Study on the Uncertainty Bound due to a PDS Approximation of the Level 1 ET Sequence Cut Sets

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1. Introduction

While a strict PDS operation requires that all the Level 1 ET core damage sequences are assigned to all the relevant PDS categories and that their sum is equal to the total CDF, the current practices of the ET/FT combinations causes an inevitable approximation of the total PDS frequency (PDSF) to the total CDF value. The main objective of this paper is to estimate a type of uncertainty bound for the total PDSF (or a degree of PDSF approximation to the CDF) due to a propagation of the Level 1 ET sequence cut sets into the relevant PDSs, consequently leading to a change of the corresponding Level 2 risk metrics (such as containment failure frequencies or large early release frequency). This approach would be useful to establish the cut sets associated with the Level 2 PSA sequences and the related importance of the Level 1 events to the Level 2 risk metrics [1].

2. Methods and Results

As a starting of the Level 2 PSA, the PDS approach provides pinch points between the Level 1 plant model and the Level 2 containment model. Its main concept is to map the Level 1 accident sequence (or cut sets) extended to the containment systems into the relevant similar plant states. As a logical tool for the PDS analysis, we utilize a type of Level 1/2-bridge tree (called 'PDS ET'), and a mapping of all the ET sequences to PDS categories to obtain the corresponding single operational FT model [1]. Then, the bridge tree given in the form of 'PDS ET' contains the additional top events needed to define the initial conditions for the accident progression analysis in sufficient detail. With these types of event trees, all the PDS ET sequence cut sets can be transferred into the relevant PDS categories, without a loss of the Level 1 information

2.1 Evaluation Approach

With the foregoing approach for the PDS analysis, a type of sensitivity analysis has been implemented to obtain an uncertainty bound for the PDSF of the underlying PDS model, with a one-by-one change of a PDS grouping scheme (e.g., different categorization of the PDSs). Whereas, the bridge trees themselves between the Level 1 and 2 remain unchanged for all the sensitivity analyses, and the same cutoff value is applied to identity the impact of the PDS binning scheme itself. Its practical implementation has been made with a help of a coupled software package [2,3], which is currently controlled by 'AIMS-PSA Manager'. The AIMS system has been recently modified to match the end points of the Level 1 ETs (or Level 1/2 bridge trees) with the corresponding PDS categories. This approach is particularly useful in a mapping of the Level 1 ET sequences to the corresponding PDS, when a type of bridge trees is utilized for a PDS categorization. As implemented in most PSAs, the present quantification of an ET/FT with negates is also made by a success operation of (a) use of a 'delete-term procedure' to remove the nonsense cut sets related to the success branches and (b) a 'minimization between sequences' to remove the non-minimal cut sets between the ET sequences. It is noted that when the present PDS binning operation is made, all the ET sequence cut sets obtained from both operations are independently treated.

2.2 Evaluation Results

The foregoing approach for the PDS analysis has been applied to the existing UCN 3&4 Level 1/2-bridge trees and PDS logic tree [4]. A PDS logic tree is utilized systematically to group the Level 1/2-bridge trees into the relevant PDS categories. The PDS logic tree is not quantified by it, but used for the PDS binning from the PDS ET sequences with the user-supplied PDS classification parameters [3]. As a result of the sensitivity analysis, Figure 1 shows a change of the total PDSF according to the change of a different PDS binning scheme from the Level 1/2-bridge trees (PDS ET models).

As shown in Figure 1, the uncertainty bound of the UCN 3&4 PDSF always lies between when a single PDS is utilized and when all the individual ET sequences are treated as the corresponding unique PDS categories. The latter portion is equivalent to the case without a minimization operation between the ET sequences and so all the ET sequences are treated independently. It is also noted that when the cutoff value of 1.0E-11 is applied, the PDSF approaches the CDF value of 6.828E-6 as the number of PDS categories approaches 37 while a sum of all the PDS ETs provides a frequency of 6.746E-06 (this is

a CDF-equivalent frequency). The foregoing difference between the PDSFs and the CDF-equivalent frequency is due to a mixture of two factors: (a) one is an increase of the truncated cut sets due to the additional top events considered in the Level 1/2-bridge trees (i.e., loss of truncated frequencies), and (b) another is an increase of the individual PDSFs due to an independent treatment of the PDS categories. For the 37 PDS categories utilized for the UCN 3&4 Level 2 PSA, the PDS approximation of the Level 1/2-bridge trees is overestimated by about 1.2%, when compared to the corresponding CDF-equivalent value.

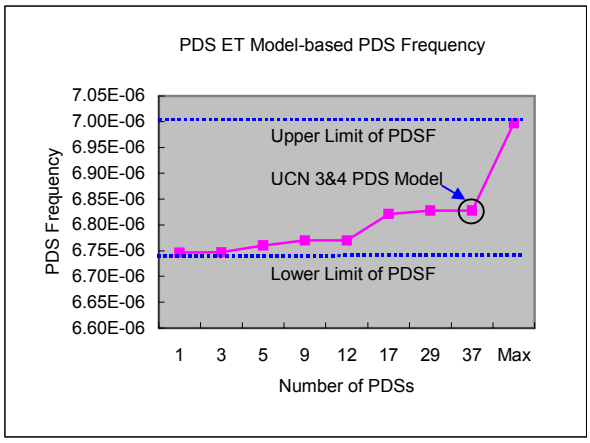

Figure 1. A change of PDS ET-based PDSF due to the different binning of PDS

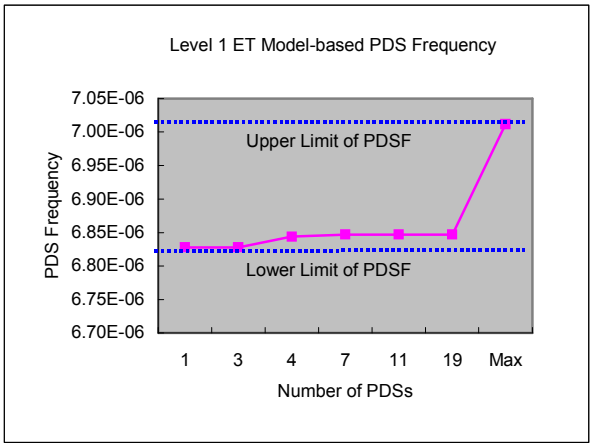

Figure 2 A change of Level 1 ET-based PDSF due to the different binning of PDS

Another type of sensitivity analysis has been performed to assess an impact of the Level 1/2 ET models on the potential PDSF. For this, the Level 1 ET models for a CDF estimation have been propagated into the same PDS logic tree. The foregoing situation indicates that the number of Level 1 ET sequences to be binned into the PDSF is greatly reduced when compared to that of the Level 1/2-bridge trees. Figure 2 shows that the resultant change of the PDSF according to a given PDS structure is less sensitive when compared to that of Figure 1. The difference between the total PDSF due to a PDS approximation of the Level 1 ETs and the CDF value is just 0.3%.

3. Concluding Remarks

Based on the present study, we have drawn the following findings and conclusions:

(a) When the Level 1 ET sequence cut sets are propagated into the relevant PDSs, the resultant PDS frequencies are a function of both the utilized Level 1/2-bridge trees and PDS structure. More specifically, for the same cutoff value, the total PDS frequency increases as the number of PDSs increases and decreases as it decreases, requiring a need for a balanced PDS structure when it is applied to the calculation of the Level 2 risk metrics;

(b) For the same cutoff value, the resultant PDSF is subject to its upper and lower bound. That is, the given PDSF always lies in between a single-PDS-based PDSF and all the ET sequences-based PDSF. The present analysis shows that the PDS approximation from the Level 1/2-bridge trees may vary the PDSF value from –1.2% to 2.5% due to the different binning of PDS, compared to the CDF value of 6.828E-6 estimated from the Level 1 ET/FT models).

(c) When the PDS categories are independently treated froe each other, a total PDSF for the corresponding PSA cut sets is always equal to or greater than the Level 1 CDF value. This is mainly due to an inherent nature of the PDS binning process that particular cut sets of one PDS may be subsets (or super sets) in another PDS.

ACKNOWLEDGEMENTS

This study was performed as a part of the '*long term research and development plan for the nuclear energy*' supported by the Ministry of Science and Technology.

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