ENCLOSURE 2

MFN 15-009

Comment Summary Table and Draft SE Markup

Non-Proprietary Information– Class I (Public)

IMPORTANT NOTICE

This is a non-proprietary version of Enclosure 1, which has the proprietary information removed. Portions of the enclosure that have been removed are indicated by white space with an open and closed bracket as shown here [[ ]].

Comment Summary for Draft Safety Evaluation for NEDE-33766P Revision 0,

"GEH Simplified Stability Solution (GS3)"

Note: Page numbers shown in this table reflect the page numbers in this enclosure. Due to suggested changes in the Safety Evaluation (SE) and the addition of a change summary table, these page numbers differ from the page numbers in the draft SE sent to GEH for review.

Location	Comment
Section 1.1 Background	Page 13: 2nd paragraph under the listed stability options: GEH suggests the following changes: "It is a solution licensed by GEH and based on Option III; it increases the likelihood of necessary scram when ~~an~~ growing power oscillations are ~~is~~ detected by setting all required solution parameters to its most sensitive limit when a rapid change of flow (indicating a recirculation pump trip) is detected. ~~To minimize the likelihood of spurious scrams,~~ To provide a rigorous solution, DSS-CD requires that a number of OPRM strings confirm with the determination that an oscillation is indeed occurring (thus the name confirmation density). DSS-CD has been approved by the staff for use in MELLLA+." *This clarifies that DSS-CD does not increase the chance of scram, but rather increases the likelihood of necessary scram when growing oscillations are detected. Confirmation density is not only to minimize the likelihood of spurious scrams.* Suggested changes shown in the markup.
Section 3.1 Overview of GS3 Methodology	Page 17: The paragraph starting with "Section 10 of the LTR describes…": 3rd sentence: The link is broken in the parenthetical expression "(see Section 0)". It should be changed to "(see Section 9)". *This is the section in the LTR that contains further discussion about the GS3 applicability envelope.* Suggested changes shown in the markup.
Section 3.1 Overview of GS3 Methodology	Page 17: The paragraph starting with "Section 10 of the LTR describes…": Last sentence: Change the section number from Section 4.4 to Section 10. *This is the section in the LTR that contains further discussion about the procedure and checklist for plant-specific applications.* Suggested changes shown in the markup.
Section 3.2 Technical Information	Page 18: Last paragraph in the section: 2nd to last sentence: Please provide a reference citation for the staff audit, which is Reference 8. Suggested changes shown in the markup.

Location	Comment
Section 4.2 Applicability of Proposed Envelope for Plants Using Stability Option III	Page 20: 1st paragraph in the section: GEH suggests the following changes: "As shown in that figure, the recirculation flow reduction at t≈20 s results in a significant power-level reduction, which in turn increases the ~~available~~ CPR because, even though the power-to-flow ratio and void fraction remain essentially constant during the 2RPT, the lower power results in larger margins to ~~critical heat flux~~ boiling transition. If the transient is allowed to progress, large amplitude oscillations would occur (in the Figure 2 example, oscillations [[ ]] and grow exponentially). Eventually, the oscillations grow large enough to challenge SAFDLs (in the Figure 2 example, ~~critical heat flux~~ boiling transition is [[ ]]). The LTS setpoint must be reached and the scram must take place before margins to MCPR are depleted. In the Figure 2 example, a simulation of the Option III algorithm shows that the scram would have initiated [[ ]] and suppress the oscillations~~. (Note that for a typical TRACG calculation, the Option III algorithm scram is not modeled and the transient is allowed to progress without scram; the Option III algorithm is applied as a post-processing step to identify when the oscillations would have been mitigated)~~." *These changes were made to make the terminology consistent with BWRs, and the parenthetical expression pertaining to how the calculation is performed is unnecessary* Suggested changes shown in the markup.
Section 4.2 Applicability of Proposed Envelope for Plants Using Stability Option III	Page 21: 3rd paragraph in the section: 2nd sentence: Change the reference number from "[Ref. 8]" to "[Ref. 9]" *Reference 9 is the correct reference for the RAI responses.* Suggested changes shown in the markup.
Section 4.4 Applicability of the Plant-Specific Applicability Checklist	Page 24: 2nd paragraph in the section: The link is broken in the parenthetical expression "(see Section 0)". It should be changed to "(see Section 9)". *This is the section in the LTR that contains further discussion about the GS3 applicability envelope.* Suggested changes shown in the markup.
Section 4.5 Applicability of [[ ]]	Page 24: 1st paragraph in the section: Change the reference number from "[Ref. 7]" to "[Ref. 8]" *Reference 8 is the correct reference for the July 24, 2014 NRC staff audit.* Suggested changes shown in the markup.

Location	Comment
Section 4.6 Legacy Fuel	Page 26: 1st paragraph in the section: Change the reference number from "[Ref. 7]" to "[Ref. 8]" *Reference 8 is the correct reference for the July 24, 2014 NRC staff audit.* Suggested changes shown in the markup.
Section 4.6 Legacy Fuel	Page 27: 2nd paragraph in the section: GEH suggests the following change: "By the time a fuel bundle has been in the core for two or more cycles (twice- burned), the Gd has essentially been depleted and the U-235 content is relatively low, so that these bundles are not likely to have ~~neither~~ high powers ~~nor~~ or be close to safety limits." Suggested changes shown in the markup.
Section 4.6 Legacy Fuel	Page 27: 4th paragraph in the section: GEH suggests the following changes: This situation is also likely to occur with LTAs. By its very nature, test assemblies are never located at peak power positions, so that they burn slower than regular fuel. [[ ]] *The intent that was discussed in the audit is not to explicitly model LUAs/LTAs in TRACG analyses, because of the few fuel bundles involved and because they are loaded in non-limiting core locations. This is a common practice in most reload analyses. The sentence seemed to indicate that the LUAs/LTAs needed to be explicitly modeled until they became "Legacy Fuel."* Suggested changes shown in the markup.
Section 4.6 Legacy Fuel	Page 27: Last paragraph in the section: GEH suggests the following change: "[[ ]]" Suggested changes shown in the markup.
Section 4.7 [[ ]]	Page 27: 1st paragraph in the section: Change the reference number from "[Ref. 7]" to "[Ref. 8]" *Reference 8 is the correct reference for the July 24, 2014 NRC staff audit.* Suggested changes shown in the markup.

Location	Comment
Section 4.8 [[ ]]	Page 28: 1st paragraph in the section: Change the reference number from "[Ref. 7]" to "[Ref. 8]" *Reference 8 is the correct reference for the July 24, 2014 NRC staff audit.* Suggested changes shown in the markup.
Section 4.8 [[ ]]	Page 28: 1st paragraph in the section: GEH suggests the following changes: "[[ ]] It is noteworthy, that for most cases, the final MCPR ~~is larger~~ at the moment of scram is larger than the IMCPR because of the margin increase provided by the pump trip and associated flow and power decrease." *The numerical value has been corrected to be consistent with Table 2 in the RAI response package.* Suggested changes shown in the markup.
Section 4.9 [[ ]]	Page 29: 1st paragraph in the section: Change the reference number from "[Ref. 7]" to "[Ref. 8]" *Reference 8 is the correct reference for the July 24, 2014 NRC staff audit.* Suggested changes shown in the markup.
Section 4.9 [[ ]]	Page 29: 2nd paragraph in the section: GEH suggests the following changes: "[[ ]]" Suggested changes shown in the markup.
Section 4.10 [[ ]]	Page 31: 1st paragraph in the section: Change the reference number from "[Ref. 7]" to "[Ref. 8]" *Reference 8 is the correct reference for the July 24, 2014 NRC staff audit.* Suggested changes shown in the markup.

Location	Comment
Section 4.11 Mixed Cores Considerations	Page 33: Paragraph between Figure 12 and Figure 13: GEH suggests the following changes: Figures ~~12~~ 13 and ~~13~~ 14 show the [[ ]] *The FMCPR values were revised to be consistent with the response to RAI 4.* Suggested changes shown in the markup.
Section 4.12 Impact of LPRM Failures	Page 34: 1st paragraph in the section: Change the reference number from "[Ref. 7]" to "[Ref. 8]" *Reference 8 is the correct reference for the July 24, 2014 NRC staff audit.* Suggested changes shown in the markup.
Section 4.12 Impact of LPRM Failures	Page 34: 2nd paragraph in the section: 2nd sentence: Change the reference number from "[Ref. 8]" to "[Ref. 9]" *Reference 9 is the correct reference for the RAI responses.* Suggested changes shown in the markup.
Section 4.13 Applicability of GS3 to Future Operating Conditions	Page 36: 3rd paragraph in the section: Last sentence: Change the reference number from "[Ref. 7]" to "[Ref. 8]" *Reference 8 is the correct reference for the July 24, 2014 NRC staff audit.* Suggested changes shown in the markup.
Section 4.13 Applicability of GS3 to Future Operating Conditions	Page 37: 5th paragraph in the section: Item 3: GEH suggests adding a link for "Figure 3".

Location	Comment
Section 5.0 Conclusions	Page 38: Item 5: GEH suggests the following change: "5. The use of TRACG04 for the GS3 flow reduction ~~calculations~~ events is acceptable." Suggested changes shown in the markup.
Section 6.0 References	Page 39: Reference 3: GEH suggests citing the -A version of this reference, as follows: "3. GE Hitachi Nuclear Energy, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications," ~~NEDO~~ NEDE-32465 Supplement 1P-A, Revision ~~0~~1, ~~September 2011~~ October 2014. (ADAMS Accession number ~~ML112550358~~ ML14304A306)" Suggested changes shown in the markup.
Section 6.0 References	Page 39: Reference 9: GEH suggests the following correction to the reference title: "9. GE Hitachi Nuclear Energy, "Response to Request for Additional Information Re: GEH Licensing Topical Report NEDE-33766P, GEH Simplified Stability Solution (GS3)," September 19, 2014. (ADAMS Accession number ML14262A445)" Suggested changes shown in the markup.
Section 6.0 References	Pages 39 through 41: GEH suggests deleting References 10 through 37 since they are not cited in the draft SE. Suggested changes shown in the markup.
Appendix A: Request for Additional Information Evaluation	Page 42: RAI 1: 2nd paragraph of the evaluation: GEH suggests the following change: "GEH has committed to incorporate this modified pages in the approved "-A" version of the ~~code~~ LTR." Suggested changes shown in the markup.
Appendix A: Request for Additional Information Evaluation	Pages 42 and 43: RAIs 1 through 5: For the following sentence in each RAI evaluation: "The information requested was discussed during the July 2014 audit [Ref. 8], and was documented in the RAI response [Ref. ~~8~~9]." GEH suggests changing the reference number from "[Ref. 8]" to "[Ref. 9]" *Reference 9 is the correct reference for the RAI responses.* Suggested changes shown in the markup.

Markup of Draft Safety Evaluation for NEDE-33766P Revision 0,

“GEH Simplified Stability Solution (GS3)”

The following markup illustrates the GEH proprietary content and suggestions per the comment summary table.

TABLE OF CONTENTS

LIST OF FIGURES

ACRONYMS

2RPT	Two-Pump Recirculation Pump Trip
ΔCPR	Delta Critical Power Ratio
AOO	Anticipated Operational Occurrences
APRM	Average Power Range Monitor
BE	Best Estimate
BOC	Beginning of Cycle
BSP	Backup Stability Protection
BWROG	Boiling Water Reactor Owners Group
CPR	Critical Power Ratio
CSAU	Code Scaling Applicability and Uncertainty
D&S	Detect and Suppress
D&SS	Detect and Suppress Solution
DIVOM	Delta Over Initial MCPR Versus Oscillation Magnitude
DSS-CD	Detect and Suppress Solution - Confirmation Density
eDRF	Electronic Design Record File
EOC	End of Cycle
FMCPR	Final Minimum Critical Power Ratio
FWHOOS	Feedwater Heater Out Of Service
Gd	Gadolinium
GDC	General Design Criteria
GEH	General Electric, Hitachi
GS3	GEH Simplified Stability Solution
ICPR	Initial Critical Power Ratio
LPRM	Local Power Range Monitor
LTA	Lead Test Assemblies
LTR	Licensing Topical Report
LTS	(Stability) Long Term Solution
MCPR	Minimum Critical Power Ratio
OLMCPR	Operating Limit Minimum Critical Power Ratio
OPRM	Oscillation Power Range Monitor
PBDA	Period Based Detection Algorithm

PHE	Peak Hot Excess
PIRT	Phenomena Identification and Ranking Table
RAI	Request for Additional Information
RPT	Recirculation Pump Trip
SAFDL	Specified Acceptable Fuel Design Limits
SER	Safety Evaluation Report
SLMCPR	Safety Limit Minimum Critical Power Ratio
SLO	Single Loop Operation
TER	Technical Evaluation Report
TH	Thermal Hydraulic
TLO	Two Loop Operation
U-235	Uranium-235

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION REGARDING LICENSING TOPICAL REPORT NEDE-33766P FOR GEH SIMPLIFIED STABILITY SOLUTION GE-HITACHI NUCLEAR ENERGY AMERICAS LLC

1.0 INTRODUCTION

By letter dated September 10, 2013 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13254A137), as supplemented on September 19, 2014 (ADAMS Accession No. ML14262A445), GE-Hitachi Nuclear Energy Americas LLC (GEH) submitted licensing topical report NEDE-33766P, "GEH Simplified Stability Solution (GS3)," Rev.0. The proposed topical report would allow an additional methodology for boiling water reactor (BWR) stability.

GS3 is a methodology to demonstrate the validity of stability-related scram setpoints. It does not require any hardware and/or software change for plants already implementing Options I-D, II, or III, to which GS3 applies. None of these options are approved for use in MELLLA+; thus GS3 is not applicable in the MELLLA+ domain. The implementation of the GS3 scram setpoint methodology does not alter any other plant limitations or restrictions such as SLO or FWHOOS. GS3 is intended to replace the TRACG DIVOM methodology described in NEDO-32465-A [Ref. 2] and NEDO-32465, Supplement 1 [Ref.3]. The GS3 methodology improvements are partly based on approved methodology concepts used in the DSS-CD methodology [Ref. 5].

The staff has reviewed the information provided in the LTR and accepted it without limitations. The main conclusion of the staff evaluation is that the proposed GS3 approach for Option I-D, II, and III plants provide ample margin for the conditions inside the envelope of applicability and is an acceptable approach to define scram setpoints.

1.1 BACKGROUND

Following the March 1988 instability event in the LaSalle boiling water reactor, the Boiling Water Reactor Owners Group (BWROG) initiated a task to investigate actions that industry should take to resolve the stability issue as an operational concern. Through analysis, the BWROG found that the existing plant protection system, which was based on a scram on high average power range monitor (APRM) signal, may not provide enough protection against out-of-phase modes of instability; thus, the BWROG decided that a new automatic instability suppression function was required as a long-term solution and that this function should have a rapid and automatic response which does not rely on operator action.

The BWROG pursued and the staff approved three different long-term stability options, and it is up to the individual licensees to choose which solution will be implemented in their reactor. These options can be summarized as follows:

I. Exclusion Region. A region outside which instabilities are very unlikely is calculated for each representative plant type using well-defined procedures. If the reactor is operated inside this exclusion region, an automatic protective action is initiated to exit the region. This action is based exclusively on power and flow measurements, and the presence of oscillations is not required for its initiation. Two concepts of type I have been pursued by the BWROG:

I-A Immediate protection action (either scram or select rod insert) upon entrance to the exclusion region.

I-D Some small-core plants with tight inlet orifices have a reduced likelihood of out-of-phase instabilities. For these plants, the existing flow-biased high APRM scram provides a detect and suppress function to avoid safety limits violation for the expected instability mode. In addition, administrative controls are proposed to maintain the reactor outside the exclusion region.

II. Quadrant-Based APRM Scram. In a BWR/2, the quadrant-based average-power-range monitor is capable of detecting both in-phase and out-of-phase oscillations with sufficient sensitivity to initiate automatic protective action to suppress the oscillations before safety margins are compromised.

III. LPRM-Based Detect and Suppress. LPRM signals or combinations of a small number of LPRMs are analyzed on-line by using three diverse algorithms. If any of the algorithms detects unstable power oscillations, automatic protective action is taken to suppress the oscillations before safety margins are compromised.

All the above solutions have been implemented in the United States with some degree of success. Nevertheless, there are four significant areas of consideration, which merit a revisit of these long-term solutions. These areas are: (a) deficiencies identified in the CPR versus oscillation amplitude correlation used for detect and suppress solutions (i.e., the DIVOM correlation,) which resulted in a Part 21 notification, (b) proposed increases in power density, (c) the July 2003 Nine Mile Point 2 event, and (d) the December 2004 Perry event. For MELLLA+ applications, the staff has reviewed and approved two solutions: DSS-CD and EO3.

DSS-CD stands for detect and suppress solution – confirmation density. It is a solution licensed by GEH and based on Option III; it increases the likelihood of necessary scram when ~~an~~ growing power oscillations are ~~is~~ detected by setting all required solution parameters to its most sensitive limit when a rapid change of flow (indicating a recirculation pump trip) is detected. ~~To minimize the likelihood of spurious scrams,~~ To provide a rigorous solution, DSS-CD requires that a number of OPRM strings confirm with the determination that an oscillation is indeed occurring (thus the name confirmation density). DSS-CD has been approved by the staff for use in MELLLA+.

EO3 stands for enhanced Option III. EO3 is a mixture of Option III and Option I-A. It sets an area in the power-flow map where a scram is enforced even if oscillations are not detected. This region is based on stability criteria for the hot channel, which allows for a well-defined calculation of the DIVOM slope. EO3 has been approved by the staff for use in MELLLA+.

The DIVOM methodology [Refs. 2, 3] is conservative by design. It was developed to avoid having to perform a large number of best estimate calculations to demonstrate compliance; thus a number of conservatisms were required. In the past, industry determined that these conservatisms were a good trade off when best-estimate calculations were very difficult and expensive to perform. However, experience over many years of implementation has shown that the scram setpoints developed using the DIVOM methodology were conservative and satisfied SAFDL requirements with large margins.

GS3 implementation does not require any hardware and software changes for plants licensed with Options I-D, II, or III, because it is used exclusively to demonstrate the acceptability of the solution setpoints or exclusion regions. The GS3 standard procedure for plant-specific confirmations of reload designs is applicable for the GEH BWR/2-6 product lines using TRACG methodology [Ref. 6], which has been qualified for stability analysis as part of DSS-CD licensing [Ref. 5].

The GS3 LTR [Ref. 1] describes a proposed methodology to replace the DIVOM methodology [Refs. 2, 3], which is used to demonstrate that LTS scram setpoints satisfy GDC criteria. Specifically, the GS3 methodology is designed to guarantee that SAFDLs are maintained should an LTS scram be required. The GS3 methodology is only applicable to D&S-type solutions where a reactor scram is required to ensure that SAFDLs are maintained. These LTS options are I-D, II, and III.

For plants implementing Option I-D, GS3 is applied to the flow-biased APRM scram line, which protects the reactor in case of core-wide oscillations. GS3 applies to the quadrant-based APRM scram in plants implementing Option II, which protects the reactor in case of both core-wide and regional oscillations. For plants implementing Option III, GS3 applies to the OPRM scram, which must protect the reactor for both core-wide and regional oscillations.

2.0 REGULATORY EVALUATION

The regulatory criteria for this review are based on relevant sections of the Standard Review Plan [Ref. 7]. Of specific relevance is SRP Section 15.9, "Boiling Water Reactor Stability."

The following GDC are applicable to this review:

Criterion 10, "Reactor design," requires that:

> The reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.

Criterion 12, "Suppression of reactor power oscillations," requires that:

> The reactor core and associated coolant, control, and protection systems shall be designed to assure that power oscillations which can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed.

To ensure compliance with GDC 10 and 12, the NRC staff confirms that the thermal and hydraulic design of the core and the reactor coolant system has been accomplished using acceptable analytical methods, provides acceptable safety margins from conditions that could lead to fuel damage during normal reactor operation and anticipated operational occurrences, and is not susceptible to thermal-hydraulic instability or can be reliably and readily detected and suppressed.

Regulatory guidance for the review of the thermal and hydraulic design and the suppression of reactor power oscillations is provided in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (SRP) Section 4.4, "Thermal and Hydraulic Design," and SRP Section 15.9, "BWR Core Stability." As prescribed in NUREG-0800, Chapter 4, the NRC staff will confirm that the licensee performs the plant-specific trip setpoint calculations using NRC-approved methodologies. SRP Section 15.9 describes review procedures to evaluate the possibility of thermal-hydraulic instability in BWRs, analytical methods and codes to predict the stability characteristics of BWRs, and the use of approved long-term stability solutions.

3.0 <u>SUMMARY OF TECHNICAL INFORMATION</u>

3.1 OVERVIEW OF GS3 METHODOLOGY

GS3 is only a methodology to demonstrate the validity of stability-related scram setpoints. It does not require any hardware and/or software change for plants already implementing Options I-D, II, III. The implementation of the GS3 methodology in these plant types does not change any aspect of the implemented BSP solutions, because the BSP exclusion regions are preventive in nature (i.e., the scram occurs before oscillations develop) and do not require to demonstrate additional margins to CPR other than the required steady state operation limits.

The DIVOM methodology [Refs. 2, 3] is conservative by design. It was developed to avoid having to perform a large number of best estimate calculations to demonstrate compliance; thus a number of conservatisms were required. In the past, industry determined that these conservatisms were a good trade off when best-estimate calculations were very difficult and expensive to perform. However, experience over many years of implementation has shown that the scram setpoints developed using the DIVOM methodology were conservative and satisfied SAFDL requirements with large margins. The results of these conservatisms in the DIVOM methodology have caused a significant increase in the stability-related OLMCPRs (for any given setpoint), making stability the limiting event setting the OLMCPR for several units operating cycles.

The proposed GS3 methodology is essentially a pre-calculation of the required OLMCPR as a function of either: (1) the selected OPRM scram setpoint for Option III plants, (2) the flow-biased APRM scram setpoints for each Option I-D plant, or (3) the quadrant based APRM scram setpoints for each Option II plant. In essence, the plant choses [[ ]] to prevent spurious scrams, and GS3 specifies the minimum OLMCPR the plant must operate under.

The implementation of GS3 for a reload application uses the following steps:

1. Verification of GS3 applicability. The GS3 LTR defines an envelope of applicability, which defines the type of plant, operating parameters and fuel loaded.

2. For Option III plants, definition of the OPRM scram setpoint that is necessary to avoid spurious scrams.

3. Table lookup (in Tables 9-5 to 9-9 of the GS3 LTR [Ref. 1]) to define the minimum OLMCPR that must be maintained during steady state operation.

Tables 9-5 through 9-9 in the GS3 LTR define [[ ]] that is acceptable based on either the chosen setpoint (for Option III) or the existing flow-biased or quadrant based APRM scram (for Option I-D and Option II, respectively). [[ ]] is the standard "delta-over-initial" CPR, which is customarily used in other approved applications (see Ref. 2 or Ref. 5 for other examples where delta-over-initial CPR is used) and has been demonstrated by example [[ ]]

Different acceptable OLMCPR values are calculated for rated conditions or for single loop operation because, for SLO, the initiating transient is a one-pump trip and the initial conditions are not full power, which allow for more operating flexibility, and thus, larger margins are required.

In cases that lay outside the applicability envelope (for example, introduction of new fuel lines), the GS3 LTR [[ ]]

Section 10 of the LTR describes the procedure to implement the GS3 scram-setpoint methodology in plant-specific applications. Table 10.-1 of the LTR defines the applicability checklist that is used [[

]] (see Section 09)). Further discussion about the procedure and checklist for plant-specific applications can be found in Section ~~4.4~~10.

Table 10-3 of the GS3 LTR, defines the procedures to be followed for the introduction of new fuel types. The GS3 LTR specifies that [[ ]]

[[ ]] The full CSAU results are documented in Sections 3-7 of the GS3 LTR, and Section 8 shows an example application result.

3.2 TECHNICAL INFORMATION

The LTR is divided into 12 sections. Sections 1 and 2 present an introduction to the report and the licensing requirements. They also define the scope of the TRACG04 application, which is limited to [[ ]]

Sections 3, 4, 5, 6, and 7 document the application of the CSAU methodology to GS3 calculations. This CSAU results form the basis for the uncertainty treatment applied to the GS3 setpoints.

Section 8 provides an example demonstration analysis. [[ ]]

Section 9 documents the generic methodology applicability envelope and [[ ]] (Section 9.5).

Section 10 documents the procedures to be followed for plant-specific applications to verify that the plant lies within the applicability envelope, and [[ ]].

Sections 11 and 12 present the conclusions and list of references.

The information presented in the LTR has been reviewed by the staff along with the responses to additional information and the information presented during the staff audit [Ref. 8]. This review is documented in Section 4, "**4.0 TECHNICAL EVALUATION**".

4.0 TECHNICAL EVALUATION

Long term stability (LTS) solutions are designed to protect the reactor for two different types of transients (See **Figure 1** for reference):

1. Slow transients associated with startup procedures, where the instability region is entered slowly and slightly because of control rod motion. These transients have been observed in the fleet and result in small amplitude oscillations that could be handled manually by the operator, but the LTS are designed to provide protection. Using **Figure 1** as a reference, this type of event would start at low flow-low power, and slowly increase power by either withdrawing control rods or from an unexpected FW heater transient.

2. Fast transients associated with loss of recirculation flow. These transients occur when one or two recirculation pumps are tripped. The instability region may be entered fully and rapidly, resulting in large amplitude oscillations that would be hard to manage manually by the operator. For this event, the initial operating conditions would be a full power and the flow reduction (e.g., a recirculation pump trip) would force a trajectory parallel to the blue lines in **Figure 1**, which would enter the exclusion region.

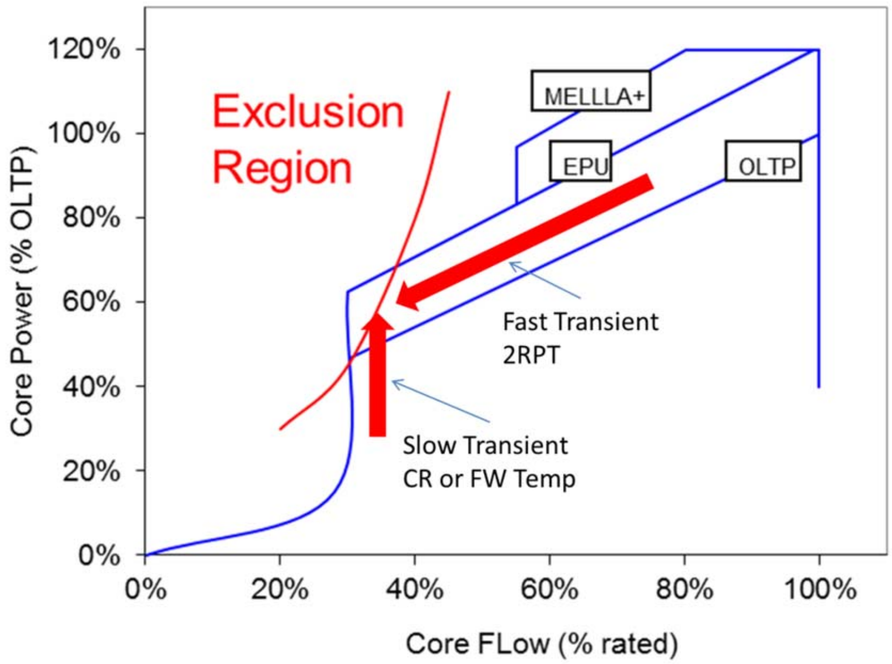

Figure 1. Typical stability exclusion region in the power-flow map

Fast RPT as described in the second transient above are, thus the most challenging transients from the point of view of instability and are used to verify the adequacy of the LTS scram setpoints. Experience has shown that the [[ ]] A 2-pump RPT (2RPT) [[ ]] is a reasonable transient to demonstrate performance of a LTS solution performance.

4.1 APPLICABILITY OF TRACG04 FOR GS3 CALCULATIONS

The GS3 scram-setpoint methodology is based on TRACG04 calculations, which are similar to the calculations performed for DSS-CD [Ref. 4]. These calculations involve [[ ]] that results in unstable power oscillations. As part of the staff review of DSS-CD, TRACG04 was approved for these types of calculations [Ref.5]. The staff concludes that the use of TRACG04 for GS3 calculations is within the scope of the previous TRACG04 review [Ref.5]. Therefore, the use of TRACG04 for the GS3 flow reduction calculations is acceptable.

4.2 APPLICABILITY OF PROPOSED ENVELOPE FOR PLANTS USING STABILITY OPTION III

Figure 2 shows a typical hot channel CPR following a 2RPT at t≈20 s. As shown in that figure, the recirculation flow reduction at t≈20 s results in a significant power-level reduction, which in turn increases the ~~available~~ CPR because, even though the power-to-flow ratio and void fraction remain essentially constant during the 2RPT, the lower power results in larger margins to ~~critical heat flux~~boiling transition. If the transient is allowed to progress, large amplitude oscillations would occur (in the Figure 2 example, oscillations [[ ]] and grow exponentially). Eventually, the oscillations grow large enough to challenge SAFDLs (in the Figure 2 example, ~~critical heat flux~~boiling transition is [[ ]]). The LTS setpoint must be reached and the scram must take place before margins to MCPR are depleted. In the Figure 2 example, a simulation of the Option III algorithm shows that the scram would have initiated [[ ]] and suppress the oscillations. ~~(Note that for a typical TRACG calculation, the Option III algorithm scram is not modeled and the transient is allowed to progress without scram; the Option II algorithm is applied as a post-processing step to identify when the oscillations would have been mitigated).~~

A key result of these simulations is that, for the typical 2RPT, the MCPR at the time of LTS scram is larger (i.e., safer) at the time of scram than at full-power steady state at t≈0 s. This indicates that the LTS scram is effective. The large conservatisms in the DIVOM methodology assumptions tend to mask these results, and a best estimate (BE) calculation as presented in GS3 always presents a more complete picture of the real physics.

The 2RPT with instability transient of **Figure 2** is a particular example of the increase in CPR that results from an RPT. However, it is not unrepresentative. In the responses to request for additional information (RAI) [Ref. ~~8~~9], GEH submitted similar [[ ]] **Figure 3** shows the result of these calculations. It is seen in this figure that [[ ]]

The results shown in Figure 3 are BE calculations performed at the real operating conditions expected [[ ]]

It must be re-emphasized that the [[ ]] Under licensing conditions, the plant is allowed to operate just at the OLMCPR limit, [[ ]]

It can be concluded from this data that the scram setpoints calculated using the GS3 LTR methodology provide ample margin for conditions inside the envelope of applicability. Should [[ ]]

[[

]]

Figure 2. Typical CPR after a 2RPT that develops unstable oscillations (Fig 9-5, Ref. 1)

[[

]]

Figure 3. CPR response to a 2RPT with unstable oscillations [[
]]

4.3 APPLICABILITY OF GS3 TO PLANTS USING STABILITY OPTIONS I-D AND II

Because of the reduced number of US plants using Option I-D and II, the GS3 LTR proposes to use plant-specific calculations for each plant. GEH has performed these plant-specific calculations and they are documented in Tables 9-8 and 9-9 of the GS3 LTR [Ref. 1]. This plant-specific approach for Options I-D and II is acceptable for each of the analyzed plants [[ ]]

4.4 APPLICABILITY OF THE PLANT-SPECIFIC APPLICABILITY CHECKLIST

Section 10 of the LTR describes the procedure to implement the GS3 scram-setpoint methodology in plant-specific applications. Table 10.-1 of the LTR defines the applicability checklist that is used to determine if the generic GS3 setpoints may be used for this application.

This checklist is used to ensure that the plant and operating conditions lie inside the GS3 applicability envelope (see Section ~~0~~9).

[[ ]]

The staff has reviewed both the applicability checklist and the extension procedure and concludes that they constitute an acceptable methodology for GS3 implementation.

4.5 APPLICABILITY OF [[ ]]

During the July 24, 2014 audit [Ref. ~~7~~8], the staff reviewed a number of electronic design record files (eDRFs), as well as plots and tables derived from them. For all the calculations reviewed by the staff, [[ ]]

[[ ]] On a typical 2RPT, the CPR increases when the flow is reduced. Later in the transient, CPR is degraded if oscillations are established. The CPR increase due to the initial flow/power reduction tends to dominate the final results of the analysis.

[[ ]] An example is shown in Figure 4. For all the cases that the staff reviewed, a similar trend was observed. [[ ]]

Figure 5 shows a calculation for [[ ]]

[[

]]

Figure 4. [[ ]]

[[

]]

Figure 5. [[

]]

4.6 LEGACY FUEL

During the July 24, 2014 audit [Ref. ~~7~~8], the staff reviewed an eDRF of the current Nine Mile Point, Unit 1 cycle, which contains a mixture of legacy GE11 and GNF2 fuel in order to determine the effect legacy fuel has on [[ ]]. All GE11 fuel is twice burned (i.e. loaded three times in the core). A complete listing of [[

]] This makes it highly unlikely that twice burned GE11 fuel could control the response of the core to an OPRM scram. In this particular example, [[

]]

For a given core loading, the “dominant” fuel type is the one with bundles that are closer to safety limits than the rest of the core. Typically fuel types become “dominant” towards the end of their first cycle and beginning of the second, when the gadolinium (Gd) burnable poison is essentially removed, but significant Uranium-235 (U-235) loading remains and these fuel bundles carry a larger fraction of the power load than the rest of the core. By the time a fuel bundle has been in the core for two or more cycles (twice- burned), the Gd has essentially been depleted and the U-235 content is relatively low, so that these bundles are not likely to have ~~neither~~ high powers ~~nor~~or be close to safety limits. Once this occurs, these fuel bundles are no longer “dominant”.

“Legacy” fuel types are a consequence of the fuel management chosen by a particular core designer. As the U-235 content is depleted, the core designer will move these bundles towards the periphery, where the power is lower and not as much U-235 is needed. Typically, most fuel bundles stay in the core for three cycles and are removed to the spent fuel pool. However, under some loading strategies, a few of the thrice-burned bundles will be used in the core periphery and you can have four- or even five-times burned fuels in a particular core design. These bundles are always loaded in the periphery, where the power is low. If the plant switched to a more modern fuel design, the old bundles become known as “legacy” fuels, which are never located in a core position where they could become close to safety limits. As stated in Section 10.1 of the LTR, [[

]]

This situation is also likely to occur with LTAs. By its very nature, test assemblies are never located at peak power positions, so that they burn slower than regular fuel. [[

]]

[[

]]

4.7 [[ ]]

During the July 24, 2014 audit [Ref. ~~7~~8], GEH presented results of a sensitivity study for [[

]] Figure 6 shows a summary of these results. Nevertheless, because of [[

]] as it is customary. The staff has reviewed the sensitivity [[ ]]

[[

]]

Figure 6. Sensitivity [[ ]]

4.8 [[ ]]

During the July 24, 2014 audit [Ref. ~~7~~8], GEH presented a number of calculations to attempt to quantify the impact of [[

]

] It is noteworthy, that for most cases, the final MCPR ~~is larger~~ at the moment of scram is larger than the IMCPR because of the margin increase provided by the pump trip and associated flow and power decrease. The NRC staff concluded that [[ ]] The staff has reviewed the [[ ]]

[[

]]

Figure 7. [[ ]] **sensitivity results**

4.9 [[ ]]

During the July 24, 2014 audit [Ref. ~~7~~8], a study was presented [[

]] The staff has reviewed the sensitivity to [[
]]

[[

]]

Figure 8. Sensitivity [[ ]]

[[

]]

Figure 9. Sensitivity to [[ ]]

4.10 [[ ]]

During the July 24, 2014 audit [Ref. ~~7~~8], analyses were presented for [[ ]] The results of the analyses are presented in Figure 10. [[ ]] The staff has reviewed the sensitivity [[ ]]

[[

]]

Figure 10. [[ ]] **sensitivity**

4.11 MIXED CORES CONSIDERATIONS

GEH has performed a study of the impact of mixed core on [[ ]]. The LTR defines a mixed core as, [[ ]] Figure 11 and Figure 12 show the assumed core loadings.

[[

]]

Figure 11. Mixed core loading [[ ]]

[[

]]

Figure 12. Mixed core loading [[ ]]

Figures ~~12~~ 13 and ~~13~~ 14 show the [[

]]

[[

]]

Figure 13. [[ ]]

[[

]]

Figure 14. [[ ]]

4.12 IMPACT OF LPRM FAILURES

During the July 24, 2014 audit [Ref. ~~7~~8], the staff reviewed calculations that show the impact of LPRM failures on GS3 performance is small and well within the allowed margins. Two types of failures were analyzed:

1. [[
2.]]

Figure 15 shows a typical LPRM to OPRM cell assignment, and Figure 16 shows [[ ]] As seen in the RAI response from September 19, 2014 [Ref. ~~8~~9], all analyzed [[ ]] of scramming the reactor earlier than the nominal condition, resulting on a slightly smaller FMCPR (i.e., conservative). Overall, the [[ ]]

Figure 17 shows the results of introducing [[

]]

The staff concludes that LPRM failures [[
]]

[[

]]

Figure 15. Typical LPRM to OPRM cell assignment

[[

]]

Figure 16. LPRM failure cases studied

[[

]]

Figure 17. Results of random LPRM failures

4.13 APPLICABILITY OF GS3 TO FUTURE OPERATING CONDITIONS

[[ ]] In order to capture these changes and ensure ample margin to SAFDLs while continuing to use the GS3 methodology, the GS3 methodology provides the licensee of the nuclear power plant using Option III with two options:

1. [[ ]]

These two options are described further below.

[[ ]] The staff reviewed the [[ ]] during the July 24, 2014, audit and made the following assessment as documented in the audit report [Ref. ~~7~~8]:

[[

]]

Considering the following sensitivity analyses:

1. [[

]]

[[

]]

For plants currently using Options I-D or II, [[

]]. The acceptable limits are documented in Tables 9-8 and 9-9 of the LTR. The staff has reviewed these limits and they are acceptable.

5.0 CONCLUSIONS

The NRC staff review of GS3 has reached the following conclusions. No restrictions or limitations are applied to the GS3 LTR approval.

1. The proposed GS3 approach for Option III plants provide ample margin for the conditions inside the envelope of applicability and is an acceptable approach.

2. The proposed plant-specific GS3 approach for Option I-D and II plants provides demonstrated margin and is an acceptable approach.

3. The plant-specific applicability checklist defined in Table 10-1 of the LTR is acceptable to determine whether a plant-specific application lies within the applicability envelope.

4. [[

]]

5. The use of TRACG04 for the GS3 flow reduction ~~calculations~~ events is acceptable.

6. The proposed [[ ]] because it bounds the results of the sensitivity analyses provided during the RAI process.

7. [[ ]]

8. For new fuel introductions, [[ ]]

9. Stability analyses for GNF2 fuel following a 2RPT are [[ ]]

10. Legacy fuel does not need to be explicitly analyzed for GS3 purposes. The generic table for the dominant fuel in the core can be applied to the legacy fuel.

6.0 REFERENCES

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APPENDIX A: REQUEST FOR ADDITIONAL INFORMATION EVALUATION

RAI-1 REVISED LTR

Provide any changes to the submitted LTR by topic. Include the revised envelope in Table 9-1, mixed core procedures, a definition of legacy fuel, removal of "BWR/3" in Table 9-5, and inclusion of [[ ]] *in Section 9.4 of the cycle-specific application.*

The information requested was discussed during the July 2014 audit [Ref. 8], and was documented in the RAI response [Ref. ~~8~~9].

Attachment 1 to RAI-1 MFN 14-058 Enclosure 1 provides the modified sections of NEDE-33766P, "GEH Simplified Stability Solution (GS3)." GEH has committed to incorporate this modified pages in the approved "-A" version of the ~~code~~LTR. The response to this RAI is acceptable.

RAI-2 REALISTIC CPR LIMITS FOR GS3 APPLICATION

Provide a chart of example calculations for cycle-specific GS3 application of GE/GNF fuel in the US BWR fleet. Include BWR type, cycle, fuel, initial minimum critical power ratio (MCPR), final MCPR, and margin to safety limit MCPR. For each plant provide the worst case scenarios when the hot channel is assumed to operate at the anticipated operational occurrence operating limit MCPR limit and at the GS3 OLMCPR limit.

The information requested was discussed during the July 2014 audit [Ref. 8], and was documented in the RAI response [Ref. ~~8~~9]. The response to this RAI is acceptable.

RAI-3 GS3 SENSITIVITY ANALYSES

Provide results of a GS3 sensitivity study for [[ ]] *for a representative plant. Provide the best estimate and worst case initial condition scenarios*

The information requested was discussed during the July 2014 audit [Ref. 8], and was documented in the RAI response [Ref. ~~8~~9]. The response to this RAI is acceptable.

RAI-4 MIXED CORE CONSIDERATIONS

Provide an analysis of a sample transition from GE 14 to GNF2 over three cycles for a representative plant. Provide radial peaking factors for the two transition cycles identifying the fuel type.

The information requested was discussed during the July 2014 audit [Ref. 8], and was documented in the RAI response [Ref. ~~8~~9]. The response to this RAI is acceptable.

RAI-5 IMPACT OF LPRM FAILURES ON GS3 RESULTS

Provide a sensitivity analysis for the impact of LPRM failures on GS3 results.

The information requested was discussed during the July 2014 audit [Ref. 8], and was documented in the RAI response [Ref. ~~8~~9]. The response to this RAI is acceptable.