Comparison between ISA RP67.04 and Plant Protection System Setpoint Methodology for Advanced Power Reactor 1400

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1. Introduction

Safety-related setpoints of a nuclear power plant (NPP) are determined by satisfying requirements of regulations and industry standards. For the Advanced Power Reactor 1400 (APR1400) NPPs, the plant protection system (PPS) trip setpoint (TSP) complies with both the ISA S67.04 [1] that provides minimum requirements to calculate TSPs for safety systems and the regulatory guide 1.105 [2] that endorses the standard requirements in terms of regulation. Furthermore, the ISA RP67.04 [3] provides recommendations for the implementation of the ISA standard [1] in order to facilitate the performance of instrument uncertainty calculations and setpoint determination for nuclear safety-related instrument setpoints. There are two setpoint determination methods ensuring the TSP does not exceed the analytical limit assumed in safety analysis. Therefore, it is crucial to specifically compare APR1400 setpoint calculation with two recommended methods and then evaluate relative conservatism in the aspect of safety. Both qualitative and quantitative conservatism evaluations are presented herein.

This paper provides the appropriateness of determining the PPS TSP of APR1400, comparing with ISA RP67.04 methods.

2. Methods and Results

To evaluate the conservatism of APR1400 TSP, two TSP determination methods ISA RP67.04 presents and APR1400 method are analyzed and compared. In addition, qualitative and quantitative evaluations are performed to identify the relative conservatism of APR1400 TSP method.

2.1. ISA RP67.04 Methods

Fig. 1 illustrates two kinds of TSP determination methods provided by ISA RP67.04. Method 1 uses an algebraic summation way to combine uncertainties and Method 2 applies a statistical uncertainty combination way of the square root of the sum of the squares (SRSS).

Regarding the first method, the TSP is calculated subtracting the total channel uncertainty from the analytical limit. The total channel uncertainty used in this method is calculated by the sum of untestable channel uncertainty (UTCU) and testable channel uncertainty (TCU). TCU indicates an uncertainty that can be identified by channel calibration and periodic surveillance test. UTCU is the remaining portion of total channel uncertainty except TCU.

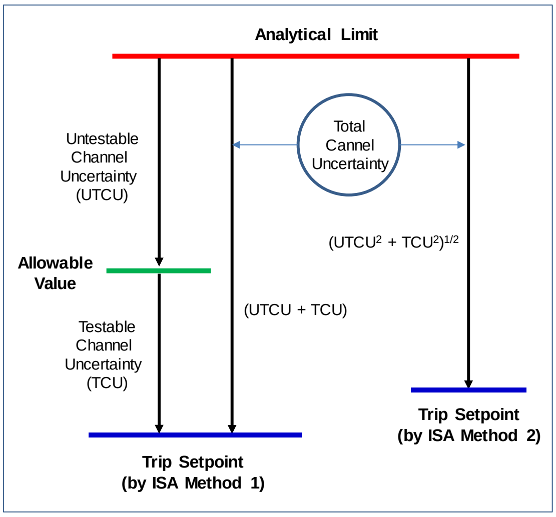

Fig. 1. ISA RP67.04 trip setpoint determination methods for rising trip parameter

The TSP calculation of ISA method 1 is given by (1).

$$TSP_{ISA1} = AL - (UTCU + TCU) \qquad (1)$$

Where:
TSP_{ISA1} = trip setpoint of ISA method 1
AL = analytical limit
UTCU = untestable channel uncertainty
TCU = testable channel uncertainty

Regarding the second method, the SRSS combination way is used that combines random and independent uncertainties. Thus, the total channel uncertainty is calculated by the SRSS of UTCU and TCU. The TSP of ISA method 2 is given by (2).

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

2.2. APR1400 Method

As shown in Fig.2, the draft TSP is calculated from the analytical limit by subtracting the total channel uncertainty which is calculated by the SRSS of UTCU and TCU. The allowable value means the maximum tolerance which a TSP may have during the time interval between periodic surveillance tests. The allowable value is calculated adding the testable PPS uncertainty (TPU) to the draft TSP. The TSP is determined subtracting some margin from the allowable value. The margin between the allowable value and the TSP is greater than the TPU in order to reduce the possibility that the TSP exceeds the allowable value.

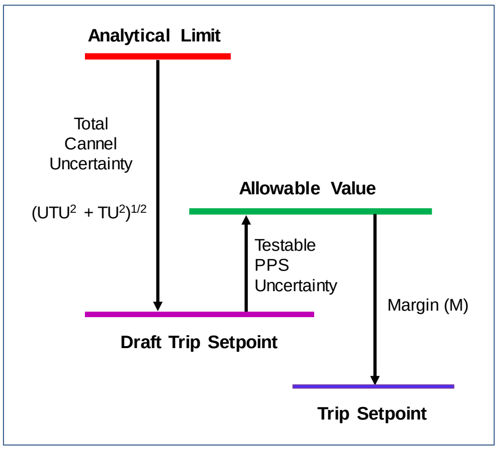

Fig. 2. APR1400 trip setpoint determination method for rising trip parameter

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

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

Where:
$TSP_{APR1400}$ = trip setpoint of APR1400
AL = analytical limit
UTCU = untestable channel uncertainty
TCU = testable channel uncertainty
TPU = testable PPS uncertainty
M = Margin

2.3. Comparison

The APR1400 setpoint method is more conservative than ISA method 2 since the margin between the allowable value and the TSP is greater than the TPU. Thus, the conservatism in terms of safety is equal to the difference between the margin and the TPU.

In ISA method 1, the TCU used for calculating the total channel uncertainty includes testable uncertainties of transmitter, signal processing device, and PPS. However, the TPU which is a portion of the TCU is relatively small. Since the conservatism of APR1400 method to ISA method 1 depends on the margin used for calculating the TSP, a quantitative evaluation is necessary to identify the conservatism between them.

2.4. Conservatism Evaluation

The high steam generator level (HSGL) trip function in which the process is increasing toward the analytical limit during a design basis event is selected to quantitatively evaluate the conservatism of APR1400 method.

For APR1400 HSGL trip function, the uncertainty data used for calculating the PPS TSP is shown in Table I. In particular, the TPU is zero because the uncertainty of a digital processor module including the TSP is negligible. The margin of 0.5% which is greater than TPU is generally used for calculating the PPS TSP in Korean NPPs.

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
Margin	0.5

In order to evaluate TSPs for HSGL trip function, we consider that the analytical limit is X% assumed and accepted in safety analysis. Using (1) and (2), TSPs of ISA methods 1 and 2 are calculated as X-4.827% and X-3.437%, respectively. Using (3), the TSP of APR1400 is calculated as X-3.937%. Therefore, APR1400 TSP is more conservative than ISA method 2 by the amount of 0.5% margin since the TPU is zero. However, APR1400 TSP is less conservative than ISA method 1. Regarding ISA method 1, arithmetic uncertainty combination method is too conservative in consideration of the random and independent characteristics.

As a result, APR1400 TSP determination method is reasonable to ensure that the process variable does not exceed the analytical limit during a design basis event since it fulfills ISA method 2 with further margin.

3. Conclusions

The PPS TSP determination method of APR1400 is evaluated to satisfy ISA method 2 that uses an appropriate uncertainty combination way of SRSS approved by regulatory authorities with regard to random and independent uncertainties. Therefore, it is concluded that the TSP established by APR1400 methodology can prevent the corresponding process parameter from exceeding the analytical limit assumed in safety analysis.

REFERENCES

[1] Setpoints for Nuclear Safety-Related Instrumentation, ISA-S67.04, Part I, Sep. 1994.
[2] Setpoint for Safety-Related Instrumentation, U.S.NRC Regulatory Guide 1.105, Rev. 3, Dec. 1999.
[3] Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation, ISA-RP67.04, Part II, Sep. 1994.