

Preliminary Plan to Develop SMART Emergency Operating Guidelines

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1. Introduction

SMART (*System-integrated Modular Advanced Reactor*) adopting fully passive safety system is being under development [1] and the accident management plan should be prepared in accordance with the Korean regulatory requirements [2, 3].

Emergency Operating Procedures (EOPs) are a component of the accident management included in level 3 of defense in depth, the control of accident within design basis as shown in Fig. 1 [4].

A set of EOPs will be constructed based the fundamental (or critical) safety functions of a nuclear reactor: the safety functions, whatever the reactor is, are the same: 1) controlling reactivity (or power), 2) cooling the radioactive materials, i.e., fuels and confining the radioactive material [4].

The SMART with unique design features and operating characteristics of integral reactors has most of design basis events in common with conventional commercial loop-type PWR plants.

This paper presents a preliminary strategy to develop Emergency Operating Guidelines of SMART covering safety functions, defense-in-depth, and sorts of accidents handled by the accident management.

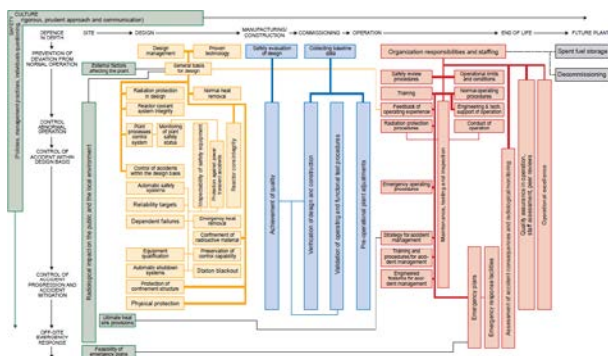


Fig. 1. Schematic presentation of the INSAG specific safety principles showing their coherence and their interrelations [4].

2. References of EOPs in Korea

The status of the EOPs for NPP in Korea are as shown in table 1 [5, 6]. The references shows that the EOPs are composed of a set of event and symptom based procedures or a set of optimized for events and functional procedures.

Table 1: EOP Status of Korean NPP [5, 6]

| Plant Type (vendor /units) | EOG Supplier | EOG Structure | EOG Developer | EOG /EOP Format | Characteristics |
|----------------------------|--------------|--|---------------|-----------------|--|
| PWR (W.H. /6) | W.H. | ORG(24) FRG(25) | KHNP | 2-column | Complex Easy to use |
| PWR (Framatome /2) | Framatome | Event-Oriented (40) Symptom-Oriented(3) | KHNP | Flowchart | Broad Coverage Complex Easy to use |
| PHWR (AECL /4) | KOPEC | Event-Oriented (13) Symptom-Oriented(2) | KHNP | Flowchart | Simple & Large Flexibility Need more knowledge to use |
| PWR (ABB-CE & KOPEC /8) | KOPEC | ORG(9) FRG(1) | KHNP | 2-column | Simple & Large Flexibility Need more knowledge to use |

The examples of operating procedures by IAEA members are as shown in Table 2 [5, 7]. The typical procedures are based on symptom within design basis accident (DBA) and beyond design basis accident (BDBA).

Table 2: Examples of Operating Procedures by IAEA [5, 7]

| Plant Status | IAEA | | |
|---|--|--------------------------------------|------------------------|
| | Strategy | Procedures | Typical |
| Normal | Prevent unsafe condition | Written and authorized instructions | Normal event based |
| Anticipated operational occurrences | Verify normal control system functions to limit transients | Incident system instructions | Abnormal event based |
| DBAs (safety functions challenged) | Verify functions of engineered safety features | EOPs aimed at going to cold shutdown | EOPs Symptom based |
| BDBAs (design basis barriers challenged) | Restore critical safety functions(CSFs) | Function restoration | AMP/EOPs symptom based |
| Severe accidents (reactor core degraded) | Mitigate consequences of degraded core | Mitigation actions | AMP/SAGs symptom based |

Another reference is an application for a research reactor, Jordan Research and Training Reactor. The emergency operating procedures for a research reactor

are much simpler than that for power reactors but it was shown that the procedures, whichever those are symptom-based or functional, can be constructed to cover all the DBEs and even BDBEs in a comprehensive and systematic way using the concrete concept of the safety functions [5].

3. Identification of Safety functions of SMART

A preliminary set of safety functions of SMART are shown in Fig. 2. The set covers the fundamental safety functions by reactivity control, maintenance of vital auxiliaries, reactor coolant system (RCS) inventory, RCS pressure control, core heat removal, reactor heat removal, containment isolation, containment temperature and pressure control, containment burnable gases control in a separate way.

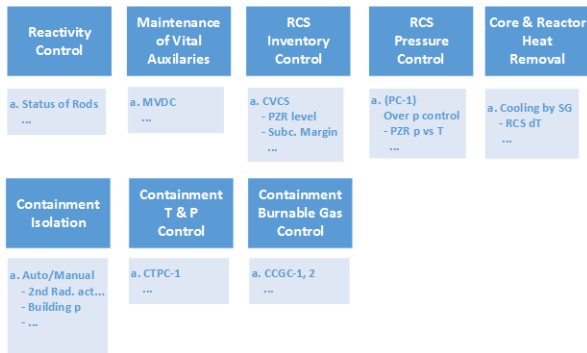


Fig. 2. Safety functions of SMART.

4. Preliminary plan to Develop SMART EOG

A plan to prepare EOPs is described as follows:

1. Structure and plan of Technical Guidelines for Emergency Operating Guidelines (EOGs)
2. Translating EOGs Technical Background to Emergency Operating Procedures-Guidelines
3. Verification and Validation Methods of Emergency Operating Procedures-Guidelines
4. Education and Training Program of Emergency Operating Procedures-Guidelines

4.1 Structure and plan of Emergency Operating Guidelines Technical Guidelines

The Technical Guidelines for EOGs provide the technical bases of SMART-specific EOGs. The structure and plan of the technical guidelines are as follows:

- 1) Type of technical guidelines: Plant-specific technical guidelines
- 2) Coverage of accident management
Including the DBEs of SMART, the multiple failure accidents as per the Nuclear Safety and Security

Council (NSSC) notice 2017-34 are covered by the EOGs.

3) Structure of Technical Guidelines

- Background of EOGs
- SMART-specific Design Characteristics
- Main Features of SMART Design
- Operation of SMART

4) Preparation Plan of Contents

As per NUREG-0899, SMART Technical Guidelines for EOGs provide the operators' actions necessary to mitigate the consequences of transients and accidents that have caused plant parameters to exceed the reactor protection system (RPS) setpoints or the engineered safety features (ESF) setpoints, or other established limits

5) Capability to prepare Technical Guidelines for EOGs

Technical Guidelines for EOGs are prepared by the system designers with expertise about SMART as per QA requirements of SMART.

4.2. Translating Technical Guidelines for EOGs to Emergency Operating Procedures-Guidelines

The process of translating SMART-specific EOGs technical guidelines into Emergency Operating Procedures-Guidelines, i.e., a series of information about action steps that make up EOPs will vary, depending upon the particular content and approach adopted in the technical guidelines as per NUREG-0899.

In principle, the process will be based on the role and activities of the owner and the NSSS developer.

4.3 Verification and Validation Methods of Emergency Operating Procedures-Guidelines

By a process of verification and validation, which must be undergone after EOPs-EOGs have been developed as per NUREG-0899, it will be demonstrated that the procedures are adequate to mitigate transients and accidents from both technical and human engineering.

Verification/Validation of the EOPs-EOGs may be accomplished in a number of ways as per NUREG-0899. Some of these are as follows and some combination of these or other methods will be used:

- Exercising EOPs-EOGs on either a SMART-specific simulator (if available) or a generic simulator,
- Control room walk-throughs,
- Desk top reviews,
- Seminars and workshops,
- Computer modeling/analysis.

As per NUREG-0899, the verification/validation process will address all the objectives as below:

- That EOPs are technically correct
- That EOPs are written correctly
- That EOPs are usable.

4.4. Education and Training Program of Emergency Operating Procedures· Guidelines

Education and Training will be accomplished in a number of ways including a combination of classroom lectures, exercises on plant-specific simulators (where available), and self-study to optimize training outcomes.

The applicant will ensure that all operators receive education and training on the use of EOPs·EOGs prior to their implementation. Other personnel will be familiarized with or trained on the EOPs·EOGs, as necessary.

6. Concluding remarks

The references of EOPs were studied for a wide range of nuclear reactors with the Korean regulatory requirements and a set of safety functions for SMART reactor were identified.

A preliminary plan was prepared to develop SMART specific EOG/EOP.

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