ANALYSIS OF THE ORGANIZATIONAL AND HUMAN FACTORS IN NUCLEAR POWER PLANT BY SYSTEM DYNAMICS SIMULATION

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Abstract- This work aims to analyze the impact of the organizational and human factors(OHF) on the two incident cases which are a failure of diagnosis and unintended reactor trip in nuclear power plant. To test the OHF, System Dynamics models are established and Monte-Carlo simulation is performed. In particular, the simulation results show that safety consciousness, learning and education, communication and punishment can significantly influence the incidents.

Keywords- Nuclear Power Plant, Organizational and Human Factors, System Dynamics, Nuclear Incidents.

I. INTRODUCTION

In high reliability organization such as refinery and chemical plant, coal mines and nuclear power plant, degradation of organizational safety culture and human errors could make an irreversible incident and would heavily damage the society and Environment. Although a very low possibility of leaking the radioactive materials, nuclear power plant has many protection systems and regulations for preventing an incident and accident. In contrast, organizational factors and human errors are often neglected, and(or) do not have a good performance.

Three Miles Island reactor core melt accident, Chernobyl Nuclear Power plant explosion and Fukushima nuclear power plant explosion have the common causes of the accident as the lowest safety culture and human errors with mechanical troubles. Fortunately, the nuclear reactor core melting or explosion of nuclear power plants have not been happening in Korea, hundreds of human errors have occurred and provoked the severe incidents. In this paper, two incidents that are the failure of diagnosis and reactor trip will be analyzed by fault tree and computer simulation for revealing the impacts of diverse factors.

II. THEORETICAL BACKGROUND

There are a significant number of studies regarding the safety culture and human errors. They identified the factors of safety culture and human errors and analyzed the priorities or weights in incidents cases. Leveson et al. established the simulation model for NASA to test the behaviors of safety culture and human factors that can cause the failure of projects of explosion of spaceships. Lyneis and Madnick revealed that operator's learning and adherence to the rules are the critical factors to encourage the organizational safety culture. Kim et al. studied the condition of workers and organizational characteristics which could change the safety culture and risks of nuclear power plants. These prior studies have been just focusing on the theoretical and conceptual models that describe the organizational and individual factors affecting unrealistic situations and accidents. That leads to the useless complex model and impedes to understand the worker's experiences.

To overcome these limitations, the real incidents cases in nuclear power plant were adopted for setting the simulation model. The goals of the simulation modeling are to find out why these incidents happen under some conditions, what factors are affecting the incidents. Adding to the descriptive analysis from the fault tree mapping of incidents cases, the simulation results shows a clearer whole picture of real properties of organizational and human factors.

III. MODELING

A. Incidents Cases

Nuclear accident refers to the reactors melting and the leakage of radioactive materials to outside. Since these accidents have the lowest probability and the diverse factors involved such as mechanical disorder, natural disaster, etc., the modeling pays attention to the prior incidents before the tremendous accidents.

First case we deal is the diagnosis failure of Enlargement of tube rupture point of the nuclear steam supply system(NSSS) due to the supervisor's overconfidence. The causes of the incident are the lacks of judgment and responsiveness, a bad safety awareness, an excessive horizontal communication, a self-conceit, strong performance-base leadership that obstruct the recognition of the mechanical breakdown. And then, the automatic safety injection is blocked by operator.

Second Case is the reactor trip by dropping the foreign materials during refueling. The primary reasons are the adherence of rules and procedures in maintenance processes and the concealment attitudes that the

director of maintenance has. Particularly, this incidents based on the deep selfishness, shortages of education and bad safety awareness.

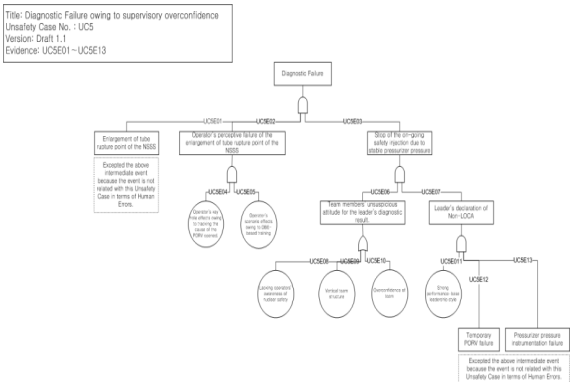


Fig. 1: Fault tree of Diagnosis Failure of NSSS

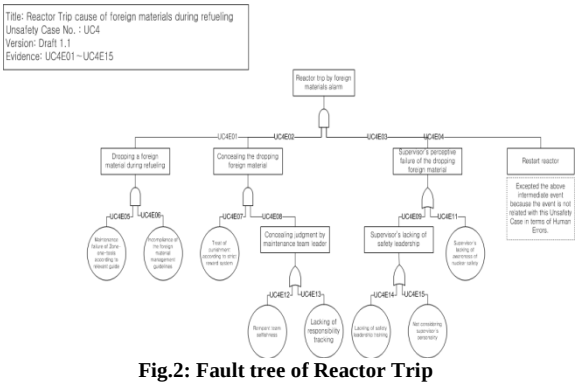


Fig.2: Fault tree of Reactor Trip

B. System Dynamics Modeling

The causes of two incident cases in nuclear power plant affects each other and change simultaneously. Analyzing the inter-relationship among variables and chronic problems evoked periodically in organization need the dynamic and holistic simulation technique In these conditions, System Dynamics is an adequate approach and then, can evaluate the effect of learning and education, safety culture movement, adherence of a rules and procedures, leadership to the incidents. Fig. 3 and Fig. 4 show the System Dynamics modeling examples of safety awareness, confidence, perceived punishment and rule compliance.

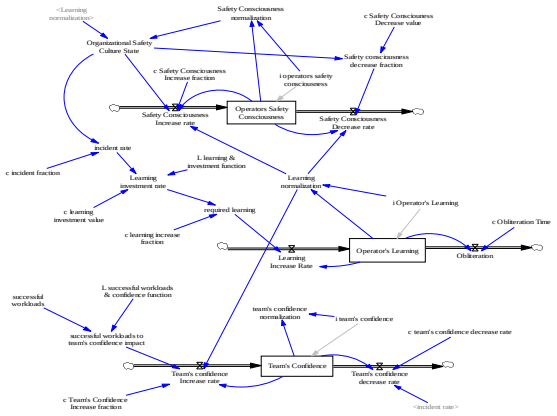


Fig. 3: Learning and Punishment Model

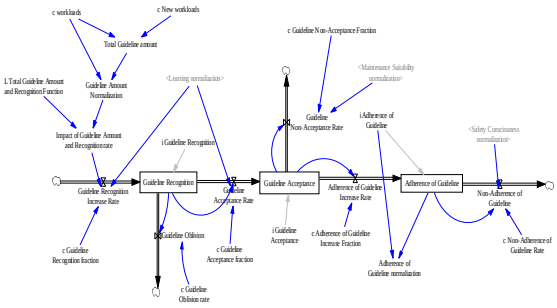


Fig. 4: Rule Compliance Model

IV. SIMULATION RESULTS

A change of some organizational and human factors will make differences in the event time and per se incidents. To test the effects, a Monte Carlo simulations were performed in 500 times. The target variable is 'Safety Consciousness Increase Fraction' which represents an auxiliary variable of safety awareness rate and has the random uniform probability distribution(0.001~0.1).

Figure 5 shows the diagnosis failure incident and Figure 6. is the reactor trip results. We recognize that same variable makes the tremendous different impacts in variant situations because the factors exists in other contexts. The variable, Safety Consciousness Increase Fraction, has more powerful and comprehensive impact in reactor trip environment than in case 1.

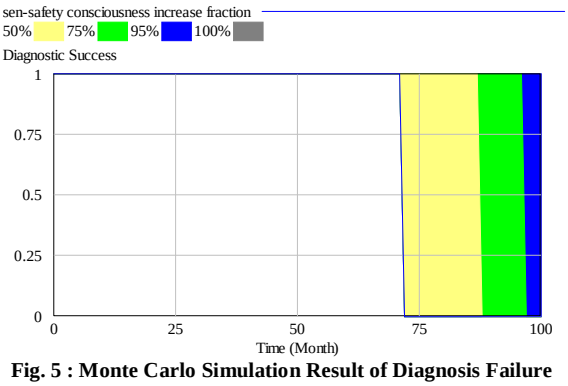


Fig. 5 : Monte Carlo Simulation Result of Diagnosis Failure

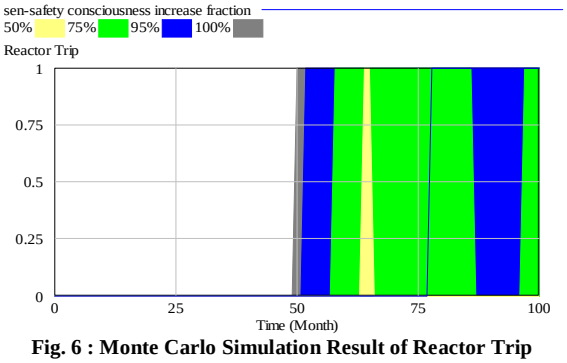


Fig. 6 : Monte Carlo Simulation Result of Reactor Trip

To examine the condition that make the occurrences of the incidents, we postulate a particular events which will happen at 72 in diagnosis failure and 78 in a reactor trip. In this simulation process, the specific

conditions will be revealed. Table 1 shows the simulation results of main organizational factors when the event occurs at 72. Diagnosis Failure happened if Safety Consciousness has the value of less than 0.678, Operator's Learning has the value of less than 0.967, Team Over-Confidence has the value of 1.365 or more, Team Communication has the value of 1.909 or more, Operator's Key Hole effects has the value of 1.384 or more and Responsiveness of Incident has the value of less than 0.742.

In case of reactor trip at 72, the event occurs if Maintenance State has the value of less than 0.979, Compliance of Guidelines has the value of less than 0.858, Perceived Punishment has the value of 1.487 or more, Team Selfishness has the value of 1.366 or more, Lacking of Tracking has the value of less than 0.889, Education of Leadership has the value of less than 3.076, Personnel Management Adequacy has the value of less than 0.676, Supervisor's Safety Consciousness has the value of less than 0.631.

Table 1: Case 1. Diagnostic Failure(T=72)

Variables	Reference Value	Value if the Incident Occurs
Safety Consciousness	1.0	≤0.678
Operator's Learning	1.0	≤0.967
Team Over-Confidence	1.0	≥1.365
Team Communication	1.0	≥1.909
Operator's key Hole Effects	1.0	≥1.384
Responsiveness to Incident	1.0	≤0.742

Table 2: Case 2. Reactor Trip(T=78)

Variables	Reference Value	Variable value if the Incident Occurs
Maintenance State	1.0	≤0.979
Compliance of Guidelines	1.0	≤0.858
Perceived Punishment	1.0	≥1.487
Team Selfishness	1.0	≥1.366
Lacking of Tracking	1.0	≤0.889
Education of Leadership(Time)	10.0	≤3.076
Personnel Management Adequacy	1.0	≤0.676
Supervisor's Safety Consciousness	1.0	≤0.631

CONCLUSION

The simulation results confirm that the organizational characteristics and human factors affect the events in nuclear power plant critically and clearly. Also, same factors in different contexts have a significant and diverse effects that will require the well-thought-out treatment and policy remedy.

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