Incorporation of Truncation Errors in Auxiliary Feed Water System PSA by CUTREE

Dongil Lee and Nam Zin Cho*
373-1 Gusong-dong, Yusong-gu, Daejeon 305-701, Republic of Korea
**Corresponding author: nzcho@kaist.ac.kr*

1. Introduction

In fault tree analysis of probabilistic safety assessments (PSA), truncation errors (TE) which take place during a minimal cut set (MCS) generation process are usually unknown. Therefore, the top-event probability and the importance measures from an incomplete cut set equation could be unreliable without quantifying the truncation errors.

For overcoming these drawbacks of conventional tools, the CUTREE code[1-3] can be used to estimate the truncation errors in incomplete Boolean expressions. It also contributes to quantify the importance measures which are used for ranking basic events in risk-informed regulatory application, taking truncation errors into account. It allows the user to calculate the top event probability by assessing the equivalent sum of disjoint products (SDP) and by the rare event approximation (REA) compensated for its conservatism by the correction factor approach (CFA). In this paper, the actual auxiliary feed water system (AFWS) is used to demonstrate the advantages of the CUTREE code[1-3].

2. Methods and Results

The information of the fault tree of AFWS is based on *Level I Probabilistic Safety Assessment For Kori Units 3&4 Final Report* [4]. The tool used for MCS quantification is FTREX[5]. The number of batches used for TE and CFA module is 10E9. The cut-off value which is used in CFA module is 10E-13.

2.1 Top Event Probability and Comparison of Results of Each Module.

Fig. 1 shows a comparison of AFWS top event probabilities calculated by REA, SDP, and CFA as a function of cut-off value (without taking truncation errors into account).

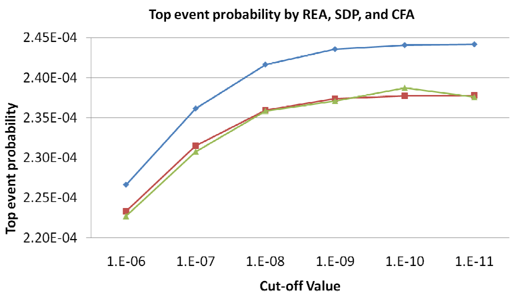

Fig. 1 Top event probability by REA, SDP, and CFA

The top event probability calculated by the SDP module (no approximation for given MCS) approaches a plateau if the cut-off value is around 10E-11 (which may be considered reference value SDP_{ref}).

In Fig. 2, it is verified that CFA module generates more accurate top event probabilities, which are closer to the results of SDP than REA.

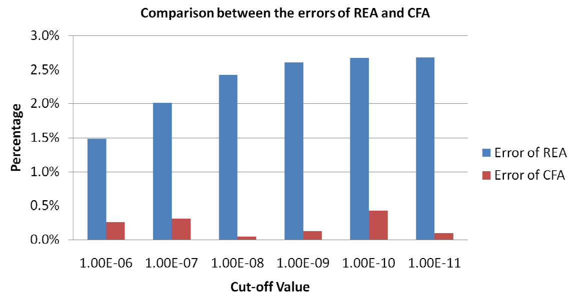

Fig. 2 Comparison of REA and CFA errors

Figs. 3 and 4 show the top event probabilities and errors by CFA with truncation errors incorporated, compared with SDP.

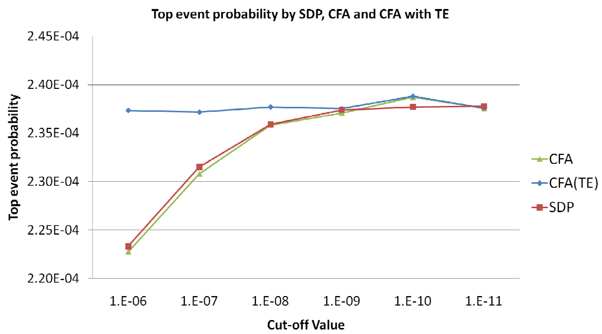

Fig. 3 Top event probability by SDP, CFA and CFA with TE

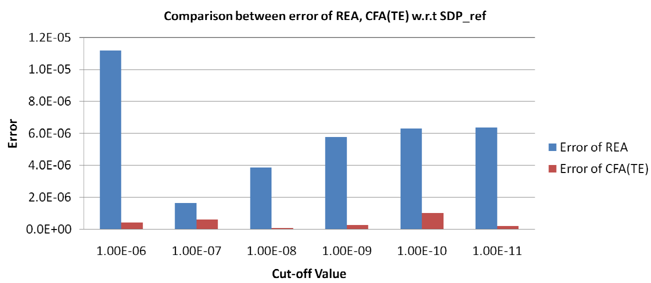

Fig. 4 Comparison between errors of REA, and CFA(TE) with respect to SDP_{ref}

If we take the truncation errors into account, without lowering the cut-off value enough such as 1.00e-11, very similar top event probability with SDP_{ref} can be obtained by CFA (TE). It means that even with a very limited number of minimal cut sets (much shorter computing time), we can calculate top event probability very accurately by CFA.

2.2 FV and RAW Importance Measures

Figs. 5 and 6 show Fussell-Vesely (FV) and Risk Achievement Worth (RAW) importance measures, respectively, for several basic events, evaluated with and without truncation errors incorporated. The rankings are different for some of the basic events, depending on whether the truncation errors are incorporated or not.

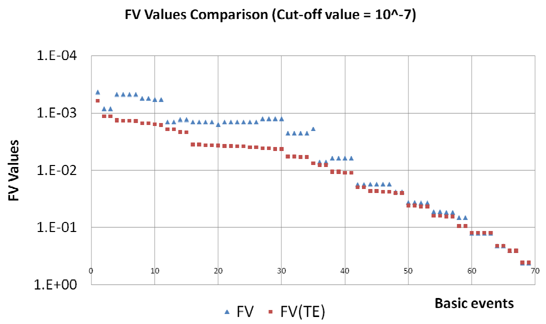

Fig. 5 Comparison of FV values

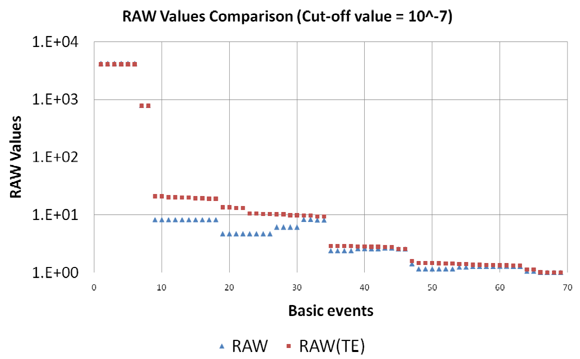

Fig. 6 Comparison of RAW values

2.3 CPU Time Comparison

Fig. 7 shows that CPU time of SDP module is increasing exponentially with cut-off values decreasing. On the other hand, CPU time of CFA is almost constant as about 1.00e+3 (1200) seconds. It is expected that the SDP module will take much longer times for smaller cut-off values and/or for larger or more complex fault trees.

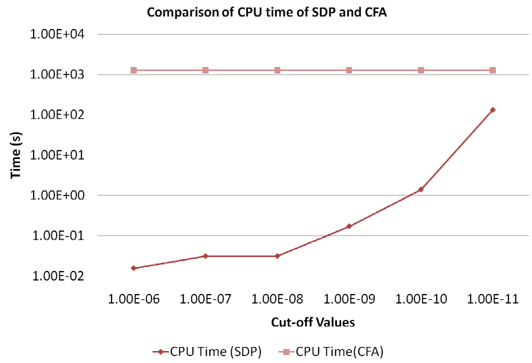

Fig. 7 CPU times of SDP and CFA modules

3. Conclusions

When the CUTREE code is used, we expect at least five improvements which have rarely been achieved in the literature. 1) Quantifying truncation errors is helpful to determine how much truncation errors are sufficient for an acceptable top event probability. 2) SDP module calculates it accurately without errors, although exponentially increasing computing time with a very low cut-off value. 3) When facing these problems, CFA module can be used to compute the results which are closer (less than 0.5%) to that of SDP without requiring too high computing load. 4) Taking truncation errors into account, even with a small number of minimal cut-sets, quite accurate top event probability can be obtained very efficiently by CFA (TE). 5) If CUTREE is used to evaluate importance measures such as FV and RAW values with truncation errors, it provides more accurate values and rankings of the basic events.

REFERENCES

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