

Setpoint Evaluation Technique Considering Instrument Uncertainty Change

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1. Introduction

The Plant Protection System (PPS) trip setpoint (TS) is established in accordance with the regulatory requirements and industry standards to ensure that it does not exceed the corresponding analytical limit (AL) during a design basis event [1-3]. The AL is not only an analysis setpoint used in safety analysis for a nuclear power plant, but also a starting point to determine an appropriate TS by incorporating a total channel uncertainty. Thus, when a process variable increases under a design basis event condition, the TS is determined by subtracting from the analytical limit the final instrument uncertainties confirmed by equipment suppliers. However, instrument uncertainties could be changed by equipment upgrade, analysis method modification, or additional uncertainties found during commercial operation. In this case, the TS must be reevaluated using the changed uncertainty. The results of the evaluation are classified as three types. Firstly, the PPS TS can remain its original value when the minor uncertainty change does not affect the setpoint calculation. Secondly, if the changed uncertainty is sufficiently greater than the existing value, the PPS TS can be modified conservatively in terms of safety in a nuclear power plant. For the PPS TS, conservatism in terms of safety is defined as a status that the PPS safety functions are early initiated by the increasing difference between the TS and the AL. On the other hand, if the TS approaches the AL, the initiation of PPS safety functions will be delayed. This change is non-conservative in terms of safety. Lastly, the PPS TS can be moved to the non-conservative direction while the reduced instrument uncertainty causes setpoint modification. Regarding the first and second cases, there is no consideration except incorporating the evaluation result even though the operating margin decreases. Since the third case indicates that the existing PPS TS is more conservative in the aspect of safety, it is not definitely appropriate to apply a newly calculated TS to the PPS. Therefore, it is necessary to develop a new setpoint evaluation technique to determine an optimized TS.

This paper proposes a new method that determines a reasonable PPS TS when a non-conservative value in terms of safety is calculated by instrument uncertainty change.

2. Methods and Results

To determine a new TS in case where a total channel uncertainty is reduced due to any instrument uncertainty change, a new method to calculate the final TS is presented and then the quantitative evaluation is also carried out to ensure the proposed method is reasonable.

2.1. Setpoint Evaluation Method

Fig. 1 illustrates a general PPS TS evaluation method that incorporates instrument uncertainty change. First of all, the Draft TS 1 is calculated by subtracting total channel uncertainty from the AL. The allowable value 1 is calculated by adding the PPS periodic test uncertainty to the draft TS 1. Finally, the TS 1 is established by subtracting some margin from the allowable value 1. If instrument uncertainty is changed to a smaller value than the original one, the total channel uncertainty is also reduced as illustrated in Fig. 1. Thus, should the same method used for calculating TS 1 be applied, the determination of the TS 2 will be less conservative in terms of safety.

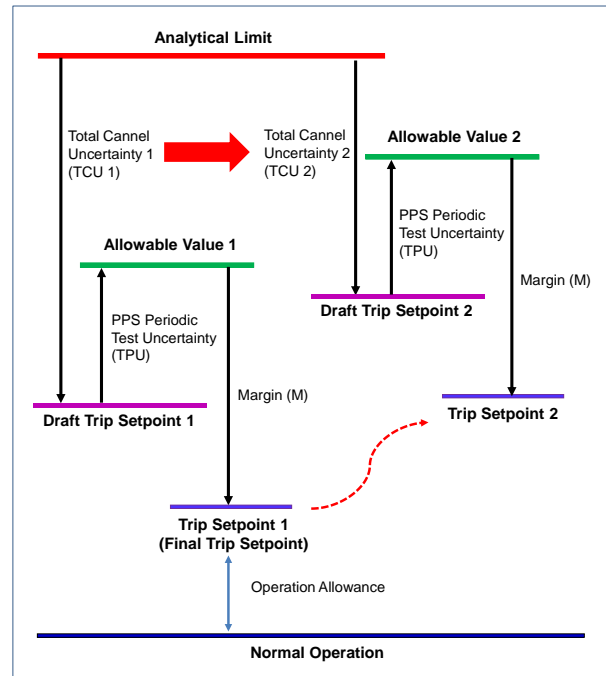


Fig. 1. PPS trip setpoint evaluation due to instrument uncertainty change

The calculations of TS 1 and TS 2 are given by equations (1) and (2), respectively.

$$TS 1 = AL - (TCU 1 - PPTU + M) \quad (1)$$

$$TS 2 = AL - (TCU 2 - PPTU + M) \quad (2)$$

Where:

TS 1 = trip setpoint 1

TS 2 = trip setpoint 2

AL = analytical limit

TCU 1 = total channel uncertainty 1

TCU 2 = total channel uncertainty 2

PPTU = PPS periodic test uncertainty

M = Margin

Since the TS 2 determined by (2) ensures that the process variable does not exceed the AL during a design basis event, it can be used as a new TS for the PPS. However, the new one that is less conservative than the TS 1 causes the initiation of safety functions to be postponed.

To avoid a non-conservative TS, a new method to calculate a reasonable TS value is given by equation (3). TS_{final} indicates a final trip setpoint.

$$\text{If } TCU\ 1 > TCU\ 2, \\ TS_{final} = AL - (TCU1 - PPTU + M) \quad (3)$$

If a newly evaluated TCU 2 is less than the existing uncertainty value of TCU 1, TS 2 is calculated more highly than TS 1. In calculating TCU 1 and TCU 2, it is required to reflect all relevant uncertainty factors including common ones. However, TS 2 does not affect the safety functions because it is calculated by the acceptable method to determine safety-related trip setpoints.

TS 1 guarantees that the AL is not exceeded using the setpoint determination method in compliance with the related regulatory guide and industry standards. In addition, TS 1 has already been confirmed to be appropriate in performing the PPS safety functions during commercial operation. Therefore, the final TS can be determined by (3) in which the final value is the same as TS 1.

2.2. Quantitative Evaluation

To quantitatively evaluate the appropriateness of the proposed method, the high steam generator level (HSGL) trip function for the advanced power reactor 1400 (ARPI400) is chosen and it has a characteristic that the process variable is increasing toward the analytical limit during a design basis event.

For the HSGL trip parameter, the typical uncertainty data used to calculate the PPS TS is shown in Table I. The TCU 1 of 3.437% is based on [4] and the TCU 2 is an assumed value due to anticipated instrument uncertainty reduction. Particularly, the PPTU is negligible because the uncertainty of a digital processor module including the TS is extremely small. In order to reduce the possibility of exceeding the AV during a periodic surveillance test, the margin that is greater than

the PPTU is generally used to calculate the PPS TS in Korean nuclear power plants [4].

Table I: Typical Uncertainty Data for HSGL Trip Function

Parameter	Value (%)
Total Channel Uncertainty 1 (TCU 1)	3.437
Total Channel Uncertainty 2 (TCU 2)	3.125
PPS Periodic Test Uncertainty (PPTU)	0
Margin (M)	0.5

The typical AL of 95% for the HSGL trip function is assumed to evaluate a new TS. Using (1) and (2), TS 1 and TS 2 are determined as 91.063% and 91.375%, respectively. As the TS 2 is higher than the TS 1, the initiation of the HSGL trip function will be delayed. This relatively causes a non-conservative TS 2 in the aspect of safety. Using (3), the final TS is determined as the same value of TS 1.

As a result, the proposed TS determination method is reasonable since the safety of a nuclear power plant is verified more conservatively and the operating margin was confirmed through commercial operation.

3. Conclusions

After a safety-related trip setpoint is determined and applied to the PPS, it needs to be reevaluated if the instrument uncertainty is changed to a larger or smaller value than the original one. When the instrument uncertainty increases, the new TS that is more conservative than the original one shall be applied to the PPS.

However, since the reduced instrument uncertainty causes a non-conservative TS, a new method proposed can be used to establish the final PPS TS that is the same as the existing one. This approach prevents the PPS TS from changing to a non-conservative value and can reduce the burdens of modifying the TS, revising setpoint documents, and performing relevant tests. Therefore, it is concluded that the proposed TS determination method is reasonable to obtain an appropriate setpoint in terms of both safety and performance.

REFERENCES

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