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Fault Tree Modeling of Seismic Monitoring Analysis System(SMAS) of HANARO

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1. Introduction

HANARO is a research reactor located in Daejeon, South Korea. It stands for "High-flux Advanced Neutron Application Reactor." HANARO is used for a variety of purposes, including basic and applied research in material science, biotechnology, and environmental science, as well as production of radioactive isotopes for medical and industrial applications. The Seismic Monitoring Analysis System (SMAS) at HANARO is used to monitor and analyze seismic activity around the research reactor. This system is critical to ensuring the safety of the reactor and surrounding area. The SMAS is designed to detect even small earthquakes and to provide real-time information on the magnitude, location, and direction of seismic activity. This information will be used by HANARO's operators to assess the potential impact of earthquakes on the reactor and to make decisions about what actions are needed to ensure the safety of the facility and the surrounding area.

The previous SMAS had a disadvantage of not having an analysis device that can accurately analyze on earthquake, so it has been improved with a digital SMAS that includes an analysis device [1].

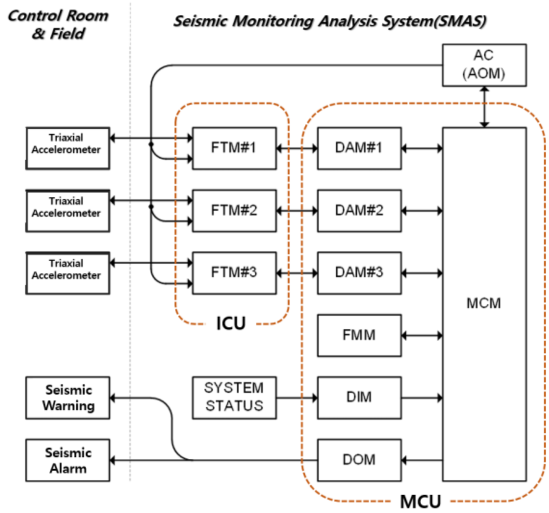
This paper describes a Fault Tree (FT) model for the new digital SMAS of HANARO is based on the Event Tree (ET) for earthquake scenarios. The FT presents the logical relationships between the system's failure modes and the events that lead to those failures. The goal of this paper is to identify the potential failure causes in the SMAS and determine the probability of such failures occurring through the FT model. This information will utilized to improve the system's reliability and safety. Furthermore, the FT model developed in this paper will serve as the foundation for future studies aimed at comparing it with previous analog and digital systems. By conducting such comparisons, the FT model can assist in predicting and preventing potential failures in the new digital SMAS of HANARO.

2. Methods and Results

In this section, a brief overview of the SMAS of HANARO and a detailed analysis of the FT model are provided along with a description of the system's components and the logic gates.

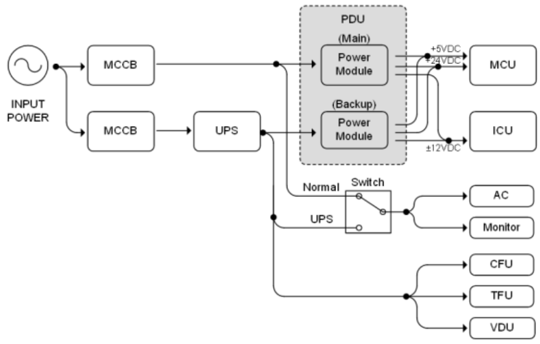
2.1 Seismic Monitoring Analysis System (SMAS) of HANARO

Figure 1 shows the signal flow of SMAS and Figure 2 shows the process of power supply to the system [2].



* *AC : Analysis Computer*
* *AOM : Analog Output Module*
* *FTM : FBA-3 TB Module*
* *DAM : Data Acquisition Module*
* *FMM : Flash Memory Module*
* *DIM : Digital Input Module*
* *DOM : Digital Output Module*
* *MCM : Main Control Module*
* *MCU : Main Control Unit*
* *ICU : Interface Card Unit*

Figure 1. Signal Flow of SMAS



* *PDU : Power Distribution Unit*
* *AC : Analysis Computer*
* *CFU : Cooling Fan Unit*
* *TFU : Top Fan Unit*
* *VDU : Voltage Display Unit*

Figure 2. Process of Power Supply to SMAS

As shown in the Figure 1, the signal from the sensor (Triaxial Accelerometer) is received and compared with the setpoint in the MCU to generate an alert. The power supply of SMAS consists of a PDU and the UPS, and serves to the sensors installed in the field and the modules installed in the cabinet.

The detailed function of each module is described in Table 1.

Table 1: Detailed Function of Each Module [2]

Module		Function
AC		Computer for MMI and analysis
AOM		Generate an analog output for simulated signal
MCU	MCM	Up/down communication and Judgment of alarm occurrence.
	FMM	Storage of event and alarm data.
	DIM	Check system status
	DOM	Display the system status and Give alarm signal
	DAM	Determine whether an event has occurred and converts it into a digital signal.
	PSM	Power supply of 24Vdc and 5Vdc
VDU		Display the supply voltage status of sensor, MCU and DIM/DOM
FTM (in ICU)		Supply the signal to interface and DAM
UPS		Stable power supply module even if the main power is cut off
PDU		Power supply configured in redundancy

In addition to modules specified in Table 1, there are several more modules such as Annunciator Unit and LCD Monitor. These functions are irrelevant to the main functions of SMAS because they display various information of the current system with LED and buzzer and provide convenient user interface [2]. Therefore, these modules are not considered for FT model in next section.

2.2 Fault Tree (FT) Model of SMAS

An FT is a deductive decomposition process using the logic gates AND, OR, and NOT when depicting cases where a system fails or becomes unavailable. The FT model includes mechanical failure, CCF (Common Cause Failure), human error, and maintenance/test unavailability. During system design, it is possible to identify weakness and create improvement plans using the functional failure ranking of the FT model [3]. CCF is defined by the International Atomic Energy Agency (IAEA) as two or more structures, systems, or components that fail due to a single specific accident or cause. Recent research suggests that CCF severely worsens a system's unavailability and impacts both the safety function [4].

As mentioned, FT model of SMAS excludes some modules that do not generate seismic alarm.

Figure 3 shows the top-level FT model for the SMAS. Failures in SMAS consist of signal failures and power supply failures.

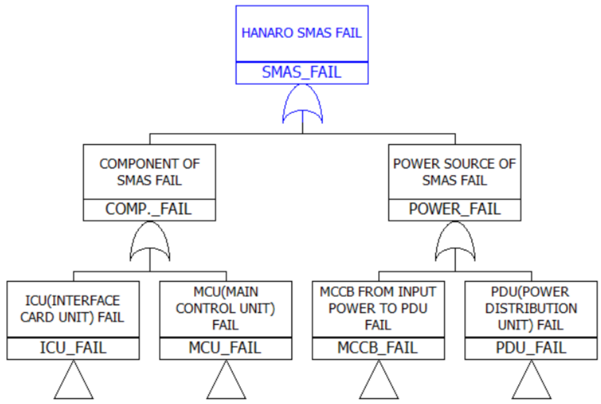


Figure 3. Top-level FT model of SMAS

Figure 4 shows the FT of signal failure consisting of ICU failure and MCU failure.

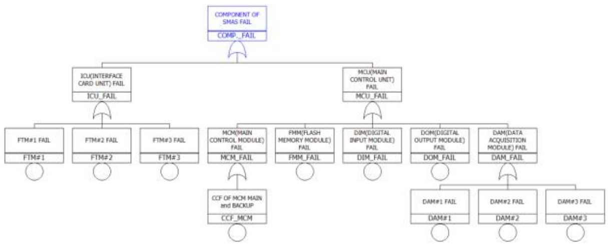


Figure 4. FT of Signal(component) Failure

FTM, FMM, DIM, DOM, and DAM are not configured for redundancy, so there are no CCFs between them. Since the MCM consists of main and backup, if both fail at the same time, the MCM will also fail. This means that the CCF of MCM main and backup should be considered as Figure 4.

Figure 5 shows the FT of power supply failure. The power supply consists of MCCB and PDU. As both are designed for redundancy, CCF should be considered.

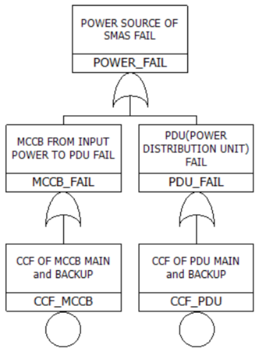


Figure 5. FT of Power Supply Failure

3. Conclusions

This study analyzed FT model of the SMAS at HANARO by considering the function of each module and CCFs. It is noted that SMAS is not classified as a safety system, and as such, most of the modules are non-redundant except for the power modules.

In the subsequent phase of the study, the unavailability of SMAS will be calculated by applying the failure rate of each module, which will be obtained from the manufacturer, to the FT model. Furthermore, a comparative analysis of the unavailability of SMAS with the FT model of the analog system will be conducted to identify potential areas for improvement. The findings of this analysis will provide valuable insights into the performance and reliability of the system, thereby facilitating the identification of opportunities to enhance the safety. Therefore, even though SMAS is not designated as a safety-critical system, if the unavailability of SMAS is deemed significant compared to other systems, a redundant design for the system may be necessary to improve its reliability and safety.

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