Developing a Monitoring Logic Process to Support LCO Compliance

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1. Introduction

Korea Hydro & Nuclear Power (KHNP) has established technical specifications to ensure the safe operation of nuclear power plants (NPPs). These technical specifications are documents that define the operational limits and conditions necessary to prevent abnormal situations and accidents in the reactor and related systems [1]. The limiting conditions for operation (LCO) in the technical specifications define the minimum requirements for equipment and systems to ensure safe operation [2]. In other words, if the LCOs are met, the NPP is operating within the design criteria, indicating that it is in a safe condition. Therefore, operators must comply with the LCOs to maintain safe operation and take appropriate measures to prevent and minimize nuclear power plant accidents.

However, complying with the LCO requires the operator's professional judgment and can be a significant responsibility. While many LCOs are defined with clear quantitative limits, some include qualitative descriptions. In such cases, operators are required to make subjective assessments to determine whether the LCOs are not met. In addition, many variables related to the LCO change rapidly during periods such as overhauls, which can make it difficult for operators to make accurate judgments. Accordingly, KHNP is developing an operation support system for technical specifications and conducting research to reduce the burden on operators [3,4].

In this paper, we propose a monitoring logic process to immediately detect LCO abnormalities (i.e., limit exceedances) as part of the operation support system for technical specification. This monitoring logic process not only detects abnormalities in LCOs but also includes evaluation logic and documentation. Through this monitoring logic process, we expect to reduce the burden on the technical specifications and help prevent violations of LCOs.

2. Functions of Monitoring Logic Process

The monitoring logic process consists of the following functional blocks: 1) an operation mode block, 2) a test mode block, 3) a monitoring logic block, and 4) an evaluation logic block. Fig. 1 shows an overview of these functional blocks. Each functional block is integrated into the monitoring logic process to detect and evaluate LCO abnormalities. Finally, the process is designed to support decision-making on whether to apply the detected LCO abnormalities and to document them. A description of each function block is provided in the following subsections.

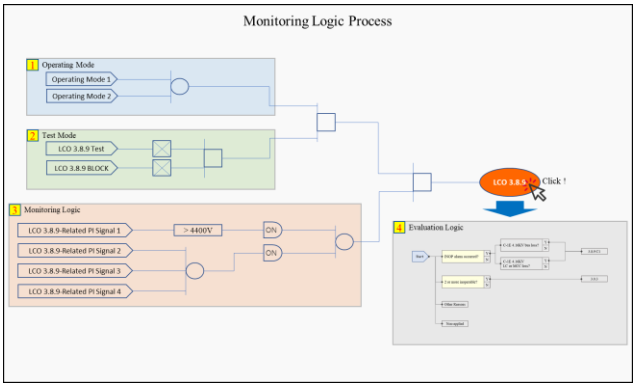

Fig. 1. Overview of monitoring logic process

2.1 Operating Mode

The operating mode refers to the operational status of an NPP. It represents a step-by-step classification of the NPP's status from power operation to cold shutdown, based on various factors (e.g., thermal power, multiplication factor, reactor coolant average temperature, etc.) that indicate the NPP's condition. The operating modes are described in Table I.

The LCO application criteria vary depending on the operating mode, and abnormalities are detected by applying the appropriate LCO based on the operating mode. The operating mode block automatically identifies the current operating mode using the plant information system (PI) signal and enables the monitoring of the corresponding LCO. In cases of reactor power increase, the operating mode is determined by operator's declaration, and the operating mode block provides alarms for transitions to higher modes, supporting the operator's judgment.

Table I: Classification of Operating Modes

Mode	Title	K_{eff}	Rated Thermal Power (%)	Reactor Coolant Average Temperature (℉)
1	Power operation	≥ 0.99	> 5	-
2	Startup	≥ 0.99	≤ 5	-
3	Hot standby	< 0.99	0	$\geq \|350\|$
4	Hot shutdown	< 0.99	0	$\|350\| > T_{avg} > \|200\|$
5	Cold shutdown	< 0.99	0	$\leq \|200\|$
6	Refueling	-	0	-

2.2 Test Mode

Test mode is a function that prevents the monitoring logic from operating due to equipment manipulations during regular testing. During these tests, numerous LCO abnormality alarms may occur, which can make it difficult for operators to make accurate judgments. Therefore, the test mode was implemented to automatically map and block related LCOs during regular testing.

2.3 Monitoring Logic

The monitoring logic operates based on PI signals and detects LCO abnormalities. It is implemented using logical conditions and considers the operating mode and test mode described above. This monitoring logic is designed based on operators' professional experience and detailed procedures. By utilizing real-time NPP data, it can immediately detect LCO abnormalities. When an LCO abnormality is detected, the final determination of whether the LCO is met or not met is made through the evaluation logic.

2.4 Evaluation Logic

The evaluation logic was implemented to assist the operator in determining whether LCO not met conditions are present for detected abnormalities. It is structured as a decision tree that ultimately helps decide whether the condition of LCO not met applies, relying on the operator's professional judgment. The evaluation process involves the operator manually selecting "yes" or "no" based on comparisons with power plant information, thus requiring the operator's judgment. To support this decision-making, relevant technical specifications are provided in a pop-up format, enhancing the operator's confidence in their judgment. Through this evaluation logic, expert knowledge (i.e., technical specification pop-ups), operator knowledge, and power plant status information are comprehensively integrated and compared, thereby improving awareness of the plant's status and bolstering confidence in the decision on whether the LCO is not met. Fig. 2 Shows the example of the evaluation logic.

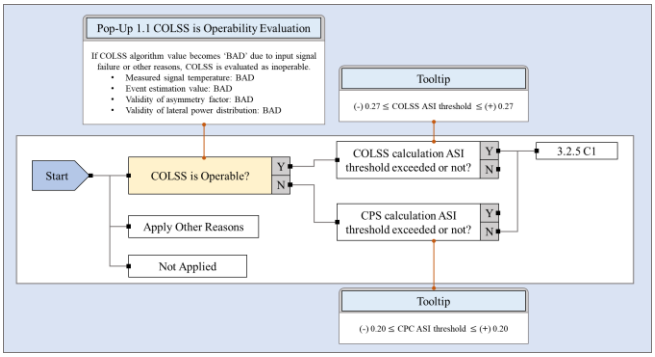

Fig. 2. The example of the evaluation logic

3. Conclusions

This study proposed a monitoring logic process to support NPP operators in managing LCOs as part of the operation support system for technical specifications. Traditionally, operators relied on professional judgment to determine LCO compliance, which posed a significant burden, particularly in cases involving qualitative assessments and rapidly changing plant conditions. The proposed system integrates monitoring and evaluation functions to enhance decision-making, prevent technical specification violations, and maximize the available response time when LCOs are not met. By reducing operator workload and improving response efficiency, this system is expected to contribute to the safe and effective management of NPP operations. Future improvements will incorporate operator feedback to further refine the system and enhance its capabilities.

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