A New Source Initialization Capability for the SCALE Burnup Credit Sequence

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INTRODUCTION

STARBUCS (Standardized Analysis of Reactivity for Burnup Credit using SCALE)[1] is an analysis sequence in SCALE 5 for automating criticality safety analyses of spent fuel systems employing burnup credit. A depletion calculation is performed for each burnup-dependent region in the modeled system (e.g., a spent fuel storage or transport system) using the ORIGEN-ARP sequence of SCALE. The spent fuel compositions are then used to generate resonance self-shielded cross sections for each region of the problem, which are applied in a three-dimensional criticality safety calculation using either of the KENO codes. This paper describes and demonstrates the addition of a new capability in STARBUCS for source initialization that is intended to mitigate concerns related to source convergence for Monte Carlo criticality calculations involving spent fuel with non-uniform burnup distributions. The new capability adds an additional step, after the depletion phase, to calculate a one-dimensional adjoint distribution that is used for the starting source in the KENO calculation, thus providing a better representation of the spatial source distribution than the current default (uniform starting source over all regions containing fissile material).

WORK DESCRIPTION

Upon completion of the STARBUCS ORIGEN-ARP depletion calculations, a one-dimensional adjoint criticality calculation using the discrete ordinates XSDRNPM code is performed. In order to perform this calculation, cross sections for each zone in the one dimensional adjoint calculation must be obtained (i.e. fuel, cladding and moderator in the radial direction for each burnup zone are run through CSASI to obtain a single cross section representing the zone). Then, XSDRNPM input is prepared from the existing STARBUCS input without modification. The geometry from the first unit containing fissile material is used to build the one-dimensional XSDRNPM model. While not necessarily applicable for all conceivable problems that STARBUCS can address, the approach in this optional capability is suitable to determining the axial source distribution for the vast majority of spent fuel systems for which STARBUCS is applied.

The adjoint data from XSDRNPM is used directly to provide an importance distribution relative to fission that is used as the starting fission source distribution in KENO V.a, decreasing the chance for inaccurate results due to an improper starting source distribution. A new source option was implemented in KENO to facilitate the use of the axial-dependent, adjoint-based source distribution.

The STARBUCS program flow is shown in Figure 1 with the additional step shown in red.

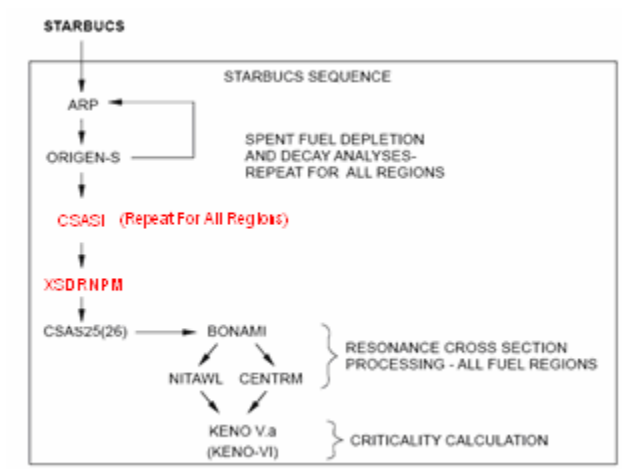

Fig. 1. Modules and Flow of STARBUCS Sequence

RESULTS

Two test cases are shown here for preliminary analysis. First, a simple pin-cell model using 18 axial regions to represent a typical axial burnup profile is analyzed. The k-eff value as a function of generation for each calculation is shown in Figure 2 for the first 50 generations. Each calculation was performed with 2700 generations of 10,000 particles per generation with 200 generations skipped. The final converged k-eff values for the cases with and without adjoint-based source initialization are 1.04000±0.00012 and 1.04008± 0.00011, respectively. Note, the case without adjoint-based source initialization used the default starting source distribution in KENO (uniform starting source over all regions containing fissile material).

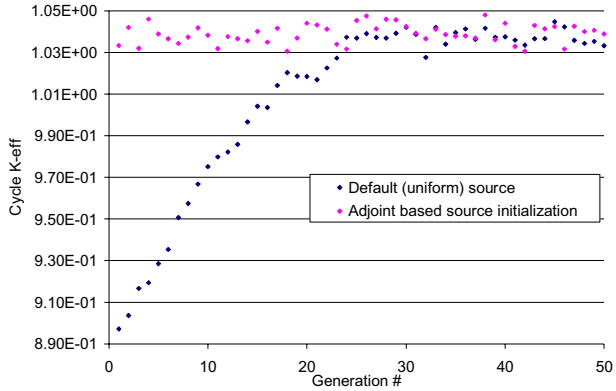

Fig. 2. k-eff by generation with and without source initialization for sample problem 1.

Clearly, the effect of the source initialization is evident from Figure 2 as immediately the generation k-eff is near the converged k-eff, thereby reducing the dependence on the skipped generations.

The second case is a high-density storage cask containing 32 17X17 Westinghouse type fuel assemblies with a typical axial burnup profile. Calculations with and without adjoint based source initialization were performed with 2000 generations and 5000 particles per generation. The average k-eff for each calculation is shown in Figure 3 without the effect of the skipped generations. Also shown in Figure 3 is the final converged k-eff for the case without adjoint based source initialization with the 500 skipped generations.

The final converged k-eff values for cases with and without adjoint-based source initialization are 0.98167±0.00028 and 0.98184± 0.00025, respectively when utilizing the 500 skipped generations for both calculations. This indicates no bias in the final result.

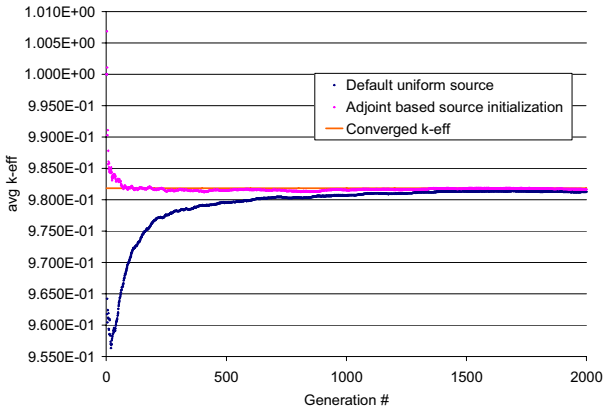

Fig. 3. Average k-eff by generation with and without source initialization for sample problem 2.

From Figure 3 the reduction in the dependence on skipped generations using the source initialization option is evident for a realistic problem. This reduction in the dependence of skipped generations clearly gives the analyst more confidence in their calculated results by providing a more accurate starting source.

REFERENCES

1. *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluations*, ORNL/TM-2005/39, Version 5, Vols. I–III, April 2005. Available from Radiation Safety Information Computational Center at Oak Ridge National Laboratory as CCC-725.