An Accident Diagnosis Methodology Using Influence Diagrams

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1. Introduction

In complex systems such as nuclear power plants, it is necessary to model a logical representation of the overall system interaction with respect to the individual subsystems. For nuclear power plants, EOPs (Emergency Operating Procedures) help operators to diagnose and analyze accidents. But it is very difficult that operators diagnose and analyze similar accidents with EOPs in a given short time. There are also possibilities to follow wrong procedures due to complex and extensive procedures. Therefore, it is important to develop a methodology for diagnosing accidents in a short time and reduction of human errors that made by complex signals and indicators.

2. Methods and Results

In this study, Influence Diagrams have been applied for construction of accident diagnosis model. And parameters in the model have been collected from EOPs.

2.1 EOPs

EOPs offer operators procedures to mitigate accidents occurred with reactor shutdown. It is organized with 4 types of procedures: SPTA (Standard Post Trip Actions), Diagnostic Actions, Optimal recovery procedure and Functional recovery procedure.[1] Diagnostic Actions are logical tools for offer operators diagnosis of given accidents. This part has been applied for collecting parameters to construct a diagnosis model in this study.

2.2 Influence Diagrams

This methodology useful for complex systems such as a nuclear power plant has been applied for representing the time-dependent behavior (feedback and dependency, etc) and uncertain behavior of complex physical system. And Bayesian Theorem has been applied for quantification of this model. The employment of Bayesian operation for quantification offers an appropriate method to model the human decision process.[2-5]

Figure 1 is an example of quantification in Influence Diagrams. The calculation proceeds as follows:

In case without dependency, $p(A)$ is

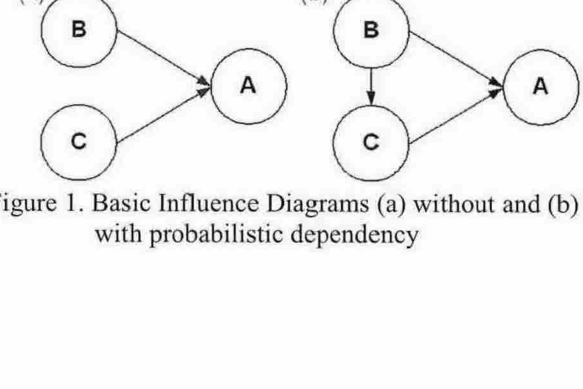

Figure 1. Basic Influence Diagrams (a) without and (b) with probabilistic dependency

$$\begin{aligned} P(A) &= \int_{B,C} P(A,B,C) \\ &= \int_{B,C} P(A|B,C)P(C|B)P(B) \\ &= \int_{B,C} P(A|B,C)P(C)P(B) \end{aligned} \quad (1)$$

In case with dependency, $p(A)$ is

$$\begin{aligned} P(A) &= \int_{B,C} P(A,B,C) \\ &= \int_{B,C} P(A|B,C)P(C|B)P(B) \end{aligned} \quad (2)$$

Also, Bayesian operation in Influence Diagrams model is,

$$\begin{aligned} P(AE) &= P(A)P(E|A) \\ &= P(E)P(A|E) \end{aligned}$$

$$P(A|E) = P(A)\frac{P(E|A)}{P(E)}$$

where, $p(A|E)$: Posterior

$p(A)$: Prior

$\frac{p(E|A)}{p(E)}$: Likelihood of Evidence

$$P(A_j|E) = \frac{P(A_j)\times L(E|A_j)}{\int_{j=1}^{N} L(E|A_j)P(A_j)} \quad (3)$$

2.3 Accident Diagnosis Model

The purpose of this study is development of accident diagnosis model and application of given accident such as SLOCA (Small Loss Of Coolant Accident) and SGTR (Steam Generator Tube Rupture). It is difficult that diagnosis of this accidents because of similar symptoms. Therefore, in this study, diagnosis model has been constructed with parameters of these accidents.

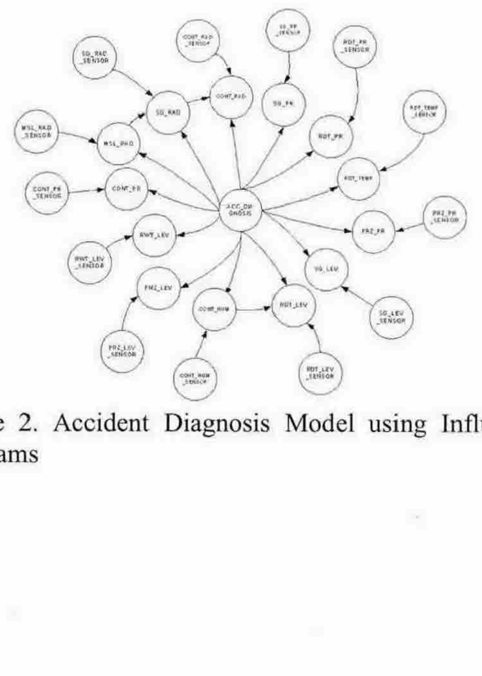

Figure 2. Accident Diagnosis Model using Influence Diagrams

Table 1. Parameters and descriptions in Accident Diagnosis Model

Parameters	Description	Parameters	Description
ACC_DIAGNOSIS	Accident Diagnosis	RDT_PR_SENSOR	RDT PressureSensor
RDT_PR	RDT Pressure	RDT_LEV_SENSOR	RDT Level Sensor
RDT_LEV	RDT Level	RDT_TEMP_SENSOR	RDT Temperature Sensor
RDT_TEMP	RDT Temperature	SG_PR_SENSOR	S/G Pressure Sensor
SG_PR	S/G Pressure	SG_LEV_SENSOR	S/G Level Sensor
SG_LEV	S/G Level	SG_RAD_SENSOR	S/G Radiation Sensor
SG_RAD	S/G Radiation	CONT_PR_SENSOR	Containment Pressure Sensor
CONT_PR	Containment Pressure	CONT_HUM_SENSOR	Containment Humidity Sensor
CONT_HUM	Containment Humidity	CON_RAD_SENSOR	Containment Radiation Sensor
CON_RAD	Containment Radiation	PRZ_PR_SENSOR	Pressurizer Pressure Sensor
PRZ_PR	Pressurizer Pressure	PRZ_LEV_SENSOR	Pressurizer Level Sensor
PRZ_LEV	Pressurizer Level	RWT_LEV_SENSOR	RWT Level Sensor
RWT_LEV	RWT Level	MSL_RAD_SENSOR	MSL Radiation Sensor
MSL_RAD	MSL Radiation		

This model contains 1 diagnosis node, 13 symptom nodes and 13 measurement nodes. These nodes are connected with arc. Initiating event frequency and component unavailability have been used for data of diagnosis node and measurement nodes. For symptom nodes, 0 or 1 value has been applied according to given symptoms of accidents. When evidences are given by symptoms, quantification of this model is performed by Bayesian calculation procedures mentioned above.

2.4 Results

From the developed model, changes of probability of each accident caused by evidences (symptoms) are observed. As a result, probabilities of each accident have been changed by applied evidence (SG_RAD increase and RDT_LEV increase) in Figure 3 and 4.

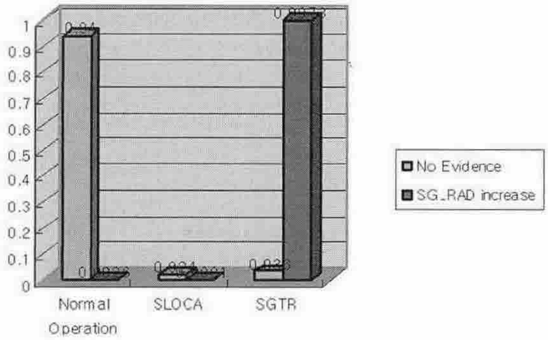

Figure 3. Probabilities of accidents with increasing SG_RAD evidence

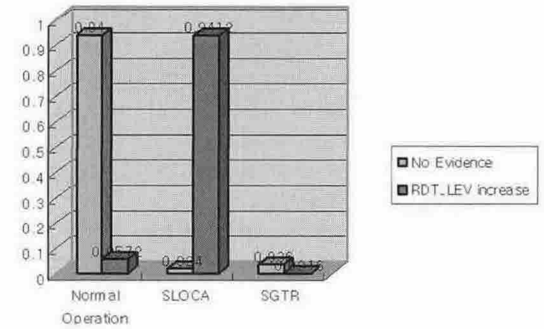

Figure 4. Probabilities of accidents with increasing RDT_LEV evidence

3. Conclusion

Using influence diagrams, a quantitative methodology that could diagnose accidents has been introduced in this study. It is shown that the diagnosis results might help operators have enough reaction time and select the appropriate procedure to prevent or mitigate accidents that may occur during normal operation.

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