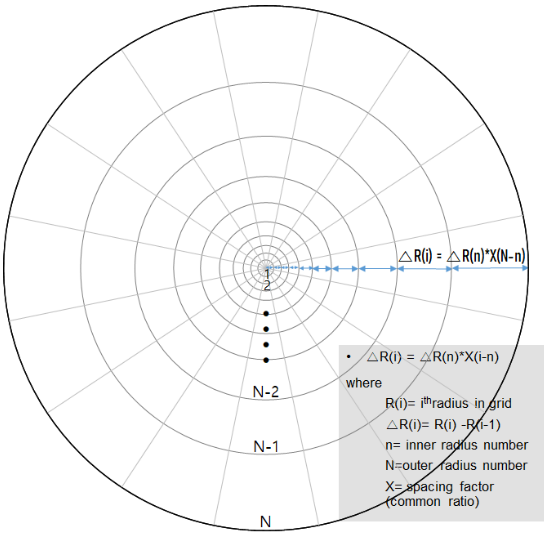
The reason for setting 30 radial rings is to set the maximum distance of the UPZ (Urgent Protective Action Planning Zone), 30 kilometers, to be uniformly spaced. UPZ is a zone where residents take action (e.g., sheltering) based on the emergency action level and its maximum range is 30 km. In addition, in order to evaluate the near-field sensitivity by grid setting, 30 radial rings were applied for a 5 km range of PAZ (Precautionary Action Zone).

2.2 Various grid settings

For various spatial grid settings, arithmetic sequence and geometric sequence used in this study. Fig. 1 illustrates the concepts of spatial grid setting using arithmetic sequence and geometric sequence.



(a) Spatial grid (Arithmetic Sequence)



(b) Spatial grid (Geometric Sequence)

Fig. 1. The concept of spatial grid setting

Arithmetic sequence means that the analysis range is divided into equal intervals, as shown in (a) in Fig. 1, with equal spacing between each ring. Geometric sequence divides the spacing between the rings based on the product of a certain ratio, as shown in (b) in Fig. 1, with wider spacing as the distance from the source increases. This method of analysis reflects the dilution of diffuse and deposited concentrations as the radioactive material moves away from the source of the accident.

3. Variation on spatial grid settings

3.1 Spatial grid settings for far-field (UPZ)

For spatial grid settings for UPZ, we set the analysis range (distance), analysis direction, and spatial grid as follows.

- Analysis range: 30 km
- Angular direction: 16
- Number of radial rings: 30
- Grid setting: Arithmetic Sequence and Geometric Sequence

Table 1 shows examples of spatial grid settings for far-field using arithmetic sequence and geometric sequence used in this study. The arithmetic sequence is shown for the base case of setting radial spatial elements of 30 with a spacing of 1 kilometer in each ring for a maximum analysis distance of 30 kilometers, followed by the case of setting the spacing to 2 kilometers and the case of setting the spacing to 3 kilometers. The geometric sequence also shows the distance of each ring when the ratio is set to 1.25, 1.5, 1.75, and 2, respectively.

Table 1. Example of Spatial grid settings (for far-field)

Arithmetic Sequence				Geometric Sequence				
Grid #	Radius (km)			Radius (km)				
	Delta (1)	2	3	Delta (1)	1.25	1.5	1.75	2
1	1.00	2.00	3.00	1.00	1.00	1.00	1.00	1.00
2	2.00	4.00	6.00	2.00	1.25	1.50	1.75	2.00
3	3.00	6.00	9.00	3.00	1.56	2.25	3.06	4.00
4	4.00	8.00	12.00	4.00	1.95	3.38	5.36	8.00
5	5.00	10.00	15.00	5.00	2.44	5.06	9.38	16.00
6	6.00	12.00	18.00	6.00	3.05	7.59	16.41	32.00
7	7.00	14.00	21.00	7.00	3.81	11.39	28.72	
8	8.00	16.00	24.00	8.00	4.77	17.09	50.27	
9	9.00	18.00	27.00	9.00	5.96	25.63		
10	10.00	20.00	30.00	10.00	7.45	38.44		
11	11.00	22.00		11.00	9.31			
12	12.00	24.00		12.00	11.64			
13	13.00	26.00		13.00	14.55			
14	14.00	28.00		14.00	18.19			
15	15.00	30.00		15.00	22.74			
16	16.00			16.00	28.42			
17	17.00			17.00	35.53			
18	18.00			18.00				
19	19.00			19.00				
20	20.00			20.00				
21	21.00			21.00				
22	22.00			22.00				
23	23.00			23.00				
24	24.00			24.00				
25	25.00			25.00				
26	26.00			26.00				
27	27.00			27.00				
28	28.00			28.00				
29	29.00			29.00				
30	30.00			30.00				

3.2 Spatial grid settings for near-field (PAZ)

For spatial grid settings for PAZ, we set the analysis range (distance), analysis direction, and spatial grid as follows.

- Analysis range: 5 km
- Angular direction: 16
- Number of radial rings: 30
- Grid setting: Arithmetic Sequence and Geometric Sequence

Table 2 shows examples of spatial grid settings for near-field using arithmetic sequence and geometric sequence used in this study. The arithmetic sequence is shown for the base case of setting radial spatial elements of 30 with a spacing of 0.1 kilometer in each ring for a maximum analysis distance of 5 kilometers, followed by the case of setting the spacing to 0.2 kilometers and the case of setting the spacing to 0.3 kilometers. The geometric sequence also shows the distance of each ring when the ratio is set to 1.25, 1.5, 1.75, and 2, respectively.

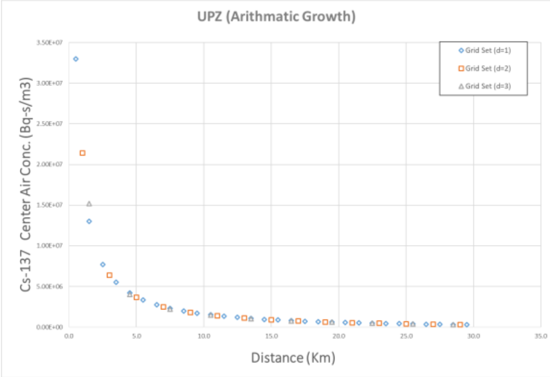
Table 2. Example of Spatial grid settings (for near-field)

Grid #	Arithmetic Sequence			Geometric Sequence				
	Radius (km)			Radius (km)				
	Delta (1)	2	3	Delta (1)	1.25	1.5	1.75	2
1	0.17	0.33	0.50	0.17	0.17	0.17	0.17	0.17
2	0.33	0.67	1.00	0.33	0.21	0.25	0.29	0.33
3	0.50	1.00	1.50	0.50	0.26	0.38	0.51	0.67
4	0.67	1.33	2.00	0.67	0.33	0.56	0.89	1.33
5	0.83	1.67	2.50	0.83	0.41	0.84	1.56	2.67
6	1.00	2.00	3.00	1.00	0.51	1.27	2.74	5.33
7	1.17	2.33	3.50	1.17	0.64	1.90	4.79	
8	1.33	2.67	4.00	1.33	0.79	2.85		
9	1.50	3.00	4.50	1.50	0.99	4.27		
10	1.67	3.33	5.00	1.67	1.24	6.41		
11	1.83	3.67		1.83	1.55			
12	2.00	4.00		2.00	1.94			
13	2.17	4.33		2.17	2.43			
14	2.33	4.67		2.33	3.03			
15	2.50	5.00		2.50	3.79			
16	2.67			2.67	4.74			
17	2.83			2.83				
18	3.00			3.00				
19	3.17			3.17				
20	3.33			3.33				
21	3.50			3.50				
22	3.67			3.67				
23	3.83			3.83				
24	4.00			4.00				
25	4.17			4.17				
26	4.33			4.33				
27	4.50			4.50				
28	4.67			4.67				
29	4.83			4.83				
30	5.00			5.00				

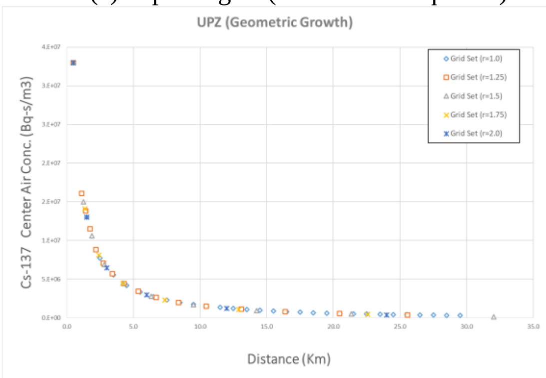
4. Impact of spatial grid settings

An impact analysis of offsite consequences was performed on the spatial grid settings by the arithmetic sequence and geometric sequence suggested in this study. Both far-field (UPZ) and near-field (PAZ) sensitivity analyses were conducted and the results were represented in Fig. 2 and Fig. 3.

Fig. 2 depicts the UPZ analysis results of spatial grid setting by arithmetic sequence and geometric sequence. As seen in Fig. 2 (a), the Cs-137 concentration results of grid sets 2 and 3 are on the result line of grid set 1 (base case) for arithmetic growth. Likewise in the case of geometric growth, in Fig. 2 (b), the grid sets 2, 3, and 4 have accurate results compared to the base case as well.

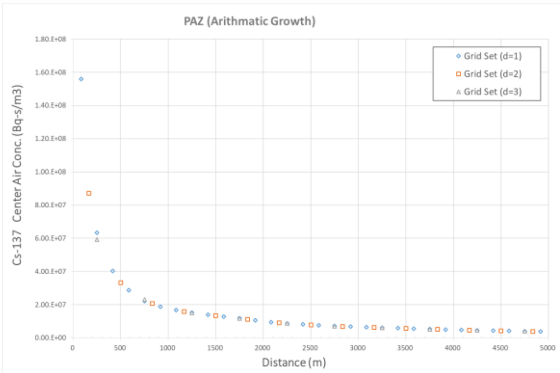


(a) Spatial grid (Arithmetic Sequence)

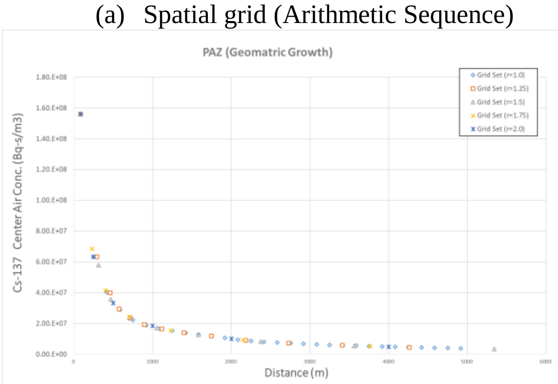


(b) Results of spatial grid setting (Geometric Sequence)

Fig. 2. Impact of spatial grid settings (UPZ)



(a) Spatial grid (Arithmetic Sequence)



(a) Spatial grid (Geometric Sequence)

Fig. 3. Impact of spatial grid settings (PAZ)

The results of PAZ analysis, as seen in Fig. 3, also have a similar aspect to the results of UPZ analysis. The results of impact analysis show that spatial grid settings using arithmetic growth and geometric growth do not affect the results of accuracy for ground-level air concentration. However, dose and health effect results should be different between fine gridded case and coarse gridded case since dose and health effect of each grid are calculated by concentration of corresponding grid regardless of the size of grid. Concentration of each grid is represented by midpoint concentration. Therefore, concentration of coarse grid is representing relative wide range of grid compared to fine gridded case. Accordingly, there would be result differences when dose and health effect are calculated for fine gridded case and coarse gridded case. It should be investigated in further studies.

5. Conclusions

In this study, various divisions of spatial grids are defined and their influences on the result accuracy of offsite consequence analysis were investigated. Various numerical sequences such as arithmetic sequence and geometric sequence, etc., are applied to set the radius of the polar coordinate of spatial gird to evaluate influences on the accuracy of analysis compared to the best estimate case. Other grid analyses may include logarithmic spacing, grid settings using Fibonacci and natural logarithms, etc., but these were excluded in this study. It is expected that the insight gained from this study can be used in the optimization study of spatial grid setting as a further work.

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