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Determination of Component Failure Modes for a Fire PSA by Using Decision Trees

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1. Introduction

KAERI developed the method, called a 'mapping technique' [1], for the quantification of external events PSA models with one top model for an internal events PSA. The mapping technique can be implemented by the construction of mapping tables. The mapping tables include initiating events and transfer events of fire, and internal PSA basic events affected by a fire. This year, KAERI is making mapping tables for the one top model for Ulchin Unit 3&4 fire PSA with previously conducted Fire PSA results for Ulchin Unit 3&4 [2].

A Fire PSA requires a PSA analyst to determine component failure modes affected by a fire. The component failure modes caused by a fire depend on several factors. These several factors are whether components are located at fire initiation and propagation areas or not, fire effects on control and power cables for components, designed failure modes of components, success criteria in a PSA model, etc. Thus, it is not easy to manually determine component failure modes caused by a fire.

In this paper, we propose the use of decision trees for the determination of component failure modes affected by a fire and the selection of internal PSA basic events. Section 2 presents the procedure for previously performed the Ulchin Unit 3&4 fire PSA and mapping technique. Section 3 presents the process for identification of basic events and decision trees. Section 4 presents the concluding remarks.

2. Fire PSA and Mapping Technique

2.1 Fire PSA procedure for Ulchin Unit 3&4 [2]

The procedure of fire PSA for Ulchin Unit 3& 4 consists of four steps: determination of compartments, qualitative screening, quantitative screening, detailed quantification.

The determination of compartments is to define the physical boundary of the analysis, and to divide the area within that boundary into analysis compartments.

Qualitative screening identifies fire analysis compartments that can be shown to have little or no risk significance without a quantitative analysis. Fire compartments may be screened out if they contain no components or cables and if they cannot lead to a plant trip due to either plant procedures and an automatic trip signal, or technical specification requirements.

Quantitative screening needs a fire PSA model with conservative values of the probabilities of the damaged event, the fire propagation, and human errors. The fire PSA model for Ulchin Unit 3&4 was constructed by the modification of internal 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, quantification of a core damage frequency (CDF) for that specific room is conducted by setting the damaged events for components '1'. If power or control cables for components go through the specific room where a fire initiates or propagates, quantification of a CDF for that specific room is conducted by setting the damaged events for the components 'the estimated probability'.

Detailed analyses were performed for unscreened fire compartments. Some compartments were divided into several sub-compartments. Fire initiation frequencies were re-quantified. Other detailed analyses were not performed.

The fault trees for fire PSA of Ulchin Unit 3&4 include basic events for internal events PSA and damaged events caused by a fire. Also, the quantification to estimate a core damage frequency coming from a fire was performed several times.

2.2 Mapping Technique

By using the mapping technique, a PSA analyst can quantify the fire events PSA without detailed fault tree models for them and several quantification works [1]. However, the mapping technique requires a PSA analyst to identify internal PSA basic events to add new events besides them with 'OR' logic. The addition works of new events are automatically executed by 'AIMS'[3] if a PSA analyst makes mapping tables. The mapping tables include initiating events and transfer events of a fire, and internal PSA basic events with the frequency of a fire initiation and the probabilities of a fire propagation.

The fire transfer event shows the fire propagation area. Its probability is estimated by a multiplication of the probability of a fire propagation and the probability of a component failure caused by a fire. Before an estimation of a component failure probability, the failure mode of component caused by a fire should be determined. The component failure probabilities are generally pre-estimated based on its failure mode and component circuit configuration. In the previous Ulchin Unit 3&4 fire PSA, detailed circuit analysis was not performed.

3. Determination of Component Failure Modes

Two tables should be prepared to use the decision trees. One is a table for the information for the components in the fire compartment. The other is a table for the information for the design and modeling of components. The former table includes the component name and name of fire initiation and propagation compartments with component location and cables location. The latter includes name, type, and description of a component, name and description of related internal PSA events, status of a normal operation, etc.

We developed three kinds of decision trees according to the failure modes and the operation characteristics of the components:

- motor operated valves and power operated valves,
- Solenoid operated valves and air operated valves
- Components having running operation mode (pump, compressor, etc.)

Figure 1 shows the decision trees for a determination of failure modes for the motor operated valves and power operated valves. The logics of the decision trees were converted into the Excel Macro file. The Excel Macro file was applied to the two tables mentioned before. A sample test was performed for room 000DGA of Ulchin Unit 3 & 4. Reasonable results were obtained through the sample test run. Once the Macro file was executed for each room, the failure modes of the components were determined and internal basic events were selected.

4. Concluding Remarks

It is expected that the use of decision trees in the determination of failure modes and the identification of internal PSA basic events can reduce the man-hours and a PSA analyst's potential error for them. However, more studies are required for treating the components not modeled into a internal PSA and for incorporating new sequences induced by a fire. The approach of this paper can be applied to other PSAs for external events and vital area identification.

Acknowledgements

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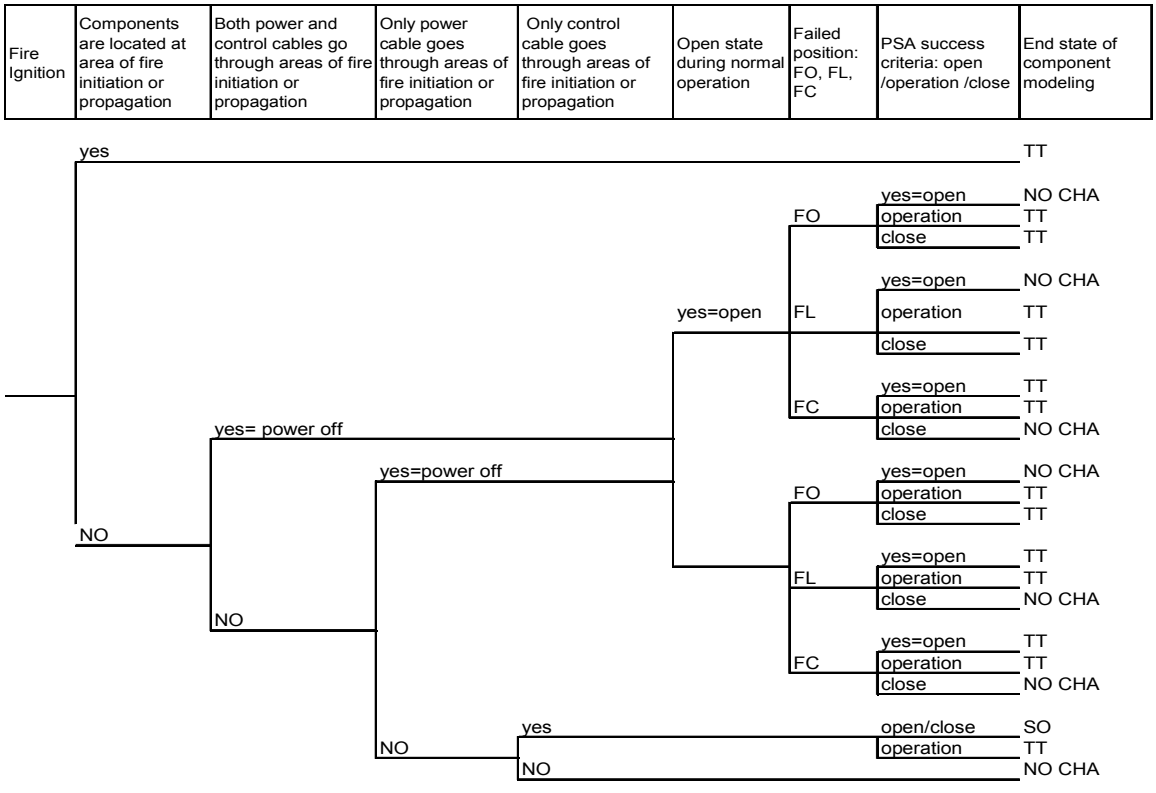

TT: functional failure, SO: spurious operation, NO CHA: no change, FL: fail as is, FC: fail closed, FO: fail open

Figure 1. Decision Tree for the Determination of Component Failure Modes