Improvement of the Emergency Operating Procedures for Domestic CANDU Plants

Se-Hoon Oh [a*], Dong-Cheol Kim [a],and Seong-Soo Choi [a] and Chang-Soo Kim [b]
[a]*ACT, #406 IT Venture Town, 35, Techno 9-ro, Yuseong-gu, Daejeon, 34027, Korea*
[b]*Wolsong Nuclear Power Site, KHNP Co., Ltd., Donghaean-ro 696-13, Gyeongju-si, 38218, Korea*

[*]*Corresponding author: shoh@actbest.com*

1. Introduction

The Emergency Operating Procedures (EOPs) of the domestic CANDU plants have been improved in their organization and contents reflecting design changes, requirements of the utility and those of the regulatory body and are now under review by the regulatory body.

In order to improve the entry conditions and instruction steps of the current CANDU EOPs, the relevant requirements of CNSC, NRC and the domestic regulatory body were reviewed [1,2,3,4,5,6]. In addition, a set point basis document has been rewritten considering uncertainties and operating margins for the set points used in the EOPs.

The improvement of the EOPs has been performed on the entry conditions, instruction steps and set point values and verified by both safety analysis and simulator runs.

2. Methods and Results

In order to elicit what improvement is needed for the current Domestic CANDU EOPs, they were reviewed from various perspectives. And the requirements from the utility and the regulatory body were investigated. In addition, the other improvement items were examined by reviewing the EOPs of domestic and foreign nuclear power plants.

The EOP improvement items have been elicited by the above process, and the improved EOPs have been prepared through on-site review of the utility.

Major improvement items of the EOPs are as follows.

Table I: Major Improvement Items of the EOPs for Domestic CANDU Plants

Item	Improvement
EOP Format	Step logic format using conditional key words, "IF-THEN-ELSE"
Accident Selection	Elimination of the event-oriented EOP titled "Moderator Cover Gas System Failure"
Entry Conditions	Removal of Stepback / Setbeck Condition
Recovery of CSPs	Separation of CSP Recovery Procedures by using the handouts in EOP-002
Turbine Trip Action	Early turbine trip action for operators to concentrate on stabilizing the plant
Continuing/Parallel Action	Adoption of "Continuing Action" and "Parallel Action

2.1 Improvement of EOP Format

The current EOPs of Domestic CANDU plant is in the form of a flowchart. The flowchart format has an advantage that it is easy for operators to understand, but there is a disadvantage like the contents that can be displayed on one page are limited.

As a result of the operators' questionnaire survey at domestic CANDU Plants, about 76% of the operators preferred flowchart type than narrative type. Accordingly, the EOPs have been prepared in Step Logic Format, while keeping the form of flowchart and adopting the advantages of other EOPs from pressurized heavy water reactors and pressurized water reactors.

Especially, IF-THEN-ELSE conditional statement minimizes branch points in a logic diagram as well as repetition of the same procedure steps through logical reconfiguration.

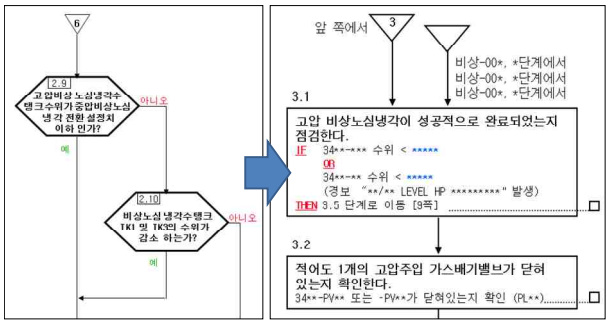

Fig. 1. Improvement to Step Logic Diagram Format

2.2 Elimination of the Event Specific EOP, "Loss of Moderator Cover Gas System"

"Loss of Moderator Cover Gas System", one of the accidents included in the current EOPs of domestic CANDU plants, is not safety significant in terms of core damage. In addition, according to the contents of the FSAR, there is little possibility of an emergency situation caused by deflagration of deuterium.

Therefore, the EOP for "Loss of Moderator Cover Gas System" is not made as a separate event specific EOP but integrated into the EOP for "Moderator System Failure" which is closely related to the moderator cover gas system.

For the other EOPs, the titles of the procedures have been changed to exactly represent the contents of those EOPs.

Table II: Event Specific EOP List

List	Current Event Specific EOP	Improved Event Specific EOP
EOP-003	Large LOCA	LOCA with Auto ECC Operations
EOP-004	Small LOCA	PHTS Leaks
EOP-005	Loss of Feedwater	Loss of Feedwater
EOP-006	Main Steam Line Break	Main Steam Line Break
EOP-007	Loss of Class IV and III	Loss of Class IV and III
EOP-008	Steam Generator Tube Rupture	Steam Generator Tube Rupture
EOP-009	Loss of Service Water	Loss of Service Water
EOP-010	Loss of Instrument Air	Loss of Instrument Air
EOP-011	Loss of Moderator System	Moderator System Failure
EOP-012	Loss of Moderator Cover Gas System	-
EOP-013	Loss of End Shield Cooling System	End Shield Cooling System Failure (EOP-012)
EOP-014	Loss of Dual Computer	Dual Computer Failure (EOP-013)
EOP-015	Loss of Class IV	Loss of Class IV (EOP-014)

2.3 Removal of Setback and Stepback Condition in Entry Conditions

In case of the EOPs of pressurized water reactors the entry conditions are set to "reactor shutdown" or "safe injection system operation". However, in case of domestic CANDU plants, it is possible to enter EOPs if setback, stepback, shutdown system #1, or shutdown system #2 is activated. Accordingly, even when setback or setback occurs due to the occurrence of an abnormal condition, the EOPs are used. As a result, the application of the EOPs is too frequent, which may result in shutdown risks. On the basis of the definition on EOPs described in NUREG-0899 [1] and the results of the trip coverage analysis of domestic CANDU plants, it is reasonable to remove setback and stepback condition from entry conditions of the EOPs. Furthermore, in order to cope effectively with the occurrence of setback and stepback, it is appropriate to deal with them in a separate abnormal operating procedure (AOM).

2.4 Recovery of Critical Safety Parameters (CSPs)

In CANDU plants, the status of a relatively small set of parameters can direct operating staffs to ensure reactor power under reactivity control, adequate fuel cooling and containment of radioactivity. These parameters are generally called Critical Safety Parameters (CSPs) [3].

The current CSP recovery procedure can be entered only when subcooling margin of the reactor inlet header exceeds the specified set point. In other words, the CSP recovery procedure is configured to enter when there is insufficient fuel cooling capacity in a heat transport system.

However, considering that an abnormal condition of a related system may degrade the fuel cooling capacity of a heat transport system, it is necessary to recognize the occurrence of an abnormality in a relevant CSP and directly try to stabilize it.

Therefore, the recovery procedure of each CSP has been prepared in a handout format so that the corresponding recovery procedure can be performed directly when each CSP exceeds its set point value.

2.5 Turbine Trip Action

Turbine trip action has been added at the earlier step in the improved EOPs. The operator will trip the turbine (if it has not already been tripped automatically as a result of an event), and ensure that the turbine trip is successful. This proactive action allows him to concentrate on stabilizing a plant against the event.

2.6 Other Improvements

The other improvements are as follows:

- Changes of some procedures' titles have been made to exactly represent the contents of the corresponding EOP
- Critical safety parameters are selected to indicate a threat to the integrity of fuel, primary heat transport system and containment. As a result, 12 CSPs have been selected. (Vital power, moderator temperature and reactor building sump level have been added in addition to current CSPs.)
- "Continuing Action" and "Parallel Action" have been applied to enable optimal emergency operation.
- The logic and contents of the EOPs have been improved in view of written correctness, technical accuracy, usability, and operational correctness.
- Tautological steps have been rewritten by logic restructuring.
- Diagnostic symptoms have been improved through main diagnosis and detailed diagnosis.

3. Conclusions

As a part of the domestic CANDU EOP improvement project, the format, entry conditions and logic of the EOPs have been substantially improved. This project is expected to produce the improved EOPs which are legible, logical and more suitable in order to effectively cope with emergency accidents at domestic CANDU plants.

REFERENCES

[1] NUREG-0899, Guidelines for the Preparation of Emergency Operating Procedures, 1982.8.
[2] INPO82-017, EOP Writing Guideline, 1982.7.
[3] EOP Standards for Canadian Nuclear Utility Rev.0, 1987.6.
[4] REGDOC-2.3.2 Ver. 2, Accident Management, 2015.9.
[5] KINS/RS-N17.0, Regulatory Standards, 2015.8.
[6] KINS/RG-N19.01, Regulatory Guidelines, 2016.11.