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NEDO-33190 Hope Creek Cycle 13 Option III ELLLA Stability Evaluation

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GE Energy, Nuclear

3901 Castle Hayne Road Wilmington, NC 28401 NEDO-33190 Class I DRF 0000-0029-5854 April 2005

# Hope Creek Cycle 13 Option III ELLLA Stability Evaluation

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# Table of Contents

| 1.0 Introduction        | 4  |
|-------------------------|----|
| 2.0 Bases & Assumptions | 5  |
| 3.0 Results             | 6  |
| 4.0 References          | 11 |

# **1.0 Introduction**

MCPR Safety Limit protection calculations for Stability Solution Option III rely on the DIVOM curve (Delta CPR Over Initial CPR Versus Oscillation Magnitude) as established in Reference 1. TRACG stability analyses have been used to establish this relationship between the hot channel oscillation magnitude and the fractional change in Critical Power Ratio (CPR), which is fairly linear. The DIVOM curve represents the thermal-hydraulic responsiveness of the fuel to a given oscillation magnitude. Thus, a steeper slope is more adverse than a flatter slope. A generic curve was established in Reference 1, with an attempt to develop a reasonably bounding slope for all fuel types and operating conditions at the time the curve was developed.

Subsequent TRACG evaluations by GE have shown that the generic DIVOM curves, specified in Reference 1, may not be conservative for current plant core design and operating conditions. Specifically, a non-conservative deficiency has been identified for high peak bundle power-to-flow ratios for the generic regional mode DIVOM curve. This deficiency results in a non-conservative curve of the DIVOM curve, resulting in a non-conservative Option III trip setpoint. The original generic analysis was based on a nominal core design with a lower fuel enrichment and for pre-Extended Power Uprate. The cycle length was generally shorter, too.

Due to the concern on the generic regional mode DIVOM curve, the plant-specific DIVOM slope has been developed based on the Cycle 13 TRACG evaluation. This plant-specific DIVOM curve also covers the non-GE fuel (SVEA96+). The plant-specific DIVOM slope is used to determine an OPRM setpoint that protects the SLMCPR during an anticipated instability event for the Cycle 13 Option III evaluation.

This report summarizes the stability based OLMCPRs for the Cycle 13 ELLLA operation. The stability based OLMCPR for a two recirculation pump trip from rated power {OLMCPR(2PT)} and the stability based OLMCPR for steady state startup operation {OLMCPR(SS)} are calculated for the Option III Oscillation Power Range Monitor (OPRM) setpoints. The stability based OLMCPR is the minimum value that provides MCPR safety limit protection for the corresponding OPRM setpoint. OLMCPR(2PT) is compared with the rated power OLMCPR and OLMCPR(SS) is compared with the 45% rated flow OLMCPR to allow Hope Creek to determine acceptability of the OPRM setpoint. If the stability based OLMCPRs are greater than the acceptance criteria, stability would be a limiting event for the corresponding OPRM setpoint.

## 2.0 Bases & Assumptions

- 1. The analysis is performed in accordance with GE internal design procedure based on the ELLLA Power/Flow map.
- 2. The initial PANACEA cases, called state points R1, are restarted from corresponding nominal wrap-ups in the Cycle 13 analysis. Using nominal wrap-ups to calculate OPRM setpoints is acceptable per GE internal design procedure.
- 3. The Cycle 13 SLMCPR is 1.06. The rated OLMCPR is estimated to be 1.340 for GE14. The off-rated OLMCPR at 45% rated core flow is estimated to be 1.561.
- 4. The Engineering Computer Programs used for this analysis are PANAC11V and ISCOR09V.
- 5. The core is loaded with 164 bundles of GE14 and 600 bundles of SVEA96+.
- 6. The minimum allowable flow at rated power is 87% of rated core flow. The rated core power is 3339 MWt and the rated core flow is 100 Mlb/hr.
- 7. The plant-specific DIVOM slope is 0.60, based on a nominal radial-peaking-factor uncertainty of 5%, or 0.70, based on a nominal radial-peaking-factor uncertainty of 10%, obtained from the Cycle 13 TRACG evaluation (Reference 2).
- 8. Two sets of Hot Channel Oscillation Magnitude (HCOM) are obtained: one based on 1 Hz corner frequency filtering effect and the other based on 1.5 Hz corner frequency filtering effect.

# 3.0 Results

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The results are provided for DIVOM slopes of 0.60 and 0.70 in the following sections.

# 3.1 0.60 DIVOM Slope Case

The analysis yields the following two sets of stability-based OLMCPR results, based on a HCOM with either 1 or 1.5 Hz-corner-frequency for the 0.60 DIVOM slope case.

| OPRM       | Δi*   | 1 Hz Corner     | 1 Hz Corner     |
|------------|-------|-----------------|-----------------|
| Setpoint   |       | Frequency       | Frequency       |
|            |       | OLMCPR(SS)      | OLMCPR(2PT)     |
| 1.050      | 0.200 | 1.205           | 1.126           |
| 1.060      | 0.238 | 1.237           | 1.155           |
| 1.070      | 0.276 | 1.270           | 1.187           |
| 1.080      | 0.315 | 1.307           | 1.221           |
| 1.090      | 0.353 | 1.345           | 1.257           |
| 1.100      | 0.391 | 1.385           | 1.294           |
| 1.110      | 0.428 | 1.426           | 1.333           |
| 1.112      | 0.434 | 1.434           | 1.340           |
| 1.120      | 0.465 | 1.470           | 1.374           |
| 1.130      | 0.502 | 1.517           | 1.417           |
| 1.139      | 0.535 | 1.561           | 1.459           |
| 1.140      | 0.539 | 1.567           | 1.464           |
| 1.150      | 0.576 | 1.620           | 1.514           |
| Acceptance |       | Off-rated       | Rated power     |
| Criteria   |       | OLMCPR @        | OLMCPR,         |
|            |       | 45% flow,       | estimated to be |
|            |       | estimated to be | 1.340           |
|            |       | 1.561           |                 |

# OLMCPR Results as a Function of OPRM Setpoint (1.0 Hz corner frequency, DIVOM Slope = 0.60)

\*  $\Delta_i$  is the licensing basis HCOM with 1-Hz-corner-frequency filtering effect for OPRM setpoint i.

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| OPRM       | Δ*    | 1.5 Hz Corner   | 1.5 Hz Corner   |
|------------|-------|-----------------|-----------------|
| Setpoint   |       | Frequency       | Frequency       |
|            |       | OLMCPR(SS)      | OLMCPR(2PT)     |
| 1.050      | 0.189 | 1.196           | 1.117           |
| 1.060      | 0.225 | 1.225           | 1.145           |
| 1.070      | 0.261 | 1.257           | 1.174           |
| 1.080      | 0.297 | 1.290           | 1.205           |
| 1.090      | 0.333 | 1.325           | 1.238           |
| 1.100      | 0.369 | 1.361           | 1.272           |
| 1.110      | 0.404 | 1.399           | 1.307           |
| 1.119      | 0.434 | 1.434           | 1.340           |
| 1.120      | 0.439 | 1.439           | 1.345           |
| 1.130      | 0.474 | 1.481           | 1.384           |
| 1.140      | 0.509 | 1.526           | 1.426           |
| 1.147      | 0.535 | 1.561           | 1.459           |
| 1.150      | 0.544 | 1.574           | 1.470           |
| Acceptance |       | Off-rated       | Rated power     |
| Criteria   |       | OLMCPR @        | OLMCPR,         |
|            |       | 45% flow,       | estimated to be |
|            |       | estimated to be | 1.340           |
|            |       | 1.561           |                 |

# OLMCPR Results as a Function of OPRM Setpoint (1.5 Hz corner frequency, DIVOM Slope = 0.60)

\*  $\Delta_i$  is the licensing basis HCOM with 1.5-Hz-corner-frequency filtering effect for OPRM setpoint i.

A linear interpolation scheme was used between values in the tables above to obtain the corresponding OLMCPR(2PT) and OLMCPR(SS) for the analytical OPRM setpoint that meets the acceptance criteria.

# **OLMCPR(2PT)** Condition

- With the corner frequency set to 1.0 Hz, the OLMCPR(2PT) values for analytical OPRM setpoints of 1.050 through 1.112 satisfy the condition of being less than or equal to the estimated GE14 rated OLMCPR, 1.340. For analytical OPRM setpoints greater than 1.112, the OLMCPR(2PT) exceeds the rated OLMCPR.
- With the corner frequency set to 1.5 Hz, the OLMCPR(2PT) values for analytical OPRM setpoints of 1.050 through 1.119 satisfy the condition of being less than or equal to the estimated GE14 rated OLMCPR, 1.340. For analytical OPRM setpoints greater than 1.119, the OLMCPR(2PT) exceeds the rated OLMCPR.

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## **OLMCPR(SS)** Condition

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- With the corner frequency set to 1 Hz, the OLMCPR(SS) values for analytical OPRM setpoints of 1.050 through 1.139 satisfy the requirement of being less than or equal to the estimated OLMCPR<sub>45</sub>, 1.561. For analytical OPRM setpoints greater than 1.139, the OLMCPR(SS) exceeds the OLMCPR<sub>45</sub>.
- With the corner frequency set to 1.5 Hz, the OLMCPR(SS) values analytical OPRM setpoints of 1.050 through 1.147 satisfy the requirement of being less than or equal to the estimated OLMCPR<sub>45</sub>, 1.561. For analytical OPRM setpoints greater than 1.147, the OLMCPR(SS) exceeds the OLMCPR<sub>45</sub>.

Therefore, with the estimated rated OLMCPR of 1.340, an OPRM setpoint of 1.112 is the highest setpoint that may be used without stability setting the OLMCPR for the case of a DIVOM slope of 0.6 and the corner frequency set to 1.0 Hz. If the corner frequency is increased to 1.5 Hz, then the OPRM setpoint will need to be increased to 1.119 such that stability does not set the OLMCPR.

# 3.2 0.70 DIVOM Slope Case

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The analysis yields the following two sets of stability-based OLMCPR results, based on a HCOM with either 1 or 1.5-Hz-corner-frequency, for the 0.70 DIVOM slope case.

| OPRM       | Δ <b>*</b> | 1 Hz Corner     | 1 Hz Corner     |
|------------|------------|-----------------|-----------------|
| Setpoint   |            | Frequency       | Frequency       |
|            |            | OLMCPR(SS)      | OLMCPR(2PT)     |
| 1.050      | 0.200      | 1.233           | 1.152           |
| 1.060      | 0.238      | 1.272           | 1.188           |
| 1.070      | 0.276      | 1.314           | 1.228           |
| 1.080      | 0.315      | 1.360           | 1.271           |
| 1.090      | 0.353      | 1.408           | 1.316           |
| 1.095      | 0.372      | 1.434           | 1.340           |
| 1.100      | 0.391      | 1.459           | 1.364           |
| 1.110      | 0.428      | 1.513           | 1.414           |
| 1.118      | 0.458      | 1.561           | 1.458           |
| 1.120      | 0.465      | 1.572           | 1.468           |
| 1.130      | 0.502      | 1.634           | 1.527           |
| 1.140      | 0.539      | 1.702           | 1.591           |
| 1.150      | 0.576      | 1.776           | 1.660           |
| Acceptance |            | Off-rated       | Rated power     |
| Criteria   |            | OLMCPR @        | OLMCPR,         |
|            |            | 45% flow,       | estimated to be |
|            |            | estimated to be | 1.340           |
|            |            | 1.561           |                 |

# OLMCPR Results as a Function of OPRM Setpoint (1 Hz corner frequency, DIVOM Slope = 0.70)

\*  $\Delta_i$  is the licensing basis HCOM with 1-Hz-corner-frequency filtering effect for OPRM setpoint i.

| OPRM       | Δ <sub>i</sub> * | 1.5 Hz Corner   | 1.5 Hz Corner   |
|------------|------------------|-----------------|-----------------|
| Setpoint   |                  | Frequency       | Frequency       |
|            |                  | OLMCPR(SS)      | OLMCPR(2PT)     |
| 1.050      | 0.189            | 1.222           | 1.141           |
| 1.060      | 0.225            | 1.258           | 1.176           |
| 1.070      | 0.261            | 1.297           | 1.212           |
| 1.080      | 0.297            | 1.338           | 1.250           |
| 1.090      | 0.333            | 1.382           | 1.292           |
| 1.100      | 0.369            | 1.429           | 1.335           |
| 1.101      | 0.373            | 1.435           | 1.340           |
| 1.110      | 0.404            | 1.478           | 1.381           |
| 1.120      | 0.439            | 1.530           | 1.430           |
| 1.126      | 0.458            | 1.561           | 1.458           |
| 1.130      | 0.474            | 1.586           | 1.482           |
| 1.140      | 0.509            | 1.647           | 1.539           |
| 1.050      | 0.189            | 1.712           | 1.600           |
| Acceptance |                  | Off-rated       | Rated power     |
| Criteria   | }                | OLMCPR @        | OLMCPR,         |
|            |                  | 45% flow,       | estimated to be |
|            |                  | estimated to be | 1.340           |
|            |                  | 1.561           |                 |

# **OLMCPR** Results as a Function of OPRM Setpoint

(1.5 Hz corner frequency, DIVOM Slope = 0.70)

\*  $\Delta_i$  is the licensing basis HCOM with 1.5-Hz-corner-frequency filtering effect for OPRM setpoint i.

A linear interpolation scheme was used between values in the tables above to obtain the corresponding OLMCPR(2PT) and OLMCPR(SS) for the analytical OPRM setpoint that meets the acceptance criteria.

# **OLMCPR(2PT)** Condition

- With the corner frequency set to 1.0 Hz, the OLMCPR(2PT) values for analytical OPRM setpoints of 1.050 through 1.095 satisfy the condition of being less than or equal to the estimated GE14 rated OLMCPR, 1.340. For analytical OPRM setpoints greater than 1.095, the OLMCPR(2PT) exceeds the rated OLMCPR.
- With the corner frequency set to 1.5 Hz, the OLMCPR(2PT) values for analytical OPRM setpoints of 1.050 through 1.101 satisfy the condition of being less than or equal to the estimated GE14 rated OLMCPR, 1.340. For analytical OPRM setpoints greater than 1.101, the OLMCPR(2PT) exceeds the rated OLMCPR.

# **OLMCPR(SS)** Condition

- With the corner frequency set to 1 Hz, the OLMCPR(SS) values for analytical OPRM setpoints of 1.050 through 1.118 satisfy the requirement of being less than or equal to the estimated OLMCPR<sub>45</sub>, 1.561. For analytical OPRM setpoints greater than 1.118, the OLMCPR(SS) exceeds the OLMCPR<sub>45</sub>.
- With the corner frequency set to 1.5 Hz, the OLMCPR(SS) values analytical OPRM setpoints of 1.050 through 1.126 satisfy the requirement of being less than or equal to the estimated OLMCPR<sub>45</sub>, 1.561. For analytical OPRM setpoints greater than 1.126, the OLMCPR(SS) exceeds the OLMCPR<sub>45</sub>.

Therefore, with the estimated rated OLMCPR of 1.340, an OPRM setpoint of 1.095 is the highest setpoint that may be used without stability setting the OLMCPR for the case of a DIVOM slope of 0.70 and the corner frequency set to 1.0 Hz. If the corner frequency is increased to 1.5 Hz, then the OPRM setpoint will need to be increased to 1.101 such that stability does not set the OLMCPR.

# 4.0 References

- 1. NEDO-32465-A, Licensing Topical Report, Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications," August 1996.
- 2. NEDC-33185P, "Hope Creek Cycle 13 TRACG DIVOM Study (ELLLA)," April 2005.