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SCAR – Post-Accident Simulator SIPA with safety analysis code CATHARE 2 and PWR cold shutdown state simulation

M. Farvacque, B. Faydide
(Commissariat à l'Energie Atomique, France),
F. Iffenecker, B. Pentori
(Electricité de France, France)
Ph. Dufeil, E. Raimond
(Institut de Radioprotection et de Sûreté Nucléaire, France)

Abstract

The use of CATHARE in the simulators of pressurised water reactors has been effective since the beginning of the Nineties firstly with the integration of a simplified version of the code CATHARE 1 named Cathare-Simu in the SIPA post-accident simulator (operated by EDF and IRSN) then in the EDF full-scale simulators.

Project SCAR is therefore the second stage of the CATHARE strategy for the simulators. The main objectives are on one hand to ensure the unicity of the version of the CATHARE 2 code for studies and the simulators and on the other hand to enable the extension of the field of simulation to the accident situations in cold shutdown states.

No simplification of the physical models must be carried out in CATHARE 2 for the applications in a simulator.

Project SCAR started in 1997 and led to the upgrade of IRSN SIPA2 simulator , including CATHARE 2 for the modelling of the NSSS and RHRS of the French 900MW PWR.

Work was carried out in 3 major areas: modelling, optimisation and integration in the simulator. A systematic validation was carried out by the project for each of the 3 areas.

To model the RHR system that is necessary for the simulation of the cold shutdown state, the general rule was to add to CATHARE the modules representing the components on the nuclear circuits (valves, flow controls valves, check valves) with controls from the data set or the simulator graphic interface.

A new functionality of initialisation was introduced to speed-up initial states generation.
Moreover, the improvements of the physical models of CATHARE were made (model of pump with electric motor, SGTR, activity-chemistry with N species, overflow of 1450MW Steam Generator, flow mixing in vessel bottom, fuel thermal coefficients).

About optimisation, the real time depends on the power of the computer and the capacity of CATHARE to calculate a computing cycle (100 ms) with the fewest possible iterations. Indeed, the two-fluid model of CATHARE is a six equation model with non condensable gases. The robust and efficient implicit numerical method is based on a solver of iterative Newton-Raphson. Any delay over the real time accumulated during a cycle generates lag. Two ways to get real time computing are detailed in a second paper:

- Improving numerical convergence of CATHARE to decrease the amount of Newton-Raphson iterations; this approach was the aim of a long and meticulous study performed throughout the project and particularly for cold shutdown states.
- Operating powerful computers and paralleling the execution of CATHARE 2 to increase the iteration count available.

A N4 (1450 MW) PWR data set made up of 1000 computing meshes is systematically used to validate all the developments of modelling and numerical optimisation work:

Integration in the SIPA simulator modelling a CP1 (900 MW) PWR required the following work:

- the creation of a CATHARE 2 data set (900 meshes) for NSSS and RHRS,

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- the design of a software interface between CATHARE 2 and the 60 other systems modelled in the simulator; this interface, which is complex because of the number of systems connected to NSSS and RHRS is automatically generated.
- the integration of a standard version of code CATHARE 2 in an external library to replace the Cathare-Simu code,
- others developments of the SIPA simulator to extend its field simulated to the cold shutdown state (RWST, spent fuel pool),
- the upgrade of the graphic interfaces of the simulator and in particular its pedagogic thermal-hydraulic Man Machine Interface by introducing a visualisation of RHR system or charts of temperature, the non condensable gases or radioactive substances.

Throughout the project, the developments were part of a three stages validation strategy:

- elementary tests of the developments of new models on the N4 data set,
- analytical tests and systems to ensure non regression of the validation of the physical laws of the CATHARE code during the modifications carried out within the optimisation stage,
- overall tests of the SIPA-CP1 simulator, controlled automatically by programmed scenarios including the transients which are carried out in PWR, the transients of the Regulatory Guides and the accident transients.

Twenty-four transients are used to validate the renovated SIPA CP1 simulator and twenty N4 transients are used to validate the models and the work of optimisation.
The renovated SIPA 2 CP1 simulator is now the first simulator that integrates a standard code for thermal hydraulic safety analysis. Its field of simulation covers from now on all the accidents treated by CATHARE for all the operating conditions, from the cold shutdown state, open NSSS, to 100%PN conditions. except LOCA and except fuel melting.

The unicity of the thermal hydraulic safety analysis code and of the NSSS code for simulators has been effective since the delivery of CATHARE 2 v15b in January 2003. Economically, the use of CATHARE 2 will cut down the management costs of the thermal hydraulic code in the simulators. Technically, this use naturally extends the degree of relevance of French PWR simulators to all the situations covered by CATHARE, in particular for the cold shutdown states. The simulators will benefit, moreover, from the wide qualification of CATHARE 2. The use of CATHARE 2 in a simulator, nearer to best-estimated conditions, should also allow CATHARE 2 to progress in terms of the relevance of PWR simulations.