Allowable Value Calculation Methodology Comparison between ISA RP67.04 and Advanced Power Reactor 1400 Nuclear Power Plant

Chang Jae Lee *, Woo Goon Kim, Ki Hoon Jung
KEPCO 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

The plant protection system (PPS) of a nuclear power plant (NPP) has various trip setpoint (TSPs) to initiate a reactor trip or engineered safety features actuation when design basis events occur. Each TSP is tested periodically to verify that it remains within its own allowable value (AV). The purpose to calculate the AV is to identify a value that, if exceeded, may indicate that the instrument has not performed within the assumptions of the TSP calculation [1, 2]. Thus, if a TSP exceeds the respective AV, the safety instrument channel is considered inoperable. In particular, AV is treated as a very important factor to ensure that a process parameter does not exceed the analytical limit established in safety analysis. The ISA RP67.04 [3] provides two recommended AV calculation methods to ensure that the analytical limit is not exceeded during a design basis event.

Since the PPS TSP determination method of APR1400 was evaluated to satisfy an ISA method that uses an appropriate uncertainty combination way of the square root of the sum of squares (SRSS) approved by regulatory authorities with regard to random and independent uncertainties, it was concluded that the TSP established by APR1400 methodology can prevent the corresponding process parameter from exceeding the analytical limit assumed in safety analysis [4]. Therefore, it is required to specifically compare APR1400 AV calculation with two recommended methods and then evaluate relative conservatism in the aspect of safety. Qualitative evaluation is basically performed and quantitative conservatism evaluation is also presented herein.

This paper provides the appropriateness of AV calculation method for APR1400, comparing with ISA RP67.04 methods.

2. Methods and Results

For evaluating the conservatism of APR1400 AV, two AV calculation methods the ISA RP67.04 provides and APR1400 method are analyzed and compared. In addition, qualitative and quantitative evaluations are conducted to verify the relative conservatism of APR1400 AV method.

2.1. ISA RP67.04 AV Methods

Two recommended AV calculation methods of the ISA RP67.04 are shown in Fig. 1. For Method 1, the AV is calculated from the analytical limit by subtracting the untestable channel uncertainty (UTCU). In this case, the total channel uncertainty is calculated by the sum of UTCU and testable channel uncertainty (TCU). For Method 2, a statistical uncertainty combination way of SRSS is used to calculate the total channel uncertainty. The TSP is first calculated by subtracting the total channel uncertainty from the analytical limit and then the AV is determined by adding TCU to the TSP.

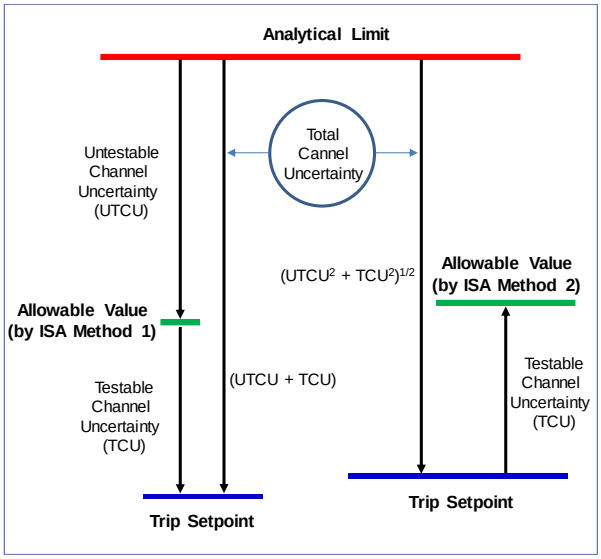

Fig. 1. ISA 67.04 allowable value calculation methods for rising trip parameter

The AV calculation using ISA method 1 is given by (1).

$$AV_{ISA1} = AL - UTCU \quad (1)$$

Where:
AV_{ISA1} = allowable value of ISA method 1
AL = analytical limit
UTCU = untestable channel uncertainty

The AV calculation of ISA method 2 is given by (2).

$$AV_{ISA2} = AL - \{(UTCU^2 + TCU^2)^{1/2} - TCU\} \quad (2)$$

Where:
AV_{ISA2} = allowable value of ISA method 2
TCU = testable channel uncertainty

2.2. APR1400 AV Method

The AV is determined by adding TPU to the draft TSP that is calculated from the analytical limit by subtracting the total channel uncertainty corresponding to the SRSS of UTCU and TCU, as illustrated in Fig.2 [4]. The TSP is calculated by subtracting some margin which is greater than TPU, from the AV.

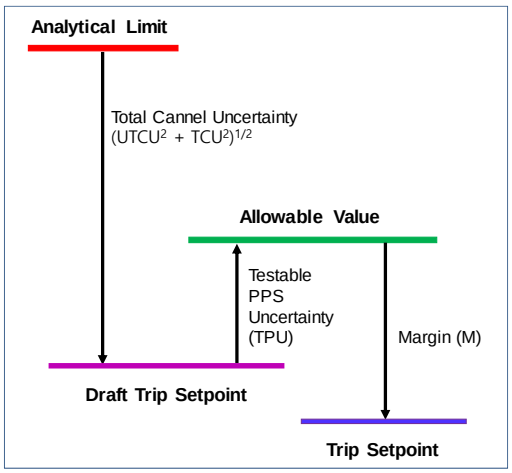

Fig. 2. APR1400 allowable value calculation method for rising trip parameter

The AV calculation of APR1400 is given by (3).

$$AV_{APR1400} = AL - \{(UTCU^2 + TCU^2)^{1/2} - TPU\} \quad (3)$$

Where:
$AV_{APR1400}$ = allowable value of APR1400
AL = analytical limit
UTCU = untestable channel uncertainty
TCU = testable channel uncertainty
TPU = testable PPS uncertainty

2.3. Qualitative Evaluation

Regarding the APR1400 method, The TPU that is considered nearly zero is used to determine the AV instead of the TCU containing uncertainties of transmitter, signal processing device, and PPS [4]. The AV calculated by the ISA method 1 is lower than the ISA method 2, as shown in equations (1) and (2). Thus, the ISA method 1 is more conservative because the allowed maximum value that the TSP may have during periodic surveillance test is maintained to deviate away from the analytical limit. In addition, the APR1400 AV is more conservative than the ISA method 1 because the difference between the analytical limit and AV is greater than UTCU. As a result, it is qualitatively evaluated that the APR1400 AV method is more conservative than two ISA methods.

2.4. Quantitative Evaluation

The high steam generator level (HSGL) trip function is used to quantitatively evaluate the conservatism of APR1400 method. For APR1400 HSGL trip function, the uncertainty data used for calculating the PPS AV is shown in Table I and the TPU is zero because the uncertainty of a digital processor module including the TSP is negligible [4].

Table I: Uncertainty Data for HSGL trip function

Parameter	Value (%)
Untestable Channel Uncertainty (UTCU)	2.698
Testable Channel Uncertainty (TCU)	2.129
Testable PPS Uncertainty (TPU)	0

For calculating HSGL trip function's AVs, we consider that the analytical limit is X% used in safety analysis. Using (1) and (2), the AVs of ISA methods 1 and 2 are calculated as X-2.698% and X-1.308%, respectively. Using (3), the TSP of APR1400 is determined as X-3.437%. Therefore, APR1400 AV is more conservative than two ISA methods.

Although the resulting value of APR1400 AV is lower than the ISA method 2, there is no difference in the aspect of methodology since a segment of TCU is applied to APR1400. If the APR1400 AV is determined using TCU, the results are actually same each other. In case of APR1400, a more conservative approach is used to take required actions when the PPS TSP exceeds the AV established by a smaller value of TPU instead of TCU.

3. Conclusions

The APR1400 AV calculation method is reasonable to ensure that the process variable does not exceed the analytical limit during a design basis event since it satisfies ISA methods 1 and 2. Therefore, it is concluded that the AV determined by APR1400 methodology can prevent the corresponding process parameter from exceeding the analytical limit, maintaining a PPS TSP within its own AV.

REFERENCES

[1] Setpoints for Nuclear Safety-Related Instrumentation, ISA-S67.04, Part I, Sep. 1994.
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[4] C. J. Lee, W. S Choi, J. S Kwon, and J. H Yun, "Comparison between Plant Protection System Setpoint Methodology and ISA RP67.04," Proceedings of Transactions of the Korean Nuclear Society Spring Meeting, Jeju, Korea, July 9~10, 2020.