ENCLOSURE 3

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Non-Proprietary Version

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NON-PROPRIETARY VERSION

FIRSTENERGY CORP
PERRY NUCLEAR POWER PLANT
12/23/04 INSTABILITY EVENT
OPRM PERFORMANCE EVALUATION

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1. BACKGROUND

Perry has implemented Boiling Water Reactor Owners Group (BWROG) Long Term Stability Solution Option III, which is described in Reference 1. Reload evaluation of the OPRM system setpoints has been performed in accordance with Reference 3 and the Perry-specific OPRM system setpoints are established.

The OPRM system monitors core thermal-hydraulic instabilities by real-time interrogation of OPRM cells, which are composed of closely packed LPRM detectors. The OPRM cell signals are analyzed by three separate detection algorithms that test for neutron flux oscillations. These algorithms are the Period Based Detection Algorithm (PBDA), the Amplitude Based Algorithm (ABA), and the Growth Rate Algorithm (GRA). Automatic protection is actuated if any one of the three algorithms meets its trip conditions. However, only the PBDA is required to provide protection of the Safety Limit Minimum Critical Power Ratio (SLMCPR) for anticipated reactor instabilities. The other two algorithms are included as defense-in-depth.

A December 23rd 2004 plant transient included unplanned recirculation pump transfer from fast to slow speed resulting in a power decrease from about 100% to 44% rated and a flow decrease from about 99% to 33% rated. As the feedwater temperature was reduced to equilibrium conditions, the power increased from about 44% to about 55% with little change in flow. The state condition just prior to the instability was in the upper left corner of the power/flow map, which may be susceptible to coupled thermal-hydraulic neutronic oscillations. Subsequently, an OPRM initiated scram occurred after the thermal-hydraulic instability (THI) event developed (see Figure 1).

The Perry core loading consists of 584 bundles of GE14 and 164 bundles of GE12, both bundles with a 10x10 fuel design. Perry is licensed to operate within the Maximum Extended Load Line Limit Analysis (MELLLA) domain.

2. ASSESSMENT OBJECTIVES

The objectives of the Perry 12/23/04 THI event evaluation are to:

- Assess the functionality of the second-order Butterworth averaging and filtering algorithms
- Analyze selected OPRM cells
- Determine the characteristics of the reactor instability event (e.g., oscillation mode, oscillation frequency, period counts, oscillation amplitude)
- Determine the algorithm that initiated the trip --- PBDA, ABA or GRA
- Assess the adequacy of the as-designed OPRM functions – alarm history, trip timing, PBDA Successive Confirmation Count (SCC) setpoint, OPRM cell signal amplitude setpoint
- Provide selected plots of OPRM cells SCC, Relative Signal (RS), and Oscillation Period (OP).

3. SYSTEM DESIGN AND KEY INPUTS

The Perry OPRM system uses a 4BL configuration with 4 LPRMs assigned to each OPRM cell. Figures 2a through 2d illustrate the LPRM to OPRM assignment for the four channels, with 32 OPRM cells per channel for Channels 1 and 2, and 29 OPRM cells per channel for Channels 3 and 4. In this report, OPRM cells are designated as xyy, corresponding to OPRM cell yy of Channel x. Table 1 lists key parameters used by the OPRM system prior to the reactor trip and its assigned values.

The amplitude trip setpoint is the relative power level, or peak over average (P/A), at which the OPRM cell generates a trip signal, provided the required number of SCC has been reached. Two conditions must be met for the same OPRM cell in an OPRM channel to result in a PBDA-based channel trip:

1. The SCC reaches or exceeds the SCC setpoint (10 for Perry).
2. The cell signal P/A reaches or exceeds the OPRM trip amplitude setpoint (1.07 for Perry).

The OPRM performance evaluation consists of post-event analysis of the OPRM data from the plant computer. About 910 seconds of LPRM and OPRM data was collected. The OPRM data includes the following information, available for all OPRM cells:

- Relative signal
- SCC
- Time-averaged base period.

Both the LPRM and OPRM data was available during the period, which provided useful data for thermal-hydraulic instability (THI) event off-line evaluation.

4. EVALUATION AND RESULTS

The OPRM performance evaluation includes identification of:

- Oscillation mode – core-wide or regional
- PBDA cutoff and averaging filter
- Pre-trip alarms
- Leading OPRM Cells and detection algorithm performance
- Period Tolerance and Oscillation period

4.1 Oscillation Mode Determination

The relative signals for four selected OPRM cells from each core quadrant from Channel 1 are shown in Figure 3. For these nearly symmetric four OPRM cells (Cells 106, 109, 124 and 127), the oscillations are all in phase, indicating that the oscillations are in the fundamental core-wide mode.

4.2 PBDA Cutoff and Averaging Filter

Based on the LPRM data provided, the LPRM signals for a few selected OPRM cells were examined.

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Both the averaging filter and cutoff frequency employ the same second-order Butterworth filter with different frequency (f_c) values. The cutoff frequency is set at 1Hz. The averaging filter is implemented with a frequency corresponding to an average time constant of 5 seconds.

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The use of a 5 second averaging time constant resulted in a relatively flat OPRM cell average signal and was adequate for this event since the growth rate was relatively low (growth rate < 1.10).

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The second-order Butterworth filter with a setting of 1Hz cutoff frequency is found to be very effective in removing residual high-frequency noise from the oscillation signal.

4.3 Pre-Trip Alarms

Based on individual SCC plots, there were a few alarms during the event. There were several occasions when the SCC exceeded the alarm count of 20 while the P/A signal remained below 1.07. Figures 6a through 6c show a few cells that might have generated pre-trip alarms, which are consistent with the several alarms observed at the plant.

4.4 Leading OPRM Cells and Detection Algorithm Performance

Table 2 lists the maximum SCC from the recorded data for all OPRM cells in Channels 1 and 3. Many cells were found to have exceeded the SCC threshold of 10 when the OPRM system tripped. The OPRM P/A signal was at about 1.070 for the leading OPRM cells when the RPS trip was actuated. (One leading OPRM cell in Channel 1 is Cell 120.) Hence, the system worked as designed.

Figures 7a through 7c show three typical leading OPRM cells. These cells reached the SCC setpoint prior to reaching the OPRM trip amplitude setpoint. This is the expected sequence of instability detection and suppression for Option III.

The general observation is that most of the OPRM cells were participating in the instability and approaching the OPRM trip setpoint around the same time. As the oscillation magnitude grew it overcame the interference from the noise and allowed fewer resets. In fact, there were very few resets in the counts once the oscillations were coherent in nature.

The other two defense-in-depth algorithms (ABA and GRA) did not generate a trip signal since the relative amplitude did not reach the 1.1 threshold. It is concluded therefore, that the OPRM system trip was generated by the PBDA algorithm and that the OPRM system provided its intended protection.

4.5 Oscillation Period and Period Tolerance

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Based on the this THI event data, the use of a 100 msec period tolerance did not result in spurious resets and the setting is appropriate for the THI protection.

The core-wide mode reactor oscillations were initiated approximately 200 seconds prior to the reactor trip. At the instability threshold, the oscillation period tended to be less coherent. [[

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5. CONCLUSIONS

The following conclusions can be drawn from the Perry OPRM instability event data analysis:

1. The oscillation mode is core-wide.
2. The reactor was tripped by the PBDA. The OPRM P/A was exactly at the cycle-specific amplitude setpoint of 1.07 when the trip occurred and the PBDA tripped as expected.
3. The Tmin and Tmax settings of 1.2 and 3.5 seconds, respectively, were appropriate for the specific Perry configuration.
4. The use of a 5 second time constant averaging filter was adequate for this event.
5. Selection of 1 Hz frequency for the condition filter cutoff is sufficient to remove high frequency noise from the OPRM cell signal to minimize SCC resets for a coherent oscillation.
6. Based on the MCPR assessment in the previous ODYSY report, the OPRM system SCC and amplitude setpoints were adequate for safety limit MCPR protection.
7. The design of 4 LPRMs per OPRM cell was adequate for this application since the OPRM cell signals did not exhibit any abnormal behavior.
8. Selection of the period tolerance at 100 msec or larger was sufficient to avoid SCC resets due to normal signal period variations, filtering residual effects that may distort the signal characteristic at peaks/valleys, and software digital processing inaccuracies.

The PBDA performed as expected since the OPRM P/A was at the amplitude trip setpoint when the reactor scram was initiated. Most of the OPRM cells performed as expected, exhibiting very few SCC resets. The Perry THI event did not produce any safety hazard and the SLMCPR was protected by the Option III OPRM system.

The lessons learned from the NMP2 THI event provided effective settings in this THI event and the OPRM system functioned and generated a trip signal as designed.

6. REFERENCES

1. NEDO-31960-A, "BWR Owner's Group Long-Term Stability Solutions Licensing Methodology," November 1995.
2. Not Used.
3. NEDO-32465-A, "Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Application," August 1996.
4. Not Used.
5. Not Used.
6. Not Used.

Table 1. OPRM System Settings

Parameter	Setting
Corner or cutoff frequency	1 Hz
Period tolerance	100 msec
OPRM P/A setpoint	1.07
OPRM CC alarm setpoint	20
OPRM CC trip setpoint	10
Tmin (Minimum oscillation period check)	1.2
Tmax (Maximum oscillation period check)	3.5
OPRM trip enabled region size	≥ 23.8% rated power, ≤ 60% rated flow
Min LPRMs per Operable OPRM cell	1
Averaging filter time constant	5 seconds
Reactor Protection System (RPS) trip logic	One of two, taken twice

Table 2. Maximum SCC for Selected OPRM channels

OPRM Cell	Channel 1	Channel 3
1	32	27
2	36	33
3	43	3**
4	33	30
5	22	44
6	36	33
7	36	42
8	33	40
9	34	33
10	33	43
11	38	53
12	35	42
13	32	33
14	38	33
15	33	41
16	48	43
17	28	31
18	35	31
19	56	28
20	49	33
21	45	33
22	26	33
23	35	35
24	36	35
25	51	29
26	40	24
27	24	37
28	29	30
29	30	40
30	26	N/A
31	32	N/A
32	28	N/A

** Might be defective. The base period was never reset after the runback. It stays as 5.5 seconds throughout the THI event.

Figure 1. Event Power/Flow Path

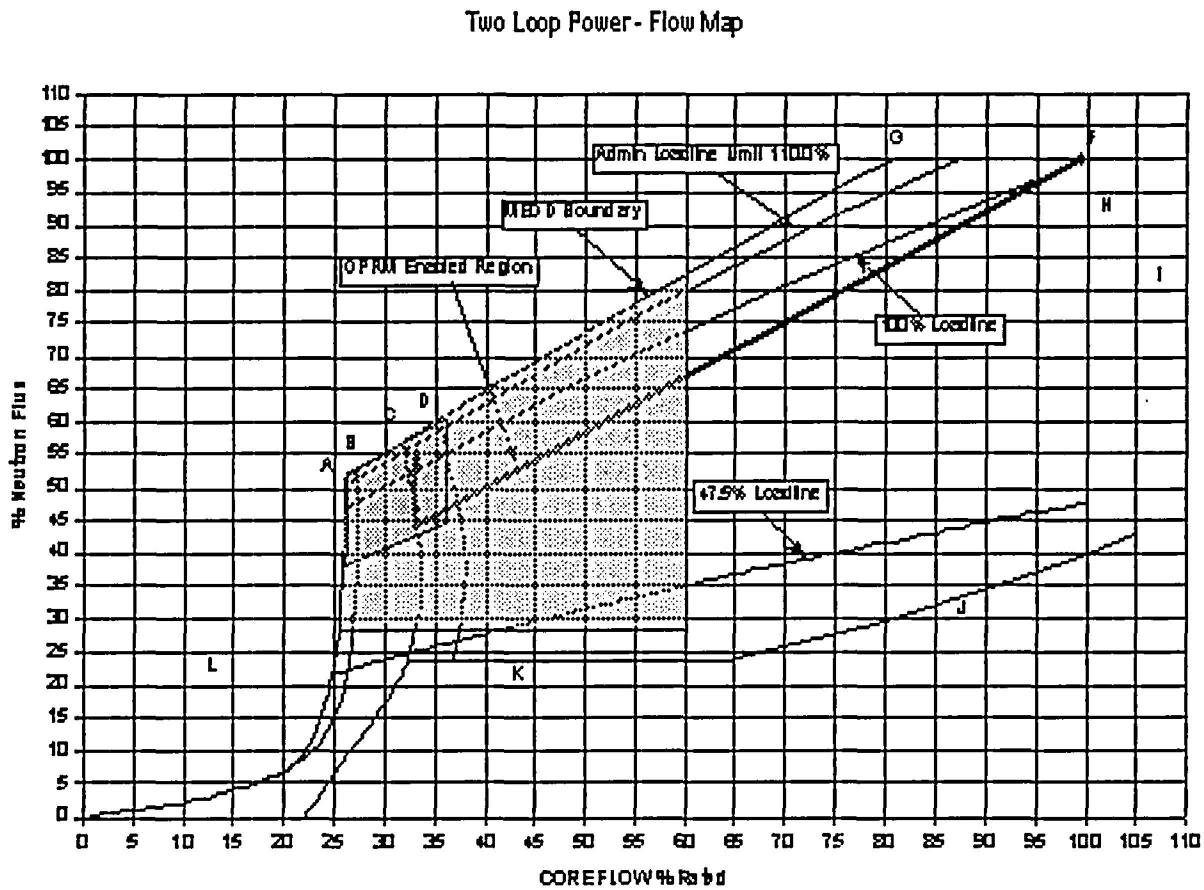

Figure 2a. Perry OPRM Channel 1 Assignment

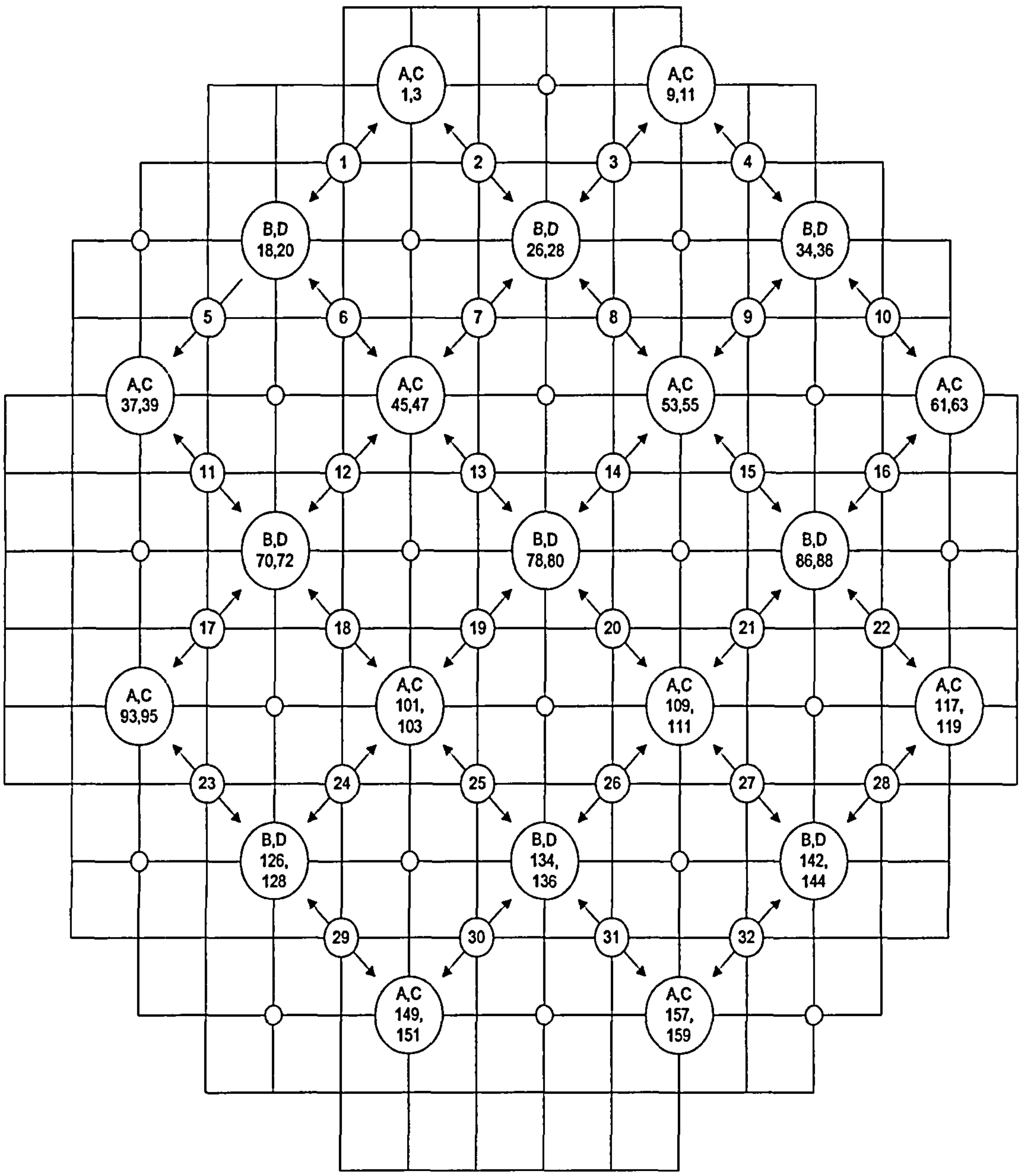

Figure 2b. Perry OPRM Channel 2 Assignment

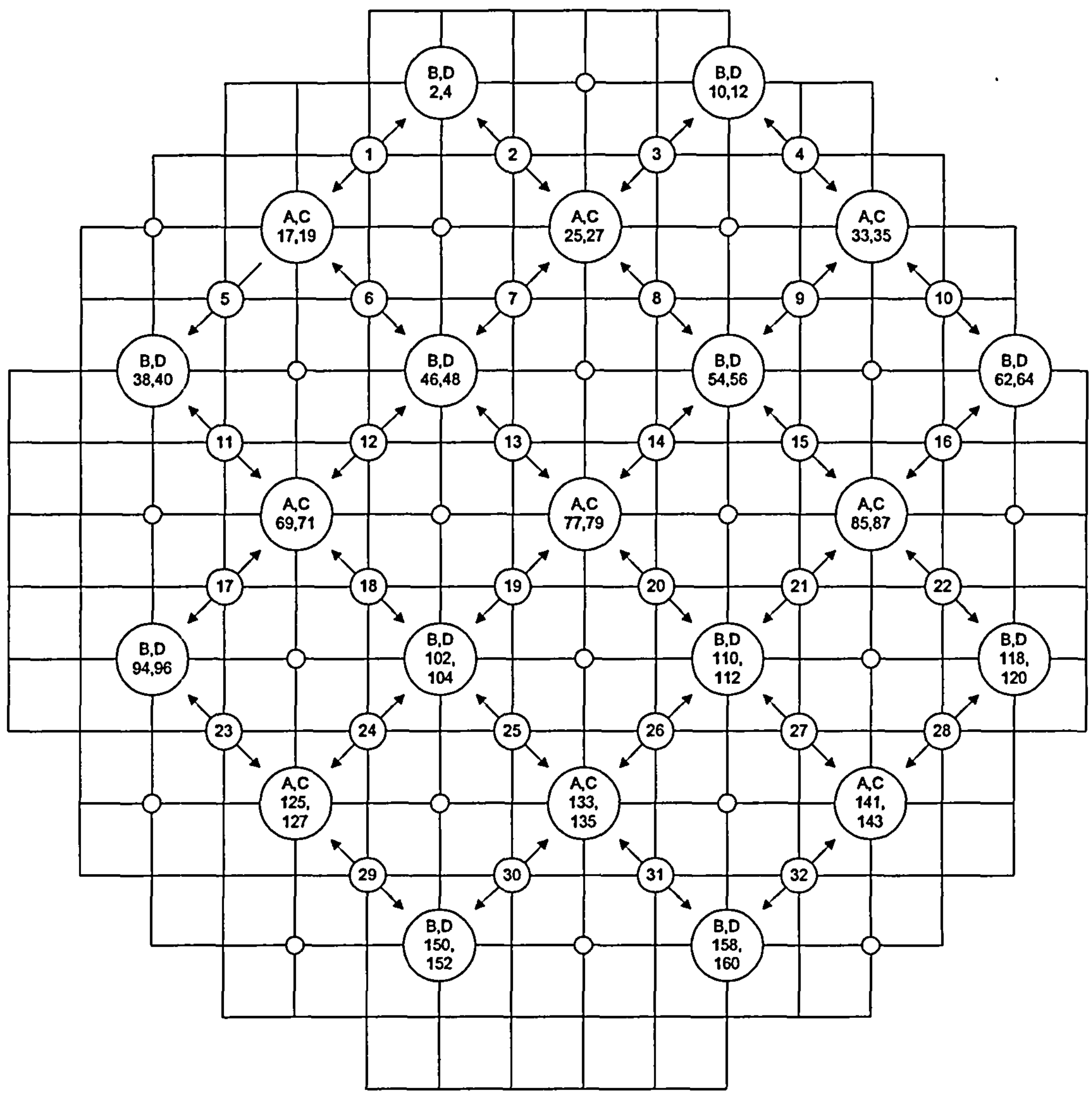

Figure 2c. Perry OPRM Channel 3 Assignment

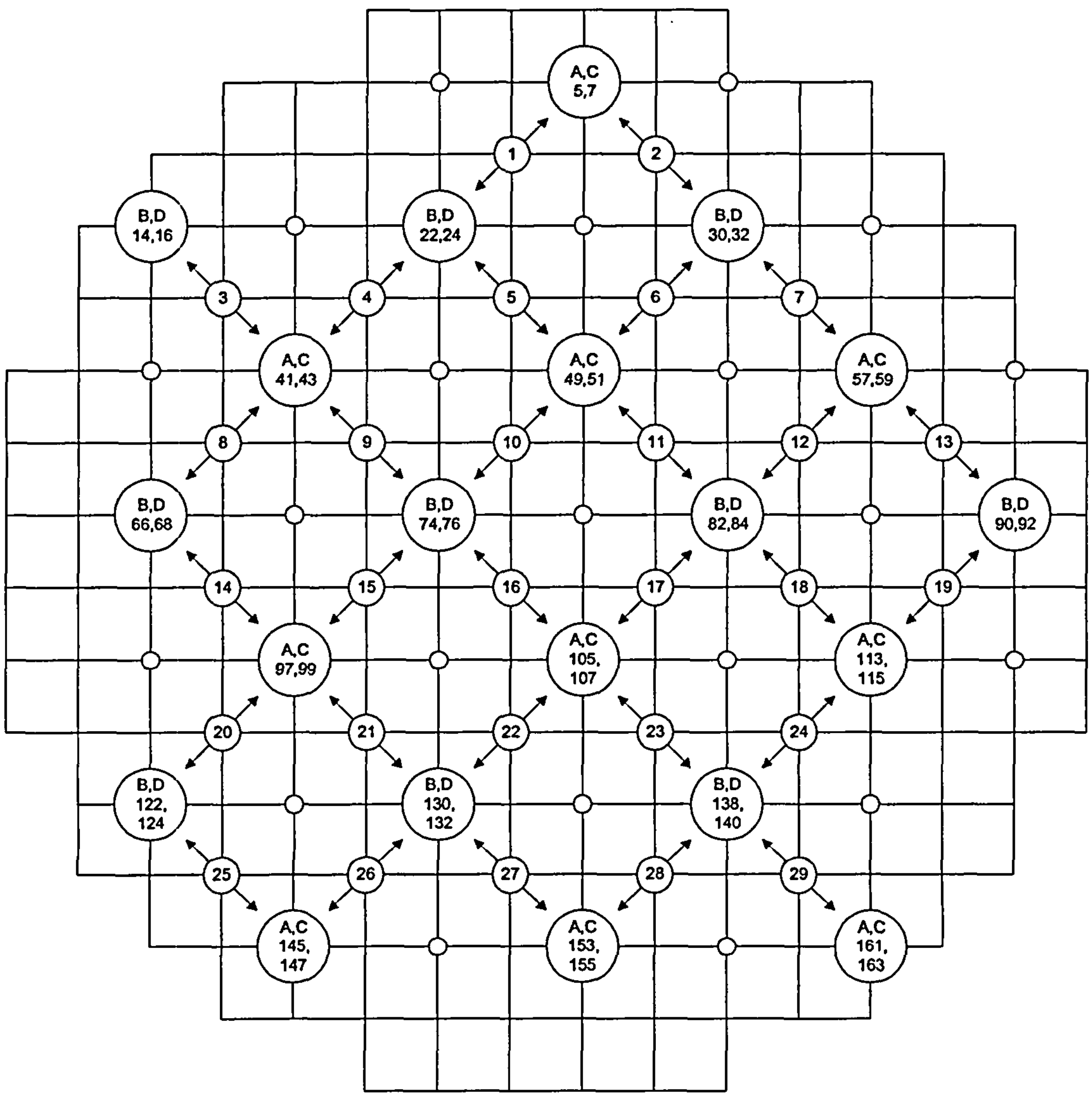

Figure 2d. Perry OPRM Channel 4 Assignment

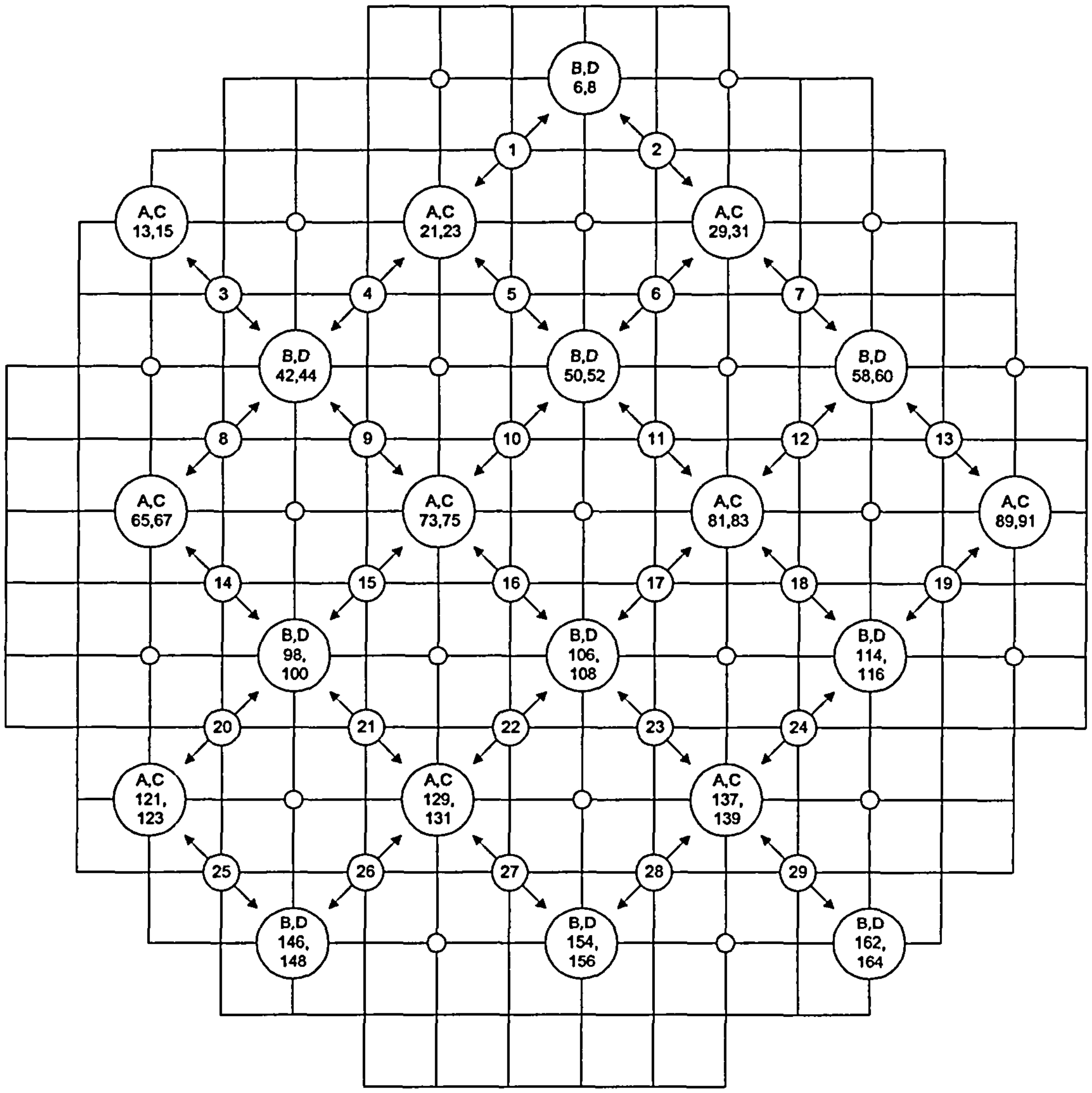

Figure 3. Core-Wide Mode Demonstration

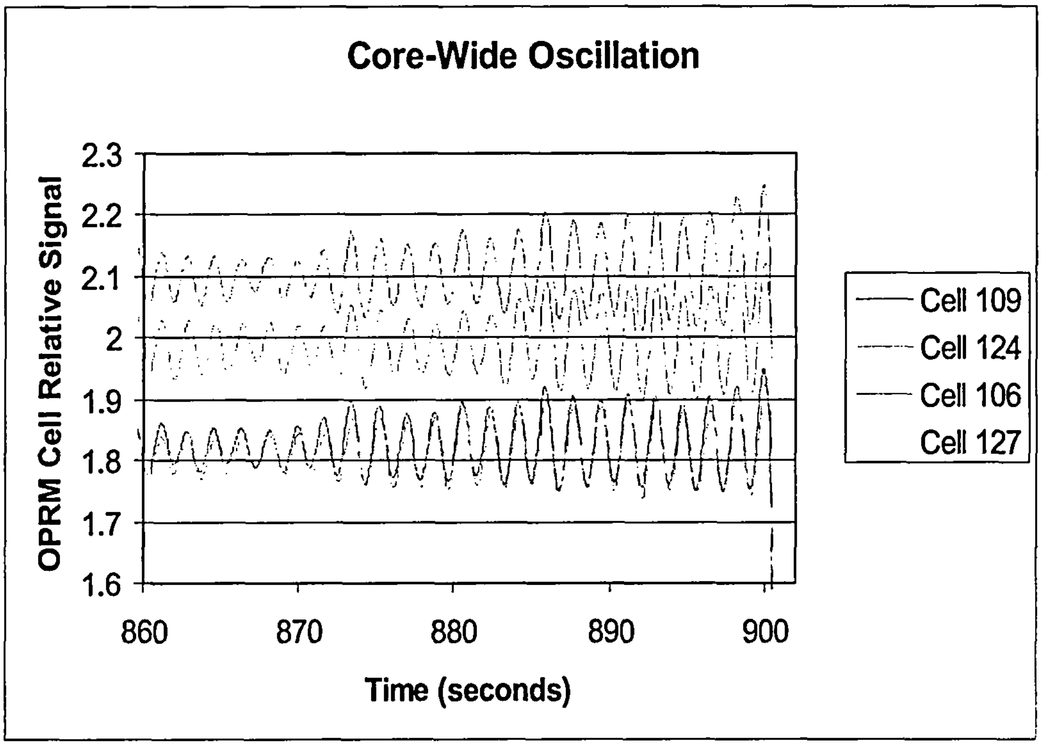

Figure 4 Cell 105 LPRM and OPRM Signals (1 Hz Cutoff)

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Figure 5a. Cell 105 OPRM Signals (4 Cutoff Frequencies)

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Figure 5b. Cell 105 OPRM Signal (1.0 and 1.5 Hz Cutoff frequency)

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Figure 6a. Pre-Trip Alarm (Cell 119)

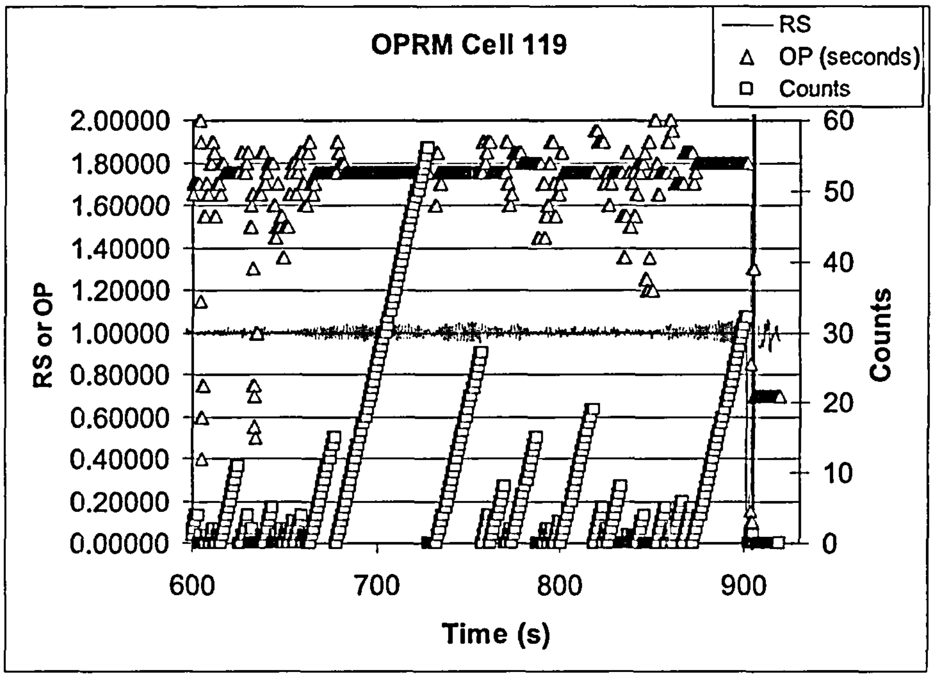

Figure 6b. Pre-Trip Alarm (Cell 115)

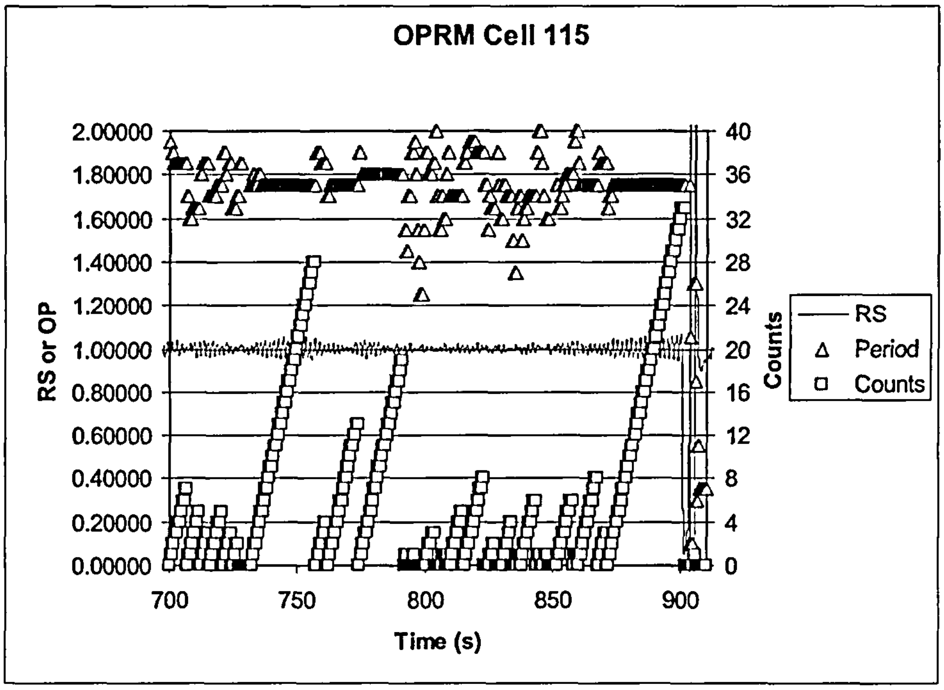

Figure 6c. Pre-Trip Alarm (Cell 128)

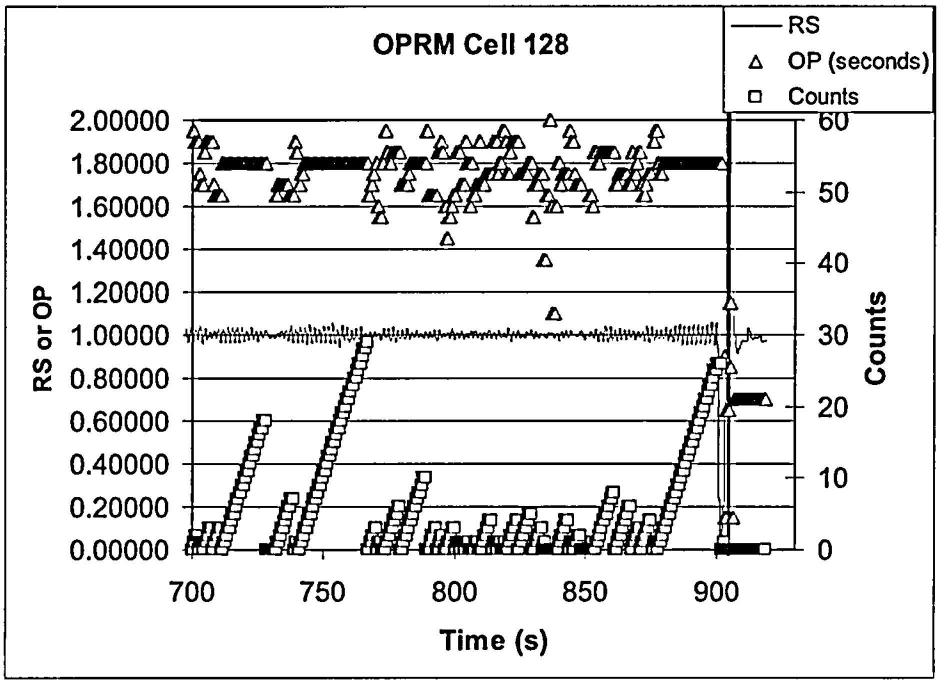

Figure 7a. One Leading Cell Performance (Cell 120)

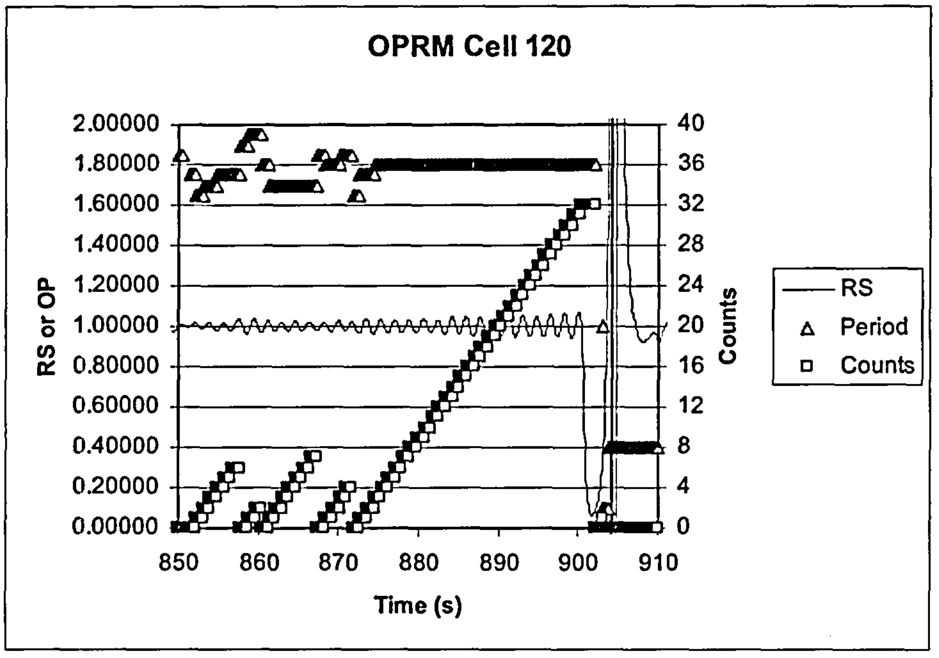

Figure 7b. One Leading Cell Performance (Cell 131)

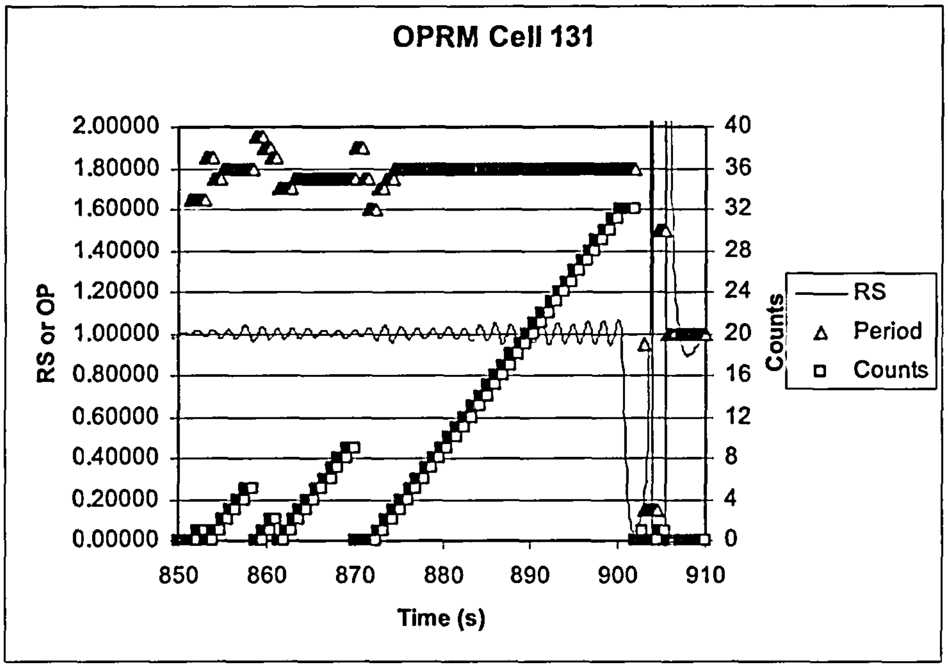

Figure 7c. Leading Cell Performance (Cell 102)