UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

ACRSR-2278

December 27, 2007

Mr. Luis A. Reyes
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: AREVA DETECT AND SUPPRESS STABILITY SOLUTION AND METHODOLOGY

Dear Mr. Reyes:

During the 548th meeting of the Advisory Committee on Reactor Safeguards (ACRS), December 6–8, 2007, we reviewed the staff's draft safety evaluations of AREVA Licensing Topical Reports ANP-10262P, Revision 0, "Enhanced Option III Long Term Stability Solution," and BAW-10255P, Revision 2, "Cycle-Specific DIVOM Methodology Using the RAMONA5-FA Code." The ACRS Thermal-Hydraulic Phenomena Subcommittee also reviewed this matter on November 14, 2007. During these reviews, we had the benefit of presentations by and discussions with representatives of the staff and AREVA. We also had the benefit of the documents referenced.

CONCLUSIONS AND RECOMMENDATIONS

1. The Enhanced Option III (EO-III) methodology, subject to the limitations and conditions imposed in the staff's draft safety evaluation and recommendations 3 and 4 below, is an acceptable methodology to detect and suppress oscillations in expanded flow window operating domains.

2. The methods and procedures documented in BAW-10255P, Revision 2, subject to the limitations and conditions imposed in the staff's draft safety evaluation and recommendations 3, 5, and 6 below, represent an acceptable methodology to calculate delta critical power ratio (CPR) over initial CPR versus oscillation magnitude (DIVOM) slope values.

3. The applicant's methodology for evaluating the impact of average power range monitor (APRM) and oscillation power range monitor (OPRM) errors caused by bypass voiding should be documented. It would be preferable if such methodology were reviewed and approved on a generic rather than a plant-specific basis.

4. Additional justification is needed for the adequacy of the proposed 5 percent hot channel oscillation magnitude (HCOM) adjustment to account for the increased oscillation growth ratios expected for operation in expanded flow window operating domains. The staff should review such justification and document the basis for its acceptability.

5. Validation of the RAMONA5-FA steady-state dryout correlations for use under unstable oscillation conditions should be documented and submitted for the staff's review and approval.

6. In the final safety evaluation, the staff should justify the adequacy of its proposed 10 percent penalty on the DIVOM slopes calculated by RAMONA5-FA for expanded flow window operating domains.

DISCUSSION

During the past decade, the Boiling Water Reactor Owners Group (BWROG) has developed and the staff has approved three different long-term stability options. Among these is the Option III long-term stability solution, which is a detect and suppress system that relies on signals from the local power range monitors (LPRMs). Small numbers of closely spaced LPRMs are grouped into OPRM cells. The OPRM signals are analyzed on-line; if instability is detected and confirmed, automatic action is taken to suppress the oscillations before compromising the safety margins.

DIVOM correlates the fractional decrease in CPR to the hot channel oscillation magnitude. The DIVOM correlation is used to define the OPRM amplitude scram setpoint. Evaluations by General Electric in 2001 identified a non-conservative deficiency in the generic DIVOM curve developed by the BWROG. For high radial peaking and high peak bundle power-to-flow ratios, the regional mode DIVOM slopes were found to be significantly higher than the licensed generic curve. A high DIVOM slope requires lowering the OPRM scram setpoint, which may result in an increase of false oscillation identifications. The generic DIVOM curve was subsequently eliminated and substituted with a cycle-specific DIVOM analysis.

Since implementation of the long-term stability solutions, two instability events have occurred, one at Nine Mile Point 2 in July 2003 and another at Perry in December 2004. Both events occurred in Option III plants. The Nine Mile Point 2 event was attributed to deficiencies in Option III related to the adjustable parameters for the period-based detection algorithm (PBDA) used to confirm the presence of an instability. The parameters have since been reset to more sensitive settings.

BWRs are licensed to operate within specific power and core-flow conditions referred to as “operating domains” in power-flow maps. In recent years, the industry has been moving toward expanded operating domains with increasing power densities and power-to-flow ratios. This trend is detrimental to the stability characteristics of the reactor, inasmuch as it increases the probability of instability events and increases the severity of such events, if they were to occur. EO-III, documented in AREVA Licensing Topical Report ANP-10262P, is an evolutionary extension of the current Option III detect and suppress solution for use in expanded flow domains up to the maximum extended load line limit analysis-plus (MELLLA+).

The key feature of the EO-III methodology is the recognition that ill-conditioned DIVOM curves are the result of multiple (superimposed) instability mode excitations. In essence, the relationship between the detected parameter (oscillation magnitude) and the fractional change in the limiting parameter (delta CPR over initial CPR) (i.e., the DIVOM relationship) breaks down when multiple instability modes coexist. Multiple instability modes are more likely to occur under expanded flow domain operations. The limiting case corresponds to single (or a few) hydraulic channel oscillations superimposed on the regional mode oscillation.

EO-III resolves the ill-conditioned DIVOM problem by defining an exclusion region enforced by an automatic scram, referred to as the stability protection trip (SPT) region. Single channel hydraulic mode excitations do not occur outside the SPT region. All detect and suppress functions of the current Option III are maintained outside the SPT exclusion region, where the

DIVOM curve should be well behaved. Cycle-specific DIVOM curves based on regional instabilities are calculated for reactor states with hydraulically stable channels. The proposed methodology to define the boundary of the exclusion region using the previously approved STAIF code is acceptable.

The high-growth ratios expected in expanded flow domain operations may not allow sufficiently rapid suppression of the instability to avoid violation of the safety limit minimum critical power ratio (SLMCPR) as the oscillation quickly grows during the scram delay. To address this issue, the applicant imposes a 5 percent penalty on the HCOM to conservatively account for the anticipated increase in the oscillation growth ratios for operation in expanded flow domains up to MELLLA+. AREVA performed sensitivity analyses by scaling the probability distributions of the growth ratio used in the licensing-basis methodology for the Option III detect and suppress solution. It is not clear that the parameter ranges used in these sensitivity analyses cover all expected conditions for expanded flow domain operations. Hence, further analyses to support the adequacy of the 5 percent HCOM penalty are necessary.

Bypass voiding at high-power/low-flow conditions can result in calibration errors for both OPRM cells and APRM signals. Increased voiding reduces the sensitivity of the LPRM detectors, particularly in the upper elevations. The LPRM errors propagate to the OPRM and APRM channels when signals from the LPRM detectors at different levels are combined. OPRM uncertainties will result in a reduction of the OPRM PBDA setpoint, while APRM uncertainties will affect the SPT exclusion region boundary. The EO-III topical report does not address the effects of bypass voiding. The staff proposes that plant-specific EO-III applications should include an evaluation of the uncertainty induced by bypass voiding on the OPRM and APRM readings. The applicant's methodology for evaluating the APRM and OPRM calibration errors and accounting for the effects of such errors on the SPT region boundary and the PBDA setpoint should be documented. To ensure uniformity of application, it would be preferable if such methodology were submitted for review and approval on a generic rather than a plant-specific basis.

Plant-specific EO-III applications will need to address issues related to hardware and software implementation, including provision for backup stability protection if the EO-III primary solution is declared inoperable. We agree with the staff's conclusion that plant-specific applications should include the specifications of the backup stability protection.

Topical Report BAW-10255(P), Revision 2, presents a methodology to evaluate the cycle-specific DIVOM curve using the transient system code RAMONA5-FA. The code is based on RAMONA3, originally developed by Brookhaven National Laboratory and later modified by Studsvik-Scandpower to become RAMONA5 V2.4. Several enhancements have been made in the transition from RAMONA5 V2.4 to RAMONA5-FA. RAMONA5-FA predictions have been compared against reactor event data, as well as data from the Karlstein Thermal Hydraulics (KATHY) stability tests and oscillatory dryout-rewetting tests.

To develop the DIVOM curve, the code needs to correctly model the loss of CPR margin caused by the power-flow oscillation. Comparisons with the KATHY hydraulic loop data and reactor benchmarks show that RAMONA5-FA can adequately predict the frequencies and growth rates of the oscillations. Comparisons between the KATHY oscillatory dryout-rewetting test data and CPR predictions obtained using the RAMONA5-FA steady-state CPR correlations show that the code can predict the dryout times reasonably well. However, the limited data included in topical report BAW-10255(P) suggest a nonconservative bias in the predicted CPR values at the onset of dryout. To ensure adequacy of the safety limit, a quantitative comparison between predictions of the steady-state dryout correlations and the test data for unstable oscillation conditions, including a statistical evaluation of the errors, should be submitted to the staff for review.

While the AREVA DIVOM methodology described in topical report BAW-10255(P) is consistent with the previously approved BWROG methodology for calculating generic DIVOM slope values, the RAMONA5-FA code has not been fully reviewed by the staff. The staff plans to perform a full review of the RAMONA5-FA code, including constitutive relations, numerics, neutronic methods, and benchmarks. In the interim, the staff proposes the addition of a 10 percent penalty to the DIVOM slopes calculated by RAMONA5-FA for expanded flow domain operations. The adequacy of this penalty needs to be demonstrated.

We look forward to further interactions with the staff on these issues.

Sincerely,

/RA/

William J. Shack
Chairman

<u>REFERENCES</u>

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2. AREVA Topical Report ANP-10262(P), Revision 0, “Enhanced Option III Long Term Stability Solution,” January 31, 2006 (ML060330647)

3. AREVA Topical Report, BAW-10255(P), Revision 2, “Cycle-Specific DIVOM Methodology Using the RAMONA5-FA Code,” January 30, 2006 (ML060330502)

4. Letter to NRC from R. L. Gardner, AREVA, ANP-10262Q1(P), Revision 1, “Response to Request for Additional Information–ANP-10262(P),” October 2007 (ML073610384)

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6. General Electric Company-Nuclear Energy Topical Report, NEDO-31960-A, “BWR Owners Group Long-Term Stability Solutions Licensing Methodology,” May 1991

7. General Electric Company-Nuclear Energy Topical Report, NEDO-31960-A, Supplement 1, “BWR Owners Group Long-Term Stability Solutions Licensing Methodology,” November 1995

8. General Electric Company-Nuclear Energy Topical Report, NEDO-32465-A, "BWR Owners Group Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications," August 1996

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10. Oak Ridge National Laboratory Technical Evaluation Report, Review of AREVA BAW-10255(P), Revision 2, "Cycle-Specific DIVOM Methodology Using the RAMONA5-FA Code," October 2007 (ML073120285)

11. Siemens Power Corporation Topical Report, EMF-CC-074(P)(A), Volumes 1 through 4, "STAIF A Computer Program for BWR Stability Analysis in the Frequency Domain," Siemens Power Corporation, 1993 through 2000 (Volume 1 through Volume 4)

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13. Letter to NRC from J. S. Post, General Electric, "Stability Reload Licensing Calculations Using Generic DIVOM Curve," August 31, 2001 (ML012490522)

14. Presentation to NRC from Michael May, Exelon Corp., "Stability Option III DIVOM Part 21 Closure Plan," August 15, 2003

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