Development of the ProFire-PSA_Model for a Fire Probabilistic Safety Assessment

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1. Introduction

Until now, most of the fire probabilistic safety assessment (PSA) for domestic nuclear power plants (NPPs) has been conducted in accordance with EPRI's Fire PRA Implementation Guide (FPRAIG)[1]. The fire risk has been assessed by manually changing the probability value of fire events related to fire areas or scenarios without using separate fire PSA programs when performing fire PSA.

Recently, NUREG/CR-6850[2] approach is widely used all over the world for the fire PSA of NPPs. In the case of applications of NUREG/CR-6850 methodology to NPPs, the level of efforts (i.e., time and cost) significantly increases because it requires a lot of cable data and modeling of spurious operation scenarios compared to the previous EPRI's FPRAIG method. In order to reduce errors and increase work efficiency, the use of computerized tools is inevitably required for fire PSA using NUREG/CR-6850 approach. As shown in Fig. 1, KAERI developed the fire PSA program, ProFire-PSA(Program for Fire Event PSA)__INT[3], consisting of ProFire-PSA_Model and ProFire-PSA:Support. The ProFire-PSA_Model was developed for a PSA analyst to facilitate identifying and modeling fire-induced component failure modes, and constructing a one-top Fire PSA model. The ProFire-PSA:Support was developed for the estimation fire ignition frequency and the generation of a fire scenario. In this paper, ProFire-PSA_Model was introduced and its application result was presented.

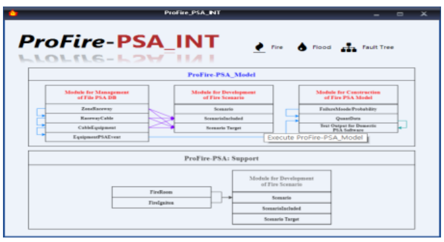

Fig. 1 Screenshot of the ProFire-PSA_INT

2. Methods and Results

2.1 Overview of the ProFire-PSA_Model

Fig. 2 shows the relation between ProFire-PSA_Model, internal event PSA model, and fire PSA model. ProFire-PSA_Model produces SIMA (for AIMS-PSA) or RID/One Top (for SAREX) files to be read in domestic PSA programs, AIMS-PSA[4] or SAREX[5], a PSA tool for building and quantifying internal event PSA models. The pre-built internal event PSA model is changed to the fire PSA model using the SIMA or RID/One Top file. The main functions of the ProFire-PSA_Model are as follows:

- Systematic use of cable data including information on fire areas and cable tray
- Incorporation of circuit analysis results
- Automatic or manual selection of equipment to be included in the fire scenarios
- Rule-based determinations of fire-induced equipment failure mode and failure probability
- Generation of fire events and logic to be modeled in the internal event PSA model

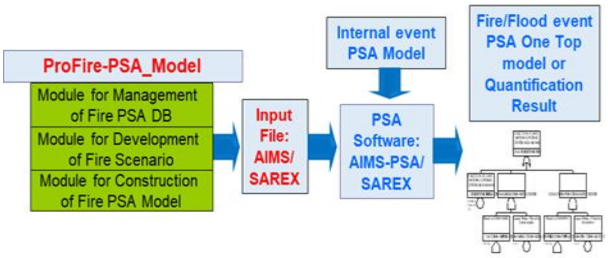

Fig. 1 Relation between the ProFire-PSA_Model and AIMS-PSA/SAREX

The ProFire-PSA_Model consist of the following three modules:

- Module for Management of Fire PSA DB - DB module
- Module for Development of Fire Scenario - Scenario module
- Module for Construction of Fire PSA Model - PSA module

In the DB module, MS-Access data such as zones and raceways are read and structured so that these data are available in Scenario and PSA modules. The Scenario module identifies the equipment and cables to be included in the fire scenario. The PSA module generates the SIMA, RID, or One Top file to be used as input to the AIMS-PSA or the SAREX. There are two main options, ‘basic’ and ‘realistic’, when determining the failure probability of equipment. If the ‘basic’ option is selected, the failure probability of equipment affected by the fire is unconditionally evaluated as one. When the ‘realistic’ option is selected, the failure probability of equipment is evaluated differently depending on the cable type, equipment type, equipment normal condition, etc.

2.2. Application of the ProFire-PSA_Model to the Reference NPP

Fire-induced small coolant loss accident (SLOCA) scenarios of the domestic reference NPP were quantified as the pilot study on the application of the ProFire-PSA_Model. The fire-induced SLOCA of the reference NPP were identified to be initiated by the following causes [6]:

- SLOCA due to malfunction of Reactor Coolant Gas Vent System (RCGV) valves
- SLOCA due to damage to the reactor coolant pump (RCP) seal.
- SLOCA due to the opening of the suction line of the shutdown cooling system.

Detailed circuit analysis of SLOCA was conducted only on motor-operated valves relating to RCP seal SLOCA scenarios. The following four cases were quantified for the comparisons:

a) All fire-induced failure probabilities are set to one without detailed circuit analysis (no-circuit + basic)
b) Application of the 'realistic' option rule without detailed circuit analysis (no-circuit + rule)
c) All fire-induced failure probabilities are set to one except for the detailed circuit analysis results (circuit + basic)
d) Application of the 'realistic' rule except for the detailed circuit analysis results (circuit + rule)

As a result of quantification, the core damage frequency (CDF) was ranked as a), c), b), and d). In the case of a), since circuit analysis was not performed, the probability of all fire-induced equipment failure was set to one, so the CDF was evaluated the highest. The CDF of the case b) without circuit analysis results was quantified lower than that of the case c) with circuit analysis results. It can be concluded that this is because the 'realistic' rules were practically applied to determining failure modes and evaluating failure probability for more equipment than those selected for the detailed circuit analysis. When the ProFire-PSA_Model is employed for estimating the probability of fire-induced equipment failure, detailed circuit analysis results have priority over the 'realistic' rules. And, the failure probability of equipment where the detailed circuit analysis is conducted is generally evaluated lower than that of equipment to which only the 'realistic' rule is applied. Therefore, case d) shows the lowest CDF. From the quantification results of the SLOCA of this study, it was confirmed that the application of the ProFire-PSA_Model can obtain reasonable quantification results without the detailed circuit analysis.

3. Concluding Remarks

To perform `NUREG/CR-6850-based fire PSA, a fire PSA computerization tool should be used because a large amount of cable data and modeling of fire-induced spurious operation scenarios are required to be addressed. KAERI has developed a Fire PSA program called ProFire-PSA_Model to reduce the working hours required for a Fire PSA in identifying fire-induced component failures, modeling them, and constructing a Fire PSA model. In this paper, the ProFire-PSA_Model was introduced, and its application result was presented. From the pilot study on the application of the ProFire-PSA_Model to the fire-induced SLOCA scenarios, it was confirmed that reasonable quantification results could be obtained without the detailed circuit analysis.

Acknowledgments

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