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Development of A Methodology for Assessing Various Accident Management Strategies Using Decision Tree Models

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1. Introduction

Severe accident refers to an event causing significant damage to reactor core beyond design basis accident. This accident is unlikely to occur at a nuclear power plant. But in case of severe accident, the social and economic effects could be serious. Therefore, it is necessary to take a severe accident countermeasures that can be applied in order to minimize a public risk of a severe accident and an occurrence probability of a severe accident in nuclear power plants [1]. According to Korea Institute of Nuclear Safety regulation guideline chapter 16, a deterministic or a probabilistic assessment is necessary when establishing a severe accident management plan [2, 3]. The methodology for assessing severe accident management strategies has been required for assessing accident management strategies in the SAMG.

2. Methods and Results

2.1 Reference Plant and Strategies

In this study, Hanul unit 5&6 was selected as a reference plant. A reactor cavity flooding strategy and a filtered containment venting strategy were selected as reference accident management strategies. A reactor cavity flooding strategy supplies cooling water in the reactor cavity to prevent damage of a Reactor Pressure Vessel (RPV). A filtered containment venting strategy expels noncondensable gas and vapor to the outside of a containment through a Filtered Containment Venting System (FCVS) to prevent damage of a containment. FCVS can capture almost the whole radionuclides excluding noble gas [4].

2.2 An Accident Scenario

Station Blackout (SBO) was selected as an accident scenario to apply accident management strategies.

2.3 Methodology

Decision making theory was adopted to solve decision making problems of multiple accident management. The theory is about how the best alternative can be chosen in an uncertain situation [6].

Decision tree is universally used in the theory. It is an effective tool suggesting optimum scenario, because it can show side effects, realizability, and effectiveness of alternatives. Also, its quantification algorithm is composed of simple multiplication and sum [7].

2.4 Plant Damage States

Plant Damage State (PDS) concept was adopted since not all SBO accident sequences can be considered.

To group the core damage accident sequences systematically, PDS grouping logic diagram was used.

Seven types of PDSs were evaluated. PDS frequencies were calculated by using a reference plant's level 2 PSA model. The result is shown in the figure 1 [5].

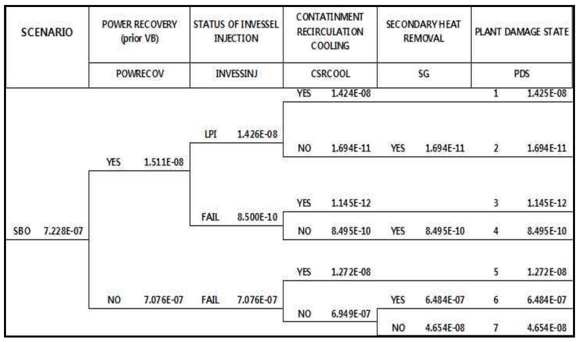


Fig. 1. Plant damage state grouping logic diagram.

The assumption of PDS 1, 3, 5 was that a reactor cavity is always flooding, because a Containment Spray System (CSS) will be available in this cases since the offsite power recovered after RPV fails. Even if the offsite power didn't recovered, a CSS will be still available by using a fire protection system branch arm piping [9]. In all cases of PDSs, we assumed that a FCVS is available since the system is independent.

2.5 Multiple Decision Tree Model

To model a multiple decision tree about the selected accident management strategies and the scenario, Containment Event Tree (CET) and Decomposition Event Tree (DET) of the Hanul unit 5&6 Level 2 PSA were analyzed [5].

In this study, the containment failure mode was classified into four categories; NO Containment Failure (NO CF), Early Containment Failure (ECF), Latent Containment Failure (LCF), and Steam Generator Tube Rupture (SGTR) [5].

Heading probabilities were determined by the severe accident analysis results of the Surry nuclear power plant, which is a pressurized water reactor, in the US and the assumptions of the Hanul unit 5&6 PSA [11].

In the case of the pre-installation systems and independent systems, calculated unavailabilities by making the Fault Trees (FTs) were used as heading probabilities [5, 8, 10].

The developed multiple decision tree is shown in the figure 2. D1 meant a reactor cavity flooding strategy, and D2 meant a filtered containment venting strategy. The developed decision tree for a filtered containment venting strategy is shown in the figure 3. The model was separated since it was large to show at the same time.

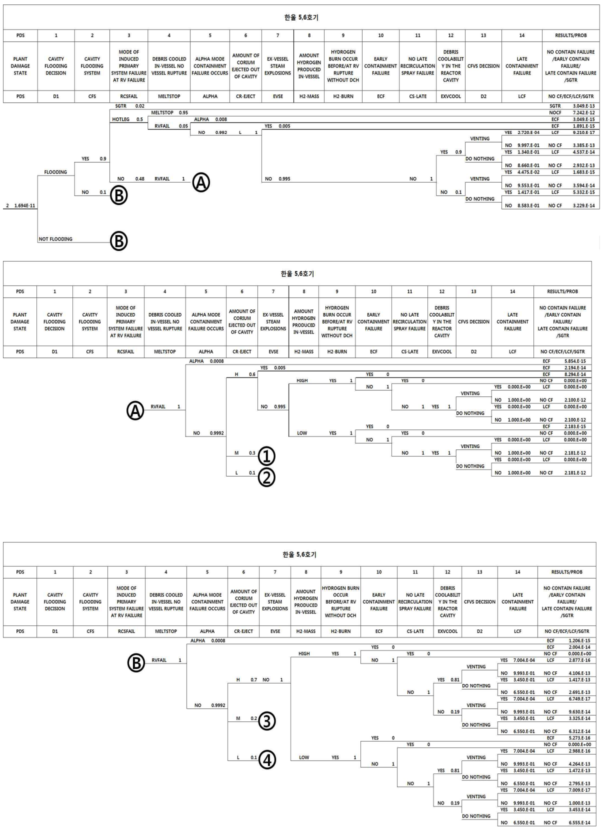


Fig. 2. The developed multiple decision tree.

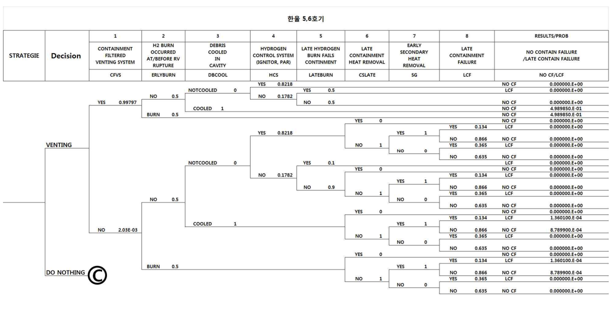


Fig. 3. The decision tree for a filtered containment venting strategy.

2.6 Results

The frequencies of each containment failure mode were evaluated by using the developed decision tree. Using the calculated frequencies and MACCS2 code, fatalities and offsite risk were evaluated. Accident management strategy from the sides of preventing containment failure and public risk was selected by comparing the results.

Evaluated strategies for preventing containment failure are shown in the table I.

Table I: Strategies for preventing containment failure of each PDS

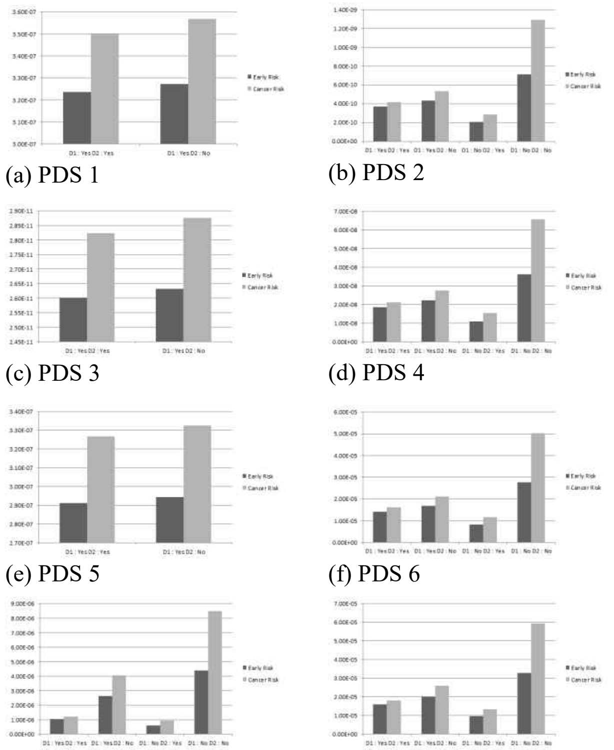
Plant damage state	Accident management strategy	
	Reactor cavity flooding	Filtered containment venting
1	O	O
2	X	O
3	O	O
4	O	O
5	O	O
6	O	O
7	O	O

This result shows that the optimum accident management strategy for preventing containment failure can be changed by availability of safety systems, such as a reactor cavity flooding system, and offsite power while station blackout.

To assess the accident management strategy from the viewpoint of public risk, the offsite consequence was calculated by using the source term analysis results for FCVS and the release group analysis results of Hanul unit 5&6. MAPP 4.0.4 code was used to analyse the source term, and MACCS2 code was used to calculate the fatalities. As a result, the most severe offsite consequence was for the SGTR. This result might be caused by the fact that radionuclides release directly to the offsite through the main steam safety valves, or the air dump valves for the SGTR [5].

In filtered containment venting strategy, the offsite consequence was small effect since almost the whole radionuclides were filtered and decayed before releasing.

Risk results from frequencies of each PDS and fatalities are shown in the figure 4.



(a) PDS 1 (b) PDS 2 (c) PDS 3 (d) PDS 4 (e) PDS 5 (f) PDS 6 (g) PDS 7 (h) total PDS

Fig. 4. Early and cancer fatalities of each PDS; D1 is a reactor cavity flooding strategy, and D2 is a filtered containment venting strategy.

It would be better not to take a reactor cavity flooding strategy from the viewpoint of the risk, except for PDS 1, 3, 5 which are always flooding. However, it would be better to take a filtered containment venting strategy in the whole cases. The risk caused by the SGTR was large since the SGTR accident had a more severe offsite consequence than the others.

Strategies for preventing public risk of each PDS is shown in the table Ⅱ.

Table Ⅱ: Strategies for preventing public risk of each PDS

Plant damage state	Accident management strategy	
	Reactor cavity flooding	Filtered containment venting
1	O	O
2	X	O
3	O	O
4	X	O
5	O	O
6	X	O
7	X	O

3. Conclusions

In this study, a methodology for assessing severe accident management strategies has been developed using Probabilistic Safety Assessment (PSA) and multiple decision trees. Risk was evaluated by the modelling decision trees. This methodology could be used as an assessment tool for severe accident management strategies, which could contribute to the improvement of the SAMG to be used during the occurrence of severe accident in nuclear power plants. Moreover, the results of this study is expected to be used as basic knowledge for integration between SAMG and EOP.

Acknowledgements

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