Spurious Trip Reduction Methodology for the Plant Protection System Using a Variable Trip Approach

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1. Introduction

The analytical limit (AL) is an analysis setpoint utilized in carrying out safety analysis in order to ensure that the process value does not exceed the safety limit [1-2]. When the process value arrives at the AL, it is considered that the safety function is initiated. After the instrumentation and control (I&C) system response time, the safety function is assumed to be completed [3]. However, the AL could not be set into the bistable processor of the plant protection system (PPS), because the AL does not incorporate the I&C system's channel uncertainty. So, the trip setpoint should be determined from the associated AL by considering the total channel uncertainty [1-2]. If the AL is a fixed type, the corresponding trip setpoint is determined as a fixed one. The variable trip setpoint is also calculated from the variable type of the AL. Most safety I&C system setpoints are calculated based on the fixed setpoint calculation method [1-2]. The variable setpoint method for the PPS has been studied to establish the variable trip setpoint from the variable AL [4].

However, if a process signal contains a high noise level, the variable setpoint is less sensitive than the fixed setpoint. Because the variable setpoint tracks its process signal, the process noise is incorporated in determining the variable setpoint. The type change of the AL causes a lot of licensing issues which include a new plant simulator development for safety analysis and the relevant setpoint calculation method improvement for the safety I&C system. The simple and reliable way to resolve the issue is to calculate the variable trip setpoint from the fixed analytical limit. This paper proposes a new method to calculate the variable setpoint from the fixed AL. The proposed method using a variable trip approach is applied to the Advanced Power Reactor 1400 (APR1400).

2. Methods and Results

The Low Reactor Coolant Flow (LRCF) trip function provides protection against a reactor coolant pump sheared shaft event. With regard to a design basis accident, the LRCF trip function also provides protection against a steam line break with loss of off-site power. In these events, the reduction of reactor coolant flow results in the reduction in the differential pressure (DP) across the primary side of the affected steam generator.

The LRCF trip function uses a variable setpoint module to initiate a reactor trip. Under steady state conditions and during a transient, the variable trip setpoint will stay below the DP input signal by a preset value called the trip function parameter STEP, unless limited by a preset maximum decreasing RATE determined by the parameter FLOOR, as shown in Fig. 1.

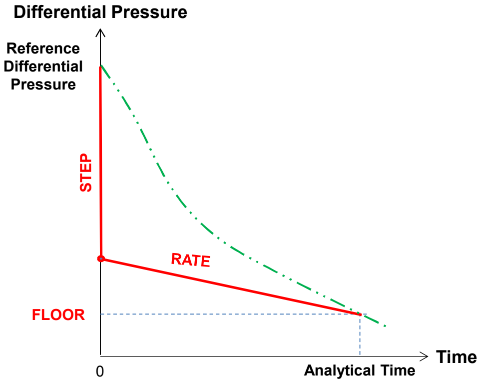

Fig. 1. Relationship between Trip Function Parameters

This study proposes a method to reduce spurious reactor trip using a variable setpoint. The variable setpoint calculation process is shown in Fig. 2.

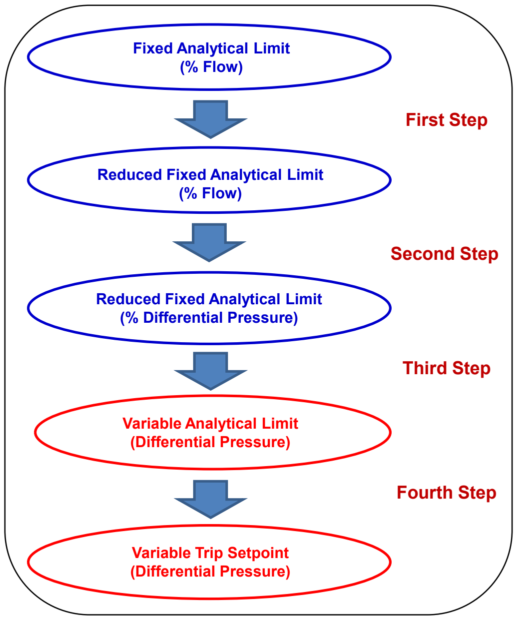

Fig. 2. Variable Setpoint Calculation Process

2.1. First Step

Firstly, the original AL is reduced using the actual I&C system response time instead of the analytical response time assumed in the safety analysis. The actual I&C response time should be shorter than the corresponding analytical response time. The reduced AL still has a percent flow unit and is determined using the margin between the analytical and actual I&C system response times.

Table I shows the reduced fixed AL of 69.6% Flow which is derived by using the actual I&C response time of 0.7 s

Table I: Reduction of Fixed AL for Steam Line Break Event

Analytical Limit	I&C Response Time
70% Flow	0.85 s
69.6% Flow	0.7 s

2.2. Second Step

Secondly, the fixed AL with a percent flow is converted to a fixed AL with a percent DP unit, using the relationship that the DP is proportional to the square of flow. The reduced fixed AL with a percent DP unit is listed in Table II.

2.3. Third Step

Thirdly, the analytical function parameters FLOOR, STEP, and RATE are derived from the fixed AL with a percent DP, using the reference DP. The FLOOR is calculated from multiplying the reference DP by the fixed AL with a percent DP unit. The STEP should be determined less than the difference between the reference DP and the FLOOR, since the RATE becomes zero if the STEP is determined as the maximum value. The function parameters for the variable AL is indicated in Table II by considering the reference DP of 1400 cmH_2O.

2.4. Fourth Step

Fourthly, the trip function parameters FLOOR, STEP, and RATE are calculated from the analytical function parameters by considering I&C system's channel uncertainty. The parameters FLOOR and STEP are calculated by considering both the total channel uncertainty and additional margin. Since the variable setpoint tracks the process value in the same cycle time of the bistable processor, the RATE is the same as the derived parameter RATE for the AL.

The FLOOR and STEP for the LRCF function are given by (1) and (2), respectively.

$$F = AF + (TCU + M) \quad (1)$$

$$S = AS - (TCU + M) \quad (2)$$

Where:
F: floor
S: step
AF: analytical floor
AS: analytical step
TCU: total channel uncertainty
M: Margin

The STEP, RATE and FLOOR for the variable trip setpoint are provided in Table II. Particularly, the RATE of 3.0 cmH_2O/s of the variable trip setpoint is the same as that of the variable AL.

2.5. Setpoint Calculation Results

The LRCF trip function parameters is derived from the original fixed AL with the percent flow unit by using the proposed method, as shown in Table II.

Table II: LRCF Setpoints

Setpoint		Values
Fixed AL (Flow)		70% Flow
Reduced Fixed AL (Flow)		69.6% Flow
Reduced Fixed AL (DP)		48.4% DP
Variable AL	STEP	700.0 cmH_2O
	RATE	3.0 cmH_2O/s
	FLOOR	677.6 cmH_2O
Variable Trip Setpoint	STEP	646.7 cmH_2O
	RATE	3.0 cmH_2O/s
	FLOOR	730.9 cmH_2O

3. Conclusions

The new setpoint determination method using a variable trip approach has been applied to the APR1400. Since the LRCF variable trip setpoint tracts the measured process value including noise, it is possible to reduce the possibility of spurious reactor trip.

REFERENCES

[1] Setpoint for Safety-Related Instrumentation, U.S.NRC Regulatory Guide 1.105, Rev. 3, Dec. 1999.
[2] Setpoints for Nuclear Safety-Related Instrumentation, ISA-S67.04, Part I, Sep. 1994.
[3] C. J. Lee and J. H. Yun, "Integrated Response Time Evaluation Methodology for the Nuclear Safety Instrumentation System," IEEE Trans. Nucl. Sci., vol. 64, no. 6, pp 1211-1218, Jun. 2017.
[4] C. J. Lee and J. H. Yun, "Variable Setpoint Determination Methodology for the Plant Protection System," Transactions of the Korean Nuclear Society Autumn Meeting, Oct. 2017.