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Subject: Supplemental Information following NRC Public Meeting on GEH Setpoint Methodology

GE Hitachi Nuclear Energy (GEH) is pleased to submit additional information in response to NRC questions raised in the public meeting on GEH Setpoint Methodology held September 28, 2010. The GEH response is in Enclosure 1.

GEH requests that the information provided herein be considered in NRC actions to revise Regulatory Guide (RG) 1.105, "Setpoints for Safety-Related Instrumentation," Revision 3, December 1999. While the information provided is generally GEH specific, it demonstrates how the regulatory guidance in RG 1.105 is implemented and, therefore, has generic implications that may be useful in assessing revisions to the guidance.

Please contact me if you have any questions.

Sincerely,

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Project No. 710

Reference

1. Email, NRC (D. Rahn) to GEH (Y. Dayal), 9/29/2010 (excerpts in Enclosure 1)

Enclosure

1. Response to NRC Summary Points on Application of Single-Sided Factor for Setpoint Margin Calculations – Non-proprietary Information

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ENCLOSURE 1

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Response to NRC Summary Points on Application of Single-Sided Factor for Setpoint Margin Calculations

Non-proprietary Information

Objective

As requested by the NRC, this document provides a response to the three summary points stated by the NRC following the GEH meeting with the NRC in Washington, DC, on September 28, 2010. The NRC summary points were contained in an email from David Rahn (NRC) to Y. Dayal (GEH), titled "Proper Application of Single-sided Setpoint Method for Setpoint Margin--non ESBWR plants" (Reference 1).

For clarity, this document first provides a general background, which forms the basis for responding to all three summary points, and then provides specific responses to the summary points. A summary is also provided at the end.

Background

Random instrument error specified by the vendor is always referenced to the nominal setpoint setting X. The specified error provides sufficient information to determine the probability of finding the setpoint between any two points on the variable axis when it is set at the specific nominal setpoint (X) on the variable axis. For example, consider a bistable pressure switch of a certain design and assume the vendor has obtained a sample data set and based on that data the vendor has specified error of ±10 psig (2-sigma). This means that the vendor has determined from a sample test that when the instrument is set at 1000 psig the data was normally distributed around 1000 psig with a standard deviation (or 1-sigma error SD_s) of 5 psig. If the instrument design were such that a bias error was possible, the vendor would have performed tests to specify the bias error separately. So when the vendor specifies a normally distributed random error with a sample standard deviation SD_s, and no bias error, the vendor is stating that the 1-sigma error around the setpoint setting of X is SD_s, which implies that:

- 68% of the sample data is within $X + 1 * SD_s$ and $X – 1 * SD_s$
- 95% of the sample data is within $X + 2 * SD_s$ and $X – 2 * SD_s$
- Virtually all of the sample data is within $X + 3 * SD_s$ and $X – 3 * SD_s$

Unless there is a bias error, the vendor specified error (or uncertainty) always describes the error around the nominal setpoint setting.

The confidence that the sample standard deviation SD_s represents the true (or population) standard deviation (SD_p) depends on the sample size used to determine SD_s. If the sample size was infinite, the sample standard deviation would equal the true population standard deviation SD_p, and the confidence in SD_s would be 100%. However, if SD_s is based on a limited sample size, then it may need to be multiplied by a factor F (which is greater than 1 and depends on sample size and manufacturing knowledge) to provide a standard deviation that has 95% confidence ($SD_{p,95}$). The meaning of $SD_{p,95}$ is that there is 95% confidence that the true population standard deviation (SD_p) is no larger than $SD_{p,95} = F * SD_s$. Once $SD_{p,95}$ is known, it can be said with 95% confidence that:

- 68% of the population data is within $X + 1 * SD_{p,95}$ and $X – 1 * SD_{p,95}$
- 95% of the population data is within $X + 2 * SD_{p,95}$ and $X – 2 * SD_{p,95}$
- Virtually all of the population data is within $X + 3 * SD_{p,95}$ and $X – 3 * SD_{p,95}$

Note that $SD_{p,95}$ is larger than SD_s by the factor F, so the requirement for 95% confidence could increase the standard deviation that needs to be considered, and make the probability density function appear wider when plotted against the setpoint as a variable in engineering units. Note also that the 95% confidence standard deviation still represents the error around the setpoint setting, so the 95% confidence requirement could increase the standard deviation around the setpoint setting but does not affect the setpoint setting, because there is no bias. These conclusions are consistent with the NRC presentation (Reference 2, NRC Slide 12) at the meeting with GEH on September 28, 2010.

Once the standard deviation is known with high confidence (95%), and assuming that it is the only error source, the required 95/95 setpoint margin to the Analytical Limit (AL) is obtained by multiplying it by the single-sided statistical factor (1.645) that assures that the area in the tail of the probability density function curve beyond the AL is 5% of the total, and the area of the rest of probability density curve below the AL is 95%. This calculational process would give the 95/95 setpoint margin to the AL given that the AL (and nominal trip setpoint) is always approached in one direction (from the conservative side). The same conclusion can be reached using the cumulative probability distribution curve that shows that the cumulative 95% probability occurs when the setpoint margin is $\pm 1.645 * SD_{p,95}$. Note that the setpoint margin to the AL would be greater in engineering units for the wider 95% confidence standard deviation than for the narrower lower confidence sample standard deviation, however the setpoint margin to the AL is still based on using single-sided statistical factor given that the AL is approached from one direction. The use of two-sided statistics is conceptually not appropriate for calculation of setpoint margin to the AL when the AL (and nominal trip setpoint) is approached from only one direction.

These conclusions based on the standard deviation concept are equivalent to those based on the tolerance limit concept. The 95/95 tolerance limits are the limits around the nominal setpoint setting that contain 95% of the data with 95% confidence. Assuming no bias, the 95/95 tolerance limits are equivalent to saying with 95% confidence that 95% of the data is within $\pm 1.96 * SD_{p,95}$ centered around the nominal trip setpoint setting. This same conclusion was reached using the standard deviation concept. For the same error distribution the 68/95 tolerance limits could also be defined, which are the limits that contain 68% of the data at 95% confidence; and these limits would be equivalent to ±1.00 * $SD_{p,95}$ limits around the setpoint setting using the standard deviation concept, assuming no bias. Note that these tolerance limits are a measure of the error around the nominal trip setpoint and are independent of the AL, and should not be confused with the margin to the AL. There are two tolerance limits that define the error around the setpoint, one on each side of the setpoint (just like the errors bands based on the standard deviation concept), and only one margin of the nominal trip setpoint to the AL given that the variable approaches the AL from only one direction (the conservative direction). In the tolerance limit concept, the 95/95 setpoint margin to the AL, given that the variable approaches the AL (and nominal trip setpoint) from only one direction (the conservative direction), would be based on the one-sided tolerance limit that would provide for 5% of the data (or probability) beyond the AL and 95% of the data (or probability) below the AL, with 95% confidence. Assuming no bias, this setpoint margin based on single-sided tolerance limit concept, is equivalent to the 95/95 margin of 1.645 * $SD_{p,95}$ obtained using the standard deviation concept.

The key in determining the 95/95 setpoint margin is to first assure that the error standard deviation used in the setpoint margin calculation is large enough to represent the population standard deviation with high degree of confidence (≥95%). The tolerance limits containing 95% of the population data would be at ± 1.96 times this population standard deviation centered around the instrument setpoint at 95% confidence. Once this population standard deviation is known it is statistically correct to multiply it by the single-sided 1.645 factor to get the 95/95 setpoint margin. In actuality, since the setpoint margin is based on a combination of errors for the instrument loop, the standard deviation of the combined loop errors must be large enough to assure with high confidence (95%) that the population standard deviation is not larger than this value. GEH setpoint calculations are based on the use of such conservative loop error standard deviation values for setpoint margin calculations. Operating BWR reactor experience over 20 years has shown that as-found values have seldom exceeded the setpoint margins calculated by GEH methodology, which are based on single-sided statistical factors multiplying these conservative standard deviations. Such operating experience data was used to validate the calculated setpoint margins by the NRC during licensing and approval of the GEH setpoint methodology (References 3 and 4).

Responses to NRC Summary Points

NRC Summary Point 1:

At the setpoint determination "decision-making" stage, when one is tasked with establishing the proper location of the limiting setpoint uncertainty probability distribution with respect to the Analytical Limit so that there is a high assurance that the Analytical Limit is protected, the trip point error/uncertainty analysis process has been largely completed (via the collection, vetting, and statistical evaluation of raw data; establishment of appropriate tolerance intervals for each; propagation of instrument errors through the channel to the ultimate bistable trip device; and appropriate combination of random and independent error terms). So, at that stage in the setpoint determination analysis, the tolerance limits associated with ensuring that 95% of the population of interest are already known to a very high degree of certainty. In fact, GEH treats the limits of the tolerance interval containing 95% of the population of interest as known quantities at this point—rather than as uncertainties.

GEH Response to NRC Summary Point 1:

The NRC summary point is basically correct. By way of explanation note that the starting point for a setpoint calculation is the identification of the Analytical Limit (AL) assumed in the Safety Analysis. It is the Safety Analysis that assures that there is no undue risk to the health and safety of the public, and therefore the safety analysis process must be very conservative. The GEH safety analysis process is conservative and the GEH setpoint calculation process described in the NRC approved GEH setpoint methodology (Reference 3), is consistent with this process.

GEH calculations use a conservative value for the instrument vendor based loop error standard deviation to assure that the population loop error standard deviation is not greater than the value used, to a high degree of confidence (95%). Therefore the tolerance limits containing 95% of the population data around the setpoint, at 95% confidence, are no greater than 1.96 times the standard deviation used in the calculation. This allows the 95/95 setpoint margin to the AL to be calculated by multiplying the standard deviation by the 1.645 single-sided statistical factor, given that the variable approaches the AL (and nominal trip setpoint) from only one direction (the conservative direction).

NRC Summary Point 2:

Since the characteristics of the trip point uncertainty probability distribution are known to a high degree, GEH is only concerned about the placement of this population distribution with respect to the Analytical Limit in a manner that assures that the NRC staff regulatory guidance is met. GEH has interpreted the NRC staff guidance to be that there should be at least a 95% probability that the channel will perform its required trip action during a postulated event associated with that channel before the Analytical Limit is exceeded. When implementing this uncertainty interval GEH looks at the probability distribution curve at a macroscopic level, and addresses the NRC Staff regulatory guidance by placing the limiting setpoint and associated trip point probability distribution in a manner that ensures that at most, a maximum of 5% of the portion of the channel trip probability distribution curve that is closest to the Analytical Limit will be able to exceed the Analytical Limit. No additional consideration is made regarding the likelihood with which the channel trip will occur at the probability value on the normal distribution curve that has been selected to cross the Analytical Limit as compared to other possible values selected. (For example, the NRC staff has noted that the probability value on the normal distribution curve corresponding to the 95% cumulative probability is higher than the probability value corresponding to the 97.5% cumulative probability value.) The GEH goal is to ensure that the first 95% of the cumulative trip point probability that lies furthest away from the Analytical Limit is maintained on the conservative side of the Analytical Limit, regardless of the individual likelihoods of trip occurrence at each point within the tolerance interval.

GEH Response to NRC Summary Point 2:

Clarification is required for the concepts described in this NRC summary point. GEH uses the standard interpretation of the probability density function that the probability that the setpoint can be found between any two values X1 and X2 on the variable axis is the fractional area of the probability density function curve between X1 and X2, assuming the area under the whole curve is equal to 1. As long as the probability density function correctly defines this probability for the "population", the probability that the trip occurs beyond the AL is the fractional area in the tail (a_{tail}) beyond the AL, and the probability that the trip occurs before the AL is reached is $1 - a_{tail}$ (Reference 5 Slides 9-10). Thus if an event occurred that required a trip, the chance that it would trip before the AL is reached is $1 - a_{tail}$, or the equivalent cumulative distribution function probability corresponding to the AL. The only assumption for this conclusion is that the standard deviation of the probability density function is wide enough to correctly represent the "population" standard deviation to a high degree of confidence (95%). Given that to be true, the statistically correct location of the setpoint relative to the AL for a probability of 95% of not exceeding the AL (or 5% of exceeding the AL) is such that the tail area is 5% and the remaining area is 95%. That setpoint margin is the single-sided statistical factor 1.645 times this standard deviation. Though it is conservative, it is not statistically correct to locate the setpoint so that the tail area is 2.5% and state that probability of not tripping before the AL is 2.5% and the probability of tripping before the AL is 95%, because these probabilities only add to 97.5%, and must add up to 100% to satisfy the definition of the probability distribution function. Location of the setpoint such that the tail area is 2.5% is not required to meet the 95% requirement of tripping before the AL (or 5% of tripping after the AL).

The key is to define the acceptable (or required) probability for not tripping before the AL (or tripping after the AL). GEH contends that the requirement for probability for not tripping before the AL has always been 95% (or 5% tripping after the AL). This position is reasonable based on the conservatisms inherent in the AL used for the BWR safety analysis. The 95% probability has historically been endorsed by the NRC, and is part of the licensing basis for BWR safety analysis and GEH setpoint methodology. GEH recommends that the upcoming revision of RG1.105 confirm that it is acceptable to locate the setpoint such that the probability of tripping before the AL is reached is 95% and the probability of tripping beyond the AL is 5%.

NRC Summary Point 3

To provide additional assurance that this methodology actually "works" in practice, in the 1990's, GE performed an evaluation of the operating history of several U.S. BWR facilities. During this evaluation, a large volume of calibration data, LER, and plant operating history status was reviewed to see if there have been a large number of events during which setpoints were found during calibration and operational conditions to have exceeded their desired "as-found" or "allowable value" limits, thus resulting in the need for LERs, corrective actions, or revisions to settings. During this evaluation, it was found that when applied properly, the methodology results in very high LER avoidance and spurious trip avoidance capabilities. Although the NRC staff would still like to be able to locate and review a report that describes the findings of this evaluation, our understanding is that GEH is satisfied that the application of this setpoint analysis methodology is conservative and that it provides a high degree of BWR plant availability and safety system reliability.

GEH Response to Summary Point 3:

GEH agrees. Practical experience has shown that setpoint margins based on the single-sided statistical factor times the conservative standard deviations for the instrument loop used by GEH, are conservative. The evidence for this conservatism is based on examining as-found data for numerous setpoints over many years in operating BWRs. Some of this data was presented to (and accepted by) the NRC during licensing of the GE setpoint methodology (References 3 and 4).

GEH communicates with utilities routinely and is not aware of any instances where the margins based on GEH methodology have been exceeded. GEH contends that the use of the single-sided statistical factor for setpoint margin calculations is justified given that the AL (and the nominal trip setpoint) is approached from only one direction (the conservative direction). Moreover, the GEH setpoint methodology is conservative in that it calculates an Allowable Value (AV) with margin to the AL that includes all errors during trip conditions except drift, and a final Nominal Trip Setpoint ($NTSP_F$) with significant margin to the AV based on all errors during calibration. By GEH methodology the $NTSP_F$ margin to the AL is equal to or greater (generally greater) than the required margin based on all errors (including drift) during trip conditions, and the single-sided 95% probability of tripping below the AL (5% probability in the tail beyond the AL). Using two-sided statistics to calculate the setpoint margin to the AL is not technically correct given that AL (and nominal trip setpoint) is approached from one direction (the conservative direction), and is not appropriate for setpoints calculated by the conservative GEH methodology. Using the two-sided 95% probability statistical factor for setpoints calculated by GEH setpoint methodology would unnecessarily increase the setpoint margin. Such an increased margin is not required from the BWR safety point of view, and would actually increase the probability of spurious trips that could lead to undesirable safety consequences.

Summary

In summary, the NRC-approved GEH setpoint methodology is conservative and consistent with NRC regulatory guidance. GEH recommends that the NRC provide additional clarification in an upcoming revision to Regulatory Guide 1.105 that accepts the use of single-sided statistics for determining the margin to the Analytical Limit (AL) for instrument trips approached from one direction. In addition, the NRC should further clarify that it is acceptable to locate the setpoint such that the probability of tripping before the AL is reached is 95% and the probability of tripping beyond the AL is 5%, with high confidence (95%). By including these additional clarifications in its regulatory guidance, the NRC will provide for adequate protection of analytical limits while preventing spurious trips that could cause plant transients that could unnecessarily challenge safety systems.

References:

1. e-mail David Rahn (NRC) to Y. Dayal (GEH), "Proper Application of Single-sided Setpoint Method for Setpoint Margin--non ESBWR plants," September 29, 2010.

2. NRC Slide presentation "NRC Staff Interpretation of 95/95 Tolerance Limits in Safety System Setpoint Analysis," NRC Public Meeting with GEH, September 28, 2010.

3. NEDC-31336P-A, "General Electric Instrument Setpoint Methodology," Class 3, September 1996.

4. Safety Evaluation (SE) from the NRC dated November 6, 1995 to NEDC-31336P-A, contained in Reference 3.

5. GEH Slide presentation "BWR Operating Units: Discussion of 1-Sided Statistics for Setpoint Margin Calculations, with USNRC and GEH," September 28, 2010.