FRAM on Fukushima NPP Accident

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1. Introduction

The Fukushima Daiichi NPP accident which occurred in March 2011 due to the earthquake by a tsunami in east Japan raises awareness of the safety management in accidents caused by natural disasters of NPPs. Many relevant agencies and researchers have analyzed the Fukushima accident and have dealt with various causes within many reports.

FRAM is a method that analyzing the functional connection of complex socio-technical systems from the perspective of resilience engineering. FRAM can provide insight into difficult-to-explain areas with linear causal analysis.

This study used FRAM to analyze the safety functions of Fukushima NPP and the response of stakeholders at the time of Fukushima accident. The result of this study may help to prepare measures to prevent the event from leading to serious accident.

2. Methods

2.1 Functional Resonance Analysis Method

In perspective of resilience engineering, the success or failure of everyday performance is emergent rather than causal. Thus, failure or malfunction of a specific component cannot be attributed to or accounted for as a performance failure. This is different from a traditional safety perspective that assumes success and failure are fundamentally different and tries to find a linear causal relationship between cause and effect.

FRAM analysis assumes that each function has variability, and this variability has functional resonance. Functional resonance means that coupling of the variability of each function reinforce each other so that the variability could be abnormally high. Since this resonance spreads through the coupling of functions, it is difficult to identify with a clear causal relationship.

2.1.1 Work Domain Analysis

The first step of the FRAM is to identify the functions that are needed for everyday work to succeed. This study analyzed the functions of Fukushima power plant and the response of stakeholders using Work Domain Analysis (WDA). The purpose of WDA is to describe tasks or functions and characterize the fundamental characteristics of a specific function or set of functions. In particular, it highlights the connections between the functions related to the accident.

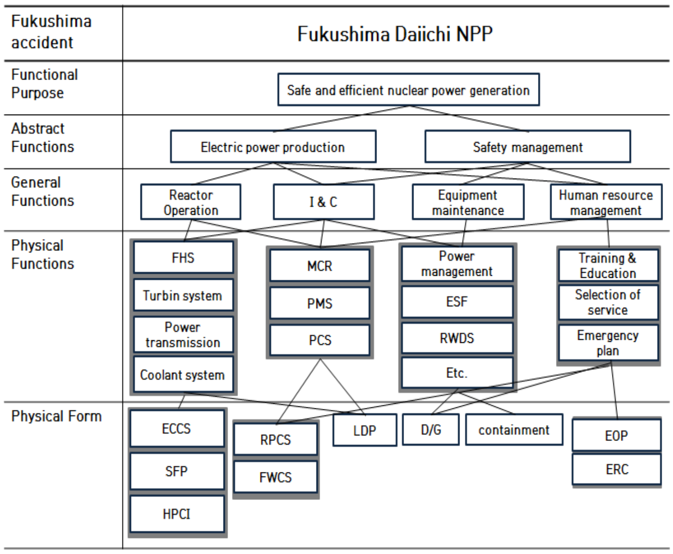

Fig.1. WDA of Fukushima NPP

In the FRAM, a function can be characterized by the six different aspects or features: input(I), output(O), preconditions(P), resources(R), time(T), control(C).

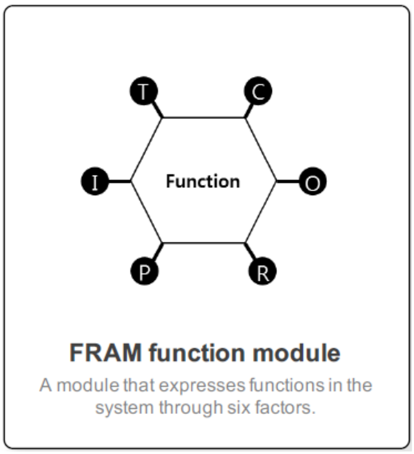

Fig.2. FRAM function module

A FRAM function is represented graphically by a hexagon, where each corner or vertex corresponds to an aspect, as shown in Figure 2.

Table 1: FRAM model description (ADS)

Name of function	Automatic Depressurization System (ADS)
Aspect	**Description of aspect**
Input	Reactor water level, containment pressure condition, manual initiating
Output	Relief steam to PSP
Precondition	Unavailable of HPCI
Resource	Relief Valve, Vent
Control	
Time	

It is also important that a FRAM model is the textual description of the functions and their aspect. A FRAM model describes the potential couplings, rather than the actual couplings, which are relevant a specific scenario or instantiation. The representation of a function is shown in Table 1.

2.1.2 Identification of Variability

The second step is to characterize the variability of the functions that constitute the FRAM model. The characterization of performance variability is needed to understand how functions can become coupled and how this can lead to unexpected outcomes. Therefore, the variability of output is more important than the variability of function itself. The variability of the output can be divided into three categories. First, the variability of the output can be result of the variability of the function itself. Second, the variability of the output can be due to the variability of the working environment or condition. Finally, the variability of the output can be a result of influences from upstream functions (as input, precondition, resource, control or time). The variability caused by the upstream function, that is, functional upstream-downstream coupling, are the basis of functional resonance.

2.1.3 Aggregation of the variability

The third step is to aggregate the variability of each function. Instantiation represents a realization of model. In other words, instantiation makes it possible to be more precise about how the potential variability can become actual variability. Functional Upstream-Downstream coupling can be described as a variability of the output of upstream function affecting other aspects of the downstream function. Functional Upstream-Downstream coupling explains how the variability in function differs from the conventional linear development of event. That is, how functions combine and everyday performance variability makes unexpected outcomes. It shows the occurrence of nonlinear effects, namely how the functional resonance occurs.

3. Results

Figure 3 shows the result of instantiation of FRAM model on Fukushima. It is a representation of a part of the expected result. The upstream-downstream couplings can describe how the variability of functions may spread in a way that is fundamentally different from the usual linear propagation

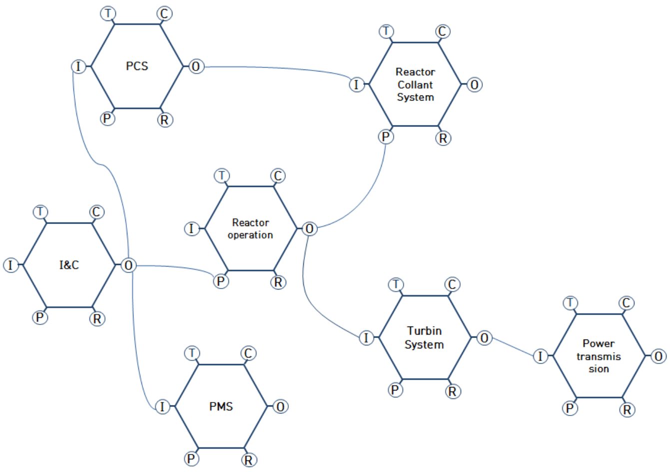

Fig.3. instantiation of FRAM model

4. Conclusions

FRAM can describe how the couplings may combine so that performance variability can lead to unexpected outcomes. The result of this study may help to find variability that produced adverse outcomes at the time of Fukushima accident and to prepare for it. Although it cannot prevent the occurrence of natural disasters, if the designed system functions are fully prepared, it will be possible to respond appropriately to minimize the damage.

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