Development Approach of General Regulatory Requirements for SFR in Korea

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1. Introduction

The Atomic Energy Commission of Korea established a long-term R&D plan for future reactor systems including sodium-cooled fast reactor (SFR) in Dec. 2008. According to the plan, an application for the design approval of an SFR demonstration reactor is scheduled in 2017. A project to develop the SFR was launched in 2010 to implement the long-term R&D plan. Korea Institute of Nuclear Safety (KINS) also started to develop general regulatory requirements (GRRs) for SFR for the preparation of the licensing application of the SFR. In this paper, the development approach of KINS was introduced.

The GRRs for SFR are developed based on the current GRRs for LWR, "Regulations on Technical Standards for Nuclear Reactor Facilities, Etc.". And design characteristics of SFRs are reflected in the current GRRs. Also, the following items are considered: strengthening of safety by the IAEA, foreign regulatory requirements for SFR, risk-informed regulations, and the lessons learned from Hukushima accident.

2. Reflection of Design Characteristics of SFR

The design of the KALIMER-600 was reviewed to reflect design characteristics of the SFR in the GRRs.

Comparing with LWRs, the SFR has various design differences. It uses the sodium as reactor coolants. Reactor coolant temperature at inlet and outlet of the core is 390℃ and 545℃, respectively. The pressure at the core is about 1 atm. Intermediate cooling system is installed between primary cooling system and steam generation system. Inert cover gases are filled in reactor vessel, intermediate cooling system, and steam generator to avoid sodium reactions with the air. Sodium heating system is installed to prevent sodium solidification. Boric acid solution is not used as reactivity control material. In case of the KALIMER-600, metallic fuel is loaded and HT9 used as a cladding material. In normal operation, reactor core cooling is performed by reactor cooling system, intermediate cooling system, and steam generation system. In accident conditions, reactor core cooling is carried out by passive decay heat removal system.

In order to reflect the design characteristics of SFR in the GRRs for SFR, the applicability of the current GRRs of Korea to SFR was evaluated, and the USNRC's assessment of the applicability of the general design criteria (GDC) to the PRISM reactor was reviewed. From the results, it was identified that 13 requirements need to be modified and 5 requirements to be newly added [1].

Since liquid reactivity control materials are not used in SFR, the requirements related to liquid reactivity control system shall be replaced by those for the substituted reactivity control system. The requirements for core cooling of LWR consist of two requirements: low pressure and high pressure conditions. However, since SFR has only low pressure condition, the requirements for the residual heat removal can be combined into one requirement. The requirement related to oxidation and hydrogen generation in the fuel cladding shall be deleted because the failure mechanism of the cladding material of metallic fuel of SFR is different from that of LWR. The fuel handling facility operating at reactor vessel of SFR has a leak-tightness function, so that the components exposed to reactor cover gas or having a leak-tightness function shall be classified as a part of the reactor coolant boundary.

New requirements that need to be added to the GRRs are as follows: intermediate cooling system, sodium heating system, and sodium & cover gas control system, which are not installed in LWR. Since the sodium reacts vigorously with air, water, and concrete, a new requirement shall be added in the GRRs for the protection against sodium reactions. Fuel pin bundles of SFR are installed in a sealed duct and reactor coolants flow into the fuel pin bundles through only the inlet port at the lower part of the duct. In order to assure core cooling, a new requirement shall be added to minimize the potential for flow blockage of reactor coolants at the core assemblies.

3. Strengthening of Safety

The current GRRs of Korea were established in 2000 and small parts of them were revised in 2006. The IAEA published the GRRs "Safety Series NS-R-1" in 2000, and its draft revision DS414 [2] has been developed and reviewed by its member states as of June 1, 2011. The DS414 contains technical changes in safety regulations since 2000 to strengthen the safety of NPPs. The SFR being developed in Korea is one of the Gen IV reactors and its level of safety shall be enhanced than that of the existing NPPs. Therefore, it is necessary to reflect the safety enhancement by the IAEA in the domestic GRRs. The DS414 has been reviewed and compared with the current GRRs of Korea. 12 requirements were identified as items that need to be reflected in the GRRs for SFR in Korea: defence-in-depth, design extension conditions, probabilistic safety assessment, decommissioning, interface of safety with security and safeguards, operating experience and safety research results, application of proven technologies, prevention of harmful effects between systems, etc.

A requirement for the defence-in-depth needs to be added in the GRRs to provide several levels of defence to prevent accidents and to mitigate their consequences. All levels of defence shall be kept available at all times and any relaxations justified. For accident conditions either more severe than design bases accidents or involving multiple failures (hereafter referred to as "design extension conditions"), a new requirement needs to be added to take the measures to maintain releases of radioactive materials within acceptable limits on the basis of the best estimated approach. It also needs to consider establishment of measures to prevent and to mitigate design extension conditions as far as reasonably practicable. Special consideration shall be given at the design stage to incorporate features to facilitate the decommissioning, so that a requirement needs to be added to take account of the choice of materials to minimize radioactive wastes and of the access capabilities. For assurance of safety, security, and safeguards, a requirement needs to be added to establish safety measures, nuclear security measures, and safeguards arrangements and to implement them in an integrated manner so that they do not compromise one another.

4. Framework and Components of GRRs for SFR

Based on the current GRRs, the items to be included in the GRRs for SFR were identified through (1) review of design characteristics of SFR, (2) evaluation of the applicability of the current GRRs for LWR to SFR, (3) review of the USNRC's assessment of the applicability of the GDC to the PRISM reactor, and (4) comparison of the DS414 with the current GRRs of Korea. The results are as follows: 24 items applicable as it is, 18 items to be modified, 17 items to be newly added, and 2 items to be excluded. Some requirements were merged, and 52 items were finally derived. These GRRs were arranged by subject into 4 groups: principal design requirements, plant design requirements, system design requirements, and other design requirements. The framework and components of the GRRs for SFR are shown in Table I.

5. Conclusions

For the preparation of the SFR developed in Korea, a study on the development of GRRs for SFR has been performed. The development approach is to modify and to supplement the current GRRs for LWR for the reflection of design differences of SFR as well as safety enhancement, based on the current GRRs. The following researches have been performed: (1) review of design characteristics of SFR, (2) evaluation of the applicability of the current GRRs of Korea to SFR, (3) review of assessment of the applicability of the GDC to the PRISM reactor, and (4) review of the DS414 of the IAEA. From the research results, 52 requirement items were derived as the GRRs for SFR. Currently, draft requirements have been developed for the items shown in Table I. In the future, foreign GRRs for SFR, requirements to reflect Hukushima lessons, and requirements related to risk-informed regulations will be reflected in the GRRs for SFR of Korea.

REFERENCES

[1] Young Gill Yune et al., Evaluation of Applicability of LWR General Design Requirements to SFR, Transactions of the Korean Nuclear Society Autumn Meeting, Jeju, Korea, Oct. 21-22, 2010.
[2] IAEA, Revision of Safety Standards Series No. NS-R-1, Draft Safety Requirements No. SSR 2/1, DS414, Safety of Nuclear Power Plants: Design, June 2011.

Table I: Framework and components of GRRs for SFR

Art.	Contents	Art.	Contents
1	Definitions	23	Reactor design
I.	**Principal Design Requirements**	24	Inherent reactor protection
2	Radiation protection	25	Suppression of reactor power oscillations
3	Defence-in-depth	26	Reactor core, etc.
4	Interfaces of safety with security and safeguards	27	Protection against flow blockage of reactor coolants
5	Proven technologies	28	Reactivity control system
6	Assessment of design safety	29	Protection system
7	Decommissioning	30	Diverse protection system
II.	**Plant Design Requirements**	31	Reactor coolant boundary
8	Postulated initiating events	32	Reactor cooling system, etc.
9	Design bases accidents	33	Overpressure protection
10	Design extension conditions	34	Residual heat removal system
11	Safety classes and standards	35	Ultimate heat sink
12	External events design bases	36	Reactor containment, etc.
13	Fire protection, etc.	37	I&C system
14	Environmental effects design bases, etc.	38	Electric power system
15	Reliability	39	Control room, etc.
16	Sharing of facilities	40	Alarm devices, etc.
17	Testability/inspectability/ maintainability, etc.	41	Radioactive waste processing & storage systems
18	Startup, shutdown, and low power operations	42	Radiation protection provisions
19	Use of qualified equipment	43	Fuel handling & storage facilities
20	Human factors	44	Supporting & auxiliary systems
21	Prevention of harmful effects between systems	45	Power conversion system
22	Protection against sodium reactions	46	Emergency response facilities and equipment
III.	**System Design Requirements**	47	Intermediate cooling system
		48	Sodium heating system
		49	Purification control of reactor coolant/intermediate coolant/ cover gas
		IV.	**Other Design Requirements**
		50	Operating experience and safety research results
		51	Limiting conditions for operation
		52	Initial tests