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Question 1 :

Document the actual response of the period based detection algorithm (PBDA) for the RAMONA and reduced-order calculations of instabilities following a recirculation pump trip from the MELLLA+ low-flow corner. Provide in graphic form all relevant PBDA variables for these transients.

Response 1:

A two-recirculation-pump-trip transient was simulated using RAMONA5-FA with initial power and flow at 100% and 80% respectively. Figure 1.1 shows the resulting trajectory of the core state on the power-flow map. At the end of the transient, the core operating point drifts into the channel instability exclusion region, as shown in Figure 1.2. The core power trace is shown in Figure 1.3 to illustrate the entry into the single channel instability exclusion region. The time trajectory of the core state (power, flow and inlet subcooling) is shown in Figure 1.4 where the pump trip is initiated at 30 seconds.

The core flow is shown to drop rapidly following the pump trip. Core power is shown with an [ ], and the power response to the pump trip is also shown. Low amplitude core power oscillations shown in Figure 1.4 are the net result of large amplitude out-of-phase oscillations. The regional oscillation is evident from Figure 1.5 where the powers of the two hot bundles located on symmetric positions across the neutral line are shown to oscillate out-of-phase. Towards the end of the simulated time, the reactor reached a highly unstable state with regional mode decay ratio of 1.2. The power and flow of the hot bundle and its symmetric bundle are shown in Figures 1.6 and 1.7 respectively. Notice that the hot bundle is defined as the one that experienced maximum oscillation magnitude. Its initial CPR prior to the pump trip is 1.4, which is higher than the initial steady state minimum CPR of 1.31 calculated for another bundle. The transition of the reactor state to natural circulation is accompanied by a CPR margin gain, which is followed by degradation due to the flow and power oscillations. As the oscillations grow, the core minimum CPR is shown in Figure 1.8 to coincide with the hot bundles oscillating with the maximum amplitude. Figure 1.9 is a magnification of the high oscillation magnitude part of Figure 1.8 showing the core minimum CPR alternating between the two symmetric hot bundles. The minimum CPR experienced by the hot bundles remained above unity for the entire simulated transient time of 107 seconds,

and well above the safety limit at the time of oscillation detection and suppression. The performance of the detection system is presented next.

The response of the 43 LPRM detector strings was calculated at four levels for each string. LPRM-to-OPRM assignments are based on the 4P arrangement discussed in NEDO-32465-A (four trip channels where each channel contains 30 OPRM cells). Signal analysis of the OPRM system was performed for all the OPRM cell signals. The settings selected were:

1. Signal conditioning. The high frequency noise is reduced by applying a low-pass second order Butterworth filter with corner frequency of [ ] .
2. Signal average is calculated by a second pass through a low-pass Butterworth filter with a low corner frequency of [ ] .
3. Signal normalization is performed by dividing the conditioned signal by the averaged signal.
4. Period counting is performed on the normalized signal using a period tolerance of [ ] second.
5. Trip signal is issued from an OPRM if the number of conformed periods reaches the threshold of [,] and the amplitude setpoint exceeds [ ] . The RPS channel containing the tripped cell will trip.
6. Scram is initiated when the trip logic condition is satisfied. The trip logic "two-out-of-four" is applied here. However, the "one-out-of-two-taken-twice" trip logic would also result in system trip at the same time in this case.

The following table summarizes the response of the most sensitive OPRM cells where the time and corresponding relative signal amplitude are given for three period confirmation values of 12, 14, and 16 respectively.

Several OPRM cells indicated with the relatively high confirmation count of $N_P = 16$ prior to reaching the assumed amplitude setpoint. These are listed in the table below.

The results of the PBDA for the most sensitive OPRM cell are shown in Figure 1.10. It is shown that the period fluctuates early in the event, resulting in low confirmation counts and frequent resetting, until [ ] after the pump trip is initiated. The counting of period confirmations continued without resetting until the end of the simulated signal (the number of confirmations is truncated to 20 in Figure 1.10 and similar figures). The threshold number of confirmations, [ ] in detectors belonging to two different trip channels which satisfies the trip logic. A trip would have been initiated at simulation time of [ ]. The CPR approaches the safety limit only at the end of the simulated transient [ ] after the scram signal would have been issued. The scram was not simulated in order to allow the examination of the oscillation growth to high amplitude.

Effect of Single Channel Oscillation Exclusion:

It should be noted that the core power/flow trajectory following the simulated RPT enters the single channel instability exclusion region, **[**

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More details about the analysis of the most sensitive OPRM signal with setpoint variations will be provided as part of the response to Question 2.

Reduced Order Model Signal:

A reduced order model is used to generate a signal similar to the RAMONA5-FA signals. The model includes a linear hydraulic channel model, linear fuel pin heat conduction model, and modal kinetics capable of simulating a regional mode oscillation. **[**

] The signal processing is performed using the same parameter settings as for the RAMONA5-FA generated signal which is shown in Figure 1.11. The corresponding PBDA results are shown in Figure 1.12.

The same observations as those discussed for the RAMONA5-FA calculation also occur in the reduced order model case. Specifically, a low number of period confirmations and frequent resetting occurred before **[** **]**, after which the confirmation counting continued to increase without resetting. More details will be provided as part of the response to Question 2.

Figure 1.1 RAMONA5-FA Simulated RPT Starting from MELLLA+ Low Flow Corner

Figure 1.2 RAMONA5-FA simulated RPT -- Zoom of Figure 1.1 showing the power-flow trajectory [

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Figure 1.3 The reactor power for the RAMONA5-FA simulated RPT [ ]

Figure 1.4 The reactor operating parameters for the RAMONA5-FA simulated RPT.

Figure 1.5 The power trace of the two hot bundles oscillating out-of-phase in the RAMONA5-FA simulated RPT.

Figure 1.6 Hot Bundle Operating Parameters for the RAMONA5-FA Simulated RPT

Figure 1.7 Operating Parameters for the Symmetric Bundle Located Opposite of the Hot Bundle Represented in Figure 1.6

Figure 1.8 The core minimum CPR and the CPR for the two maximum oscillation magnitude hot bundles as functions of time for the RAMONA5-FA simulated RPT.

Figure 1.9 The Core Minimum CPR and the CPR for the Two Maximum Oscillation Magnitude Hot Bundles as Functions of Time in the Later Part of the Transient

Figure 1.10 PBDA results for the most responsive OPRM cell signal from the RAMONA5-FA simulated RPT. Typical PBDA parameter settings are used.

Figure 1.11 Power signal produced by a reduced order model [ ] to simulate RPT.

Figure 1.12 PBDA results for the hot bundle power signal from the reduced order model simulated RPT.

Question 2:

Following a recirculation pump trip, the PBDA moving average feature may take significant time to reset to the new operating power level. Provide an evaluation of the effect on Enhanced Option III of the lag on the moving average calculation during the transient. Are the conclusions dependent on the PBDA parameter settings used?

Response 2:

The PBDA parameter settings were varied and their effects on the algorithm's performance on the most sensitive signal presented in Question 1 were studied. The averaging filter frequency, which is the parameter that affects the averaging lag, was also varied. Other settings are varied to demonstrate that the conclusions regarding the effect of the averaging filter on the system performance are not dependent on these parameters.

The effects of the filtering corner frequency, $FC2$, on an input signal is a selective damping of frequencies higher than $FC2$, and a time lag of the filtered output signal relative to the input signal.

- For an idealized sinusoidal signal with frequency F oscillating about a constant average, a high filter frequency such that $FC2 > F$ will allow the signal to pass with little damping, and is therefore not suitable for generating an average trend signal. On the other hand, a low filter frequency relative to signal frequency is suitable for that purpose. For expected density wave frequencies of $F = 0.5 \pm 0.2$ Hz, the minimum filter frequency for the purpose of signal averaging should be **[** **]** .
- **[**

  ] The filtering time lag places a lower limit on the averaging filter frequency.

A sinusoidal signal superimposed on a step change is a combination of the two above idealized signals which contain the main features of an oscillating power signal following a two-pump-trip. For this signal, the suitable filtering frequency lower limit is estimated by allowing the step

change filtering distortion to cover a maximum time interval defined by a number of density wave oscillation periods. If delaying the initial tallying of period confirmations due to the averaging signal distortion is considered acceptable for N oscillation cycles, then the limit on filtering distortion time is obtained from

[ ] (2.1)

where $\tau_{\min}$ is the minimum oscillation period for anticipated density waves. The detect & suppress system is designed to detect the maximum oscillation frequency of $f_{\max} = 0.7$ Hz. With $\tau_{\min} = 1/f_{\max}$, and allowing the distortion to cover [ ] cycles, the averaging filter frequency limit is obtained from

[ ] (2.2)

The suitable averaging filter frequency is thus constrained by the requirement of minimizing the distortion due to a step change and the requirement of reducing the amplitude of the oscillations in the frequency range of density waves. We thus obtain,

[ ] (2.3)

Notice that the allowance of [

]. Moreover, the inception of oscillations during the power drop is strongly suppressed due to the large negative reactivity. Therefore there is no expectation of oscillations to reach the amplitude setpoint. During the second half of the average signal distortion, the normalized signal is conservatively overestimated which results in reaching the amplitude setpoint prematurely. This does not adversely affect the trip function, since even if oscillation inception is possible at the earliest time of the step change itself, a sufficient number of confirmation counts cannot be reached because the entire distortion time is relatively small. Thus, relaxing the distortion time to span [ ], a more realistic range of the averaging filter is obtained as

[ ] (2.4)

The effect of the averaging filter frequency is demonstrated next using the signals provided in the response to Question 1.

Figures 2.1 and 2.2 show an OPRM signal generated by RAMONA5-FA simulation of a RPT, and the result of its filtering using second order Butterworth filter frequencies of [ ]. The larger time delay for the signal filtered with [ ].

Figure 2.3 shows the result of normalizing the signal using the calculated average signal with the same filter frequencies of [ ]. For the averaging filter frequency of [ ]. The normalized signal generated with the filter frequency of [ ]. However, as the period checking part of the algorithm is independent of the signal average level, the confirmation counting is not affected by the signal distortion, for by the time a sufficient number of confirmation counts for oscillation recognition is obtained, the signal averaging distortion decayed sufficiently. Figures 2.4a through 2.4d display the performance parameters of the PBDA with varying settings (compared with the base case displayed in Figure 1.10 of the response to question 1). It is shown by these figures that the conclusions regarding the averaging filter frequency are not affected by varying the other settings of period tolerance and high frequency noise filtering.

Figure 2.1 OPRM signal of the RAMONA5-FA simulated RPT transient and the filtered signal using a typical filter frequency [ ].

Figure 2.2 OPRM signal of the RAMONA5-FA simulated RPT transient and the filtered signal using [ ].

Figure 2.3 Normalization of the RAMONA5-FA simulated OPRM signal using the two averaged signals shown in Figures 2.1 and 2.2.

Figure 2.4a PBDA results for OPRM signal from the RAMONA5-FA simulated RPT.

Figure 2.4b PBDA Results for OPRM Signal from the RAMONA5-FA Simulated RPT

Figure 2.4c PBDA Results for OPRM Signal from the RAMONA5-FA Simulated RPT

Figure 2.4d PBDA Results for OPRM Signal from the RAMONA5-FA Simulated RPT

Question 3:

As the flow/subcooling stabilizes following a recirculation pump trip, the oscillation frequency may change causing confirmation count resets. These count resets may be dependent on the PBDA parameter settings used. Provide an evaluation of the effect on Enhanced Option III of frequency shifts during the transient. Are the conclusions dependent on the PBDA parameter settings used?

Response 3:

The operating state is defined by pressure, flow rate, inlet subcooling, and power. The initial change in state following the recirculation pump trip (RPT) is the fast reduction of the flow rate to natural circulation causing the void fraction to increase and introducing large negative reactivity which in turn results in fast power reduction. Unstable density waves are not expected during this first phase because of the large damping effect of the negative reactivity. The subsequent phase is characterized by slow equilibration of the reactor state where the core inlet subcooling increases with a corresponding increase in core power, while pressure and flow remain nearly unchanged. As power and subcooling increase, unstable density wave oscillations become possible. [

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The trends of state variable shifts during the equilibration phase following RPT have opposing effects on oscillation frequency. Specifically, increasing power contributes to increased frequency, while increased subcooling and decreased flow contribute to decreasing frequency. Therefore, the net change in oscillation frequency following an RPT event is expected to be rather small. Simulations of RPT transients with RAMONA5-FA confirm that the subsequent power oscillations occur with nearly constant frequency. A quantitative estimate of the frequency shift (or equivalently the oscillation period shift) on the performance of the PBDA following a RPT transient is presented next.

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(3.9)

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It can be concluded that typical values of the period tolerance, **[** **]** remain adequate for detecting oscillations following a two-pump RPT.

References:

3.1 "Forsmark 1 & 2 BWR Stability Benchmark - Time Series Analysis Methods for Oscillations During BWR Operation," Summary Record of the First Meeting, Consejo de Seguridad Nuclear, Madrid 18-19 February 1999, OEDC Report NEA/NSC/DOC(99)9.

3.2 G. Verdú et al., "Forsmark 1 & 2 BWR Stability Benchmark - Time Series Analysis Methods for Oscillations During BWR Operation," Final Report, OEDC Report NEA/NSC/DOC(2001)2, June 2001.

Figure 3.1 Filtered and Normalized Signal from a Stability Test

Figure 3.2 PBDA Processing of the Signal Shown in Figure 3.1

Figure 3.3 PBDA Processing of the Signal Shown in Figure 3.1

Figure 3.4 PBDA Processing of the Signal Shown in Figure 3.1

Figure 3.5 PBDA Processing of the Signal Shown in Figure 3.1

Question 4:

Provide a simulation of an instability event with small-amplitude oscillations (of the order of the setpoint S_p) and assuming a 3% noise level. Does the presence of noise produce confirmation count resets? Are the conclusions dependent on the PBDA parameter settings used?

Response 4:

The signal description in the question can be interpreted in two different ways with regard to the meaning of "noise," and responses will be based on the results of testing both ways.

Signal A: The signal is simulated with average amplitude normalized to unity and an incipient oscillation growing to a limit cycle of 10% amplitude, which is in the order of magnitude of a typical amplitude setpoint, $S_P = 1.1$, and oscillation frequency of 0.5 Hz. A random component of 3% (peak-to-peak) amplitude is superimposed on the oscillating signal to represent noise.

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Signal B: The signal is a simulated oscillation [

] (4.1)

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PBDA Analysis of Signal A:

The signal was run through the PBDA where its parameter settings were varied. The high frequency noise filter frequency of the second order Butterworth filter (FC1) is varied [

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[ ] The matrix of PBDA parameter variation is given in the table below:

It is confirmed that the presence of noise produces confirmation resets. The frequency of such resets depends on the noise-to-signal ratio and the PBDA parameter settings. As expected, the occurrence of counting resets is more frequent with smaller period tolerance and larger FC1, but appears independent of the averaging filter parameter. Figures 4.2a through 4.10a show the PBDA calculated period and number of confirmations as a function of time for test cases 1 through 9 respectively. In each of these figures, the performance of the PBDA is compared with the stability of the signal [ ] to show that a high number of confirmations is calculated by the PBDA only when the decay ratio is high, and vice versa.

PBDA Analysis of Signal B:

The signal was run through the PBDA where its parameter settings were varied the same way as was done previously for signal A. The results are depicted in Figures 4.2b through 4.10b showing the PBDA calculated period and number of confirmations as a function of time for test cases 1 through 9 respectively. [

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Conclusion: The parameter settings of the PBDA affect its performance where high noise levels cause frequent counting resets. **[**

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Figure 4.1a Simulated Signal [

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Figure 4.1b Simulated Signal [

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Figure 4.2a PBDA Processing of the Signal Shown in Figure 4.1a

Figure 4.2b PBDA Processing of the Signal Shown in Figure 4.1b

Figure 4.3a PBDA Processing of the Signal Shown in Figure 4.1a

Figure 4.3b PBDA Processing of the Signal Shown in Figure 4.1b

Figure 4.4a PBDA Processing of the Signal Shown in Figure 4.1a

Figure 4.4b PBDA Processing of the Signal Shown in Figure 4.1b

Figure 4.5a PBDA Processing of the Signal Shown in Figure 4.1a

Figure 4.5b PBDA Processing of the Signal Shown in Figure 4.1b

Figure 4.6a PBDA Processing of the Signal Shown in Figure 4.1a

Figure 4.6b PBDA Processing of the Signal Shown in Figure 4.1b

Figure 4.7a PBDA Processing of the Signal Shown in Figure 4.1a

Figure 4.7b PBDA Processing of the Signal Shown in Figure 4.1b

Figure 4.8a PBDA Processing of the Signal Shown in Figure 4.1a

Figure 4.8b PBDA Processing of the Signal Shown in Figure 4.1b

Figure 4.9a PBDA Processing of the Signal Shown in Figure 4.1a

Figure 4.9b PBDA Processing of the Signal Shown in Figure 4.1b

Figure 4.10a PBDA Processing of the Signal Shown in Figure 4.1a

Figure 4.10b PBDA Processing of the Signal Shown in Figure 4.1b

Question 5:

Provide the acceptable ranges for Enhanced Option III parameter settings for operation on extended domains (e.g. MELLLA+).

Response 5:

The parameters for the Enhanced Option III are listed below.

1. The corner frequency for filtering high frequency noise, FC1 (Hz)
2. The corner frequency for filtering to get an average signal trend, FC2 (Hz)
3. The period tolerance, ε (sec)
4. The threshold number of confirmations, N_P
5. The amplitude setpoint, S_P

The range of acceptable variation for each of these parameters is not limited by hard boundaries, rather, the parameter settings are chosen based on optimization of the system performance in a given plant environment. It must be emphasized that certain parameter settings are not independent of the other settings. Table 5.1 provides the range of the different parameters covering the expected variation in the application of EO-III, compared with the licensing basis of Option III.

Table 5.1 Parameter Setting Range

Notes on the Parameter Range Listed in Table 5.1:

1. The limits provided for the conditioning filter frequency, FC1, are not based on the differences between Option III and Enhanced Option III design. Rather, the trend to recommend lower filter frequencies is based on calculations of actual and simulated signals indicating better filtering of the noise with the result of reducing the occurrences of counting resetting of otherwise coherent oscillations.

2. [

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3. [

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4. [

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5. [

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Question 6:

The TR mentions that "appropriate allowances made to bound normal operational variations" are used in the channel exclusion region definition. Please specify what those allowances are. Will those allowances cover unplanned control rod sequences (e.g. fuel leakers)?

Response 6:

The channel exclusion region is calculated to bound hot channel instabilities for all cycle exposures. It is further enlarged by reducing the power defining the region's boundary by 5% of rated. This additional conservatism is meant to provide the allowance for normal operational variations of power peaking, which include the effects of control rod sequence exchanges, scram time testing, and inoperable control rods. If significant changes in core radial peaking, such as might occur if a large number of control rods were inserted for long periods of time (e.g., leaking fuel rod power suppression), the region boundary would have to be reevaluated.

Question 7:

The TR mentions the possibility of allowing feedwater heater out of service and other non nominal operating conditions like single loop operation. Is the intent to have multiple exclusion regions, which are selected administratively? If so, provide an example of the implementation of those administrative controls (e.g. technical specifications, special instructions...)

Response 7:

The TR states that "if" FHOOS condition is to be supported, additional measures are necessary. Specifically, a revised single channel instability exclusion region boundary would need to be calculated, and the enlarged region would need to be enforced should feedwater heaters go out-of-service. At present, FHOOS is not allowed for MELLLA+ operation.

Single loop operation offers no particular challenge to the Enhanced Option III solution, and is therefore supported without any additional measures.

Question 8:

Provide the relevant sections of a generic technical specification for implementation of Solution Enhanced Option III. Include operability requirements and backup actions if the primary solution becomes inoperable. Place special emphasis on operability requirements under extended operating domains (e.g. MELLLA+).

Response 8:

The Enhanced Option III Solution is essentially the combination of two systems:

1. The OPRM (Option III) system whose requirements are already a part of a plant's NRC approved plant technical specifications, and
2. A system possessing the capability to actuate a reactor scram at a given core power as a function of either drive flow or core flow, referred to in this response as the Stability Protection Trip (SPT) system.

Enhanced Option III is designed to provide stability protection in the MELLLA+ region. The SPT system is not explicitly defined as part of the Enhanced Option III topical report. Thus, the exact Technical Specification requirements applicable will be addressed in individual plant licensing submittals. However, to illustrate the type of Technical Specification requirements that should be considered, an example is given below. The values given in the example are not to be considered requirements, but are provided to illustrate the type of restrictions that a Technical Specification submittal would contain.

The existing NRC approved OPRM Technical Specification requirements would not necessarily need to be modified. New Technical Specification requirements for the Stability Protection Trip system would be required. However, the requirements for the SPT system would be dependent on the status of the OPRM. The Technical Specification requirements would need to address the conditions described in Table 8.1 below.

Table 8.1 – Example Technical Specification Requirements

Condition	Required Action	Completion Time
Stability Protection Trip not operable AND OPRM trip operable.	Reduce thermal power below the MELLLA boundary in the COLR.	12 hours
Stability Protection Trip operable AND OPRM trip not operable	Initiate alternate method to detect and suppress thermal hydraulic instability oscillations AND Restore OPRM trip to operable	12 hours 120 days
Stability Protection Trip not operable AND OPRM trip not operable	Reduce thermal power below the MELLLA boundary in the COLR. AND Initiate alternate method to detect and suppress thermal hydraulic instability oscillations AND Restore OPRM trip to operable	12 hours 12 hours 120 days

Question 9:

Will manual interim corrective actions (ICAs) be acceptable for extended operating domains?

Response 9:

The response to Question 8 outlines the intended actions for each of the three combinations of OPRM Trip and Stability Protection Trip (SPT) (operable/inoperable). The ICAs use the immediate trip (REGION I) and exit region (REGION II) when the OPRM is not operable. For the following discussion, it is assumed that the two regions are based on decay ratio calculations (e.g., calculated by STAIF).

1. If the OPRM is operable, the immediate trip (REGION I) and exit region (REGION II) regions (e.g., calculated by STAIF) are not required (i.e. ICAs are not needed).
2. If the OPRM is not operable and the SPT is also not operable, the ICAs would be applicable and acceptable thus operation in MELLLA+ would not be allowed, and the immediate trip (REGION I) and exit region (REGION II) regions (e.g., calculated by STAIF) would be used.
3. If the OPRM is not operable and the SPT is operable, the ICAs would be applicable and acceptable thus the immediate trip (REGION I) and exit region (REGION II) regions (e.g., calculated by STAIF) would be used. The trip region for the SPT would help limit the size of oscillations since it would trip in the high power/low flow region of the power/flow map. Also, the decay ratio based regions would be based on the same decay ratio criteria as they are for current (below MELLLA+) operation.

Question 10:

Figure 5.1 shows a straight line for exclusion region, but the document body and Figure 5.2 make reference to generic backup stability protection shapes, which are more parabolic in nature (attempting to approximate the lines of constant DR). Please provide the specific shape of the exclusion region that will be used for Enhanced Option III.

Response 10:

The Enhanced Option III specifies the exclusion of the region in the power/flow map where single channel instability is possible, regardless of its particular shape. A larger region may be excluded in a particular implementation by defining it as the area above a specified flow control line and below a given core flow or any other convenient shape. Optimally, the excluded region is bounded by a contour of a constant hot channel decay ratio.

The stability of density waves in a single heated channel under constant pressure drop boundary condition is scaled primarily with the two-phase pressure drop relative to the single phase pressure drop. This ratio is dominated by the two-phase pressure drop multiplier, which is in turn proportional to steam quality. With the latter dependent on power-to-flow ratio, it results that power-to-flow ratio is the dominant scaling parameter for channel stability under constant pressure drop boundary condition when the inlet subcooling and the axial power shape are fixed. This means that for a constant channel decay ratio, power-to-flow ratio is also constant, and the contours of constant decay ratios are defined by a linear relationship between power and flow. This linear contour is only an approximation, but it seems to apply with high accuracy especially for the case of Enhanced Option III channel exclusion region as this region is rather small and the boundary defining it spans a small range of core flow rate. This observation has been verified by STAIF calculations where the power and flow were varied and decay ratio contours constructed.

The results are shown in Figure (10.1) where the channel decay ratio as a function of channel power are plotted for a family of curves at regular flow intervals. It is shown in Figure (10.1) that the power intervals between successive curves are nearly constant at any fixed decay ratio. This is clarified in Figure (10.2) where the actual contours at decay ratios of 1.0 and 0.8 are drawn, and their linearity is evident.

[

]

The single channel instability exclusion region boundaries can be adequately represented by a linear relationship between power and flow. In plants with hardware equipped for higher order representation, one expects that full utilization of this capability may not be necessary.

Reference

10.1 Y. M. Farawila and D. W. Pruitt, "A Study of Nonlinear Oscillations and Limit Cycles in Boiling Water Reactors – I: The Global Mode," Nuclear Science and Engineering, **154** 302-315 (2006)

Figure 10.1 STAIF calculated hydraulic channel decay ratio as function of bundle power at constant flow and subcooling

Figure 10.2 Bundle power versus flow at decay ratios of 1.0 and 0.8 respectively. The data is obtained from the STAIF calculation shown in Figure 10.1.

Question 11:

Provide a plain description of the hardware implementation using either the existing NUMAC or ABB Solution III hardware, or new hardware.

Response 11:

The hardware used to implement the single channel instability exclusion region is a plant-specific issue and lies outside the scope of the Enhanced Option III solution material under review. Existing or new NUMAC or other vendor hardware are equally applicable provided that the hardware is capable of generating an automatic scram signal upon entry into the predetermined exclusion region.

Question 12:

Describe the procedure that will be used to upgrade the software to EO3 in plants that have Solution III implemented.

Response 12:

There is no software upgrade required for the Option III system which becomes part of the Enhanced Option III. It is anticipated that certain setpoints may be updated as a result of implementing Enhanced Option III, but these are input parameters and not in the software itself.