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Variable Setpoint Determination Methodology for the 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

All trip setpoints for the Plant Protection System (PPS) are analyzed, determined, and implemented in accordance with regulations and industry standards. The PPS setpoint methodology is divided into two types that include fixed and variable setpoints. U.S NRC Regulatory Guide [1] that endorses ISA S67.04 Part I [2] illustrates the relationship between setpoints and uncertainties by using a fixed type of analytical limit. A trip setpoint set into the PPS is determined from the corresponding analytical limit that is assumed in carrying out safety analysis to verify that the process value does not exceed the safety limit during design basis events [3]. If the analytical limit is analyzed as a fixed type, the trip setpoint should be determined from the analytical limit.

However, if the analytical limit is a variable type tracking the process value, the variable trip setoint should also be established. The rising trip of a variable analytical limit consists of three trip parameters of Ceiling, Step, and Rate. Ceiling is a maximum value that the variable setpoint can be within the allowed range. Step is the difference between the process input signal and the variable setpoint. Rate is the maximum ratio at which the variable trip setpoint can increase or decrease.

Although a variety of methodologies for a fixed type setpoint have been proposed [3,4], the variable setpoint method has not been actively studied. Therefore, the variable setpoint determination method for the PPS for the Advanced Power Reactor 1400 (APR 1400) is proposed herein to fully cover all setpoint types of the PPS. In addition, the result of calculating variable trip setpoints for the Variable Overpower Trip (VOT) function by applying the proposed method is presented.

2. Methods and Results

The PPS setpoint determination method using a rate limited variable type is proposed and the setpoint calculation results are also provided herein.

2.1 Parameters of variable setpoint

The variable setpoint is determined using three parameters; Ceiling, Step, and Rate. Regarding Ceiling parameter, the draft Ceiling setpoint is determined subtracting the total channel uncertainty from the Ceiling analytical limit, the Ceiling allowable value is calculated adding the PPS periodic test uncertainty to the draft Ceiling setpoint, and the Ceiling setpoint is finally established from the Ceiling allowable value by subtracting the margin that is greater than the PPS periodic test uncertainty as shown in Figure 1. Additionally, the Floor means a minimum value that the variable setpoint can be under all operating conditions. The variable setpoint can move within the variable setpoint range between the Ceiling setpoint and the Floor.

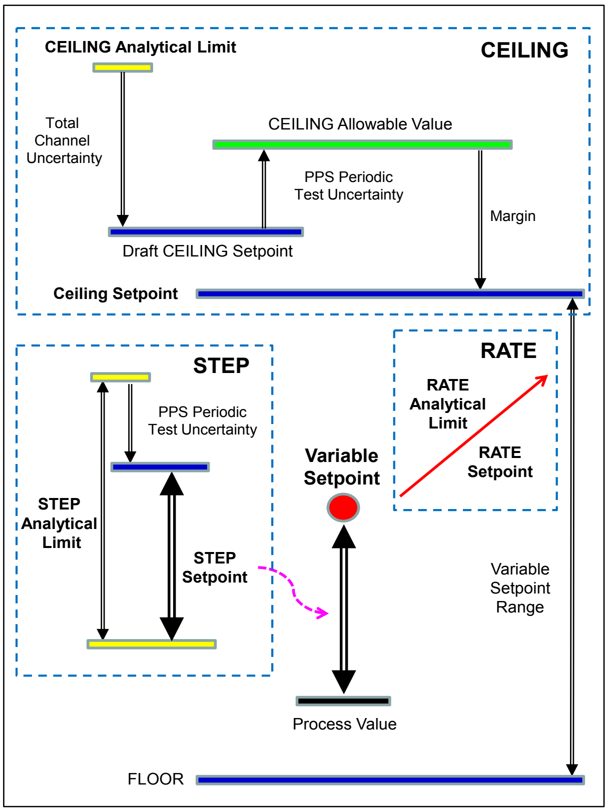

Fig. 1. Variable Setpoint Relationship for the VOT Function

Regarding Rate and Step parameters, the Rate setpoint is the same as the Rate analytical limit, and the Step setpoint is determined subtracting the PPS periodic test uncertainty from the Step analytical limit. Since the variable setpoint tracks the process value in the same bistable processor, no uncertainty is required to determine the Rate setpoint from the Rate analytical limit. In addition, the PPS periodic test uncertainty is only required to determine the Step setpoint from the band of the Step analytical limit, because the Step value is calculated in the digital bistable processor.

A variable setpoint is bounded by three constraints of Ceiling, Step, and Rate. Firstly, the variable setpoint cannot exceed the Ceiling. Secondly, the variable setpoint should be maintained to keep the interval of Step from the process value. Thirdly, when the process value increases quickly the variable setpoint needs to ascend without exceeding the ratio of Rate.

2.2 Ceiling Setpoint

The Ceiling setpoint for the VOT function is given by (1).

$$CS = AL - (TCU - PPS\ PTU + M) \quad (1)$$

Where:
CS = ceiling setpoint
AL = analytical limit
TCU = total channel uncertainty
PTU = periodic test uncertainty
M = Margin

Table I shows all data to determine the ceiling setpoint. In accordance with the proposed ceiling setpoint calculation method, the ceiling setpoint of 110.4 %Power is calculated using the analytical limit, total channel uncertainty, draft setpoint, PPS periodic test uncertainty, allowable value, and margin. This approach is similar to the fixed setpoint determination methodology.

Table I: Ceiling Setpoint

Setpoint/Uncertainty	Unit (%Power)
Analytical Limit	116.5
Total Channel Uncertainty	5.036
Draft Setpoint	114.646
PPS Periodic Test Uncertainty	0
Allowable Value	111.4
Margin	1.0
Ceiling Setpoint	110.4

2.3 Rate Setpoint

As indicated in Table II, the Rate setpoint of 15.0 %Power/min is equal to the analytical limit, since the variable setpoint has a feature to track the process value.

Table II: Rate Setpoint

Setpoint	Unit (%Power/min)
Analytical Limit	15.0
Rate Setpoint	15.0

2.4 Step Setpoint

The Step setpoint of 14.0 %Power is identical to the analytical limit because the PPS periodic test uncertainty is zero as described in Table III.

Table III: Step Setpoint

Setpoint/Uncertainty	Unit (%Power)
Analytical Limit	14.0
Step Setpoint	14.0
PPS Periodic Test Uncertainty	0
Allowable Value	14.0

2.5 Variable Setpoint Calculation Results

The setpoints and allowable values of Ceiling, Rate, and Step are presented in Table IV. When the process value is higher than or equal to 124.4 %Power the Ceiling setpont maintains at 110.4%. If the process value is lower than 124.4 %Power the variable setpoint starts to track the variation of the process value.

Table IV: VOPT Setpoint

	Setpoint	Allowable Vale
Ceiling	110.4 %Power	111.4 %Power
Rate	15.0 %Power/min	15.0 %Power/min
Step	14.0 %Power	14.0 %Power

3. Conclusions

The variable setpoint determination methodology has been established and then applied to the APR1400. The proposed method that determines three constraints of Ceiling, Rate, and Step shows the relationship between each constraint and the actual variable setpoint. Along with the fixed type setpoint method, the proposed method covers all kinds of the PPS setpoints.

REFERENCES

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