Transactions of the Korean Nuclear Society Spring Meeting
Pyeongchang, Korea, May 27-28, 2010

Verification of Fault Tree Models with RBDGG Methodology

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1. Introduction

Currently, fault tree analysis is widely used in the field of probabilistic safety assessment (PSA) of nuclear power plants (NPPs). To guarantee the correctness of fault tree models, which are usually manually constructed by analysts, a review by other analysts is widely used for verifying constructed fault tree models.

Recently, an extension of the reliability block diagram was developed, which is named as RBDGG (reliability block diagram with general gates) [1]. The advantage of the RBDGG methodology is that the structure of a RBDGG model is very similar to the actual structure of the analyzed system and, therefore, the modeling of a system for a system reliability and unavailability analysis becomes very intuitive and easy. The main idea of the development of the RBDGG methodology is similar to that of the development of the RGGG (Reliability Graph with General Gates) methodology [2]. The difference between the RBDGG methodology and RGGG methodology is that the RBDGG methodology focuses on the block failures while the RGGG methodology focuses on the connection line failures. But, it is also known that an RGGG model can be converted to an RBDGG model and vice versa.

In this paper, a new method for the verification of the constructed fault tree models using the RBDGG methodology is proposed and demonstrated.

2. The Proposed Verification Method

The verification of a fault tree model can be performed by constructing an RBDGG model for the system and then comparing the two results. Because an RBDGG model is developed in a completely different way with a fault tree model, it can be said that if the two calculation results are same, it is highly probable that both the fault tree model and the RBDGG model are correct.

Fig. 1 shows the flowchart for the verification of a fault tree model with the RBDGG methodology. The first step is to construct a fault tree model for the target system. This step is normally performed for the system reliability and unavailability analysis with the fault tree analysis method. The second step is to construct an RBDGG model for the target system, and this step is added for the purpose of the verification of fault tree models. After constructing the fault tree model and the RBDGG model, the quantification of the system unavailability is performed. In Fig. 1, U_{FT} denotes the calculated system unavailability from the fault tree model, and U_{RBDGG} denotes the calculated system unavailability from the RBDGG model. After the quantification, the two calculation results are carefully compared to find any discrepancy between the two calculation results. If the two quantification results are the same, it can be said that the fault tree model and the RBDGG model are correct and therefore it is concluded that the fault tree model is verified. If the two calculation results are different, the fault tree and the RBDGG models are reviewed and modified if necessary. After the modification of the fault tree or the RBDGG models, the quantification and comparison is performed again.

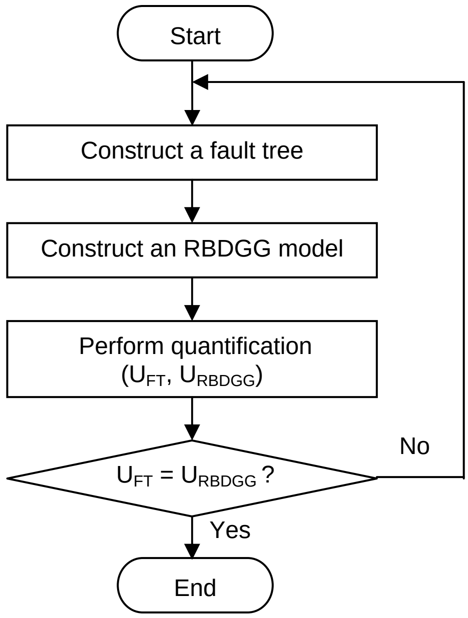

Fig. 1. Flowchart for the verification of a fault tree models with the RBDGG methodology

3. An Example

As an example, the proposed verification method is applied to a simple system. The target system is the bridge structure system, which is shown in Fig. 2. For quantification purposes, the unavailability data for A, B, C, D, and E are assumed to be 0.01, 0.02, 0.13, 0.23, and 0.21.

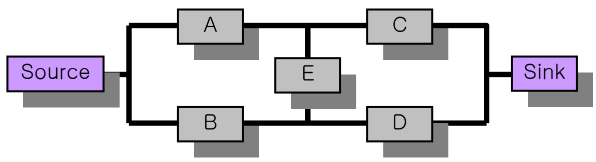

Fig. 2. Bridge structure system

Fig. 3 shows the fault tree model for the bridge structure system and the quantification result. The fault tree analysis is performed with AIMS-PSA [3], and the quantification is performed using FTREX [4], which is a fault tree solver based on coherent binary decision diagram (BDD) algorithm. The system unavailability is calculated to be 0.030922.

Fig. 4 shows the Bayesian network model constructed by the RBDGG methodology for the bridge structure and the quantification result. The Bayesian network modeling and analysis is performed with MSBNx, which is a Bayesian network analysis tool. The system unavailability is calculated to be 0.030922. The two system unavailability calculation results are found to be the same.

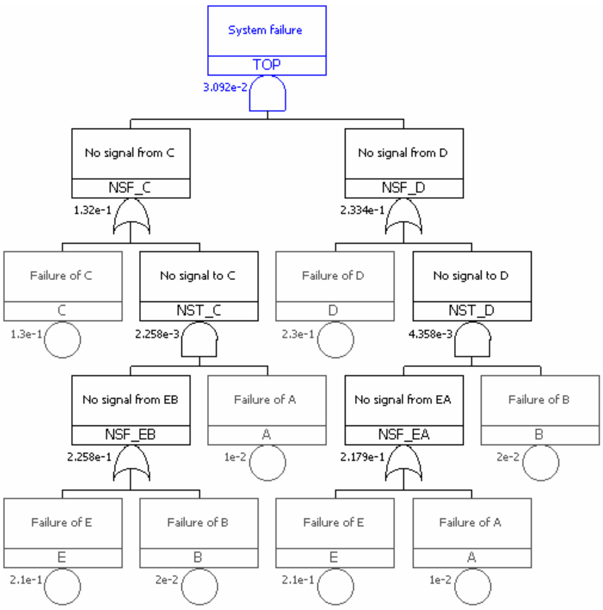

Fig. 3. Fault tree model and analysis result for the bridge structure system

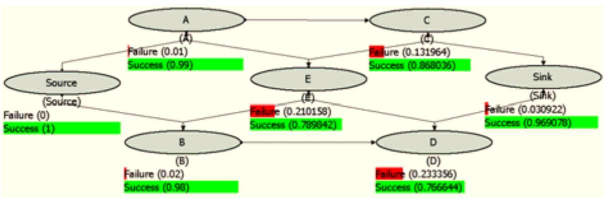

Fig. 4. Bayesian network model by the RBDGG methodology and analysis result for the bridge structure system

For a more detailed analysis, not only the system unavailability, but also other probabilities inside the bridge structure system are also compared. Table I shows the output failure probabilities of the components in the bridge structure system. For example, the probability that C will fail to provide the correct output can be found in NSF_C gate in the fault tree model shown in Fig. 3, which is 0.131964. The same probability can also be found in the C node in the Bayesian network model shown in Fig. 4, which is also 0.131964. From Table I, it can be found that the output failure probabilities calculated with the fault tree analysis and the RBDGG methodology are the same and, therefore, it can be concluded that the fault tree model shown in Fig. 3 is verified.

Table I: Comparison of quantification results

	Fault Tree	RBDGG
A	0.01	0.01
B	0.02	0.02
C	0.131964	0.131964
D	0.233356	0.233356
System	0.030922	0.030922

4. Summary and Conclusion

Currently, fault tree analysis is widely used in the field of PSA of NPPs. For the purpose of verifying constructed fault tree models, a review by other analysts is widely used. RBDGG methodology is developed as an intuitive and easy-to-use method for system reliability and unavailability analysis.

In this paper, the use of the RBDGG methodology for the purpose of verifying the fault tree model for a target system is proposed. With an application to a simple system, the bridge structure system, the proposed verification method is demonstrated.

It is concluded that the verification of the fault tree models can be performed with the RBDGG methodology.

ACKNOWLEDGEMENT

This work was partly supported by Nuclear Research & Development Program of the National Research Foundation of Korea (NRF) grant funded by the Korean government (MEST). (grant code:2010-0017475)

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