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MELLLA TRACG DIVOM Evaluation for Hope Creek at CPPU Conditions

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MELLA TRACG DIVOM Evaluation for Hope Creek at CPPU Conditions

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ACRONYMS AND ABBREVIATIONS

Item	Short Form	Description
1	BOC	Beginning Of Cycle
2	BWROG	Boiling Water Reactor Owners' Group
3	CLTP	Current Licensed Thermal Power
4	CPPU	Constant Pressure Power Uprate
5	CPR	Critical Power Ratio
6	DIVOM	Delta CPR Over Initial MCPR Versus Oscillation Magnitude
7	EOC	End Of Cycle
8	EPU	Extended Power Uprate
9	GE	General Electric
10	GENE	General Electric Nuclear Energy
11	GNF	Global Nuclear Fuels
12	HCOM	Hot Channel Oscillation Magnitude
13	ICPR	Initial Critical Power Ratio
14	LPRM	Local Power Range Monitor
15	MCAR	Mixed Core Analysis Report
16	MCPR	Minimum Critical Power Ratio
17	MELLLA	Maximum Extended Load Line Limit Analysis
18	MOC	Middle Of Cycle
19	MWt	Megawatt Thermal
20	OLMCPR	Operating Limit Minimum Critical Power Ratio
21	OM	Oscillation Magnitude
22	OPRM	Oscillation Power Range Monitor
23	RPF	Radial Peaking Factor
24	SLMCPR	Safety Limit Minimum Critical Power Ratio
25	2RPT	Two Recirculation Pump Trip
26	TLO	Two Loop Operation

REVISIONS

Revision 1:

1. Clarify the channel grouping for the peripheral channel 19 in Section 4.1.

1.0 Scope and Summary

The purpose of this analysis is to determine the relationship between the Critical Power Ratio (CPR) and Hot Channel Oscillation Magnitude (HCOM) of 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)[1] 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 resulting curve defined as the Delta CPR over Initial MCPR Versus the Oscillation Magnitude (DIVOM) provides the basis for Option III Oscillation Power Range Monitor (OPRM) setpoints to protect the plant Safety Limit Critical Power Ratio (SLMCPR).

The base case stability analysis was performed for the power/flow state point, corresponding to a post two-pump trip condition at 33.7% rated core flow along the highest licensed rod line (Maximum Extended Load Line Limit Analysis, MELLLA rod line). Three different exposure conditions were considered: beginning of cycle (BOC), middle of cycle (MOC) and end of cycle (EOC). The NRC-approved licensing methodology as documented in Reference 1 was used in this study, supplemented by the BWROG DIVOM Procedure Guideline.

The PANACEA computer program, a three-dimensional BWR core simulator, was used to obtain three-dimensional power distribution, subcriticality and harmonic contours. The harmonic contours were utilized by the CRNC computer code to perform the channel grouping for the stability analysis. The CRNC groupings were incorporated into the TRACG basedecks and the three-dimensional TRACG computer code was used to simulate the transient. Plant-specific TRACG basedecks, which reflected Hope Creek Cycle 14 core loading (348 bundles of SVEA96+ and 416 bundles of GE14) were developed. The ANALYZE computer code was used to extract the Hot Channel Oscillation Magnitude (HCOM) and the delta CPR over initial CPR (ΔCPR/ICPR) for the limiting bundles in the TRACG analysis.

For this application the TRACG04/PANAC11 codes were used in establishing the DIVOM curves. [[

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[1] The MELLLA boundary line in the power/flow map represents a generically developed load line for Hope Creek. The actual plant operating load line is expected to vary through the cycle and from cycle to cycle and may not follow this MELLLA boundary line.

2.0 Introduction

The SLMCPR protection calculations for long-term stability solution Option III rely on the DIVOM curve as established in Reference 1. The TRACG stability analyses have been used to establish this relationship between the HCOM and the fractional change in CPR, which is fairly linear. The DIVOM curve represents the thermal-hydraulic responsiveness of the fuel to a given oscillation magnitude. Thus, a steeper curve is more adverse than a flatter curve. 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 that time.

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

GE made a Part 21 Notification (Reference 2) that identified the DIVOM deficiency. Subsequently, the BWROG has developed a guideline for calculating a plant specific DIVOM to address the issue. The guideline provides instructions on calculating a regional mode DIVOM curve, which address the important parameters (e.g., cycle exposure, power/flow conditions, feedwater temperature, radial peaking, xenon concentration, etc.) on a plant-specific basis.

The plant-specific DIVOM curves in this report have been calculated in accordance with the BWROG DIVOM Procedure Guideline. The calculated DIVOM curve reflects the core/fuel designs and plant operating strategy for Hope Creek Cycle 14.

For Option III, the DIVOM curve is used to define an OPRM setpoint to protect the SLMCPR during an anticipated instability event. A steeper DIVOM curve may require a lower OPRM setpoint.

3.0 Bases & Assumptions

The Hope Creek Cycle 14 core contains both SVEA96+ and GE14 fuels.

The TRACG DIVOM calculations were performed based on specified operating conditions for Hope Creek Cycle 14. Three conditions at different exposure level were considered:

1) BOC (Cycle Exposure = 0 MWD/ST),
2) MOC (Cycle Exposure = 7500 MWD/ST), and
3) EOC (Cycle Exposure = 12000 MWD/ST).

The choice of three exposure points follows the BWROG DIVOM guideline. [[

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This analysis is a Hope Creek-specific evaluation to establish a cycle-specific DIVOM value based on Cycle 14 core loading.

The base case stability analysis was performed at the power/flow state point corresponding to a post two-pump trip condition at 33.7% rated core flow along the highest licensed rod line. Once the limiting exposure is identified, two additional sensitivity cases are run at that exposure. One is a flow sensitivity in which post two-pump trip condition is set to 38.7% of rated core flow along the highest licensed rod line. This analysis is used to identify any DIVOM curve sensitivity to core flow. The second is a radial peaking sensitivity in which the radial peaking factor is increased by 5% and 10% on the limiting channel. This analysis is used to represent expected variations in radial peaking factor as the result of normal plant operation.

The design inputs to these calculations are modeled in:

- The Hope Creek Cycle 14 TRACG basedeck,
- The Hope Creek Cycle 14 PANAC11 wrap-ups corresponding to three different cycle exposure points at rated power/flow conditions, and
- The Hope Creek Cycle 14 ISCOR basedeck.

The following TRACG bases/assumptions are used in this analysis and reflected in the TRACG basedecks:

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- Consistent with the standard stability TRACG methodology, [[

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- The core is loaded with SVEA96+ and GE14 fuels according to Hope Creek Cycle 14 core loading.

- The TRACG model incorporates twenty-six channel groups, including six individual bundles chosen as limiting hot channels. This is adequate for a regional stability analysis.

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- The feedwater enthalpy is defined as steady state feedwater enthalpy at the post two recirculation pump trip (2RPT) power and flow conditions. The feedwater enthalpy was obtained from the ISCOR steady-state analysis case.

3.1 Plant Reference Conditions

The Reference Conditions are defined by the reactor power and flow operating domain and further defined by the following:

- The core load for Hope Creek Cycle 14 is composed of SVEA96+ and GE14.
- The rated thermal power level, under normal plant operating conditions, is 3840 MWt, at which Hope Creek is licensed to operate the plant.
- The rated core flow is 100.0 Mlbm/hr.
- The reactor dome pressure under normal plant operating conditions is 1020 psia.
- The upper boundary of the reactor two loop operation (TLO) operating domain, at which Hope Creek is licensed to operate the plant. This corresponds to the MELLLA boundary for Hope Creek, with an upper intercept at 100% rated core power and 94.8% rated core flow.
- Nominal radial peaking factor and nominal rod patterns as defined in the standard reload rod patterns for normal plant operation.

4.0 DIVOM Methodology

The NRC-approved licensing methodology as documented in Reference 1 was used in this analysis, supplemented by the DIVOM Procedure Guideline developed by the BWROG Detect and Suppress Committee.

All analyses have been performed utilizing the plant power and flow conditions and event scenarios reflecting reasonably limiting operations and the plant reference conditions. The power/flow conditions for the base case represent a two-pump trip along the highest licensed rod line to the natural circulation line.

The PANACEA, CRNC, TRACG and ANALYZE calculations have been performed to evaluate the DIVOM curves for three cycle exposure conditions for Hope Creek Cycle 14. PANACEA calculations were performed to obtain three-dimensional power distribution, subcriticality and harmonic contour at 33.7% rated core flow. CRNC calculations were performed to obtain proper regional channel grouping. TRACG steady-state analyses were performed to achieve steady-state conditions at 33.7% core flow. TRACG transient analyses were performed to simulate the instability event. ANALYZE calculations were performed to extract the HCOM and ΔCPR/ICPR.

The TRACG analysis includes these steps:

Step 1. Steady-state plant conditions are obtained at prescribed power/flow/exposure points. This step is performed by utilizing TRACG implicit mode, which results in a stable solution.

Step 2. Channel thermal-hydraulic information is extracted from the steady-state conditions (TRACG dump file generated at the end of the steady state run). [[

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Step 3. [[

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TRACG graphics information is retrieved with GRIT computer code and analyzed with the ANALYZE computer code to determine the relationship between ΔCPR/ICPR and the oscillation magnitude.

4.1 Channel Grouping

The CRNC channel grouping is based on radial peaking factor (RPF) and relative first power harmonics. The RPF and harmonic data are obtained from the PANACEA analyses. CRNC channel grouping for the BOC case is illustrated in Figure 4.1 (19 channel groups with the peripheral channel group 19 split in two groups of 20 and 30 shown on Figure 5.4 makes for a total of 20 channel groups).

Next, six single channels are selected for use in the DIVOM calculation. To ensure hot channels are selected, the single channel selection criteria include the highest radial peaking channel, the channel with the highest first harmonic and the highest product of radial peaking factor and first harmonic. These six channels, plus the 20 channels from the original grouping make up the 26 channels used in a TRACG analysis.

Figure 4.1 depicts the typical BOC channel grouping generated by the CRNC computer code.

								19	19	19	19	19	19	19	19	19	19	19	19	19	19								
							19	10	10	10	10	10	8	8	8	8	8	8	8	7	7	19							
					19	19	10	10	15	10	15	10	15	18	18	18	8	18	8	17	7	7	19	19					
					19	10	6	6	6	15	6	6	10	10	10	8	8	8	17	7	7	7	7	19					
				19	10	6	4	4	14	6	15	6	15	10	10	18	8	18	7	17	7	7	7	7	19				
		19	19	15	6	14	4	14	4	4	6	15	6	15	15	8	18	8	7	7	17	9	17	9	17	19	19		
		19	10	6	14	12	12	4	4	15	15	6	6	15	15	8	8	17	17	7	9	16	16	16	9	9	19		
	19	10	6	4	4	12	12	14	4	15	15	15	6	15	18	8	18	17	17	9	17	16	16	5	5	9	9	19	
19	10	6	4	4	12	2	14	4	14	4	6	6	6	10	8	8	7	7	7	16	9	16	5	16	5	5	9	7	19
19	6	15	4	12	2	2	4	14	4	4	4	15	10	18	18	8	17	7	9	9	16	9	5	5	13	5	16	9	19
19	6	4	14	2	2	14	15	4	2	12	14	6	10	18	18	7	7	17	16	5	9	16	16	5	5	13	5	9	19
19	6	14	4	14	4	15	14	4	4	14	14	6	10	18	18	7	7	17	16	5	5	16	16	5	13	5	16	9	19
19	6	4	2	4	14	4	14	4	14	4	6	6	18	8	8	17	7	9	9	16	5	16	5	13	3	3	5	5	19
19	10	14	4	14	2	2	4	4	4	6	6	15	10	18	18	7	17	9	9	5	3	3	3	3	13	3	16	9	19
19	6	14	2	4	12	12	12	4	15	15	18	10	18	18	17	17	7	17	16	16	3	13	11	13	3	3	16	5	19
19	6	15	4	4	14	12	14	4	15	15	18	8	18	18	17	17	9	17	16	16	3	11	11	11	3	1	13	5	19
19	10	15	4	14	4	4	4	4	6	10	10	18	8	17	17	9	16	5	5	3	3	3	1	1	13	3	13	9	19
19	6	6	4	4	14	6	15	6	15	10	10	8	18	7	7	17	5	5	3	13	3	13	3	13	3	1	3	5	19
19	10	15	6	14	6	15	15	6	6	15	18	8	8	17	17	9	5	13	13	3	3	13	16	3	13	3	13	5	19
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19	10	15	6	14	6	6	10	15	10	10	8	18	7	17	17	9	16	3	3	3	13	3	1	1	11	3	16	5	19
19	8	10	6	6	15	6	15	10	15	8	8	8	7	7	9	5	5	5	3	13	3	13	1	11	3	3	5	9	19
	19	10	10	6	6	15	15	18	10	18	18	17	7	17	16	5	16	16	16	3	13	11	11	3	3	5	9	19	
		19	10	10	15	15	15	10	8	18	18	7	7	16	16	5	5	16	16	3	3	11	11	13	5	9	19		
		19	19	18	10	18	10	18	8	8	7	17	7	17	16	5	16	5	3	3	13	3	13	5	16	19	19		
				19	8	8	8	8	18	8	17	7	17	9	9	16	5	16	5	13	3	3	5	9	19				
					19	8	8	8	8	18	7	7	7	9	9	9	5	5	16	5	5	5	9	19					
					19	19	8	8	18	7	17	7	17	17	17	16	9	16	9	16	9	9	19	19					
							19	8	8	7	7	7	7	7	7	7	9	9	9	9	9	19							
								19	19	19	19	19	19	19	19	19	19	19	19	19	19								

Figure 4.1 CRNC Channel Grouping (BOC)

4.2 Computer Codes

The following computer codes are used in this analysis:

Table 4.1 Computer Codes Used

Code name	Version
PANACEA	11
CRNC	6
TRACG	4
GRIT	4
ANALYZE	1
ISCOR	9

TRACG04, which implements the approved PANAC11 kinetics, is used instead of TRACG02 to perform the DIVOM stability analysis.

5.0 Results and Discussion

5.1 PANACEA Subcriticality Results

The PANACEA harmonic analysis results of the fundamental and azimuthal eigenvalues and core subcriticality are shown in Table 5.1. [[

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The grouping was chosen based on the first harmonic output from PANACEA for all cases. The first harmonic plots are shown in Figures 5.1 through 5.3 for BOC, MOC, and EOC respectively.

Table 5.1 Hope Creek Cycle 14 Harmonics

Cycle Exposure	Fundamental eigenvalue	Azimuthal (First Harmonic) eigenvalue	Subcriticality (1st harmonic)	Subcriticality (2nd harmonic)	Subcriticality (3rd harmonic)
BOC	1.012115	1.005507	0.006493	0.006519	0.010308
MOC	1.012768	1.006359	0.006288	0.006277	0.008459
EOC	1.009649	1.002389	0.007173	0.007181	0.011063

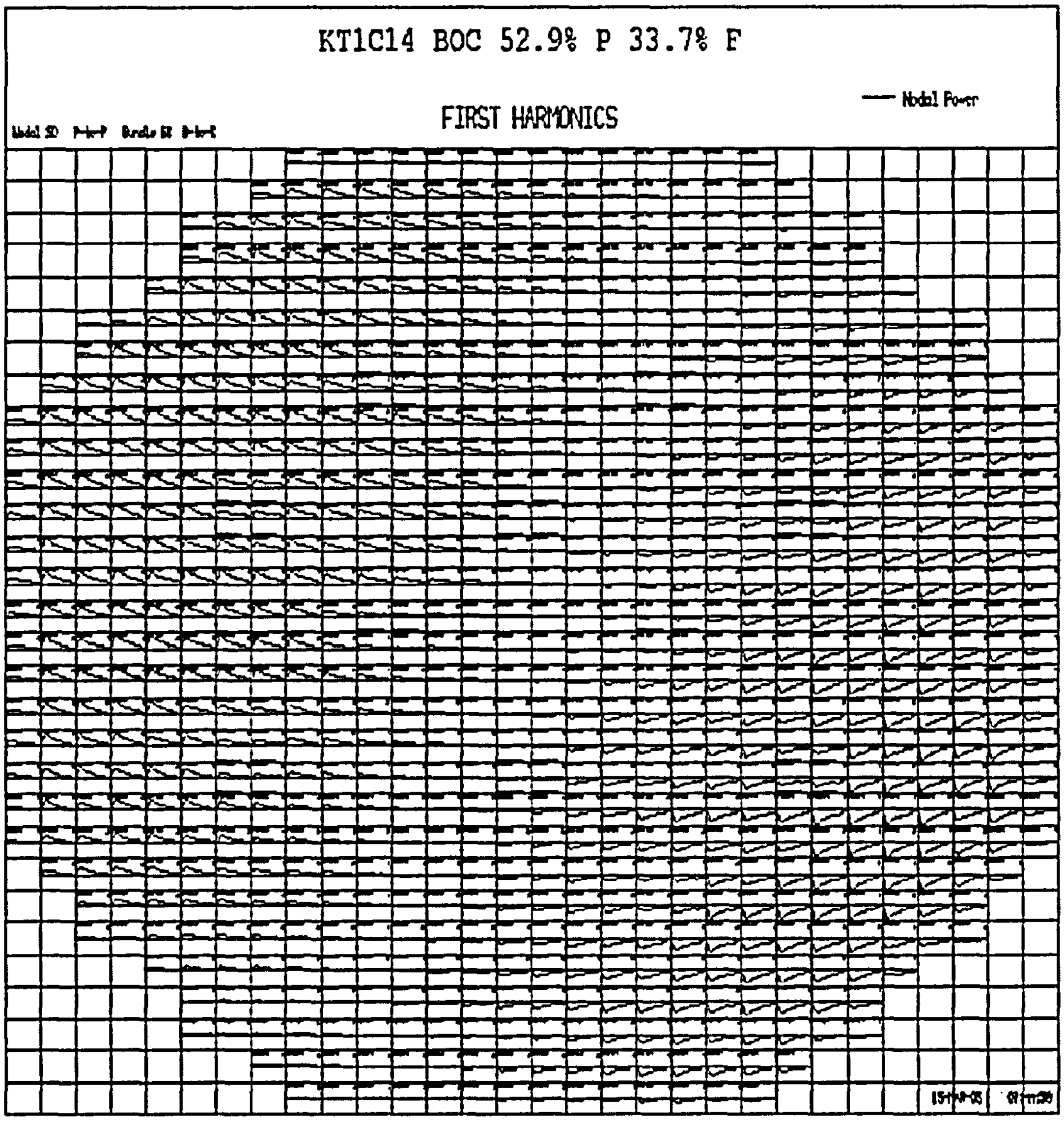

Figure 5.1 First Harmonic Flux Distribution (BOC)

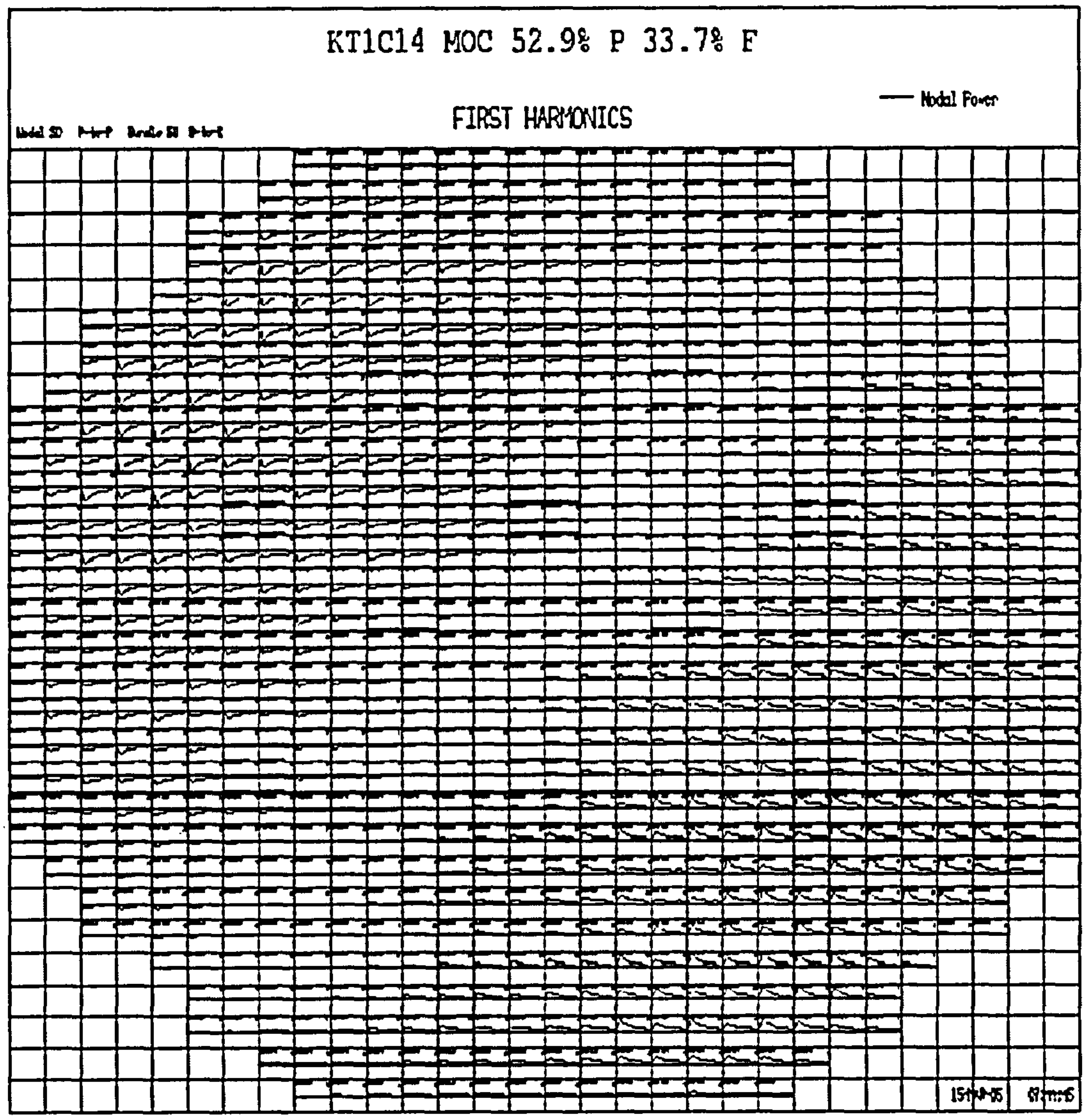

Figure 5.2 First Harmonic Flux Distribution (MOC)

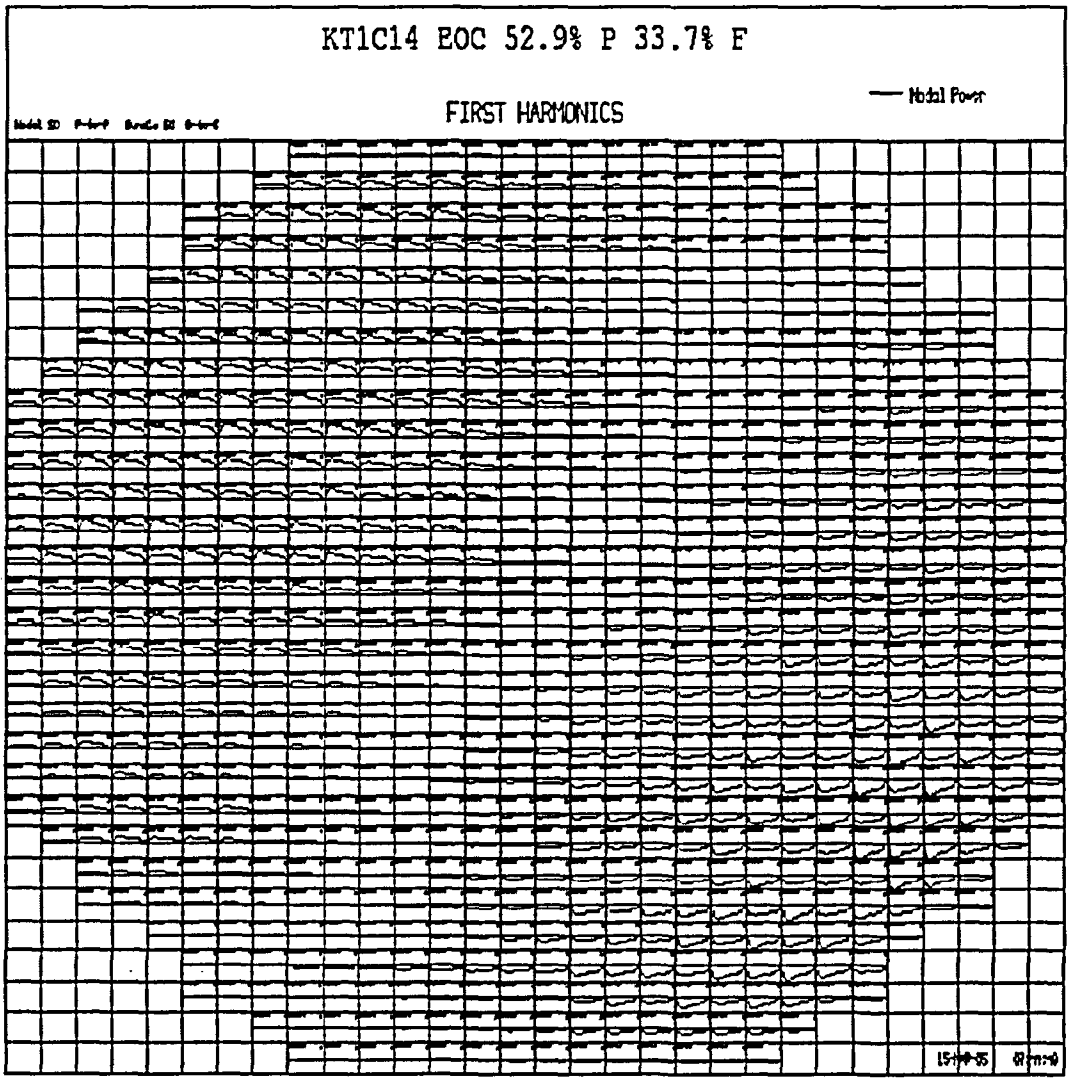

Figure 5.3 First Harmonic Flux Distribution (EOC)

5.2 CRNC Channel Grouping

The channel groupings are shown in Tables 5.2 through 5.4. The corresponding TRACG channel components are shown in Figures 5.4 through 5.6.

Table 5.2
CRNC Channel Grouping & TRACG Channel Component Number
(Exposure = BOC)

CRNC Channel Group	TRAC Channel Component Number	Number of Physical Channels	CRNC Channel Group	TRAC Channel Component Number	Number of Physical Channels
1	21	7	2	31	7
3	22	46	4	32	46
5	23	53	6	33	53
7	24	51	8	34	51
9	25	48	10	35	48
11	26	11	11	36	11
13	27	29	12	37	29
16	28	47	15	38	48
17	29	41	18	39	40
Single Channel (1st highest RPF)	82	1	Single Channel (1st highest RPF)	81	1
Single Channel (1st harmonic)	84	1	Single Channel (1st harmonic)	83	1
Single Channel (1st product)	86	1	Single Channel (1st product)	85	1
Peripheral Channel	20	46	Peripheral Channel	30	46
Total Number of Channels		**382**	**Total Number of Channels**		**382**

Table 5.3
CRNC Channel Grouping & TRACG Channel Component Number
(Exposure = MOC)

CRNC Channel Group	TRAC Channel Component Number	Number of Physical Channels	CRNC Channel Group	TRAC Channel Component Number	Number of Physical Channels
1	21	6	2	31	6
3	22	43	4	32	43
5	23	43	6	33	43
8	24	52	7	34	60
9	25	61	10	35	53
11	26	4	12	36	4
13	27	32	14	37	32
15	28	40	16	38	40
18	29	52	17	39	52
Single Channel (1st highest RPF)	82	1	Single Channel (1st highest RPF)	81	1
Single Channel (1st harmonic)	84	1	Single Channel (1st harmonic)	83	1
Single Channel (1st product)	86	1	Single Channel (1st product)	85	1
Peripheral Channel	20	46	Peripheral Channel	30	46
Total Number of Channels		**382**	**Total Number of Channels**		**382**

Table 5.4
CRNC Channel Grouping & TRACG Channel Component Number
(Exposure = EOC)

CRNC Channel Group	TRAC Channel Component Number	Number of Physical Channels	CRNC Channel Group	TRAC Channel Component Number	Number of Physical Channels
2	21	3	1	31	3
3	22	38	4	32	41
6	23	50	5	33	47
7	24	55	8	34	56
10	25	59	9	35	58
12	26	2	11	36	3
13	27	40	14	37	39
16	28	45	15	38	45
18	29	41	17	39	41
Single Channel (1st highest RPF)	82	1	Single Channel (1st highest RPF)	81	1
Single Channel (1st harmonic)	84	1	Single Channel (1st harmonic)	83	1
Single Channel (1st product)	86	1	Single Channel (1st product)	85	1
Peripheral Channel	20	46	Peripheral Channel	30	46
Total Number of Channels		**382**	**Total Number of Channels**		**382**

30 30 30 30 30 30 30 30 30 30 30 30 20 20

30 35 35 35 35 35 34 34 34 34 34 34 34 24 24 20

30 30 35 35 38 35 38 35 38 39 39 39 34 39 34 29 24 24 20 20

30 35 33 33 33 38 33 33 35 35 35 34 34 34 29 24 24 24 24 20

30 35 33 32 32 37 33 38 33 38 35 35 39 34 39 24 29 24 24 24 24 20

30 30 38 33 37 32 37 32 32 33 38 33 38 38 34 39 34 24 24 29 25 29 25 29 20 20

30 35 33 37 36 36 32 32 38 38 33 33 38 38 34 34 29 29 24 25 28 28 28 25 25 20

30 35 33 32 32 36 36 37 32 38 38 38 33 38 39 34 39 29 29 25 29 28 28 23 23 25 25 20

30 35 33 32 32 36 31 37 32 37 32 33 33 33 35 34 34 24 24 24 28 25 28 23 28 23 23 25 24 20

30 33 38 32 36 31 31 32 37 32 32 32 38 35 39 39 34 29 24 25 25 28 25 23 23 27 23 28 25 20

30 33 32 37 31 31 37 38 32 81 36 37 33 35 39 39 24 24 29 28 23 25 28 28 23 23 27 23 25 20

30 33 37 32 37 32 38 37 32 32 37 37 33 35 39 39 24 24 29 28 23 23 28 28 23 27 23 28 25 20

30 33 32 83 32 37 32 37 32 37 32 33 33 39 34 34 29 24 25 25 28 23 28 23 27 22 22 23 23 20

30 35 37 32 37 31 [illegible] 32 32 32 33 33 38 35 39 39 24 29 25 25 23 22 22 22 22 27 22 28 25 20

30 33 37 31 32 36 36 36 32 38 38 39 35 39 39 29 29 24 29 28 28 22 27 26 27 22 22 28 23 20

30 33 38 32 32 37 36 37 32 38 38 39 34 39 39 29 29 25 29 28 28 22 26 26 26 22 21 27 23 20

30 35 38 32 37 32 32 32 32 33 35 35 39 34 29 29 25 28 23 23 22 22 22 85 21 27 22 27 25 20

30 33 33 32 32 37 33 38 33 38 35 35 34 39 24 24 29 23 23 22 27 22 27 22 27 22 [illegible] 22 23 20

30 35 38 33 37 33 38 38 33 33 38 39 34 34 29 29 25 23 27 27 22 22 27 28 22 27 22 27 23 20

30 35 33 37 33 33 38 38 35 33 38 39 34 34 29 29 25 23 27 26 82 22 28 27 21 21 27 22 23 20

30 35 38 33 37 33 33 35 38 35 35 34 39 24 29 29 25 28 22 22 22 27 22 21 21 26 22 28 23 20

30 34 35 33 33 38 33 38 35 38 34 34 34 24 24 25 23 23 23 22 27 22 27 21 26 22 22 23 25 20

30 35 35 33 33 38 38 39 35 39 39 29 24 29 28 23 28 28 28 22 27 26 26 22 22 23 25 20

30 35 35 38 38 38 35 34 39 39 24 24 28 28 23 23 28 28 22 22 26 26 27 23 25 20

30 30 39 35 39 35 39 34 34 24 29 24 29 28 23 28 23 22 22 27 22 27 23 28 20 20

30 34 34 34 34 39 34 29 24 29 25 25 28 23 28 23 27 22 22 23 25 20

30 34 34 34 34 39 24 24 24 25 25 25 23 23 28 23 23 23 25 20

30 30 34 34 39 24 29 24 29 29 29 28 25 28 25 28 25 25 20 20

30 34 34 24 24 24 24 24 24 24 25 25 25 25 25 20

30 30 20 20 20 20 20 20 20 20 20 20 20 20

Figure 5.4 TRACG Channel Grouping (BOC)

								30	30	30	30	30	30	30	30	30	30	30	30	30	30								
							30	34	34	34	34	34	34	34	35	35	35	35	35	35	35	30							
					30	30	34	33	38	33	38	33	38	38	39	39	34	39	35	39	35	35	30	20					
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		30	33	33	37	37	37	31	32	38	38	33	33	38	38	34	34	39	39	35	35	29	29	29	24	24	20		
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30	34	38	33	32	37	37	37	33	38	39	39	35	39	39	29	29	24	29	29	28	23	27	27	27	22	23	28	25	20
30	34	38	33	37	33	33	33	33	34	34	35	39	35	29	29	25	28	25	23	23	22	22	22	22	27	22	28	25	20
30	34	34	33	33	38	33	38	34	38	34	35	35	29	24	24	28	23	23	23	27	22	27	22	27	22	22	23	25	20
30	34	38	33	38	34	39	39	34	34	39	39	24	24	29	29	25	23	28	27	22	22	28	28	22	27	22	27	25	20
30	35	34	38	33	34	39	39	34	35	39	39	24	24	29	29	25	23	27	27	22	22	28	28	22	21	27	23	25	20
30	35	39	34	38	34	34	35	39	35	35	24	29	25	29	28	23	27	22	22	82	27	22	22	86	26	22	28	25	20
30	35	35	34	34	39	34	39	35	39	24	24	25	25	25	23	23	22	23	22	27	22	27	21	26	[illegible]	22	23	25	20
	30	35	34	34	34	39	39	39	24	29	29	29	25	28	28	23	28	28	28	22	27	27	27	21	22	22	25	20	
		30	35	35	39	39	39	24	24	29	29	25	25	28	28	23	23	28	28	22	21	27	27	27	23	23	20		
		30	30	39	35	39	35	29	24	24	25	28	25	28	28	22	27	22	22	21	26	22	27	23	28	20	20		
				30	35	35	24	24	29	24	29	25	28	23	23	27	22	27	22	26	21	22	23	25	20				
					30	24	24	24	24	29	25	25	25	25	23	23	22	22	27	22	22	22	23	20					
					30	20	24	24	29	24	29	25	29	29	28	28	23	28	23	28	23	25	20	20					
							20	24	24	24	24	24	24	24	25	25	25	25	25	25	25	20							
								20	20	20	20	20	20	20	20	20	20	20	20	20	20								

Figure 5.5 TRACG Channel Grouping (MOC)

								30	30	30	30	30	30	30	30	30	30	30	30	30	30								
							30	34	35	35	35	35	35	34	34	34	34	34	34	34	34	30							
					30	30	35	33	39	33	39	33	39	38	38	38	34	38	34	38	34	34	20	20					
					30	35	33	32	32	37	32	33	33	35	35	35	35	34	38	34	34	24	24	20					
				30	35	33	32	32	37	32	37	32	39	33	35	39	35	38	34	38	34	24	24	24	20				
		30	30	39	33	37	32	37	31	32	32	37	33	39	39	35	38	34	34	34	28	24	28	24	28	20	20		
		30	35	33	37	37	37	32	32	37	37	33	33	39	39	35	34	38	38	24	24	28	28	28	24	24	20		
	30	35	32	32	32	37	37	37	32	37	37	37	33	39	39	35	38	38	38	24	28	28	28	25	25	25	24	20	
30	35	33	32	83	36	31	37	32	37	32	33	33	33	33	35	35	34	34	24	28	24	28	25	29	25	25	25	24	20
30	35	39	32	36	85	32	32	36	32	32	32	37	33	39	38	34	38	24	24	24	28	25	25	25	29	25	28	24	20
30	35	33	37	31	32	37	37	32	32	37	37	33	35	39	38	34	34	28	28	24	25	29	29	25	23	29	25	24	20
30	35	37	32	37	32	37	37	32	32	37	39	33	35	38	38	34	24	28	28	25	25	29	29	23	29	23	29	25	20
30	35	33	32	32	37	32	37	81	37	33	33	33	39	35	34	38	24	24	25	29	23	29	23	29	23	23	25	25	20
30	35	39	32	37	32	32	32	32	33	33	33	39	35	38	38	24	28	25	25	25	23	23	23	23	27	23	29	25	20
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30	35	39	33	37	33	33	33	33	35	35	35	38	34	28	28	25	29	23	23	23	22	22	22	22	27	22	29	25	20
30	35	35	33	33	39	33	39	33	39	35	34	34	28	24	25	29	23	23	23	27	82	27	22	27	22	22	23	25	20
30	34	39	33	39	33	39	39	35	35	38	38	34	24	28	28	25	23	29	27	22	22	27	27	22	27	22	27	25	20
30	34	35	39	33	35	39	39	35	34	38	38	24	24	28	29	25	23	27	27	22	22	27	27	22	21	27	23	25	20
30	34	38	35	39	35	35	35	38	34	34	34	28	24	28	29	23	27	22	22	22	27	22	22	86	26	22	29	25	20
30	34	35	35	35	39	35	38	34	38	34	24	24	25	25	23	23	23	23	22	27	22	27	21	26	[illegible]	22	23	25	20
	30	34	35	35	35	38	38	38	34	28	28	28	25	29	29	23	27	27	27	22	27	27	27	22	22	22	25	20	
		30	34	34	38	38	38	34	34	28	28	24	25	29	29	23	23	27	27	22	22	27	27	27	23	25	20		
		30	30	38	34	38	34	38	24	24	24	28	25	29	29	23	27	22	22	21	27	22	27	23	29	20	20		
				30	34	34	34	24	28	24	28	25	29	25	23	29	23	27	22	27	22	22	23	25	20				
					30	34	34	24	24	28	24	25	25	25	25	23	23	23	27	22	23	23	25	20					
					30	30	24	24	28	24	28	24	28	28	28	29	23	29	23	29	23	25	20	20					
							20	24	24	24	24	24	24	24	24	25	25	25	25	25	24	20							
								20	20	20	20	20	20	20	20	20	20	20	20	20	20								

Figure 5.6 TRACG Channel Grouping (EOC)

5.3 TRACG Steady-State Analysis

All TRACG steady-state analyses have been run long enough to ensure the steady-state conditions have been achieved.

The radial peaking factors for the hot channels are shown in Table 5.5.

Table 5.5
TRACG Hot Channel Information

Cycle Exposure	Channel 81 Location RPF	Channel 82 Location RPF	Channel 83 Location RPF	Channel 84 Location RPF	Channel 85 Location RPF	Channel 86 Location RPF
BOC	(10,11)	(21,20)	(4,13)	(27,18)	(7,14)	(24,17)
	1.369	1.369	1.170	1.170	1.308	1.308
MOC	(10,10)	(21,21)	(5,9)	(26,22)	(6,10)	(25,21)
	1.387	1.387	1.269	1.269	1.305	1.305
EOC	(9,13)	(22,18)	(5,9)	(26,22)	(6,10)	(25,21)
	1.371	1.371	1.252	1.252	1.308	1.308

5.4 TRACG Transient Analysis

Figure 5.7 shows the hot channel flow rates as a function of time, Figure 5.8 displays the hot channel power variation as a function of time and Figure 5.9 illustrates CPR variation as a function of time for the Hope Creek BOC condition. Figures 5.10 through 5.12 show the corresponding curves for Hope Creek MOC condition. Figures 5.13 through 5.15 show the corresponding curves for the Hope Creek EOC condition.

[[

]]Figure 5.7 Transient Stability Analysis. Channel Flow Oscillations.
Cycle Exposure = BOC

[[

]]Figure 5.8 Transient Stability Analysis. Channel Power Oscillations.
Cycle Exposure = BOC

[[

]]Figure 5.9 Transient Stability Analysis. Chan CPR Oscillations.
Cycle Exposure = BOC

[[

]]**Figure 5.10 Transient Stability Analysis. Channel Flow Oscillations.
Cycle Exposure = MOC**

[[

]]Figure 5.11 Transient Stability Analysis. Channel Power Oscillations.
Cycle Exposure = MOC

[[

]]**Figure 5.12 Transient Stability Analysis. Channel CPR Oscillations.
Cycle Exposure = MOC**

[[

]]Figure 5.13 Transient Stability Analysis. Channel Flow Oscillations.
Cycle Exposure = EOC

[[

]]Figure 5.14 Transient Stability Analysis. Channel Power Oscillations.
Cycle Exposure = EOC

[[

]]Figure 5.15 Transient Stability Analysis. Channel CPR Oscillations. Cycle Exposure = EOC

5.5 Composite DIVOM Curve

The BWROG Procedure Guideline defines a new process that takes into account that the channel with the highest ΔCPR/ICPR oscillations may not have the highest power oscillations, resulting in an unnecessarily conservative (i.e. too steep) DIVOM slope.

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[[

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For BOC the composite channel was [[

]]

For MOC the composite channel was [[

]]

No DIVOM curve for EOC was drawn since it represents limit cycle oscillation with very small amplitude with no appreciable CPR degradation (Figures 5.13 through 5.15).

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[[

]]Figure 5.16 OM vs. Time (BOC)

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]]Figure 5.17 ΔCPR/ICPR vs. Time (BOC)

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]]Figure 5.18 DIVOM Slope for Cycle Exposure = BOC, MOC

[[

]]Figure 5.19 OM vs. Time (MOC)

[[

]]Figure 5.20 ΔCPR/ICPR vs. Time (MOC)

5.6 Sensitivity Study Analysis

5.6.1 Core Flow Sensitivity

The core flow sensitivity was performed by increasing the rated core flow from 33.7% to 38.7% at the MOC exposure since the oscillation amplitude is very small at the BOC exposure with 5% flow sensitivity. The 5% flow sensitivity is specified in the BWROG DIVOM Guideline. The TRACG results for this case are shown in Figures 5.21 through 5.23. The corresponding composite DIVOM slope is 0.485 as shown in Figure 5.24. Therefore, no flow sensitivity in the DIVOM slope was found and the state-point representing natural circulation is used.

5.6.2 Radial Peaking Factor Sensitivity

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]]Figure 5.21 Transient Stability Analysis. Channel Flow Oscillations.
Cycle Exposure = MOC, Core Flow Sensitivity

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]]Figure 5.22 Transient Stability Analysis. Channel Power Oscillations.
Cycle Exposure = MOC, Core Flow Sensitivity

[[

]]Figure 5.23 Transient Stability Analysis. Channel CPR Oscillations. Cycle Exposure = MOC, Core Flow Sensitivity

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]]Figure 5.24 DIVOM Curve for Cycle Exposure = MOC, Core Flow Sensitivity

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]]Figure 5.25 Transient Stability Analysis. Channel Flow Oscillations. Cycle Exposure = BOC, Radial Peaking Sensitivity

[[

]]Figure 5.26 Transient Stability Analysis. Channel Power Oscillations. Cycle Exposure = BOC, Radial Peaking Sensitivity

[[

]]**Figure 5.27 Transient Stability Analysis. Chan CPR Oscillations. Cycle Exposure = BOC, Radial Peaking Sensitivity**

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]]Figure 5.28 DIVOM Curve for Cycle Exposure = BOC, Radial Peaking Sensitivity

6.0 Conclusions

For Hope Creek Cycle 14 MCAR, the bounding DIVOM curves are calculated to be [[

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7.0 References

1. NEDO-32465-A, Licensing Topical Report, "Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications," August 1996.

2. MFN-01-046, GENE 10 CFR Part 21 Notification, Stability Reload Licensing Calculations Using Generic DIVOM Curve, August 31, 2001.