The Development of a Fault Tree Model for Balance of Plant System

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1. Introduction

In this paper, we propose a fault tree modeling method for BOP (balance of plant) system to develop a combined risk model and trip model, and the application plans of the developed model. Where, the trip means the reactor trip and turbine & generator trip.

We have usually modeled the safety-related systems and their supporting systems to assess the risk analysis of a nuclear power plant. However, the BOP system's condition change induces the risk change. That is, the BOP system's condition is relevant to plant's performance and affects to the plant risk.

The existing model for BOP systems is a simplified system model or SPV (Single-point vulnerability) evaluation model. However, these models are not effective enough to use for the plant's performance evaluation. Also, lately an integrated decision-making framework is required for risk-informed applications.

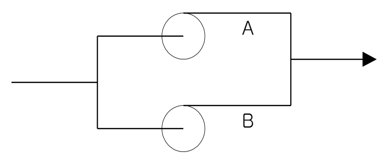
The methods for monitoring the performance of a nuclear power plant differ from the purpose. For example, MSPI (mitigating system performance index) and MR (maintenance rule) use different methods and indexes to monitor the performance. Therefore, for consistent decision-making, it is necessary to develop a risk assessment model including a system's model inducing reactor trip. The system's model inducing reactor trip and turbine/generator trip is defined as the 'trip model'.

2. A Fault Tree Modeling Method for BOP System

When we develop a BOP system model, we considered the integration and consistency of a risk model to combine the risk and trip models. We used a method to estimate the failure rate of a system in a system analysis for an initiator frequency evaluation. We modeled initiator and enabler event for a component failure in the FT model of BOP system.

- BOP FT Model (Frequency Model)
  - System top logic: System failure frequency
  - Structure of basic events are composed of initiator (frequency event) and enabler (demand event)
- The occurred dummy cutsets are deleted during quantification process
  - IE*IE cutsets: Automatically deleted during quantification process
  - Enabler*Enabler: Automatically deleted during quantification process or manually delete after quantification
- It is not necessary to model initiator and enabler for a components not inducing trip.

Fig. 1 shows the concept of initiator and enabler for a system consisted of components A and B. Where, *f* and *p* means initiator event and enabler event, respectively.

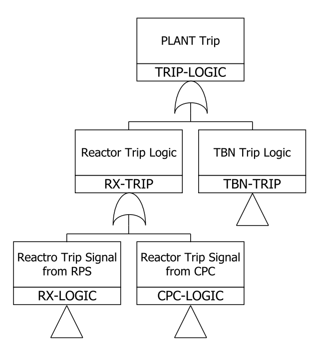


$$(f_A + p_A)\cdot(f_B + p_B)$$
$$= f_A \cdot f_B + f_A \cdot p_B + f_B \cdot p_A + p_A \cdot p_B$$

Fig. 1 The Concept of Initiator and Enabler

3. System Modeling

The boundary of BOP system model is all of systems inducing reactor trip and turbine & generator trip. Trip includes 50% power reduction operation. That is, the cases that automatic RPCS operation is required are included. This fault tree was developed based on the maintenance unit. In this model shift operation was not considered. Each system model was combined as according to the trip signal like as Fig. 2.



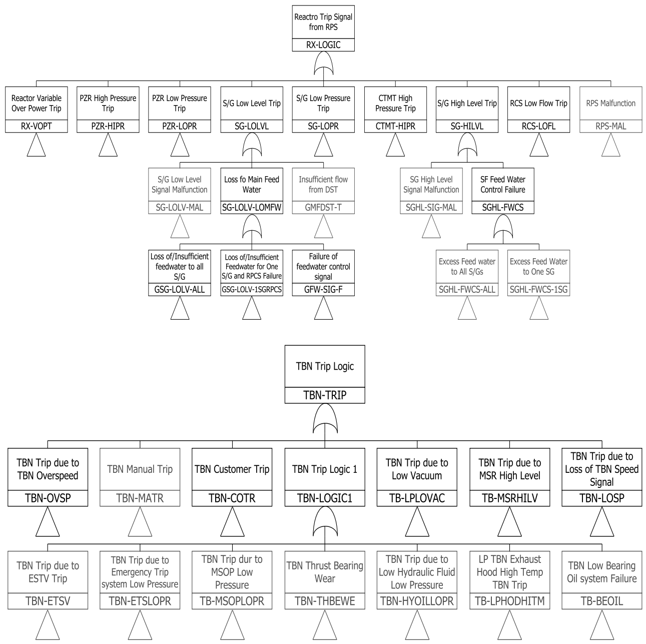


Fig. 2 Top Logic of Trip Model

The developed BOP system model is also combined with the risk model.

4. An Application of the Model

This study is a part of an on-going project. So, the final results are not available at this point. Therefore, we will introduce the plans for the applications of the developed model. The developed PSA model by combining the risk and trip is planned to be used for the improvement of issues related to risk-informed applications. Also, the performance-coupled risk assessment could greatly reduce the inefficiency of the current complicated risk-informed applications.

The applications for the developed model being performed or planned are as follows:

- Analysis of trip cause
- Monitoring of the overall plant's risk and performance
- Development of a performance index to support MSPI, MR, ASP and SDP etc. in common. (For example, MSPI and MR use unreliability and unavailability to monitor performance, but the used index is different each other)

5. Conclusions

The final study results are not available at this point. However, through the pilot estimation, we identified that a risk model which is not combined with the trip model can underestimate risk change. Also, because the risk and performance are estimated by different measures, the results are not consistent for the same object. Therefore, it is necessary to develop a model by combining the risk model and trip model for the risk-informed applications.

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