Development of Level 3 PSA Event Tree Model for Determination of Offsite Alarm Time

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1. Introduction

It is important to develop an appropriate emergency response model that reflects realistic situations when conducting a Level 3 PSA. Therefore, it is required to develop emergency response models through close cooperation between the PSA field and the radiation protection field.

In particular, as a starting point for emergency response, it is important to properly estimate the time it will take for nearby residents to be notified of evacuation instructions in the event of a nuclear emergency. This time is entered into the emergency response model as a single factor called offsite alarm time [1. 2], but in reality, this time is determined by a sequence of various events. Previous studies have used simplistic assumptions to determine this factor, thus resulting in large uncertainties. Offsite alarm time is a factor that has a significant impact on the results of offsite consequence analysis because it is directly related to the time when residents start emergency response. Therefore, it is necessary to develop a new method that can overcome the limitations of existing methods and apply alarm time to reflect more realistic situations.

In this study, a method was developed to consider the offsite alarm time probabilistically by constructing an event tree with events leading up to the alarm time rather than determining the alarm time as a single factor. As a starting point for the study, this paper will introduce how the event tree was constructed. In another collaborative study [3], the time required for each event was investigated through a survey of domestic and foreign literature.

Although the current study focuses on determining the offsite alarm time, in future research, the developed method can be extended to probabilistic approach to uncertain factors in Level 3 PSA [4].

2. Event Tree Model Development

To develop event tree, it is necessary to understand the procedure of nuclear emergency responses, since event tree is basically designed in time sequence. Based on the preparedness for a nuclear emergency, Level 3 PSA Event Tree is constructed in detail. Fault tree is employed to estimate the frequency of each consequence.

2.1 Preparedness for a Nuclear Emergency

The event tree is required to accurately reflect the sequence and timing of nuclear emergency responses. Procedures and time objectives for nuclear emergency are described in table I.

Table I: Preparedness for a Nuclear Emergency in Each Emergency Class

	Alert	Site Area Emergency	General Emergency
Licensee	**Onsite ERO** (1 hr)	*EOF operation*	*Evacuation Recommendation* (30 min)
Central government	**Preliminary Offsite ERO (Command Center)** (6 hr)	**Offsite ERO (Command Center)**	*Evacuation Decision* (15 min after Recommendation)
Local government	**Offsite ERO (Local Headquarters)** (6 hr)	*Preparedness of Public Protective Action*	*Evacuation Order* (15 min after Decision)

ERO: Emergency Response Organization
EOF: Emergency Operation Facility

In the table, bold and italic lettering represent activated organizations and protective actions, respectively. Required time for each action is added within parenthesis. The emergency response procedures and required time until offsite alarm are proposed by Lee et al. [3].

Level 3 PSA Event Tree model only considers the actions after general emergency. Because, regardless of all previous actions, if only the actions following the general emergency are taken successfully within the required time, the emergency response is regarded as success. Then, preparedness of organization and protective actions in alert and site area emergency should be included as a major factor in determining success or failure of each action in general emergency.

2.2 Level 3 PSA Event Tree Model

The headings of the Level 3 PSA Event Tree are mainly divided into four categories. The first is the declaration emergency, and then it proceeds in the following order: evacuation recommendation, evacuation decision, and evacuation order. The Fig. 1 shows the Level 3 PSA Event Tree model proposed in this study.

All four headings are divided into success and failure, and failure is further divided into delay and failure. Therefore, the 4 main headings are divided into 3 branches (Success/Delay/Failure), resulting in a total of 81 sequences. The time required for evacuation recommendation is 30 minutes, while the required time

for remaining heading is 15 minutes each as shown in the Table I. The time required for delay and failure was set to 60 minutes and 120 minutes, respectively. There is no specific standard for the time required, and it may change in the future through sensitivity test. Since there is no existing guidelines, it can provide insight into the time required for each heading.

The emergency declaration is made in 15 minutes with exceeding the standards of a general emergency, and is the role of the licensee. Key factors for success or failure include whether instrumentation/monitoring systems are operational and the operator's awareness of the accident progression. Success in delay of emergency declaration includes instrument repair and recovery, and the operator's belated recognition of the accident.

The evacuation recommendation is also a role of the licensee. Since the evacuation recommendation is carried out after emergency notification, the 15 minutes required for emergency notification was considered together [3]. Key factors of the evacuation recommendation include whether source term information is received, whether the person in charge is completely understand of the procedure, and whether the communication system is operating normally. Additionally, it should also be considered whether onsite ERO was activated normally in the previous emergency class.

The evacuation decision is the role of the central government, and the main determinants of the evacuation decision include human factors such as decision-making ability and receiving data for situational awareness. It is also important to consider whether the licensee successfully notified the government during the previous emergency class and whether the offsite ERO was activated normally as a result.

Evacuation order is the role of local governments. Actions from the previous class, such as the establishment of local headquarters and preparedness of public protective action, should be considered to determine the success of the evacuation order. Also, the possibility of breakdown of communication facilities for notification of residents should be concerned.

Total time is calculated following a total of 81 sequences. This time represents the time from the start of the general emergency to the evacuation order (offsite alarm). In Level 3 PSA Event Tree, if all succeed, it takes 75 minutes, and if all fail, it takes 480 minutes.

2.3. Method of Estimating Consequences

The Level 3 PSA Event Tree starts from a general emergency, and all accident scenarios have different times from the start of the accident to the arrival of a general emergency. Therefore, this study selected two representative scenarios, those are one early and one late releases, among the severe accident scenarios derived from level 2 PSA as the initial event. And in each representative scenario, the time to reach a general emergency from accident initiation is calculated using accident analysis code.

The probability of each branch is calculated through a fault tree, and through this, the frequency of each of the 81 sequences is calculated.

The offsite alarm time is obtained by adding the time taken from the start of the accident to the general emergency and the total time calculated through the Level 3 PSA Event Tree, and offsite consequence analysis code calculates consequences using offsite alarm time.

3. Conclusion and Further Study

This study achieved the following results.

1. The investigation into emergency preparedness across different class identified events that could affect offsite alarm time data.

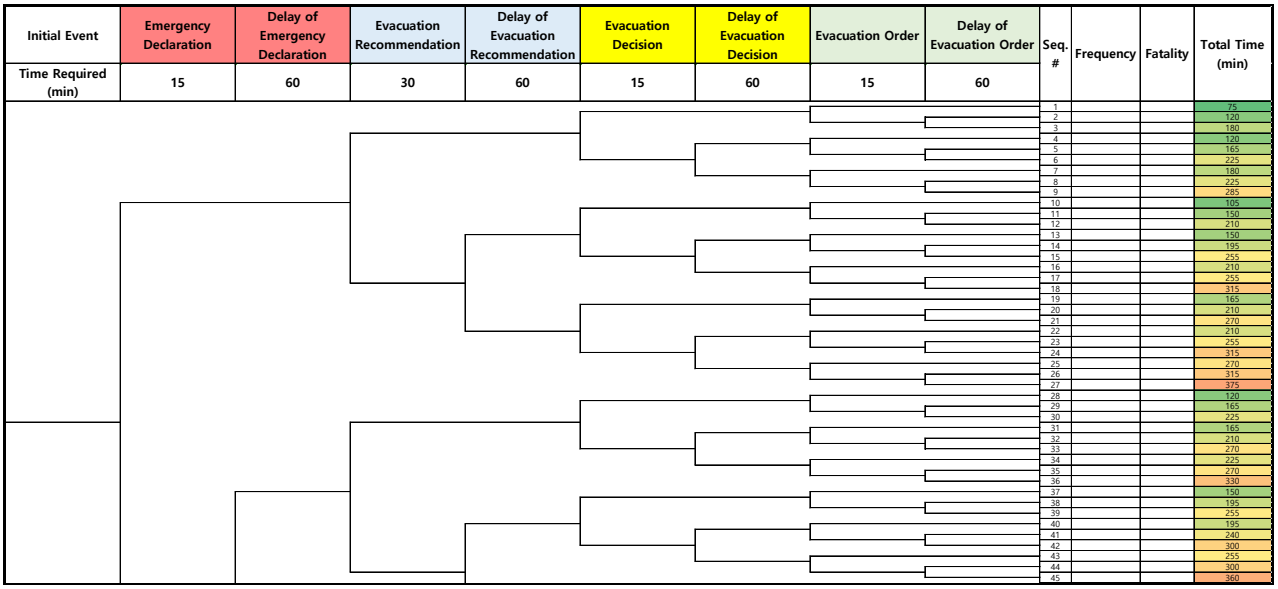

Fig. 1. Level 3 PSA Event Tree Model for Determination of Offsite Alarm Time

2. A Level 3 PSA Event Tree model was successfully developed, integrating preparedness and response time.

3. A method for estimating offsite consequences was proposed to provide a systematic and probabilistic approach to calculate radiological risks.

In future work, fault trees will be developed to calculate the frequency of each event, which can lead to various studies to obtain failure probabilities such as human error. And as mentioned in the paper introducing the concept [4] and in the introduction of this paper, the Level 3 PSA Event Tree model will enable the probabilistic consideration of various uncertain factors in Level 3 PSA. The expected effects that can be achieved through this study are as follows.

1. Offsite consequence analysis incorporating probabilistic concepts will be possible.

2. It will provide insight into factors that have a significant impact on radiological risk, which can lead to investment based on risk.

3. It can be used for developing emergency response manuals and decision making.

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