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An Evaluation for the Development of 4-channel RSPT and its Application for the OPR1000 Nuclear Power Plants

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1. Introduction

An evaluation project for the development and adaptation of 4-channel reed switch position transmitter (RSPT) has been performed by Korea Power Eng. Company, Inc. (KOPEC) as a contractor of Korea Hydro and Nuclear Power Co. Ltd (KHNP). The 4-channel RSPT is to replace the 2-channel RSPT which is currently installed for all the Optimized Power Reactor 1000 (OPR1000) type nuclear power plants (NPP). The 2-channel RSPT design of OPR1000 could lead an unwanted reactor trip caused by the deviation of a 12-finger control element assembly (CEA) position at each RSPT channel. In addition, the inconsistent channel numbers between 4-channel core protection calculator system (CPCS) and 2-channel RSPT made the system configuration and interface design of the CPCS overly complex. Thus, the 4-channel RSPT development is needed to enhance the OPR1000 plant safety and availability. In this project, while maintaining the existing OPR1000 interfacing system boundary, the 4-channel RSPT manufacturability and the proposed CPCS design with the 4-channel RSPT have been evaluated for their implementation feasibility. A reliability analysis of the proposed CPCS has been also performed. Algorithm changes and the effect of design change regarding interfacing components are also suggested.

2. Methods and Results

To achieve the 4-channel RSPT application, various design reviews and tests have been performed and their results are presented as follows:

2.1 4-channel RSPT Design and Manufacturing

Two kinds of the 4-cahnnel RSPT design are initially considered; one is a hemicycle type dual RSPTs and the other is a circular type dual RSPTs. These design concepts have been finalized and realized as the miniaturized hemicycle type dual RSPTs as in Figure 1. The miniaturized dual RSPT using small resistor and reed switch is also designed to maintain the electrical and physical separation from each other.

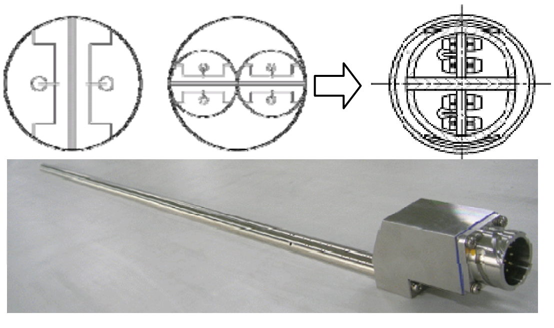

Fig. 1. Embodied Design and prototyped 4-channel RSPT

The evaluation result of the 4-channel RSPT manufacturability shows that the hemicycle type dual RSPTs can be realized and fit into the limited space inside the existing guide tube. A dummy RSPT as shown in Figure 1 has been manufactured per the design specification and performance requirements for the reed switch, resistor, printed circuit board. The performance test result shows that the dummy RSPT is acceptable in signal continuity, total resistance, insulation resistance for the reed switch position indication.

2.2 CPC Algorithm Modification and Safety Evaluation

The CPC and control element assembly calculator

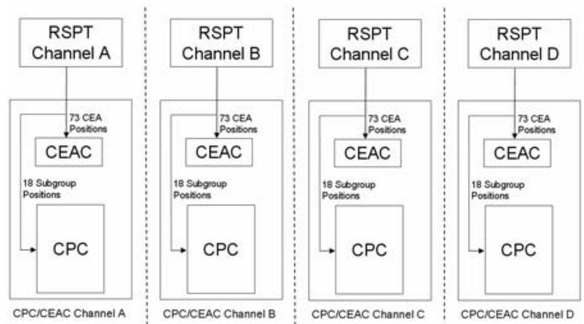

Fig. 2. 4-channel RSPT and CPC/CEAC Interface

(CEAC) configuration and algorithm change were proposed with the 4-channel RSPT as in Figure 2. The 4-channel RSPT can establish 4-channel CEAC configuration instead of the 2-channel CEACs, which enables physically and electrically separate and independent 4-channel CPCS. This configuration also enables to remove all the cross channel interfaces and software modules and/or algorithm related to the 2-channel CEAC configuration.

The algorithm change to one CEAC per each CPC channel would not affect safety analysis result compared to existing system by maintaining the main

CEAC function unchanged. It was noted that the 4-channel RSPT adaptation would increase the RSPT failure probability due to increased number of the RSPTs. However, the overall unwanted CPCS reactor trip probability can be decreased by RSPT design improvement and modified CPC/CEAC configuration. In the new configuration, if one CEAC is failed or disabled, the CPCS with 4-channel RSPT makes only one CPC channel inoperable.

2.3 Structural Integrity of the CEDM, RV Head Area and Interfacing Structure

The 4-channel RSPT doubles the number of RSPT and increases the CEDM structural load compared to the 2-channel RSPT. To analyze the CEDM structural integrity, finite element analysis models for the 2-channel and 4-channel RSPT were established, and the dynamic characteristic analysis was performed. The analysis results show that the resonance frequency and the dynamic characteristics are almost same as the 2-channel RSPT. And no adverse effect was shown between two models, and the resonance by the earthquake load did not occur. Although the loads for the CEDM and RSPT are somewhat increased, the influence on the structural integrity is insignificant with respect to the stress evaluation.

The quantity of reactor disconnect panel (RDP) and the connector holes of the RDP also need to be increased for accommodating the doubled RSPT and associated cable quantities within the limited internal space of head area cable tray (HACT). If the plants adopt the integrated head assembly (IHA), however, the 4-channel RSPT application needs to be reanalyzed.

2.4 System Reliability Analysis and Economic Evaluation

To evaluate the reliability of CPCS including 4-channel RSPT, the reliability block diagram is prepared by analyzing signal streaming considering CPCS components. The failure data of the components, such as the estimates for RSPT and the data of Common Q system with CPCS were collected. ISOGRAPH reliability workbench (V9.0) was used to analyze the failure data, and the results show that the unavailability is reduced by 3.6 times compared to OPR1000 (SKN 1&2) as in Table 1.

Table 1. Unavailability Comparison

	(A) 2-ch RSPT	(B) 4-ch RSPT	(A)/(B)
Unavailability	9.437×10^{-5}/D	2.629×10^{-5}/D	3.6

The 4-channel RSPT adoption and CPCS system re-configuration could have advantages on the overall maintenance cost mainly due to the decreased unwanted trips. Unnecessary reactor trip caused by the 2-channel RSPT may occur 0.5 times per year for OPR1000 plants and the economic loss per trip reaches about 1 billion won. Based on this assumption, the potential twenty unwanted trips may cost about 20 billion won for the OPR1000 plants. The 4-channel RSPT adoption may save 14.5 billion won by reducing the unwanted reactor trips by one fourth considering 40 years design life of OPR1000 plants.

3. Conclusions

The adaptation of 4-cahnnel RSPT into OPR1000 with the proposed 4 channel CEAC/CPC configuration has advantages on the maintenance cost and reliability of the safety system over 2-channel RSPT configuration.

In case of maintaining the current CPCS design unchanged, the 4-channel RSPT adaptation is not feasible due to its lacking design flexibility. Further more, the adaptation of the IHA must also be considered for the 4-channel RSPT implementation since it would provide almost no space for installing additional cables and maintenance for the CEDM due to its compact design characteristics.

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