SAFETY RELATED INSTRUMENT SETPOINT METHODOLOGY FOR BALANCE-OF-PLANT EQUIPMENT

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SAFETY-RELATED INSTRUMENT SETPOINT

METHODOLOGY FOR BALANCE-OF-PLANT EQUIPMENT

1.0 PURPOSE

This document describes the method of determining safety-related instrument setpoints for balance-of-plant equipment. This methodology uses the guidelines of NRC Regulatory Guide 1.105, Instrument Setpoints, Revision 1 and Revision 2 which was issued for comment. This document describes the steps to establish setpoint criteria and perform setpoint calculations.

2.0 SCOPE

Safety-related instrument setpoints must be determined to account for the tolerance (error) between a process limit established in plant safety analyses and the actual setpoint instrument measurement capabilities. The end product of setpoint calculations are the allowable value(s) and trip setpoint numbers (defined in Section 4.0) that appear in the limiting safety system settings portion of the plant technical specifications or FSAR.

Determining an instrument setpoint is a two-step process. The first step is to define the plant safety criteria upon which the setpoint is based. The criteria will provide the safety limit value, the process and environmental conditions of the instruments, time-dependent variables (e.g., calibration interval), and other factors that impact setpoint selection. The second step is the actual instrument setpoint calculation. The criteria from the first step must be translated into numbers for instrument inaccuracies resulting from range selection, seismic and environmental effects, drift calibration, etc.

3.0 REFERENCES

1. Regulatory Guide 1.105, Instrument Setpoints, Revision 1 and Proposed Revision 2 to Regulatory Guide 1.105, Instrument Setpoints, December 1981

2. Draft F of ISA Standard S67.04, Setpoints for Nuclear Safety-Related Instrumentation used in Nuclear Power Plants, May 22, 1979

4.0 DEFINITIONS

4.1 ACCURACY

The degree of conformity of an indicated value to a recognized accepted standard value or ideal value, usually measured in terms of inaccuracy and expressed as accuracy. Accuracy is normally expressed in percent of instrument measurement span.

4.2 ALLOWABLE VALUE

The sum (or difference, depending on high or low setpoint) of the process limit value and the maximum instrument error and process measurement error. Allowable values are further defined below for 30 days and 18 months. The 30-day allowable values are used when required by plant technical specification surveillance requirements.

4.3 30-DAY ALLOWABLE VALUE

The 30-day allowable value applies to the instrumentation tested every 30 days during the channel check (e.g., logic cabinet, instrument modules, excluding sensor). The 30-day allowable value will include instrumentation (e.g., logic cabinet, instrument modules, excluding sensor) drift over 30 days, plus the error of the test equipment used for the 30-day test (refer to Figure 1).

4.4 18-MONTH ALLOWABLE VALUE

The 18-month allowable value applies to the instrumentation tested every 18 months during the channel calibration test (e.g., the entire instrument string from sensor through actuation contact). The 18-month allowable value will include the 30-day allowable value plus drift over 18 months for the equipment (e.g., sensors) not tested in the channel check and test equipment error exceeding that used for channel check (refer to Figure 1).

4.5 CALIBRATION BAND

The band between the upper and lower setpoint limits within which a setpoint will be adjusted during calibration (refer to Figure 1).

4.6 DRIFT

The change in an instrument input-output relationship over the calibration interval of the instrument (refer to Figure 1).

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4.7 INSTRUMENT INACCURACY

The inaccuracy associated with an instrument or instrument string (such as engineered safety features actuation system) due to manufacturing tolerances, environment, seismic and power supply effects, or other effects that cause the instrument input-output relationship to change during operation.

4.8 PROCESS LIMIT

Equal to the safety limit less an allowance for transient overshoot and system response time.

4.9 PROCESS MEASUREMENT ERROR

Error due to sensor location or the method of measuring the desired parameter. This error may be due to sensor placement (e.g., pressure error due to piping losses, etc, between sensor and desired parameter) or method of measurement (e.g., level measured by head type sensor is affected by change in process liquid density due to temperature variations).

4.10 SAFETY LIMIT

The limiting value of a process variable from engineering analysis (e.g., pressure rating of a vessel) required in the plant safety analyses to perform a specified protective trip function (refer to Figure 1).

4.11 TEST EQUIPMENT ACCURACY

The error contribution to setpoint adjustment due to the calibration test equipment (refer to Figure 1).

4.12 TRIP INSTRUMENTATION

All instruments involved in generation of a bistable trip. For analog loops, this includes at least a process transmitter and a trip bistable. For digital loops, this includes at least the process switch. Intermediate signal conditioning instruments are included if they contribute any error to the overall trip function.

4.13 TRIP SETPOINT

The value of a process variable, expressed in engineering units and measured at the bistable input, that causes the bistable to trip (refer to Figure 1). Note that the value of the trip setpoint recorded in the plant technical specifications or FSAR

will be different than the actual trip setpoint used for plant operation.

5.0 INSTRUMENT SETPOINT CRITERIA

Before a setpoint calculation is performed, the need and bases for the trip setpoint are defined. This section describes how the following criteria are determined:

a. The safety function performed by the trip instrumentation

b. The plant parameter sensed by the trip instrumentation

c. The safety limit for the plant parameter

d. The time during the accident when the trip must occur

e. The environment at the trip instrumentation before the trip

f. The trip instrumentation itself

g. The calibration interval(s) for the trip instrumentation

h. An itemized list of all trip instrumentation error contributors

i. Combination of instrument errors to calculate total string error

With the above criteria established, the actual setpoint calculation can determine both the allowable value(s) and trip setpoint numbers for the plant technical specifications. Plant operators will further refine the trip setpoint number to determine a calibration band for the final trip setpoint value.

5.1 SAFETY FUNCTION

The safety function performed by a particular set of trip instrumentation can be found in one or more of the following documents:

a. FSAR

b. System descriptions

c. Equipment specifications

d. Logic diagrams

e. Loop diagrams

The safety functions are documented on the setpoint calculation, giving a description of the plant accident or transient conditions under which a protection system trip is required.

5.2 PLANT PARAMETER

The specific plant parameter sensed by the trip instrumentation to perform the safety function is identified. This information is immediately apparent when the instruments performing the trip function are located.

5.3 SAFETY LIMIT

The safety limit is the starting point for the entire setpoint calculation. The safety limit is usually stated in the plant safety analyses (FSAR Chapters 6 and 15) for the major safety functions (e.g., reactor protection, emergency core cooling). For safety functions that are equipment protection related (e.g., letdown cooler isolation), the safety limit may not be formalized in a safety analysis. For these cases, the safety limit should be taken as the limit used in the system design documents (system descriptions, logic diagrams, design calculations) for the safety function trip.

5.4 TIME TO TRIP

An important consideration in calculating a setpoint is the amount of time after an accident during which the trip instrumentation must function. The time to function will determine the environmental conditions that will influence instrument string error. Temperature and radiation are both significant contributors to sensor error, particularly for electronic transmitters located inside containment. Limiting the sensor environmental effects to the time period until trip occurs will limit the error contribution to a realistic value. When the environmental effects are calculated, the setpoint calculation states any assumptions on time to trip.

5.5 ENVIRONMENT

The relationship between instrument environment and time to trip is discussed in Section 5.4. The specific environment for each instrument in the trip string is determined using instrument data sheets, equipment specifications, and the equipment qualification

data base. These environmental data are used to calculate instrument errors due to temperature, humidity, pressure, seismic, and radiation effects.

5.6 INSTRUMENTS

All instruments that contribute to the trip function are identified using plant design documents and/or drawings for vendor-supplied equipment, where appropriate. Any tie-ins of the trip instrument string with other instrumentation are also identified.

The trip instrumentation is shown in the setpoint calculation by a block diagram. The plant instrument number, as well as the manufacturer data for model number, range, span, etc, are identified.

5.7 CALIBRATION INTERVAL

The interval between successive trip instrumentation calibrations determines the period over which instrument drift is considered. Calibration intervals are listed in the plant technical specification surveillance requirements.

Different instruments in the trip string may have different calibration intervals. For example, a transmitter located in an inaccessible area during power operation may be calibrated only during refueling outages. However, the trip bistable that the transmitter feeds may be calibrated monthly as part of the protection system equipment in the control room or safety-related equipment room. These differences in calibration interval are taken into account in calculating instrument drift of the components in the trip string. In the above case, monthly drift of the bistable plus an 18-month drift of the transmitter would be added together, along with the test equipment error, as part of the margin between the allowable value and trip setpoint (see Figure 1).

5.8 INSTRUMENT ERROR CONTRIBUTORS

As a minimum, the following sources of instrument error are considered in determining the setpoint.

a. The margins between the safety limit and the 18-month allowable value are (see Figure 1):

   1) Transmitter accuracy

   2) Transmitter temperature effects

3) Transmitter radiation effects

4) Transmitter seismic effects

5) Bistable accuracy

6) Bistable temperature effects

7) Bistable seismic effects

8) Bistable relative humidity effects

9) Process measurement error (e.g., effects of change in density of process liquid on ΔP - type level sensors)

b. The margins between the 18-month allowable value and the 30-day allowable value are (see Figure 1):

1) Transmitter drift

2) Transmitter calibration test equipment error

c. The margins between the 30-day allowable value and the trip setpoint upper limit are:

1) Bistable drift

2) Bistable calibration test equipment error

(Note: If only the 18-month allowable value is used, the sources of error noted in Items b and c are both considered over the 18-month interval.)

When the trip instrument string is more complex than a transmitter and bistable, other error contributors are added to the above list. Similarly, if the transmitter or bistable is not subject to some of the above errors, those items are not considered further. Any additional sources of instrument error that are applicable are noted in the calculations.

5.9 COMBINING INSTRUMENT ERRORS

The most conservative approach to combining individual error contributors is to add them. This method is used to determine overall error of a single instrument, unless otherwise justified by test data or analysis. In a two-instrument trip string, this method is also used for overall loop string error, unless otherwise justified by test data or analysis.

In instrument trip strings of three or more instruments or in cases where adding the values gives unrealistic errors that may produce setpoints close to normal plant operating limits, a square-root-of-the-sum-of-the-squares (2σ) method is used.

Use of the 2σ method requires that the individual errors be independent of any common mode influences. Similarly, this method should consider if any errors are unidirectional, rather than "plus or minus" errors. In any case, using the 2σ method must be justified by information in the setpoint calculation regarding lack of common mode influences on errors and the effect of unidirectional errors on the 2σ-method results.

6.0 SET POINT CALCULATIONS

Using the instrument setpoint criteria developed from the guidelines in Section 5.0 as a basis, the setpoint calculation is performed.

With all error contributions for each trip instrument determined, the allowable value and trip setpoint are calculated directly (refer to Figure 1).

The margin between the safety limit and the accident analysis process limit is accounted for in the accident analysis or design calculations. To determine allowable value, all error contributors for the trip instrumentation, except drift and calibration test equipment inaccuracy, are added. This combined error is subtracted from the accident analysis process limit (also called process limit) value determined from the criteria in Section 5.3 of this procedure. (If the setpoint trips on a decreasing rather than increasing value, the error would be added to the process limit.) The resulting number is the allowable value.

The trip setpoint is calculated by subtracting (or adding) the combined drift and calibration test equipment inaccuracies for the trip instrumentation from the allowable value. Note that the only test equipment inaccuracies that must be considered are for the sensor and bistable test equipment. For total trip string calibrations, any intermediate instruments between the sensor and bistable will not contribute inaccuracies to the calibration process due to test equipment because only string input and output are measured.

7.0 CONCLUSIONS

The allowable value(s) and trip setpoint determined in Section 6.0 will be listed in the plant technical specifications or FSAR as operating plant limits.

The errors calculated in Section 6.0 predict the trip instrument behavior. Therefore, maintaining the actual trip setpoint at the trip setpoint value will preclude exceeding the allowable value, even if expected drift occurs. However, maintaining the actual trip setpoint at a single, exact value is not reasonable or practical. Proper calibration practice requires a narrow band in which the setpoint may be adjusted. For this reason, the plant operators will use the trip setpoint value from Section 6.0 as the upper limit of the calibration band for the actual trip setpoint. The calibration band is chosen based on experience and ease of operation.

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FIGURE 1

SETPOINT TERMINOLOGY

Safety Limit

Margin 1

Transient Overshoot
System Response Time

Accident Analysis Process Limit

Margin 2

Instrument Errors Including
Environmental Effects
Process Measurement Errors

Allowable Value (18 Month) for Channel Calibration*

Margin 3

Sensor Drift
Test Equipment Error
Exceeding 30-Day Test
Equipment

Allowable Value (30 day) for Channel Check*

Margin 4

Module/Bistable Drift
Module/Bistable Test Equipment
Error

Field Setting Upper Limit (Technical Specification* Trip Setpoint)

Margin 5

Calibration Band

(+)
Field Setting
(-)
Field Setting Lower Limit

*Values published in plant technical specification or FSAR