Neutronics analysis of demonstration and experimental fast reactors with transport methods

Response on the report by Piero Ravetto

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First, I would like to thank Piero Ravetto (Reviewer) for his time and work spent on his detailed review. The Reviewer formulated three questions, made two remarks and a suggestion for further work.

Questions about the dissertation:

1. **Question:** It would be interesting to have some details on the interface coupling the SEnTRi code with PARTISN and to know how this interface could be adapted to the coupling with other codes. This may be relevant for extending the potentialities of the code.

The SEnTRi code has its input syntax to perform the desired calculations. Currently, the code has five primary functions in order to perform the analysis introduced in the dissertation. These controlling functions have their own part in the input syntax as the desired information for the calculations is very different; however, they use the same objects, structures and smaller functions. As an example, I will introduce the coupling of the SEnTRi with PARTISN for the Direct transient solver in more detail.

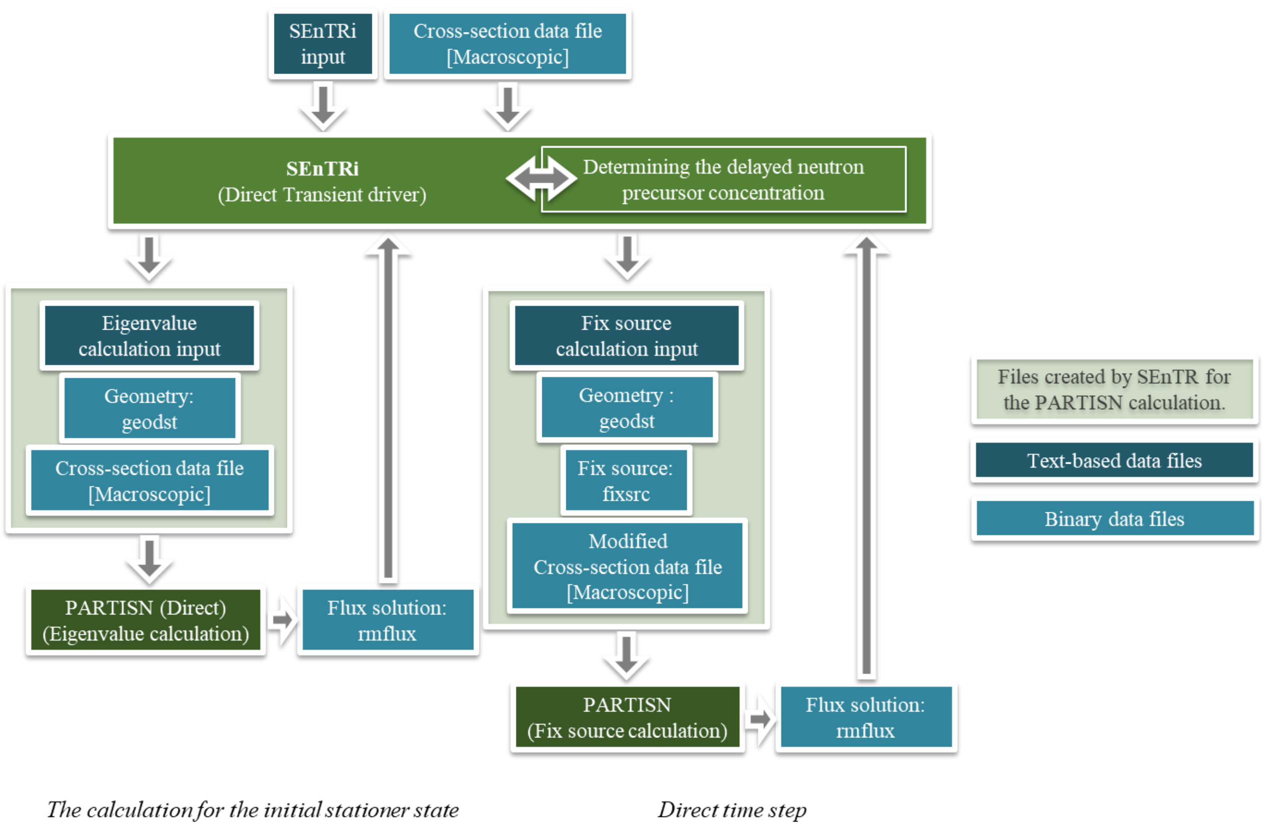

Figure 1. The workflow of the Direct transient module of the SEnTRi code

First, the code reads its input file (*SEnTRi input* on Figure 1.), which contains the following information:

- Time discretization data
- Power
- Command how to evaluate PARTISN
- Path of the cross-section library
- Neutron velocities (depending on the type of the cross-section library, it might have already been processed)
- Geometry description (Similar to the input syntax of PARTISN)
- Delayed neutron data (decay constants, fractions, neutron spectrum)
- Description of the geometry modification during the transient

The object that contains the cross-section library can process five different types of data files. Depending on the need, additional readers can be implemented here. Based on these data, the code prepares the files necessary for the PARTISN eigenvalue calculation. (The calculation for the initial stationary state.)

- PARTISN input
- The binary GEODST file, which describes the geometry
- Cross-section data file

SEnTRi executes PARTISN, and during the execution, PARTISN reads these files, performs the eigenvalue calculation, and determines a binary RMFLUX file that describes the angular-dependent flux solution (and k_{eff} is also described in this file). Then RMFLUX file is processed by SEnTRi.

In order to solve the time-dependent equation, fix source calculation is performed with the PARTISN code. In this case, the following files are prepared by SEnTRi:

- PARTISN input
- FIXSRC angular dependent neutron source data file
- The binary GEODST file
- Modified Cross-section data file

SEnTRi similarly executes PARTISN with these files and then reads the RMFLUX file.

Communications between the two codes are performed with the mentioned files, and the PARTISN code was not modified for these analyses. Objects containing this information (flux distribution, geometry, source distribution, cross-section data) in the SEnTRi code have file reading functions. New reader and writer functions needed to be implemented for these objects to extend the coupling for other codes. If the data objects are filled with the necessary information, the other part of the SEnTRi code can be executed without further modifications. (It is expected from the coupled code to be capable of performing eigenvalue and fixed source calculations and writing the flux solution into a file.)

2. Question: What is the guide to choosing micro and macro time steps in the application of the quasi-static procedure? How can the choice be adapted to the features of the transient?

Macroscopic time steps should be applied as often as "necessary", depending on how fast the shape changes in time. That means really fine time steps need to be applied if there is a strong distortion in shape during the transient or no shape calculation if there is no significant change. Ideally, depending on the transient, an adaptive macroscopic time discretization would be optimal; however, a fixed timestep is defined in the SEnTRi currently. The easiest implementation, in this case, is when the user can define the time points for the code to calculate the shape. Nevertheless, in this case, the user needs to ensure that enough shape step is applied when fast changes happen in the transient. (Usually, when something changes in the geometry or the cross-section data.)

Microscopic time steps must be fine enough to accurately solve the point kinetics equation and perform the integral for the precursor concentrations. (This depends on the point kinetic solver and the integration method implemented into the code.)

3. Question: In Fig. 4.9, the results for the reactivity difference show a decreasing trend while the order of angular detail is increasing: is there any explanation?

In Fig. 4.9, the decreasing trend corresponds to the slowly converging reactivity effect due to the increasing angular expansion in the numerical model. It might not be so evident in the dissertation. However, if we perform this analysis in even higher angular discretizations, it converges to a fixed value, as can be seen in the following figures:

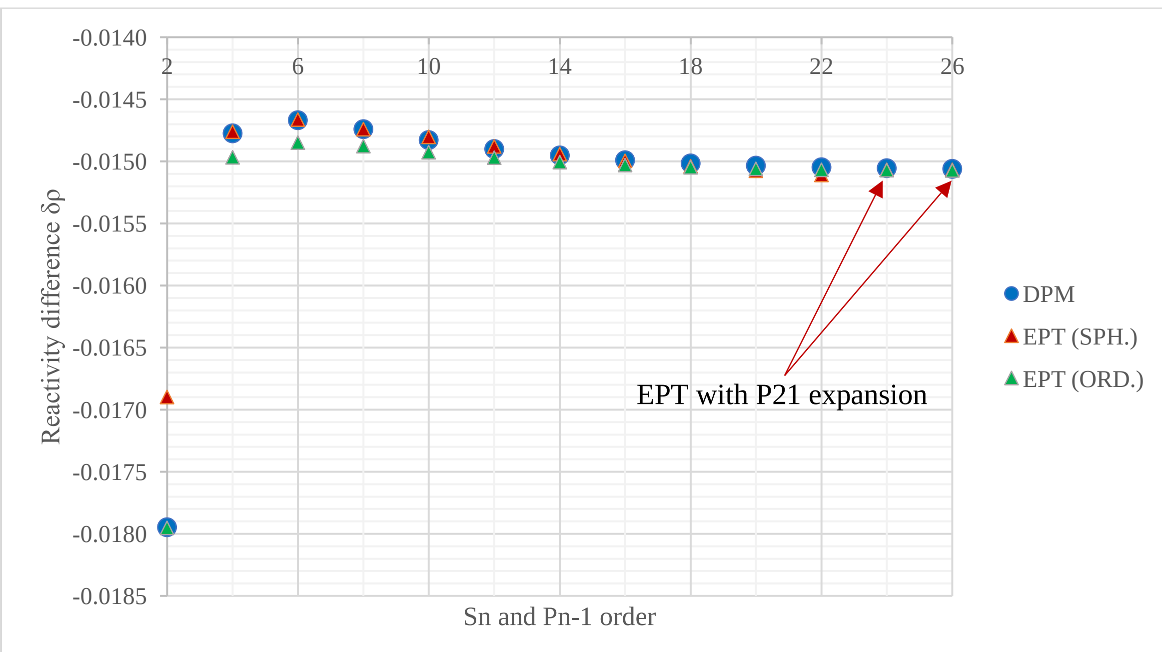

Figure 2. The effect of the higher-ordered expansion of the angular dependent flux in a curvilinear geometry.

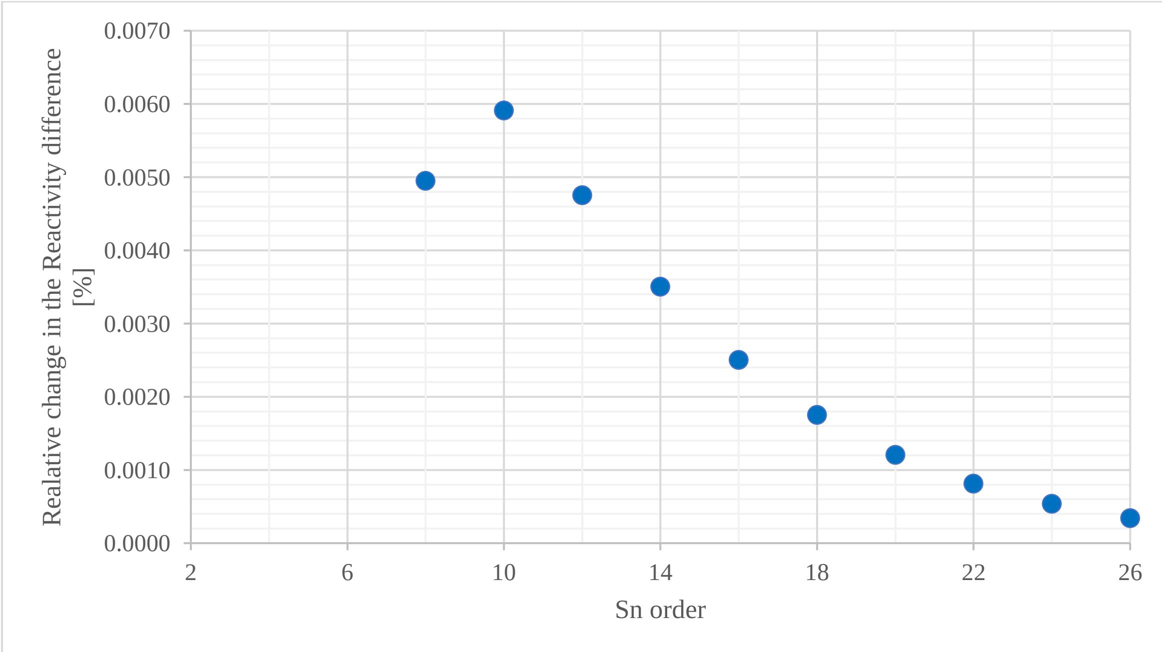

Figure 3. Convergence of the reactivity change

(Deviations start to arise at high angular expansion with the spherical harmonics (over P17). This is caused by the numerical problems in the estimation of such high order moments, which have practically zero expansion coefficients obtained from summations of positive and negative values, from the ordinate set. When S24 and S26 sets were used, the spherical harmonic expansion was kept at P21, for which correct the coefficients resulting in a better agreement.)

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