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A Study on an Accident Diagnosis Methodology Using Influence Diagrams

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1. Introduction

For nuclear power plants, EOPs help operators to diagnose, control and mitigate accidents. However, it is very difficult that operators follow appropriate EOPs for accidents with similar symptoms in a given short period of time. Also EOPs are very complicated to follow and have many procedures to do. Therefore, if operators cannot diagnose correctly, the accident would become severe.

Correct diagnostic action depends on the decision-making ability of operators. Therefore, the methodology that can diagnose accidents quickly and help operators follow appropriate procedures should be developed. Due to the complexity of the tasks, it is very important to reduce human errors during diagnostic actions. In this study, to minimize human errors an accident diagnosis model has been constructed based on EOPs, accident symptoms and component reliabilities. For construction of model, Influence Diagrams have been applied. This decision-making tool consists of nodes and arcs. It is applicable to complicated situations, such as those required for developing strategies for managing severe accidents in nuclear power plants. And quantification of model has performed with total probability and Bayesian theorem. Through this quantification, the results should help operators diagnose complex situations.

2. Modeling Methods

EOPs are composed of four types of procedures: Standard Post Trip Actions (SPTA), Diagnostic Actions, Optimal recovery procedures and Functional recovery procedures. SPTA offer operators the procedures that should be performed in the first place. Diagnostic actions are logical processes for offering operators exact diagnosis for given accidents. These actions were modeled using Influence Diagrams by collecting relevant parameters and evaluating them. Optimal recovery procedures involve procedures for each accident such as LOCA, SGTR, etc. In other abnormal states where diagnosis is not possible and other accidents, except accidents mentioned on optimal recovery procedure, functional recovery procedures are taken and performed.

2.1 Construction of Accident Diagnosis Model

In this study, Ulchin Unit 3&4 was chosen as a reference plant. And the purpose of the modeling is to discriminate between SLOCA and SGTR. The reason of this selection is that these accidents have very similar symptoms in the early stages. For construction of Influence Diagrams, selection of every node is based on EOPs of reference plant. Symptoms of two accidents are listed in Table 1.

Table 1. Symptoms of SLOCA and SGTR

SLOCA	SGTR
Pressurizer level and pressure decrease	Pressurizer level and pressure decrease
Containment pressure, temperature, radiation and moisture increase	Steam generator level increase
Reactor Drain Tank (RDT) level, temperature and pressure increase	Main Steam Line radiation increase
SIAS, CIAS, AFAS, RAS	AFAS

In this study, chance node and deterministic node are introduced for construction of accident diagnosis model. And nodes for modeling Influence Diagrams have selected from Diagnostic Actions and procedures of each accident (SLOCA and SGTR). In this selection of nodes, parameters of SPTA were ignored. Because entry condition of Diagnostic Actions are already contained SPTA which is performed. Thus, the focus of this study is on discrimination between SLOCA and SGTR.

The model has been constructed with one accident diagnosis node, 13 symptom nodes and 13 detection nodes. The accident diagnosis node has three states: ①Normal Operation, ②SLOCA and ③SGTR. Symptom nodes also have three states: ①No Change, ②Increase and ③Decrease. The Detection nodes have four states: ①Normal, ②Fail High, ③Stuck at Steady State and ④Fail Low.

Arcs are connected from accident diagnosis node and detection nodes to symptom nodes. The Symptoms are related with the type of accidents and the status of detection components. Also, the dependency between nodes has been considered in this model. For example, if containment moisture increases, it could cause the RDT level to increase. (see Fig 1.)

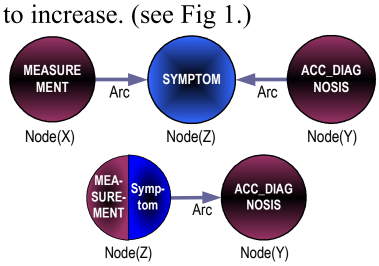

Fig.1 Total Probability and Bayesian Theory

Data of accident diagnosis node are based on PSA report of reference plant, and yields of selected accidents in terms of frequencies have been applied as probabilities. In constructed model, it can be possible that the changes of these yields represent increase or decrease of the probabilities. Also, assumed that only two types of accident exist in this model and others are included in Normal Operation for simplification.

EOPs are mainly applied to obtain symptom node data. In EOPs, each accident has their symptoms. From these symptoms and EOPs, data have been chosen. Also, probabilities of symptom nodes are known, because it is clearly shown that the types of accidents have significant symptoms. And it is possible that symptom node data has only two probability of 1.0 or 0.0 in relevant accidents.

RDT pressure increases at SLOCA when detector is operating normally. At SGTR, it has no change. And at other states of detector, data are fixed; state of "Fail High" always has value of 1.0 at "Increase" state. "Stuck at Steady State" has 1.0 at "No Change" state, and "Fail Low" has 1.0 at "Decrease" state. These are identically applied to all nodes.

2.2 Validation of Accident Procedure

At present, user can only select 3 types of symptom which are increase, decrease, changeless state about given safety parameters. However, it is difficult to apply this method for real nuclear power plant because each symptom of accident is able to very rapidly change during short time. For example, during SGTR, the steam generator pressure is perturbed. Therefore it is important to choose the base line for type of symptom. In this research, it is selected by result of nuclear thermal hydraulics system codes such as RELAP and RETRAN. And the advices of experts are also one of method for choosing the base line.

First, we show the procedure to perform the reference calculations of Steam Generator Tube Rupture (SGTR) with SG tube ruptured for validation. In addition, the thermal-hydraulic response of the reactor coolant system (RCS) was studied in detail. For the thermal-hydraulic output graph and input model delivered from USN train center was used. Then the trends of SGTR parameters are shown below. (Fig. 2)

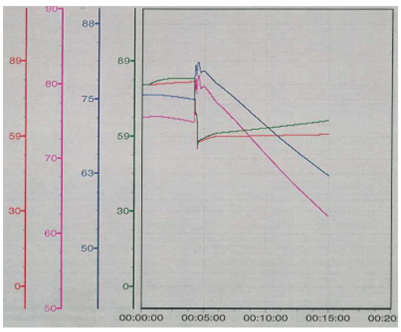

Fig.2 The trends of SGTR parameters

3. Conclusion

Operators are allowed to follow EOPs when reactor tripped because of accidents. But, it is very difficult to diagnose accidents and find out appropriate procedures to mitigate current accidents in a given short time. Even if they diagnose accidents, it also has possibility to misdiagnose. TMI accident is a good example of operators errors.

Thus, the methodology to support operators to diagnose correctly and rapidly should be developed. In this study, accident diagnosis methodology has been developed. This model based on EOPs, symptoms of accidents and components reliabilities to reduce human error. To construct and quantify the model, Influence Diagrams have been introduced. Influence Diagrams are powerful tool for decision-making. This tool is also easy to modify and quantify the model.

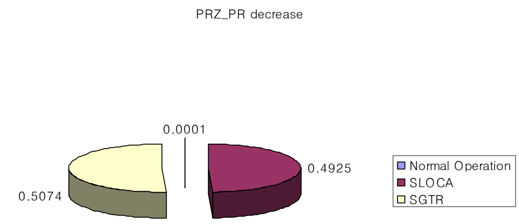

Fig.3 Probabilities of "Pressurizer Pressure decrease" Evidence

From the constructed model, operators could diagnose accidents at any states of accidents. (see Figure 3.) This model can offer the information about accidents with given symptoms. This model might help operators to diagnose correctly and rapidly. It might be very useful to support operators for reduce human error. Also, from this study, it is applicable to other accidents with similar symptoms and to analyze causes of reactor trip.

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