Global Nuclear Fuel

A Joint Venture of GE, Toshiba, & Hitachi

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Subject: **Amendment 41 to GESTAR II Incorporating the GEH Simplified Stability Solution (GS3) in the GESTAR II US Supplement**

Per our conversation on July 29, the enclosed amendment to NEDE–24011–P–A–20, General Electric Standard Application for Reactor Fuel, (GESTAR II) is submitted to incorporate the GEH Simplified Stability Solution (GS3) (Reference 1) in the GESTAR II US Supplement. The GS3 Topical Report (TR) is currently under NRC review and it is requested that the approval for these GESTAR II changes be approved at the same time as the GS3 TR such that plants wishing to implement the GS3 solution may do so without delay.

The change to the US Supplement to GESTAR II Section S.4, Stability Analysis Methods, is an extended statement to reference the approval (-A) version of the TR. In Section 4.1, Long-Term Stability Solutions, the additions include short summary statements consistent with the level of detail currently in those sections. In addition, Section S.6, References, has been revised to add a reference to the –A version of the GS3 TR, with a date TBD. The date and revision of this reference in the next revision of GESTAR II will be consistent with the –A version of the GS3 TR. Enclosure 1 illustrates the changes in revision mode.

The Enclosure 1 markups are based on Revision 20 of GESTAR II. The NRC has several amendments under review at this time, some involving stability subjects. The changes in this amendment do not overlap or depend on the other amendments to the US Supplement. However, the specific reference number for the GS3 TR may shift if the other amendments in the US Supplement are approved before this amendment.

If you have any questions about the information provided here, please contact me at (910) 819-6684 or Jim Harrison at (910) 620-1826.

Sincerely,

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References:

1. Letter from JF Harrison (GEH) to Document Control Desk (NRC), Subject: Licensing Topical Report NEDE-33766P and NEDO-33766, "GEH Simplified Stability Solution (GS3)," MFN 13-072, September 10, 2013.

Enclosure:

1. Markup of GESTAR II US Supplement – Non-Proprietary Information – Class I (Public)

cc: J Golla, USNRC
SS Philpott, USNRC
PL Campbell, GEH/Washington
JG Head, GEH/Wilmington
JF Harrison, GEH/Wilmington
PLM 001N8158 R0

ENCLOSURE 1

MFN 14-051

Markup of GESTAR II US Supplement

Non-Proprietary Information – Class I (Public)

the required safety/relief valve capacity of nuclear vessels under the provisions of the ASME safety code.

As described in the Summer 1968 Addenda of Section III, the following pressure limits are applied to the operating limit category:

(1) Under upset conditions, the code requires that reactor pressures are not to exceed 110% of design pressure (1.1 × 1250 = 1375 psig).

(2) For emergency conditions, it allows up to 120% of design pressure (1.2 × 1250 = 1500 psig).

(3) For faulted conditions, it allows up to 150% of design pressure (1.5 × 1250 = 1875 psig).

GE sensitivity studies (Reference S–49) show the effect of safety/relief valve failures on peak pressure for the MSIV closure event expectedly results in a peak pressure increase of less than 20 psi and depends on the plant total pressure relief capacity.

If an MSIV closure analysis which considers the failure of a safety/relief valve is performed, the following events are considered: (1) MSIV closure followed by indirect flux scram (estimated probability = $1 \times 10^{-3}$/demand), and (2) failure of one safety/relief valve. In addition, many conservatisms discussed previously would also be employed. According to the interpretation of the code, MSIV closure with indirect flux scram would be considered an emergency event. Therefore, the occurrence of failures in addition to the extremely low probability of this event constitutes emergency, if not faulted, conditions. Analysis of MSIV closure, flux scram and SRV failure under emergency conditions (1500 psi pressure limit) would be far less restrictive than the present analysis of MSIV closure followed by flux scram under upset conditions (1375 psi pressure limit), especially when considering the minimal effect of a failed SRV.

Overpressurization protection analysis is performed using the ODYN transient code (References S–50 and S–51). In accordance with Reference S–48, no addition of uncertainty to the calculations of pressure is needed. Results for this analysis are given in the FSAR or in the supplemental reload licensing report.

## S.4 Stability Analysis Methods

Several types of stability analyses are performed to ensure continued acceptable plant–specific implementation of NRC approved long–term stability solutions:

- Core and channel decay ratio calculations are performed to ensure that the fuel is as stable as previously licensed GE/**GNF** fuel designs. If the fuel is not as stable as previously existing fuel designs, then the stability exclusion region must be revised to provide the same level of protection. This is a generic calculation that is applicable to all long-term stability solutions.

- CPR response calculations are performed to demonstrate the SLMCPR protection against a thermal hydraulic instability event using the detect and suppress methodology outlined in Reference S-85. The plant and cycle-specific core-wide mode DIVOM (Delta CPR over Initial CPR Vs. Oscillation Magnitude) data is required for Option I-D plant stability analysis and must be calculated in accordance with the BWROG plant-specific core-wide mode DIVOM procedure guideline specified in Reference S-102. The plant and cycle-specific regional mode DIVOM data is required for Option II and Option III plant stability analyses and must be calculated in accordance with the BWROG plant-specific regional mode DIVOM procedure guideline specified in Reference S-103. This is applicable to Option I-D, Option II and Option III.

- **The GEH Simplified Stability Solution (GS3) methodology (Reference S-111) is applicable to plants implementing Option I-D, Option II, or Option III stability solutions. The GS3 methodology can replace the TRACG DIVOM methodology described in References S-85, S-102, and S-103. GS3 is a methodology improvement rather than a new Long Term Solution. For Option III plants, GS3 uses the existing detection algorithm, the Period Based Detection Algorithm (PBDA), which reliably detects the inception of power oscillations and generates a power suppression trip signal prior to exceeding the SLMCPR. For Option I-D and Option II plants, GS3 uses the Average Power Range Monitor (APRM) and flow-biased scram line, which reliably detects the power oscillations and generates a power suppression trip signal prior to exceeding the SLMCPR. The GS3 methodology does not affect the Backup Stability Protection or Exclusion Region determination for the Option I-D, Option II, or Option III stability solutions.**

- CPR margins calculations are performed to demonstrate the SLMCPR protection against a thermal hydraulic instability event using the integrated TRACG methodology outlined in Reference S-104. The demonstration of new fuel types beyond the currently approved fuel designs (up to GE14) and the BWR product line (up to BWR/6) must be demonstrated in accordance with the integrated TRACG methodology outlined in Section 6 of Reference S-104. This is applicable to DSS-CD.

The core and channel decay ratios are calculated with a NRC approved frequency domain model. The ODYSY code (References S-106 and S-96) is used in the frequency domain evaluations, even though the older FABLE code may be used in some legacy calculations (e.g., the E1A Standard Cycle). This calculation provides assurance that plants with prevention based long–term stability solutions will not have to unreasonably increase the size of their stability–based regions for the evaluated fuel design.

The continued applicability of the interim/backup stability solution is based on exclusion regions and reload validation of these exclusion regions is required to ensure full stability protection.

The applicability of the plant and cycle-specific DIVOM curve is demonstrated with a best–estimate coupled neutronic – thermal hydraulic model using TRACG. This is the same model that was used to generate the plant and cycle-specific DIVOM data. The DIVOM data is required for plants with a detect and suppress solution to demonstrate safety limit MCPR compliance.

The plant-specific CPR margins demonstration based on integrated TRACG model is required of all plants implementing the DSS-CD solution for the first time to ensure the safety limit MCPR compliance.

**The GS3 is a TRACG Best-Estimate Plus Uncertainty (BEPU) stability methodology. The plant and cycle-specific application of GS3 is defined in the approved TR, Reference S-111.**

### S.4.1 Long–Term Stability Solutions

#### S.4.1.1 Enhanced Option I–A

The BWROG Enhanced Option I–A (EIA) is a prevention solution. EIA was reviewed and approved by the USNRC as documented in References S–80 through S–84 and Reference S–96 for operation up to and including the Maximum Extended Load Line Limit Analysis (MELLLA) domain. For plants implementing EIA, the prescribed reload validation (Reference S–80) is performed each cycle and the results documented in the supplemental reload licensing report. The validation confirms that the existing E1A stability regions provide adequate stability margin. If E1A reload validation criteria are not met, new E1A stability regions must be defined and implemented.

#### S.4.1.2 Option II

The BWROG Option II is a combination prevention and detect and suppress solution. Option II was reviewed and approved by the USNRC as documented in Reference S–79 for operation up to and including the MELLLA domain. Option II is only applicable to BWR 2 plants. A reload review criterion has been defined for Option II to ensure that the existing exclusion region is acceptable for each fuel cycle. If reload criteria are not met, the exclusion region must be recalculated. In addition, continued safety limit MCPR protection is demonstrated for each fuel cycle using the methodology documented in References S–85 and S-103 and in plant–specific Option II licensing topical reports. The results of the reload review and safety limit MCPR protection calculation are documented in the supplemental reload licensing report.

**The Option II stability solution may use the GS3 methodology as described in Reference S-111 to confirm safety limit MCPR protection by using the APRM setpoints. The cycle-specific confirmation checklist described in Reference S-111 is documented in the supplemental reload licensing report.**

#### S.4.1.3 Option I–D

The BWROG Option I–D is a combination prevention and detect and suppress solution. Option I–D was reviewed and approved by the USNRC as documented in Reference S–79 for operation up to and including the MELLLA domain. Option I–D is only applicable to plants which can demonstrate that the core wide is the dominant oscillation mode for anticipated reactor instabilities. A reload review criterion has been defined for Option I–D to ensure that the existing exclusion region is acceptable and that the safety limit MCPR is protected for each fuel cycle. If reload criteria are not met, the exclusion region must be recalculated. In addition, continued safety limit MCPR protection is demonstrated for each fuel cycle using the methodology documented in References S–85 and S-102 and in plant–specific Option I-D licensing topical reports. The dominance of the core–wide mode of reactor oscillation is demonstrated at the most limiting power/flow point using the NRC–approved frequency stability code (e.g., Reference S–96 or S-106). The results of the reload review and safety limit MCPR protection calculation are documented in the supplemental reload licensing report.

**The Option I-D stability solution may use the GS3 methodology as described in Reference S-111 to confirm safety limit MCPR protection by using the APRM setpoints. The cycle-specific confirmation checklist described in Reference S-111 is documented in the supplemental reload licensing report.**

#### S.4.1.4 Option III

The BWROG Option III is a detect and suppress solution. Option III was reviewed and approved by the USNRC as documented in Reference S–79 for operation up to and including the MELLLA domain. Continued safety limit MCPR protection is demonstrated for each fuel cycle using the methodology documented in References S–85 and S-103.

The results of the safety limit MCPR protection calculation are documented in the supplemental reload licensing report.

**The Option III stability solution may use the GS3 methodology as described in Reference S-111 to determine the OPRM setpoint that confirms the safety limit MCPR protection. The cycle-specific confirmation checklist described in Reference S-111 is documented in the supplemental reload licensing report.**

#### S.4.1.5 DSS-CD

The GEH Detect and Suppress Solution – Confirmation Density (DSS-CD) is a detect and suppress solution. DSS-CD was reviewed and approved by the USNRC as documented in Reference S–104 for operation up to and including the Maximum Extended Load Line Limit Analysis Plus (MELLLA+) domain. Continued safety limit MCPR protection is demonstrated for each fuel cycle using the methodology documented in Reference S-104.

The results of the safety limit MCPR protection calculation are documented in the supplemental reload licensing report.

### S.4.2 Interim/Backup Stability Solution

#### S.4.2.1 Interim Corrective Action (ICA)

The ICA is an interim prevention solution based on exclusion regions for EIA, Option I-D, Option II and Option III. The currently used ICA regions were established in Reference S–91 based on original licensed thermal power, generally shorter fuel cycles, and more stable core designs. These regions are defined based on relative core flow and rod line points and not on specific stability criteria. New aggressive core design changes may have reduced stability margins. GE recommends that the impact of core design changes be included in plant/cycle–specific evaluations to assess the continued applicability of the ICA regions. The results of the ICA analysis are documented in the supplemental reload licensing report.

#### S.4.2.2 Backup Stability Protection (BSP) for Option III

The BSP for Option III is an alternative interim prevention solution based on exclusion regions. The currently used BSP regions were established in Reference S–90 based on revised ICA regions. These regions are defined based on relative core flow and rod line points and not on specific stability criteria. New aggressive core design changes may have reduced stability margins. GEH recommends that the impact of core design changes be included in plant/cycle–specific evaluations of the BSP regions.

The BSP for Option III is generated in accordance with Reference S-90. The BSP for Option III methodology is applied in the fuel cycle reload stability analysis. To calculate the BSP Scram and Controlled Entry Region boundaries, ODYSY decay ratio calculations are performed on the High Flow Control Line (HFCL) and on the Natural Circulation Line (NCL). Rated feedwater temperature and rated xenon concentrations are assumed for calculating the BSP Scram Region boundary endpoints. The two endpoints (A1 and B1 in Figure S-3), where the ODYSY acceptance criteria are met, are connected using either the Generic or Modified Shape Function to define the Scram Region boundary. The BSP Controlled Entry Region is calculated in a similar manner, also using the ODYSY acceptance criteria to define the two endpoints (A2 and B2), with either the Generic or Modified Shape Function as the connecting curve. Off-rated equilibrium feedwater temperature is assumed for calculating the Controlled Entry Region endpoints (A2 and B2). Equilibrium xenon condition is assumed for the HFCL endpoint (A2) while xenon-free condition is assumed for the NCL endpoint (B2).

If the MSF is used, each calculated BSP region boundary must be validated at a mid-point against the DR acceptance criterion, respectively. This mid-point MSF validation should be performed based on the calculated BSP boundaries. A mid-point can be defined as a state point that its flow is the average flow of the two corresponding bounding state points, i.e., A1 and B1 or A2 and B2 or another power/state point close to the mid-point on the MSF. The MSF validation point should be based corresponding to the HFCL conditions and its associated limiting exposure.

The typical calculated stability region boundaries are illustrated in Figure S-3 where the four calculated endpoints A1, A2, B1, B2 are based on a core decay ratio criterion of 0.80. Please

note that the actual implemented BSP boundaries might be larger due to the Base BSP region definitions. The Base BSP regions for Option III are defined in Reference S-90.

According to Reference S-90, deliberate entry into the BSP Controlled Entry Region requires compliance with at least one of the stability controls outlined below:

1. Maintain core average Boiling Boundary (BB) ≥ 4.0 feet,

2. Maintain core average BB > Reference value (demonstrated to produce stable operation) and ≥ 3.0 feet,

   Maintain radial peaking factor ≤ Reference value (demonstrated to produce stable operation),

3. Maintain core decay ratio (DR) < 0.6 as calculated by an on-line core stability monitor,

4. The individual owner will determine appropriate limits for core DR (< 0.60) as calculated by a core stability monitor, or by pre-analysis of a reactor state trajectory through the Controlled Entry Region, or

5. Continuous dedicated monitoring of real time control room neutron monitoring instrumentation with manual scram required upon indication of a reactor instability induced power oscillation.

Usually, two sets of BSP regions may be generated for different rated feedwater temperature ranges. The results of the BSP for Option III analysis are documented in the supplemental reload licensing report.

#### S.4.2.3 Backup Stability Protection (BSP) for DSS-CD

The BSP for DSS-CD is a backup solution based on exclusion regions in case the DSS-CD solution is not operational.

The BSP for DSS-CD is generated in accordance with Reference S-103. The BSP for DSS-CD methodology is applied in the fuel cycle reload stability analysis. To calculate the BSP Scram and Controlled Entry Region boundaries, ODYSY decay ratio calculations are performed on the HFCL and on the NCL. Rated feedwater temperature and rated xenon concentrations are assumed for calculating the BSP Scram Region boundary endpoints. The two endpoints (A1 and B1 in Figure S-4), where the ODYSY acceptance criteria are met, are connected using the Generic Shape Function to define the Scram Region boundary. The BSP Controlled Entry Region is calculated in a similar manner, also using the ODYSY acceptance criteria to define the two endpoints (A2 and B2), with the Generic Shape Function as the connecting curve. Off-rated equilibrium feedwater temperature is assumed for calculating the Controlled Entry Region endpoints (A2 and B2). Equilibrium xenon condition is assumed for the HFCL endpoint (A2) while xenon-free condition is assumed for the NCL endpoint (B2).

Please note that there are several differences between the BSP for DSS-CD and BSP for Option III:

a) The ODYSY core decay ratio (DR) acceptance criterion used for the Controlled Entry Region boundary intercept (A2) along the HFCL is different between the methodologies. The BSP for Option III uses a core DR acceptance criterion of 0.80 while the BSP for DSS-CD uses a core DR acceptance criterion of 0.60.

b) For BSP for Option III, the HFCL is defined as the highest licensed load line, up to the MELLLA boundary. For BSP for DSS-CD, the HFCL is defined as the MELLLA+ boundary.

c) The BSP for DSS-CD solution imposes the BSP Boundary restriction on the DSS-CD solution for short-term manual operation if the OPRM system is inoperable.

d) The Generic Shape Function is used in the BSP for DSS-CD.

The typical calculated stability region boundaries and the BSP Boundary are illustrated in Figure S-4; the three endpoints A1, B1 and B2 are calculated based on a core DR criterion of 0.80 while the A2 endpoint is calculated based on a core DR criterion of 0.60. The 0.60 criterion for the A2 endpoint (as illustrated in Figure S-4) provides additional stability margins for operation at off-rated conditions and for a two-pump trip to natural circulation flow.

Please note that the actual implemented BSP boundaries might be larger due to the Base BSP region definitions. The Base BSP regions for DSS-CD are defined in Reference S-103.

Deliberate entry into the Manual BSP Controlled Entry Region requires compliance with at least one of the stability controls outlined in Section 7.2.3.2 of Reference S-103.

Usually, two sets of BSP regions may be generated for different rated feedwater temperature ranges. Only the Automated BSP option is approved for use as an extended backup solution to DSS-CD. The results of the BSP for DSS-CD analysis are documented in the supplemental reload licensing report.

## S.5 Analysis Options

Three groups of analysis options are presented in the following sections. The first group involves options that may be chosen to improve MCPR margin. The second group of improvements represents a collection of possible operating flexibility options. Also noted in the second group is the GE Licensing Topical Report, *Applicability of GE Methods to Expanded Operating Domains* (Reference S-101), which may be part of the licensing basis for EPU and MELLLA+ plants. The third group includes the requirements for applying the generic analysis in Reference S-99 for the Fuel Loading Error event. In some cases separate plant specific reports are submitted for approval before the option is available. Other options are supported by generic analyses that have been approved and only require that the plant choose to activate the option. In each case, the plant options are selected for each cycle and

## S.6 References

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S–2 *General Electric Fuel Bundle Designs*, NEDE–31152–P, Revision 8, April 2001.

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S–4 *Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, LWR Edition*, Regulatory Guide 1.70, Revision 3, November 1978.

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S–7 Letter from L. S. Rubenstein (NRC) to R. E. Engel (GE), *Change in General Electric Analysis of Rod Withdrawal Error*, November 25, 1981.

S–8 (Not Used)

S–9 Letter from J. S. Charnley (GE) to C. O. Thomas (NRC), *Licensing Credit for Banked Position Withdrawal Sequences on Group Notch Plants*, May 10, 1985.

S–10 Letter from T. Pickens (BWROG) to G. C. Lainas (NRC), *Amendment 17 to General Electric Licensing Topical Report NEDE–24011–P–A*, August 15, 1986.

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S–16 *Steady–State Nuclear Methods*, April 1985 (NEDE–30130–P–A and NEDO–30130–A).

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S–19 *Analytical Model for Loss–of–Coolant Analysis in Accordance with 10CFR50 Appendix K*, September 1986 (NEDE–20566–P–A and NEDO–20566–A).

S–20 S. O. Akerlund et al, *The GESTR–LOCA and SAFER Models for the Evaluation of the Loss–of–Coolant Accident: Volume I — GESTR–LOCA — A Model for the Prediction of Fuel and Thermal Performance*, February 1985 (NEDE–23785–1–P–A and NEDO–23785–1–A).

S–21 K. C. Chan et. al., *The GESTR–LOCA and SAFER Models for the Evaluation of the Loss–of–Coolant Accident: Volume II – SAFER –Long–Term Inventory Model for BWR Loss–of Coolant Analysis*, February 1985 (NEDE–23785–1–P–A and NEDO–23785–1–A).

S–22 B. S. Shiralkar et al, *The GESTR–LOCA and SAFER Models for the Evaluation of the Loss–of–Coolant Accident: Volume III – SAFER/GESTR Application Methodology*, February 1985 (NEDE–23785–1–P–A and NEDO–23785–1–A).

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S–28 Letter from J. F. Quirk (GE) to L. S. Rubenstein (NRC), *General Electric Analytical Model for Calculation of Local Oxidation in LOCA Analysis*, September 14, 1981 (MFN–168–81).

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S–43 Letter from D. G. Eisenhut to all Operating BWR's, *High Burnup MAPLHGR Limits (Generic Letter 82–03)*, March 31, 1982.

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S–52 (Not Used)

S–53 *Nine Mile Point Unit One SAFER/CORECOOL/GESTR–LOCA Loss–of–Coolant Accident Analyses*, NEDC–31446P, June 1987.

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