Construction and Quantification of the One Top model of the Fire Events PSA

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1. Introduction

KAERI constructed the one top model of the fire events PSA for Ulchin Unit 3&4 by using the 'mapping technique' [1]. The mapping technique was developed for the construction and quantification of external events PSA models with a one top model for an internal events PSA. With 'AIMS'[2], the mapping technique can be implemented by the construction of mapping tables. The mapping tables include fire rooms, fire ignition frequency, related initiating events, fire transfer events, and the internal PSA basic events affected by a fire. The constructed one top fire PSA model is based on previously conducted fire PSA results for Ulchin Unit 3&4 [3].

In this paper, we introduce the construction procedure and quantification results of the one top model of the fire events PSA by using the mapping technique. As the one top model of the fire events PSA developed in this study is based on the previous study [3], we also introduce the previous fire PSA approach focused on quantification.

2. Previous Approach

The main steps for the quantification of the previous Ulchin Unit 3&4 fire PSA models consist of a screening analysis and a detailed analysis.

Quantitative screening analysis needs a fire PSA model with conservative values of the probabilities of events for the damaged components and human errors. The fire PSA model for Ulchin Unit 3&4 was constructed by the manual addition of basic events for the damaged components to an internal PSA model. New sequences induced by a fire were separately quantified without using the previous internal events PSA model. To develop the fire PSA model, components located at rooms of a fire initiation or propagation and cables going through them were identified. After that, the damaged events with a zero probability were modeled into the fire PSA model. If components are located at a specific room where a fire initiates or propagates, quantifications of a core damage frequency (CDF) for that specific room were conducted by setting the damaged events for components to '1'. If power or control cables for components go through the specific room where a fire initiates or propagates, quantifications of a CDF for that specific room were conducted by setting the damaged events for the components as 'an estimated probability'.

Detailed analyses were performed for unscreened fire compartments. Some compartments were divided into several sub-compartments. Fire initiation frequencies were re-quantified. CDF due to a fire can be represented as the following equation:

$$\mathrm{CDF} = \sum_{i=1}^{n} \mathrm{FI}(i)*\mathrm{SV}(i)*\mathrm{NS}(i)*\mathrm{BA}(i)*\mathrm{CCDP}(i) \quad (1)$$

Where,

FI(i) : fire ignition frequency of room *i*
SV(i) : severity factor of ignited fire in room *i*
NS(i) : non-suppression probability of a fire in room *i*
BA(i): failure probability of barrier for the propagation of ignited fire in room *i* to other room
CCDP(*i*):conditional core damage probability for a fire in room *i*

In the screening analysis, the severity factor and non-suppression probability of Eq.(1) were assumed to be one, respectively. As shown in Eq.(1), a PSA analyst quantifies a CDF of each room several times.

Table 1 shows an example of the input for the quantification of a CDF due to a fire in room i. For a fire in room *i*, a PSA analyst should estimate a CCDP due to a fire in room *i*. itself, and a propagated fire to room *j* from room *i*. In the screening analysis of Ulchin Unit 3&4, a CCDP for room *i* itself was quantified by setting 'AAA-BBB-CCC' to '1'. A CCDP for room *j* was quantified by setting 'AAA-BBB-CCC' and 'DDD-EEE-FFF' to '1'.

In the previous study of the fire events PSA for Ulchin Unit 3&4, there were 50 fire rooms for quantification. Total number of fire areas including propagation room was identified as 151. Among the 50 fire rooms, 16 fire rooms remained for a detailed analysis.

3. Mapping technique

The construction of a one top model for a fire events PSA is automatically executed by 'AIMS' if a PSA analyst makes mapping tables. To make mapping tables, a PSA analyst should identify the internal PSA basic events corresponding to the damaged components. In this study, the rule-based approach was used for an identification of the basic events [4]. An example of a mapping table is presented in Table 2. The first row of Table 2 shows the required input for the quantification of a CDF for a fire 100-A03A itself. The second row shows the required input for the quantification of a CDF for a propagated fire to room 100-A01A from room 100-A03A. The fault trees for the damaged components due to a fire are constructed by adding new events to the internal PSA basic events with an 'OR' logic. The new events consist of two events for a fire ignition room and a conditional probability with an 'AND' logic. The added new events are also automatically modeled as sub-events for initiating events of the related event tree with an 'OR' logic. The conditional probability was estimated by a multiplication of the severity factor, the non-suppression probability, the probability of a barrier failure, and the probability of a component failure caused by a fire. We developed separate fault trees for new sequences not mapped to the basic events of the internal PSA model.

Compared with the previous study [3], construction and quantification of the fire events PSA model by a mapping technique has two merits. One is an easy and systematic construction of a one top model for a fire events PSA. Other is that we can obtain cutsets representing propagations of both fire rooms. Cutsets for a propagation of more than two fire rooms may be truncated by a cutoff value. Cutsets for a propagation of more than two fire rooms reflect a real phenomena of a fire because it can be propagated in any direction.

Quantification results show that the effects on multi-room propagations of a fire are not great. In the screening analysis, 4 rooms were additionally identified for a detailed analysis. The CDF contribution resulting from the cutsets for multi-room propagations is less than 1% of the total CDF in the detailed analysis.

4. Concluding remarks

In this paper, we introduce the construction procedure and quantification results of the one top model of the fire events PSA by using the mapping technique. The use of the mapping technique enables us to easily and systematically construct a one top model for a fire events PSA if one top model for an internal events PSA is made. It also provides us with cutsets for multi-room fire propagations. More studies are needed to address the approaches of NUREG/CR-6850 and the issues of a fire PSA.

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References

[1]. 양준언 외, "위험도 정보 활용 기반 기술 개발", KAERI/RR-2722/2006, KAERI

[2]. 한상훈, "AIMS Manual", 2007, KAERI

[3]. "Probabilistic Safety Assessment for Ulchin Units 3&4", 2004, KOPEC

[4]. 강대일 외, "Determination of Component Failure Modes for a Fire PSA by Using Decision Trees", 2007 KNS 추계학회

Table 1. Example of Input for the Estimation of Core Damage Frequency due to a Fire in Room *i*

Fire Ignition Area	Fire Propag' Area	Related Initiating event (I.E)	Frequency of Fire Ignition (IF)	Fire Severity (SV)	Non-suppression probability (NS)	Name of Barrier for Fire Propag' (BA)	Failure probability of barrier for fire propagation	Basic events for the damaged components in fire ignition or propagation area
i	i	General Transient	3.0E-3	0.7	0.5	BA(i->i)	1	AAA-BBB-CCC
i	j	Loss of CCWS	3.0E-3	0.6	0.4	BA(i->j)	0.08	DDD-EEE-FFF

Table 2. Example of Mapping Tables for the Construction of One Top Model of Fire Events PSA

Room	Frequency	Transferred Room	Event Tree	Cond Proba Name	Cond Proba	Basic Events	Desc
100-A03B	5.63E-04		%U3-LODC-01B	P%F-100-A03B	1.00E+00	CCMVO0106B, CVMVCCH504, EDBCYBC01B, EDBSYDC01B, EDBYABT01B	Fire in 100-A03B
100-A03A	5.85E-04	100-A01A	%U3-LOKV	P%F-100-A03A_100-A01A_SO	3.00E-03	AFLVT0037AB, AFMVT0043AA, ATAVO009B, HSMVT0667A, HSMVT0699A, LSMVT0669A, LSMVT307A, NDBSYDC01M, SCMVC0689A	Fire in 100-A03A