Toward an UMAE-like methodology for CFD uncertainty quantification in nuclear safety related applications

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ABSTRACT

According to Best Estimate Plus Uncertainty (BEPU) approaches, the application of best estimate computer codes and models to the predictive analysis of thermal-hydraulic (TH) nuclear reactor transients within a licensing framework requires the quantification of the uncertainties affecting the obtained results. As far as system TH codes are concerned, several methodologies exist and are being applied for the uncertainty analysis. Basically, they divide into two main classes: those based on the propagation of input uncertainties, and those based on the propagation of output errors. The former generally rely on the execution of a huge number of calculations with most influential input parameters spanning over user defined ranges; they are sound from the mathematical point of view, but require huge calculation effort and may be prone to "user effect" at the stage of influential parameter identification. On the other hand, the Uncertainty Method based on Accuracy Extrapolation (UMAE), developed at the University of Pisa, focuses on the propagation of the output errors: it does not evaluate individual input uncertainties, rather obtains NPP analysis uncertainty by "extrapolating" the accuracy from the comparison of code calculations with relevant experimental and real plant data. The UMAE (integrated by the Code with capability of Internal Assessment of Uncertainty, CIAU) is a complex multi-step iterative methodology that includes and emphasises the nodalization and user qualification, which relies on the Fast Fourier Transform Based Methodology (FFTBM). An existing validation database (for specific plant types and scenarios) can be exploited to generate a database of uncertainty information, applicable to new plant analyses.
The application of Computational Fluid Dynamics (CFD) to nuclear reactor safety analysis also demands for uncertainty evaluation, and appropriate methodologies still have to be established. In this respect, a possible way consists in extending/adapting the UMAE-CIAU to CFD, i.e. in developing a methodology to extrapolate uncertainty from the accuracy information embedded in a validation database. The present paper outlines the basic ideas for the development of such UMAE-like methodology, also addressing the issues related to "qualification" (of inputs, meshes, user, etc.) and the definition of appropriate metrics for accuracy quantification.