

An Integrated Decision Support Structure for Technical Specifications in Nuclear Power Plants

Sang Won Oh*

KHNP Central Research Institute, 70, 1312 beon-gil, Yuseong-daero, Yuseong-gu, Daejeon

*Corresponding author: sangwon.oh@khnp.co.kr

***Keywords** : Technical Specification, Limiting Conditions for Operation, Operator Support System

1. Introduction

To ensure the safe operation of nuclear power plants (NPPs), operators are required to continuously monitor plant operating conditions in accordance with technical specifications (TS) [1]. Operators must also determine whether the limiting conditions for operation (LCOs) are met. Since this decision-making process is directly related to plant safety, operators must make careful judgments by considering various instrumentation signals, operating procedures, and operational experience.

However, in actual operating environments, information from the plant information (PI) system, TS documents, and operational experience records is distributed across multiple sources. As a result, operators are required to search for and integrate relevant information, which increases cognitive burden. In particular, when alarms are frequently generated due to signal hunting, instrumentation uncertainty, and temporary deviations, it is often difficult to establish objective bases for judgment. Consequently, decision-making may be influenced by subjective experience. Such fragmented information environments increase cognitive workload and may reduce the consistency and reliability of decisions.

Currently, TS expectations are managed as documents. These documents are intended to support training and decision-making in cases where the application of LCOs is unclear. However, document-based TS expectations have limitations in reflecting dynamic signal variations, instrumentation characteristics, and decision rationales in real time. In addition, constraints exist in rapidly retrieving, comparing, and utilizing past cases and accumulated judgment experiences [2].

To address these limitations, this study proposes an integrated decision support structure for TS within the TS operator support system. The proposed structure supports evidence-based decision-making by presenting signal trends, historical cases, and TS expectations in an integrated manner during LCO-related events.

The objective of this study is to improve access to decision-making evidence and reduce cognitive workload by structuring the judgment process. To this end, the proposed framework is examined using operational cases, and its usefulness is assessed through operator-oriented utilization scenarios. The results are

expected to contribute to enhanced operational experience management and future development of intelligent operator support technologies.

2. System Overview and Problem Statement

2.1 Overview of the TS Operator Support System

Korea Hydro & Nuclear Power (KHNP) has developed and operates a TS operator support system (TOSS) to support operators in monitoring plant operating conditions and making appropriate decisions [3]. TOSS integrates monitoring, evaluation, history management, and document linkage functions based on PI signals.

The monitoring function identifies situations in which LCOs are not met by comparing real-time input signals with predefined criteria. The monitoring logic consists of input signals, set points, and delay times, and detects conditions in which LCO requirements may not be met. When such conditions are identified, the system generates alarms to support operator awareness of relevant plant states. Fig. 1 shows an overview of monitoring logic process.

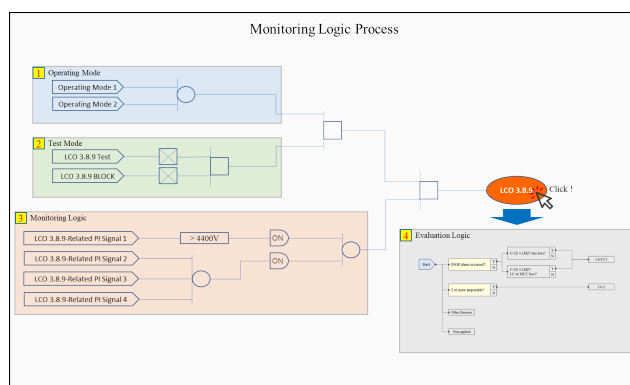


Fig. 1. Overview of monitoring process.

The evaluation function provides structured procedures to determine whether the detected conditions correspond to an actual LCO not met state. The evaluation process is organized in a step-by-step Y/N format, and relevant TS criteria are linked to each step. Based on this information, operators determine whether the conditions require application of TS actions

and record the rationale. Fig. 2 presents an example of the evaluation logic structure.

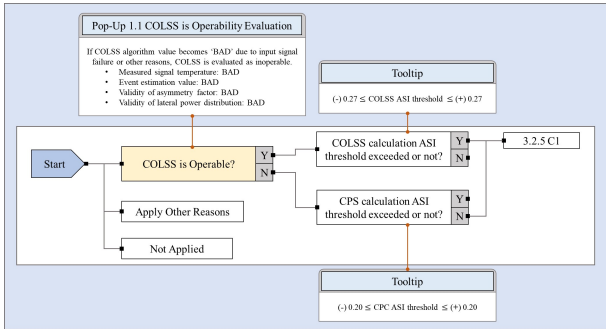


Fig. 2. The example of the evaluation logic.

2.2 Signal Information and History Management

TOSS utilizes various instrumentation signal data to support LCO-related monitoring and evaluation. The input signals consist of analog and digital signals representing major operational variables used in the monitoring logic. The system provides trend displays that allow operators to examine changes in signals over time and compare related variables. In addition, for multi-channel signals, the system supports channel-to-channel comparisons to assess instrumentation reliability. Fig. 3 shows an example of the trend display.

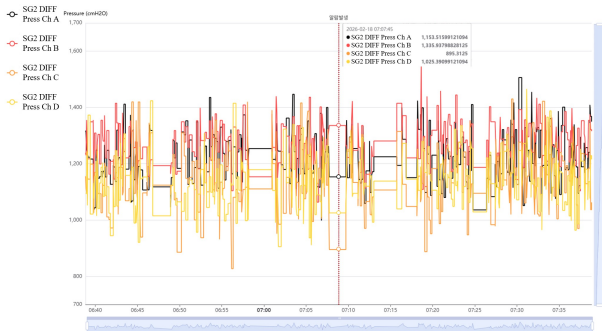


Fig. 3. Example of trend display for input signals.

Moreover, TOSS systematically manages historical data, including alarm occurrences, evaluation results, and operational actions. Each record contains information such as occurrence time, related signals, and the recorded decision and its rationale. In particular, the system stores the monitoring logic configuration and input conditions at the time of events as snapshots. These records enable reconstruction of operating conditions at specific time points. These snapshots include major signal values, logic states, and decision criteria, and can be utilized for case analysis and operator training.

Furthermore, TS expectations and related reference documents are linked within the system through item-based reference structures. This linkage enables operators to simultaneously access official TS criteria

and operational information during the decision-making process.

3. Proposed Integrated Decision Support Structure

This study proposes an integrated decision support structure for TS within TOSS, combining PI trends, snapshot data, historical records, and TS expectations. The proposed structure supports consistent decision-making during LCO-related events.

When an LCO-related alarm occurs, the system presents related trend data, multi-channel signal information, snapshot records, and linked TS expectations within a unified interface. This allows operators to review operational data and reference information without searching across fragmented sources.

In addition, the system provides functions for recording and managing operational cases and personal annotations. These functions facilitate accumulation of operational experience and contribute to reducing cognitive workload.

4. Conclusion

This study proposed an integrated decision support structure for TS within the TOSS environment. The proposed structure integrates signal trends, snapshot data, historical records, and TS expectations to support consistent decision-making during LCO-related events.

By providing unified access to operational data and reference information, the proposed structure reduces fragmented information searches and contributes to lowering cognitive workload. In addition, functions for case recording and experience management facilitate consistent judgment processes and support knowledge accumulation.

Future work will focus on applying the proposed structure to actual operating environments and evaluating its effectiveness through long-term operational data. The accumulated data are expected to contribute to advanced operational experience management and the development of intelligent operator support technologies.

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