Development of the General Safety Requirements for New Innovative Reactors

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1. Introduction

Since 2007, new innovative reactors, such as VHTR (Very-High-Temperature Reactor) for hydrogen production and Gen. IV SFR (Sodium-cooled Fast Reactor) have been developed by the KAERI (Korea Atomic Energy Research Institute) under auspices of the MEST (Ministry of Education, Science and Technology). The design concepts and characteristics of new innovative reactors are substantially different from existing LWRs, as denoted in Table 1.

Table 1 the comparison of design concepts and characteristics between LWR and new reactors

Gen IV System	LWR	SFR	VHTR
nuclear fuel	UO2	U-TRU-Zr	TRISO
neutron	thermal neutron	fast neutron	thermal neutron
power density	100W/cc	280W/cc	4 - 7W/cc
primary coolant	water	Liquid metal	helium gas
primary circuit pressure	150 atm	1 atm	7 atm
coolant inlet/outlet temperature	290℃/350℃	350℃/550℃	640℃/950℃

USNRC and IAEA have proposed to adopt regulatory technology-neutral framework (TNF) which can be applied regardless of their reactor types in order to enhance the effectiveness, efficiency, and predictability of future plant licensing. Especially, USNRC has provided an approach that appropriately integrates deterministic and probabilistic elements in the development of technical requirements for future reactors. The approach considers more extensive use of risk-informed and performance-based applications. In this study, utilizing the approach by the USNRC, the general safety and technical requirements for new innovative reactors are developed through several steps.

2. Outline of New Regulatory Framework

As shown in Figure 1, the new regulatory framework is proposed, adopting risk-informed & performance-based approach and defense-in-depth principles to that of existing reactors. Existing general requirements (ex.: GDC), lessons learned from the past, and risk-informed and performance-based requirements were considered in developing the general safety requirements for new innovative reactors [1].

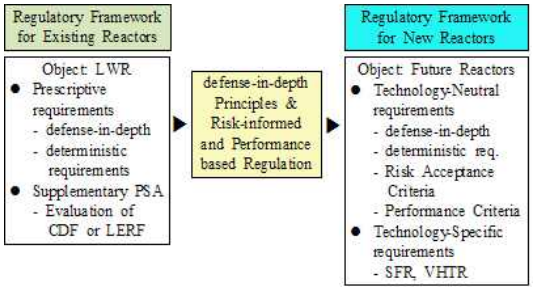

Figure 1: Regulatory framework for new reactors

3. Steps for developing the general safety requirements

3.1 Establishment of the roadmap to develop the requirements

Figure 2 shows the roadmap to develop the general safety requirements. Safety objectives consist of qualitative objective and quantitative objective, where the latter is Quantitative Health Objectives (QHOs) in the MEST's Severe Accident Policy. In order to ensure protection of the public health and safety, and accomplish the safety, security and preparedness goals, the basic principles are defined in terms of five protective strategies (physical protection, stable operation, protective systems, barrier integrity, and protective actions). The defense-in-depth principle is then applied to safety fundamentals (protective strategies) and key factors of licensing basis (probabilistic process and technical acceptability). Through the integrated process for safety requirements, the topics for which requirements are needed are categorized into the areas of design, construction, and operation, respectively. At the final step of this roadmap, safety requirements are reflected into our legal system through demonstration or consensus process.

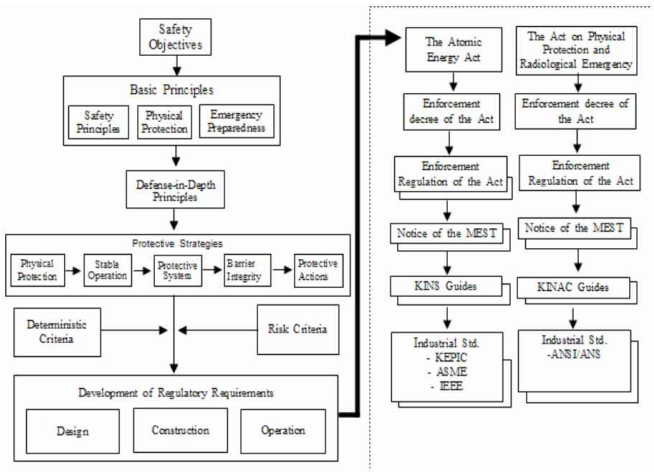

Figure 2: Roadmap for developing the safety requirements

3.2 Topic identification process and structuring

Figure 3 shows topic identification process. The general design criteria (GDC) of 10 CFR 50 serve as a good example for this study. It may be possible to properly use some of the existing GDC requirements. In NUREG-1338 (1989), 53 topics were found to be applicable to SFR. In NUREG-1368 (1994), 38 topics were found to be applicable to MHTR. In IAEA-TECDOC-1570 [2], 82 Topics to be applicable to new reactors were suggested. The topics of the general safety requirements, which finally consist of 69 topics, were selected from NUREG-1860 [3]. Regulations on Technical Standards of MEST were also referred to elaborate these requirements.

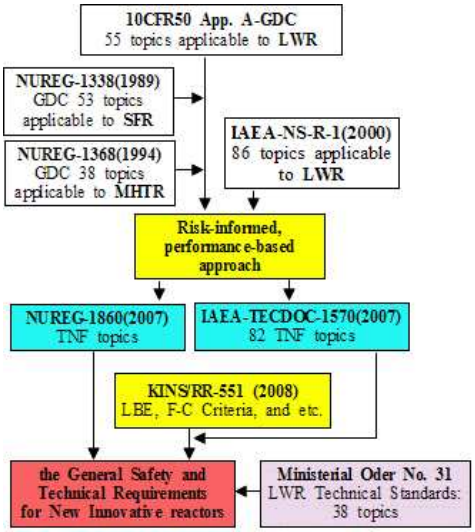

Figure 3: Topic Identification Process

Table 2 shows the general safety requirements categorized into 4 areas; common, design, construction, and operation.

Table 2 List of the general safety requirements

1. Common Safety Requirements	
1) QA/QC 2) PRA scope and quality	3) Use of risk information 4) Integration of Safety and Preparedness
2. Design Safety Requirements	
1) Plant risk 2) Criteria for selection of LBEs 3) LBE acceptance criteria 4) Initiating event severity 5) Safety classification and special treatment 6) Equipment qualification 7) Licensing analysis 8) Siting and site specific considerations 9) Use consensus design codes and standards 10) Materials qualification 11) Protection against natural phenomena 12) Dynamic effects 13) Sharing of structures, systems and components 14) Reactor shutdown and decay heat removal 15) Barriers to release of radioactive material 16) Radiological containment functional capability 17) Radiological containment atmosphere cleanup 18) Fracture prevention of radiological containment pressure boundary 19) Electric power system 20) Piping systems penetrating radiological containment boundary	21) Closed system isolation valves 22) Vulnerability to a single human action or hardware failure 23) Plant aging and degradation 24) Reactor inherent protection 25) Human factors/man-machine interface 26) Fire protection 27) Control room design 28) Alternate shutdown location 29) Reactor core flow blockage and bypass prevention 30) Reliability and availability 31) Research and development 32) Use of prototype testing 33) Combustible gas control 34) Energetic reaction control 35) Prevention of reactor coolant boundary brittle fracture 36) Reactor coolant pressure boundary 37) Reactor coolant activity monitoring and cleanup 38) I & C system 39) Protection of operating staff 40) Control of releases of radioactive materials to the environment 41) Monitoring radioactivity releases 42) Qualified analysis tools
3. Construction Safety Requirements	
1) Use accepted codes, standards, practices 2) Security during construction/ fabrication 3) NDE during construction/fabrication	4) Inspection during construction/ fabrication 5) Testing during construction/ fabrication
4. Operation Safety Requirements	
1) Radiation protection 2) Maintenance program 3) Personnel qualification 4) Training 5) Use of Procedures 6) Use of simulators 7) Staffing 8) Aging management program 9) Surveillance program	10) In-service inspection 11) Testing 12) Technical specifications 13) Emergency Preparedness 14) Monitoring and feedback 15) Work and configuration control 16) Maintenance of the PRA 17) Fuel and replacement part quality 18) Security

3.3 Peer review of the draft requirements

The draft requirements were reviewed by 13 experts in industries, universities, and research institutes. A lot of comments from the experts were reflected in the first draft requirements. Most of comments were mainly to adjust the context, and some comments should be considered to achieve completeness, as follows:

- Risk criteria (frequency-consequence curve, etc.) to be technically confirmed
- Selection process of LBE (licensing basis event) to be defined
- Emergency preparedness and exclusive area boundary (EAB) to be considered or not, and so on.

4. Conclusions

The regulatory framework for new innovative reactors has been under development by referring the TNF proposed by USNRC and IAEA. This paper presents the current research results on the development of the general safety requirements for new innovative reactors.

This is an initiative to develop a risk-informed and performance-based approach for new innovative reactor licensing. Through a broad consensus process involving designer, stakeholders, etc., the general safety requirements will be refined and finalized. As a next step, detailed implementation guides will be also developed in order to specify the safety requirements.

We expect that our results would be utilized in constructing the regulatory framework for new innovative reactors licensing.

References

[1] Survey on probabilistic elements among potential safety requirements of TNF, Transaction of the Korean Nuclear Society Autumn Meeting, Oct., 2008

[2] Proposal for a tech. neutral safety approach for new reactor designs, IAEA-TECDOC-1570, 2007

[3] Framework for development of a risk-informed, performance-based alternative to 10 CFR Part 50, NUREG-1860, 2007