PHISICS Reactor Physics Package in RELAP5-3D

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The latest release of RELAP 5-3D, version 4.0.2 introduces a completely new and extended reactor physics package. This package has been developed in the last 3 years at INL under the name of PHISICS (Parallel Highly Innovative Simulation INL Code System). PHISICS contains almost all classical features of a reactor physics design code except the cross section (lattice physics) generation.

Both the optional PHISICS package and NESTLE are available for reactor physics computations. The user must select only one through input. PHISICS accepts all the current reactor physics input in existing RELAP5-3D input decks, but has additional input to its more extensive models.

Several modules are part of PHISICS that combined in a modern software infrastructure allow the user to deal with many different analysis needs. A special Fortran module-based interface has been developed to interface PHISICS with RELAP 5 3D to allow RELAP users to access most of the functionality relevant to transient analysis.

First of all this interface allows the use of a modern 3D nodal kinetics solver (INSTANT) to determine flux and power distribution. The solver is based on the second order form of the transport equation. Thus it can be used at the lowest angular approximation to deliver diffusion-like results while providing capability to increase the angular approximation to catch transport effects that are typical of fast reactors and localized material discontinuity. Spatially the solver has also a high degree polynomial representation to correctly follow sharp gradients.

The PHISICS package also gives RELAP5-3D a completely new cross section handling capability. The cross section manipulation can be done outside RELAP5-3D removing many of the previous limitations. The number of energy group is now unbounded, as the number of tabulation parameters and point this last feature extend the cross section to piecewise linear approximation versus the old linear approximation.

The external manipulation of cross sections creates the opportunity to use the PHISICS depletion module, MRTAU (another INL program). As a consequence, short-lived poisoning nuclides could be treated more accurately by new and more stable algorithms (the assumption of quasi-equilibrium is not anymore used). The whole depletion of the core could be followed.

The following brief example illustrates the simulation capability of this new product:

1. A fresh core is loaded and a steady-state is attained.
2. A few half-days worth of depletion steps are performed, without plant feedback, to seek xenon and Iodine equilibrium.

3. After 3 days RELAP is asked to re-compute the thermal field with the new power profile (xenon affected).
4. Step 2 and 3 are repeated several times up to 10 day if life of the reactor than the depletion steps get larger (days) and the plant feedback is sought every months (so to follow the core depletion at ~200 isotopes) up to the point…
5. An accident scenario is initiated (E.G. Control Rod ejection), the reactor status migrated in full (composition, delay neutron density, power profile and TH status) to a transient mode and the transient analysis initiates.

This example demonstrates several improvements to RELAP5-3D capabilities. First, this is a means to increase the overall simulation accuracy (higher spatial and angular order of the flux, unlimited energy group and tabulation point of the cross section, second order time integration scheme). Second, this gives RELAP5-3D the capability to follow the history of the reactor to create the initial condition for a transient analysis that are truly the one seen by the reactor at that moment. Third, by integrating reactor physics and plant analysis in the same code and automating the information transfer them, it reduces the possibility of human error and related QA issues.

A simulation performed using RELAP5-3D using the PHISICS option will be posted in the LinkedIn group.