NEDO-33185
Hope Creek Cycle 13 TRACG DIVOM Study (ELLLA)

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Hope Creek Cycle 13 TRACG DIVOM Study (ELLA)

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ACRONYMS AND ABBREVIATIONS

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

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) for use in Hope Creek Cycle 13 operation. 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 37% rated core flow along the highest licensed rod line (Extended Load Line Limit Analysis, ELLLA 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 (Reference 2) and an internal GENE/GNF 50.59 evaluation for TRACG04.

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 13 core loading (600 bundles of SVEA96+ and 164 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. Based on the Cycle 13 core loading, which includes the first reload of GE14, [[

]] Because the calculated DIVOM is conservative, its applicability beyond Cycle 13 may be assessed for future application based on the similarity in core design and operating strategy.

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 has made a Part 21 Notification (Reference 3) that identified the DIVOM deficiency. Subsequently, the BWROG has developed a guideline (Reference 2) 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 (Reference 2). The calculated DIVOM curve reflects the core/fuel designs and plant operating strategy for Hope Creek Cycle 13.

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 13 core contains both SVEA96+ and GE14 fuels. This cycle is the first reload of GE14 fuel.

The TRACG DIVOM calculations were performed based on specified operating conditions for Hope Creek Cycle 13. Three conditions at different exposure level were considered:

1) BOC (Cycle Exposure = 0 MWD/ST),
2) MOC (Cycle Exposure = 6000 MWD/ST), and
3) EOC (Cycle Exposure = 10347 MWD/ST).

The choice of three exposure points follows the BWROG DIVOM guideline (Reference 2). [[

]]

This analysis is a Hope Creek-specific evaluation to establish a cycle-specific DIVOM value based on Cycle 13 core loading. [[

]] (Reference 1).

The base case stability analysis was performed at the power/flow state point corresponding to a post two-pump trip condition at 37% rated core flow along the highest licensed rod line (Reference 4). 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 42% of rated core flow along the highest licensed rod line. This analysis is used to identify any DIVOM curve sensitivity to core flow (Reference 2). The second is a radial peaking sensitivity in which the radial peaking factor is increased by 5% to 10% on the limiting channel (Reference 4). This analysis is used to reasonably 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 13 TRACG basedeck,
- The Hope Creek Cycle 13 PANAC11 wrap-ups corresponding to three different cycle exposure points at rated power/flow conditions, and
- The Hope Creek Cycle 13 ISCOR basedeck.

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

- [[ ]]

- Consistent with the standard stability TRACG methodology, [[ ]]

- The core is loaded with SVEA96+ and GE14 fuels according to Hope Creek Cycle 13 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.

- [[ ]]

- [[ ]]

- 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 13 is composed of SVEA96+ and GE14.
- The rated thermal power level, under normal plant operating conditions, is 3339 MWt, at which Hope Creek is currently 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 currently licensed to operate the plant. This corresponds to the ELLLA boundary for Hope Creek, with an upper intercept at 100% rated core power and 87% 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 (Reference 2) and an internal GENE/GNF 50.59 evaluation of the TRACG04 executable.

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 13. PANACEA calculations were performed to obtain three-dimensional power distribution, subcriticality and harmonic contour at 37% 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 37% 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. [[

]]

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 (RPINDS). The RPF and RPINDS 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 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 either the second radial peaking or 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	17	17	17	17	18	18	18	18	18	18	18	18	18	18	19							
					19	19	17	17	17	17	17	18	18	18	18	18	18	18	18	18	18	18	19	19					
					19	17	17	17	17	17	17	18	8	18	18	8	15	15	18	15	18	18	18	19					
				19	17	17	17	7	17	7	17	7	18	8	8	15	6	15	6	15	8	15	18	18	19				
		19	19	17	7	17	7	17	7	17	7	17	18	18	18	15	15	6	15	6	15	8	18	8	18	19	19		
		19	17	17	17	17	17	7	17	17	17	7	18	18	18	18	6	15	13	15	6	18	18	18	15	18	19		
	19	17	16	16	7	17	17	17	7	17	17	17	7	18	18	8	15	15	15	6	15	15	18	6	15	15	18	19	
19	17	16	16	5	16	5	16	5	16	7	17	7	17	8	8	18	6	15	6	15	6	15	6	15	6	15	15	18	19
19	16	16	14	14	3	14	5	16	16	16	7	17	17	18	18	15	15	6	13	13	13	4	12	4	12	13	15	15	19
19	16	14	14	3	14	11	14	5	16	16	17	7	17	18	18	18	8	18	15	13	4	12	12	13	4	13	13	15	19
19	14	16	11	11	3	14	11	14	5	17	17	17	7	18	18	8	15	15	15	6	13	12	12	2	12	12	15	13	19
19	14	14	11	1	11	3	11	3	14	5	16	7	17	7	8	15	6	15	6	13	4	12	4	12	2	10	12	13	19
19	11	9	1	11	9	11	3	14	14	14	5	16	17	17	18	18	15	6	13	13	13	4	12	10	10	2	10	12	19
19	11	11	11	1	11	14	16	5	14	14	16	5	17	17	18	18	6	15	13	13	6	15	13	12	2	12	12	12	19
19	11	11	11	1	11	14	16	5	14	14	16	5	17	17	18	18	6	15	13	13	6	15	13	12	2	12	12	12	19
19	11	9	1	9	9	11	3	14	14	14	5	16	17	17	18	18	15	6	13	13	13	4	12	10	12	2	10	12	19
19	14	11	11	1	11	3	11	3	14	5	16	5	17	7	8	18	8	15	6	13	4	12	4	12	2	12	13	13	19
19	14	16	11	11	3	11	11	14	5	16	16	16	7	17	17	8	18	18	18	6	13	12	13	4	12	13	15	13	19
19	16	14	14	3	14	11	11	3	14	16	17	7	17	17	17	18	8	18	15	15	6	13	12	13	4	15	15	15	19
19	16	16	14	14	3	11	3	14	14	14	5	16	16	17	17	18	18	8	15	15	15	6	13	6	13	13	15	15	19
19	17	16	16	5	16	5	16	5	16	5	16	5	17	7	7	18	8	18	8	15	6	15	6	15	6	15	18	18	19
	19	17	16	16	5	17	16	16	5	16	16	16	7	17	17	8	18	18	18	8	18	18	18	8	15	15	18	19	
		19	17	16	17	17	17	5	16	16	16	5	17	17	17	18	8	18	18	18	8	18	18	18	18	18	19		
		19	19	17	7	17	7	16	5	16	5	16	16	17	17	17	18	8	18	8	18	8	18	8	18	19	19		
				19	17	17	16	7	16	5	16	5	16	7	7	17	8	18	8	18	8	18	18	18	19				
					19	17	17	17	16	17	16	16	7	17	17	7	17	18	18	18	18	18	18	19					
					19	19	17	17	17	17	17	17	17	17	17	17	17	18	18	18	18	18	19	19					
							19	17	17	17	17	17	17	17	17	17	17	18	18	18	18	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. An internal GENE/GNF 50.59 evaluation of the TRACG04 versus TRACG02 DIVOM analysis showed essentially the same results. Therefore, the application of TRACG04 for the current DIVOM evaluation is acceptable.

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. [[
]]

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 13 Harmonics

Cycle Exposure	Fundamental eigenvalue	Azimuthal (First Harmonic) eigenvalue	Subcriticality (1st harmonic)	Subcriticality (2nd harmonic)	Subcriticality (3rd harmonic)
BOC	1.011711	1.004754	0.006844	0.007074	0.012007
MOC	1.012061	1.004874	0.007067	0.007348	0.010109
EOC	1.010953	1.003016	0.007827	0.007965	0.009767

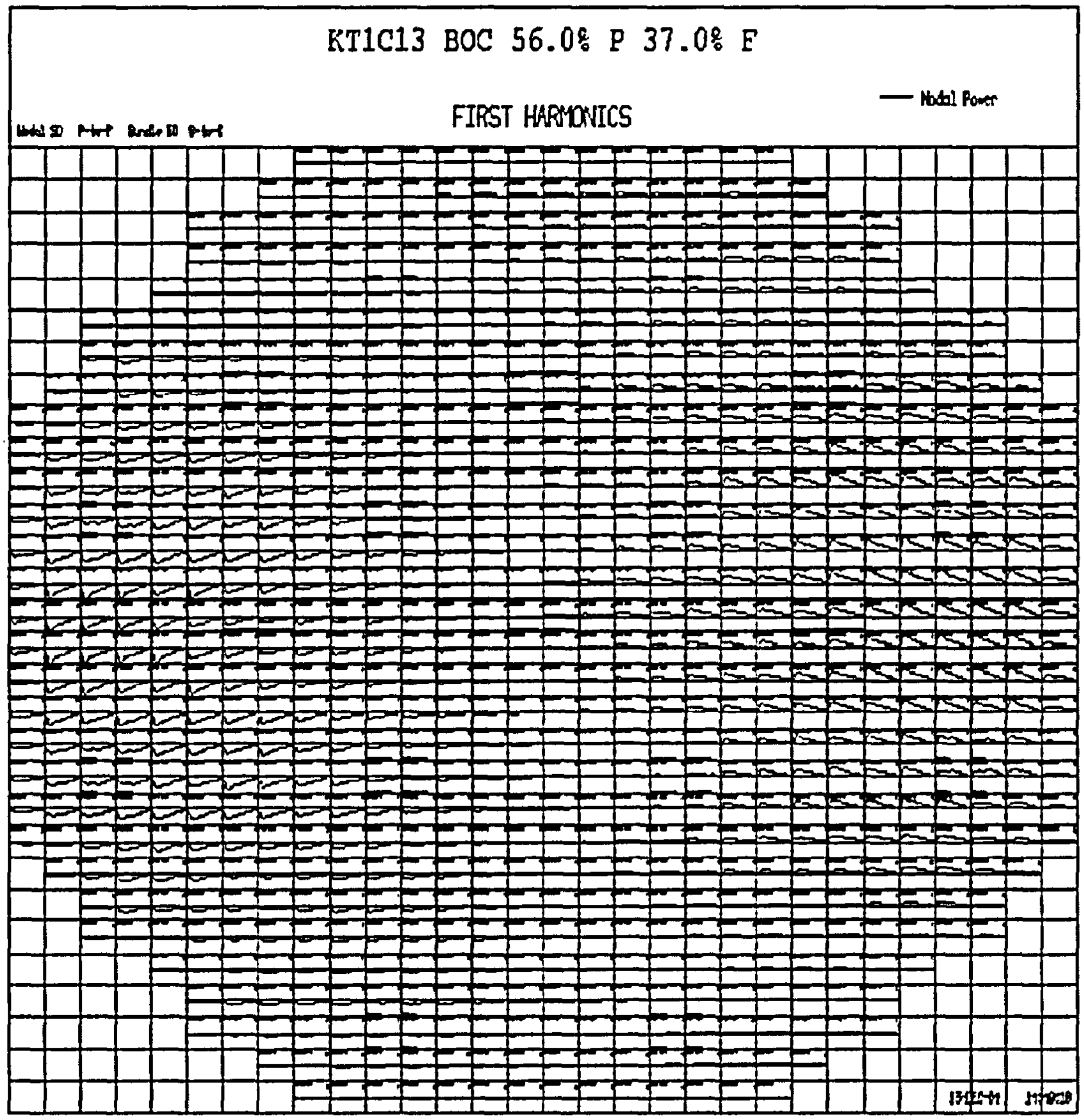

Figure 5.1. First Harmonic Flux Distribution (BOC)

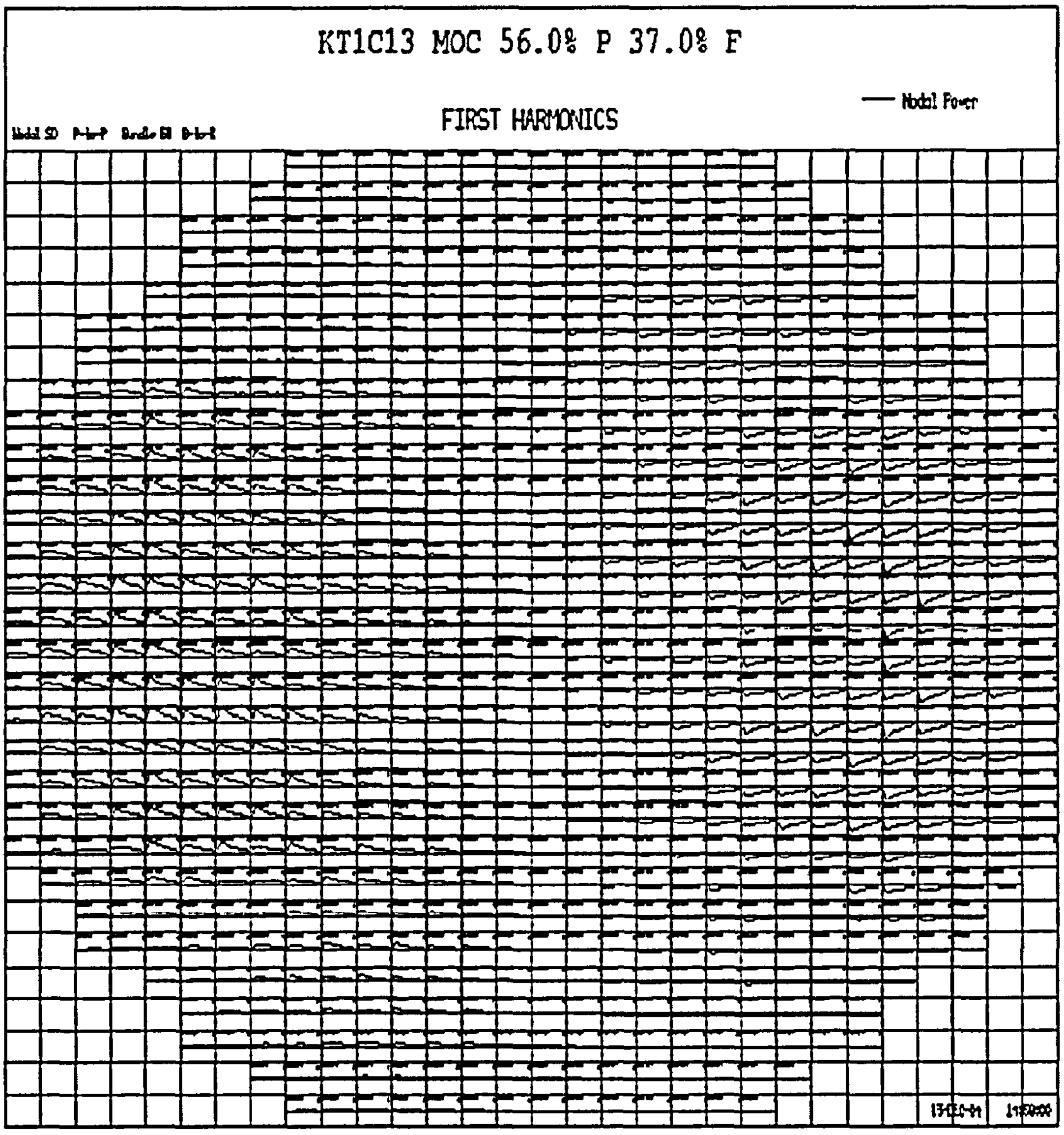

Figure 5.2. First Harmonic Flux Distribution (MOC)

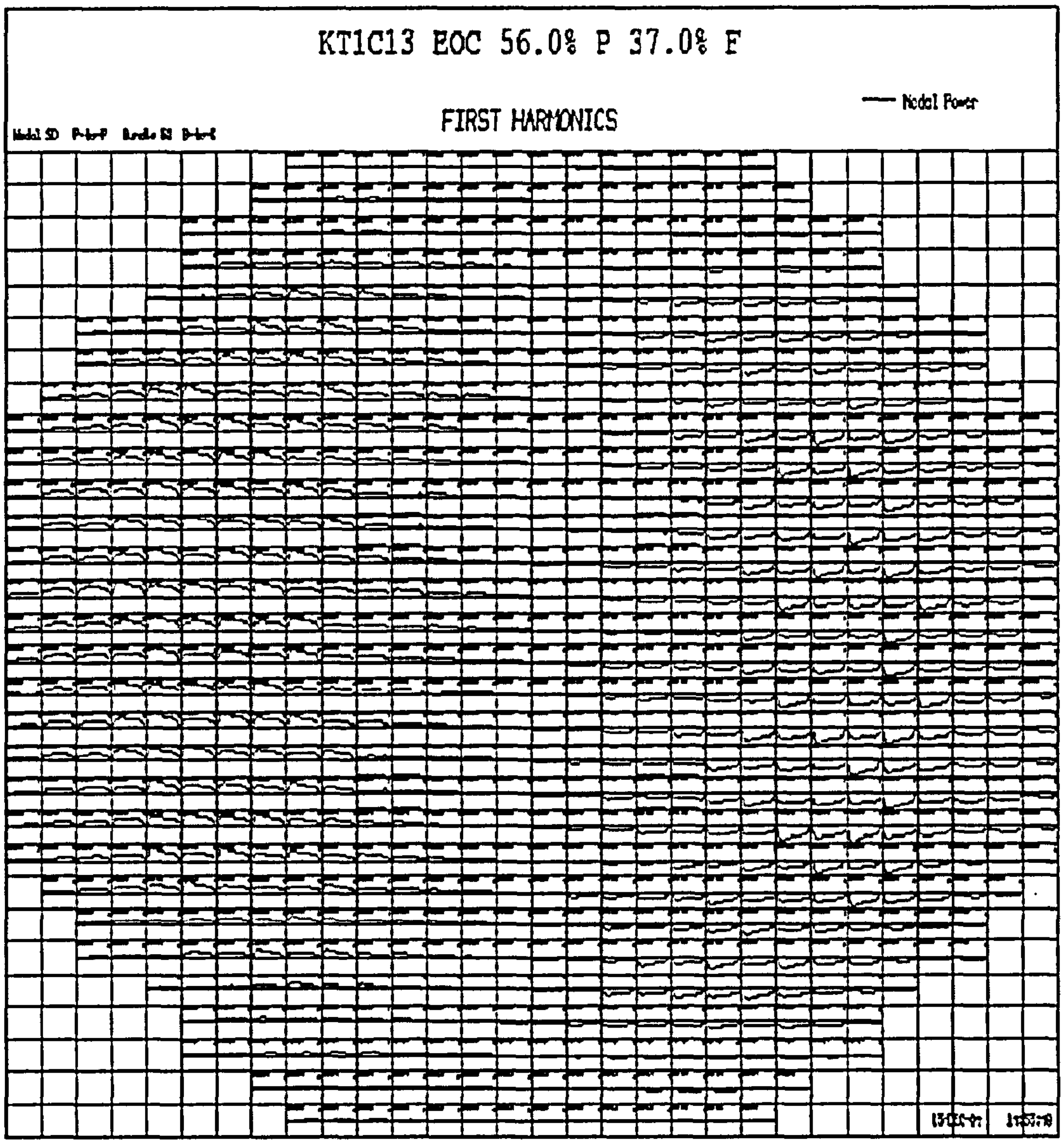

Figure 5.3. First Harmonic Flux Distribution (EOC)

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
2	21	7	1	31	6
4	22	12	3	32	14
6	23	31	5	33	30
8	24	32	7	34	32
10	25	5	9	35	4
12	26	30	11	36	31
13	27	35	14	37	36
15	28	63	16	38	62
18	29	119	17	39	117
Single Channel (1st highest RPF)	82	1	Single Channel (1st highest RPF)	81	1
Single Channel (2nd highest RPF)	84	1	Single Channel (2nd highest RPF)	83	1
Single Channel (1st harmonic)	86	1	Single Channel (1st harmonic)	85	1
Peripheral Channel	20	46	Peripheral Channel	30	46
Total Number of Channels		383	Total Number of Channels		381

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	2	2	31	2
3	22	16	4	32	16
5	23	33	6	33	33
7	24	28	8	34	28
10	25	4	9	35	5
11	26	30	12	36	29
14	27	44	13	37	40
16	28	64	15	38	63
17	29	113	18	39	116
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 (2nd harmonic)	86	1	Single Channel (2nd harmonic)	85	1
Peripheral Channel	20	46	Peripheral Channel	30	46
Total Number of Channels		**383**	**Total Number of Channels**		**381**

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	5	1	31	4
3	22	25	4	32	26
5	23	26	6	33	26
7	24	23	8	34	23
9	25	11	10	35	10
12	26	28	11	36	30
13	27	51	14	37	50
15	28	70	16	38	71
18	29	94	17	39	93
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 (2nd harmonic)	86	1	Single Channel (2nd harmonic)	85	1
Peripheral Channel	20	46	Peripheral Channel	30	46
Total Number of Channels		**382**	**Total Number of Channels**		**382**

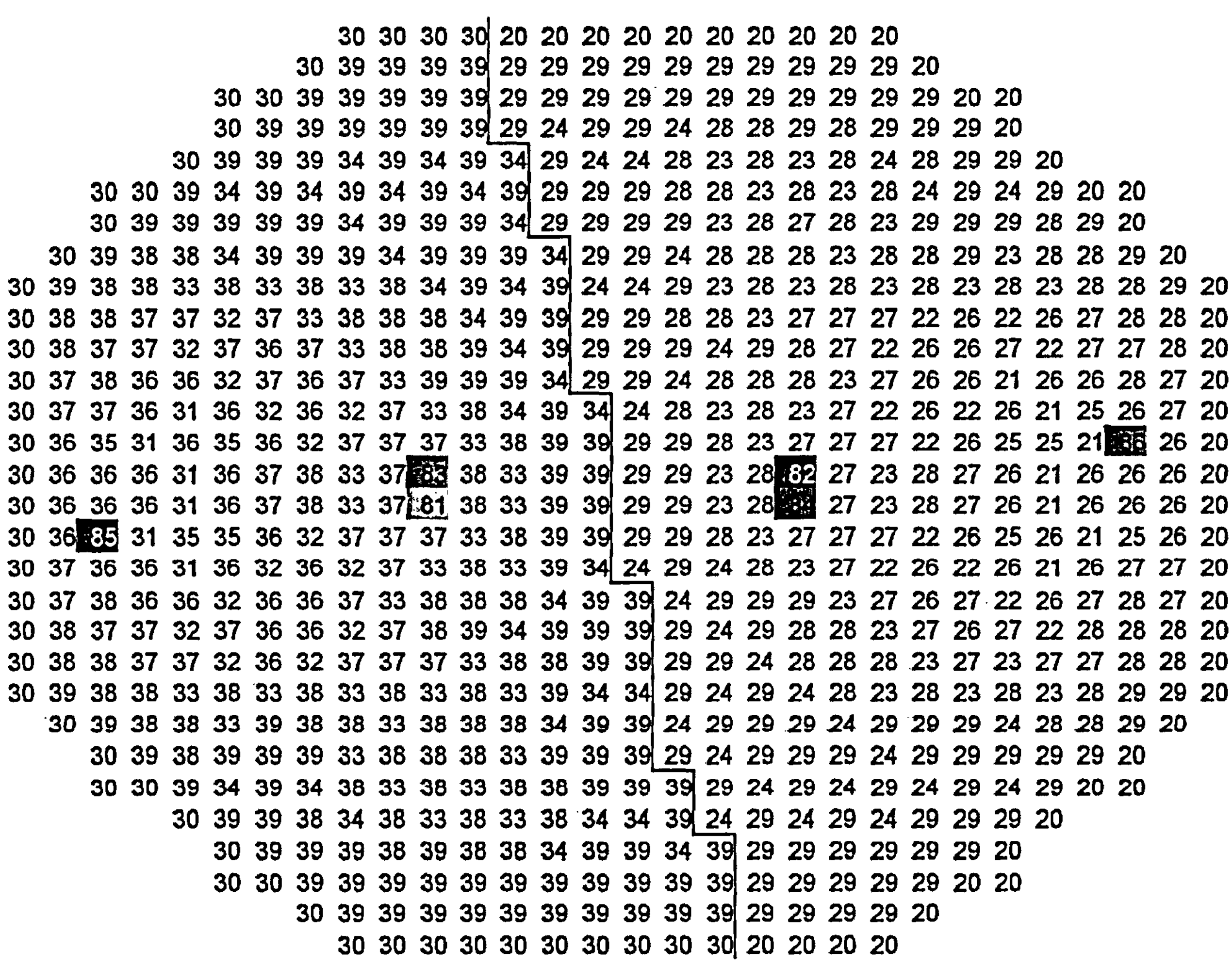

Figure 5.4 TRACG Channel Grouping (BOC)

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

Figure 5.5 TRACG Channel Grouping (MOC)

								30	30	30	30	30	30	30	30	20	20	20	20	20	20								
							30	39	39	39	39	39	39	39	39	29	29	29	29	29	29	20							
					30	30	39	39	39	39	39	39	39	39	39	29	29	29	29	29	29	29	20	20					
					30	39	39	38	38	38	38	38	34	39	39	24	29	29	29	29	29	29	29	20					
				30	39	39	38	33	37	33	38	33	39	34	34	29	24	28	24	28	23	28	29	29	20				
		30	30	39	34	38	33	37	33	38	33	38	38	39	39	29	29	24	28	23	28	23	28	24	29	20	20		
		30	39	38	38	37	37	32	37	37	38	33	38	39	39	29	24	28	28	27	23	28	28	28	28	29	20		
	30	39	38	37	32	37	37	37	32	37	37	38	34	39	39	24	28	28	28	23	27	27	27	23	27	28	29	20	
30	39	39	38	32	36	32	37	32	37	33	38	33	39	34	34	29	24	28	23	27	22	27	22	27	23	28	29	29	20
30	39	38	37	36	32	35	32	37	37	37	33	38	39	39	29	29	29	24	28	27	27	22	26	22	26	27	28	29	20
30	38	38	37	32	36	35	36	32	37	38	38	34	39	39	29	29	24	29	28	27	22	26	26	26	22	27	28	29	20
30	38	38	36	35	85	36	35	36	32	38	38	38	34	39	29	24	28	29	28	23	27	26	26	21	26	27	28	28	20
30	38	38	36	83	36	31	35	32	37	33	38	33	38	34	24	29	24	28	23	27	22	25	21	26	21	26	28	28	20
30	38	37	32	36	35	35	81	36	37	37	33	38	39	39	29	29	28	23	27	27	26	21	26	25	26	22	27	28	20
30	38	37	37	32	36	35	36	32	37	37	38	33	39	39	29	29	23	28	27	27	22	26	25	26	22	27	27	28	20
30	38	37	37	32	36	36	36	32	37	37	38	33	39	39	29	29	23	28	27	27	22	26	25	26	22	27	27	28	20
30	38	37	32	36	35	36	31	36	37	37	33	38	39	39	29	29	28	23	27	27	26	82	25	25	26	22	27	28	20
30	38	38	36	32	36	31	35	32	37	33	38	34	39	34	24	28	23	28	23	27	22	25	21	26	[illegible]	26	28	28	20
30	38	38	37	36	31	36	36	36	33	38	39	38	34	39	29	24	28	28	28	22	26	25	26	86	25	26	28	28	20
30	39	38	37	32	36	36	36	32	37	38	39	34	39	39	29	29	24	28	28	27	22	26	25	26	22	27	28	29	20
30	39	38	37	36	32	36	32	37	37	38	34	39	39	39	29	29	28	23	27	27	27	22	25	22	26	27	28	29	20
30	39	39	38	33	37	32	37	32	37	33	38	34	39	24	24	29	23	28	23	27	22	27	22	26	22	28	29	29	20
	30	39	38	37	33	37	37	37	33	38	38	38	34	29	29	24	28	27	27	22	27	27	27	22	27	28	29	20	
		30	39	38	38	38	38	33	37	38	38	34	39	29	29	28	23	28	27	27	22	27	27	28	28	29	20		
		30	30	39	34	38	33	38	33	38	34	39	39	29	29	28	28	23	28	23	27	23	28	24	29	20	20		
				30	39	39	38	33	38	34	38	34	39	24	24	29	23	28	23	27	23	28	29	29	20				
					30	39	39	39	39	39	39	39	34	29	29	24	28	28	28	28	28	29	29	20					
					30	30	39	39	39	39	39	39	39	29	29	29	29	29	29	29	29	29	20	20					
							30	39	39	39	39	39	39	29	29	29	29	29	29	29	29	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	(11,16)	(20,15)	(11,15)	(20,16)	(3,17)	(28,14)
	1.523	1.525	1.521	1.524	1.296	1.296
MOC	(13,16)	(18,15)	(5,18)	(26,13)	(5,13)	(26,18)
	1.503	1.510	1.418	1.425	1.422	1.418
EOC	(8,14)	(23,17)	(5,13)	(26,18)	(6,12)	(25,19)
	1.507	1.508	1.389	1.386	1.439	1.438

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 Nominal DIVOM Curve

The DIVOM result based on nominal radial peaking for the BOC exposure is shown in Figure 5.16.

5.5.1 Composite DIVOM Curve

New BWROG guideline (Reference 2) defines the new process to determine the limiting exposure [[

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[[

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The composite channel was [[

]] No DIVOM curves for MOC and EOC were drawn since they represent limit cycle oscillations with very small amplitude with no appreciable CPR degradation (Figures 5.10 to 5.15).

[[

]]Figure 5.16 DIVOM Slope for Cycle Exposure = BOC

[[

]]Figure 5.17 OM vs. Time (BOC)

[[

]]Figure 5.18 ΔCPR/ICPR vs. Time (BOC)

5.6 Sensitivity Study Analysis

5.6.1 Core Flow Sensitivity

The core flow sensitivity was performed by increasing the rated core flow from 37% to 42% at BOC exposure. The 5% flow sensitivity is specified in the BWROG DIVOM Guideline (Reference 2). The TRACG results for this case are shown in Figures 5.19 through 5.21. The corresponding DIVOM slope is 0.50 as shown in Figure 5.22. Therefore, no flow sensitivity in the DIVOM slope was found and the state-point representing natural circulation can be used.

5.6.2 Radial Peaking Factor Sensitivity

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]]Figure 5.19 Transient Stability Analysis. Channel Flow Oscillations. Cycle Exposure = BOC, Core Flow Sensitivity

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]]**Figure 5.20 Transient Stability Analysis. Channel Power Oscillations. Cycle Exposure = BOC, Core Flow Sensitivity**

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

[[

]]Figure 5.22 DIVOM Curve for Cycle Exposure = BOC, Core Flow Sensitivity

[[

]]Figure 5.23 Transient Stability Analysis. Channel Flow Oscillations.
Cycle Exposure = BOC, Radial Peaking Sensitivity

[[

]]Figure 5.24 Transient Stability Analysis. Channel Power Oscillations.
Cycle Exposure = BOC, Radial Peaking Sensitivity

[[

]]**Figure 5.25 Transient Stability Analysis. Chan CPR Oscillations. Cycle Exposure = BOC, Radial Peaking Sensitivity**

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]]Figure 5.26 DIVOM Curve for Cycle Exposure = BOC, Radial Peaking Sensitivity

6.0 Conclusions

For Hope Creek Cycle 13, the reasonably 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. GE-NE-0000-0028-9714-R0, "Plant-Specific Regional Mode DIVOM Procedure Guideline," June 2004.

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

4. Hope Creek Cycle 13 TRACG DIVOM Evaluation Design Input Request (DIR), DRF 0000-0029-5864, November 18, 2004.

5. TDP-0138, "TRACG Procedure for Stability Applications," Revision 0, January 2003.