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MELLLA Option III Stability Evaluation for Hope Creek at CPPU Conditions

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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 hot channel 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 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 and cycle-specific DIVOM slope has been developed based on a Cycle 14 TRACG evaluation. This plant and cycle-specific DIVOM slope, which also covers the non-GE fuel (SVEA96+), is used to determine an OPRM setpoint that protects the SLMCPR during an anticipated instability event for the Cycle 14 Option III evaluation.

This report summarizes the stability based OLMCPRs for the a mixed core of SVEA96+ and GE14 fuel at a Constant Pressure Power Uprate (CPPU) condition of 115% of the Current Licensed Thermal Power (CLTP) with operation in the Maximum Extended Load Line Limit Analysis (MELLLA) domain and no change in the normal maximum operating pressure. The evaluation was performed for a Hope Creek core containing 348 SVEA96+ fuel assemblies and 416 GE14 fuel assemblies. The quantity of each fuel type may vary in the actual Cycle 14 core.

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 MELLLA Power/Flow map.

2. The initial PANACEA cases, called state points R1, are restarted from corresponding nominal wrap-ups in the Cycle 14 analysis. Using nominal wrap-ups to calculate OPRM setpoints is acceptable per GE internal design procedure.

3. The Cycle 14 SLMCPR is 1.07. The rated OLMCPR is estimated to be 1.350. The off-rated OLMCPR at 45% rated core flow is estimated to be 1.573.

4. The Engineering Computer Programs used for this analysis are PANAC11V and ISCOR09V.

5. The minimum allowable flow at rated power is 94.8% rated core flow for MELLLA operation. The rated core power is 3840 MWt and the rated core flow is 100 Mlb/hr.

6. The plant and cycle-specific DIVOM slope is 0.802, based on a nominal radial-peaking-factor uncertainty of 5%, obtained from the Cycle 14 TRACG evaluation (Reference 2).

7. 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

The results are provided for DIVOM slopes of 0.802, in the following.

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 0.802 DIVOM slope.

OLMCPR Results as a Function of OPRM Setpoint
(1.0 Hz corner frequency, DIVOM Slope = 0.802)

OPRM Setpoint	Δ_i*	1 Hz Corner Frequency OLMCPR(SS)	1 Hz Corner Frequency OLMCPR(2PT)
1.050	0.200	1.274	1.145
1.060	0.238	1.322	1.188
1.070	0.276	1.374	1.235
1.080	0.315	1.432	1.286
1.090	0.353	1.493	1.341
1.092	0.359	1.503	*1.350*
1.100	0.391	1.559	1.401
1.102	0.399	*1.573*	1.413
1.110	0.428	1.629	1.464
1.120	0.465	1.706	1.533
1.130	0.502	1.791	1.609
1.140	0.539	1.885	1.693
1.150	0.576	1.989	1.787
Acceptance Criteria		Off-rated OLMCPR @ 45% flow, estimated to be 1.573	Rated power OLMCPR, estimated to be 1.350

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

OLMCPR Results as a Function of OPRM Setpoint
(1.5 Hz corner frequency, DIVOM Slope = 0.802)

OPRM Setpoint	Δ_i*	1.5 Hz Corner Frequency OLMCPR(SS)	1.5 Hz Corner Frequency OLMCPR(2PT)
1.050	0.189	1.261	1.133
1.060	0.225	1.306	1.173
1.070	0.261	1.353	1.216
1.080	0.297	1.405	1.262
1.090	0.333	1.460	1.312
1.097	0.359	1.503	*1.350*
1.100	0.369	1.520	1.365
1.108	0.399	*1.573*	1.413
1.110	0.404	1.583	1.422
1.120	0.439	1.651	1.484
1.130	0.474	1.726	1.551
1.140	0.509	1.808	1.625
1.150	0.544	1.898	1.705
Acceptance Criteria		Off-rated OLMCPR @ 45% flow, estimated to be 1.573	Rated power OLMCPR, estimated to be 1.350

* Δ_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 1.092 satisfy the condition of being less than or equal to the estimated rated OLMCPR, 1.350. For analytical OPRM setpoints greater than 1.092, the OLMCPR(2PT) exceeds the estimated rated OLMCPR.
- With the corner frequency set to 1.5 Hz, the OLMCPR(2PT) values for analytical OPRM setpoints of 1.050 through 1.097 satisfy the condition of being less than or equal to the estimated rated OLMCPR, 1.350. For analytical OPRM setpoints greater than 1.097, the OLMCPR(2PT) exceeds the estimated 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 1.102 satisfy the requirement of being less than or equal to the estimated $OLMCPR_{45}$, 1.573. For the OPRM setpoints greater than 1.102, the OLMCPR(SS) exceeds the rated OLMCPR.
- With the corner frequency set to 1.5 Hz, the OLMCPR(SS) values analytical OPRM setpoints of 1.050 through 1.108 satisfy the requirement of being less than or equal to the estimated $OLMCPR_{45}$, 1.573. For the OPRM setpoints greater than 1.108, the OLMCPR(SS) exceeds the rated OLMCPR.

Therefore, with the estimated rated OLMCPR of 1.350, an OPRM setpoint of 1.092 is the highest setpoint that may be used without stability setting the OLMCPR for the case of a DIVOM slope of 0.802 and the corner frequency set to 1.0 Hz. If the corner frequency is increased to 1.5 Hz, then the OPRM setpoint could be increased to an optional setpoint of 1.097 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-33186P, "MELLLA TRACG DIVOM Evaluation for Hope Creek at CPPU Conditions," April 2005.