Development of an Update to ISA S67.04 and RP 67.04: "Setpoints for Nuclear Safety-Related Instrumentation for Nuclear Power Plants"

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1. ABSTRACT

The purpose of this paper is to provide an overview of the update to International Society of Automation (ISA) Standard ISA S67.04 – 2006, "Setpoints for Nuclear Safety-Related Instrumentation for Nuclear Power Plants," (Reference 1) and ISA RP 67.04-2000,

"Methodologies for Determination of Setpoints for Nuclear Safety-Related Instrumentation" (Reference 2). Significant advances have occurred on the utility, Nuclear Steam Supply System (NSSS) vendor, and regulatory side, related to improved techniques for analysis and monitoring. These and other changes, including those related to Technical Specifications and surveillance interval extensions, are being included in the latest update to this primary standard for setpoint control in nuclear plants in the U.S. and around the world.

In 2016, the ISA S67.04 Committee agreed to proceed with a revision to this Standard and Recommended Practice, with major updates in the following areas:

1. Definitions – Updates for improved definitions based on TSTF-493, Rev 4 (Reference 3), RIS-2006-17 (Reference 4) and NRC updated Regulatory Guide (RG) 1.105 (Reference 5)
2. 95/95 – Updates based on improved guidance on the development of component input data and analysis techniques for 95% probability/95% confidence calculations
3. TSTF-493, RIS 2006-17 updates for Technical Specification input and to support changes
4. NRC input from updates in the Regulatory Guide 1.105 (Reference 5) and Branch Technical Position BTP-7-12 (Reference 6) revision process.
5. Improved guidance from the Electric Power Research Institute (EPRI) in References 7, 8 and 9.

These standards are being updated with a new version anticipated to be issued as a draft in 2017 and submitted for ISA approval in 2019.

2. Overview of the Revision Process

Since the 2011 reaffirmation of ISA S67.04, updates to the regulatory process have occurred in conjunction with the application of Technical Specification Task Force action TSTF-493, Revision 4 (Reference 3) and other regulatory-related input, including a proposed revision 4 to Regulatory Guide 1.105 (draft Regulatory Guide DG-1141 (Reference 10)), and incorporation of an update to Branch Technical Position BTP-12, Rev 6 (Reference 6). These updates identify the need for a greater focus on the assurance that the setpoint devices perform within required limits and that setpoint devices are regularly monitored to ensure the required performance is being attained. In the previous (2006) version of the ISA S67.04 standard, guidance on surveillance practices had been provided, including the need to address As-Found Tolerance (AFT) and As-Left Tolerance (ALT) and the need for evaluation of the setpoint device performance history in a more systematic way.

The ISA S67.04 Standard Committee is currently considering revising the standard to address the following areas:

- Additional definitions of terms and expanded definitions identified as gaps in Nuclear Regulatory Commission (NRC) DG-1141,
- Provision of a standard method for addressing the analytical limit avoidance probability and appropriate statistical confidence level, as identified within previous guidance in NRC RG 1.105,

- Incorporation of improved guidance developed by the Electric Power Research Institute (EPRI) for establishing statistical confidence in establishing and maintaining setpoints.
- Referencing the definition of tolerance interval as described within NRC NUREG-1475, Revision 1 "Applying Statistics," and a recommended method of combination of uncertainties as defined in ISA Recommend Practice 67.04.02,
- Incorporating standards for performance monitoring to support the ISA 67.04's new performance monitoring methodology and to align with Technical Specification Task Force TSTF-493, Rev 4 (Reference 3), and RIS 2006-17 (Reference 4),

Each of these topical areas are address in detail in the following sections.

3. Definitions

This revision will include an update to Section 3, Definitions, to include agreement within the ISA S67.04 committee to address NRC and industry concerns and clarifications. The review of these definitions is ongoing and includes:

- As-Found Tolerance (AFT)
- As-Left Tolerance (ALT)
- Setting Tolerance vs. Calibration Tolerance vs. Leave Alone Zone
- Limiting Trip Setpoint (LTSP)
- Nominal Trip Setpoint (NTSP)
- Allowable Value (AV) for those plants that include AV values in their Technical Specifications

Additional Definitions will be added/modified, through the committee review, and will address updates and clarifications to meet the needs of users and regulators in applying and reviewing the associated calculations and programs.

4. Addressing the analytical limit avoidance probability and statistical confidence guidance in RG 1.105

The existing version of ISA S67.04 does not specify a standard regarding the appropriate parameters for estimating the magnitude of an allowance for instrument loop performance uncertainty between the calibration setpoint and the process analytical limit. RG 1.105 Rev 3 included an analytical limit avoidance probability and statistical confidence guidance. NRC RG 1.105 states: *"Section 4 of ISA-S67.04-1994 specifies the methods, but not the criterion, for combining uncertainties in determining a trip setpoint and its allowable values. The 95/95 tolerance limit is an acceptable criterion for uncertainties associated with SL-LSSS functions. That is, there is a 95% probability that the constructed limits contain 95% of the population of interest for the surveillance interval selected.*" The RG 1.105 statement identifies a gap in the ISA standard and provides criteria to fill the gap. Uncertainty terms for instrument channels having a significant importance to safety must be estimated using rigorous means.

The Recommended Practice ISA 67.04.02 states: *"The purpose of the setpoint calculation is to ensure that protective actions occur 95 percent of the time with a high degree of confidence before* *the analytical limit is reached."* The probability in the criterion is to provide 95% avoidance probability for reaching or exceeding the analytical limit.

The ISA Committee is currently considering including within the ISA S67.04 standard, a statement regarding how to estimate the magnitude of a standard allowance for instrument channel performance uncertainty, using statistical tolerance intervals for random, independent uncertainty terms. Under consideration is a statement that such allowances must be estimated using statistical methods such that the tolerance interval estimate bounds the uncertainty of interest with a 95% probability, at a 95% confidence level. If there is not sufficient data available to justify a statistical estimate of the uncertainty tolerance interval at the 95/95 level, then a bounding uncertainty term must be determined, and the basis for determining the bounds of the uncertainty must be documented in an engineering analysis supporting the Total Loop Uncertainty (TLU) estimate. However, the incorporation of such a statement presupposes that there is a sufficient sample size of uncertainty data from which to make adequate statistical inferences. The committee and NRC are addressing the issue of sample size versus probability/confidence level, as applied to the uncertainty analysis for both existing and new reactors.

Many phenomenon and effects are considered in determining setpoints that accommodate the expected instrument channel performance uncertainty, including temperature, pressure, humidity, radiation, vibration, seismic, aging, drift, and others. The input data to calculations which determine calibration setpoints come from diverse sources, including factory tests, Environmental Qualification test results (Reference 12, Institute of Electrical and Electronic Engineers (IEEE), IEEE 323, "Qualifying Class 1E Equipment for Nuclear Power Generating Stations"), plant surveillance requirements, and results of processes for applying commercial grade equipment of adequate quality for use in safety related applications. The results of factory performance tests have been reported to have sample sizes which are as large as the production runs of device types, but are often not quantified at a specific confidence level. Environmental qualification tests are costly to perform—therefore they are often of limited sample size to optimize cost. Plant surveillance test results represent potentially large sample sizes, which have been helpful in supporting the application of statistical tolerance interval estimates at high confidence levels to the performance of setpoint calculations supporting fuel cycle/surveillance interval extensions.

The criterion stated in RG 1.105 Revision 3 regarding confidence level includes the words *"for the surveillance interval selected"*, which appears to be related to the evaluation of instrument drift over a specified surveillance interval. Much of the ISA 67.04 committee discussion on addressing the RG 1.105 probability/confidence level requirement has been with regard to the feasibility of application and cost to operating plants, which occasionally make licensing submittals or 10 CFR 50.59 evaluations referencing current NRC guidance. The guidance within RG 1.105 is considered by NRC inspectors and reviewers when evaluating license applications and amendments and when performing inspections. However, final decisions regarding the adequacy of plant safety are made based on the current licensing basis for a plant. Deviations from the guidance applicable to a plant licensing basis need to be justified.

5. Tolerance Interval, Probability and Confidence level of individual uncertainty terms.

A tolerance interval is a statement of probability that a certain proportion of the population is contained within a defined interval. The EPRI document 3002000864-2013 (Reference 9) includes a definition of tolerance interval in Section 6. It includes an assessment of the level of confidence in the statement of probability. For example, a 95/95 tolerance indicates a 95% probability and a 95% level of confidence that 95% of the population is contained within the stated interval.

For safety-related instrumentation, an appropriate setpoint is determined such that a device set at its required initial calibration value, plus or minus its estimated uncertainty, will ensure that an analytical limit will not be reached or exceeded when the device is challenged to perform its required safety action during the interval between successive calibration or performance testing intervals. The total loop uncertainty band is determined through an appropriate combination of bias uncertainty terms added algebraically, and random uncertainty terms added in quadrature. The guidance in the current version of RG 1.105 for estimating the magnitude of the uncertainty estimate should consider encompassing a 95% probability using random uncertainties at the 95% confidence level.

NUREG-1475 Revision 1, "Applying Statistics", states: *"Many, if not most, practical applications require a one-sided confidence interval to guard against excess in one direction (either too much or too little)."* NUREG-1475 Examples 9.3 and 9.4 determine in tolerance intervals analogous to setpoint calculations with one random uncertainty. In these examples the tolerance interval is stated as the population above a stated value, or below a stated value. In other applications the tolerance interval is stated as being within a stated value of the mean. In the case of instrument setpoints there are direct adverse safety consequences if random uncertainties cause a delay of the trip. It's sufficient to state the tolerance interval as encompassing 95% of the population of interest at a 95% confidence level, which causes a trip at or before the analytical limit is reached. There can be indirect consequences if the tolerance interval is expanded resulting in moving the NTSP closer to plant normal operating limits, including potentially more plant events where an unnecessary channel trip occurs that is not needed to protect the analytical limit, or premature operator actions associated with operator action triggers or setpoints. These events can be precursors to other scenarios with safety consequences and can reduce plant availability. It must be noted that the uncertainty margin established through the method of combining all bias and random uncertainty terms is in addition to the margin established thru the use of probability/confidence levels for the tolerance interval associated with the statistical analysis of input data, thus providing an extra margin of safety.

6. Combining Uncertainties

Square-root-sum-of-squares (SRSS) and arithmetic are appropriate techniques for combining uncertainties. Alternate techniques, including probabilistic modeling, stochastic modeling, or a combination of these techniques may also be used.

Square-root-sum-of-squares method
It is acceptable to combine uncertainties that are random, normally distributed, and independent by the SRSS method. When two independent uncertainties, (± a) and (± b), are combined by this method, the resulting uncertainty is (± c), where $c = \mathrm{SQRT}(a^2 + b^2)$. Uncertainty tolerance intervals of like magnitude shall be combined. For example, to combine uncertainties at the 95% probability/95% confidence level, each uncertainty term's sample standard deviation must be multiplied by a tolerance interval factor corresponding to a 95% probability/95% confidence level, determined as function of the specific sample size of each uncertainty term.

Arithmetic method
It is acceptable to combine uncertainties that are not random, not normally distributed, or are

dependent by the arithmetic method. In this method, the combination of two dependent uncertainties, (+a, -b) and (+c, -d), results in a third uncertainty distribution with limits + (a+c), - (b+d).

The formulas and discussion below present the basic principles of this methodology. Another recognized methodology to estimate instrument measurement uncertainty is described in ANSI/ASME PTC 19.1, Measurement Uncertainty, Part I.

The basic formula for uncertainty calculation takes the form:

$$Z = \pm[(A^2 + B^2 + C^2)]^{1/2} \pm |F| + L - M \quad \text{(Equation 1)}$$

Where:

A,B,C = random and independent terms. The terms are zero-centered, approximately normally distributed, and indicated by a ± sign. Each term should be determined at the tolerance interval, TI, defined above or justification provided the value bounds the variation in the term.

F = abnormally distributed uncertainties and/or biases (unknown sign). The term is used to represent limits of error associated with uncertainties that are not normally distributed and do not have known direction. The magnitude of this term (absolute value) is assumed to contribute to the total uncertainty in a worst-case direction and is also indicated by a ± sign.

L & M= biases with known sign. The terms can impact an uncertainty in a specific direction and, therefore, have a specific + or - contribution to the total uncertainty.

Z = resultant uncertainty. The resultant uncertainty combines the random uncertainty with the positive and negative components of the nonrandom terms separately to give a final uncertainty. The positive and negative nonrandom terms are not arithmetically combined before combination with the random component.

The addition of the F, L, and M terms to the A, B, and C uncertainty terms allows the formula to account for influences on total uncertainty that are not random or independent. For biases with known direction, represented by L and M, the terms are combined with only the applicable portion (+ or -) of the random uncertainty. For the uncertainty represented by F, the terms are combined with both portions of the random uncertainty. Since these terms are uncertainties themselves, the positive and negative components of the terms cannot be arithmetically combined into a single term. The positive terms of the nonrandom uncertainties should be summed separately, and the negative terms of the nonrandom uncertainties should be summed separately and then individually combined with the random uncertainty to yield a final value. Individual nonrandom uncertainties are independent probabilities and may not be present simultaneously. Therefore, the individual terms cannot be assumed to offset each other.

If R equals the resultant random uncertainty $(A^2 + B^2 + C^2)^{1/2}$, the maximum positive uncertainty is:

$$Z^+ = +R + |F| + L$$

and the maximum negative uncertainty is

$$Z^- = -R - |F| - M$$

SRSS combination for bias uncertainties is inappropriate since by their nature, they do not satisfy the prerequisites for SRSS. Bias uncertainties are not random and are not characterized by a normal probability distribution. Since the number of known biases is typically small and they may or may not be present simultaneously, the bias uncertainties which could have a non-conservative effect in the scenario where the trip is required to protect the analytic limit should be added arithmetically.

In the determination of the random portion of an uncertainty, situations may arise where two or more random terms are not totally independent of each other but are independent of the other random terms. This dependent relationship can be accommodated within the SRSS methodology by arithmetically summing the dependent random terms prior to performing the SRSS determination. The formula takes the following form:

$$Z = \pm [A^2 + B^2 + C^2 + (D + E)^2]^{1/2} \pm |F| + L - M \quad \text{(Equation 2)}$$

Where:

D and E = random dependent uncertainty terms that are independent of terms A, B, and C.

Additional guidance on combining instrumentation uncertainties can be found in ISA-RP67.04.02-2010, *Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation*.

The use of the 95% tolerance limit definition from NUREG-1465 and the combination of uncertainties definition from ISA Recommended Practice 67.04.02 in a new version of the ISA Standard 67.04.01 will allow it to incorporate the probability criteria in NRC Regulatory Guide 1.105. Additional content in the standard to clarify application of 95% confidence level to adequately controlled measurements of drift over surveillance intervals and to address use cases where available data is Equipment Qualification (EQ) type testing, in accordance with IEEE-323, with sample sizes of one are probably necessary to obtain consensus to advance the standard.

7. ISA 67.04 Performance Monitoring and TSTF-493

In the 2006 revision of ISA 67.04, Allowable Value (AV) was replaced with the use of performance based criteria, section 4.6 “Performance Test Acceptance Criteria.” This criteria should be based upon a prediction of expected instrument performance and support the early identification of degrading instrument performance. Currently the ISA 67.06 (Reference 13) working group is working to further develop best practices and methods for performance monitoring and this criteria. In the interim, many licensees are still operating under existing

Technical Specification AV's.

TSTF-493 has also been developed to address NRC concerns in this area that focus on performance based criteria associated with As Left and As Found tolerances. This TSTF revision includes changes to Sections 4.6 and 6.1 to provide more specific requirements on, and required actions when instrumentation fails performance test criteria, in accordance with RIS 2006-17 and TSTF-493 guidance.

This change required the inclusion of a definition for As Found Tolerance, "the maximum amount by which the measured setpoint is expected to change over the course of a calibration interval. Note that the AFT should be expressed as a (one limit each for positive and negative changes)."

Specifically within Section 4.6, the change indicates that the performance test acceptance criteria may also be known as the AFT and ALT limits for the test being performed. The limits of the band are determined by the application of AFT and ALT for the instrumentation tested. Methods are provided for the computation of the maximum values for AFT and ALT, based on the methods provided in RIS 2006-17, while also allowing for the use of drift (performance) analysis of plant specific instrumentation. The method used must result in an AFT that is small enough to detect abnormal channel performance.

Verification that the measured setpoint is within the AFT is determined by calculating the difference between the current as-found value and the Setpoint (within the AFT) or by calculating the difference between the current as-found value and the previous as-left value. In order to use the as-found minus setpoint methodology, the ALT should (including additional measureable terms must be justified) be less than or equal to that provided by the guidance within RIS 2006-17. Clarifications are also made that the tolerances to be used are bi-directional and are applied to the actual setpoint, as opposed to a setpoint limit that is not equal to the actual setpoint. It is noted that excessive deviation in the conservative direction, while not directly resulting in a challenge to the analytical limit, might indicate degrading equipment or analytical problems and therefore might be a matter of concern.

Since the NRC RIS 2006-17 ALT and AFT criteria was not developed in a consensus environment, the RIS criteria is being evaluated for inclusion into ISA 67.04 in some consensus form. In Section 6.1, additional guidance and clarification is provided regarding the required actions when instrumentation fails performance test criteria. Specifically, if the as-found channel setpoint is outside its predefined AFT but within the AV, then the channel shall be evaluated to verify that it is functioning as required before returning the channel to service (i.e., reset to within As Left tolerance, stability, etc.). Also, the instrument channel setpoint shall be reset to a value that is within the ALT around the NTSP at the completion of the surveillance; otherwise, the channel shall be declared inoperable.

NRC input from the proposed draft update to Reg Guide 1.105 (Reference 10) and Branch Technical Position BTP-7-12 (Reference 6) revision process is also being addressed in the revision process for ISA Standard S67.04, as well as improved guidance from the Electric Power Research Institute (EPRI), as documented in References 7, 8 and 9.

8. CONCLUSION:

ISA S67.04 is being revised to address the current issues within the user and regulator community as addressed in this paper. As the primary standard on instrument setpoints in the U.S., it is important to maintain the standard current with all constituent groups and as endorsed by the U.S. NRC. The revision should be issued for committee review by the end of 2017.

9. REFERENCES

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