A STUDY ON PRA FOR SPENT FUEL POOL OF HANUL UNIT 3

Kilyoo Kim[1], Kwangil Ahn

[1] *Integrated Safety Assessment Division, Korea Atomic Energy Research Institute,*
P.O. Box 105, Yuseong, Daejeon 305-600, South Korea
kykim@kaeri.re.kr

After Fukushima accident, the safety of spent fuel pool (SFP) has become important. In 2014, EPRI published a PWR SFP PRA which included the impact on SFP by the reactor core melting and containment failure, and considered 7 days as a mission time. Since the EPRI PWR SFP PRA methodology can be easily applied to any PWR, a SFP PRA of Hanul Unit 3 was performed by adopting the EPRI methodology. In this paper, it is described how the EPRI methodology is adapted to the SFP PRA of Hanul Unit 3. Also, the characteristics of SFP PRA of Hanul Unit 3, after reflecting the reactor and containment failure through level 2 PRA, are discussed. In SFP PRA of Hanul Unit 3, the impact of the reactor and containment failure on SFP derived from level 2 is not considerable. For SFP PRA, however, the impact of the reactor and containment failure on SFP derived from level 2 seismic PRA should be further studied, and then. based on this new SFP PRA, a severe accident management could be enhanced.

I. INTRODUCTION

After Fukushima accident of 2011, the safety of spent fuel pool (SFP) has become important. In 2014, EPRI published a PWR SFP PSA (Ref.1) which included the impact on SFP by the reactor core melting and containment failure, and considered 7 days integrity of SFP instead of 24 hours. Since the EPRI PWR SFP PSA is a generic framework which can be easily adapted to a plant specific one, a SFP PSA of Hanul Unit 3 is being built up by adopting the EPRI framework. In this paper, it is described how the EPRI framework is adapted to the SFP PSA of Hanul Unit 3.

II. METHODS

Before Fukushima accident of 2011, the PSA of SFP considered only the failure of SFP during full power operation or shutdown. However, after Fukushima accident, the impact on SFP caused by a severe accident such as SFP failure due to containment failure is considered in the SFP PSA. Also, the evaluation time of SFP was extended to 7 days instead of 24 hours to reflect whether a nuclear power plant can endure for a long term loss of cooling.

Since EPRI suggested a generic PWR SFP PSA framework (Ref.1), every plant can easily perform his own plant specific SFP PSA by adopting the EPRI SFP PSA framework. In the adoption point of view, how Hanul Unit 3 SFP PSA was prepared through an adaptation is explained in the following subsections. The whole adaptation steps are shown in Fig.1.

II.A. Level 2 PRA Results

In Fig. 1, the first step is mapping from Hanul CET release sequence bins to the containment conditions.

The existing full power level 2 containment event tree (CETs) are divided into release sequence bins representing the following conditions of containment:

a. Energetic containment failure (ECFSFP)
b. Containment Isolation failure (CIFSFP)
c. Break Outside Containment (BOCSFP)

d. Containment Intact (Core Damage occurs) (CISFP)
e. OK (Core damage does not occur) (SFP-IE)

The plant specific frequency of each release sequence bin is derived from the Level 2 PSA of Hanul Unit 3 (Ref.2). The results are shown in Table 1 although the value of Hanul level 2 PSA are not official. In Table 1, the probability of containment intact even though a core damage occurs is much higher in Hanul Unit 3.

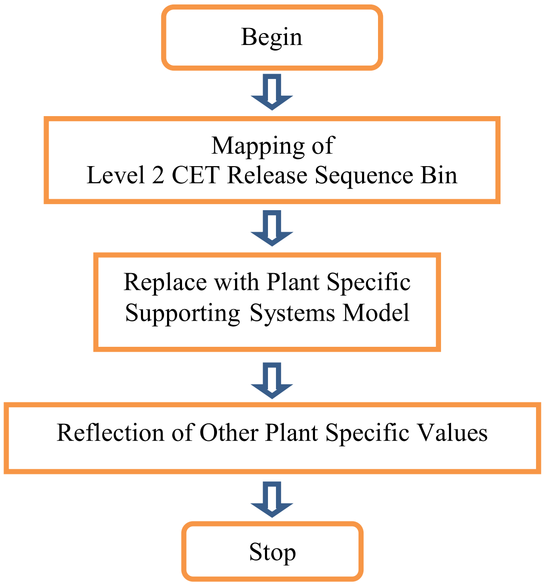


Fig. 1. The Adaptation Steps for Hanul Unit 3 SFP PSA Model

TABLE I. Mapping of Release Sequence bins of CET

EPRI SFP PSA		Level 2 CET of Hanul 3	
Containm't Condition	Freq.	Sequences	Freq.
ECFSFP	4.57e -6	3,4,5,6,7,8,9,10,11,12,13,14,16,17	8.07e-7
CIFSFP	1.08e-8	18,19	3.71e-9
BOCSFP	1.06e-6	20, 21	2.12e-7
CISFP	1.08e-8	1, 2, 15	1.80e-6

II.B. Supporting Systems

The supporting systems such as electrical system, component cooling water system, and HVAC system should be used and modeled in SFP PSA as well as in level 1 reactor PSA model. Therefore, since the level 1 reactor PSA model is the plant specific one, the supporting systems for SFP PSA should be modified with the plant specific supporting systems. Also, the river water which is used as an inventory source in the EPRI pilot plant is not used in the Hanul unit 3 model.

II.C. Event Trees

Five event trees (ETs) are developed according to the following 5 containment conditions.

a. Energetic containment failure (ECFSFP)
b. Containment Isolation failure (CIFSFP)
c. Break Outside Containment (BOCSFP)
d. Containment Intact (Core Damage occurs) (CISFP)
e. OK (Core damage does not occur) (SFP-IE)

For example, SFP-IE is the SFP IE when plant is operating or plant is successfully shut down with no core damage. This IE is the conventional SFP IE without considering the impact of core melting and containment failure. SFP-IE is shown in Fig. 2. The event sequences or names at each branch of SFP-IE are the same in the other four ETs.

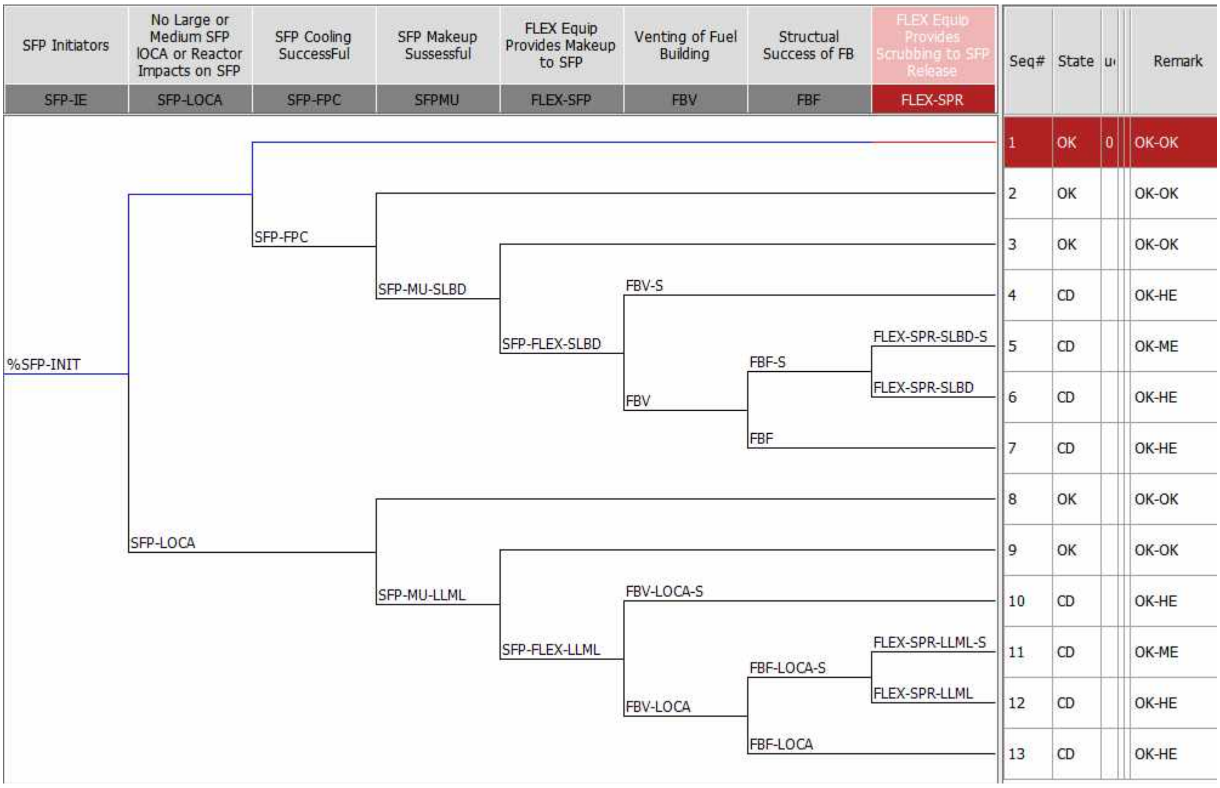
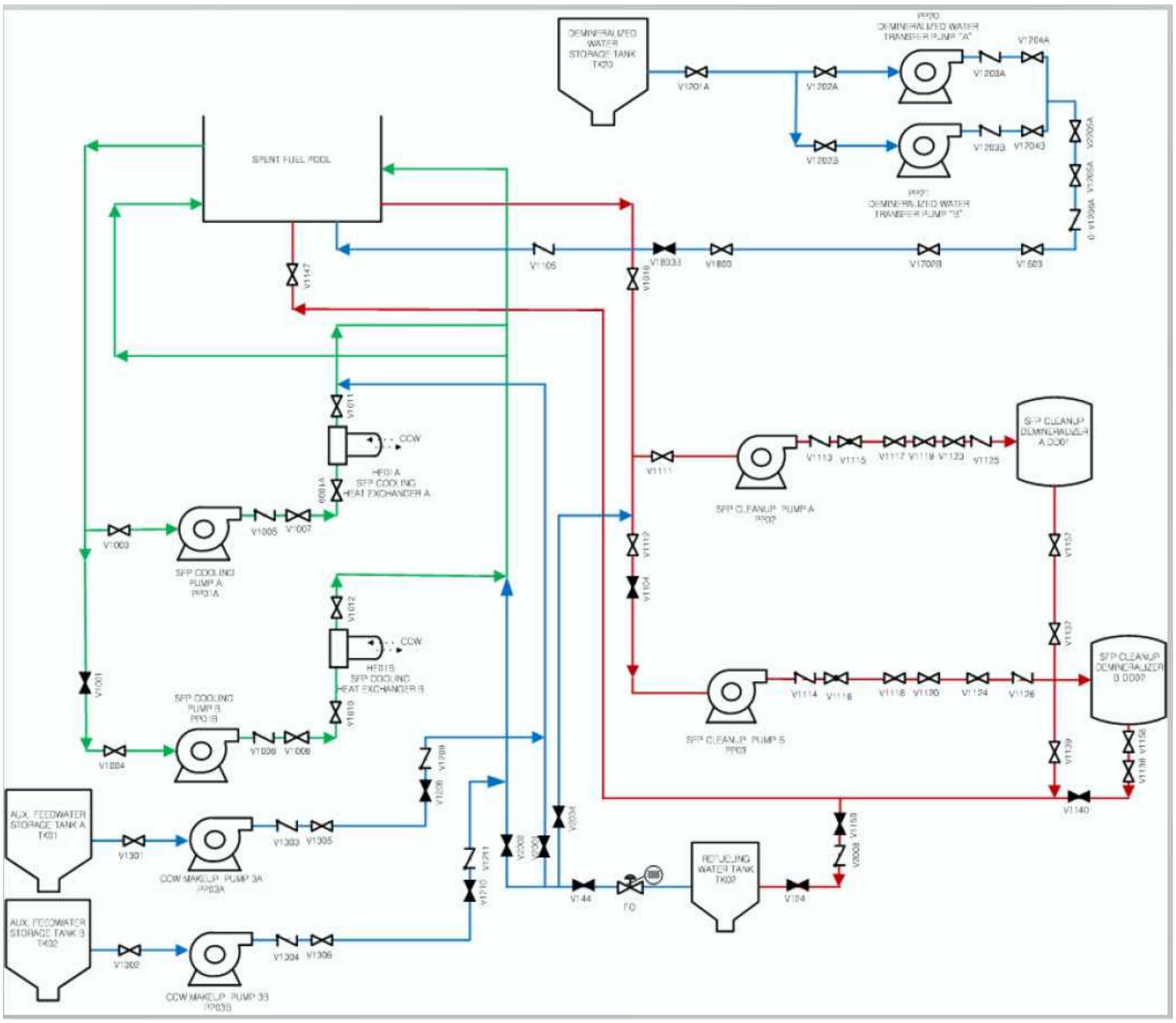


Fig. 2. SFP-IE ET of Hanul Unit 3 SFP

The cooling, purification, and make up systems for SFP of Hanul unit 3 are shown in Fig. 3. It is assumed that the purification system and the makeup system can be used for inventory control.



Cooling Line of SFP
Purification Line of SFP
Makeup Line of SFP

Fig. 3. Cooling and Makeup of Hanul Unit 3 SFP

II.D. Ohers

The frequencies of plant specific data such as loss of offsite power frequency should be used instead of those of EPRI generic framework model. It is modeled that spent fuels could be cooled with air without water in the EPRI generic framework. However, since it is not analyzed in the Hanul unit 3, the air cooling should be conservatively deleted. In Hanul unit 3, since all spent fuels are stored in the SFP, there are always spent fuels aged less than 150 days, and its related factor DECAY150 is modified to 1.0.

Also, it is also assumed that the occurrence of large LOCA of SFP is rare as the EPRI pilot plant.

III. RESULTS

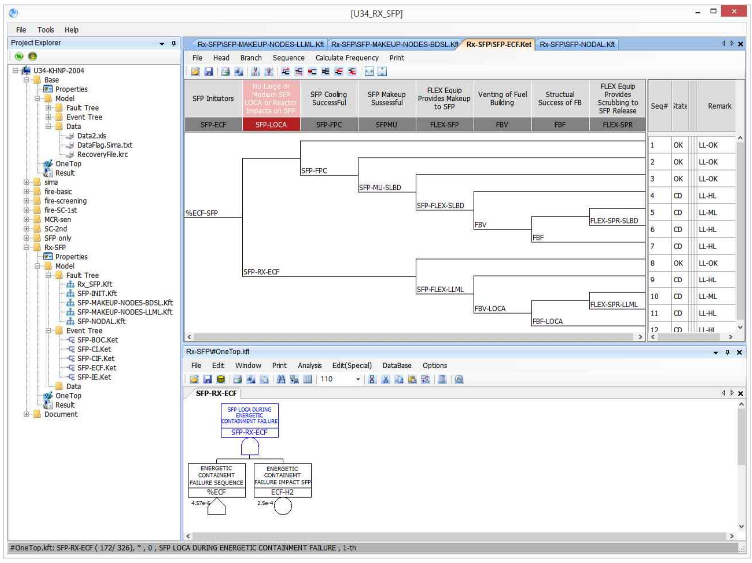


Fig. 4. An Example Screen of Hanul Unit 3 SFP PSA Model

A Hanul unit 3 full power internal SFP PSA is developed as shown in Fig. 4. However, it should be further enhanced by considering external events and shutdown mode.

Like the 7 day SFP evaluation of EPRI SFP PSA, Hanul SFP PSA adopts the same evaluation time. Practically, the evaluation time should be long enough since the spent fuel will not be damaged before about 58 hours even though there would occur a loss of SFP cooling in Hanul Unit 3 according to a thermal hydraulic calculation (Ref.3). In other words, there would be no risk in the SFP due to the loss of SFP cooling if the mission time is assumed as 24 hours.

Containment failures would cause damage on SFP and other supporting system. The probabilities of the damages are given in the EPRI generic framework, and the values are used in this Hanul SFP PSA. An example is shown in the fault tree of Fig. 4. However, plant specific data should be used in the later study.

In EPRI SFP PSA model, internal reactor PSA model and SFP PSA model are separately quantified even though they are related to each other. It is the same case in Hanul Unit 3 SFP PSA.

The portion of the severe accident including core melt and containment failure which causes SFP fuel damage was 35% in the EPRI report (Ref.1). However, the portion of that is smaller as much as below 1% in Hanul unit 3. The reason is that the value (CISFP), i.e., containment is intact event though core was damaged, is relatively large in Hanul unit 3 due to the large and strong containment.

As shown in the example event tree of Fig. 4, since the EPRI generic framework has considered several mitigating methods in the SFP accident, such as FLEX equipment which provides scrubbing to SFP release, a sensitivity analysis can be easily performed for a severe accident management. Those mitigating methods in the SFP accident can be easily reflected as house events in the plant specific model.

IV. CONCLUSIONS

The new approach considering the impact on SFP from reactor accident & containment failure, suggested by EPRI PWR SFP PSA Ref.1), is appropriate trend, and Hanul Unit 3 SFP PSA is being developed with the same approach. However, the impact on the SFP during the severe accident including core melt and containment failure in the Hanul unit 3 is negligible small due to the large and strong containment in the internal PRA point of view.

The generic framework suggested by EPRI can be well adopted to develop the plant specific SFP PSA. However, the probability and impact on SFP and its supporting system caused by the reactor accident & containment failure should be studied further. With this new SFP PRA model, the severe accident management of Hanul Unit 3 could be further enhanced.

ACKNOWLEDGMENTS

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