DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT ANP-10301P, REVISION 0,

"STATISTICAL UNIVERSAL POWER RECONSTRUCTION WITH FIXED MARGIN

TECHNICAL SPECIFICATIONS" FOR LICENSING APPLICATIONS

AREVA NP, INC.

PROJECT NO. 728

1.0 INTRODUCTION AND BACKGROUND

By letter dated September 15, 2009, AREVA NP Inc. (AREVA) submitted Topical Report (TR) ANP-10301P, Revision 0, "Statistical Universal Power Reconstruction with Fixed Margin Technical Specifications" (Reference 1), to the U.S. Nuclear Regulatory Commission (NRC) for review and approval. The objective of the TR is to allow the implementation of an online relative power distribution reconstruction and margin calculation system applicable to pressurized water reactors (PWRs). This system computes a reconstructed power distribution that is the best estimate of all available information in terms of relevant measurement, design specifications, and operating states, together with estimates of their uncertainties. This new methodology allows meeting the Limiting Conditions for Operation (LCO) parameter limits that assure that fuel integrity is maintained during Condition I (Normal Operation) and Condition II (Incidents of Moderate Frequency) events by limiting local power peaking. This is achieved through direct continuous online core power distribution monitoring, as opposed to the current methodology based on indirectly limiting the power distribution by limiting the LCO parameters (i.e., rod insertion, axial power shaping rod, axial imbalance, and quadrant power tilt)

The "Statistical Universal Power Reconstruction with Fixed Margin Technical Specifications" (SUPR-FMTS) methodology supersedes the previously NRC approved methodology "Fixed Margin Technical Specifications" (FMTS) (Reference 2), and expands its applicability from Babcock & Wilcox PWRs to other operating PWRs, provided the conditions and limitations of the Safety Evaluation (SE) are met.

2.0 REGULATORY EVALUATION

Section 50.34 of Title 10 of the *Code of Federal Regulations* (10 CFR) requires that licensees (or vendors) provide safety analysis reports to the NRC detailing the performance of structures, systems, and components provided for the prevention or mitigation of potential accidents. AREVA is seeking review and approval of ANP-10301P, Revision 0, "Statistical Universal Power Reconstruction with Fixed Margin Technical Specifications" (SUPR-FMTS), so that implementation of this new methodology will enhance the safety of operating PWRs by improving the estimate of the margin of the LCO limits for Condition I and Condition II events.

3.0 TECHNICAL EVALUATION

The SUPR-FMTS methodology for on-line monitoring of the core power distribution builds on the previously approved FMTS methodology (References 2 and 3). FMTS monitors the LCOs for operation by computing a peaking margin as the figure of merit. The estimate of the margin is constructed from on-line core simulator calculations of the relative power density (RPD) at all core nodes, and Fixed In-Core (FIC) detector measurements at limited nodal positions. The uncertainty in this margin estimate is dependent on global considerations such as symmetry and quadrant tilt, and pre-calculated limits based on conservative assumptions that take into account design tolerances and the entire possible range of operation. These pre-calculated limits are applied in the form of a penalty factor, that consists of statistically and non-statistically quantified components, to the estimate of the nodal relative power density.

The SUPR-FMTS methodology shifts some of the estimation of the nodal RPDs and their uncertainty from the global considerations, used in FMTS for estimating nodal RPDs and the pre-calculated penalty factors, to more local estimates and dynamic evaluation of some sub-factors that contribute to the total penalty factor. This approach brings local measurement information to all nodes, and, thereby, allows some relaxation of the conservative assumptions used with FMTS.

Furthermore, SUPR-FMTS extends the applicability of FMTS to cores with Traveling In-Core Probe (TIP) detector systems that take core measurements roughly monthly, as opposed to being limited, as was FMTS, to FIC systems that make core measurements typically in one to six minute intervals. This extension is achieved by introducing a RPD Check methodology that uses the measurements from the ex-core flux detectors and the fuel assembly exit thermocouples that are measured on a frequent basis.

To these ends, SUPR-FMTS exploits the statistical estimation method referred to as Kriging (Reference 4). In this method, the core simulator computed RPDs at each spatial core node are corrected to the information from measured values at instrumented assemblies, such as FICs or TIPs. This is achieved by computing the best unbiased linear estimator of an unmeasured core node by using a stochastic model of the spatial variance of all the core nodes, and by minimizing the variance of the prediction error, subject to the constraint that the expectation of the difference between the measure and computed RPDs is zero. In this computation, with each node there is associated a three-dimensional “domain of influence” consisting of neighboring measured and unmeasured core nodes, wherein the spatial covariance function between the nodes in a domain of influence is specified as Gaussian.

Since the dynamically computed Kriging prediction is based on flux measurements and flux core simulator calculations, this prediction does not take into account core design tolerances and operating conditions of the reactor system. The effect on peaking of these uncertainties is taken into account through penalty factors. These are divided into two sets: a set of plant-specific factors established off-line before plant operation, that can be roughly divided into tolerances and system operating uncertainties that include instrument failure fraction; and a set of dynamically computed factors, that account for the change in pin peaking and the Kriging variance over the operating cycle.

For cores with TIP measurement systems the time between measurements is sufficiently long to introduce some changes in the core composition and other factors. To assure that the on-line core simulator estimates between TIP measurements capture the effects of these changes, SUPR-FMTS applies an RPD Check methodology. Should any deviation be beyond that expected, an additional penalty is computed and applied. This methodology uses the real-time fuel assembly exit thermocouple and excore flux detector data that is available at each reactor. The check is performed by computing an expected response from the Kriging-estimated RPDs and reactor conditions, in the form of computed assembly exit thermocouple temperatures and excore flux detector responses. These are compared to the on-line measurements. If the test fails, the Kriging-process variance is adjusted with penalty factors computed from the thermocouple and excore detector estimate-to-measurement comparisons, and the margin is recomputed. This RPD Check methodology serves to control the margin estimate between TIP measurements.

4.0 LIMITATIONS AND CONDITIONS

To implement SUPR-FTMS, at a plant, for on-line LCO core monitoring based on peaking margin as a figure of merit, a License Amendment Request (LAR) must be submitted to the NRC for review and approval. The LAR must identify and justify the adequacy of the approved systems in place at the plant that will contribute the measured data and the computed data for the implementation of the SUPR-FMTS methodology.

If the NRC's criteria or regulations change so that its conclusions about the acceptability of the assumptions made during this review are invalidated, the organization referencing the report (Reference 5) will be expected to revise and resubmit its respective documentation, or submit justification for the continued effective applicability of these methodologies without revision of the respective documentation.

5.0 CONCLUSION

Based on the foregoing considerations, the NRC staff concludes that the use of SUPR-FMTS by AREVA as described in ANP-10301P, Revision 0, "Statistical Universal Power Reconstruction with Fixed Margin Technical Specifications," is acceptable for licensing calculations and may be used to perform on-line relative power distribution reconstruction for PWRs and provide input to a LCO power peaking margin calculation provided the limitations and conditions in Section 4.0 of this SE are met.

6.0 REFERENCES

1. Letter from Ronnie L. Gardner (AREVA NP Inc.) to U.S. Nuclear Regulatory Commission Document Control Desk, Request for Review and Approval of ANP-10301P, "Statistical Universal Power Reconstruction with Fixed Margin Technical Specifications," September 15, 2009 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML092610436).

2. R. A. Kochendarfer, C.T. Rombough, A. Y. Cheng, "Fixed Margin Technical Specifications," BAW-10158P-A, Babcock & Wilcox, Lynchburg, Virginia, August 1988.

3. Nuclear Applications Software Package," BAW-10123, Babcox & Wilcox, Lynchburg, Virginia, February, 1978.

4. Brian D. Ripley, *Spatial Statistics*, John Wiley & Sons (1981).

5. ANP-10301P, Revision 0, “Statistical Universal Power Reconstruction with Fixed Margin Technical Specifications”, September 2009 (ADAMS Accession Nos. ML092610437 and ML092610438 (Non-Publicly Available/Publicly Available)).

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Date: July 2, 2013