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Discussion on Safety Analysis Approach for Sodium Fast Reactors

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1. Introduction

Utilization of nuclear energy is increasingly necessary not only because of the increasing energy consumption but also because of the controls on greenhouse emissions against global warming. To keep step with such demands, advanced reactors are now world-widely under development with the aims of highly economical advances, and enhanced safety. Recently, further elaborating is encouraged on the research and development program for Generation IV (GEN-IV) reactors, and in collaboration with other interested countries through the Generation IV International Forum (GIF). Sodium-cooled Fast Reactor (SFR) is a strong contender amongst the GEN-IV reactor concepts [1]. Korea also takes part in that program and plans to construct demonstration reactor of SFR [2]. SFR is under the development for a candidate of small modular reactors, for example, PRISM (Power Reactor Innovative Small Module) [3].

Understanding of safety analysis approach has also advanced by the demand of increasing comprehensive safety requirement. Reviewing the past development of the licensing and safety basis in the advanced reactors, such approaches seemed primarily not so satisfactory because the reference framework of licensing and safety analysis approach in the advanced reactors was always the one in water reactors. And, the framework is very plant specific one and thereby the advanced reactors and their frameworks don't look like a well-assorted couple. Recently as a result of considerable advances in probabilistic safety assessment (PSA), risk-informed approaches are increasingly applied together with some of the deterministic approaches like as the ones in water reactors. Technology neutral framework (TNF) can be said to be the utmost works of such risk-informed approaches, even though an intensive assessment of the applicability has not been sufficiently accomplished [4,5].

This study discusses the viable safety analysis approaches for the urgent application to the construction of pool type SFR. As discussed in above paragraphs the conventional deterministic approach has some defects in directly applying to SFR mainly because of its reactor specific framework and the complete risk-informed approach (TNF) has not been verified sufficiently with much uncertainty. This study presents some insight from critical review of the deterministic approach, risk-informed approach, recent trend in each country, and past SFR licensing approach experiences. The insights are expected to give useful guide for the setup of licensing approach in blending safety analysis approach in stand of deterministic position for the urgent application of the approach.

2. Critical review of the approaches

Safety of nuclear power plant may be surely achieved by safe management of the plant throughout the life time, i.e. safe design, safe construction, safe operation, and safe decommission. In particular, to demonstrate the fundamental safety in the design stage a comprehensive safety assessment of the design is required to identify all possible sources of radiation and to evaluate the possible doses that could be received by workers at the installation and by members of the public, as well as the possible effects on the environment. The safety assessment is required in order to examine: (i) normal operation of the plant, (ii) the performance of the plant in anticipated operational occurrences (AOO), and (iii) accident conditions [6].

One of the most principal issues pertaining to the advanced reactor is surely an accident evaluation, and the issue of it is to identify appropriate event categories, associated frequency ranges, and evaluation criteria for events that will be used to assess the safety of the advanced reactor [7]. The appropriate event categories should follow the identification of initial events, too.

Therefore, for the sake of the discussion on a safety analysis approach in the licensing process of SFR this study focus on: (i) initial events, (ii) event categories associated with frequency range, and (iii) acceptance criteria. Strategy to explore the discussion is to elaborately review: (i) deterministic approach, (ii) risk-informed approach, (iii) recent trends in some countries, and (iv) past SFR licensing approach experiences.

2.1 Review of deterministic approach

Deterministic approach includes ANSI N18.2-1973, ANSI/ANS-51.1-1983, Reg. Guide 1.70, SRP Chapter 15, and Reg. Guide 1.206. Noticeable features in this approaches are: (i) that initial events are treated more important than the sequences, (ii) that accident scenario for detailed analysis is determined using single failure and concurrent occurrence, (iii) that initial events are categorized into AOO and accident, and AOO is, in some approaches, further divided into two

subcategories, and (iv) that acceptance criteria are imposed on barriers and final consequences.

2.2. Review of risk-informed approach

Risk-informed approach includes MHTGR-1986, PRISM-1986, Westinghouse RISA-2003, PBMR-2006, TNF, and KALIMER-2007. Important findings are: (i) that licensing basis event is used rather than design basis event, (ii) that PSA is intensively used in the identification of initial events and event sequences, (iii) that single failure and concurrent occurrence are not considered because of PSA assessment, (iv) that some approach imposes the acceptance criteria on event sequences rather than initial events, (v) that finer event categories are adopted in some approaches, and (vi) that some approaches use 'per plant-year' instead of 'per reactor-year'.

2.3 Review of recent trend in each country

IAEA recently consider DEC (design extension conditions) more importantly, and it means the events of lower frequency should be carefully considered. Some country extents the lower cut-off level to 1.0E-5 or 1.0E-6/r-y. Some country proposes finer event categories. Finer categorization is coincidence with the approach concepts in TNF. And it also gives the benefit of margin of the achievement of acceptance criteria. Every country uses deterministic approach in actual licensing process. GenIV approach is noticeable[9]

2.4. Review of SFR specific licensing approach experiences

In PRISM safety analysis approach [3] a lower cut-off level was sometimes used and residual risk events were prudently treated because of the uncertainties in non-water reactors caused by less experience of construction and operation. Acceptance criteria seem, in some approach, confusedly applied to initial events or event sequences. A recent research of reference 8 discussed on the event categorization with defense-in-depth (DiD) level concept. In the research of reference 8 1.0E-8/r-y is proposed for the practical elimination of event, which is corresponding to DiD level 5.Specific discussion on core disruptive accident (CDA) are presented on that paper.

3. Insight on the safety analysis approach for SFR as an advance reactor

Insights are: (i) that PSA is to be used more widely in SFR but experiences in conventional nuclear plant and the other industries should be intensively adopted in order to overcome the uncertainties in PSA in design step of new plant, (ii) that finer event categories for AOO is believed more appropriate because it can give must margin in acceptance criteria, (iii) that event categories are to be based on the event sequences rather than initial events for obvious application of acceptance criteria, and (iv) that acceptance criteria are to be imposed not only on the final consequence but also on the barriers on the base of the traditionally accepted values, and acceptance criteria against sodium reaction are needed in order to prevent the minor accident from deteriorating. Discussion of the identification of barriers that should have the acceptance criteria in stand of effectiveness is needed.

4. Conclusions

From the critical review of past experiences in safety approach some useful insights were derived, and such insights should be more intensively discussed in order to apply it in actual licensing process. More detailed discussion will be presented in the meeting.

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