

How to Improve Graded Approach in Nuclear Safety Regulation

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1. Introduction

As new and complex nuclear safety issues continue to rise, there is an increasing demand for the development of regulatory framework and related methodologies that systematically assess and manage the safety performance of nuclear power plants using risk information as a representative option. To establish an internationally recognized level of safety regulation, it seems inevitably necessary to advance toward performance-based regulation utilizing risk-informed approaches[1, 2]. For this, the establishment of graded approaches and methodologies that align with safety philosophy and standards is required.

Accordingly, this study aims to analyze whether there is any improvement in the current legal systems, application processes, or methodologies concerning the application of a graded approach in nuclear safety regulation. Additionally, considering the recent licensing issues emerging with light-water Small Modular Reactors (SMRs) or the future licensing framework for non-light-water SMRs, the role of Probabilistic Safety Assessment (PSA) as a key decision-making tool for the initial designs has been emphasized, and this study explores a graded approach strategy leveraging PSA[3].

2. Justification of the Graded Approach

2.1 Legal Status

The graded approach, which mandates varying the intensity of safety regulation commensurate with the degree of risk, is implemented based on South Korean law. The graded approach is presented as one of the principles of administrative action through the General Act on Public Administration, and is well articulated in Article 10 (Principle of Proportionality). This principle serves as a criterion for judging the legality of discretionary powers in the context of administrative law, ensuring that when considering proportionality, the degree of disadvantage to the parties involved in the administrative action, as well as the benefits achieved through such action, are taken into account. Furthermore, Article 5 (Principles of Regulation) of the Framework Act on Administrative Regulations also states that the targets and means of regulation should be

set within the minimum scope necessary to achieve the intended objectives.

According to the definition provided by the International Atomic Energy Agency (IAEA), a graded approach is “For a system of control, such as a regulatory system or a safety system, a process or method in which the stringency of the control measures and conditions to be applied is commensurate, to the extent practicable, with the likelihood and possible consequences of, and the level of risk associated with, a loss of control.” In the IAEA Safety Fundamentals SF-1 ‘Fundamental Safety Principles,’ which offers high-level declarative guidance, the graded approach is explained through Principle 3, ‘Leadership and Management for Safety,’ and Principle 5, ‘Optimization of Protection.’

2.2 Graded Approach in the Nuclear Safety Act

In the Nuclear Safety Act, the graded approach is already applied in many areas. This has been effectively and rationally employed to address regulatory issues regarding to the license review of nuclear power plants based on light-water reactors including research reactors, nuclear fuel cycle facilities, radioactive isotopes and radiation-generating devices, and other waste management facilities. It has been also applied in safety-related rule-making, licensing (review and inspection), enforcement, safety management, and safety assessments according to the level of risk. However, it is also true that there is a growing need for the graded approach to be more specific and formalized to better address the evolving and complex issues in nuclear industry.

Moreover, despite the dictionary definition of ‘adaptation,’ ‘by reference,’ or ‘mutatis mutandis’ - which is used 126 times in the Nuclear Safety Act - as “the application of provisions concerning one matter to a similar but fundamentally different matter,” it is generally perceived by those on the front lines of safety regulation that it is difficult to execute this reasonably in practice. The Ministry of Government Legislation’s ‘Standards for Reviewing Legislation’ also explains that ‘adaptation’ means “applying provisions to a subject of regulation with similar characteristics, with some modifications according to those characteristics,” but it can be inferred that appropriate application is

impossible if the extent and specifics of these modifications are left entirely to the discretion of the reviewer. Similarly, in the Nuclear Safety Act and various subordinate regulations and notices, the phrase "may not apply" is used to indicate that certain requirements may be waived when certain conditions are met, but, as with 'adaptation,' there is difficulty in determining whether these conditions are met. This raises the question of whether "may not apply" implies that there is discretion to apply additional requirements in some cases.

In conclusion, while the necessity for a more active implementation of the graded approach is widely acknowledged, it is essential to first fundamentally confirm whether the graded approach can be seamlessly applied to nuclear safety regulation. A sophisticated methodology is also needed to implement this effectively. The principle of the graded approach is conceptually based on differentiating the risk of radiological hazards and the characteristics of facilities by means of evaluating grades(scores). Therefore, it is closely linked to decision-making methodologies that can quantify these factors.

2.3 Methodology for the Graded Approach

IAEA TECDOC-1980 provides a relatively detailed methodology for the graded approach, which could serve as a foundation for deriving the application process[4]. Generally, nuclear regulatory bodies perform the following six key regulatory functions as outlined in IAEA GSR Part 1 (Rev. 1), and the graded approach can be applied to each of these functions.

- Regulations and guides
- Notification and authorization
- Review and assessment of facilities and activities
- Inspection of facilities and activities
- Enforcement
- Communication and consultation with interested parties

The general methodology presented in this publication is divided into three main steps:

(1) Identifying the decision associated with the regulatory function: regulatory decisions related to the regulatory function and possible alternatives are identified.

(2) Identifying and ranking the applicable factors: this step gathers all necessary information to support the analysis of the safety significance of the generic and specific factors associated with the regulatory decision. Risks and impacts associated with the factors are assessed. At the end of Step 2, the applicable factors are analyzed and ranked.

(3) Integrating the applicable factors into regulatory decision-making, including resource allocation: factors are integrated to support regulatory decision-making.

3. Improvement in Applications of the Graded Approach

3.1 Special Limitations

While the necessity of applying a graded approach in nuclear safety regulation has been discussed in previous sections through domestic and international guidelines, the reasons for its difficulty in this field can be attributed to the following specialties:

- **Alignment with International Standards:** Safety regulations must adhere to international standards and guidelines. However, since these international standards are often based on successful cases from various countries, the process of selecting and adapting them to the domestic context can be challenging due to the difficulty in reconciling differing opinions among stakeholders.
- **Rigidity of Laws and Regulations:** If existing laws and regulations are normative and inflexible, it becomes difficult to amend laws or improve systems to accommodate the graded approach. South Korea's legal system, influenced by the civil law traditions of Germany and Japan, inherently tends to be normative.
- **Complex Stakeholder Relationships:** The nuclear industry involves a complex network of stakeholders, including the government, corporations, local communities, and environmental organizations. Given that the Nuclear Safety and Security Commission (NSSC) itself operates on a consensus basis, applying a graded approach while balancing the demands and expectations of these stakeholders is inherently difficult. The challenges in decision-making arising from the relationship between the NSSC and the Korea Institute of Nuclear Safety (KINS), which carries out regulatory functions on behalf of the NSSC, need to be addressed.
- **Consistency and Fairness:** It is crucial to maintain consistency and fairness in all regulations. The introduction of a graded approach could undermine regulatory consistency, potentially leading to questions about fairness.
- **Technical Complexity and Uncertainty:** Nuclear technology is highly complex and requires specialized knowledge, making the technical barriers to effectively implementing safety regulations quite high. On the other hand, in a regulatory decision-making, if the data and information provided by operators are insufficient, inaccurate, or suspected to be so, there may be resistance to applying the graded approach.
- **Tangible and Intangible Costs:** If the costs or resources associated with introducing the graded approach exceed its benefits, not only financial difficulties but also complications arising from an overly complex process can be expected.
- **Changes in Societal Norms Over Time:** Although this issue is not unique to the nuclear field, the generational gap in perceptions could also be a significant obstacle to the graded approach.

3.2 Graded Approach Triplet

3.2.1 Legal Aspects

To secure the flexibility necessary for applying the graded approach, it may be beneficial to amend existing higher-level laws (e.g., Act, Degree, and so on) by removing provisions that impose specific numerical or prescriptive requirements targeting particular facilities, and instead, present a directional focus that safety regulations should aim for. Additionally, it is essential to formally incorporate the methodology for the graded approach into the regulatory framework, so that the graded approach itself becomes an integral part of regulatory activities.

On a practical level, the rationality and fairness of notices or review plans seem to be of paramount importance. Therefore, it is crucial to continuously monitor and evaluate the effectiveness of regulations that utilize these guidelines, particularly during the rule-making process or in the first instances of their application, ensuring sufficient stakeholder participation.

3.2.2 Process Aspects

The rotational system in government departments often creates challenges in securing expertise in specific technical areas, which is why specialized agencies or entrusted institutions are established to handle administrative tasks that require expert judgment. This often results in a dual structure where specialized organizations are entrusted with tasks, but the final decisions are made by the relevant government departments.

Improving the application process for graded regulation requires examining the relationship between the NSSC's staffs and the entrusted institutions. It is also necessary to consider the differences in perspectives between the NSSC's standing and non-standing commissioners. Although entrusted institutions provide a variety of opinions and proposals, the final authority to decide rests with the government departments. This structure raises concerns that proposals and opinions based on expertise may not be fully reflected and that decisions may be influenced by other policy reasons. Moreover, when an agenda is brought to the consensus-based commission, there is potential for political factors to intervene in the discussion process. Of course, even if the entrusted institutions were given authority, such situations might not be entirely avoided.

Regardless of who makes the decision, there is accountability involved, and in order to make accountable decisions, it is inevitable to compare and quantify the benefits and costs associated with the decisions. Therefore, it is necessary to establish official communication channels between the staffs and entrusted institutions at key intermediate stages before reaching a final decision.

3.2.3 Methodology Aspects

While there is currently no explicit legal requirement for the use of risk information, requirements for conducting PSA are specified in regulations such as those for evaluating accident management capabilities or performing periodic safety review. The U.S.NRC's Regulatory Guide 1.174 provides basic guidelines for utilizing risk information, and the framework proposed therein is considered the best way to integrate risk concepts with deterministic safety assessment to date. It is necessary to formalize the implementation of this approach within the domestic legal system as well.

The methodology for using PSA in decision-making appears to be sufficiently understood in South Korea. However, the most significant issue is the quality of PSA, which ultimately depends on model development standards, reliability databases, and professional expertise.

Currently, South Korea applies the U.S. standards, but given the different objectives and environments for using risk information, there is a need to develop an "adapted" standard. Due to the validity issues for utilities' reliability databases, the U.S.NRC currently operates its own comprehensive database, the Reliability and Availability Data System (RADS). Meanwhile, in the U.S., only individuals who have passed the PSA qualification examination, administered by industry expert organizations such as INPO, are permitted to participate in related tasks. Establishing a solid infrastructure for these methodologies is expected to ultimately provide a useful tool for the graded approach.

4. Conclusions

The research findings can be utilized to establish a foundation for incorporating the principles and methodologies of the graded approach from international organizations and other countries into domestic regulations. This is expected to enhance the confidence and effectiveness of safety regulation implementation. Additionally, securing objective criteria for the application of the graded approach will contribute to the rationality and consistency of regulatory decision-making. The development of additional required application processes will be carried out in subsequent research.

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