The European Project NURISP for Nuclear Reactor Simulation

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INTRODUCTION

The NURISP project aims at developing the European NURESIM reference simulation platform [1] for nuclear reactor. A first version of NURESIM was delivered in 2008. 22 organizations from 14 European countries contribute to the further development of this platform. NURISP also includes a User's Group (UG) whose members are not NURISP partners and come from the industrial nuclear sector or European and non-European R&D labs. Users can benefit from the use of the NURESIM platform, methods, results and modules and they provide concrete input and feedback on the use of these elements.

OBJECTIVES AND CONTENT OF THE WORK

NURISP intends to incorporate the latest advances in core physics, two-phase thermal-hydraulics and fuel modeling for present and future reactors together with, sensitivity and uncertainty tools. It includes multi-scale and multi-physics features, especially for coupling core physics and thermal-hydraulics models for reactor safety. Easy coupling of the different codes and solvers is provided through the use of a common data structure and functions for supervision, interpolation between nonconforming meshes, pre and post-processing… These functions are provided by the SALOME open-source software.

Core Physics

Neutron kinetics analysis is usually performed at the coarse 3D core scale, with averaged nodes of a quarter of assembly size, though the assessment of safety limits would need a more detailed scale up to the pin-by-pin level. The NURISP project is building a software platform able to simulate neutron kinetics at the required space resolution including pin-by-pin scale and at the required time scale, for an enhanced understanding of safety margins. For Monte-Carlo methods, the project aims to add a thermal-hydraulic feedback capability to TRIPOLI4. The platform include:

- TRIPOLI4 Monte-Carlo code [2] with a continuous energy range, used as a reference tool.

- APOLLO2 deterministic transport code which provides:

- a high resolution in neutron energy by hundred of groups and in space, by detailed intra-pellet and coolant material [4],
- few-group cross section libraries for homogenized cells or fuel assemblies, covering the full parameter space of operating conditions, with spectral history isotopic effects.

- COBAYA3, CRONOS2 and DYN3D codes [6], [7] provide the consistent neutronics 3D simulations of core at the relevant scales, for both static and transient situations, coupled with thermalhydraulics.

Thermalhydraulics

Two-phases CFD models are developed with application to Departure from Nucleate Boiling, Pressurized Thermal Shock (PTS), BWR thermalhydraulics, and Lost of Coolant Accident (LOCA). The NEPTUNE_CFD code [3] and TransAT are in the platform. A variety of model options are available for the number of fields, for the space and time filtering of the equations (Reynolds Averaged Navier Stokes (RANS), Large Eddy Simulation (LES), Direct Numerical Simulation (DNS)) and for the choice between a deterministic or statistical treatment of interfaces. They are benchmarked and confronted to many validation experiments.

New models are also developed and validated for advanced system codes and component codes including multi-field and turbulence modeling. LOCA is particularly analyzed and revisited with new models. The CATHARE [5] and ATHLET [8] system codes are in NURESIM platform and are used in a multiscale approach.

Multiphysics

The coupling techniques and interfaces are enhanced within NURISP project in order to simulate transients necessary for the safety evaluation of current and future LWR with a high spatial resolution in selected regions. Coupling of neutron kinetics and thermalhydraulics codes will also include the effect of cross-flow. These coupling techniques are tested in the framework of benchmarks.

Thus, NURISP will provide a reactor analysis tool allowing analysis of highly asymmetric transients.

Furthermore, the development of adaptive modeling based on the automatic switching between 3D and lower-dimensional neutronics models will offer solutions for the reduction of computing resources.

In addition, the system codes of the platform are connected to:

- a fuel thermo-mechanics code, DRACCAR, for a better understanding of the impact of fuel deformation (ballooning) during a LOCA
- a CFD code, TRIO_U, for the modeling of mixing phenomena occurring in a PWR boron dilution or main steam line break (MSLB).

Model Validation and Uncertainty Quantification

The effort aims to improve the statistical methods used for the validation of physical models by comparison with experiments. The developed methods are implemented into a software called URANIE. URANIE is a platform dedicated to the study of propagation uncertainties, sensitivity analysis or model calibration in an integrated environment.

In the frame of NURISP, work includes the development of modules based on stochastic finite element method as well as the development of formal procedures for sensitivity, uncertainties and model validation.

RESULTS

Major progresses have been obtained up to the delivery of the first version of NURESIM in 2008. Further improvements are in progress in the frame of NURISP. Some results or work in progress are:

- Implementation of a coupling scheme between a thermalhydraulics subchannel code and neutron kinetics codes integrated in NURESIM platform at the pin level and including cross-flow for the PWR boron dilution analysis and MSLB analysis.
- The use of DNS and LES for modeling PTS is benchmarked with a RANS approach. PTS modeling by coupled system and CFD codes and validation with the new TOPFLOW program (European experimental program) and the ROSA-IV OECD tests are in progress [9].

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