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An Assessment for A Filtered Containment Venting Strategy Using Decision Tree Models

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1. Introduction

In Korea, the filtered containment venting system has been installed for the first time in Wolsong unit 1 as a part of Fukushima follow-up steps, and it is planned to be applied gradually for all the remaining reactors. Filtered containment venting system, one of severe accident countermeasures, prevents a gradual pressurization of the containment building exhausting noncondensable gas and vapor to the outside of the containment building [1]. In this study, a probabilistic assessment of the severe accident management strategy through a filtered containment venting system was performed by using decision tree models.

2. Methods and Results

2.1 Reference Plant and Strategy

Hanul unit 5&6 was selected as a reference plant in this study. The reactor type of Hanul unit 5&6 is OPR1000, which has accounted for half of the 24 operating nuclear power plants in Korea. The filtered containment venting strategy was selected as a reference accident management strategy.

2.2 An Accident Scenario

Station Blackout (SBO), like Fukushima nuclear power plant accident, was selected as an accident scenario to build the decision tree models.

2.3 Decision Tree Methodology

In this study, the filtered containment venting strategy was assessed by using decision tree models. The decision tree is a branchlike schematic diagram which shows the alternatives being selected in decision making problems, the phenomena or conditions being realized in uncertain situation, and the results being caused by aforesaid things [2]. It could be used to select the optimum accident management strategy considering effectiveness, realizability, and side effects.

2.4 Plant Damage States

Plant damage states (PDS) were used to reduce the amount of accident analysis to be performed. The characteristics of the accident progression could be maintained by grouping a large number of core damage accident sequences into several groups representing the plant conditions when the core damage occurred.

Plant damage states for the station blackout scenario which presented in Hanul unit 5&6 level 2 probabilistic safety assessment (PSA) report is shown in figure 1. An assessment of the filtered containment venting strategy was performed with the PDS 16 which accounts for the largest proportion of 89.72 % among the station blackout scenario in Hanul unit 5&6 level 2 PSA report [3]. PDS 16 include the following accidents.

- Power recovery failure
- Invessel injection failure
- Containment recirculation cooling failure
- High reactor coolant system (RCS) pressure
- Secondary heat removal success
- No cavity flooding

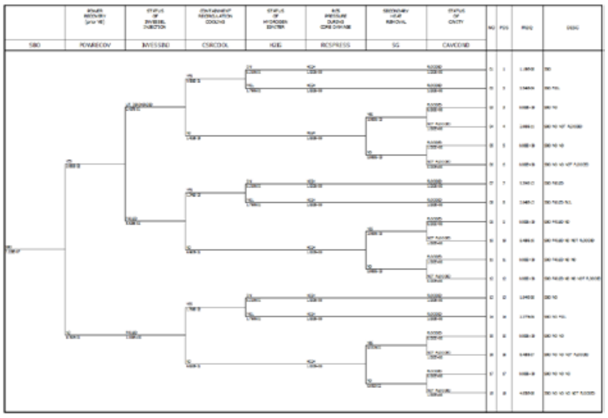

Fig. 1. Plant damage states for the station blackout scenario [4].

2.5 Decision Tree Model

The developed decision tree model for the PDS 16 is shown in figure 2. The basic structure of the model and probabilities of each heading were based on Hanul unit 5&6 containment event tree (CET), and decomposition event tree (DET) models. The containment failure modes were categorized into four categories; no containment failure (NO CF), early containment failure (ECF), late containment failure (LCF), and steam generator tube rupture (SGTR) [3]. The ECF and SGTR failure modes were not considered in assessing a filtered containment venting strategy since the strategy is for a gradual pressurization of the containment building.

Decision nodes D1 to D5, devided into venting or not venting, denote whether to perform the filtered containment venting strategy or not. The probability of the filtered containment venting system failure was assumed to be 4.736×10^{-3} [5]. The probabilities of the CF-LATE heading were evaluated by modeling each DET [3].

Since there is a possibility of hydrogen explosion due to the localized accumulation of hydrogen flowing in the filtered containment venting system, late hydrogen burn was considered as a side effect of the filtered containment venting strategy. Late hydrogen burn probability, considering the operation of the filtered containment venting system, was assumed to be 0.1, and the sensitivity analysis was performed by increasing the probability 0.1 at a time.

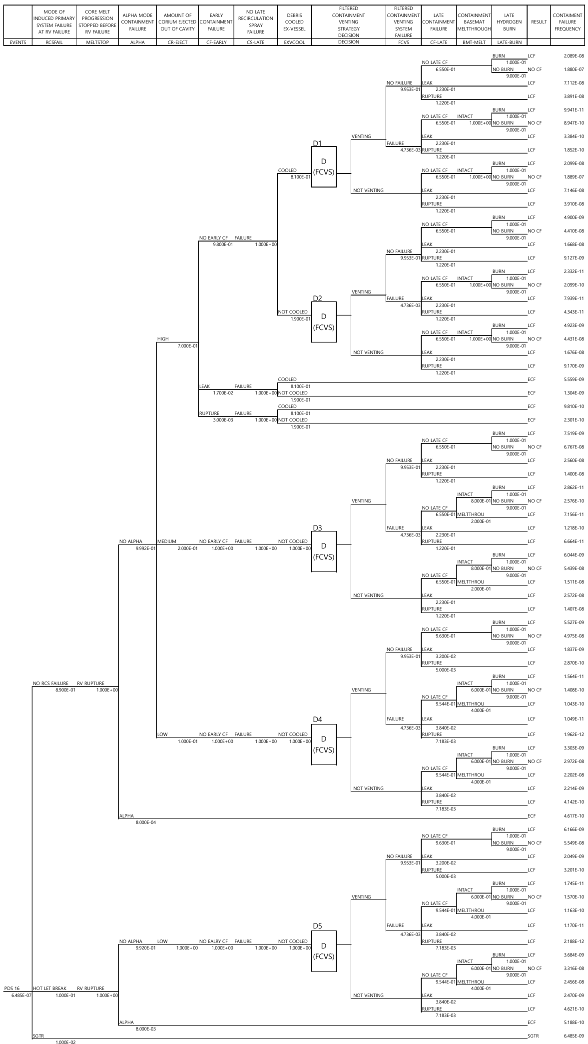

Fig. 2. Decision tree model for the plant damage state 16.

2.6 Sensitivity Analysis, and Results

The results of sensitivity analysis, no containment failure frequencies for each decision node, are shown in table I. The optimum accident management strategy was different depending on the late hydrogen burn probability for each decision node as in table Ⅱ. The higher probability of the late hydrogen burn, the filtered containment venting strategy became disadvantageous in terms of containment failure frequency.

Table I: No containment failure (NO CF) frequencies as late hydrogen burn probabilities for each decision node (/RY)

	Decision	Late Hydrogen Burn Probability				
		0.1	0.2	0.3	0.4	0.5
D1	VENTING	1.889×10^{-7}	1.680×10^{-7}	1.471×10^{-7}	1.262×10^{-7}	1.053×10^{-7}
	NOT VENTING	1.889×10^{-7}	1.889×10^{-7}	1.889×10^{-7}	1.889×10^{-7}	1.889×10^{-7}
D2	VENTING	4.431×10^{-8}	3.941×10^{-8}	3.451×10^{-8}	2.961×10^{-8}	2.471×10^{-8}
	NOT VENTING	4.431×10^{-8}	4.431×10^{-8}	4.431×10^{-8}	4.431×10^{-8}	4.431×10^{-8}
D3	VENTING	6.793×10^{-8}	6.041×10^{-8}	5.289×10^{-8}	4.537×10^{-8}	3.785×10^{-8}
	NOT VENTING	5.439×10^{-8}	5.439×10^{-8}	5.439×10^{-8}	5.439×10^{-8}	5.439×10^{-8}
D4	VENTING	4.989×10^{-8}	4.436×10^{-8}	3.883×10^{-8}	3.330×10^{-8}	2.778×10^{-8}
	NOT VENTING	2.972×10^{-8}	2.972×10^{-8}	2.972×10^{-8}	2.972×10^{-8}	2.972×10^{-8}
D5	VENTING	5.565×10^{-8}	4.948×10^{-8}	4.332×10^{-8}	3.715×10^{-8}	3.099×10^{-8}
	NOT VENTING	3.316×10^{-8}	3.316×10^{-8}	3.316×10^{-8}	3.316×10^{-8}	3.316×10^{-8}

Table Ⅱ: Optimum accident management strategies as late hydrogen burn probabilities for each decision node

	Late Hydrogen Burn Probability				
	0.1	0.2	0.3	0.4	0.5
D1	-	NOT VENTING	NOT VENTING	NOT VENTING	NOT VENTING
D2	-	NOT VENTING	NOT VENTING	NOT VENTING	NOT VENTING
D3	VENTING	VENTING	NOT VENTING	NOT VENTING	NOT VENTING
D4	VENTING	VENTING	VENTING	VENTING	NOT VENTING
D5	VENTING	VENTING	VENTING	VENTING	NOT VENTING

3. Conclusions

In this study, a probabilistic assessment of the filtered containment venting strategy, one of the severe accident management strategies, was performed by using decision tree models. Containment failure frequencies of each decision were evaluated by the developed decision tree model. The optimum accident management strategies were evaluated by comparing the results. Various strategies in severe accident management guidelines (SAMG) could be improved by utilizing the methodology in this study and the offsite risk analysis methodology.

Acknowledgements

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