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Development of Network Safety Assessment Methodology for Loss of Off-site Power System

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1. Introduction

The off-site power system directly or indirectly affects the safety and operation of nuclear power plants. Recently, there have been events that have caused nuclear power plants to shut down due to the failure of the off-site power network caused by typhoons Maisak and Haisun in 2020[1]. According to the Operational Performance Information System for Nuclear Power Plant (OPIS) operated by the Korea Institute of Nuclear Safety (KINS), 20 incidents of nuclear power plant shutdowns occurred due to failures in the off-site power system from 1978 to 2021[2]. The intensity and frequency of natural disasters are expected to increase due to climate change. It is thought that the effects of nuclear power plants due to the failure of the off-site power network will increase due to climate change. In this study, a network safety assessment methodology is developed to efficiently perform off-site power networks' safety assessment.

2. Methods and Verifications

In general, probabilistic safety assessments of nuclear power plants are performed using event trees and fault trees. Figure 1 shows the off-site power system around a Kori nuclear power plant site in Korea. The off-site power system can be represented as a fault tree to calculate the probability of failure, but it is very complex. However, it is easier and more intuitive when the off-site power system is constructed as a network than constructed by the fault tree. In this section, the developed network safety assessment technique is verified through examples.

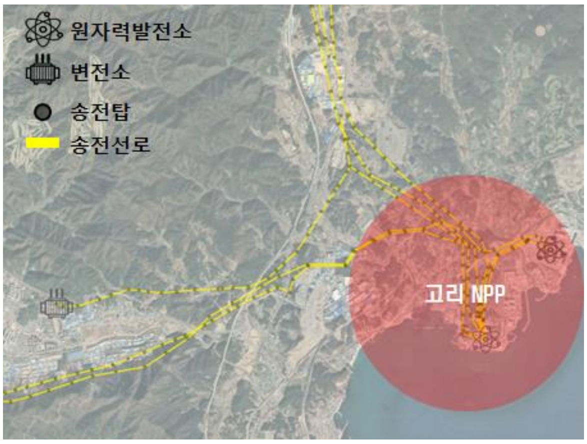

Fig. 1. Off-stie power system near the Kori NPP site

2.1 Example 1

The fault tree of Example 1 is shown in Figure 2, with a failure probability of 0.12593/yr[3]. The failure probability of each component is assumed to be 0.1. The network configured is shown in Figure 3 to perform the network safety assessment. The failure probability of the system derived through the proposed method is 0.12593/yr, and the error rate is 0.0011%.

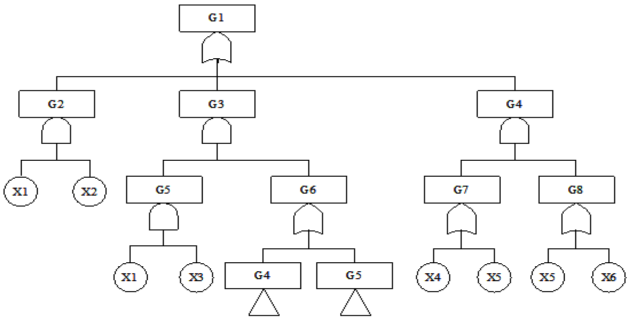

Fig. 2. Fault tree in Example 1[3]

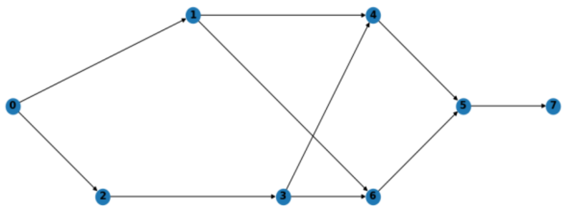

Fig. 3. Network in Example 1

2.2 Example 2

In this example, the probability of failure is calculated for a two-pump train. Figure 4 shows the system of the two-pump train. The failure probability of the system is 2.11×10^{-5}/yr. The network representation of the two-pump train is shown in Figure 5. The failure probability of the system derived from the network safety assessment technique is 2.116×10^{-5}/yr, with an error rate of 0.2844%.

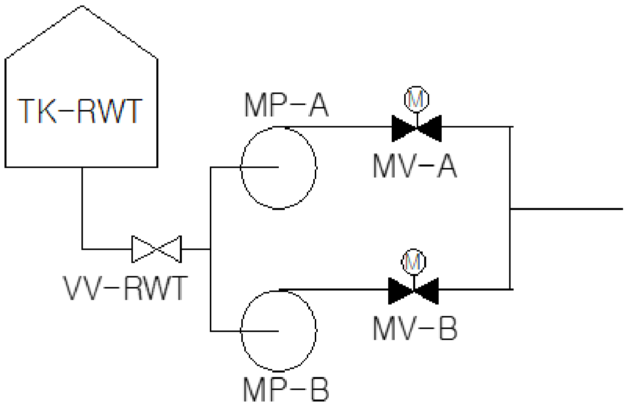

Fig. 4. The two-pump train

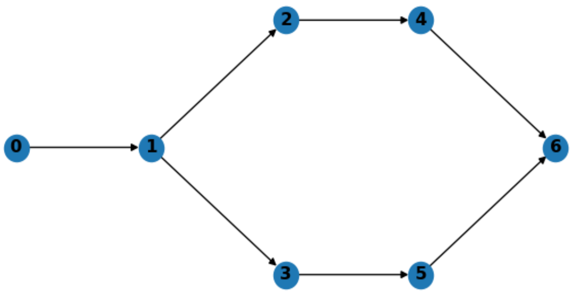

Fig. 5. Network of the two-pump train system

3. Conclusions

The network safety assessment methodology successfully calculated the failure probability of the system by utilizing the failure probability of SSCs. In each verification example, the error rate was 0.0011% and 0.2844%, respectively. In addition, it is easier to configure the complex system by the network compare to configuring with fault trees for the complex network. Therefore, it is expected to be more efficient in complex networks such as off-site power systems or transportation networks.

Acknowledgement

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