Comparison of Design Criteria under Development for Sodium-cooled Fast Reactor

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1. Introduction

Because the Gen-IV SFR is progressing into conceptual design stage, the GIF (Gen-IV International Forum) is developing SFR SDC (Safety Design Criteria) in preparation for the forthcoming licensing. Also ANS (American Nuclear Society) is developing [2] ANS 54.1 "Nuclear Safety Criteria and Design Process for Liquid-Sodium-Cooled-Reactor Nuclear Power Plants" based on the LWR GDC (General Design Criteria) , planning to finish by June of 2014. Since KINS is developing general safety requirement to prepare for the licensing of the KAERI's prototype SFR, it will be of use to review the current development activities and to compare the key features of the two design criteria under development.

2. SDC under Development by GIF

GIF is developing SFR SDC since October 2010, basically referencing the IAEA safety standards framework and SDC itself is based on the safety requirements of IAEA SSR 2/1.[1] The hierarchy of IAEA safety standards and that of SFR is given in Fig.1 below.

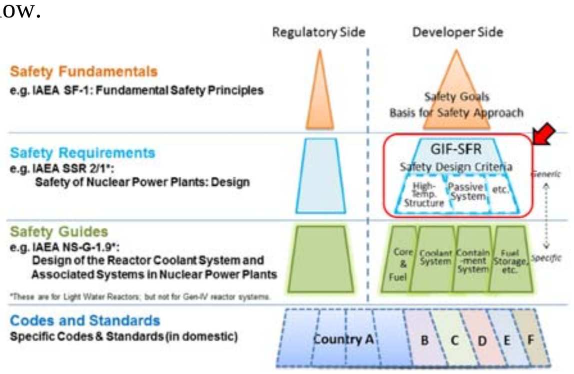

Fig. 1. Hierarchy of Safety Standards

Three safety & reliability goals pursued in developing the SDC are;

- SR-1: Excel in operational safety and reliability
- SR-2: Very low likelihood & degree of reactor core damage
- SR-3: Eliminate the need for offsite emergency response

Defence-in depth, risk-informed, built-in safety functions and not add-on, utilization of passive safety features, and high level safety meeting to GIF's safety & reliability goals are the basic safety approach of GIF to fulfill those safety & reliability goals. The strategy in developing the GIF SDC is to incorporate the particular features for SFR and lessons learned from Fukushima accident into the reference structure of SDC based on IAEA SSR 2/1. The overall scheme is depicted in Fig.2 below.

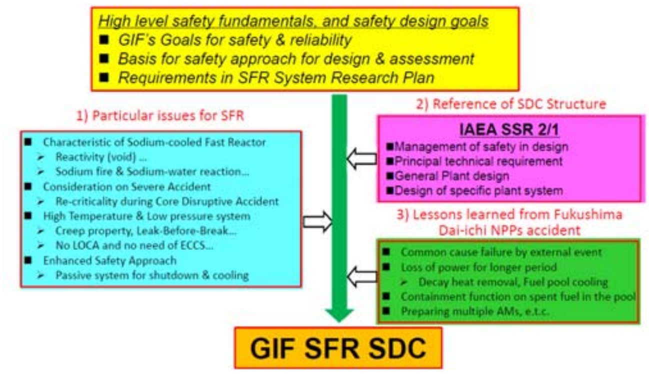

Fig. 2. Basic Scheme of SDC Development

The GIF SDC has 82 criteria beginning from Criterion 1 "Responsibilities in the management of safety in plant design" to Criterion 82 "Means of radiation monitoring". Example of differences between the IAEA SSR 2/1 and the GIF SDC defining the Design Extension Conditions is shown in Table 1 below.

Table 1: Comparison of IAEA SSR 2/1 of LWR and GIF SDC for Design Extension Condition

IAEA SSR 2/1	GIF SDC
5.31 The design shall be such that design extension conditions that could lead to significant radioactive releases are practically eliminated. If not, for design extension conditions that cannot be practically eliminated, only protective measures that are of limited scope in terms of area an time shall be necessary for protection of the public, and sufficient time shall be made available to implement these measures.	5.31 The design shall be such that design extension conditions that could lead to significant radioactive releases are practically eliminated. Since a fast reactor core is not in its most reactive configuration under normal operating conditions, the following design features for prevention and mitigation of severe accidents in postulated design extension conditions shall be considered: (a)Additional reactor shutdown measures against failure of active reactor shutdown systems, (b)Mitigation provision to avoid recriticality leading large mechanical energy release during a core degradation progression, (c)Means for decay heat removal of a degraded core, and (d)Containment capability of enduring thermal and mechanical loads under severe accident conditions.

3. SFR GDC of ANS

U.S. NRC (Nuclear Regulatory Commission) uses the GDC as acceptance criteria during the review of the applicant's LWR safety analysis. During the licensing of the Clinch River Breeder Reactor (CRBR) in the United States, a revised set of GDC were developed by the NRC staff to assist in the review of the CRBR design. These were again used to review the preliminary design information documentation for the PRISM design and it was incorporated into a standard by the ANS. The standard was withdrawn in 1989 because of decline of the U.S. sodium reactor program, but ANS is now revising the earlier one to incorporate into ANS standard. The standard defines safety objectives, GDC, selection of LBEs, and classification of SSCs that may be used by designers and regulators of SFR. The SFR GDC is based on the GDC from Appendix A of 10CFR50. The adopted approach for creating SFR GDC is the following

- keep existing GDC where applicable (including the numbering)
- minor modifications in wording to reflect SFR vs. LWR technology
- major changes based on unique SFR characteristics
- new GDC to reflect unique SFR characteristics (10)
- addition of GDC (not restricted to SFR) that are needed – post Fukushima (9)

Example of differences between the two GDCs is shown in Table 2 for GDC 34 Residual Heat Removal.

Table 2: Comparison of LWR and SFR GDC 34

LWR GDC	SFR GDC
Residual Heat Removal	Residual Heat Removal
A system to remove residual heat shall be provided. The system safety function shall be to transfer fission product decay heat and other residual heat from the reactor core at a rate such that specified acceptable fuel design limits and the design conditions of the reactor coolant pressure boundary are not exceeded.	A reactor residual heat removal system shall include means to reliably transfer reactor residual heat to an ultimate heat sink under shutdown conditions following normal operations, anticipated operational occurrences, or postulated accidents, such that appropriate fuel design limits, fuel damage limits and the design conditions of the reactor coolant boundary are not exceeded. Suitable redundancy, independence and diversity in components and features shall be provided to assure adequate protection against common cause failures and to assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished, assuming a single failure.
Suitable redundancy in components and features, and suitable interconnections, leak detection, and isolation capabilities shall be provided to assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished, assuming a single failure.	Any fluid in the reactor residual heat removal system that is separated from the reactor coolant by a single passive barrier shall be compatible with sodium. Where a single barrier separates the reactor coolant from the working fluid of the reactor residual heat removal system, a pressure differential shall be maintained such that any leakage would flow from the reactor residual heat removal system to the reactor coolant system unless other provisions can be shown to be acceptable on some defined basis.
	A passive boundary shall separate reactor coolant from the working fluid of the reactor residual heat removal system.

4. Characteristic Features of Two Design Criteria

Key features and differences of/between the two design criteria are the following;

-SFR GDC do not address the new IAEA DEC condition, because it is not part of the U.S. licensing process.

-LWR GDC use the phrase "systems important to safety", but this is not defined in the U.S. regulatory structure. So the phrase in the SFR standard was changed to "safety related systems". The definition of safety related SSC is SSC that are relied upon to remain functional during and after a DBA to assure the integrity of the reactor coolant boundary, the capability to shutdown the reactor and maintain it in a safe shutdown condition, and the capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposure set forth in the regulation. This definition is similar to but not the same as "items important to safety" used by the IAEA.

-ANS GDC does not consider design management, construction, nor operations , and DEC requirements except as BDBA compared to GIF SDC.

-Inspection requirements for both RHR and containment, environmental qualification of equipment, aircraft impact, intermediate loop design requirements, and fuel failure detection requirements are found in ANS GDC but not in GIF SDC.

5. Conclusion

The two SFR design criteria under development both by GIF and ANS are introduced, compared and the major different features are identified. The two design criteria will be referenced in developing the Korean general design criteria which will be utilized during the licensing review of the Korean prototype SFR under development by KAERI.

REFERENCES

[1] IAEA SSR 2/1, "Safety of Nuclear Power Plants:Design", IAEA, 2010.
[2] George F. Flanagan, ANS54.1-Nuclear Safety Criteria and Design Process for Liquid-Sodium-Cooled-Reactor Nuclear Power Plants", IAEA/GIF SDC Meeting, Feb.2013.