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Florida Power Corporation
Crystal River Unit 3

Graded Approach Methodology for Instrument Uncertainty

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Background

Instrumentation effectiveness is critical to the safe control of any nuclear power facility as well as its compliance with applicable regulatory requirements. Instrumentation effectiveness is adversely impacted by a large number of variables. These include but are not limited to: manufactures' stated tolerances, calibration equipment accuracy, environmental effects (normal and accident), drift, readability and installation considerations. The methodology for assessing the uncertainty of such a multi-variant system is statistical in nature. If all variables are assumed to simultaneously occur at the extreme of their hypothetical range the results would be conservative but would not be an accurate representation of the actual uncertainty under most conditions. Thus, valid statistical methods are utilized to more precisely predict uncertainty.

The key to an appropriate methodology is providing "reasonable assurance" that actuation or control setpoints and information communicated to the user are appropriate for their intended purpose(s). This involves at least two key elements:

(1) The design (location, range, qualification, etc.) must be appropriate;

(2) The setpoints (for actuation, control, alarm, display, limits, recording, etc. - referred to as "values") must be established in a manner commensurate with their use and safety significance. Some values must meet very rigorous standards (95% certainty with 95% confidence), while others may rely on lower levels of rigor and some may use nominal values.

There are a number of standard techniques used to establish such values in an appropriate manner. These have been used over the years as well as in current applications. This document addresses application of these methods at Crystal River Unit 3 principally as they relate to instrumentation. The methods also apply to similar values (electrical) and generally can be applied to all numerical values within the Technical Specifications.

Some techniques can be appropriately employed to only include uncertainty data that must be accounted for in the various values. These generally involve focusing the analysis on more specific or appropriately limited conditions, statistically combining uncertainties (i.e. square root of the sum of the squares), reliance on actual historical data, and others. These techniques are addressed under "BASIC METHODS" in this document and are applicable to any value.

Other techniques can be applied to a limited extent depending on the safety significance of the value. These involve varying the degree of conservatism by eliminating or reducing certain factors, achieving lower confidence levels, and others. These techniques are addressed under "GRADED APPROACH" in this document.

In order to apply such an approach, the values must be categorized in some manner. Such values may be categorized on a specific parameter, instrument string or even system level where appropriate. The values are used in a number of places or documents: actuation setpoints established by appropriate calibration procedures or other work controls; contingency operational procedures (e.g. EOPs, APs, ARs, etc.); various test procedures (e.g. SPs, PTs, etc.) or routine operational procedures (OPs, etc.). Therefore, for such categorization to be effective, it must involve integrated input from Operations, Nuclear Engineering Design, Nuclear Plant Technical Support, Licensing, Maintenance and others at appropriate management levels. The basis should be technically sound, adequately clear for all users and readily retrievable.

Calculational methods that were followed prior to the recent development of detailed industry standards are and will be considered acceptable. If actual nonconformances (clearly invalid inputs, significant errors in implied configuration or use of the values calculated) are detected while revising calculations to recent standards, they will be handled via standard procedures and processes. Changes to field values or procedures, which are appropriate based upon revised calculations, are to be made in an orderly and controlled manner under FPC's prioritization and work control practices.

The following methods and techniques to achieve a Graded Approach are guidelines and should be followed as closely as possible. Circumstances or situations particular to a value, parameter or instrument string may dictate some deviation from this document. The development of instrument uncertainty calculations may deviate, with appropriate approval of the I&C Design Supervisor, from this document to satisfy the intent of developing uncertainties commensurate with their use and safety significance. This should be addressed on a case-by-case basis and justification for deviations should be provided in the governing document.

BASIC METHODS

In addition to the "Graded Approach" methodology, the following methods may be utilized as appropriate.

1. The readability error will be applied in the "Results" section of the calculation instead of being treated as an additional variable (Reference 4). Actions will be specified to fall on a scale division (major or minor). A half minor division could be used if defining the action at a full scale division unnecessarily restricts the operating band.

   Example: An indicator on the Main Control Board has a range of 0 to 3000 psig, with minor divisions every 50 psig. The total error for the loop to the indicator (without considering readability in the component error for the indicator) is 17.6 psig. If the operator must maintain the process at a pressure greater than or equal to 2200 psig, the indicator could read as high as 2217.6 psig when the actual pressure is 2200 psig.

   Since the operator can only read the indicator to one-half minor division (25 psig), the operator must be instructed to maintain the pressure to the nearest half minor scale increment in the conservative direction, which would be 2225 psig.

2. Historical calibration information can be used. If records indicate that the instrumentation can be calibrated to a tighter tolerance or performs better between calibrations than calculated or provided by the vendor, the historical value can be used (As-Left or As-Found tolerances).

3. A reduction in a variable's contribution to calculated uncertainty can be achieved by focusing on predetermined points of interest or limited ranges. Many instruments have wide ranges for a variety of reasons. The uncertainty over that wide range over-states the likely uncertainty over narrower ranges of actuation or monitoring interest.

4. If a value is approached from a single side, appropriate statistical methods should be employed to appropriately consider uncertainty.

5. Only the environment for which the components need to operate will be considered.

   Example: If a transmitter is located in the IB, but only needs to operate for a LOCA in the RB, then the effects of an IB HELB will not be considered.

GRADED APPROACH

A "Graded Approach" is a methodology for classifying values into different categories with varying degrees of rigor being applied to develop instrument uncertainties. Section 4 of Reference 2 notes that the full application of the methodology developed for automatic protection system actuation setpoints, to other values, may not always be appropriate due to its conservative nature. The classification of the value within this hierarchy of categories establishes the calculational methods which would be applied. The Instrumentation Society of America (ISA) recommends the use of a "Graded Approach" for determining which and how variables should be accounted for in uncertainty calculations. The approach used must be commensurate with the importance to safety of the value. Reference 4 provides some guidance in the development of a Graded Approach but specifies the utility should provide the rationale and technical basis for the classification scheme.

Category Descriptions

The four Graded Approach categories (A, B, C, and D) are listed below along with the criteria that defines the values included in each category. These general criteria describe the content of each category and the relative importance between the categories. The criteria are guidelines and should not be viewed or utilized as absolute definitions. Further, the criteria may overlap somewhat within a category and between categories. That is part of the reason why it is important for personnel with a wide range of expertise, experience and responsibility to be involved in establishing categories and in the selection of calculational options available within each.

The categorization scheme is based on the specific function of a value, parameter, or indication. In some cases a single instrument or instrument string provides functions that reside in more than one category. Given this, it may be necessary to provide more than one set of channel uncertainty values. In addition, some limits, parameters or values are considered to be "Nominal Values" and will require no offset or margin. The justification for considering a limit, parameter or value a "Nominal Value" should be documented.

Category A

1) Reactor Protection System (RPS) actuation setpoint

2) Emergency Safeguards Actuation System (ESAS) actuation setpoint

3) Emergency Feedwater Initiation & Control (EFIC) actuation setpoint

Category B

1) A value which is directly used in applicable safety analysis. (The value has an impact on the performance of the safety function and no margin was allotted in the analysis.)

2) A value/indication relied upon for the manual performance of an accident mitigation function (i.e. Reg. Guide 1.97 Type A variables)

3) A value relied upon to maintain the reactor in a safe shutdown condition, maintain the integrity of the safety related pressure boundary, or prevent exceeding 10CFR100 limits

4) A value relied upon to protect or support operation of equipment required for design basis accident mitigation

Category C

1) Other actuation's, alarms, indications or control settings relied upon for continued operation and equipment protection, excluding items classified as Category D.1 (see below).

2) Values derived from commitments in the Licensing Basis (including Technical Specification) not classified in Category A or B and which <u>cannot</u> be appropriately treated as a Category D or nominal values.

3) Reg. Guide 1.97 Category B, C, and D variables

Category D

1) Vendor supplied equipment (i.e.: Cardox system, turbine protective features, etc.)

2) Reg. Guide 1.97 Category E

3) Other values not meeting the criteria of Category A, B, or C

4) Values derived from commitments in the Licensing Basis (including Technical Specification) not classified in Category A, B or C and which <u>can</u> be appropriately treated as nominal values with engineering judgment.

TREATMENT OF ERRORS FOR GRADED APPROACH CATEGORIES

Category A

This is the highest category in the "Graded Approach". References 1 and 2 shall be used for development of the Analyses/Calculations. All applicable errors shall be statistically accounted for in the Analyses/Calculations to provide a high confidence level. The following formula is used.

$$CE_{LOOP} = \pm[(E_{LOOP})^2 + (AF_{LOOP})^2]^{1/2} \pm E_{BIAS} \pm E_{PROCESS}$$

Where:

CE_{LOOP} = Calibrated Loop Error - The overall instrument channel error, which is used to determine setpoints and action values from the design limit/analytical limit.

E_{LOOP} = Calculated Loop Error - The instrument channel error, not taking into account calibration, drift, process errors and known biases.

AF_{LOOP} = As-Found Tolerance - The tolerance in which a channel/loop can be found after a period of operation, prior to calibration. This term includes the errors due to M&TE and Drift/Stability.

E_{BIAS} = Bias Errors - Know biases that affect the operation of an instrument loop, such as static pressure shifts, IR effects, etc.

$E_{PROCESS}$ = Process Errors - The error that results from the range of process operation limits, based on the scaling of the sensing instruments.

Category B

This is the second category in the "Graded Approach". The methodology for this category will be the same as for Category A instrument strings, except that the Normal Process Errors will be combined via the SRSS method with the other random loop errors. In addition 2/3 of the M&TE error will be used.

This method still ensures appropriate actuation's/actions are taken. Nevertheless it does not compromise the ability to use the instrumentation by more accurately reflecting actual uncertainty.

$$CE_{LOOP} = \pm[(E_{LOOP})^2 + (E_{NPE})^2 + (AL_{LOOP} + [(2/3\ MTE_{LOOP})^2 + (SB_{LOOP})^2]^{1/2})^2]^{1/2} \pm E_{BIAS} \pm E_{APE}$$

Where:

E_{NPE} = Normal Process Errors - The error that results from the range of Normal process operation limits, based on the scaling of the sensing instruments.

AL_{LOOP} = As-Left Tolerance or Calibration Tolerance - The tolerance to which a channel/loop is left after calibration. This term is determined from the Reference Accuracy of the components.

MTE_{LOOP} = M&TE (Maintenance & Test Equipment) error - The errors due to the M&TE used in the calibration of the loop.

SB_{LOOP} = Stability/Drift - The error due to the stability/drift of the components in the loop.

E_{APE} = Accident Process Errors - The error that results from the range of Accident process operation limits, based on the scaling of the sensing instruments.

In addition, if the AL_{LOOP} (setting tolerance) is less than or equal to the SRSS of the Reference Accuracy of the components in the loop, AL_{LOOP} will not be accounted for. Therefore, the above formula will be reduced as follows:

$$CE_{LOOP} = \pm[(E_{LOOP})^2 + (E_{NPE})^2 + (2/3\ MTE_{LOOP})^2 + (SB_{LOOP})^2]^{1/2} \pm E_{BIAS} \pm E_{APE}$$

Category C

This is the third category in the "Graded Approach". The methodology for this category will be the same as for Category B values or variables, except the overall error is reduced as shown below. The final values provided will be more in line with what can be expected from the variable on a normal daily basis.

$$CE_{LOOP} = \pm 2/3 * ([(E_{LOOP})^2 + (E_{NPE})^2 + (MTE_{LOOP})^2 + (SB_{LOOP})^2]^{1/2} \pm E_{BIAS} \pm E_{APE})$$

Note: If any biases or uncertainty data should not be reduced by 1/3 (i.e.: flow orifice errors), they would be added onto the end of CE_{LOOP}.

Category D

This is the fourth category in the "Graded Approach". The values or variables that would fall into this category have no impact on plant safety. Errors/uncertainties for this category are based solely on engineering judgment or can be treated as Nominal Values.

Additional instrument strings that would fall into this category are vendor supplied systems (primarily skid mounted). If the vendor provides initial or final setting values for their equipment, it would not be appropriate for engineering to change these values through error correction. The values provided are normally from operational experience with their systems and may be changed by the vendor upon installation to optimize the performance.

TECHNICAL BASIS

1. SRSS of Process Errors:

   A method commonly used in the industry is to combine the normal process errors with other random errors using a SRSS methodology. Normal process errors vary randomly between design limitations based on several factors (such as plant conditions, chemical compositions of the process and environmental conditions) and may have an additive or subtractive impact on the total channel uncertainty. Given this, it is reasonable to assume that the normal process errors can be treated as a random event thus justifying their inclusion under the radical with other random errors. Treating these errors as random yielding a reduction in the overall channel uncertainty will more reasonably represent the actual combination of errors seen at any given time during normal conditions. In addition, this methodology is consistent with the methodology used by much of the industry.

   This method of combining normal process errors is not intended to be used on those errors which are considered bias errors such as IR drop errors, transmitter static pressure span compensation errors or reference leg temperature errors during accident conditions. Reference 5 specifically cautions about the treatment of these type errors in the development of channel uncertainties. Due to the potential impact on channel uncertainties as a result of biases and process errors during accident conditions, these terms will not be reduced.

2. Omission of AL_{LOOP} Tolerance:

   AL_{LOOP} (calibration tolerance) is the acceptable parameter variation limits above or below the desired output for a given input standard associated with the calibration of the instrument channel. Typically, this is referred to as the setting tolerance of the width of the "As-Left" band adjacent to the desired response. Depending on the method of calibration or performance verification, an allowance for the calibration tolerance need not be included in the uncertainty calculation. If the method of calibration or performance verification verifies all attributes of reference accuracy (reference accuracy is typically assumed to have four attributes: linearity, hysteresis, dead band and repeatability) and the method of calibration verifies all attributes of reference accuracy, then the calibration tolerance does not need to be included in the total instrument channel uncertainty. In this case, the calibration or performance verification has explicitly verified the instrument channel performance to be within the allowance for the instrument channel's reference accuracy in the uncertainty calculation.

If the method of calibration does not verify all attributes of the reference accuracy, this method should not be used in the analyses/calculation. If specific values for linearity, hysteresis, deadband and repeatability are provided by the vendor, they are addressed in the analyses/calculation under the calculated loop error.

This methodology is discussed in Section 6.2.6.2 of reference 2.

3. Reduction of MTE_{LOOP} by 1/3:

   MTE_{Loop} (Measurement & Test Equipment uncertainty of the loop) errors are considered production lot specifications and are certified for use in the field by our calibration lab. These errors are considered to have a 3 sigma confidence level due to the tight controls applied to them. This error term will be reduced to the same confidence level as the overall analyses/calculation. Hence, MTE errors will be reduced to two-sigma (two-thirds of the 3-sigma values) to more reasonably represent the actual combination of errors seen.

4. Reduction of CE_{LOOP} by 1/3 (Category C only):

   CE_{Loop} (Calibrated Loop Errors) for instrumentation typically apply the worst case (maximum and minimum) design limits for each parameter, (reference accuracy, drift, process errors, etc.), to assure the bounding or worst case errors are obtained. The approach of assuming all parameters at the worst case design limits assures maximum conservatism, but can unnecessarily increase instrument total loop uncertainty and result in reduced operating margins or cause operations personnel to initiate manual actions at an inappropriate time.

   Typically systems will not be operated at worst case limits nor will accident transients force all process parameters to the worst case limits simultaneously. Hence a reduction in total channel uncertainty is warranted for Category "C" parameters. The combination of worst case errors encompass or represent 100% (3-sigma) of all errors. It is reasonable to assume that the errors represented in the Category "C" calculations should provide a 95% confidence level that the actual worst case errors are enveloped. Hence, the worst case error limits will be reduced to 2-sigma (two-thirds of the 3-sigma values) to more reasonably represent the actual combination of errors seen at any given time during the normal or accident conditions.

   This reduction in normal and accident errors is not intended to be used to reduce process errors which are known to be 2-sigma.

TERMS USED IN THE ABOVE GRADED APPROACH DOCUMENT

CE_{LOOP} = Calibrated Loop Error - The overall instrument channel error, which is used to determine setpoints and action values from the design limit/analytical limit.

E_{COMP} = Component Error - The SRSS of the errors associated with an individual component (i.e.: Reference Accuracy, Temperature Effect, etc.), with the exception of Drift.

E_{LOOP} = Calculated Loop Error - The instrument channel error, not taking into account calibration, drift, process errors and known biases.

$$E_{LOOP} = \pm[(E_{COMP1})^2 + (E_{COMP2})^2 + \ldots (E_{COMPN})^2]^{1/2}$$

MTE_{LOOP} = M&TE (Maintenance & Test Equipment) error - The errors due to the M&TE used in the calibration of the loop.

SB_{LOOP} = Stability/Drift - The error due to the stability/drift of the components in the loop.

AL_{LOOP} = As-Left Tolerance or Calibration Tolerance - The tolerance to which a channel/loop is left after calibration. This term is determined from the Reference Accuracy of the components.

$$AL_{LOOP} = \pm[(COMP1\text{-}E_{REF})^2 + (COMP2\text{-}E_{REF})^2 + \ldots (COMPN\text{-}E_{REF})^2]^{1/2}$$

AF_{LOOP} = As-Found Tolerance - The tolerance in which a channel/loop can be found after a period of operation, prior to calibration. This term includes the errors due to M&TE and Drift/Stability.

$$AF_{LOOP} = \pm\{AL_{LOOP} + [(MTE_{LOOP})^2 + (SB_{LOOP})^2]^{1/2}\}$$

E_{BIAS} = Bias Errors - Know biases that affect the operation of an instrument loop, such as static pressure shifts, IR effects, etc.

$E_{PROCESS}$ = Process Errors - The error that results from the range of process operation limits, based on the scaling of the sensing instruments.

E_{NPE} = Normal Process Errors - The error that results from the range of Normal process operation limits, based on the scaling of the sensing instruments.

E_{APE} = Accident Process Errors - The error that results from the range of Accident process operation limits, based on the scaling of the sensing instruments.

Nominal Value = A value determined to require no error correction.

REFERENCES

1. ISA-S67.04, Part I, "Setpoints for Nuclear Safety-Related Instrumentation", dated 1994

2. ISA-RP67.04, Part II, "Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation", dated 1994.

3. Draft Technical Report ISA-dTR67.04.03, "Indication Uncertainties and Their Relationship with Indicated Values", Draft 4, April 1996

4. Draft Technical Report ISA-dTR67.04.09, "Graded Approach to Setpoint Determination", Draft 1, 1994

5. IE Bulletin No. 79-21, "Temperature Effects on Level Measurements", August 13, 1979