NUCLEAR ENERGY UNIVERSITY PROGRAMS

Advanced Mesh-Enabled Monte Carlo Capability for Multi-Physics Reactor Analysis

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Abstract

This project will accumulate high-precision fluxes throughout reactor geometry on a non-orthogonal grid of cells to support multi-physics coupling, in order to more accurately calculate parameters such as reactivity coefficients and to generate multi-group cross sections. This work will be based upon recent developments to incorporate advanced geometry and mesh capability in a modular Monte Carlo toolkit with computational science technology that is in use in related reactor simulation software development. Coupling this capability with production-scale Monte Carlo radiation transport codes can provide advanced and extensible test-beds for these developments.

Continuous energy Monte Carlo methods are generally considered to be the most accurate computational tool for simulating radiation transport in complex geometries, particularly neutron transport in reactors. Nevertheless, there are several limitations for their use in reactor analysis. Most significantly, there is a trade-off between the fidelity of results in phase space, statistical accuracy, and the amount of computer time required for simulation. Consequently, to achieve an acceptable level of statistical convergence in high-fidelity results required for modern coupled multi-physics analysis, the required computer time makes Monte Carlo methods prohibitive for design iterations and detailed whole-core analysis. More subtly, the statistical uncertainty is typically not uniform throughout the domain, and the simulation quality is limited by the regions with the largest statistical uncertainty. In addition, the formulation of neutron scattering laws in continuous energy Monte Carlo methods makes it difficult to calculate adjoint neutron fluxes required to properly determine important reactivity parameters. Finally, most Monte Carlo codes available for reactor analysis have relied on orthogonal hexahedral grids for tallies that do not conform to the geometric boundaries and are thus generally not well-suited to coupling with the unstructured meshes that are used in other physics simulations.