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Response Time Evaluation for the Plant Protection System Using a Combined Technique of Analysis and Test

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1. Introduction

Various studies on setpoint determination methodology for safety instrumentation have been actively performed. The main purpose of determining the trip setpoint for safety systems is to meet the requirement of an analytical limit assumed in performing safety analyses. In addition, the response time assumed during safety analyses shall also be satisfied by the safety-related instrumentation. The response time is another critical factor required to ensure that the safety-related instrumentation channels accept the crucial assumptions of safety analyses [1-3]. However, integrated evaluation methods that cover the whole design process have not been systematically developed.

This paper proposes the response time evaluation methodology for the plant protection system (PPS) trip channel for the advance power reactor 1400 (APR1400) nuclear power plant. To demonstrate that the PPS tip channel is functioning within its allowable response time limit, the proposed methodology uses the combined technique of both the response time analysis and test. The response time evaluation methodology proposed herein is applied to the low steam generator level (LSGL) reactor trip parameter for the APR1400.

2. Methods and Results

2.1 Response Time Evaluation Method

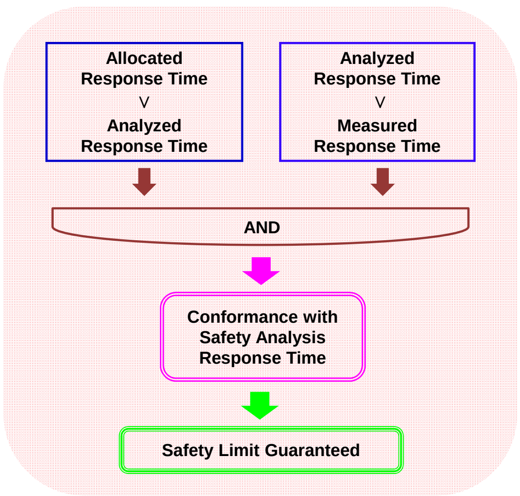

Fig. 1. Response Time Evaluation Process

As shown in Fig. 1, if the logical relationship among the allocated response time determined through a system design, the analyzed response time, and the measured response time satisfies the safety analysis response time, then the safety limit will be guaranteed.

2.2 Response Time Analysis

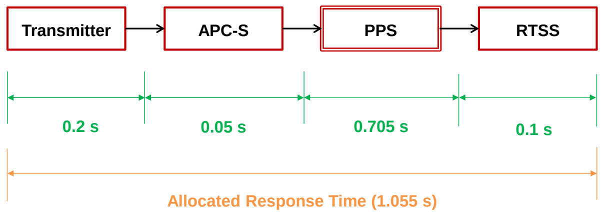

Fig. 2. Response Time Allocation for LSGL Reactor Trip Function

The LSGL reactor trip function channel is composed of transmitter, auxiliary process cabinet-safety (APC-S), PPS, and reactor trip switchgear system (RTSS) as shown in Fig.2. Reactor trip response time is defined as the interval between when the monitored parameter exceeds the trip setpoint value at the input to the transmitter and when electrical power is interrupted to the control element assembly drive mechanism through the actuation of the RTSS. Fig. 2 indicates that the allocated response time for LSGL reactor trip parameter is determined adding individual response times designed. The safety analysis response time of 1.25 s was assumed in performing safety analyses regarding the trip parameter. The allocated response time should be designed to be less than the safety analysis response time.

For LSGL trip parameter, the analyzed response time is calculated summing the response times of transmitter, APC-S, PPS, and RTSS. In this case, the PPS should be analyzed in detail to consider the worst-case operating conditions because the PPS contains software modules programmed with dedicated cycle times.

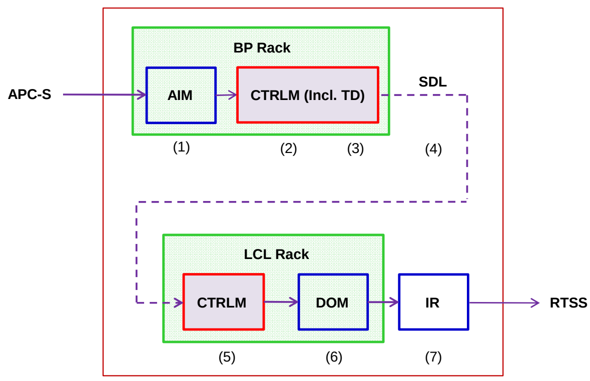

Fig. 3. Response Time Analysis for PPS

The PPS consists of bistable processor (BP) rack, safety data link (SDL), local coincidence logic (LCL) rack, and interposing relay (IR) as illustrated in Fig. 3. The BP rack includes analog input module (AIM) and control module (CTRLM) including time delay (TD), and the LCL rack contains CTRLM and digital output module (DOM).

The detailed response time for the individual PPS components is described in Table I and indicates the analyzed response time of 0.642 s does not exceed the designed response time of 0.705 s. Therefore, it can be demonstrated that the allocated response time is met by the response time analysis technique.

Table I: Individual PPS Response Time

Components	Response Time (s)
(1) AIM	0.02
(2) CTRLM	0.058
(3) TD	0.48
(4) SDL	0.013
(5) CTRLM	0.034
(6) DOM	0.012
(7) IR	0.025
PPS Analyzed Response Time	**0.642**
PPS Allocated Response Time	**0.705**

Since the central processing unit (CPU) load assigned to each processor module will be designed not to exceed 70% of CPU full load, the execution time is defined as 70% of the CTRLM's cycle time. If the CTRLM is assumed to miss the AIM output signal change, it is needed to await an additional execution time. Thus, the response time of the CTRLM in the BP rack is 0.058 s which results from adding the CTRLM's cycle time of 0.034 s to its execution time of 0.024 s. The TD of BP rack is to reduce the possibility of spurious reactor trip due to the fluctuation of steam generator water level.

If the CTRLM in the LCL rack is assumed to miss the output signal change of the CTRLM in the BP rack, it is necessary to await an additional execution time. Thus, the response time of the CTRLM in the LCL rack is 0.034 s which results from adding the CTRLM's cycle time of 0.020 s to its execution time of 0.014 s. Since the analyzed response time for the PPS is 0.642 s and the remaining parts are the same as the designed response times, the analyzed response time for the LSGL trip parameter is 0.992 s that is less than the allocated response time of 1.105 s.

2.3 Response Time Test

In order to perform the response time test for the LSGL reactor trip parameter, the test configuration should be determined considering the individual system characteristics that may have constraints against a response time test. In case of LSGL trip parameter for APR1400, the trip channel is divided into three regions as shown in Fig. 4. When the response time test is not performed on all components and systems at the same time, an overlap test should be implemented and then the test results should be added to ensure that the channel response time meets the corresponding requirement.

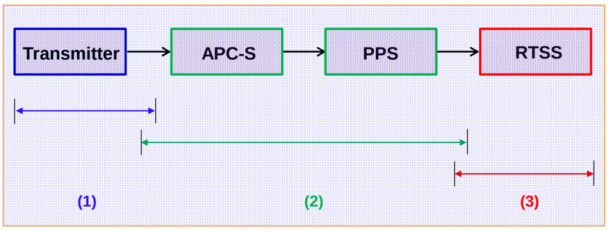

Fig. 4. Response Time Test Configuration

The response time test results for LSGL reactor trip parameter for the APR1400 are depicted as Table II. The response time test was performed on the trip parameter that has four redundant channels A, B, C, and D. Table II indicates that each measured response time does not exceed the analyzed response time of 0.992 s. Therefore, it has been verified that the analyzed response time is completely satisfied by the test.

Table II: Response Time Test Results for SG No.1

Systems	Channel Response Time (s)			
	CH. A	CH. B	CH. C	CH. D
(1) Transmitter	0.091	0.055	0.104	0.120
(2) APC-S & PPS	0.610	0.609	0.614	0.615
(3) RTSS	0.084	0.084	0.084	0.084
Measured Response Time	**0.785**	**0.748**	**0.802**	**0.819**
Analyzed Response Time	**0.992**			

3. Conclusions

The response time analysis for the LSGL trip parameter demonstrated that the analyzed response time would not exceed the allocated response time. The results of the response time also showed that all of the measured response times would be less than the analyzed response time. Therefore, the safety of a nuclear power plant can be enhanced using the proposed methodology since the conservative combination of the response time analysis and test fully guarantees the safety analysis response time.

REFERENCES

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