Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2017

A Lumped Response Time Test Methodology for the Digital Plant Protection System

Chang Jae Lee * and Jae Hee Yun
KECO E&C, Inc., I&C System Engineering Dept., 989-111 Daedeok-Daero,Yuseong-gu, Daejeon, 34057, Korea
**Corresponding author:cjlee1@kepco-enc.com*

1. Introduction

Analysis setpoints and response times for safety instrumentation and control systems are assumed in performing safety analyses in order to guarantee the safety of a nuclear facility. The trip setpoint set into the plant protection system should be determined from the analysis setpoint considering the total safety system channel uncertainty [1,2]. The safety system should also satisfy the requirement of the analysis response time [2-4]. The safety system consists of four redundant channels carrying out the safety functions as realized in the reactor protection system (RPS) and the engineered safety features actuation system (ESFAS). In case of optimized power reactor (OPR) 1000, each RPS channel is comprised of a sensor, signal processing device, digital plant protection system (DPPS), and reactor trip switchgear system (RTSS). Each ESFAS channel contains a sensor, signal processing device, digital plant protection system (DPPS), digital engineered safety features actuation system – actuation cabinet (DESFAS-AC), and final actuation equipment. The DPPS having trip setpoints is an important safety system which generates RPS and ESFAS signals. The RPS and ESFAS signals are sent to the RTSS and the DESFAS-AC, respectively. In this paper, the response time test methodology for the DPPS is proposed using a lumped technique in order to meet the corresponding requirement.

The DPPS includes four cabinets which correspond to four channels A, B, C, and D, respectively. The four DPPS channels are configured with a set of four adjoining cabinets located in the main control room. The response time test for each channel is required by the surveillance requirement of the Technical Specifications. However, a lumped measurement technique is proposed herein to improve the efficiency and conservatism of a DPPS response time test, considering the physical configuration of the DPPS cabinets. The test results that satisfy the response time requirement of both the signal processing device and DPPS are presented.

2. Methods and Results

In this section the DPPS response time test method using a lumped measurement technique is described considering the configuration of response time test equipment, combination of test input and output signals, ESFAS signal blocking method, and response time test results.

2.1 Configuration of response time test equipment

The DPPS response time is tested using response time test equipment that injects an initiation signal to a signal processing device in a channel and receives resulting signals from four DPPS channels. Figure 1 illustrates the response time test configuration for channel A of the DPPS. In case of the RPS function, each channel of the DPPS receives a process value from its dedicated signal processing device. If the processed value exceeds the trip setpoint set into the bistable logic, a trip signal is generated and then provided to all 2/4 coincidence logics of four channels. The output of each 2/4 coincidence logic is connected to under voltage (UV) and shunt trip (ST) relays, which are a part of each corresponding initiation circuit. The response time test for the signal path which has the UV relay is tested separately from the ST relay as shown in Figure 1.

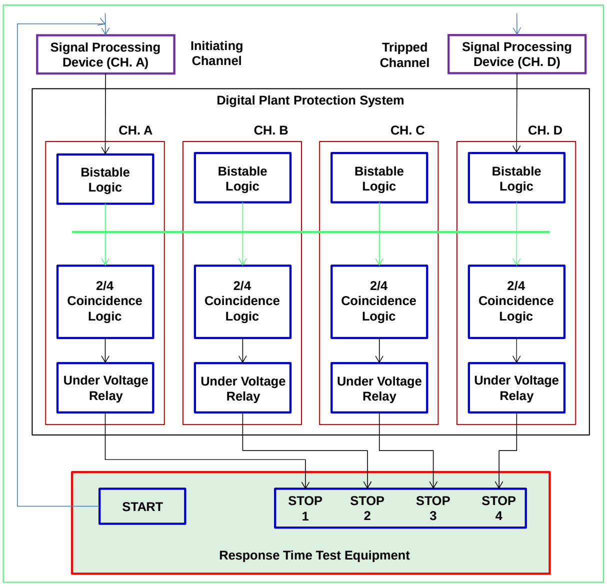

Fig. 1. Response Time Test Signal Configuration for Channel A of the Digital Plant Protection System

The response time test equipment consists of both start and stop parts. The start portion generates a simulated input signal that exceeds the trip setpoint and then sends it to the signal processing device. In addition, another trip signal is indispensable to comply with the 2/4 coincidence logic. The equipment displays four channels' response time results, measuring one starting time and four stopping times and calculating the elapsed time from the same starting time to each channel's stopping time.

In case of ESFAS function, the output of the 2/4 coincidence logic is provided to the DESFAS-AC via the fiber optic transmitters (FOTs) which are connected to fiber optic receivers (FORs) located in the DESFAS-AC.

2.2 Combination of test input and output signals

Table I indicates the detailed input signal combinations for the RPS response time test that are minimum conditions to meet the 2/4 coincidence logic. The signal combination for the UV relay is different from that of the ST relay, considering the diversity of the RPS response time test. The possibility of confusing a tester due to the different signal combination is low, since four channels of the DPPS are configured as a set of adjacent cabinets in the main control room.

Table I: DPPS Response Time Test Input Signals

UV		ST	
Initiating Channel	Tripped Channel	Initiating Channel	Tripped Channel
A	D	A	C
B	C	B	A
C	B	C	D
D	A	D	B

Although the corresponding channel output signal is necessary to carry out the response time test for a channel, the longest response time among four results is conservatively selected as a final value. This approach is also available based on the physical arrangement of the DPPS cabinets.

2.3 ESFAS Signal Blocking Method

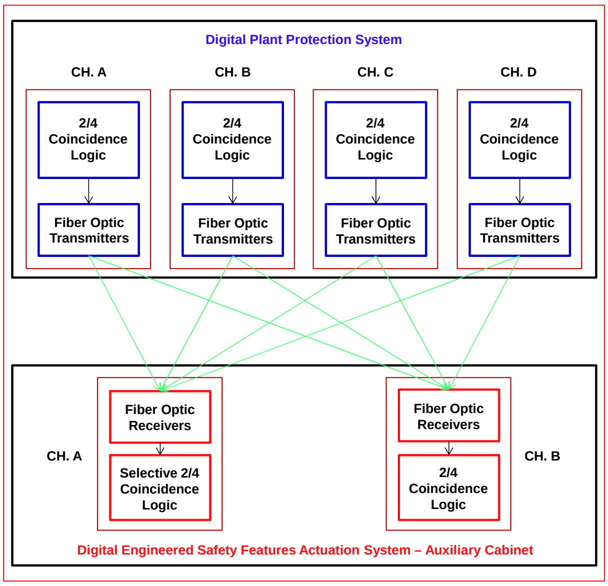

Fig. 2. Fiber Optic Communication between DPPS and DESFAS-AC

When performing the RPS response time test for the trip parameters which have both RPS and ESFAS functions, the output signals of the 2/4 coincidence logic of the DPPS are provided to the DESFAS-AC as well as the RTSS. If the DESFAS-AC cabinets are connected to the final actuation devices, it is required to block the ESFAS signals from being sent to the DESFAS-AC in order to avoid an unwanted actuation of engineered safety features. All fiber optic cables should be detached from the FOTs so that the ESFAS signals are not transmitted to the FORs, as shown in Figure 2.

2.4 Response Time Test Results

The test results for the RPS low pressurizer pressure trip which has both RPS and ESFAS functions are shown in Table II. Each channel’s final response time is determined as a longer value between UV and ST. Therefore, the resulting response times for Channels A, B, C, and D, which correspond to 0.156s, 0.186s, 0.166s, 0.162s, respectively, meet the requirement of 0.275s that covers both the signal processing device (0.05s) and DPPS (0.225s). The test result for channel B is longest, because only the test input is sent to the signal processing device via the remote shutdown panel.

Table II: Test Results for Low Pressurizer Pressure Trip

Channel	Response Time	
	UV (s)	ST (s)
A	0.156	0.147
B	0.183	0.186
C	0.166	0.141
D	0.146	0.162
Requirement	**0.275**	**0.275**

3. Conclusions

The response time test methodology which uses a lumped measurement technique has been applied to the OPR1000. The proposed method that takes advantages of the DPPS hardware configuration is useful for measuring more conservative response times for safety functions. In addition, the test results indicate that the response time requirement of the DPPS including a signal processing device is satisfied.

REFERENCES

[1] Setpoint for Safety-Related Instrumentation, U.S.NRC Regulatory Guide 1.105, Rev. 3, Dec. 1999.
[2] Spoints for Nuclear Safety-Related Instrumentation Used in Nuclear Power Plants, ANSI/ISA-67.04.01-2000.
[3] Guidance on Digital Computer Real-Time Performance, U.S.NRC, NUREG 0800, SRP, BTP 7-21, 2007.
[4] Performance Monitoring for Nuclear Safety-Related Instrument Channels in Nuclear Power Plants, ANSI/ISA-67.06.1, 2002.