Shapley indices estimation in multi-physics nuclear transient modeling

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Abstract:

Nuclear reactors are complex systems modeled through coupled Best Estimate codes that can represent the most important physical phenomena under steady state and transient situations. Each code represents a different discipline: Neutronics (heat production), Fuel-Thermal (heat conduction) and Thermal-Hydraulics (heat extraction). The various sources of uncertainties present in each discipline either related to natural variability of physical quantities either to modeling must be identified and taken into account.

In the thesis, we study a Rod Ejection Accident (REA) in a Pressurized Water Reactor (PWR) where strong multi-physics coupling effects occur between the three disciplines and thus a multi-physics uncertainty analysis is necessary to capture the interaction effects.

The transient analysis is performed on a small scale geometry (MiniCore) studied in a previous thesis [4], in order to capture the main effects. The codes APOLLO3®[1] (Neutronics) and FLICA4 [2] (Fuel-Thermal and Thermal-Hydraulics) developed at CEA are used for the coupled calculations.

For this work, the following uncertain variables were considered: macroscopic two group cross-sections in Neutronics, fuel heat capacity and cladding conductivity in Fuel-Thermal and convective heat transfer coefficient and recondensation in Thermal-Hydraulics. The cross-sections are correlated through a correlation matrix estimated by UAM Benchmark library [3], while the rest of the uncertain variables are considered independent. One local output of interest is defined for each discipline: maximum linear power (Neutronics), maximum stored fuel enthalpy (Fuel-Thermal) and minimum Departure from Nucleate Boiling Ratio (Thermal-Hydraulics).

The codes, being computationally costly, were used to train an Artificial Neural Network with whom uncertainty propagation and sensitivity analysis were performed. The Shapley indices were estimated to quantify the importance of each input variable.

References

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Short biography – I graduated from the School of Electrical and Computer Engineering at Aristotle University of Thessaloniki in Greece. I continued with a Master 2 in Nuclear Reactor Physics and Engineering at INSTN of Paris Saclay University and currently I am a PhD student at CEA Saclay with subject: "Uncertainty quantification methodology based on an MPUI (Multi Physics Integrated Uncertainties) type approach".