Development of Transient Capabilities for the NEAMS Neutronics Code PROTEUS

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ABSTRACT:

Under the DOE-NE's NEAMS program, a high fidelity transport code PROTEUS is being developed as part of the reactor simulation toolkit SHARP. PROTEUS includes two transport solver options: PROTEUS-SN and PROTEUS-MOC. The former is a discrete ordinates unstructured finite element based solver, and the latter is a method of characteristics (MOC) solver. Both solvers allow the explicit representation of detailed geometry for reactor simulations. PROTEUS-SN has been validated against various benchmarks, including various fast reactor critical experiments, but PROTEUS-MOC is a newer code and is still under development. In this study, the researchers will develop efficient transient transport methods for the PROTEUS-SN and PROTEUS-MOC solvers and perform transient benchmark analyses.

An innovative Improved Quasi-Static (IQS) method will be implemented to minimize the computational burden for the transient transport solution and to provide a consistent basis to compare the point kinetics solution in existing codes with the time dependent angular flux solution in PROTEUS. An efficient acceleration method for solving the transient fixed source problem at each time step of the IQS method will be developed and implemented into PROTEUS. In addition to developing a multi-level, acceleration method by extending the existing diffusion synthetic acceleration method to the outer iteration, an alternate acceleration will be implemented based on the coarse mesh finite difference (CMFD) method that has been very successful for LWR applications. A modified 3-D CMFD formulation will be developed for PROTEUS-SN and PROTEUS-MOC in which the current continuity is not enforced at the element boundary or the axial mesh interfaces. The CMFD method will be implemented on two different energy group structures: a one-group and a multi-group structure.

In order to extend the applicability of PROTEUS to a wider range of reactor types, the work here will expand the cross section application-programming interface of PROTEUS such that the resulting multi-group cross sections properly account for the appropriate thermal feedback mechanisms. In order to facilitate the development of transient transport capability of PROTEUS, the researchers will implement a simpler thermal-hydraulics model that is able to capture the main physical phenomena important to thermal feedbacks but computationally efficient. For this, PROTEUS will be coupled with the LWR subchannel code CORBA-TF. The overall coupled nonlinear system will be initially solved using a fixed-point iteration algorithm, but more sophisticated coupling algorithms will be investigated later. The transient capabilities developed in PROTEUS will be tested using the TWIGLE and SPERT benchmarking problems. The principal purpose of TWIGLE is to provide initial code verification since TWIGL has been analyzed by all other spatial kinetics codes. The data measured during the E-Core experiments of SPERT will be used to validate the neutronics performance of the PROTEUS code for both steady state and transient conditions in a LWR.