Contribution ID: **246**

Type: **Poster presentation**

Development of Integrated Response Time Evaluation Methodology for the Plant Protection System

Tuesday 7 June 2016 15:00 (1h 30m)

Studies on setpoint determination methodologies for the plant protection system (PPS) for a nuclear power plant have been actively performed. The objective of determining a trip setpoint for the PPS is to meet the requirement of the analytical limit assumed in performing the safety analyses for a nuclear power plant.

However, the PPS instrumentation channel which contains a transmitter, a signal conditioning processor, a protection system cabinet, and a final actuator should also meet the response time requirement assumed during the safety analysis. The response time is another critical factor required to ensure that the PPS accepts the crucial assumptions of the safety analysis. Researches on the response time for the PPS have been partially performed to cover an individual component or system using either analysis or test method. Furthermore, although the response time evaluation considers the whole instrumentation channel on the trip signal path, the evaluation task such as analysis or test has been separately performed. In other words, the response time evaluation for the PPS has not been handling the whole design process that contains safety analyses, system designs, response time analyses, and response time test. Additionally, definite relationship between the results from the analysis and test has not been considered. In this case, the safety of a nuclear power plant cannot be guaranteed since the related process variable could exceed the analytical response time (ART) confirmed by the results of the safety analysis.

In order to solve the problems regarding the response time evaluation for the PPS, this paper proposes the integrated response time evaluation methodology that ensures the PPS meet a critical requirement of the ART. The proposed methodology has been applied to the PPS instrumentation channels for the advanced power reactor 1400 (APR1400) and the optimized power reactor 1000 (OPR1000) to fully verify the satisfaction of the ARTs for the low steam generator trip parameter. The two approaches indicate the appropriateness of the proposed methodology regardless of the type and size of nuclear power plants.

The whole design process that covers the safety analysis, the system design, the response time analysis, and the response time test is addressed in the proposed methodology. Each output of the design process is the ART, the designed response time (DRT), the estimated response time (ERT), and the measured response time (MRT). The proposed methodology is composed of three steps for evaluating the response time of the PPS. The first, second, and third steps, respectively, are to demonstrate that the DRT is less than the ART, the ERT is less than the DRT, and the MRT is less than the ERT.

Since the three steps were sequentially satisfied for the APR1400 and OPR1000, it can be guaranteed that the plant's process variable does not exceed the safety limit during and after design basis events. Therefore, the safety of a nuclear power plant can be enhanced using the proposed methodology because the integrated response time evaluation methodology fully guarantees the safety analysis response time.

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Session Classification: Poster session 1

Track Classification: Control, Monitoring,Test and Real Time Diagnostics Systems