Seismic Considerations in the Replacement of RPS Safety Parameter Indicators

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Introduction

- HANARO is South Korea's high-flux research reactor supporting nuclear R&D and isotope production. Aging instrumentation and control (I&C) systems require replacement to maintain operational safety
- The study focuses on replacing key safety indicators such as pressure, flow, and temperature with seismic-compliant alternatives.

- Objective :
  (1) Evaluate replacement options for pressure, flow, and temperature indicators
  (2) Assess compliance with seismic standards
  (3) Propose structured seismic testing approach

Seismic Compliance and System Upgrade

❖ Need for Replacement and System Overview

- The Reactor Protection System (RPS) of HANARO is designed to automatically shut down the reactor when safety limits are exceeded, helping protect the reactor and maintain safety during events like earthquakes.
- To ensure safe operation during such events, all RPS components must meet **Seismic Class 1** requirements.
- However, key instruments—such as those for measuring reactor outlet temperature, coolant flow, and pressure—had been in use since the start of HANARO's operation and reached the end of their design life, while the original models from DIXSON had been discontinued.
- The replacement process focused on selecting new equipment that meets seismic and safety standards, ensures long-term maintenance, and prefers domestic products for stable supply.

❖ Review of Seismic Report

- Seismic qualification testing was conducted on three types of indicators installed inside the RPS cabinet, at their actual installation height of 85.55 ft.
- Accelerometers were placed at key points to accurately measure the system's response to seismic input.
- The layout of the RPS and the placement of accelerometers are shown in Figure 1, with the indicators located at positions 4, 5, 6, and 7.
- To evaluate the new indicators, the Required Response Spectrum (RRS) was generated based on the In-structure Experimental Response Spectrum (IERS) at these positions.
- If IERS data was unavailable at a specific location, conservative values from nearby points—such as 4X, 5Y, and 7Z—were used to ensure safety.
- During testing, the output voltage of the indicators was continuously monitored to confirm that they remained stable and functional under simulated seismic conditions.
- A resonance search test, using sine sweep excitation from 1 to 50 Hz at 0.1g acceleration, was also conducted to analyze the system's dynamic characteristics.
- The seismic tests, which applied damping values of 2% for OBE and 5% for SSE, confirmed that the Test Response Spectrum (TRS) fully covered the RRS, with the cross-correlation remaining below 0.3, ensuring proper seismic excitation and system safety.

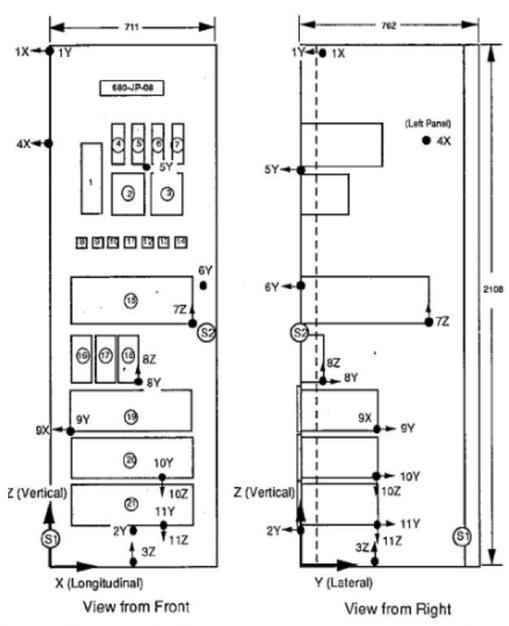

Figure 1. Equipment Arrangement & measuring point of RPS

❖ Seismic Standards and Testing Approach

- The HANARO indicators, manufactured by Woojin Co., Ltd, are microprocessor-based digital instruments designed to provide real-time operational data for the RPS.
- These indicators must meet the seismic qualification requirements of IEEE Std 344-1987, ensuring they maintain their structural integrity and functionality during seismic events, which is critical for reactor safety.
- Instead of conducting full cabinet testing, the replacement process uses an analytical approach, leveraging existing seismic qualification data, as only the indicator modules within the cabinet are being replaced.
- To verify compliance, these indicators must undergo seismic testing and analytical evaluation based on the interpretation of existing seismic qualification reports, as illustrated in Figure 2.

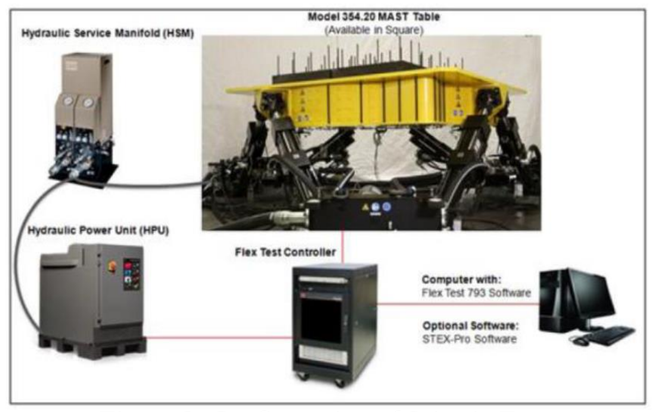

Figure 2. Configuration of Seismic Test

- The analysis must confirm that replacing the indicator modules does not negatively affect the seismic performance of the cabinet, ensuring that it remains compliant with regulatory standards and continues to provide the required safety functions.
- The seismic testing parameters, including frequency response characteristics, spectral amplitudes, and damping factors, must align with the specified standards. For this project, damping factors of 2% for OBE and 3% for SSE are applied.
- Two main types of seismic tests—resonance search tests and random multi-frequency (RMF) vibration tests—are planned to assess the dynamic characteristics and structural integrity of the indicators. The resonance search test will use low-amplitude sine wave excitation within a frequency range of 1 Hz to 100 Hz, while the RMF tests will apply three-axis excitation with repetitions under OBE and SSE conditions to simulate realistic seismic loading.
- These tests are designed to ensure that the replacement indicators maintain the same seismic robustness as the original equipment, confirming their ability to perform reliably during seismic events.
- The seismic tests will ensure the new indicators are strong enough to handle seismic events and maintain reliable operation, confirming they meet all safety and performance standards.

Conclusions and Future Work

❖ Conclusions

- This study proposes a structured approach for replacing outdated I&C components in nuclear reactors while ensuring seismic compliance.
- Instead of conventional cabinet-level testing, a component-level evaluation is used to assess the impact on existing seismic qualification reports, allowing for targeted replacements without full cabinet upgrades. Future seismic tests will validate this approach, ensuring its effectiveness and confirming the feasibility of modular component replacements in reactor systems.

❖ References

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