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Spurious Trip Prevention of the Diverse Protection System Using an Improved Setpoint Methodology

Chang Jae Lee [a*], Kwang il Baik [a], Sang Jeong Lee [b]
[a] KECO E&C, Inc., 1045 Daedeok-Daero,Yuseong-gu, Daejeon, 305-353, Korea
[b]Chungnam National University, 99 Daehak-ro, Yuseong-gu, Daejeon 305-764, Korea
[*]Corresponding author:cjlee1@kepco-enc.com

1. Introduction

The Diverse Protection System (DPS) provides a diverse means to trip the reactor to satisfy the requirements related to Anticipated Transients Without Scram as well as Diversity and Defense-In-Depth in digital computer-based Systems [1]. The Advanced Power Reactor 1400 (APR1400) nuclear power plants in Korea have featured the DPS, which has the diverse reactor trip function and the initiation of diverse Auxiliary Feedwater Actuation Signals for the Engineered Safety Feature – Component Control System components. The DPS reactor trip function is based on high pressurizer pressure parameter and high containment pressure parameter. The DPS is a backup system that performs a diverse function when the Plant Protection System (PPS) fails to perform its safety functions. Particularly, the DPS reactor trip function has no interlock that prevents the DPS from performing its own function before the PPS actuates a reactor trip function. In this case, if trip setpoint allowance for the same parameter between the DPS and PPS is not sufficient, the DPS could perform its reactor trip function earlier than the PPS does. Since the allowance for the high pressurizer pressure trip parameter for APR1400 is less than the DPS total channel uncertainty, the DPS setpoint determination methodology is required to be improved in order to avoid the unwanted reactor trip. A new trip setpoint and allowable value were produced by the methodology presented in this paper.

2. Methods and Results

2.1 DPS Trip Setpoint Determination Methodology

The DPS trip setpoint is basically determined by the safety analysis that evaluates whether the consequence of Beyond Design Basis Events (BDBEs) meets their respective acceptance criteria or not by using a best estimate method. The analytical trip setpoint (ATS) is defined as a trip setpoint established by the best estimate safety analysis for the BDBEs. The ATS is not an analytical limit established by a safety analysis for DBEs but another trip setpoint that can be directly applicable to the DPS because the best estimate safety analysis incorporates the DPS channel uncertainties. However, the analytical limit used for determining the PPS trip setpoint should be also utilized for the DPS trip setpoint in order to improve the safety of the NPPs.

When the final trip setpoint for DPS as shown in Fig.1 is greater than or equal to the ATS as in Cases I and II, the ATS should be determined as a new trip setpoint that considers both DBE and BDBE. While the final trip setpoint for DPS is less than the ATS for DPS as in Case III, the final trip setpoint for DPS can be determined as a new trip setpoint. In this case, if the allowance between the new trip setpoint for DPS and the final trip setpoint for PPS is not sufficient, the trip setpoint should be reevaluated. In order to avoid the situation that the DPS trips the reactor earlier than the PPS does, the less conservative ATS can be determined as a final DPS trip setpoint. The reason is that the acceptability of the ATS was already verified by the best estimate safety analysis. The criterion of conservatism prioritizes an early reactor trip.

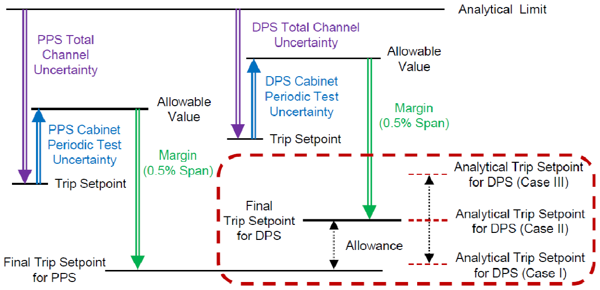

Fig. 1. DPS Trip Setpoint Determination Methodology

2.2 DPS Allowable Value Determination Methodology

While the final trip setpoint for DPS is determined as a new trip setpoint, the allowable value for the final trip setpoint can be determined as a new allowable value for both DBE and BDBE. When the ATS is determined finally as the DPS trip setpoint for both DBE and BDBE, a new allowable value related to the ATS must be determined as depicted in Fig. 2.

The most crucial point is how to determine the margin between the ATS and the new allowable value. The margin between the final trip setpoint for DPS and its allowable value for APR1400 is 0.5%, which has been used for 14 nuclear power plants in Korea. Since the value is sufficiently bigger than the DPS cabinet periodic test uncertainty, the possibility that the trip setpoint exceeds the allowable value can be reduced. Therefore, it is appropriate to use the same margin for determining the new allowable value. The verification of the suitability of the margin is required because the new allowable value should be determined to be less conservative than the ATS.

The allowable value means a limiting value that the trip setpoint may have when the system is tested periodically. In other words, the ATS can be changed to the allowable value. Therefore, the additional best estimate safety analysis should be conducted to verify the suitability of the new allowable value determined for the ATS.

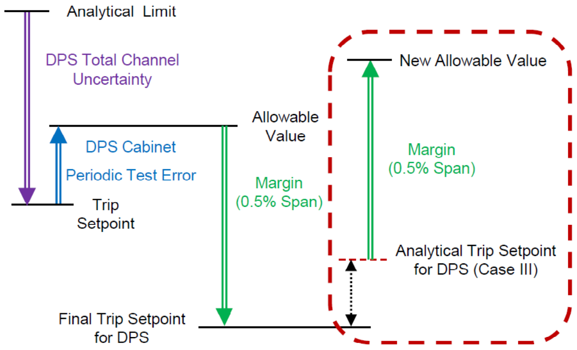

Fig. 2. DPS Allowable Value Determination Methodology

2.3 Quantitative Evaluation of DPS Trip Setpoint

A high pressurizer pressure reactor trip parameter for the APR1400 DPS has no enough allowance between the PPS final trip setpoint and the DPS final trip setpoint as described in Fig. 1. To reduce the possibility of DPS actuating the reactor trip earlier than the PPS does, the ATS for DPS should be determined as a new trip setpoint instead of the DPS final trip setpoint. Although the ATS is less conservative than the DPS final trip setpoint derived from the analytical limit, it was verified by the best estimate safety analysis that the ATS is acceptable. Thus, the safety of the NPPs can be guaranteed by using the ATS. Data for determining the DPS new trip setpoint for the high pressurizer pressure reactor trip parameter in APR1400 are summarized in Table I.

Table I: DPS Setpoint Data

Items	Values
Instrument Range	10.30 ~ 17.16 MPa
Span	6.86 MPa
Analytical Limit	16.64 MPa
Total Channel Uncertainty	+/- 0.140 MPa
DPS Cabinet Periodic Test Uncertainty	Negligible (0 MPa)
Allowable Value	16.49 MPa
Margin	0.035 MPa (0.5% Span)
Final Trip Setpoint	16.46 MPa
Analytical Trip Setpoint	16.55 MPa
New Trip Setpoint	16.55 MPa

2.4 Quantitative Evaluation of DPS Allowable Value

The ATS was determined as a new trip setpoint in accordance with the Table I. A new allowable value related to the new trip setpoint needs to be determined. The new allowable value of 16.585 MPa is determined by adding the margin of 0.035 MPa to the new trip setpoint of 16.55 MPa. In this case, the new allowable value has to be verified by the best estimate safety analysis.

We conducted the best estimate safety analysis for the Steam Line Break (SLB) concurrent with a CCF by using the high pressurizer pressure ATS of 16.62 MPa that has the margin of 1%, 0.07 MPa, from the ATS of 16.55 MPa. The dynamic behaviors of Reactor Coolant System (RCS) pressure during SLB concurrent with a CMF event was simulated using CESEC-III computer programs [2]. The analysis result as illustrated in Fig. 3 shows that the maximum RCS pressure (17.84) MPa is below the acceptance criteria of 22.06 MPa.

Therefore, the new allowable value considering the margin of 0.5% Span is acceptable.

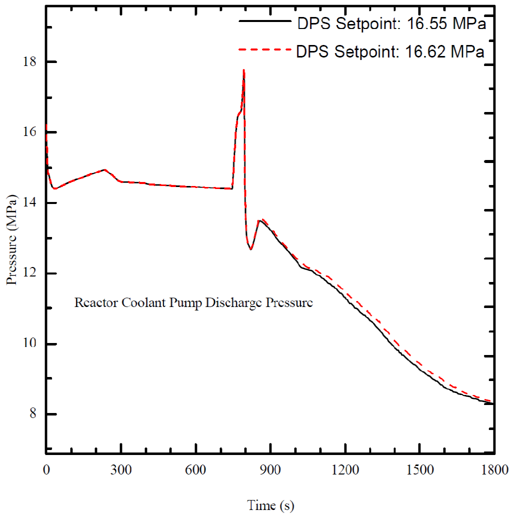

Fig. 3. Reactor Coolant System Pressure for Steam Line Break concurrent with a Common Cause Failure.

3. Conclusions

The spurious trip prevention was improved by the advanced setpoint methodology that proposes a reasonable solution to resolve an insufficient allowance between the PPS trip setpoint and the DPS trip setpoint. In particular, the suitability of the new allowable value determination method was verified by the best estimate analysis using CESEC-III computer.

The improved methodology will be applied to determining the DPS trip setpoint and allowable value for newly constructed plants.

REFERENCES

[1] USNRC, NUREG-0800, BTP 7-19 (Rev. 6), “Guidance for Evaluation of Diversity and Defense-in-Depth in Digital Computer-based Instrumentation and Control Systems”, 2012.

[2] Nuclear Power Systems, CESEC Digital Simulation of a Combustion Engineering Nuclear Steam Supply System, CENPD-107, Combustion Engineering Inc., Windsor, CT, 1974.