Annals of Nuclear Energy 114 (2018) 149–153

Contents lists available at ScienceDirect

Annals of Nuclear Energy

journal homepage: www.elsevier.com/locate/anucene

Analysis of nuclear fire safety by dynamic complex algorithm of fuzzy theory and system dynamics

Tae Ho Woo

Department of Mechanical and Control Engineering, The Cyber University of Korea, 106 Bukchon-ro, Jongno-gu, Seoul 03051, Republic of Korea

ARTICLE INFO

Article history:
Received 21 July 2017
Received in revised form 20 October 2017
Accepted 9 December 2017

Keywords:
Fire
Nuclear Power Plants (NPPs)
Risk
Safety
Fukushima

ABSTRACT

The cognitive architecture is investigated for the disaster management in the nuclear accident site. The fire-based nuclear facility catastrophe is a very significant considerable factor in the aspect of the nuclear safety. There are simulation results as the graphs by each time step composing of the simulations of 3 factors of Fire Caution, Fire Control, and Personal Factor. Each graph shows the instability of the designed event. There is the simulation result for Instability of Fire Protection System. The highest value is 0.67584 in 56th year in which the system is very unstable in fire protections. In the graph, the later time part of the operations has higher values comparatively. This could be explained by the system aging of the plant. In the system dynamics (SD) method combined with fuzzy set algorithm, the tractable modeling is liable to be adapt to any kinds of situations in the NPPs. Needless to say, the complex algorithm could be usable in the cases of normal as well as emergency circumstances.

1. Introduction

It is investigated for the fire in the nuclear power plant (NPP) to be controlled under the designed conditions in the commercial facility. The related variables are needed to be examined for the modeling in the safety aspect. After Fukushima accident, the non-nuclear material-induced accident has been one of major issues like the natural disaster of earthquake. So, the fire-based nuclear facility catastrophe is a very significant considerable factor in the aspect of the nuclear safety. There are the major goals of the fire protection programs in the NPP as follows (The Nuclear Pool's Forum, 2015),

1. Preventing of starting and spreading of fire
2. Rapid detect, control, and extinguish of fire
3. Provide adequate protection and safe shutdown
4. Provide reasonable assurance not to unacceptable radiological release and to unacceptable economic consequences

It is needed to construct the relevant protocols and its related technological assessment tools. Although non-radioactive material cause could be the fire, the consequence can make the dangerous situation.

According to EPRI/NRC fire probabilistic risk assessment (PRA), the severity factor was defined for the conditional probability (Elicson et al., 2011). Furthermore, the mean time to failure (MTTF) and the target set failure probabilities were related to the severity factors (Elicson et al., 2011). Therefore, the dynamic description was focused in the study. In this work, the non-linear algorithms as fuzzy set algorithm-based system dynamics (SD) is imported for the logical analysis and quantification in the safety assessment. The limitations of the probability could be for the possibility of the adaptations of a certain circumstances like the human error-based incident and the unexpected natural disaster which happened at the Fukushima case in 2011, Japan. Although the designed based accident (DBA) could be prepared, the multiple caused accidents as the human failure and natural disaster incorporated with mechanical components failure made the Japanese catastrophe in 2011. So, the complex and non-linear method could control the ambiguous situations of the nuclear accident. For example, the fuzzy set algorithm could manage for these kind of matters, which was created for treating the ambiguous descriptions in the language. Alkandari et al. (2014) showed the case of traffic light system where the fuzzy logic could detect an accident incorporated with multiple factors. Furthermore, there are complex and non-linear methods such as the artificial intelligence (AI) processes. Fig. 1 shows the curve with ideal 4 points in hypothetical heat release which was taken NUREG/CR-6850 Figure G-1 (Elicson et al., 2011). The actual heat release rate is variable by time in which there are growth, steady burning, and decay stages (EPRI, 2005). It is important the PRA could reflect the dynamic behavior, because the fire status is changed by the fire dynamics. It is mean-

E-mail addresses: thwoo@cuk.edu, thw@snu.ac.kr

https://doi.org/10.1016/j.anucene.2017.12.033
0306-4549/

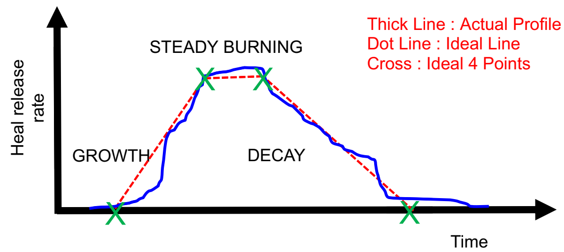

Fig. 1. Curve with ideal 4 points in hypothetical heat release. This shows the graphical description for the hypothetical heat release.

ingful to investigate the dynamic behavior of the fire related incident in the industrially concerning facility like the NPP. So, it is one of major goals of this study to control dynamically the fire sequences in the NPP.

There are some literatures about the topic. Okano et al. studied that the potential analysis for a NPP by a forest fire were considered for the risk assessment (Okano and Yamano, 2015). The aerosol emission during the degradation of material was investigated for the nuclear industry by Ouf et al. (2015). In addition, Jeon et al. worked for the fire consequences in the commercial air plane crash (2012). The Section 2 explains the method of the study. The Section 3 describes results of the study. There are some conclusions in Section 4.

2. Method

The fuzzy set algorithm is applied to the quantifications of the analysis. Conditional statement in the fuzzy set theory is utilized in the comparisons of the interested events. The fire related events are classified in the Table 1 (IAEA, 2004). In the top event of Insatiability Protection System, the event are multiplied which is the similar meaning of OR gate in the conventional event-fault tree based modeling. For the sub-events of Personnel Factor, Fire Caution, and Fire Control, the events are summed, which is like the AND gate in the conventional tree algorithm.

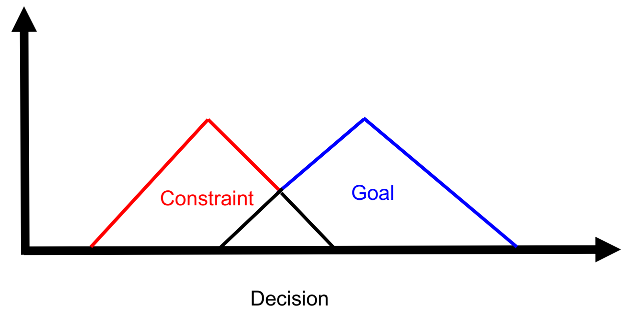

Fig. 2. Fuzzy decision with triangular functions. This is the graph of Fuzzy based decision.

2.1. Fuzzy set system

The fuzzy set theory is used in summation by AND gate which is described by the mathematical descriptions (Bellman and Zadeh, 1970; Mutingi and Mbohwa, 2012). Assuming a fuzzy goal G and constrain C in the a certain space, G and C are combined to a decision F which is the intersection representing the AND gate for in assessment quantification,

Table 1
Fire accident related event in the nuclear power plants (NPPs).

Event		Value
Selection		if then else(random 0 1 () < 0.3, Positions, if then else(random 0 1 () < 0.5, Education, Testing))
	Positions	random normal(−1, 1, 0.1, 0.3, 0)
	Education	random normal(−1, 1, −0.1, 0.3, 0)
	Testing	random normal(−1, 1, 0.1, 0.5, 0)
Training		if then else(random 0 1 () < 0.3, Necessity, if then else(random 0 1 () < 0.5, Method, Qualification))
	Necessity	random normal(−1, 1, 0.1, 0.3, 0)
	Method	random normal(−1, 1, 0, 0.3, 0)
	Qualification	random normal(−1, 1, 0.3, 0.3, 0)
Health Physics Staffs		random normal(−1, 1, −0.1, 0.3, 0)
Contractors		random normal(−1, 1, 0.1, 0.3, 0)
Identifications		if then else(random 0 1 () < 0.3, Inspection, if then else(random 0 1 () < 0.5, Governmental Regulations, Assessments))
	Inspection	random normal(−1, 1, 0.1, 0.3, 0)
	Governmental Regulations	random normal(−1, 1, −0.1, 0.3, 0)
	Assessments	random normal(−1, 1, 0.2, 0.3, 0)
Controls		if then else(random 0 1 () < 0.2, Rules, if then else(random 0 1 () < 0.4, Design, if then else(random 0 1 () < 0.6, Actions, if then else(random 0 1 () < 0.8, Work, Procedures))))
	Rules	random normal(−1, 1, 0, 0.3, 0)
	Design	random normal(−1, 1, 0.2, 0.3, 0)
	Actions	random normal(−1, 1, −0.2, 0.3, 0)
	Work	random normal(−1, 1, 0.1, 0.4, 0)
	Procedures	random normal(−1, 1, 0.1, 0.3, 0)
Passive Methods		if then else(random 0 1 () < 0.4, Modification1, System1)
	Modification1	random normal(−1, 1, −0.1, 0.3, 0)
	System1	random normal(−1, 1, 0.1, 0.3, 0)
Active Methods		if then else(random 0 1 () < 0.3, Modification2, System2)
	Modification2	random normal(−1, 1, 0, 0.3, 0)
	System2	random normal(−1, 1, 0.3, 0.3, 0)
Responses		if then else(random 0 1 () < 0.4, Primary, Secondary)
	Primary	random normal(−1, 1, 0.1, 0.3, 0)
	Secondary	random normal(−1, 1, −0.1, 0.3, 0)