Implementation of improved quasi-static, time-dependent, multiphysics methodology in Shift

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ABSTRACT:

We will develop a practical reference calculation route for time-dependent Coupled Monte Carlo (MC) calculations using Shift. The proposed framework will be tailored to depletion and slowly varying transients, but with the flexibility to perform thermal-hydraulic (T/H) time-dependent calculations with minimal computational overheads. Our method relies on a hybrid-resolution stochastic approach in conjunction with a substep technique. The current brute-force approach to couple MC codes with depletion solvers may exhibit issues associated with poor convergence, numerical instabilities, and prohibitively large computational requirements. The inclusion of T/H and other feedback further challenges these coupled routines. We propose to remedy these challenges by developing a new method for coupled MC-T/H-depletion calculations by linking:

- Generation of few-group homogenized macroscopic and microscopic coarse-meshed cross sections.
- An efficient microscopic depletion algorithm embedded in a substep technique.
- Computationally efficient few-group calculation routine using the Shift multi-group (MG) solver; leveraging existing capabilities that are already available in the code.
- On-the-fly expansion of cross sections in terms of elementary thermal field's spatial profiles.

Our methodology stems from the need to produce an efficient and highly reliable time-dependent framework that can produce reference solutions. The few-group macroscopic cross sections are condensed from known detailed 3D reaction rates distributions, and thus preserve the physics of the model. The micro-depletion algorithm is used to predict the variation in the few-group constants. These are then used by the MG transport solver to partially replace high-resolution MC solutions, and therefore greatly speed-up time-dependent calculations. The proposed approach places strong emphasis on the integration with other multi-physics effects, e.g. T/H, through the use of Transfer Functions (TF), allowing to calculate the variation to general perturbation in the T/H fields. This multiphysics emphasis sets the new technique apart from the standard decoupled approach typically employed for MC codes. Finally, considerable efforts will be spent on validating and verifying the efficiency and accuracy of our method. The benchmarking stage will include a fully analytic space-time depletion benchmark, and a full core BEAVERS-style test case suggested by Framatome.

The key tasks for this project are: (1) Implementation of the MG homogenized workflow into Shift. (2) Develop spatial homogenization and remapping techniques. (3) Develop a time-dependent substep workflow. (4) Develop a thermal interface through the application of transfer functions. (5) Test, validate and benchmark the framework.

Key deliverables and outcomes are: (1) An efficient time-dependent methodology embedded in Shift to capture slowly varying transient, such as fuel cycles and xenon transients, (2) A ready-to-go T/H interface embedded within the time-dependent methodology, and (3) Validation and verification report confirming the developed computational framework and its efficiency.