Development of a FT Modeling Method for Initiating Event Frequency Estimation

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1. Introduction

We developed a Fault Tree (FT) modeling method to estimate the initiating event frequency by reflecting a systems' configuration change and to handle it directly in the Core Damage Frequency (CDF) FT.

In the case of obtaining the initiating event frequency through the FT analysis, we have used a complicated estimation process in the existing Probabilistic Safety Assessment (PSA) as follows:

- ✓ Estimating the each initiating event frequency through the FT analysis and,
- ✓ Putting the initiating event frequency estimated into the FT for CDF and,
- ✓ Estimating the CDF frequency through the quantification of CDF FT

However, this means that it is necessary to perform several quantifications to obtain the initiating event frequency in case that a systems' configuration change. A component failure related to the initiating event is modeled in duplicate in the fault tree for the initiating event frequency estimation and for the CDF estimation. Therefore, we might have a problem with the estimation of the importance for the component because we quantify separately these two fault trees. Thus, in this paper, we propose a method to quantify the fault tree for the initiating event frequency and the CDF simultaneously [1].

2. Initiating Event Frequency Estimation

In this paper, we developed a time-averaged model for estimating support system initiating event frequency. However, the time-averaged models have limitations [2]. Thus, we focused on how to handle system configuration change and quantify directly the CDF without quantifying the initiating event frequency previously.

2.1 Development of FT modeling method for initiating event frequency FT addition to CDF FT

In a powered or shutdown PSA for a nuclear power plant, the initiator frequencies are typically obtained through two basic approaches, i.e., Bayesian analysis of the historical data, and system FT analysis [2].

Once the initiator frequency of a support system is obtained, it will be treated in the same way as any other initiating event is treated in the event tree, i.e., the initiating event leads to various scenarios that are separated into a set of plant damage states. This paper focuses on the initiating event frequency estimation through a system analysis.

The method will be explained with Loss of Component Cooling Water (LOCCW) as an example. For the derivation of this method, we used the definitions as follows:

f_x = Initiating fault tree (frequency)
g_x = Mitigating system fault tree (Unavailability)

According to these definitions, the fault tree for a LOCCW and CCW can be defined as follows:

f_{LOCCW} = LOCCW initiating event fault tree (frequency)
g_{CCW} = CCW system fault tree (Unavailability)

Other fault trees for initiating events except for LOCCW and other fault trees for systems except for CCW are defined as follows:

f_{Other} = Frequency or fault tree for other initiating events except for LOCCW (Occurring frequency)
g_{Other} = Fault trees for other systems except for CCW system (Unavailability)

For the simultaneous quantification of the initiating event fault tree and system fault tree when we quantify the CDF frequency, all of the CCW system fault tree modeled in the CDF fault tree, g_{CCW}, should be replaced with $g_{CCW} + f_{LOCCW}$.

$$g_{CCW} \rightarrow g_{CCW} + f_{LOCCW} \quad \ldots\ldots (1)$$

The verification for equation (1) can be described as follows. The accident sequences related to the CCW system and LOCCW can be expressed as equation (2) and (3). Equation (2) means the sequences which the initiating event is LOCCW and equation (3) means the sequences which the initiating event is other ones.

$$f_{LOCCW} * g_{Other} \quad \ldots\ldots (2)$$

$$f_{Other} * g_{CCW} * g_{Other} \quad \ldots\ldots (3)$$

First, in case that the initiating event is LOCCW, the sub set of $f_{LOCCW} * g_{other}$, $f_{other} * g_{ccw} * g_{Other}$, is removed during the quantification process and a sequence, $f_{LOCCW} * g_{other}$ are only quantified.

$$f_{LOCCW} * (g_{ccw} + f_{LOCCW}) \rightarrow f_{LOCCW} * g_{Other} \quad \ldots\ldots (4)$$

Second, in the case that the initiating event is not LOCCW, the multiple of the occurring frequency, $f_{Other} * f_{LOCCW}$, is automatically removed during the quantification process and f_{other} * g_{ccw} * g_{other} are only quantified. Therefore,

$$f_{Other}*(g_{CCW}+f_{LOCCW})*g_{Other} \rightarrow f_{Other}*g_{CCW}*g_{Other} \quad \text{............(5)}$$

2.2 Example: LOCCW

The cause of the initiating event frequency change can be divided into two cases as follows:

- ✓ Change of the initiating event frequency due to a component unavailability according to the system configuration change
- ✓ Change of the initiating event frequency due to a configuration change of shared components among units such as alternative AC Power

In this paper, we focused on the first case and we performed analysis for LOCCW as an example. The CCW system of the Korea Standard Nuclear Power Plant (KSNP) consists of Train A pumps (1A and 2A), and Train B pumps (1B and 2B). Two pumps, one pump from each train, are operated normally and the operating pumps are switched on periodically (Figure 1).

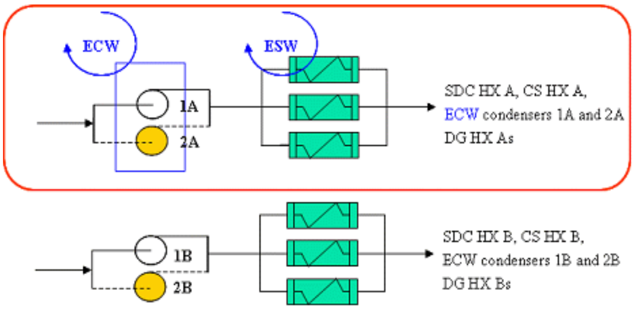

Figure 1. CCW System (KSNP)

2.2.1 LOCCW FT Modeling

Changes of the newly developed LOCCW FT via a comparison with the existing one are as follows:

- ✓ Modeling 'fails to start' CCF events for the all pumps (including train B) on standby
- ✓ Modeling 'fails to run' CCF events for the all pumps(1A, 2A, 1B, 2B)
- ✓ Loss of CCW Pump Room Cooling is removed because it is too conservative.

Figure 2 shows the basic FT logic reflecting the symmetry and we developed the LOCCW FT with it.

2.2.2 Results

The frequency of LOCCW estimated with the fault tree newly developed is 1.53e-2/yr. This is lower than the LOCCW frequency (4.28e-1/yr) of UCN 3, 4 because CCW pump room cooling failure was removed and we found that there is no problem in the developed FT modeling method through reviewing the cutsets. Figure 3 shows a part of the cutsets for the CCW train A failure.

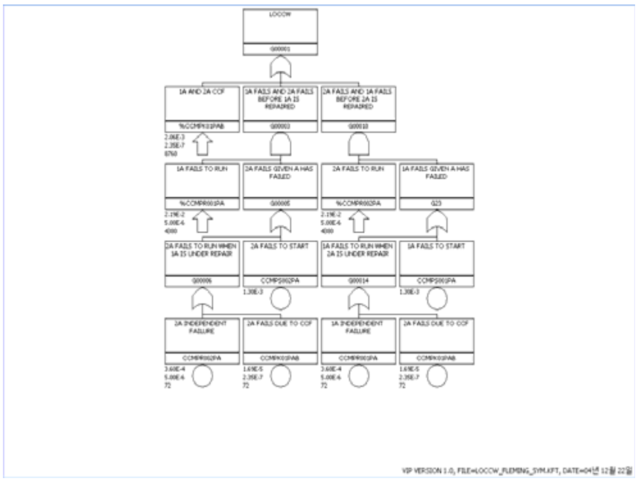

Figure 2. The basic FT logic reflecting symmetry

1. 2.400e-002 %U3-LOKV
2. 1.670e-002 HCTEYCC-57A
3. 1.300e-002 HCOPUCC-TE57A
4. 1.300e-002 FLAG-XTIE HHOPUTE-055A
5. 6.580e-003 HHOPUTE-05556
6. 6.580e-003 HCOPUCC-TE5758
7. 6.500e-003 HHOPUTE-055A SWOPHXTIE
8. 4.380e-003 %CCHXBHE01A CCOPHHE02A
9. 4.380e-003 %CCHXBHE02A CCOPHHE01A
10. 3.720e-003 FLAG-XTIE HHTEY-055A

Figure 3. Minimal cutsets on GCCTRA

3. Conclusions

Newly developed FT model for LOCCW can reflect the effect of a system configuration change. Therefore, we do not need to estimate the initiating event frequency several times according to the system configuration change. We also found mistakes in the CCF modeling and modeling logic for LOCCW FT, and the newly developed model has no problem during the quantification process. Thus, the development of the FT for other initiating events estimated through a FT analysis would be necessary.

Acknowledgments

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