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Revision of a Preliminary Safety Classification of a Hybrid Low Power Research Reactor

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1. Introduction

Within a Research Reactor Development Project by KAERI, a Hybrid Low Power Research Reactor (H-LPRR) is being under consideration targeted on a national education and training facility for nuclear start-up countries.

A nuclear reactor which is Ultimately Safe, Simple, and Cheap (USSC) must be on the top of the Top-Tier Requirements (TTR) for the H-LPRR.

Safety Classification, part of a systematic safety assessment, is the starting point for a reactor design. This paper presents a revision of a preliminary safety classification of an H-LPRR [1] as well as the design information based on a preliminary deterministic safety analysis as the design gets clearer.

2. Summary of Regulatory position on Safety Classification

This paper is a revision of the original paper [1] and in this section only a short summary of regulatory positions on safety classification of nuclear facilities for understanding in this paper.

SSCs in pressurized light water reactors (PWR) are classified as one of safety class 1, safety class 2, safety class 3, and non-nuclear safety (NNS) in accordance with the notice by the Nuclear Safety and Security Commission (NSSC).

Codes and standards for each classification shall be in accordance with the KEPIC codes and standards by the notice, which includes quality assurance requirements, construction requirements, seismic requirements, qualification requirements, instrumentation and control (I&C) requirements, and electric requirements, and so on [2, 3].

International standards provided a systematic and comprehensive approach to classify SSCs according to the significance to the nuclear safety in a technology-neutral way including graded approaches for application into research reactors [4~8].

An essential set of tasks includes the safety fundamentals on the top, general safety requirements for safety assessment of the general safety requirements, safety of research reactors of specific safety requirements, and classification and graded approach.

Of the engineering aspects considering overall safety of nuclear facilities, safety classification is a major process to reach a design goal of nuclear facilities. The classification process starts from basic understanding of a plant design followed by identification of all safety functions and design provisions as in Fig. 1. The last activity is to select applicable engineering design rules for SSCs as in the following figure by IAEA standard. But the IAEA standards do not force to follow any specific rules but are open to select [8].

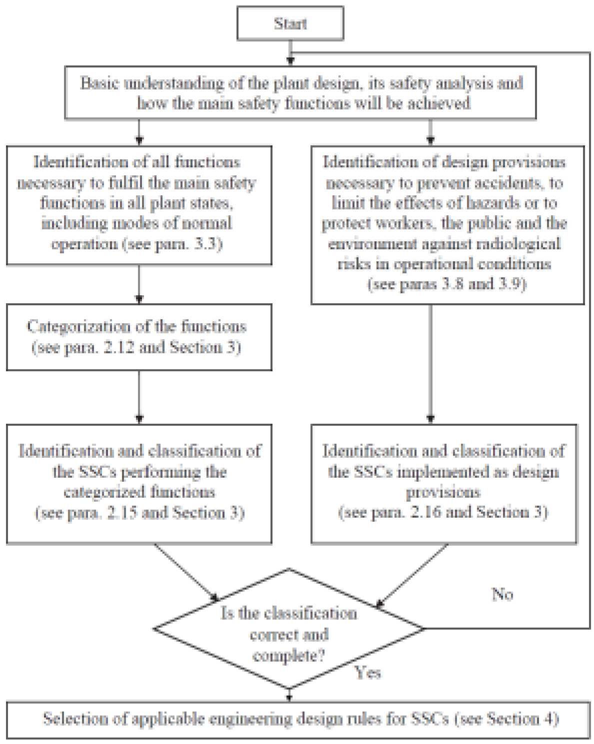

Fig. 1. Flow chart indicating the classification process. [8]

The office of nuclear regulation (ONR) provides its inspectors with a guidance for categorization and classification, which is very explanatory [9].

The roles and scheme of safety function categorization and classification, the initial safety function categorization, and off/on site frequency/ consequences regions were given as an acceptance criteria for further classification as given in Fig. 2 by the ONR.

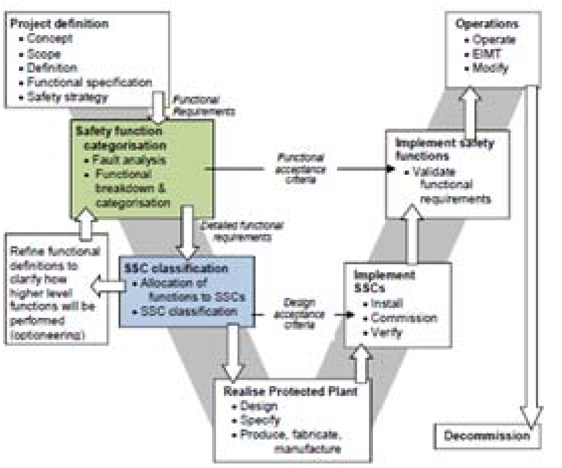

Fig. 2. Role of safety function categorization (green box) and SSC classification (blue box) within the lifecycle model. [9]

A practical reference about the Category III reactor, of which the first subgroup (< 1 MW) includes the pool type reactors that generally do not require active systems for reactor heat removal, which is adequately removed by natural convection during the normal operation, proposes a realistic approach and an example to determine the classification of the SSCs depending on the significance to the nuclear safety [10].

3. Revision of Preliminary Safety Classification

A typical process includes understanding of design with acceptance criteria, defense in depth, categorization (initial classification), classification, and verification [7, 9].

A succinct overview of the conceptual design of the H-LPRR is as given in Tab. 1.

Table I: A set of the specifications of the H-LPRR [11]

Reactor		Open pool in tank
Core	Thermal Power	~ 50 kW_{th}
	Neutron flux	~4.0×10^{12} (n/cm^2-sec)
	Size	53.7cm×53.7cm×53cm
	Fuel dimension	27cm×27cm×39.6cm
Fuel	Shape	Rod type
	Type	UO_2
	Enrichment	4.65 wt%
	Cladding	Zr-4
	Material	Light water
Coolant	Cooling method	Natural circulation
Moderator	Material	Light water
Reflector	Material	Beryllium, Carbon
Control Rods	Material	B_4C
	Function	Power control
Reactor Structure	Material	Zr-4

Ultimately Safe, Simple, and Cheap (USSC) on the top of the top tier requirements (TTR) for the H-LPRR should be realized without any active systems or components within the ALARA (As Low As Reasonably Achievable) as well as the stringent acceptance criteria for exposure dose of radiation.

Tab. II presents the levels of defense-in-depth for a safety function: reactivity control among 3 functions such as reactivity control, core cooling, and water inventory control.

Table II: Levels of defense-in-depth for a safety function: reactivity control

Level	Functions and Design Provisions
1	Conservative selection of fuel properties Conservative selection of fuel oxidation Conservative design of core (inherent safety features) Conservative design/manufacturing/construction/installation /inspection of Fuel, Core, Core Structures Quality assurance of fuel, core, core structures Qualification Fuel/Core management
2	Power Control System Alarm response (Abnormal Operating Procedures)
3	No protection but inherent properties of core Emergency Operating Procedures

There is not any safety system with safety function and the nuclear safety must be assured only with the design provisions by a deterministic safety analysis for the conceptual design.

All SSCs are categorized as “non-categorized” initially since, with no SSCs except for the design provision, there will be expectedly no hazards from ionizing radiation risks to the workers and public by using the H-LPRR, which shall be verified by a deterministic safety analysis.

The transients for both ramp and step reactivity insertion cases, expectedly the most severe event for the risk of the fuels, were simulated by RELAP5. As the design is so conservative (the excess reactivity is limited and the temperature coefficients are ensured to be negative) that there is no tragedy against the fuels. No fuel failure is assured by verifying that the temperature rise is so limited to the extent of just 300 degree in Celsius that the resulting enthalpy rise, the fuel acceptance criteria, is maintained within the regulatory requirement with a reasonably huge margin.

4. Concluding remarks

A preliminary safety classification was revised as in Tab. III based on the preliminary safety analysis [11] for the H-LPRR targeted on countries starting nuclear programs, based on the IAEA standards.

Except for fuel system all SSCs are classified as Non-Nuclear Safety and quality group and seismic category was selected as well.

Table III: A revised safety classification of the SSCs of the H-LPRR [11]

System or Component	Safety Class	Quality Group	Seismic Category
Reactor Core Assembly	-	-	II
Fuel System (Cladding)	3	C	I
Fuel System (Reflector)	-	-	-
Reactivity Control System	-	-	II
Reactor I&C	NN	D	I
Reactor pool	NN	D	II
Reactor cooling system	-	-	-
Confinement	NN	D	-
HVAC	-	-	-
Radiation Monitoring System	NN	D	-

The safety classification should be refined by the future works such as justification of the design bases, detailed design, comprehensive deterministic safety analyses with probabilistic safety analysis, and design verification.

Acknowledgement

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