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New Approach for Nuclear Safety and Regulation

- Application of Complexity Theory and System Dynamics -

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1. Introduction

The methodology being used today for assuring nuclear safety is based on analytic approaches. In the 21st century, holistic approaches are increasingly used over traditional analytic method that is based on reductionism. Presently, it leads to interest in complexity theory or system dynamics. In this paper, we review global academic trends, social environments, concept of nuclear safety and regulatory frameworks for nuclear safety. We propose a new safety paradigm and also regulatory approach using holistic approach and system dynamics now in fashion.

2. Discussions on Safety Approach

Up to now, various methods based on engineered safety features and Probabilistic Risk Analysis (PRA) are used for nuclear safety. Probabilistic safety approach, which Risk-informed regulation is based on, accompanied by deterministic one is widely used today. With the development of information and communication technology and the emergence of digital era, a new approach or paradigm that is based on the cognition or perception of nuclear safety becomes necessary. Engineering safety has been the concept used so far, however, it solely is not enough for making regulatory decision, obtaining public confidence in utilities and regulators, and providing society with public satisfaction or sense of security. Recently, stakeholders such as media, Non-Governmental Organizations (NGO) and residents actively participate in regulatory process. In this circumstance, utility-led engineering safety followed by regulator's activities of safety oversight and enforcement is not enough for achieving regulatory goals of offering sense of safety to the public. It is therefore necessary for us to take engineering safety, cognitive safety, and furthermore perceived safety together into consideration today.

2.1 Engineering Safety and Cognitive Safety

Engineering safety is calculated by data from safety performance of systems, components of the facilities, which is assured by engineered safety features. However, this activity should undergo cognitive processes of human sensory organs and brain, which makes engineering safety related to cognitive process. Safety concept used in the decision making process is actually not engineering safety alone, but safety perceived by experts or stakeholders and constituted through the social integration and collective process. In this regard, it can be called societal safety, and safety discussions in this perspective are needed.

2.2 Individual Safety Function and Social Safety Function

Dealing with societal safety, the concept of individual utility function and social welfare function in economics was adopted. Let engineering safety S, and we define individual cognitive safety as Si or Individual Safety Function (ISF). Safety discussed in the society of **n** individuals and used in decision making can be called Social Safety Function (SSF), and this is an average of Si for **n** people. Because not all members in the society equally participate in socialization or decision making, and people of high involvement in the society affects much, this integration process should be adjusted according to the characteristics of the society concerned. This socialization process involves many interactions among individuals or parties, and therefore this should be understood as a safety model considering holistic approach or feedback loop by interactions.

2.3 Instantaneous Risk or Risk Monitor

Instantaneous risk means that risk or safety of nuclear facilities varies instantaneously(by hours or days) according to the configuration of systems. Average risk exists but the facility's risk rises promptly due to the disabled system or components. This concept is illustrated in Fig 1.These days risk monitor is devised from this concept.

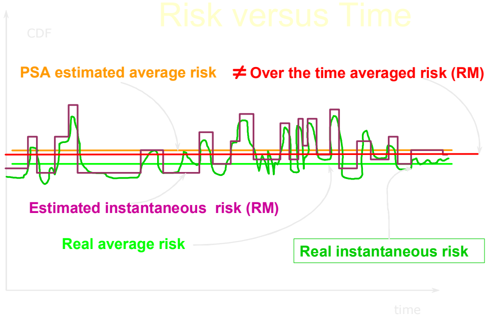

Figure 1. Instantaneous risk and average risk

3. New Model of Nuclear Safety

3.1 Reductionism and Holism

Reductionism is a procedure or theory that reduces complex data and phenomena to simple terms. On the other hand, holistic approach pays attention to interactions between individual components and handles the system itself. Holism is becoming more important as systems become complex and interactions between components or parties increase. We expect that nuclear safety related issues should be handled with this holistic approach.

3.2 Complex System and System Dynamics

Complexity is synthesis of characteristics of components interacting within a system. Complexity is characterized as nonlinearity, unpredictability, dissipative structure, open and irreversible system, and holism. This appears as compound systems, and possesses emergence and hierarchy, and is expressed as multiple networks. This is also understood as continuous learning, and has self-organization and intentionality**.** Because complex system is for moving continuity and irreversible time, new scientific philosophy and research method are needed to understand it. It requires holistic approaches considering the interactions and feedback loops among system variables to understand the behavior of complex system. System dynamics, one of holistic approaches for complex system, interprets the behavior as changes with time as consequences from interactions and feedback loops among system variables.

3.3 Nuclear Safety in view of system dynamics

The system for assuring nuclear safety is a complex one with interactions between systems, components of nuclear facility, parties and diverse feedback loops. This is based on utilities' safety operation, and regulators, residents, NGO and the media constitute feedback loops actually influencing safety operation, and today we need to perceive it as a complex system involving international organizations, utilities in other countries, regulatory bodies, neighboring countries. As safety is assured and constituted through complex interactions among them, regulators, residents, NGO are not irresponsible interferers, but the main doers and contributors for assuring safety. This is shown in Figure 2. Poor safety performance causes regulatory work increase, and it increases operator's knowledge on safety that enhances safety performance. However, it also increases operator's workload and also backlog, leading to reduction of operator's regular safety activities that may deteriorate safety performance. This implies that when safety performance decreases and regulator plan to strengthen regulatory activities, limited resources of the utilities should be also considered. Resident people intervention and public confidence can also make various feedback loops as well. These interactions and feedback loops are constituted rather long time frame, monthly or yearly basis.

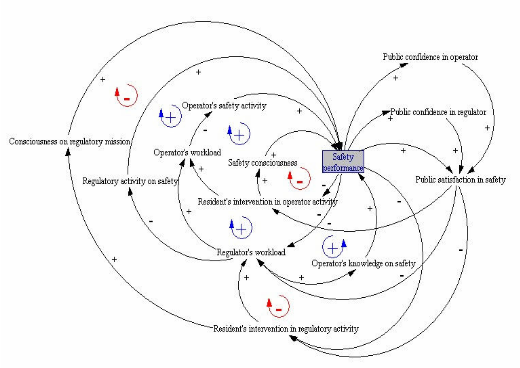

Figure 2. Feedback loops related safety or safety performance

3.4 Combined Model of Instantaneous and Long Term Safety

Based on the discussions above, we propose a combined model integrating instantaneous risk from the configuration of systems in nuclear facility and long-term safety(degree of departure from risk) constituted by various feedback loops made from interactions among various doers involved.

In figure 3, safety of nuclear facilities varies with the configuration of systems for a short period(hour, day and week), and for long period, monthly or yearly, interactions and feedback loops of stakeholders or doers like utilities, regulatory body, residents, NGO, the media for a long period. Understanding nuclear safety in this way may provide a new paradigm viewing short-term, long-term and societal safety. With this model or approach, establishing regulatory policy and implementation plan and major regulatory activities such as decision making, handling public confidence in utility and regulator, public satisfaction and so on can be discussed.

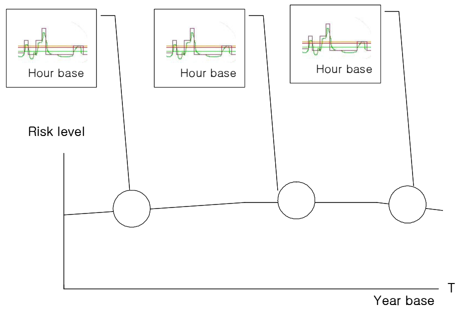

Figure 3. Combined model of instantaneous and long term safety(expressed in terms of risk)

4. Conclusion

The combined model proposed in this paper implies changes in the paradigm viewing nuclear safety. When perceiving safety, cognitive safety as well as engineering safety should be considered, and the former plays an important role. The notion that nuclear safety is achieved by utility, regulatory body, media, residents and NGO demands more responsibility when they get involved for safety. Limited resources of utilities should be considered when strengthening regulatory activities in the case of decreasing safety performance. This does not mean reduction in regulatory activities is needed and it does not imply that regulation always decreases safety. Rather, it implies regulator and stakeholders should care for resources when intervention is attempted for safety. Researches to find policy leverage for effective safety enhancement using system dynamics in safety regulation are needed. This may be also a way for enhancing regulatory effectiveness and further rationalization of regulation.

REFERENCES

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