Contribution ID: **116** Type: **ORAL**

Phénix Control Rod Withdrawal test analysis using a multiphysics methodology

Thursday 21 April 2022 11:16 (12 minutes)

Before the definitive shutdown of the Phénix reactor, a series of end of life tests were performed in 2009 and 2010, by CEA (Commissariat à l'Energie Atomique et aux Energies Alternatives), EDF (Électricité de France) and AREVA. The main objectives were to enlarge experimental database for the research and design of Sodium cooled Fast Reactors (SFR). Due to this important opportunity, the IAEA (International Atomic Energy Agency) decided to establish a Coordinate Research Project from 2007 to 2011 to stimulate computational codes validation among different countries involved in fast reactors development. In this context, a benchmark was established on the "static Control Rod Withdrawal Test"(CRW) with the objective of the investigation on the flux and power local deformations related to different control rod insertions in the core. Such valuable experimental data are useful to improve calculation schemes used to analyze control rod withdrawal transient, which could potentially trigger a core melting accident in a SFR. The objective of the current study was to perform multi-physics simulation based on a loosely coupled approach to take into account local Doppler feedback effect on power deformations. The probabilistic particle transport code Serpent 2 (VTT Technical Research Centre of Finland, Ltd), associated with the JEFF-3.1 nuclear library, was chosen as reference neutron calculation code and was coupled to an in-house static thermal-hydraulic solver. Firstly, purely neutron transport calculations were done in order to build-up and check the overall core model. The uncoupled results were compared to benchmark results already published and show a correct accordance with experimental and calculated results providing that a heterogeneous description of control rods was used. A convergence study to estimate the required precision level of neutron calculations with respect to multiplication factors and power estimations was also performed. Secondly, coupling between neutron and thermal-hydraulics solvers were done through the Serpent 2 multiphysics interface with a regular exchange of the main coupled parameters such as fuel temperatures and neutron deposited powers for each axial node of each subassemblies of the fissile core. The coupled results on the power deviation are globally slightly nearer to the experimental ones than uncoupled results but are affected by probabilistic uncertainties and batch-to-batch inter correlation problems responsible for light power oscillations with respect to the number of simulated neutrons instead of a straight convergence.

Country/Int. organization

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Session Classification: 6.3 Multiscale and Multiphysics Calculations

Track Classification: Track 6. Modelling, Simulations, and Digitilization