Development of IPRO-ZONE to Construct One Top Fire Event PSA Model

Daeil Kang and Sang-Hoon Han
KAERI,150 Deogjin-Dong, Yuseong-Gu, Daejeon, 305-353, dikang@kaeri.re.kr

1. Introduction

An internal fire event probabilistic safety assessment (PSA) model has been generally quantified by modifications of a pre-developed internal events PSA model. New accident sequence logics not covered in the internal events PSA model are separately developed to incorporate them into the fire PSA model. Kang et al. proposed modification rules to construct the one top fire events PSA model by using the pre-developed one top internal events PSA model. A one top fault tree is a one fault tree representing the PSA logics including all the event trees and fault trees for the core damage frequency (CDF) and large early release frequency (LERF) quantifications. Constructions of one top fire events PSA model are needed for risk management due to fire in risk-informed decision-makings such as risk informed technical specification changes, fire significant determination process, on-line maintenance, etc. To manually construct one top fire events PSA model, a PSA analyst should determine components failure modes relating to the equipment or cables located in each fire compartment or scenario, estimate their failure probabilities, and modeled them into PSA logics.

KAERI has been developing the IPRO-ZONE (interface program for constructing zone effect table) to construct one top fire events PSA model. With the output of the IPRO-ZONE, the AIMS, and internal event one top PSA model, one top fire events PSA model is automatically constructed. The output of the IPRO-ZONE include information on fire zones/fire scenarios, fire propagation areas, equipment failure modes affected by a fire, internal PSA basic events corresponding to fire-induced equipment failure modes, and fire events to be modeled. In this paper, we introduce the overview of the IPRO-ZONE, and the approaches for determining component failure modes and modeling of fire induced equipment failure events.

2. Overview of IPRO-ZONE

The main function of the IPRO-ZONE is to produce the SIMA [1] input file to be read in the AIMS-PSA for the construction of one top fire event PSA model. With one top internal event PSA model and the SIMA input file for fire PSA, the AIMS-PSA builds the one top fire event PSA model. Figure 1 shows the relation between the IPRO-ZONE, the AIMS-PSA, and one top fire event PSA model. The IPRO-ZONE cannot be used for new fire-induced accident sequences if the corresponding non-fire induced accident sequences do not already exist in the internal PSA model.

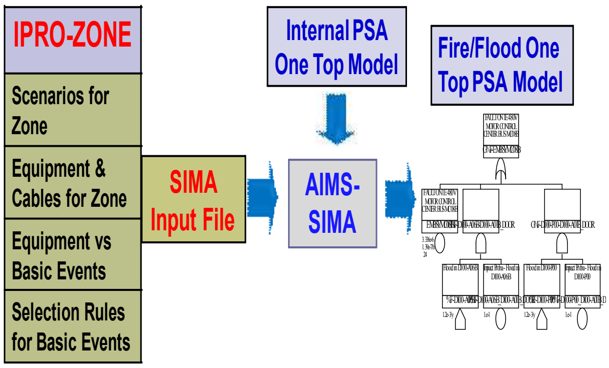

Fig. 1 Relation between the IPRO-ZONE, the AIMS-PSA, and one top fire event

3. Determination of equipment failure modes and modeling of fire induced equipment failure events

The rules for determining equipment failure modes due to a fire are based on general fire PSA approaches. The basic assumptions to determine the fire induced equipment failure modes are as follows:

- All equipment and cables in the fire zone are assumed to fail due to a fire
- Types of equipment failure modes are no failure, complete function loss, and spurious operation.
- Effects of instrumentation failures are not considered because they may introduce new accident sequence logics not shown in the internal PSA model.
- If equipment or cables related to motive power and control power for components exist simultaneously in the same zone, motive powers for components are assumed to be available when the failure of control cable is considered for the spurious operations.

The rules for determining the equipment failure modes were classified according to its operation characteristics, normal status, desired status in PSA, etc.

Detailed modeling approaches are presented in references [2, 3]. The following general criteria were applied for modeling fire induced equipment failure events.

- If fire induced equipment failure probability is one, set internal PSA basic event to true.
- If fire induced equipment failure probability is not one and greater than zero, fire induced equipment failure events are modeled with information on the fire zones.

- If more than one fire induced equipment failure event for the same equipment for the same zone/ fire occurrence event are considered and the largest equipment failure probability is one, leave the largest equipment failure event and eliminate the other fire induced equipment failure event

4. Results and Concluding remarks

The IPRO-ZONE was applied to the previous fire PSA model of Korean Nuclear Power Plant, Ulchin Unit 3, which was developed based on Fire PRA Implementation Guide [4]. The IPRO-ZONE was also applied to the fire and flooding event PSA projects for the SMART (System-integrated Modular Advanced Reactor) under design in KAERI. Figure 2 shows quantification results of one top fire PSA model of the SMART.

From the two pilot studies, we can confirm that the IPRO-ZONE is a useful tool for construction of one top fire event PSA model and quantitative screening analysis in fir PSA. Also, the IPRO-ZONE decrease the working hours of a PSA analyst in a fire PSA. More efforts are needed to improve the function and the user-interface of the IPRO-ZONE.

ACKNOWLEDGEMENTS

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References

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[2]. DAE IL KANG ET AL., "An approach to the construction of a one top fire event PSA model", Nuclear Engineering and Design 239 2514-2520,2009

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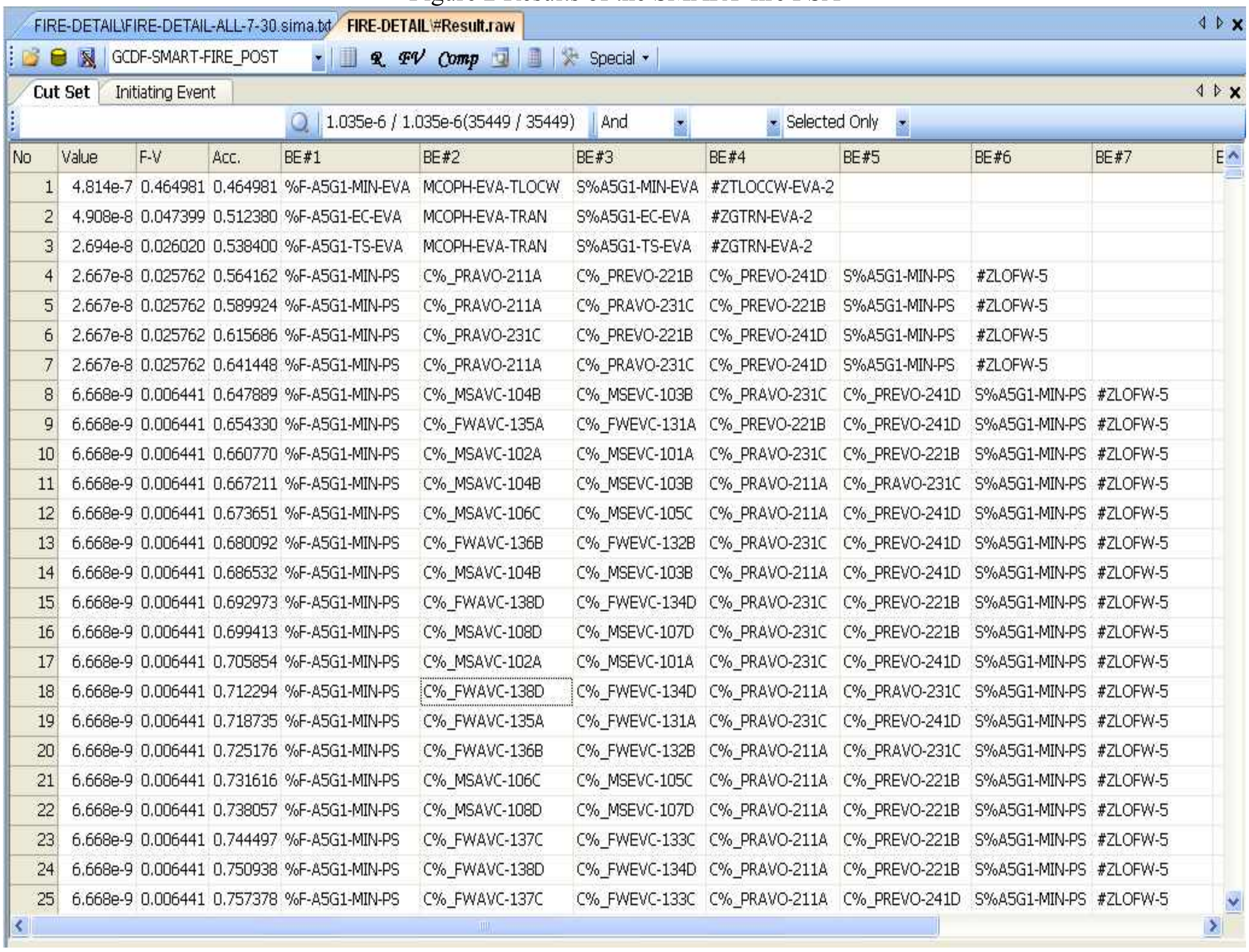
Figure 2 Results of the SMART fire PSA



No	Value	F-V	Acc.	BE#1	BE#2	BE#3	BE#4	BE#5	BE#6	BE#7
1	4.814e-7	0.464981	0.464981	%F-A5G1-MIN-EVA	MCOPH-EVA-TLOCW	S%A5G1-MIN-EVA	#ZTLOCCW-EVA-2			
2	4.908e-8	0.047399	0.512380	%F-A5G1-EC-EVA	MCOPH-EVA-TRAN	S%A5G1-EC-EVA	#ZGTRN-EVA-2			
3	2.694e-8	0.026020	0.538400	%F-A5G1-TS-EVA	MCOPH-EVA-TRAN	S%A5G1-TS-EVA	#ZGTRN-EVA-2			
4	2.667e-8	0.025762	0.564162	%F-A5G1-MIN-PS	C%_PRAVO-211A	C%_PREVO-221B	C%_PREVO-241D	S%A5G1-MIN-PS	#ZLOFW-5	
5	2.667e-8	0.025762	0.589924	%F-A5G1-MIN-PS	C%_PRAVO-211A	C%_PRAVO-231C	C%_PREVO-221B	S%A5G1-MIN-PS	#ZLOFW-5	
6	2.667e-8	0.025762	0.615686	%F-A5G1-MIN-PS	C%_PRAVO-231C	C%_PREVO-221B	C%_PREVO-241D	S%A5G1-MIN-PS	#ZLOFW-5	
7	2.667e-8	0.025762	0.641448	%F-A5G1-MIN-PS	C%_PRAVO-211A	C%_PRAVO-231C	C%_PREVO-241D	S%A5G1-MIN-PS	#ZLOFW-5	
8	6.668e-9	0.006441	0.647889	%F-A5G1-MIN-PS	C%_MSAVC-104B	C%_MSEVC-103B	C%_PRAVO-231C	C%_PREVO-241D	S%A5G1-MIN-PS	#ZLOFW-5
9	6.668e-9	0.006441	0.654330	%F-A5G1-MIN-PS	C%_FWAVC-135A	C%_FWEVC-131A	C%_PREVO-221B	C%_PREVO-241D	S%A5G1-MIN-PS	#ZLOFW-5
10	6.668e-9	0.006441	0.660770	%F-A5G1-MIN-PS	C%_MSAVC-102A	C%_MSEVC-101A	C%_PRAVO-231C	C%_PREVO-221B	S%A5G1-MIN-PS	#ZLOFW-5
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12	6.668e-9	0.006441	0.673651	%F-A5G1-MIN-PS	C%_MSAVC-106C	C%_MSEVC-105C	C%_PRAVO-211A	C%_PREVO-241D	S%A5G1-MIN-PS	#ZLOFW-5
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17	6.668e-9	0.006441	0.705854	%F-A5G1-MIN-PS	C%_MSAVC-102A	C%_MSEVC-101A	C%_PRAVO-231C	C%_PREVO-241D	S%A5G1-MIN-PS	#ZLOFW-5
18	6.668e-9	0.006441	0.712294	%F-A5G1-MIN-PS	C%_FWAVC-138D	C%_FWEVC-134D	C%_PRAVO-211A	C%_PRAVO-231C	S%A5G1-MIN-PS	#ZLOFW-5
19	6.668e-9	0.006441	0.718735	%F-A5G1-MIN-PS	C%_FWAVC-135A	C%_FWEVC-131A	C%_PRAVO-231C	C%_PREVO-241D	S%A5G1-MIN-PS	#ZLOFW-5
20	6.668e-9	0.006441	0.725176	%F-A5G1-MIN-PS	C%_FWAVC-136B	C%_FWEVC-132B	C%_PRAVO-211A	C%_PRAVO-231C	S%A5G1-MIN-PS	#ZLOFW-5
21	6.668e-9	0.006441	0.731616	%F-A5G1-MIN-PS	C%_MSAVC-106C	C%_MSEVC-105C	C%_PRAVO-211A	C%_PREVO-221B	S%A5G1-MIN-PS	#ZLOFW-5
22	6.668e-9	0.006441	0.738057	%F-A5G1-MIN-PS	C%_MSAVC-108D	C%_MSEVC-107D	C%_PRAVO-211A	C%_PREVO-221B	S%A5G1-MIN-PS	#ZLOFW-5
23	6.668e-9	0.006441	0.744497	%F-A5G1-MIN-PS	C%_FWAVC-137C	C%_FWEVC-133C	C%_PRAVO-211A	C%_PREVO-221B	S%A5G1-MIN-PS	#ZLOFW-5
24	6.668e-9	0.006441	0.750938	%F-A5G1-MIN-PS	C%_FWAVC-138D	C%_FWEVC-134D	C%_PRAVO-211A	C%_PREVO-221B	S%A5G1-MIN-PS	#ZLOFW-5
25	6.668e-9	0.006441	0.757378	%F-A5G1-MIN-PS	C%_FWAVC-137C	C%_FWEVC-133C	C%_PRAVO-211A	C%_PREVO-241D	S%A5G1-MIN-PS	#ZLOFW-5