Development of a Seismic Setpoint Calculation Methodology Using a Safety System Approach

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1. Introduction

The Automatic Seismic Trip System (ASTS) automatically actuates reactor trip when it detects seismic activities whose magnitudes are comparable to a Safe Shutdown Earthquake (SSE), which is the maximum hypothetical earthquake at the nuclear power plant site. To ensure that the reactor is tripped before the magnitude of earthquake exceeds the SSE, it is crucial to reasonably determine the seismic setpoint. The trip setpoint and allowable value for the ASTS for Advanced Power Reactor (APR) 1400 Nuclear Power Plants (NPPs) were determined by the methodology presented in this paper.

2. Methods and Results

2.1 ASTS Configuration

The ASTS consists of sensor module, ASTS cabinet, and motor generator set circuit breaker. The sensor module is divided into seismic sensor, low pass filter, bipolar to unipolar converter, and voltage to current converter. ASTS cabinet includes analog input module, bistable, and 2/4 coincidence logic. Fig. 1 illustrates the ASTS block diagram.

In order to determine the ASTS trip setpoint and allowable value, all uncertainty elements caused by corresponding equipment that is from seismic sensor to bistable are required to be evaluated. Since the ASTS trip setpoint is set into bistable in the ASTS cabinet, the rear portion of bistable does not need to be considered in calculating the ASTS total channel uncertainty.

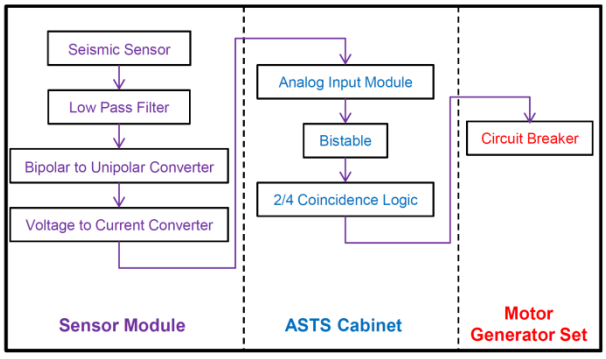

Fig. 1. ASTS Block Diagram

2.2 PPS Setpoint Calculation Methodology

The setpoint calculation methodology for the Plant Protection System (PPS) complies with the nuclear regulations and industry standards [1-3]. The PPS is an important safety system that generates signals to actuate reactor trip when the monitored process value exceeds the trip setpoint. The trip setpoint is determined from the analytical limit by considering the total channel uncertainty that is calculated by combining all identified uncertainty elements in the PPS channel. The criterion of conservatism prioritizes an early reactor trip.

The allowable value is less conservative than the trip setpoint by the amount of the PPS cabinet periodic test uncertainty. This error, already included conservatively in the trip setpoint, accommodates the expected measurable equipment drift that could occur in a specified calibration interval. The final trip setpoint is a more conservative value than the allowable value by some margin. The margin is greater than the PPS cabinet periodic test error to reduce the possibility of the trip setpoint exceeding the allowable value. The PPS setpoint methodology is shown in Fig. 2 that depicts a rising trip.

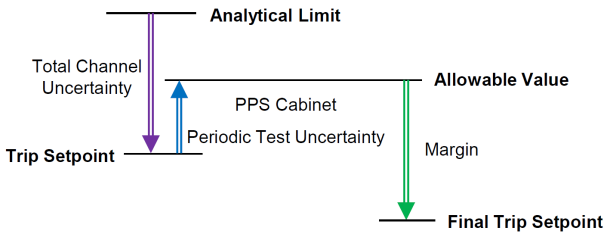

Fig. 2. PPS Setpoint Calculation Methodology

2.3 ASTS Setpoint Calculation Methodology

The setpoint calculation methodology for the ASTS is more conservative than that of the PPS. The ASTS allowable value is determined by considering both total channel uncertainty and some margin. The biggest difference of the setpoint calculation methodology between the PPS and ASTS is to conservatively calculate allowable value by adding some margin and excluding periodic test uncertainty. Since there is no enough operating experience for the ASTS, unexpected uncertainty elements might appear in the newly installed system in the NPPs. Therefore, the margin is considered in calculating allowable value. The trip setpoint for the ASTS is determined from the allowable value by considering both ASTS cabinet periodic test

uncertainty and some Margin. By determining a more conservative allowable value that makes the trip setpoint more conservative, the safety of the NNP can be improved in case of large earthquake occurrence. Fig. 3 describes ASTS setpoint calculation methodology.

There is no actual analytical limit for the ASTS because the safety analysis is not conducted for the seismic event that is not categorized as a design basis event. The zero period acceleration (ZPA) obtained from the safe shutdown earthquake (SSE) Floor Response Spectrum (FRS) of the ASTS sensor location is used as the ASTS analytical limit.

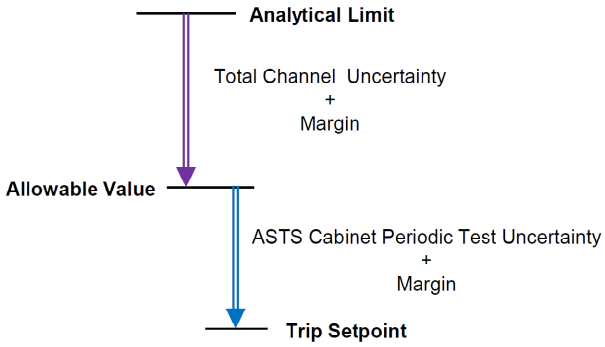

Fig. 3. ASTS Setpoint Calculation Methodology

2.4 ASTS Allowable Value Calculation

In this section the ASTS allowable value calculation for APR1400 is quantitatively performed using the plant specific data.

The ASTS sensor module is located at the 55-foot elevation of the auxiliary building. The ZPA from the SSE FRS of the floor where the sensor module is located is the analytical limit of 0.3 g. The ASTS total channel uncertainty is derived from both sensor module and ASTS cabinet. The "Square-Root-Sum-of-Squares (SRSS)" method is used for combining all random and independent uncertainty elements that exist in their respective equipment. The margin used to calculate the allowable value is 0.00426 g that is engineering judgment to cover the uncertainty evaluation risk caused by a lack of operating history regarding the new system. The allowable value is calculated from the analytical limit by subtracting both total channel uncertainty and margin. Data for determining the ASTS allowable value are shown in Table I.

Table I: ASTS Allowable Value Related Data

Items	Values
Analytical Limit	0.3 g
Total Channel Uncertainty	+/- 0.02174 g
Margin	0.00426 g
Allowable Value	0.274 g

2.5 ASTS Trip Setpoint Calculation

In this section the ASTS trip setpoint calculation for APR1400 is quantitatively performed using the plant specific data.

The trip setpoint for the ASTS is determined from the allowable value by subtracting ASTS cabinet periodic test uncertainty and margin. The allowable value means a limiting value that the trip setpoint may have when the system is tested periodically. The allowable value is less conservative than the trip setpoint by the amount of the ASTS cabinet periodic test uncertainty. The margin added between the trip setpoint and allowable value is considered to reduce the possibility of the trip setpoint exceeding the allowable value during the periodic test. This margin is also being considered in calculating the PPS trip setpoint from the PPS allowable value even though the value of margin is different each other. Data for determining the ASTS trip setpoint are described in Table II.

Table II: ASTS Trip Setpoint Related Data

Items	Values
Allowable Value	0.274 g
ASTS Cabinet Periodic Test Uncertainty	+/- 0.00101 g
Margin	0.00299 g
Trip Setpoint	0.27 g

3. Conclusions

The ASTS that trips the reactor when a large earthquake occurs is categorized as a non safety system because the system is not required by design basis event criteria. This means ASTS has neither specific analytical limit nor dedicated setpoint calculation methodology.

Therefore, we developed the ASTS setpoint calculation methodology by conservatively considering that of PPS. By incorporating the developed methodology into the ASTS for APR1400, the more conservative trip setpoint and allowable value were determined. In addition, the ZPA from the Operating Basis Earthquake (OBE) FRS of the floor where the sensor module is located is 0.1g. Thus, the allowance of 0.17g between OBE of 0.1 g and ASTS trip setpoint of 0.27 g is sufficient to prevent the reactor trip before the magnitude of the earthquake exceeds the OBE. In result, the developed ASTS setpoint calculation methodology is evaluated as reasonable in both aspects of the safety and performance of the NPPs.

This will be used to determine the ASTS trip setpoint and allowable for newly constructed plants.

REFERENCES

[1] Setpoint for Safety-Related Instrumentation, U.S.NRC Regulatory Guide 1.105, Rev. 3, Dec. 1999.
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[3] Nuclear Power Plants-Instrumentation Important to Safety - Determination and Maintenance of Trip Setpoints, IEC-61888, Aug. 2002.