A Comparison between Fault Tree Analysis and Reliability Graph with General Gates

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1. Introduction

Currently, level-1 probabilistic safety assessment (PSA) is performed on the basis of event tree analysis and fault tree analysis. Kim and Seong [1] developed a new method for system reliability analysis named reliability graph with general gates (RGGG). The RGGG is an extension of conventional reliability graph, and it utilizes the transformation of system structures to equivalent Bayesian networks for quantitative calculation. The RGGG is considered to be intuitive and easy-to-use while as powerful as fault tree analysis.

As an example, Kim and Seong [2] already showed that the Bayesian network model for digital plant protection system (DPPS), which is transformed from the RGGG model for DPPS, can be shown in 1 page, while the fault tree model for DPPS consists of 64 pages of fault trees. Kim and Seong also insisted that Bayesian network model for DPPS is more intuitive because the one-to-one matching between each node in the Bayesian network model and an actual component of DPPS is possible.

In this paper, we are going to give a comparison between fault tree analysis and the RGGG method with two example systems. The two example systems are the recirculation of in Korean standard nuclear power plants (KSNP) [3] and the fault tree model developed by Rauzy [4].

2. Comparison between Two Methods

2.1 Recirculation in KSNP

Figure 1 shows a simplified process and instrumentation diagram (P&ID) for the high pressure safety injection (HPSI) system of KSNP. When recirculation actuation signal (RAS) is generated after safety injection in a LOCA situation, the water in the containment sump will be injected into the hot legs of reactor coolant system (RCS) loops through various valves, check valves and HPSI pumps. Figure 2 shows the Bayesian network model for the recirculation in KSNP. Even though the fault tree model is not shown in this paper, the comparison between the fault tree model and the Bayesian network model shows that the Bayesian network model is much simpler. Moreover, the Bayesian network model is more intuitive in that the Bayesian network model is quite similar to the actual structure of the system.

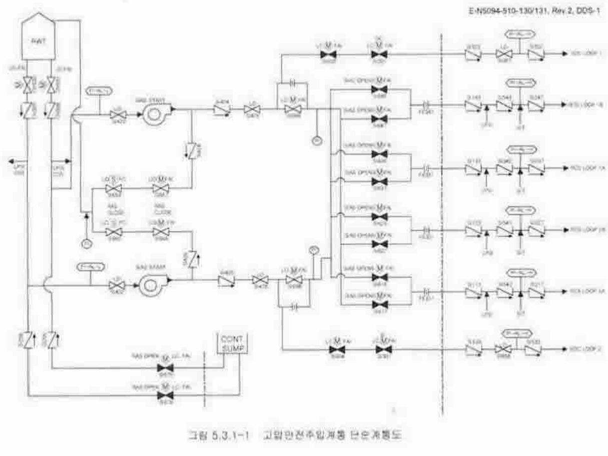

Figure 1. Simplified P&ID for high pressure safety injection (HPSI) system of KSNP

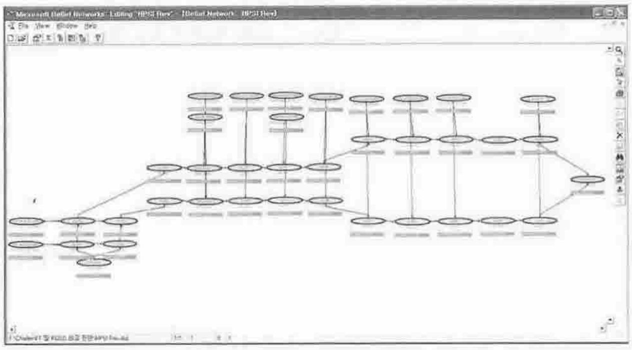

Figure 2. Bayesian network model for recirculation in KSNP

The following is the quantitative analysis result when the two methods are used. From the calculation result, it can be seen that the Bayesian network calculates similar results with the fault tree analysis. In fact, the calculation result using Bayesian networks is the exact value, while the calculation result of the fault tree analysis is an approximation such as the sum of minimal cut set probabilities.

o Fault tree analysis (KwTree) : 2.785×10^{-3}

o RGGG (MSBNx) : 2.77466×10^{-3}

When we compare the calculation speed, it is generally known that the calculation speed of fault tree analysis is much faster. But, due to the small size of the problem, the difference of calculation speed was not quite distinguishable. Both methods generated the results almost immediately.

2.2 Fault Tree developed by Rauzy

The fault tree in Ref. 4 has been used to test the performance of fault tree analysis algorithms. It is a small but very complex fault tree that has 183 gates and basic events. Even though the most important advantage of the RGGG is its intuitiveness, it can be also applied to develop equivalent Bayesian networks for fault trees. In fact, the transformation of fault trees into equivalent Bayesian networks can also be found in Bobbio et al.[5].

Figure 3 shows the Bayesian network model for the fault tree model developed by Rauzy and Table 1 shows the comparison of calculation results of fault tree analysis (FTREX-MCSs and KIRAP[6]), binary decision diagrams (FTREX-BDD [7,8]) and Bayesian networks (MSBNx [9]). It can be seen from Table 1 that Bayesian networks calculates the exact top event probability, which is same with the calculation result of FTREX-BDD, in a quite short time. FTREX-MCS generated all MCSs and calculated the sum of all MCS probabilities as a top event probability,

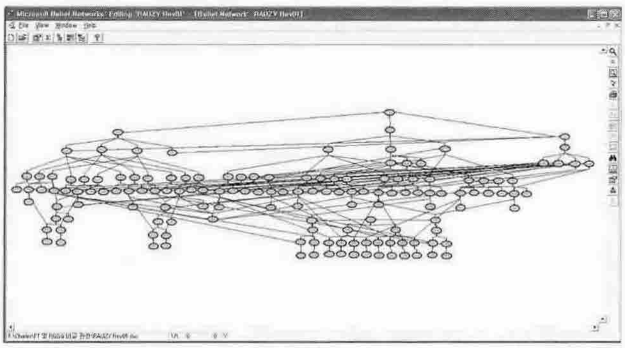

Figure 3. Bayesian network model for the fault tree model developed by Rauzy.

Software tool	Calculation time	Truncation Limit	Calculation Result
FTREX-MCSs	0.50 sec	0×10^{-0}	1.6815×10^{-6}
FTREX-BDD	0.25 sec	N/A	1.2823×10^{-6}
KwTree	About 2 sec	1×10^{-12}	1.679×10^{-6}
MSBNx	< 1 sec	N/A	1.2823×10^{-6}

Table 1. A comparison of calculation results among FTREX, KwTree and MSBNx for the fault tree model developed by Rauzy

3. Conclusion

The sample Benchmark tests show that Bayesian network could calculate the exact top event probability of a fault tree in a short time. where the RGGG models are developed instead of the fault trees.

From the application of fault tree analysis and the RGGG method to two different example systems, it can be found that the RGGG model is intuitive and Bayesian networks calculate the exact value for the unavailability of a system in a quite short time. Therefore, we believe that the RGGG method can be widely used for an intuitive and practical method for system reliability analysis.

In the fields of PSA, the unavailability calculation is already well established with fault tree analysis. Even though we cannot fully utilize the intuitiveness of the RGGG, which is the most important advantage of the RGGG, we can make use of the RGGG method for verification of the calculation results of fault tree analysis. If we conduct more researches on the RGGG method, we believe that we can develop a new principle for solving large fault trees which can compete to binary decision diagrams (BDDs).

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