A Preliminary Fire PSA on PGSFR

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1. Introduction

A Prototype Generation IV Sodium Fast Reactor (PGSFR) is under design with defense in depth concept with active, passive, and inherent safety features to acquire a design approval for PGSFR from Korean regulatory authority by around 2017.

A preliminary fire PSA on PGSFR is done in 2016 and a final fire PSA of PGSFR will be done in 2017. The characteristics of the preliminary fire PSA on PGSFR are described in this paper.

2. Methods

The first step of fire PSA is to find ignition sources and the possible damage items caused by fires of the ignition sources.

The difference between normal nuclear power plants and sodium fast reactors is that there would be a fire caused by sodium leak. Therefore, sodium flow path would be additional ignition source.

2.1 Prepared Necessary Data

Since many BOP design output developed by KEPCO ENC are delivered in 2017, final fire PSA on PGSFR will be completed at the end of 2017. However, since the following data can be prepared by using a part of BOP design, a preliminary fire PSA on PGSFR can be done.

- PSA equipment located in each fire area
- Ignition source existed in each fire area
- Fire transfer path in each fire area
- Sodium piping in each fire area
- Fire frequency in each fire area

2.2 Initiating Events for Fire PSA

The following initiating events which cannot occur by a fire are not modeled in the PGSFR fire PSA;

- Steam generator tube rupture
- Large secondary side break
- Vessel leak

The other initiating events considered in the internal PSA on PGSFR are all considered in the PGSFR fire PSA.

2.3 Quantification of PGSFR Fire PSA

The CDF induced by a fire is derived by the following equations:

$$CDF = \sum_{k=1}^{n} \lambda_k CCDP_k \quad (1)$$

where,

λ_k = Ignition frequency of fire area k
$CCDP_k$ = Conditional CDF of fire area k

The Eq. (1) is based on the assumption that if there is a fire in a fire area, all equipment and cables are lost in the fire area.

2.4 Ignition Frequency of PGSFR Fire PSA

The ignition frequencies of the fire areas are calculated by the methodology and data of NUREG-2169[1]. And, an example of ignition frequency is shown in the Table 1. However, the ignition frequency of Table 1 is based on the commercial nuclear power plants(NPPs) where there are many equipment, and systems are very complicated. The equipment number ratio of PGSFR vs commercial NPPs is 592 vs 1177. Thus, it is assumed that the ignition frequency of PGSFR is smaller by the (592/1177) factor.

Table 1: Example of Ignition Frequencies of PGSFR

Fire Area No	Room No	Name	Fixed	Transient	Total
F-RB		REACTOR BUILDING	2.65E-03	4.23E-04	3.07.E-03
	C104	CONTAINMENT ANNULUS AREA	0	1.80E-04	
	C205	CONTAINMENT ANNULUS AREA	6.56E-04	8.46E-05	
	C304	CONTAINMENT ANNULUS AREA	6.56E-04	8.46E-05	
	C401	OPERATING AREA	1.33E-03	7.37E-05	
F-C101		REACTOR CAVITY	1.37E-03		1.37.E-03

	C101	REACTOR CAVITY	1.37E-03		
F-C103		STORAGE ROOM	0	9.57E-05	9.57.E-05
	C103	STORAGE ROOM	0	9.57E-05	9.57.E-05
F-A102A		ESSENTIAL CHILLER RM	3.53E-03	8.82E-05	3.62.E-03
	A102A	ESSENTIAL CHILLER RM	3.53E-03	8.82E-05	3.62.E-03
F-A102B		ESSENTIAL CHILLER RM	3.53E-03	8.82E-05	3.62.E-03
	A102B	ESSENTIAL CHILLER RM	3.53E-03	8.82E-05	3.62.E-03

2.5 Increased Fire Frequency By Sodium Leak

The ignition frequency caused by the sodium leak is estimated by the following assumption:

> "In BN-600 SFR, there occurred 14 fires during 30 years (1980 ~2010) [2], and fire occurs evenly in the fire areas which have a sodium flow path without considering the complexity of sodium piping system"

With this assumption, the ignition frequency caused by the sodium leak is 1.67 x 10^{-2} /yr. [← (14/30)/28]

2.6 Fire PSA Modeling of PGSFR

Fire PSA model of PGSFR is based on the internal PSA, and it is derived by the Eq. (1). The illustrative example is shown in the Fig. 1. In Fig. 1, CCDP of each fire areas is derived by the sensitivity method.

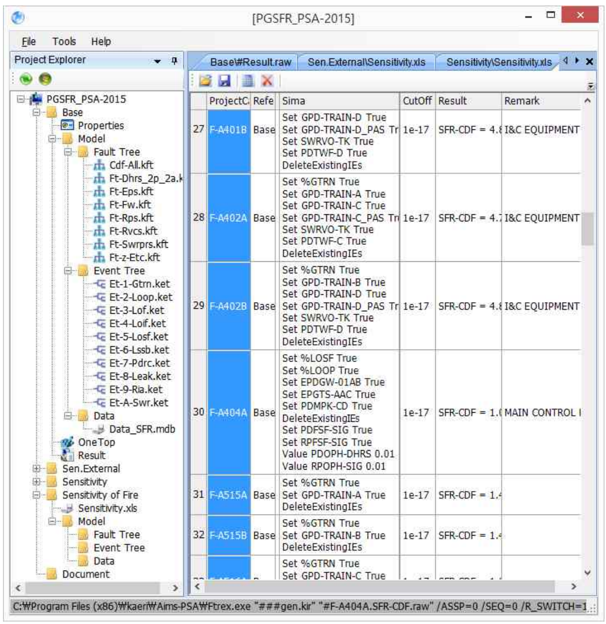

Fig. 1. An Example Screen of PGSFR PSA Model

3. Results and Conclusions

The 4th column of Table 2 is derived the 3rd column by multiplying the factor (592/1177). The 5th column is the ignition frequency caused by the sodium leak. The 6th column is derived by summing the 4th column and the 5th column. The 7th column is the CDF portion of each fire area. The control room (fire area F-A404A) is the most important area since the control room fire takes 89% portion of total CDF.

Table 2: CDF portion of each fire area

Fire Area	IEs	Ignition Freq. (NUREG-2169)	PGSFR Ignition Freq.	Sodium Fire	Total Ignition Freq.	CDF %
F-A116A	ET-LOIF	3.00E-05	1.51E-05	1.67E-02	1.67E-02	0.02%
F-A116B	ET-LOIF	3.00E-05	1.51E-05	1.67E-02	1.67E-02	0.02%
F-A121A	ET-GTRN	2.90E-05	1.46E-05	1.67E-02	1.67E-02	0.00%
F-A121B	ET-GTRN	2.90E-05	1.46E-05	1.67E-02	1.67E-02	0.00%
F-A205A	ET-GTRN	1.85E-03	9.32E-04	1.67E-02	1.76E-02	0.00%
F-A205B	ET-GTRN	1.85E-03	9.32E-04	1.67E-02	1.76E-02	0.04%
F-A206A	ET-GTRN	7.10E-04	3.57E-04		3.57E-04	0.00%
F-A206B	ET-GTRN	7.10E-04	3.57E-04		3.57E-04	0.00%
F-A209A	ET-GTRN	2.39E-03	1.20E-03		1.20E-03	0.00%
F-A209B	ET-GTRN	2.39E-03	1.20E-03		1.20E-03	0.00%
F-A316A	ET-GTRN	2.29E-05	1.15E-05		1.15E-05	0.00%
F-A316B	ET-GTRN	2.29E-05	1.15E-05		1.15E-05	0.00%
F-A319A	ET-GTRN	2.69E-05	1.35E-05	1.67E-02	1.67E-02	0.04%
F-A319B	ET-GTRN	2.69E-05	1.35E-05	1.67E-02	1.67E-02	3.51%
F-A322A	ET-GTRN	2.69E-05	1.35E-05	1.67E-02	1.67E-02	3.51%
F-A322B	ET-GTRN	2.69E-05	1.35E-05	1.67E-02	1.67E-02	0.04%
F-A401A	ET-GTRN	1.97E-03	9.89E-04		9.89E-04	0.00%
F-A401B	ET-GTRN	1.97E-03	9.89E-04		9.89E-04	0.00%
F-A402A	ET-GTRN	1.97E-03	9.89E-04		9.89E-04	0.00%
F-A402B	ET-GTRN	1.97E-03	9.89E-04		9.89E-04	0.00%
F-A404A	ET-LOOP	8.38E-03	4.22E-03		4.22E-03	88.90%
F-A515A	ET-GTRN	2.18E-05	1.10E-05	1.67E-02	1.67E-02	0.05%
F-A515B	ET-GTRN	2.18E-05	1.10E-05	1.67E-02	1.67E-02	0.05%
F-A516A	ET-GTRN	7.01E-04	3.52E-04	1.67E-02	1.70E-02	0.07%
F-A516B	ET-GTRN	7.01E-04	3.52E-04	1.67E-02	1.70E-02	0.07%
F-RB	ET-GTRN	3.07E-03	1.54E-03	3.33E-02	3.49E-02	3.66%
						100.00%

Since PGSFR is very safe reactor, it is not bad approach to use a conservative assumption in the preliminary PSA. In addition, several drawings including cable routing are not yet issued, a conservative calculation for CDF is performed. As shown in Table 2, the CDF caused by the fire in the control room takes 89% portion of total CDF. Thus, a detailed fire modeling for control room is necessary for the final fire PSA on PGSFR. Also, the increased ignition frequency due to sodium leak would be derived by considering the sodium piping complexity in the final fire PSA on PGSFR.

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