Nuclear Engineering and Technology 50 (2018) 997–1005

Contents lists available at ScienceDirect

Nuclear Engineering and Technology

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

Review Article

Review of the regulatory periodic inspection system from the viewpoint of defense-in-depth in nuclear safety

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ARTICLE INFO

Article history:
Received 1 September 2017
Received in revised form
8 June 2018
Accepted 16 July 2018
Available online 18 July 2018

Keywords:
Periodic inspection
Regulatory inspection
Safety inspection
Defense in depth
Risk-informed regulation
Inspection items

ABSTRACT

The regulatory periodic safety inspection system is one of the most important methods for confirming the safety of nuclear power plants and the defense in depth in nuclear safety is the most important basic means for accident prevention and mitigation. Recently, a new regulatory technology based on risk-informed and safety performance has been developed and used in advanced countries. However, since the domestic periodic inspection system is being used in the same way over 30 years, it is necessary to know how the inspection contributes to the safety confirmation of the nuclear power plants. In this study, the domestic periodic inspection system currently in use was analyzed from the perspective of defense in depth in nuclear safety. In addition, the analysis results were compared to the U.S. NRC's safety inspection system to obtain consistency and lessons in this study. As a result of analysis, the NRC's safety inspections were distributed almost evenly at the all levels of defense in depth, while in the case of domestic inspection, they were heavily focused on the level 1 of defense in depth. Therefore, it appeared urgent to improve the inspection system to strengthen the other levels of defense in depth in nuclear safety.

1. Introduction

Accidents at TMI, Chernobyl, and Fukushima nuclear power plants further strengthened nuclear safety-related regulatory systems and raised the need for a comprehensive review of the safety management systems for nuclear power plants. The U.S. NRC adopted a risk-informed and performance based nuclear regulatory system including the concept of defense in depth (DiD) [1] at the end of 1990, and then it spread to regulatory agencies around the world. The International Atomic Energy Agency (IAEA) defined DiD as the most important means for the prevention and mitigation of nuclear power plant accidents in Fundamental Safety Principles published in 2006 [2]. Also, the most important lesson of the Fukushima accident in Japan in 2011 was that DiD was the most important factor in nuclear safety. Therefore, in order to secure the safety of nuclear power plants from the viewpoint of reflection of lessons learned and operating experience, it is necessary to secure the barriers by incorporating the concept of DID to the nuclear power plant and to confirm whether the barriers about each level of DID are secured. Since then, the Nuclear Regulation Authority, Japan has made major changes to the safety inspection system, and now it is shifting its engineering technology to risk-informed and performance based advanced one including DiD concepts, which is currently used in the U.S. NRC. In Korea, the Nuclear Safety and Security Commission (NSSC) issued a Severe Accident Policy (2001.08), Recommendation of the Risk-Informed Safety Inspection Implementation (2002.12), and Risk-Informed, Performance Based Comprehensive Regulation Plan (2006). The Korea Institute of Nuclear Safety (KINS) conducted an international joint research project Establishment of Advanced and Future-oriented Nuclear Safety Regulatory System [3] from 2007 to 2012. For this, a regulatory study of Establishment of Implementation Program for Graded Regulation Using Risk and Performance Information [4] was conducted in order to enhance the safety regulation effect, efficiency, and overall safety by differentiating regulatory resources and activities based on the performance and design/operational characteristics of the nuclear power plants. Also, a research project by the title of Establishment of Implementation System for Risk Communication based on Nuclear Issues [5] was conducted with the aim of contributing to the promotion of social acceptance of nuclear energy by eliminating the public awareness and information gap inherent in nuclear conflict issues by combining risk

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https://doi.org/10.1016/j.net.2018.07.008

communication with policies. However, due to Korea's inherent regulatory system and environment, regulation on the use of risk information has not yet been put into practical institutionalization except for some limited application.

Regulatory agencies in most countries with nuclear power plants are conducting periodic or regular basis inspections. KINS has recently revised the Periodic Inspection Guideline (Rev. 3, 2015.10) [6] to consider the conditions of site surveillance and determine the target items and methods of regulatory inspection (in other words, periodic inspection, regular inspection, or safety inspection) using risk information. However, these inspection items are specified and controlled by the law, and the assessment methodology is still a deterministic one with single line defense. Actually, this method was introduced from Japan in early 1980s when the only three nuclear power plants (Kori 1, 2 and Wolsong 1) were operated in Korea and is still being used. It aims to check whether the performance of each inspection items satisfies the acceptance status at the time of the Pre-Service Inspection for each facility and system in accordance with Article 35, Enforcement Decree of the Nuclear Safety Act. In other words, the domestic regulatory inspection of nuclear power plants including all the facilities focuses more on confirming readiness for operation rather than confirming safety function. In addition, since all systems and facilities in a plant are subject to inspection, it is inefficient and ineffective to inspect them all with limited regulatory resources during operational phase.

Therefore, it is necessary to improve the regulatory periodic safety inspection system for domestic nuclear power plants. Nowadays, the safety of nuclear power plant draws more public attention than ever before so that the regulatory inspection is recognized as one of the most important safety verification tools. As pubic concern on safety increase, two approaches can be taken: one is to tighten regulation and the other is to improve regulatory effectiveness by strengthening DiD measure. The objective of this investigation is to suggest way to improve the effectiveness of periodic safety inspection through three approaches: (1) to compare KINS periodic safety inspection with NRC baseline inspection practices, (2) to evaluate event reports and (3) to review preliminary initiating events.

2. A methodology to estimate the regulatory inspection system

2.1. Estimation method

Fig. 1 shows the estimation procedure. This method focuses on confirming safety in terms of level of DiD and each cornerstone in U.S. NRC Reactor Oversight Process (ROP) [10], rather than focusing on checking whether the nuclear power plant can be operated through periodic inspections. For this method to be effective in practice, it is necessary to match 1) inspection objectives of items and detailed sub-items for the target facility and 2) design objectives of the structure, system, and component (SSC) included in the target item with the objectives and functions required in each level of DiD and cornerstone in ROP.

Ultimately, this approach allows us to see how the current periodic inspection items are distributed in terms of levels of DiD in nuclear safety (and additionally in terms of cornerstones in the ROP) and thus to identify vulnerabilities in safety verification.

In order to classify all SSC included in the facilities subject to periodic inspection according to the design purpose, function and safety level, Final Safety Analysis Report (FSAR) 3.2 “System Quality Classification” [11] and the Maintenance Rule (MR) (10 CFR 50.65 “Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants”) [12] were used. The MR provides criteria for

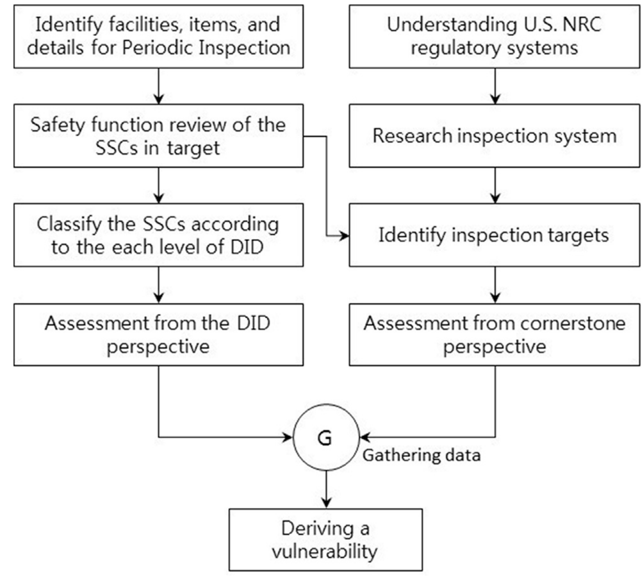

Fig. 1. An analysis method for deriving vulnerability of periodic inspection from the view point of defense in depth.

the management scope of nuclear power plant based on SSC, and NRC Reg. Guide 1.160 [13] that is the regulatory guidelines for the implementation of MR provides an alternative to determine the management scope by function. This is an important issue that determines whether the criteria should be classified as a facility or a function. First, an analysis of the DiD perspective was conducted, followed by an analysis of the ROP Cornerstone perspective. The latter is to confirm the consistency of the analysis, linking the purpose of each cornerstone with the concept of each level of DiD and matching the analysis results of the DiD perspective analyzed earlier. For example, periodic inspection items identified as level one of DiD can be classified as “Initiating Events”, “Barrier Integrity”, “Occupational Radiation Safety”, and “Public Radiation Safety” by overlapping items, the identified items as level two of DiD were classified as “Initiating Events” only. The U.S. regulatory system has been developed based on operating experiences and R&D results accumulated over the years. This system been considered as the most reliable and robust in most of nuclear countries in the world. Therefore, valuable insights can be obtained from comparative approach on the inspection methodologies between NRC's baseline inspection where the DiD concept is well incorporated and KINS's Periodic safety inspection that was no visible DiD concept.

2.2. Periodic inspection model

2.2.1. KINS model

Regulatory inspections of domestic nuclear power plants are carried out on the basis of Article 22 (Inspection) of Nuclear Safety Act [7]. As referred to in this law, all nuclear power plants must be operated in compliance with the operating license in accordance with Article 21 (Standards for License) of the Nuclear Safety Act, and the performance of each facility and system must maintain standard status at the time of Pre-Service Inspection in accordance with Article 35 (Regular Inspection) of the Enforcement Decree of the Nuclear Safety Act [8]. Periodic inspection is to confirm this. According to this law system, the standards for license of regulatory inspection are focused on maintaining the performance for normal operation of all systems in a nuclear power plant, and ultimately preventing disaster caused by nuclear reactor or radioactive material under the conditions of operation as well. This, in a legal context, seems to be well consistent with the 8th Principles ("All practical efforts must be made to prevent and mitigate nuclear or radiation accidents") of the IAEA Fundamental Safety Principles, No. SF-1 [2]. In Article 19 (Periodic Inspection) of the Enforcement Regulations for the Nuclear Safety Act [9], the periodic inspection period is defined as the term from the day when the reactor is stopped for the purpose of refueling until the day when full power operation is resumed. If the inspection result satisfies the standards of Article 21 of the Nuclear Safety Act, it is stipulated that the reactor criticality is allowed. Table 1 shows the legal system for periodic inspections of domestic nuclear power plants.

In particular, Article 19 (Periodic Inspection) of the Enforcement Regulations for the Nuclear Safety Act stipulates that the inspection target items and methods for each facility shall be prescribed in the NSSC's notification. According to this, the NSSC Notice No. 2017-09 [14] specifies eleven facilities including the Other Facilities Pertaining to the Safety of a Nuclear Reactor (OFPSNR) Facility and one operational technical capability field for regulatory inspections as shown in Table 2. The OFPSNR Facility is defined in detail in NSSC Notice No. 2016-30 [15] Article 2. The total number of inspection target items was 100 and the total number of detailed inspection items was 322 on the basis of the facility-specific checklist of the Periodic Inspection Guideline [6].

2.2.2. U.S. NRC model

The U.S. NRC operates a regulatory framework called Reactor Oversight Process (ROP) [10] which is a tiered approach to assessing performance indicators and utilizing risk information to inspect, measure and evaluate the safety and security of nuclear power plants. As shown in Fig. 2, this system has three key strategic performance areas of nuclear safety, radiation safety and safeguard to protect the health and safety of the public from nuclear power plants. Within each area, there are cornerstones that reflect the essential safety aspects of facility operation. It provides a means to collect information about licensee performance, assess the information for its safety significance, and provide for appropriate license and NRC response (Fig. 3). There are a total of seven cornerstones in the ROP framework, each of which has a goal in Table 3. The ROP has a principle that when a regulator guarantees that a company meets the safety objectives of each of these seven cornerstones, the regulator's goal of ensuring the safety of the nuclear power plants (ensuring public health and safety) is achieved. Table 3 summarizes intentions and goals that are included in the seven cornerstones.

The NRC's regulatory inspection comparable to the domestic periodic inspection is a risk-informed baseline inspection. This inspection program is an integral part of the NRC's ROP and supports the goals and objectives of that process. This program is comprised of three parts. They are cornerstone-based inspections, verification of performance indicators, and identification and resolution of problems. Baseline inspection can be divided into Resident Inspection and Region Based Inspection depending on the inspector performing this inspection: the former by resident inspectors and the latter by region-based inspectors. Under the baseline inspection program, all areas where there is a need to evaluate a licensee's performance are defined as inspectable areas. Inspections within these areas were adjusted where licensee performance to meet a cornerstone objective is adequately gauged by performance indicators. In baseline inspection, as shown in Table 4, a total of 41 inspectable areas are designated for seven cornerstones and related inspection procedures are developed and implemented. This presents a listing of inspectable areas associated with each cornerstone of safety.

3. Applications and results

3.1. Characteristics of domestic periodic inspection system from the viewpoint of DiD in nuclear safety

In order to understand the extent to which the detailed items to be inspected contributes to the safety verification of the nuclear power plant based on the KINS's Regulatory Inspection Guideline [6], which is the purpose of the regulatory inspection, the results of mapping and re-grouping them into each level of DiD in nuclear safety are shown in Table 5 below. The regulatory inspection items projected by the level of DiD are 417 in total if they allow overlapping items depending on the functions that are suitable for the purpose of each level of DiD in nuclear safety. Fig. 4 shows the distribution of the safety inspections for each target facility to be inspected, with 112 in the OFPSNR facility, followed by 58 in the Power Supply System Facilities and the third 45 items in the Power Conversion System Facilities. A total of 215 items were distributed in these three facilities, accounting for 51.56% of all items. As shown in Fig. 5, the distribution of safety verification in DiD levels is 58.8% in the level one, 17.0% in the level two, 20.4% in the level three, and 3.8% in the level four respectively. It is because most periodic inspections are concentrated on the SSCs included in the Radioactive Waste Disposal Facilities, Radiation Control Facilities, and Power Conversion System Facilities, and OFPSNR Facility, which include most of the SSCs for DiD level one that are not dependent on or affect engineered safety features actuation system (ESFAS) and mitigating systems for design based accidents or severe accidents. In addition to the prevention of the early events (associated with DiD level 1) according to the lessons of the Fukushima accident, preparations for abnormal or even more situations such as transient (associated with DiD level 2), design basis accidents (associated with DiD level 3), and severe accidents (associated with DiD level 4) must be made to secure safety. As a measure of this lesson, the current domestic regulatory inspection system, concentrated in the level 1 of DiD, seems to be far from securing the safety of the nuclear power plant.

Table 1
Legal system concerning periodical inspections of domestic nuclear power plants.

Law Title	Article	Provisions
Nuclear Safety Act	22 (Inspection)	Operator of a nuclear power reactor shall undergo an inspection of the Commission, as prescribed by Presidential Decree.
Enforcement Decree of the Nuclear Safety Act	35 (Regular Inspection)	Each operator of a nuclear power reactor shall undergo a regular inspection of the operation and performance of reactor facilities according to the objects to be inspected and methods of inspection prescribed by Ordinance of the Prime Minister pursuant to Article 22 (1) of the Act.
Enforcement Regulations for the Nuclear Safety Act	19 (Periodic Inspection)	(1) Inspection targets and methods to be applied at each facility: The Commission shall determine and publish. (2) Inspection cycle: Within 20 months of the start of initial commercial operation or inspection (3) Inspection implementation: During a regular maintenance or refueling outage
Nuclear Safety and Security Commission Notification	2017–09	Selection of inspection items: Selection of inspection targets considering the impact on safety and performance. Designated items subject to inspection by reactor type: facilities subject to light water reactor inspection.
	2016–30	Regulations on facilities related to the "Other facilities pertaining to the safety of a nuclear reactor"

Table 2
Items subject to regulatory inspection of domestic nuclear power plants.

Inspection target facilities	No. of Items	No. of detailed items
1. Nuclear reactor (including fuels)	6	20
2. Nuclear reactor coolant system facility	6	20
3. Instrumentation and control system facilities	11	22
4. Nuclear fuel material handling and storage facilities	2	6
5. Radioactive waste disposal facilities	5	26
6. Radiation control facilities	7	16
7. Reactor containment facilities	6	19
8. Reactor safety system facilities	5	14
9. Power supply system facilities	17	54
10. Power conversion system facilities	10	36
11. Other facilities pertaining to the safety of a nuclear reactor	20	73
12. Technical Operation	5	16
Sum	100	322

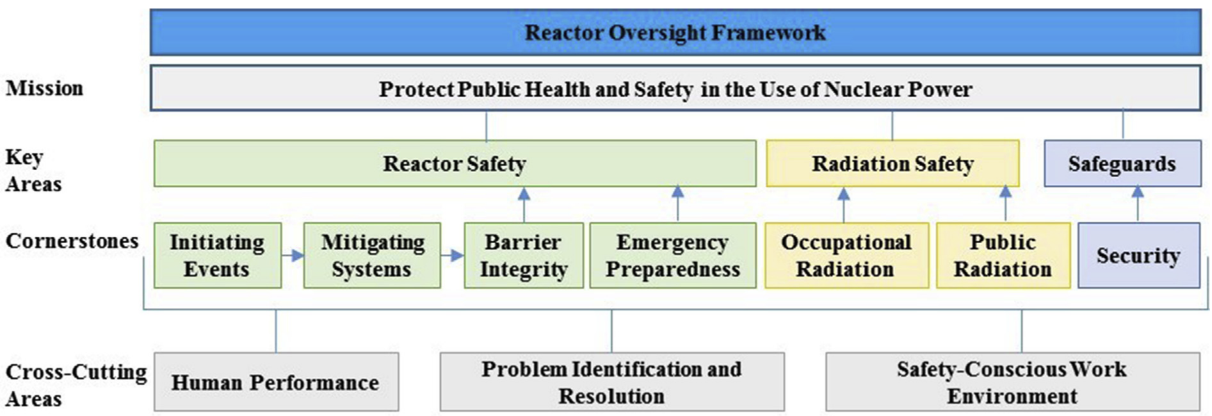

Fig. 2. U.S. NRC reactor oversight process framework.

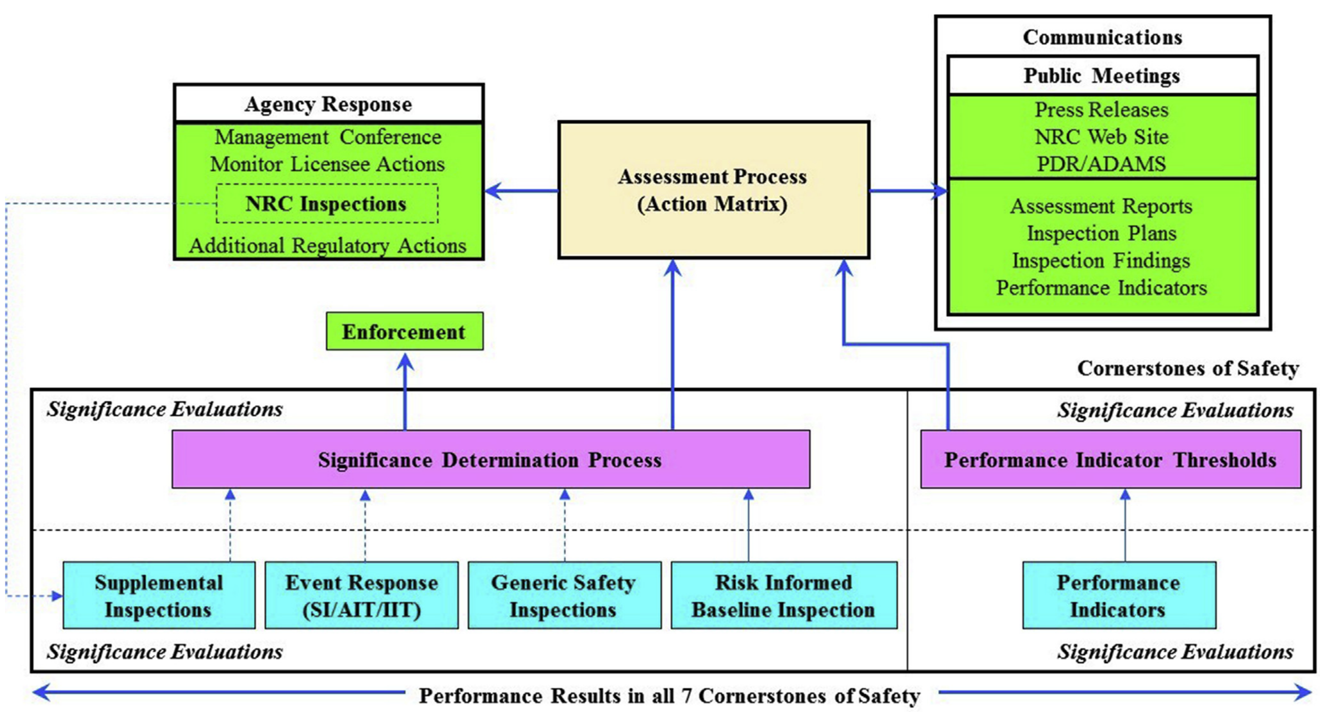

Fig. 3. Overview of the reactor oversight process.

Table 3
Objectives of the cornerstones in ROP framework.

Area	Cornerstone	Objectives
Reactor Safety	Initiating Events	Limit the frequency of those events that upset plant stability and challenge critical safety functions, during shutdown as well as power operations.
	Mitigating Systems	Monitor and maximize the availability, reliability, and capability of systems that mitigate the effects of initiating events to prevent core damage.
	Barrier Integrity	Provide reasonable assurance that the physical design barriers protect the public from radionuclide releases caused by accidents.
	Emergency Preparedness	Ensure that licensees are capable of implementing adequate measures to protect public health and safety during a radiological emergency.
Radiation Safety	Occupational Radiation	Ensure adequate protection of worker health and safety from exposure to radiation from radioactive material during routine civilian nuclear reactor operation.
	Public Radiation	Ensure adequate protection of public health and safety from exposure to radioactive material released into the public domain as a result of routine civilian nuclear reactor operations.
Safeguards	Security	Provide assurance that the licensees' security system and material control and accounting programs use a defense-in-depth approach and can protect against (1) the design basis threat if radiological sabotage from external and internal threats, and (2) the loss of radiological materials.

Table 4
Inspectable areas in baseline inspection program [19].

No.	Inspectable Area
1	Access control to radiologically significant areas
2	Access authorization program
3	Access control
4	Adverse weather protection
5	ALARA planning and controls
6	Alert and notification system testing
7	Component Design Bases Inspection
8	Contingency response
9	Drill evaluation
10	Emergency response organization augmentation testing
11	Emergency action level and emergency plan changes
12	Equipment alignment
13	Equipment performance, testing, maintenance
14	Evaluations of changes, tests, or experiments and Permanent Plant Modifications
15	Exercise evaluation
16	Fire protection
17	Fitness for duty program
18	Flood protection measures
19	Heat sink performance
20	Identification and resolution of problems
21	Information technology security
22	In-service inspection activities
23	Irradiated fuel transportation security
24	Licensed operator requalification
25	Maintenance risk assessments and emergent work evaluation
26	Maintenance Effectiveness
27	Material control and accountability
28	Operability evaluations
29	Plant modifications
30	Owner controlled area controls
31	Post maintenance testing
32	Protective strategy evaluation
33	Radiation monitoring instrumentation
34	Radiation worker performance
35	Radioactive material processing and transportation
36	Radioactive Gaseous and liquid effluent treatment and monitoring systems
37	Radiological environmental monitoring program
38	Refueling and outage activities
39	Response to contingency events
40	Security Training
41	Surveillance testing

The type analysis of inspection findings noted for the periodic inspection items listed in Table 2 provides information on how the actual inspection activity contributes to the comprehensive nuclear safety verification of the current periodic inspection. Table 6 shows the types of inspection findings noted (including recommendations) in the Regulatory Inspection Reports of Hanul Unit 5 (1st ~ 8th inspections) and Hanul Unit 6 (1st to 8th inspections) [16,17]. According to this analysis results, about 27.5% of the inspection findings noted are related to OFPSNR Facilities, about 17.4% are in the Power Supply System Facilities, about 13.8% in the Power Conversion System Facilities, and 11.9% were in the Radioactive Waste Disposal Facilities. These facilities accounted for about 70.6% of the all inspection findings noted. Looking at the inspection results noted, procedural nonconformity that is classified as human error accounts for about 42.2% of the total inspection findings. The type analysis of inspection findings noted for the periodic inspection items are shows, like the results of mapping and re-grouping detailed inspection items into each level of DiD, the current

Table 5
The analysis results of regulatory inspection items in DiD perspective.

Inspection target facilities	No. of items		No. of items associated with defense in depth* (counting overlapped)					
	General items	Detailed items	1	2	3	4	5	sum
1. Nuclear reactor (including fuels)	6	20	20	3				23
2. Nuclear reactor coolant system facility	6	20	19	3	1			23
3. Instrumentation and control system facilities	11	22	14	14	4			32
4. Nuclear fuel material handling and storage facilities	2	6	6					6
5. Radioactive waste disposal facilities	5	26	26					26
6. Radiation control facilities	7	16	15	1				16
7. Reactor containment facilities	6	19			3	16		19
8. Reactor safety system facilities	5	14	6		11			17
9. Power supply system facilities	17	54	21	8	29			58
10. Power conversion system facilities	10	36	36	5	4			45
11. Other facilities pertaining to the safety of a nuclear reactor	20	73	69	25	18			112
12. Technical Operation	5	16	13	12	15			40
Sum	100	322	245	71	85	16		417
rate(%)			58.8	17.0	20.4	3.8	0.0	100

*Defense in Depth

Level	Objective	Essential Means
Level 1	Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation
Level 2	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance features
Level 3	Control of accidents within the design basis	Engineered safety features and accident procedures
Level 4	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Complementary measures and accident management
Level 5	Mitigation of radiological consequences of significant releases of radioactive materials	Off-site emergency response

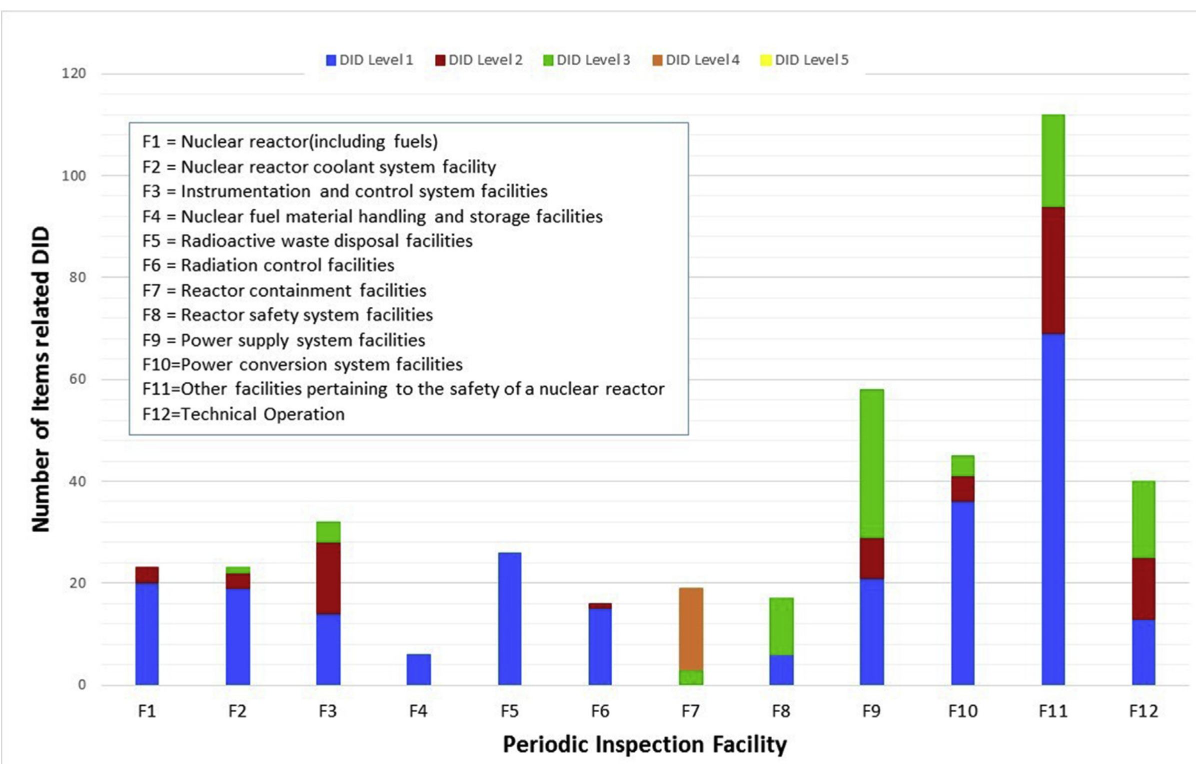

Fig. 4. The distribution of inspection items in DiD perspective (by facility).

domestic regulatory inspection system seems to be far from securing the safety of the nuclear power plant. In fact, it is not unreasonable for periodic inspections to appear to be very formal and ineffective without contributing significantly to safety verification, because these facilities include inspection items that do not contribute to, or even contribute to, anything except DiD level 1 but

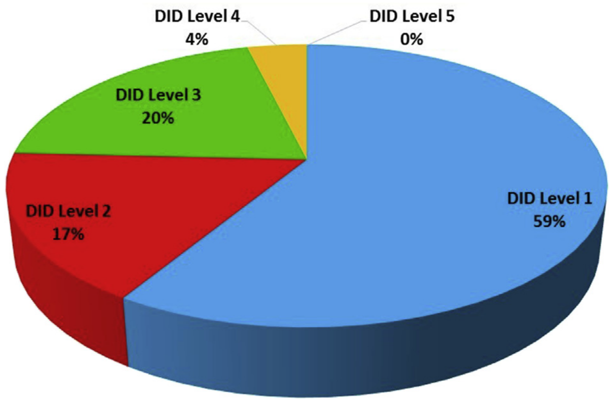

Fig. 5. The distribution of inspection items in DiD perspective (total).

dominate, and their inspection activities are not focused on safety verification.

3.2. Characteristics of domestic periodic inspection system from the viewpoint of ROP cornerstones

Table 7 shows the results of analyzing the 41 items of the NRC baseline inspection and the domestic regulatory inspection items from the seven cornerstones view of the NRC ROP framework. Domestic periodic inspection items were mapped by allowing overlapping items for each purpose by seven cornerstones. Fig. 6 shows a comparison of regulatory inspection items between KINS and NRC. The NRC baseline inspection items were relatively highly classified as mitigating systems associated with the level 3 of DiD in nuclear safety, while the domestic items were mainly distributed at a high rate of 42.6% in Initiating Event associated with the level 1 and 2 of DiD. This result also shows almost the same pattern as before. It should be noted that the NRC baseline inspection items are almost evenly distributed throughout the cornerstones. In particular, the fact that security has a higher distribution after the mitigating system suggests a something important to us.

4. Review and discussion

The inspection target selection method between NRC baseline inspection and domestic regulatory inspection shows a significant difference. The selection method of NRC baseline inspection follows a systematic ROP regulatory framework. The selection processes for NRC baseline inspection focus to accomplish the objectives for each cornerstone, and are shown in IMC 2515 Appendix A [18]. The selection processes for NRC baseline inspection specifies the range of sub-items so that the item selection for inspection target is possible depending on the property of the applicable nuclear power plants. And the target item inspection procedure in accordance to the

Table 6
The analysis results of regulatory inspection findings noted for Hanul Unit 5&6.

Inspection target facilities	Inspections		Type of inspection findings (1)								
	1–4	5–8	a	b	c	d	e	f	g	h	sum
Nuclear reactor (including fuels)	1	2			3	1					4
Nuclear reactor coolant system facility	2	–		1	1						2
Instrumentation and control system facilities	4	–			3	1					4
Nuclear fuel material handling and storage facilities	–	–									–
Radioactive waste disposal facilities	11	2	1	2	6	1	3				13
Radiation control facilities	5	1	1		4			1			6
Reactor containment facilities	5	–		2	3	1					6
Reactor safety system facilities	5	2		3	1	1				3	8
Power supply system facilities	11	8		3	8	1	3	4			19
Power conversion system facilities	10	4		2	6	3				4	15
Other facilities pertaining to the safety of a nuclear reactor	22	6		3	13	5	2		1	6	30
Technical Operation	1	1			1				1		2
sum	77	26	2	16	49	14	8	5	2	13	109

(1)NSSC Notification 2015-07(2015.06.05) “Regulations on disposal of inspection items of nuclear facilities”.
a: Device function is not suitable.
b: Inconsistent test or inspection.
c: procedural nonconformity.
d: Failed procedure.
e: Construction or maintenance unsuitable.
f: Design or manufacturing unsuitable.
g: Other requirements not met.
h: Etc.

Table 7
Comparison of the regulatory inspection items between NRC and KINS.

Cornerstone	Defense in Depth Level	Baseline Inspection(1), %	Periodic Inspection(2), %
Initiating Events	1, 2	15.2	42.6
Mitigating Systems	3	24.2	21.3
Barrier Integrity	1, 4	16.7	17.9
Emergency Preparedness	5	10.6	0.0
Occupational Radiation Safety	1	6.1	8.5
Public Radiation Safety	1	7.5	6.7
Security	–	19.7	3.0
sum		100.0	100.0

(1) Percentage of total 41 inspectable areas, overlapping allowed, (IMC 2515 Appendix A).
(2) Inspection items in Periodic Inspection Guideline with 322 detailed items, overlapping allowed.

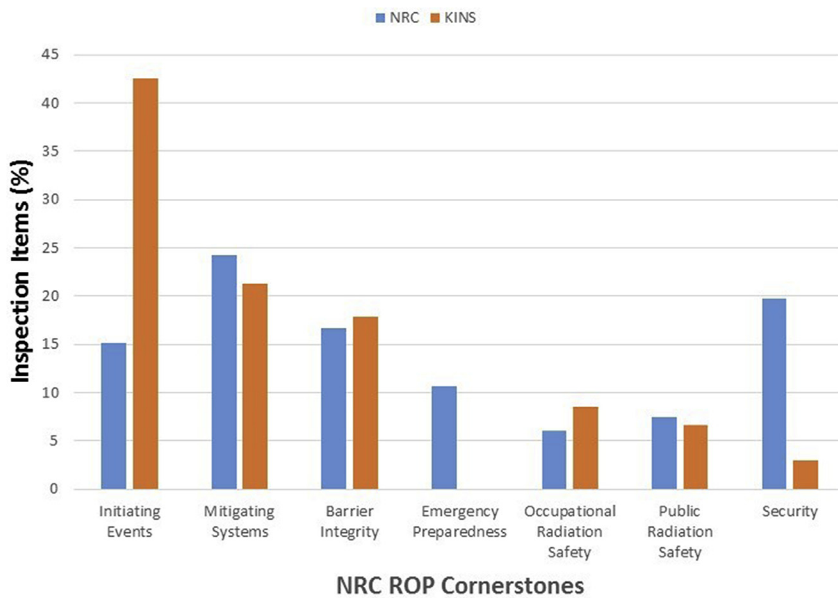

Fig. 6. The distribution of inspection items in cornerstones perspective.

cornerstone and inspectable area correlation is developed. On the contrary, since domestic regulatory inspection is executed to satisfy the performance and operability of plant facility by law, it must establish the selection criteria for target facility and SSC in it to inspect the performance of disaster prevention of radiation material. Consequently, the target items and sub-items will be specified by the type of reactor; where the complete inspection should be followed for each target item. Therefore, the regulatory agency has developed the inspection guidelines according to it. In Table 8, the comparison between NRC baseline inspection Program and domestic regulatory inspection system is shown. Overall, NRC baseline inspection confirms the plant safety performance by specific plant inspection based on risk information, the inspection procedure is divided into activity units, the inspection procedure ensures the inspection objectives by showing the relationship between the inspection and ROP cornerstones, and the selection criteria for target items are system approach, risk significance and low margin approach, and event scenario approach. On the other

Table 8
Comparison of the regulatory inspection system between NRC and KINS.

Characteristic.	NRC, Baseline Inspection	Periodic Inspection
Basic characteristics	• One of the four inspections that make up the ROP • Planned Activity to confirm Cornerstone goals • Risk informed	• Regular inspection of the performance of reactor facilities • Check the performance of the facility • Allow criticality of nuclear reactors when passed
Selection of inspection items	• Systematic selection according to the regulatory framework • Item selection process is given as a procedure to fulfill the Cornerstone objectives (IMC 2515, Appendix A) • Being able to develop target procedure associated with the relationship between Cornerstone and Inspectable Area	• Establishment of targets for testing the performance of radioactive material disaster prevention facilities due to compliance with operation/facility performance, in accordance with the law • Designated facility/system/equipment and detailed inspection items for each reactor type • General inspection principle for target items
Inspection Cycle	• Determine various cycles based on the risk of Inspectable Area (6 cycles)	• Refueling outage only
Defense in Depth	• Cornerstones already reflect a systematic defense-in-depth concept • Strengthened by level 3 of defense in depth, but having an almost uniform weight in all levels • In addition, consider security	• Tendency concentrated in level 1 of defense in depth • No security considered
Performance Assessment	• Plant Performance = Inspection Findings + Performance Indicators (17) • Carry out an assessment of the significance of the inspection findings noted	• There is no significance assessment for results • Manage separately the inspection results and nuclear performance indicators (15)
Comprehensive opinion	• Assessment of plant safety performance based on the risk-informed plant specific inspection • Procedure classification: Activity unit • Selection Criteria: - System Approach - Risk Significance/Low Margin Approach - Event Scenario Approach	• Execute the same inspection items in a single cycle without consideration of characteristics of each unit for each type • Procedure classification: Facility/System/SSC • Recognition of refueling and in-service inspection performance status • Inadequate achievement of the purpose of regulatory inspection of safety confirmation

hand, the domestic regulatory inspection is executed for the same target item in the single period without considering the characteristic features for each plant unit by the type of reactors, the inspection procedure is divided into facility/system, and the inspection needs to satisfy the objectives of regulatory inspection to confirm safety since it tends to confirm the performance status during overhaul and in-service inspection.

In addition, although the regulatory periodic inspection is the most important activity to confirm the safety of nuclear power plants, the domestic regulatory inspection is executed from the perspective of confirming the performance of all systems stipulated in the law rather from the DiD perspective in nuclear safety. In this manner, the current inspection method puts the same degree of importance on every system and does not consider the degree of importance of safety on each level of DiD. Therefore, in order to improve the availability and effectiveness of regulatory resources, it is essential to provide change to the current domestic regulatory inspection system. An example of the change is to exclude some items with insignificant impact on safety from the DiD perspective, such as OFPSNR Facilities and Power Conversion System Facilities.

5. Conclusions

In this study, we have discussed the weakness of the current domestic regulatory inspection system, as well as the need to change the safety confirmation of nuclear power plants from the perspective of DiD in nuclear safety. As a result, further study is required to develop the applicable method. In order to strengthen level 1 of DiD, which means the prevention of any abnormal operation and accident, it is required to ensure whether each cause of individual accidents is inspected accordingly through the current target item by analyzing each accident rather than analyzing conventional inspection activity for the existing target item. To do this, it is possible to strengthen the target item by plant units. In order to strengthen the level 2 of DiD for abnormal operation control and failure detection, as well as level 3 of DiD for accident mitigation, it is necessary (1) to examine the event tree that can prevent the core damage from the initial event by utilizing the Level 1 PSA at full power internal event report, (2) to examine the required facility, system, equipment and procedure for the relevant event tree, and subsequently (3) to inspect the SSCs associated with the relevant event tree defined in (1) through periodic safety inspection. Moreover, it is required (1) to examine the system, equipment, and procedure by utilizing the minimal cut set of failure paths, which have a higher contribution to reactor damage among all failure paths, and then (2) to inspect these failure paths through periodic regulatory inspection. As for level 4 of DiD related to severe nuclear accident mitigation, it is essential (1) to analyze the failure paths which have a higher contribution to the damage path for the containment building by utilizing the Level 2 PSA at full power internal event results, (2) to select the facility, system, equipment, and procedure that cause the damage to the containment building as an inspection item, and then (3) to objectify the paths and scenarios that could cause damage to the containment building of Level 2 PSA. By executing these requirements, it could strengthen the safety of on-power plant.

Acknowledgments

This work was supported by the Nuclear Safety Research Program through the Korea Foundation of Nuclear Safety(KoFONS), granted financial resource from the Nuclear Safety and Security Commission, Republic of Korea. (No. 1603012)

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