ENCLOSURE

Review of the Topical Report WCAP-10665-P
"Excore Axial Power Monitor"

Introduction and Background

The Westinghouse Topical Report WCAP-10665-P, "Excore Axial Power Monitor", discusses aspects of a relatively "new" Westinghouse methodology for online monitoring of core power distributions via a multiple section excore neutron detector and associated analysis-computing system. This report is an addition to previous discussions of the subject, primarily related to the review of RESAR 414, and a Topical Report, WCAP-9105, "Axial Power Distribution Monitoring Using Four-Section Ex-Core Detectors", which had been reviewed and approved (eight years ago). That review indicated that there were still unreviewed areas for the system, primarily related to the assignment of uncertainties to the analyses. This new report is intended to complete the record, and in particular to present the analysis algorithms and input information, system calibration methodology and associated uncertainty analysis. The report is generally generic in nature, but it is specifically addressed to the Shearon Harris reactor.

This system is of interest to Shearon Harris principally because of the need, especially in the first cycle, to reduce the effective total (power distribution) peaking factor, F_Q, from the standard analysis value of 2.32 to the 2.11 or less required to meet LOCA limits, and permit operation above 91 percent power. Similar problems have been solved for other Westinghouse reactors by using an approved moveable incore detector measurement system, "Axial Power Distribution Measurement System" (APDMS). Because of the present unavailability of that system, Shearon Harris has elected to use the proposed excore system, "Ex-Core Axial Power Monitor" (ECAPM). ECAPM is conceptually similar to APDMS, but differs greatly in all details of design, operation, analysis and uncertainty assignment.

Content Review

The previous Topical Report (WCAP-9105) described the four segment excore neutron detectors, some aspects of the algorithm and calibration process and some comparisons of experimental output vs incore maps. The present Topical Report briefly presents the system's internals description (e.g. processor functions) and operation, primarily in order to present and discuss the system input, calibration and calculational algorithms, leading in turn to (1) the calculation-limit relationship, (2) the analysis of uncertainty and (3) Technical Specification description.

The processing system gets dynamic information from (1) a (single) four axial section excore neutron detector, (2) the highest (of the three, for Shearon Harris) core delta-T signal (for power level) and (3) a control rod bank D position signal. The system is also given processing data, via several periodically updated correlation matrices derived from calibration procedures, to translate the dynamic information into peak core power density as a function of core height, kW/ft (z), via the calculational algorithms. The algorithms determine the core average axial power distribution from the excore currents and matrices and multiplies that by the radial peaking factor (as a function of Z) matrix to determine $F_Q(Z)$ and then by average power density to get KW/Ft. The system then compares kW/ft(z) with Technical Specification limits reduced by the system uncertainty [= F_QLimit x K(Z)/(1 + U)] and then alarms when necessary. The system can present continuous information (via a control room cabinet) on measured $F_Q(Z)$ and margins to limits using a CRT or a printer.

There are three correlation matrices relating excore flux to incore power distribution information, (1) the primary correlation [M], (2) the correction for rod bank position [N], and (3) the correction for fuel depletion related effects [G]. The previous Topical Report described this processing via a Fourier Series representation, while the present report discusses a second methodology more easily used for error analysis. There is also a matrix

for $F_{xy}(Z)$ as a function of rod bank insertion which is partially measured and partially calculated. It is noted that the F_{xy} values used are "measured," not the Technical Specification limit values. The Topical Report presents details of the calculation algorithms and their use of the correlation matrices, the functional relationship between the existing "measured-calculated" power distribution and limits, and the calibration process to provide the values for the correlation matrices.

Calibration of the matrices is intended to be done (and is so indicated in the proposed Technical Specification) during initial (cycle) start up and quarterly for [M], [N] and monthly for [G] and [F_{xy}] thereafter. The quarterly calibrations are done as part of the normal (required) quarterly incore-excore detector calibration mappings and can use the same rod insertions followed by xenon transient axial offset conditions. The monthly maps are done as part of the normally required checks for F_{xy} and $F_{\Delta H}$.

A primary purpose of the Topical Report is to present the background and analysis for the ECAPM uncertainty assignment (U in the limit formulation). There are three general areas contributing to uncertainty: (1) uncertainties in incore flux-power distribution maps, (2) instruments uncertainties, (3) variations related to algorithms and correlation matrices. The report examines each of these areas.

The uncertainties assigned for the use of incore flux maps for determining radial and axial, and thus total, power distributions are the standard Westinghouse uncertainties commonly accepted for the relevant areas of measurement, engineering and rod bow uncertainty. In addition a value for the uncertainty from the reduction of the number of axial points used in the ECAPM analyses (24) vs the basic data was derived from appropriate comparisons, and is used as a multiplier in the ECAPM algorithm.

Instrumentation uncertainties have been analyzed for the power level delta-T input, the control bank position input and the excore detector current systems. For the first two the input is such that either the data are conservative (e.g., high auction delta-T signal) or it is of no significance to the error analysis (e.g., peak values do not occur near control rod tips). Thus an explicit uncertainty is not involved. The uncertainty for the excore signals in the ECAPM system is related to reproducibility of the signals. This has been investigated and a term added to the uncertainty summation.

The correlation matrices [M], [N], and [G] each have associated uncertainties and these have been investigated by examining (axial, pointwise) deviations of ECAPM determined core average axial distributions for a number of INCORE measured power distribution (calibration type data) examples relevant to each of the matrices.

For the M and N matrices there is sufficient data to develop a value for uncertainty via standard methods. These have been included in the summation of the uncertainties. For the G matrix only very limited data relevant to burnup are available. These data are inconclusive, although apparently indicative of conservatism in the calculational system and no need for a related uncertainty component. Consequently, Westinghouse proposes to accumulate more relevant data by performing weekly (rather than the proposed normal monthly) [G] data gathering during the early operation of Shearon Harris, and altering the [G] uncertainty component, if necessary, after an analysis of that data.

The various mapping, instrument and correlation components discussed above were evaluated as being statistically independent and have been combined with this as a basis. This combination is the value of U in the ECAPM limit comparison.

The report presents proposed modifications to Technical Specifications to use the ECAPM, using an example of F_Q limit = 2.10 and assumed F_{xy} surveillance. The specifications are similar in character to those for APDMS but differ in detail. For example, the complex rules for APDMS operating frequency are

unnecessary for the continuously operating ECAPM, and the ECAPM measurement-limit relationship and uncertainty are not explicitly given. Standard Technical Specifications 3.2.1 and 3/4.2.2 are modified slightly to indicate ECAPM "turn on" level related changes, and 3/4.2.6 added for ECAPM operability and calibration. No bases are given for 3/4.2.6.

Evaluation

The general descriptions of the ECAPM functions and related components, and interface with operators, including data entry, are reasonably complete and acceptable. The descriptions of the algorithms used and their interactions are also clear and acceptable, and the use of correlations other than the Fourier Series described in the previous Topical Report for error evaluations is a satisfactory equivalent alternative. This system, with appropriate input data should be capable of providing suitable representations of axial average and peak power densities, and should be able to provide this for all relevant operating conditions. It has a distinct advantage over APDMS by offering continuous output and margin to limit information.

The calibration processes are well described and appropriately broken down into data types and corresponding test procedures and intervals, and are conveniently, directly associated with existing required data collection tests and intervals. Both the procedures and (with the exception of the [G] data, to be discussed shortly) the intervals appear to be reasonable and are acceptable. These calibration descriptions (all of report Section 3.0), including the discussion 3.3 "Plant Operation with ECAPM", should be directly referenced in the Bases for Technical Specification 3/4.2.6 in a discussion of operability, calibration and "turn on."

The uncertainty analysis, the primary motivation of this report, appears to have examined the appropriate areas, including all aspects of input, algorithm and parameter use, and the report supplies sufficient background material to put the analysis acceptably within the context of system operations.

The uncertainty components assigned to the standard full core or quarter core INCORE flux maps (used to provide incore power distribution values for the correlation matrices and F_{xy}) are standard Westinghouse values for measurement, engineering and rod bow uncertainties. They are acceptable in this use.

The information and analysis used to determine the effect of the reduction of the number of axial points (24) used in ECAPM from the number in the standard mapping data is sufficient and is conservatively treated, and the use within the ECAPM algorithms is acceptable.

The information, arguments and analyses presented for the uncertainties attributed to instruments for the dynamic input appear reasonable. There is conservatism in the use of a high auction selection for delta-T power level indication, and the bank position uncertainty over its expected range of variation should not be a significant factor in peak axial power determination. The excore signal reproducibility is not described in great detail but the values provided are reasonable. The overall instrument contribution to uncertainty is thus acceptable.

The uncertainty introduced by the correlations matrices [M], [N], and [G] requires the examination and comparison of ECAPM predictions (using matrices calibrated using previous INCORE maps) and INCORE maps. Sufficient relevant cases for comparison are needed to provide adequate statistics and characterization. There was a reasonably large amount of data for [M] (the basic correlation) uncertainty analysis and the results of the axial pointwise comparisons appear to be conservative and acceptable. There are less data for [N] (the control bank correlation), but it appears to be reasonably sufficient and is treated conservatively in arriving at a resulting uncertainty. It appears to be acceptable.

The information for [G] (the burnup related correlation) is not adequate and the single available comparison (which extends over a burnup longer than that in the proposed calibration process) is not sufficiently conclusive to provide

an unambiguous uncertainty value compatible with the proposed calibration monthly frequency. Westinghouse has selected an uncertainty value indicated by the conservative nature of the very limited data and also proposes a high frequency (weekly) data accumulation early in the Shearon Harris first cycle to explore this uncertainty and provide a new value if necessary.

Our review of this uncertainty area has concluded that a temporary use of the Westinghouse proposed value for this uncertainty value is acceptable provided that [G] is recalibrated (using quarter core maps) approximately weekly (on a full power week basis) and that the data accumulated in the course of these measurements also be used to provide a more definitive value for the uncertainty. We note that the power distributions change sufficiently over the course of the entire cycle that it appears prudent that the exploration should continue over the entire first cycle. We would expect this data gathering and analysis process, and possible revision of the assigned uncertainty, to result in a supplement to this Topical Report at the end of the period. The frequent recalibration (as opposed to just data gathering) could be terminated (reverting to monthly) earlier in the cycle (and perhaps even data gathering reduced) if the accumulated information were sufficient to indicate more reasonable corrections were being made and a likely uncertainty value derived and implemented. We would expect an interim report if that were the case. We also note that further information relative to [N] uncertainty could be accumulated in the cycle and the basis for the value, or a new value, improved upon. This task could be reported on in the supplement. Given this temporary more restrictive calibration and accumulation of information, we conclude that the use of the proposed uncertainty values is acceptable.

The various uncertainty components are reasonably independent, and the Westinghouse processes for combining them appears to be statistically acceptable. The combination process is less conservative than that used in some (older) uncertainty areas, including that commonly applied to the APDMS, but many Regulatory uncertainty evaluations and approvals have moved in the direction of such combinations, and we have concluded that it is acceptable for the

ECAPM use. The combination process results in the standard flux map uncertainties tending to dominate the final result (for U), and thus any questions relating to the instrument and correlation uncertainties are somewhat decreased in importance by this process. This helps make it possible to accept the Westinghouse proposal for interim use of a [G] uncertainty which is less than complete.

The Technical Specification changes to 3.2.1 and 3/4.2.2 are relatively minor but properly indicate the transfer (for a 2.10 F_Q system) to ECAPM above the "turn on" power level and other related changes, and are acceptable. The new ECAPM specification 3.2.6 is much less detailed in presenting algorithms and uncertainty values than the corresponding standard APDMS specification, but it is acceptable if a suitable Basis is provided. The Basis should reference the Topical Report and should explicitly reference the algorithm equations of Section 2, the calibration process descriptions and plant operation of Section 3, and the resulting uncertainty value, U, of Section 4. If the uncertainty is eventually changed via a report supplement, it too should be referenced. For clarity the phrase "and in use" (or an equivalent) should be added after "operable" in the first line of 3.2.6. The meaning(s) of "limit" in 4.2.6.1 should also be clarified. The frequency of calibration may remain as stated even though more frequent calibration should be used for Shearon Harris for (part of) the first cycle.

Conclusions

Westinghouse has described the algorithms to be used in the ECAPM system and the input and calibration processes to provide information for the system. From this they have developed an uncertainty analysis and results to be used with the system power distribution output - limit algorithm as the primary output of this report. Our review of this system and in particular the development of the uncertainty has concluded that the algorithms and calibration processes are acceptable and that the associated uncertainties and final resulting uncertainty are generally satisfactory and acceptable, with the possible exception of the uncertainty component associated with the burnup correlation matrix, which requires more operational information and

analysis. This component can be properly derived in first cycle operation. To accomplish this, more frequent data gathering and recalibration of this component matrix is required throughout the first cycle of Shearon Harris operation or until a documented analysis of earlier results indicates a reasonable value has been developed. Furthermore, a supplement to the Topical Report covering first cycle experience with this component should be submitted following cycle completion. Proposed Technical Specification changes and additions relating to ECAPM use are generally satisfactory (with minor changes) but a Bases with appropriate reference to algorithms, calibration and uncertainty should be added.