A Study of Improving Response Time Verification Method for Pressure Transmitters

Jungyang Lee, Jaehong Ha, Insoo Jung, Junghee Jo, HangBae Kim
Korea Power Engineering Company, Inc. NSSS Instrumentation & Control System Engineering Dept.
150 Deokjin-dong, Yuseong-gu, Daejeon, 305-353, jylee2@kopec.co.kr

1. Introduction

Technical Specifications (TS) of OPR1000 type nuclear power plants in Korea require pressure sensor response time testing (RTT) to ensure sensor performance per assumption in plant safety analyses. However, the need for pressure sensor response time testing is not clear because the nominal sensor response times are in the order of milliseconds while overall loop response time limits being from several seconds to tens of seconds. Additionally, response time testing does not appear to identify response time degradation or failures. Consequently, the need for this testing has been questioned, and a study to determine if response time testing is necessary to justify the assumptions in plant safety analyses in the United States has been conducted and NRC has approved to remove the test requirements for them. A similar study was conducted for OPR1000 type nuclear power plants and the results are presented here.

2. Methods and Results

Generic safety system RTT requirements were established by IEEE Standard 338-1975, "Criteria for the Periodic Testing of Class 1E Power and Protection Systems". IEEE Std. 338-1975 requirements were adopted by NRC Regulatory Guide 1.118, "Periodic Testing of Electric Power and Protection Systems" Revision 1, issued in 1977. IEEE Std. 338-1977 establishes a basis for eliminating RTT. Section 6.3.4 states: "…response time testing of all safety related equipment, per se, is not required if, in lieu of response time testing, the response time of the safety system equipment is verified by functional testing, calibration check, or other tests, or both...". Demonstrating that sensor response time cannot degrade without being detected by periodic (non-RTT) methods would leave the plant safety analyses assumptions unchallenged. Therefore, RTT would not be necessary in accordance with IEEE 338.

The method in this study for determining whether or not response time degradation is accompanied by other changes in sensor output is the Failure Modes and Effects Analysis (FMEA) method defined in IEEE Std. 352, "General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems". FMEAs, along with plant drift and RTT data, are used in this study as the bases for eliminating RTT.

2.1 FMEA

The Rosemount differential pressure (DP) transmitter which is used for Reactor Protection System consists of the differential pressure transducer assembly, electronic signal processing circuits, and the transmitter housing. For transmitters without the variable damping feature, no electronic failure modes were found that could affect the sensor response time. Degradation or failure of the electric damping circuits for the transmitters with variable damping feature occurs in such a way as to decrease rather than increase response time.

A fill fluid leak can affect the transmitter range and/or response time. The loss of fill fluid could be due to several factors including microscopic failures of the glass-to-metal seal, sensing diaphragm, isolation diaphragm, and fill tube of welds. Depending on the varied quantity of the fill fluid and the relative stiffness of the diaphragms, this may or may not result in a detectable signal offset prior to a significant change in the differential pressure or response time. An increase in fill fluid viscosity would act to increase response time but no mechanism, other than known temperature effects, has been identified as causing fill fluid viscosity changes.

Periodic testing rather than RTT can detect the failures in the Rosemount DP transmitter except slow loss of fill fluid and variable damping potentiometer misadjustment.

2.2 Drift History

The drift of the subject transmitters were calculated using As-found/As-left (AF/AL) data on the transmitter calibration records. The equation is as follows:

$$Drift_i = \frac{(AF_i - AL_{i-1})}{Span}$$

$$where:$$

$$Drift_i : Drift\ at\ i^{th}\ Calibration$$

$$AF_i : As-found\ Value\ at\ i^{th}\ Calibration$$

$$AL_{i-1} : As-left\ Value\ at\ i-1^{th}\ Calibration$$

Typically, figure 1 shows the drift trend of UCN Unit 4 P-101A channel. It shows that the drift becomes stable as time goes by. No failure symptoms were found. Slow loss of fill fluid can be found by monitoring the drift trend.

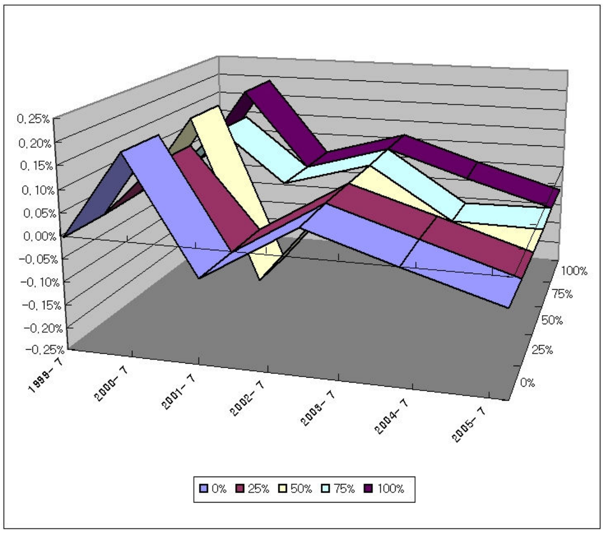

Figure 1 Drift trend of UCN Unit 4 P-101A

2.3 Response Time Test Results

TS requires RTT on a staggered test basis of once every 18 months per function such that all channels are tested at least once every n times 18 months where n is the total number of redundant channels in a specific reactor protection function. All 8 units', YGN Unit 3,4,5,6 and UCN Unit 3,4,5,6, data for the same variable are statistically processed together because the design conditions of the 8 units are same. The fixed response times of the subject transmitters were calculated in accordance with the procedure shown in figure 2.

Table 1 shows the acquired record number of RTT for each unit. The RTT records may contain several types of error: database input errors, operator errors during test, measuring equipment errors or instrument errors. The outliers are analyzed using the T-test[4] method with the 5% level of significance.

$$T_i = \frac{x_i - \bar{x}}{s}$$

$where:$

$x_i = data\ value$

$\bar{x} = arithmatic\ averge\ of\ all\ n\ values$

$s = standard\ deviation$

Once the data has been edited, the Chi-Square Goodness of Fit Test was used for the normality test and the maximum expected value was calculated for 95/95 tolerance interval. If it is determined that the data is not normally distributed, the maximum expected value as a fixed response time was selected conservatively considering the characteristics of the data.

Table 1 The number of RTT records

Plant	Pre-op. test date	Latest test date as of 2005 Oct.	Number of test
YGN 3	1994. 07	2004. 10	12
YGN 4	1995. 01	2005. 09	12
UCN 3	1997. 09	2004. 10	9
UCN 4	1998 .05	2005. 01	9
YGN 5	2001. 08	2005. 06	7
YGN 6	2002. 03	2005. 02	6
UCN 5	2003. 07	2005. 07	5
UCN 6	2004. 05	-	4

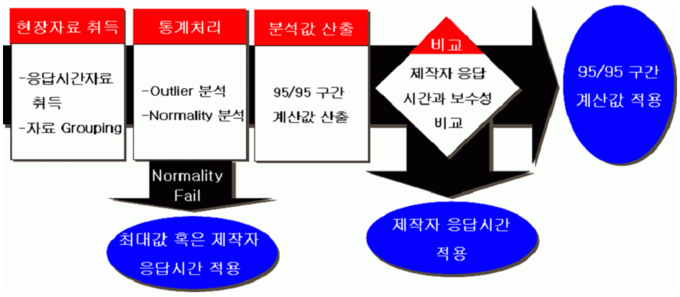

Figure 2 Fixed response time calculating procedure

3. Conclusion

The FMEAs for all presently supplied qualified pressure and differential pressure transmitters used in OPR1000 type nuclear power plants indicate that RTT is redundant to other periodic testing for all cases except for slow loss of fill fluid and variable damping potentiometer misadjustment. With complementary measures for these two cases, fixed response times can be used instead of doing RTT for all the subject transmitters. The fixed response times for each transmitter were calculated using statistical analyses of RTT records at the operational plants and manufacturer's nominal data.

REFERENCES

[1] RG 1.118, Rev. 3, "Periodic Testing of Electric Power and Protection Systems", Apr. 1995.
[2] ANSI/IEEE Std 338-1987, "IEEE Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems".
[3] ANSI/IEEE Std 352-1987, "IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems".
[4] ASME Standard E 178-02, "Standard Practice for Dealing with Outlying Observations".