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Safety Functions and Objective Provision Tree Application to Sodium-Cooled Fast Reactor

Huichang Yang [a*], Namduk Suh [b]
[a]*TÜV Rheinland Korea Ltd., Goro-dong 197-28, Guro-go, Seoul 152-719*
[b]*Korea Institute of Nuclear Safety, 62 Gwahak-ro, Yuseong-gu, Daejeon 305-338*
[*]*Corresponding author: huichang.yang@kor.tuv.com*

1. Introduction

The Objective Provision Tree (OPT) is a methodology to ensure and document the provision of essential "lines of protection" for successful prevention, control or mitigation of phenomena that could potentially damage the nuclear system[1]. The OPT methodology has been developed mainly by International Atomic Energy Agency (IAEA) and the application of OPT methods to development of new reactors such as GEN-IV was strongly recommended by GEN-IV International Forum (GIF) Risk and Safety Working Group (RSWG). Examples of OPT applications during new reactor design can be found in reference [2] and [3].

We are developing draft OPT for KALIMER, sodium-cooled fast reactor(SFR) developed by Korea Atomic Energy Research Institute (KAERI). The OPT is normally developed by designer to confirm the safety function design but we will use the developed OPT in developing the specific safety requirement. This paper presents our preliminary results and concepts about this topic.

2. OPT Application to Sodium-cooled Fast Reactor

The OPT method is a top-down approach which starts from the level of Defense-in-Depth (DiD), objectives and barriers, safety functions, challenges, mechanisms and finally ends with provisions. OPT application should start with the application of DiD concept to KALIMER.

2.1 Defense-in-Depth Concept for KALIMER

In reference [4], levels of DiD was specified as in table 1. These definition of DiD levels can be applied to all nuclear facilities including SFRs. Levels of DiD defined in table 1 was applied to the OPT development in this study.

2.2 Safety Functions for KALIMER

In reference [5], safety functions in general form were specified as following;

- control of the reactivity
- removal of heat from the core, and
- confinement of radioactive materials and control of operational discharges, as well as limitation of accidental releases.
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Table 1. Levels of Defense In Depth

Levels of DiD	Objective	Essential Means
Level 1	Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation
Level 2	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance features
Level 3	Control of accidents within the design basis	Engineered safety features and accident procedures
Level 4	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Complementary measures and accident management
Level 5	Mitigation of radiological consequences of significant releases of radioactive materials	Off-site emergency response

Based on the fundamental safety functions suggested in reference [5], safety functions for KALIMER were defined as in table 2.

Table 2. KALIMER Safety Functions for OPT

Fundamental Safety Functions	KALIMER Safety Functions	Remarks
Control of reactivity	Reactivity control	Reactivity control function by control rods and other shutdown features
Removal of heat from the core	PHTS heat removal IHTS heat removal SGS heat removal RHRS heat removal SPFP heat removal	Heat removal functions from PHTS, IHTS, SGS, RHRS and SPFP respectively
Confinement of radioactive materials, control of operational discharges, as well as limitation of accident releases	Containment integrity	Functions to maintain containment integrity including; - Pressure/temperature control - Combustible gas control - Sodium fire and explosion protection - Radioactive material release control - Spent fuel building integrity(if applicable)

PHTS : Primary Heat Transport System
IHTS : Intermediate Heat Transport System
SGS : Steam Generation System
RHRS : Residual Heat Removal Systems

The safety function, heat removal from core for KALIMER consisted of five design-specific sub-safety functions, which can be matched to challenges directly, based on the system boundary definitions. This approach for the definition of core heat removal function has several benefits as following;

- clear logic development for challenges, mechanisms to degrade, and provisions,
- benefits in verification of OPT integrity and coverage of safety requirements, and
- reflection of design specificity

In examples of reference [2] and [3], different approaches in defining challenge to safety functions were applied. In other words, a challenge to a safety function was defined. The benefit of approaches in reference [2] and [3] is that they can ensure the comprehensiveness of OPT by adopting the highly deductive approach. However, there might be potential complexity of OPT logic when the complex design features are considered.

Schematic OPT of level 3 DiD and removal of heat from the core was illustrated in figure 1.

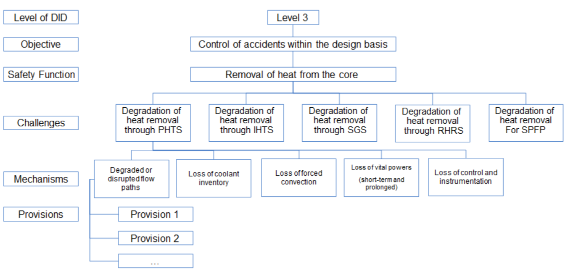

Figure 1. Example of KALIMER OPT

2.3 Consideration of Fukushima Lessons

Lessons-learned from Fukushima accident can be summarized as following;

(1) flooding/seismic re-evaluation, and

(2) mitigating capability enhancement for;

- prolonged station blackout
- loss of ultimate heat sink including spent fuel pool
- combustible gas control capability in containment and spent fuel pool building, and
- organizational emergency response including communication and training.

In defining challenges and mechanisms, the appropriate logic boxes to reflect Fukushima lessons will be included OPT.

2.4 Milestones for KALIMER OPT Development

The OPTs for level 3 DiD, removal of heat from the core is under development as a first reference for verification and these will be developed by the end of this year. All OPTs and the evaluation results using OPT will be developed within 2013.

3. Conclusions

In general, the OPT is developed by designers based on the phenomenology. We are developing OPT based on system boundary and the developed OPT will be applied in checking whether the specific regulatory requirements embodies all the safety functions and no requirements are missed. This is the first-of-a-kind application of OPT. The results will contribute to the completeness of the regulatory requirement under development by KINS.

REFERENCES

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