RAMONA5-FA Best-Estimate Option III Pre-Application Overview

AREVA/NRC Meeting

NRC Two White Flint North
11555 Rockville Pike
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RAMONA5-FA
Best-Estimate Option III
Pre-Application Overview

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Agenda

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- Background
- Methodology Elements
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- Summary
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Objectives

- Provide an overview of the RAMONA5-FA Best-Estimate methodology for LTSS Option III
- Summarize methodology elements per SRP 15.0.2
- Obtain NRC feedback on approach

NRC's Prioritization Factors RAMONA5-FA BEO-III

▶ Classification

◇ New technology improves safety

- Option III LTSS relies on a piecemeal stack-up of computational components to determine the 2PT MCPR response
  - MCPR response for the flow runback to natural circulation
  - 95/95 Monte-Carlo to determine the hot channel oscillation magnitude
  - Relative MCPR response versus oscillation magnitude (DIVOM) evaluated at highest rod line / natural recirculation conditions
- An expedient approach when the BWROG desired a generic methodology for all fuel vendors and fuel designs
- Results in lower PBDA scram setpoints at rated conditions to accommodate conservatism and a higher probability of a spurious scram as evidenced at Hope Creek, Perry and Dresden
- **BEO-III provides best-estimate plus uncertainty analyses of the entire event scenario and eliminates the inherent conservatisms of the piecemeal approach**

RAMONA5-FA BEO-III
Preliminary Cycle Design Results

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RAMONA5-FA BEO-III Preliminary Cycle Design Results

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- **BEO-III is expected to provide greater margin to reactor scrams**

NRC's Prioritization Factors RAMONA5-FA BEO-III

▶ Classification, continued

◇ Revision reflects current hardware requirements

- Option III is applicable to MELLLA operation
- The original generic solution was modified to a plant specific solution since the generic DIVOM curve could be non-conservative
- AREVA developed the RAMONA5-FA DIVOM Methodology (BAW-10255P-A) that demonstrated that the DIVOM curve is well behaved except for the hypothetical condition where decoupled hydraulic oscillations might occur
- The AREVA Enhanced Option III (EO-III, BAW-10262P-A) solution extended Option III to MELLLA+ operation and imposed a conservative exclusion region on the operating power/flow map to exclude unstable channels

NRC's Prioritization Factors RAMONA5-FA BEO-III

- ▶ **Classification, continued**
  - ◇ **Revision reflects current hardware requirements**

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NRC's Prioritization Factors
RAMONA5-FA BEO-III

- ▶ **Classification, continued**
  - ◇ **Revision reflects current hardware requirements**

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NRC's Prioritization Factors RAMONA5-FA BEO-III

- **Applicability**
  - All BWR Licensees that use Option-III / Enhanced Option-III LTSS
  - Support AREVA fuel design evaluations for BWR Licensees that use MELLLA+
- **Implementation Certainty**
  - Currently proposed solution for MELLLA+ and Fuel Transition proposals to Licensees

NRC approval is requested by early 2019 for ATRIUM-11

RAMONA5-FA BEO-III Background

- **RAMONA5-FA code was reviewed and approved to determine LTSS Option III MCPR Operating Limits**
  - BAW-10255PA, Revision 2, "Cycle-Specific DIVOM Methodology Using the RAMONA5-FA Code", AREVA NP, May 2008.
  - EMF-3028P-A, Volume 2 Revision 4, RAMONA5-FA: Computer Program for BWR Transient Analysis in the Time Domain, Volume 2: Theory Manual, AREVA NP Inc., March 2013.
- **RAMONA5-FA was also used to simulate two pump trip scenarios in support of the Enhanced Option III LTSS**
  - ANP-10262PA Revision 0, "Enhanced Option III Long Term Stability Solution", AREVA NP, May 2008.

RAMONA5-FA BEO-III Background

- The RAMONA5-FA Best Estimate Option III methodology repurposes the approved code version to perform cycle specific event simulations to evaluate the MCPR response.
- The 95/95 MCPR limit for the cycle design will use Monte-Carlo methods to combine uncertainties.
- The LTR will focus on the methodology elements and will include quantification of uncertainties and sample analyses results.

Methodology Elements

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RAMONA5-FA BEO-III Evaluation Model

- The frozen version of the RAMONA5-FA model is expected to be nearly identical to the NRC reviewed and approved model (EMF-3028P-A)
- The expected modifications include:
  - Implementation of coding to identify the plant specific LPRM assignments to OPRM cells and evaluation of the OPRM signals to determine the time of reactor scram

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  - Implementation of methods to adjust highly ranked phenomena based on select samples of the associated uncertainties in support of determining the 95/95 critical power response

Preserves fidelity of the approved RAMONA5-FA

RAMONA5-FA BEO-III Event Scenario

- The limiting event for the BEO-III methodology is the Two-Pump Trip from rated reactor power.
- The phases of the event are:
  - ◇ Rapid reduction in core power and flow to natural circulation due to the pump trip and associated reductions in the vessel pressure and feedwater flow rates.
  - ◇ Increasing core power at natural circulation due to feedwater temperature reduction and eventual onset of reactor power oscillations.
  - ◇ Continued feedwater temperature reductions resulting in increasing oscillation growth rates and oscillation magnitudes until either a limit cycle is established or the PBDA suppresses the oscillations by reactor scram.

RAMONA5-FA BEO-III
Regulatory Requirements

- The regulatory requirements are Criteria 10 and 12 in Part 50 of Title 10 of the *Code of Federal Regulation* (10 CFR), Appendix A, "General Design Criteria for Nuclear Power Plants"
  - Criterion 10, "The reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including effects of anticipated operational occurrences"
  - Criterion 12, "The reactor core and associated coolant, control, and protection systems shall be designed to assure that power oscillations which can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed."

RAMONA5-FA BEO-III Figure of Merit

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RAMONA5-FA BEO-III
Draft PIRT

Phenomenon	Comments

RAMONA5-FA BEO-III
Draft PIRT - Continued

Initial Conditions	Comments

RAMONA5-FA BEO-III Code Assessments

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RAMONA5-FA BEO-III Code Assessments

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RAMONA5-FA BEO-III Code Assessments, cont.

RAMONA5-FA BEO-III
Code Assessments, cont.

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Code Assessments, cont.

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RAMONA5-FA BEO-III Code Assessments, cont.

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RAMONA5-FA BEO-III
Code Assessments, cont.

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RAMONA5-FA BEO-III Code Assessments, cont.

RAMONA5-FA BEO-III
Code Assessments, cont.

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RAMONA5-FA BEO-III Uncertainty Analyses

- **Uncertainty analyses will use a statistical process based on non-ordered statistics.**
  - The Monte Carlo method is widely accepted in the industry.
  - Method uses an ensemble of sampled cases (typically 59 to 208 cases), each with a set of randomly sampled modeling uncertainty parameters.
  - Non-ordered statistics allows the FoM results from the ensemble to be used to determine the value which bounds a specific fraction of the full ensemble results at a specific confidence level.
  - The ensemble average FoM results are sorted in descending order, and the result is the acceptance number line corresponding to the sample size.

Acceptance Numbers for 95% Probability and 95% Confidence

Acceptance Number	Sample Size
1	59
2	93
3	124
4	153
5	181
6	208
7	234
8	260
9	286
10	311

RAMONA5-FA BEO-III
Change Control Process

- AREVA maintains a formal change control process to assure licensing remains consistent with the NRC approval and will propose the following elements:
  - Modification specific testing to verify changes.
  - Maintenance of Continuity of Assessment (CoA) test suite as new benchmarking is performed.
  - Regression testing using CoA to evaluate changes relative to the previous released version and the NRC approved LTR.
  - Definition of "essentially the same" with respect to evaluation of changes.

RAMONA5-FA BEO-III Summary

- The BWROG Option III LTSS contains inherent conservatisms as a result of the desire to bound all fuel designs and plants.
- The level of conservatism can result in a higher probability of spurious plant scrams.
- The Option III licensing basis can be replaced by a best-estimate methodology with appropriate statistical assessments of the uncertainties to maintain a 95/95 conservatism in the OLMCPR.

RAMONA5-FA BEO-III
Summary

- The RAMONA5-FA code has been reviewed and approved by the NRC, by ACRS request, for the DIVOM Methodology LTR.
- The approved code can be repurposed for the statistical analyses of the entire 2PT scenario to determine the retained OLMCPR margin to the SLMCPR.

Next Steps

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Acronyms/Nomenclature

- CPR — Critical Power Ratio
- DIVOM — Relative change in CPR versus Oscillation Magnitude
- EO-III — Enhanced Option III
- ICO — Independent Channel Oscillation
- LPRM — Local Power Range Monitor
- LTSS — Long Term Stability Solution
- MCPR — Minimum Critical Power Ratio
- OLMCPR — Operating Limit Minimum Critical Power Ratio
- OPRM — Oscillation Power Range Monitor
- PBDA — Period Based Detection Algorithm
- SLMCPR — Safety Limit Minimum Critical Power Ratio
- 2PT — Two Recirculation Pump Trip