Objective Provision Tree Application to the Effectiveness Evaluation of Accident Management Guidelines

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1. Introduction

After the Fukushima accident in 2011, various lessons and safety enhancement action items were announced by national regulatory bodies. Among those items, the enforcement of procedural efficiency verification for accidents management guidelines including emergency operating procedures (EOPs), severe accident management guides (SAMGs) and extensive damage mitigating guidelines (EDMG) if applicable, was raised.

The Objective Provision Tree (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[1]. The benefit of OPT application to safety concerns includes that the OPT enables the comprehensive review for the verification of consistency and integrity of safety requirements for a specific safety issue.

In this study, the preliminary framework for the application of OPT to the effectiveness evaluation of accident management guideline was introduced.

2. Objective Provision Tree Methods

The OPT method was developed mainly by International Atomic Energy Agency (IAEA) and recommended for new reactor developers as a part of Integrated Safety Assessment Methodology (ISAM)[2].

However, the application of OPT cannot be limited to the area of new reactors. Due to the highly deductive characteristics of methodology, the main objectives of the method can be applied to other safety concerns such as effectiveness evaluation of accident management guidelines.

OPT adopted hierarchical structures consisted of levels of defense-in-depth (DiD), objectives and barriers, safety functions, challenges to safety functions, mechanisms of safety function degradation and provisions to such degradation mechanisms. The overall structure of OPT was shown in figure 1 and this was quoted from reference [1].

2.1 Defense-in-Depth Concept for OPT

In reference [2], the concept of DiD for nuclear power plants was specified. Table 1 summarized the definition of DiD from level 1 to level 5.

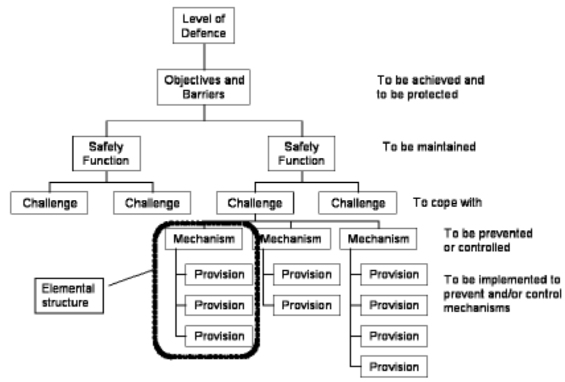

Figure 1. Hierarchy Structure of OPT

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

Level 3 DiD can be matched to EOPs, Level 4 to SAMGS, and Level 5 DiD to emergency preparedness. EDMGs if applicable, can cover the levels of DiD from 3 to 5.

2.2 General Safety Functions for LWRs

In reference [3], 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.

Based on the fundamental safety functions suggested, reference [4] and [5] defined the general safety functions for light water reactors as following;

- Power operation key safety functions
  - Reactivity control,
  - Containment integrity,
  - Reactor coolant heat removal, and
  - Reactor coolant inventory control,
- Shutdown operation key safety functions
  - Decay heat removal capability,
  - Inventory control,
  - Power availability,
  - Reactivity control and,
  - Containment inventory.

2.3 Consideration of Fukushima Lessons

Among many Post-Fukushima lessons, mitigating capability for prolonged station blackout (SBO) and loss of ultimate heat sink (LUHS) will be considered additionally in OPT development for our purpose. In defining challenges and mechanisms, the appropriate logic boxes to reflect Fukushima lessons will be included in OPT.

2.4 Safety Functions for Evaluation

Considering fundamental safety functions by IAEA, general safety functions for LWRs by NUMARC, and the Fukushima lessons, safety functions in table 2 will be used for the effectiveness evaluation in this study.

To ensure the comprehensiveness of evaluation, fundamental safety function of core heat removal was divided into several sub-functions. The evaluation for power availability safety function can be performed by adding logic blocks into the mechanisms for safety functions in Table 2, regarding short and long-term power availability.

Table 2. Safety Function Definitions

Fundamental Safety Functions	Safety Functions	Remarks
Control of reactivity	Reactivity control	Reactivity control function by control rods and other shutdown features
Removal of heat from the core	Decay Heat Removal Inventory Control Spent Fuel Pool Cooling	Heat removal functions and inventory control functions for primary and secondary circuits and spent fuel pool 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 - Radioactive material release control - Spent fuel building integrity(if applicable)

2.5 Consideration in Challenges and Mechanisms

For reactivity control, the diversity of engineered safety features (ESFs) and the independence from the power availability will be focused mainly. For heat removal functions including spent fuel pool cooling, the mitigation capability for the loss of ultimate heat sink will be evaluated by OPT. For containment integrity, the capability to maintain containment integrity including spent fuel pool building integrity will be asked. The measures to prevent or mitigate the consequence of containment bypass will be considered also. Besides the installed features, strategies under development and the portable equipment in plan[6], will be included in the scope of OPT evaluation.

Figure 2 showed an example of OPT for the effectiveness evaluation of accident management guidelines.

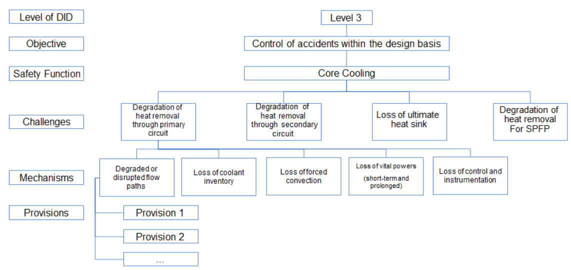

Figure 2. Example of OPT for Evaluation

3. Conclusions

As a tool to evaluate the effectiveness of accident management guidelines, OPT method were suggested and the application was tried. This will contribute to the enhancement of regulatory framework for operating reactors and new-builds in future by providing a comprehensive method to evaluate the effectiveness of the current procedural systems regarding accident management guidelines.

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