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Development of innovative overlapping-domain coupling between SAM and NEK5000

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ABSTRACT:

The SAM code is being developed at Argonne National Laboratory (ANL) as the thermal-hydraulic, system-level NEAMS tool for the simulation of advanced non-LWR reactors accident scenarios. As for LWRs, several safety-related transients can be identified for advanced non-LWR reactor designs for which three-dimensional flow patterns are important and where a 1D system-level approach would not be able to capture all relevant phenomena correctly. Therefore, the coupling with a CFD code to correctly capture thermal-hydraulics three-dimensional effects is desirable.

Over the past several years research efforts have been dedicated to the coupling of best-estimate system codes with CFD codes. Most of these efforts have been based on the so-called separate domain approach, in which CFD is used to model the plant component(s) where 3D flow effects are important, while the rest of the plant is modeled with a 1D system-level code. The time-stepping between the two codes can follow explicit, semi-implicit of implicit numerical schemes (the latter requires a more complex implementation with access to the source code of both system-level and CFD codes, and require more data storage due to the need for time-step inner iterations backups). Separate domain approaches have been found to be not robust numerically and, in several instances, convergence has been proven difficult to achieve. Some efforts on overlapping domain approaches have also been reported in the literature, with the system-level code modeling the entire system and with selected components modeled both by the system code and the CFD code. More recently, a novel overlapping domain approach has been proposed and tested in Manera's group, that has been proven to be significantly more robust than conventional separate-domain approaches and has resulted in superior convergence and accuracy performance even when simple explicit coupling numerical schemes are used for the coupling time-stepping.

The methodology developed at the University of Michigan was applied to the correction of the system-level momentum equation. In this project we propose to:

- extend our overlapping domain methodology to include also the correction of the energy equation of the system-level code, using on-the-fly CFD data;
- implement the methodology for the coupling of the NEAMS codes SAM and NEK5000, including code verification similar to what was performed by the PI in past efforts;
- validate the coupling with unique experimental datasets available at UM that have been specifically designed for the validation of multi-scale thermal-fluid simulations.