ABSTRACT

ALTAHHAN, MUHAMMAD RAMZY. Extension and Optimization of a Nodal Adjoint Methodology for Nuclear Reactors Analysis. (Under the direction of Dr. Maria Avramova and Dr. René van Geemert).

Many current mathematical and numerical tools (e.g., machine learning, optimization, and perturbation analysis, to name a few) can use the adjoint or the dual function in their core computations. The adjoint function has become then a building block of modern numerical analysis and acquiring a good adjoint solution opens new research possibilities as it is shown in this thesis. A higher-order nodal mathematical adjoint, conjugate to the NEM-M2B2 nodal diffusion forward model, is developed and introduced in this thesis for nuclear reactor core analysis. The developed-model verification is presented through applications in perturbation analysis and the IAEA-3D benchmark including modified forms of it. Extending and optimizing a low-order nodal mathematical adjoint capability found in the industrial reactor-code ARTEMIS is the thesis main objective.

Nodal mathematical adjoint derivation is equivocal in the literature, and its physical interpretation is not agreed upon, if not totally avoided by many. But through preconditioning of the base NEM-M2B2 model and by using variational analysis, we have obtained a nodal-mathematical adjoint that can have a physical interpretation associated with it as a Lagrangian multiplier. The nodal-mathematical adjoint is then developed for several RoI that can lead to homogeneous and inhomogeneous adjoint system of equations. A solution verification of the adjoint developed is done through analyzing, for different RoI, the effects coming from perturbations in the absorption and the scattering cross-sections. The applications investigated include axially and radially traveling perturbations along the important locations of a reactor's core.

A methodology to simulate large perturbations, using the developed and verified VIPER-SIF and VIPER-LF algorithms, is introduced. The methodology depends on the incremental-perturbation idea in which the targeted perturbation is incrementally divided into smaller steps. An individual-step simulation takes around 10^{-4} seconds, even without compilers' code-