Challenge Identification for the Objective Provision Tree Application to the Effectiveness Evaluation for the Accident Management Guidelines

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1. Introduction

Originally, the Objective Provision Trees (OPT) is a recommended method during the concept and design phases of new type reactors such as GEN-IV reactors. However, the OPT method is a highly logical and top-down approach to identify the vulnerable aspect of the framework which includes the accident management guidelines, such as Emergency Operating Procedures (EOPs), Severe Accident Management Guides (SAMGs) and even Extensive Damage Mitigating Guidelines and FLEX[1] guides. In virtue of this logical tool, the evaluation for the framework of the accident management guidelines was tried in this study.

2. OPT Structure

In the reference [2], the overall structure of OPT was explained. Generally, OPT has the leveled structure as following;

- Level of defense-in-depth,
- objective,
- safety function,
- challenges,
- mechanisms, and
- provisions

Detailed definitions for each level were provided in the reference [3].

2.1 Safety Function Definition

As a starting point for the effective evaluation of the accident management guidelines using OPT methods, safety functions were defined as in the reference 1, and those safety functions were suggested in table 1. In this study, only light-water reactor types were considered.

2.2 Considerations for the Challenge Identification

For each safety function in table 1, relevant challenges which threaten the safety functions should be identified. Considerations for the selection of challenges to each safety function are as following;

- Operational status: the consideration should cover the all possible plant operating status from full power to shutdown operation,

Table 1. 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)

- Safety functions: consideration for the existing safety functions, which are generally prescribed in implemented accident management guidelines such as EOPs and SAMGs, should be included.
- Available methods to mitigate or minimize consequences: installed engineered safety features as well as flexible and diverse methods which were defined in the reference [1] should be considered. Nevertheless, FLEX equipment are not installed or implemented, consideration should be expanded to this level for the future planning. Consideration for this kind of equipment can be done during the identification of provisions, later phase of developing OPTs.

2.3 Challenge Identification

Based on the above considerations, challenges were identified as below;

- SF1: Reactivity control
  - o Failure of reactivity control during power operations,
  - o Failure of reactivity control during low power and shutdown operations, and
  - o Failure of reactivity control within spent fuel pool
- SF2: Decay heat removal
  - o Degradation of heat removal using safety injections,

  - Degradation of heat removal using feed and bleed operations,
  - Degradation of heat removal using secondary systems,
  - Degradation of heat removal during reduced inventory operations,
  - Degradation of heat removal during mid-loop operation, and
- SF3: Inventory control
  - Failure of inventory make-up using safety injections,
  - Failure of inventory make-up using CVCS,
  - Failure of inventory make-up during reduced inventory operations,
  - Failure of inventory make-up during mid-loop operations, and
  - Failure of inventory make-up in spent fuel pool
- SF4: Spent fuel pool cooling
  - Degradation of heat removal in spent fuel pool during normal operations, and
  - Degradation of heat removal in spent fuel pool during refueling operations
- SF5: Containment integrity
  - Failure of containment temperature control,
  - Failure of containment pressure control,
  - Failure of combustible gas control within containment,
  - Failure of combustible gas control within spent fuel pool building, and
  - Failure of maintaining containment integrity

2.4 Provision Identification

Based on the above identified challenges for each safety function, provisions in the accident management guidelines were identified.

For the reactivity control in EOPs, methods including the insertion of control rods and injection of borated water using ECCS and CVCS were provided. For the reactivity control in spent fuel pool, it is not clearly stated in EOPs and SAMGs. In SAMGs, there was no measure or strategy for the reactivity control in spent fuel pool for the case that whole core would be transferred to spent fuel pool. Regarding the implementation of FLEX equipment especially for the inventory control using the injection of non-borated water, the possible re-criticality should be considered.

For the decay heat removal and inventory control, there were many provisions to achieve the goal for relevant safety functions. Moreover, to cope with the situations those were not originally postulated, diverse methods to supply water to reactor vessel and steam generators are being considered and on the way of implementation.

For spent fuel pool cooling, it was not explicitly included in the scope of current accident management guidelines. Therefore appropriate provisions to achieve this safety function are required.

For containment integrity, passive combustible gas control device, PAR, will be implemented as a main safety feature. Such provision should be considered to control the possible combustible gas in spent fuel pool area or building.

Vital powers to cope with the total loss of electricity, was not included in the safety functions defined in this study explicitly, the provisions for this safety functions can be evaluated in the lower level of OPT trees.

Regarding the containment integrity safety functions, several issues are still remained especially regarding other aspects of severe accidents, after core melt, such as Molten Corium-Concrete Interaction (MCCI), basemat melt-through and resulting containment bypass. Prevention or mitigation for these phenomena, which are highly feasible during the progress of severe accidents, should be considered in the evaluation using OPT.

3. Conclusions

As a part of the OPT application for the effectiveness evaluation of the accident management guidelines, challenges which could threaten the safety functions required to maintain the safety, were identified. The identification of detailed provisions in terms of the accident management guidelines is being performed and the visualizing the identified elements of OPT is also under performance. With this logical structure of OPT, the provision of useful tool to evaluate the effectiveness of accident management guideline framework, is expected.

REFERENCES

[1] Nuclear Energy Institute, Diverse and Flexible Coping Strategies (FLEX) Implementation Guide, NEI 12-06, Rev.B1, 2012.

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