Development of A Risk Assessment Methodology and An Application

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1. Introduction

Probabilistic Safety Assessment (PSA) is consists of three types of analysis, level 1, 2 and 3 PSA. Level 1 PSA estimates core damage frequency and Level 2 PSA estimates large early release frequency. Finally, effect of released radioactive materials to environment is evaluated in level 3 PSA. Level 1 and 2 PSA are performed for domestic nuclear power plants. But level 3 PSA is not conducted yet except constructing plant Shin-Kori Unit 3,4. For this reason, domestic Level 3 PSA is in low level at this time. But domestic Level 3 PSA level is expected to be improved by developing some methodologies. For instance, Shin-Kori Level 3 PSA, which used constant value of evacuation speed for risk assessment, is expected to be improved by applying fluctuation of evacuation speed depending on weather conditions.

In this paper, a methodology about how to reflect and apply relationship between evacuation speed and weather condition is introduced.

2. Methods and Results

In this section influence of evacuation speed to public risk and method about application of fluctuation of evacuation speed is described.

2.1 Sensitivity Analysis of Evacuation Speed

In emergency state, people reside in Emergency Planning Zone (EPZ) have to escape to outer region. This kind of action is the evacuation in emergency state.

Evacuation speed depends on traffic and weather conditions. Especially, weather condition highly affect to evacuation speed. So, evacuation speed is separated depending on weather condition at Emergency Plan of Nuclear License. In addition, weather capacity factors are applied to evacuation speed at NUREG/CR-7002 in this reason.

As shown above, Evacuation speed is assumed constant in Shin-Kori 3,4 level 3 PSA. But according to Hanul 5,6 Emergency Plan of Nuclear License, evacuation speed is 40~50km/hour in normal weather condition and 20~25km/hour in severe weather condition assuming that evacuation is performed by vehicles.

Evacuation speed can be slowed by some reasons. Confusion in emergency state, traffic jam, unexpected severe weather, etc. can cause slowed evacuation speed.

In this section, sensitivity analysis for evacuation speed is conducted to confirm influence of evacuation speed for early fatality and cancer fatality.

Followings are Assumptions for sensitivity analysis.

- Reference nuclear power plant is Hanul Unit 5&6
- Evacuation is performed in 10km radial region from Hanul Unit 5&6 (EPZ area)
- Radioactive material inventory data refer Hanul 5&6 level 2 PSA report.
- Hanul 5&6 level 2 PSA report is referred for inventory of Radioactive material data
- 2009 Ul-Chin Weather data is used.
- Evacuation speed depends on only weather condition. (Because evacuation speed is specified only by weather condition at Hannul 5,6 Emergency Plan of Nuclear License)

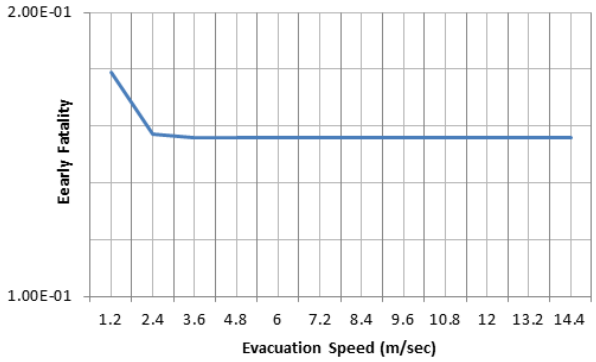

Figure 1. Early Fatality per Evacuation Speed

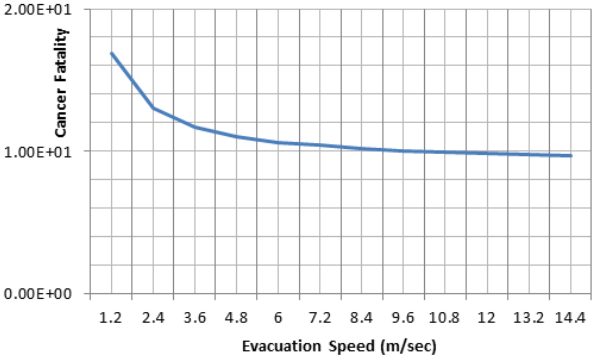

Figure 2. Cancer Fatality per Evacuation Speed

Above Graph shows early fatality and cancer fatality in 1.6km radial region. From the result of sensitivity analysis, early fatality shows remarkable difference

when evacuation speed reach 1.2m/s to 2.4m/s. But no noticeable change is shown when evacuation speed is faster than 2.4m/sec. On the other hand, cancer fatality is decrease steadily although slope becomes gentle more and more.

This result shows that evacuation speed influence to plant surrounding residents especially when speed is slow.

As referred above, evacuation speed highly depend on the weather conditions. Decision methodology of evacuation speed considering weather condition will be described at next section.

2.2 Decision of Evacuation Speed

Evacuation speed is specified to be 40~50km/hour at normal weather condition and 25~30km at severe weather condition in Hanul Unit 5&6 Radiological Emergency Plan of Nuclear License. But it is not described how to classify normal or severe weather. So, classification standards should be established.

In this paper, evacuation speed is classified considering wind speed and rain rate. Evacuation Speeds are determined assuming weather is in severe states when rain rate and wind speed exceed 10mm/hour and 15m/sec(Average wind speed and rain rate when Ul-Chin is suffer from typoon) respectively. Minimum speed is allocated at severe condition and maximum speed is allocated when rain rate is below 5mm/sec and wind speed is below 10m/sec (ordinary weather condition in Ul-Chin). Classification is performed qualitatively except assumption of severe and normal condition. Classification standards for evacuation speed are shown at below table.

Table 1. Evacuation Speed per wind speed and rain rate

Rain Rate (mm/hour) / Wind Speed (m/sec)	0 ~ 5	5 ~ 10	Above 10
0 ~ 10	50 km/hour	40 km/hour	30 km/hour
10 ~ 15	40 km/hour	30 km/hour	25 km/hour
Above 15	30 km/hour	25 km/hour	20 km/hour

Evacuation speed is not affected by wind speed and weather when they are not remarkable. If rain rate and wind speed exceed 5mm/hour and 10m/sec respectively, it can cause slowed transport speed. Although rain rate and wind speed give effect to transport speed, the influence expected to be small when they are no remarkable. So, I assigned evacuation speed in this weather condition as 40km/hour, which is the minimum evacuation speed in normal weather condition.

When both rain rate and wind speed exceed 5mm/sec and 10m/sec respectively, not only slowed evacuation speed but also delay of transport preparation can be caused. For this reason, I assign 30km/hour evacuation speed assuming that weather is in severe statement in this condition.

If Rain rate exceeds 10mm/hour or wind speed exceeds 15m/sec, it can be considered as severe weather condition and evacuation speed would be fairly slowed compared to above condition. So, minimum evacuation speed in severe weather condition is assigned in this condition.

When both rain rate and wind speed exceed 10mm/hour and 15m/sec respectively, extreme traffic condition and confusion of public will be happened. These causes can slow evacuation speed quitely. In this reason, evacuation speed is assigned as 20km/hour in this weather condition.

Considering above classification standard, I analyzed 2009 Ul-Chin weather data to estimate occurrence frequency for each weather conditions. Occurrence Rates of each Weather conditions are described at below table.

Table 2. Occurrence rate of each Weather conditions

Rain Rate (mm/hour) / Wind Speed (m/sec)	0 ~ 5	5 ~ 10	Above 10
0 ~ 10	90.87%	7.21%	0.08%
10 ~ 15	1.53%	0.01%	0.01%
Above 15	0.29%	0.00%	0.00%

2.3 Calculation Result

Calculation is performed by MACCS2 code. Evacuation inputs are consists of five scenarios and specific evacuation speeds are assigned to each scenario. Assumptions is same with which used in sensitivity analysis.

Calculated result is compared with some result using constant evacuation speed. There are no significant differences in early fatality. But some difference in cancer fatality is founded.

Graph shown below shows distribution of cancer fatality in 0~1.6km radial region for each evacuation speeds.

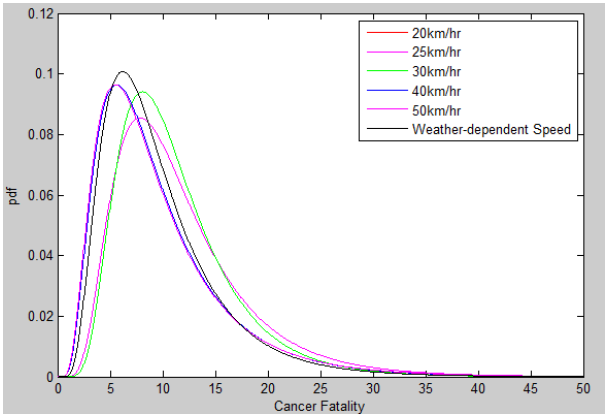

Figure 2. Distribution of Cancer Fatality per Evacuation Speed

From above graph, it is confirmed that curve which adapting evacuation speed for some cases of weather

conditions shows sharper figure. This means that result is more reliable.

Peak of weather-dependent speed curve is expected to be formed near the peak of 50km/hour curve because 50km/hour evacuation speed shows most frequent occurrence rate. It is confirmed that peak of weather-dependent speed curve is formed between 50km/sec peak and 40km/sec peak as expected.

3. Conclusion

In this paper, a methodology which not using constant evacuation speeds but flexible speeds which depend on weather conditions are suggested. Evacuation speeds for each weather conditions are normally assumed in this paper. It is expected that this methodology can be improved if relationship between weather condition and evacuation are researched more.

REFERENCES

[1] KHNP, Hanul 5,6 Radiological Emergency Plan of Nuclear License Rev 16.
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