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Development of a Base Frame for the New Fire PSA Training, and Lessons Learned

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1. Introduction

US NRC/EPRI issued a new fire PSA method represented by NUREG/CR 6850[1], and since it is about time to introduce the new fire PSA method as a regulatory requirement for the fire protection in Korea, a simple and easy-understandable base model for the fire PSA training is required, and thus KAERI-KINS jointly prepared a base model[2] for the new fire PSA training last year. In this year, as a base frame development, fire ignition frequencies and severity factors, which were assumed in developing of the base model, are calculated. The fire modeling is performed to get the severity factor.

This paper describes how the base frame i developed.

2. Educational Base Frame for the New Fire PSA

In this section, the base frame to be used for the new fire PSA training is described.

2.1 Fire Ignition Frequency

When the base model of fire PSA was developed, the fire ignition frequencies are assumed. Now how to calculate the fire ignition frequencies is described with a suitable Excel software. The fire ignition frequencies can be calculated by fixed ignition sources and transient ignition sources.

In Fig. 1, an example calculation of transient ignition frequency is shown.

2.2 Initiator for Fire PSA Model

As a simple example, let's assume the following simple internal PSA model.

Internal Event CDF ={ IE_1ABCE, IE_2ACDF}

And let's assume that cables and equipment locate as shown in Fig. 2. With Table 1 (Mapping Table), we can calculate CDF of the fire PSA with two methods. One method is to use CCDP (Conditional Code Damage Probability), and the other one is to modify the fault trees (FTs) of internal PSA model by adding 'initiator' (Let's call this method 'Initiator' method)

CCDP Method

$$CDF = \Sigma(R_i \times CCDP_i)$$

here,

R_i = the i^{th} room fire occurrence event having a frequency unit,
$CCDP_i$ = conditional core damage probability given R_i

$$\text{Internal CDF} = IE_1ABCE + IE_2ACDF$$

$$\rightarrow IE_1(A+A_f)(B+B_f)(C+C_f)E + IE_2(A+A_f)(C+C_f)(D+D_f)F$$

$$\rightarrow CCDP_1 = \Omega(A+\Omega)(B+\Omega)(C+\Omega)E + \varphi = E$$

$$CCDP_2 = \Omega(A+\varphi)(B+\varphi)(C+\Omega)E + \Omega(A+\varphi)(C+\Omega)(D+\Omega)F = ABE + AF$$

Thus,

$$CDF = R_1E + R_2ABE + R_2AF \text{ --------- Eq. (1)}$$

Initiator Method

$$\text{Internal CDF} = IE_1ABCE + IE_2ACDF \text{ ------- Eq. (2)}$$

With Table 1 (Mapping Table),

$$\rightarrow (R_1+R_2)(A+R_1)(B+R_1)(C+R_1+R_2)E + R_2(A+R_1)(C+R_1+R_2)(D+R_2)F$$

$$\rightarrow (R_1A+R_1+R_2A+R_2R_1)(B+R_1)(C+R_1+R_2)E + (R_2A+R_2R_1)(C+R_1+R_2)(D+R_2)F$$

$$\rightarrow (R_1+R_2A)(B+R_1)(C+R_1+R_2)E + (R_2AC+R_2A)(D+R_2)F$$

$\rightarrow (R_1B+R_1+R_2AB)(C+R_1+R_2)E + (R_2A)(D+R_2)F$

$\rightarrow (R_1+R_2AB)(C+R_1+R_2)E + (R_2A)(D+R_2)F$

$\rightarrow (R_1C+R_1+R_2AB)E + (R_2A)(D+R_2)F$

$\rightarrow (R_1+R_2AB)E + (R_2AD+ R_2A)F$

Thus, CDF = $R_1E+R_2ABE + R_2AF$ ---------- Eq. (3)

Therefore, Eq. (1) = Eq. (3). In other words,

CCDP Method = Initiator Method.

2.3 Fire Modeling

As an example to calculate a severity factor, a fire modeling of switchgear access room (see Fig, 3) is done. Among several scenario, the scenario in which MCC-A ignition fire occurs and damages tray HCBT-35A and HCBT-37B. As shown in Fig. 4, the selected scenario induces severity factor 0.655, and non-suppression probability 7.53E-2, and eventually damage frequency 4.88E-5.

2.4 Lessons Learned

After preparing the base frame of fire PSA including the base model, two days trainings courses were provided twice for plant engineers and regulators. Lessons learned from the training are the followings;

1) The training of fire PSA requires lot of background knowledge about PSA, such as system knowledge, constrained non-informative prior, data correlation, etc.
2) Two days training course is not enough to learn the fire PSA.
3) Since the base model of fire PSA and the spread sheet for the ignition frequency calculation are provided for the trainees, the trainee could easily understand the fire PSA model and ignition frequency.
4) Since FIVE is proprietary of EPRI, it is desirable to develop a similar tool in Korea.
5) It was difficult for the trainees to understand the severity factor.
6) For a while, the fire PSA training course should be provided for plant engineers.

3. Conclusions

Using an imaginary simple NPP, a base frame of fire PSA following the new fire PSA method was developed, and with which two days training course was provided twice for the plant engineers and regulators. Several lessons learned from the training are described. The two methods in quantification, i.e., CCDP method and initiator method are described.

Acknowledgements

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REFERENCES

[1] EPRI/NRC-RES, "Fire PRA Methodology for Nuclear Power Facilities," NUREG/CR-6850, Nuclear Regulatory Commission, Washington, DC, (2005).

[2] Kilyoo Kim, DaeIl Kang, A Study on Developing a Base Model for New Fire PSA, KINS/HR-1293, June 2013

FIRE AREA		
FIRE COMPARTMENT(Room No)	3	Cable Spreading Room
LOCATION	PW	

2. Calculation					RETURN
ID	Location	Ignition Source	WFIS	(FF)	(FISF)
3	Containment	Transients Hotwork		2.3E-03	0.0E+0
5	Control/Aux/Reactor	Cable fires caused by welding and cutting		1.2E-03	0.0E+0
6	Control/Aux/Reactor	Transient fires caused by welding and cutting		2.4E-03	0.0E+0
7	Control/Aux/Reactor	Transients		4.8E-03	0.0E+0
11	Plant-Wide	Cable fires caused by welding and cutting	7.4E-02	9.4E-04	7.0E-05
12	Plant-Wide	Cable Run(Self-ignited cable fires)	7.6E-04	1.3E-03	1.0E-06
18	Plant-Wide	Junction Box	7.6E-04	1.1E-03	8.5E-07
24	Plant-Wide	Transient fires caused by welding and cutting	3.3E-01	3.6E-03	1.2E-03
25	Plant-Wide	Transients	3.3E-01	8.2E-03	2.7E-03
31	Turbine Building	Cable fires caused by welding and cutting		4.5E-04	0.0E+0
36	Turbine Building	Transient fires caused by welding and cutting		7.5E-03	0.0E+0
37	Turbine Building	Transients		3.4E-03	0.0E+0
				3.7E-02	4.0E-03

3. Result

NUREG/CR-6850 Calculation	Value
FireFrequencyforPlantWideIgnitionSources=$F^{PW}_{T}=\sum F^{PW}_{IF}$ (Transient)	4.05E-03

Fig. 1 Room 3 Fire Frequency by Transient Ignition Source

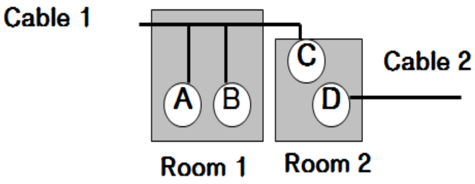

Fig. 2 An Example Rooms, Cables, and Equipment

Table 1. Mapping Table Given Room Fires

Fire Occurrence Events	Basic Events	Initiating Events
R_1	A_1, B_1, C_1	IE_1
R_2	C_2, D_2	IE_1, IE_2

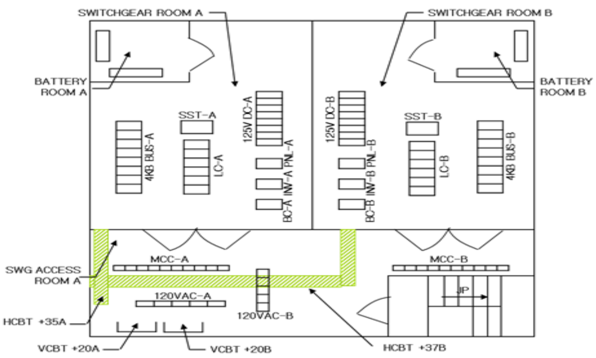

Fig. 3 Switchgear Access Room for Fire Modeling

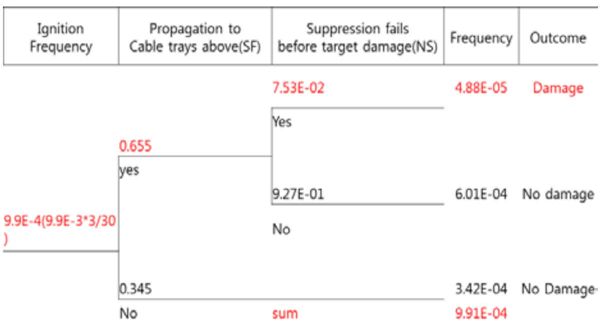

Fig. 4 Severity Factor and Non-Suppression Prob. for the Selected Scenario