Development of a Monte Carlo based calculation sequence for reactor core safety analyses (MONSOON)

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Scope

The computational modelling of an operating nuclear reactor requires solving a coupled problem between neutronics, heat transfer and coolant flow, also taking into account the isotopic and mechanical changes in the nuclear fuel. Reactor safety analyses are traditionally based on a multi-stage calculation scheme, in which the physical complexity of the problem is gradually reduced, while simultaneously moving towards lager spatial scale. The goal of the MONSOON project was to establish a complete and independent calculation sequence for the safety analyses of Finnish power reactors. The work was largely based on the Serpent Monte Carlo code, developed at VTT since 2004.

2015 - 2016

The first two years of the project were devoted to completing the computational methodology for spatial homogenization, and demonstrating that the Serpent code can be used for producing input data for VTT's nodal diffusion codes. This was accomplished by running full-core fuel cycle simulations using the ARES code with Serpent-generated group constants. The MIT BEAVRS benchmark was chosen as the test case, and the Serpent-ARES code sequence was verified by comparison to reference Serpent 3D calculations. The studies also showed that the continuous-energy Monte Carlo method is a viable option for spatial homogenization, despite its relatively high computational cost.

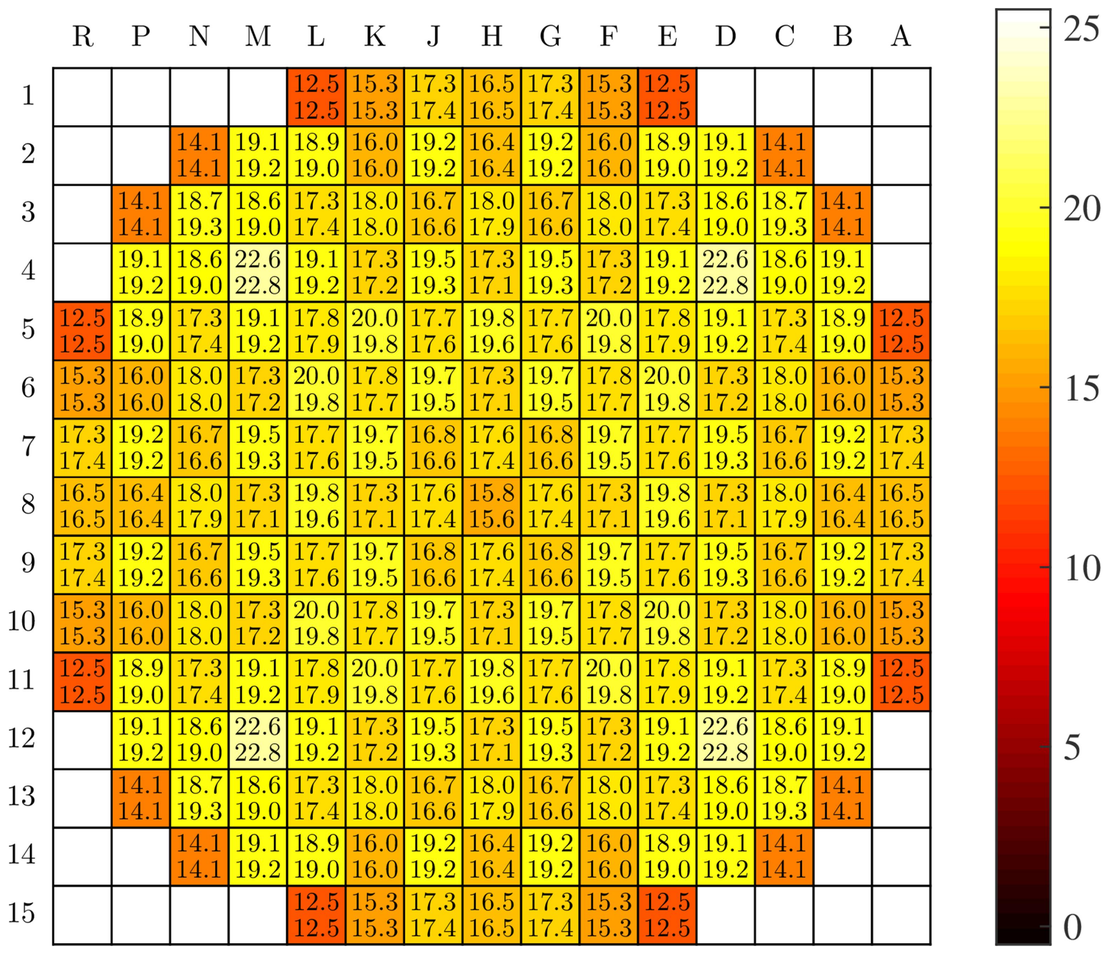

Figure 1. *Radial power distribution in the hot full-power state of a PWR core (MIT BEAVRS benchmark). The values are assembly powers in MW calculated using a reference Serpent 3D model (top) and the Serpent-ARES code sequence (bottom).*

2017 - 2018

The nodal diffusion codes used at VTT for reactor core safety analyses rely on methods that were originally developed in the 1970's. In 2017 it was decided to gradually renew the entire code basis to bring the methodology up to date. Continuing the tradition of in-house code development was also seen as the best way to educate a new generation of core physics experts. The work was started in the MONSOON project with the development of a new nodal solver "Ants" as part of the Serpent-based computational framework "Kraken". The development effort is continued in the LONKERO project of SAFIR 2022.

Serpent user community

The Serpent code has a large international user community consisting of more than 900 users in 200 universities and research organizations in 42 countries around the world. Interaction and close collaboration with Serpent users has been an important part of the MONSOON project as well. Forms of interaction include discussion forum, Serpent wiki, and annual international user group meetings organized since 2011. The 8th Serpent UGM was hosted by Aalto University in Espoo in May 2018.

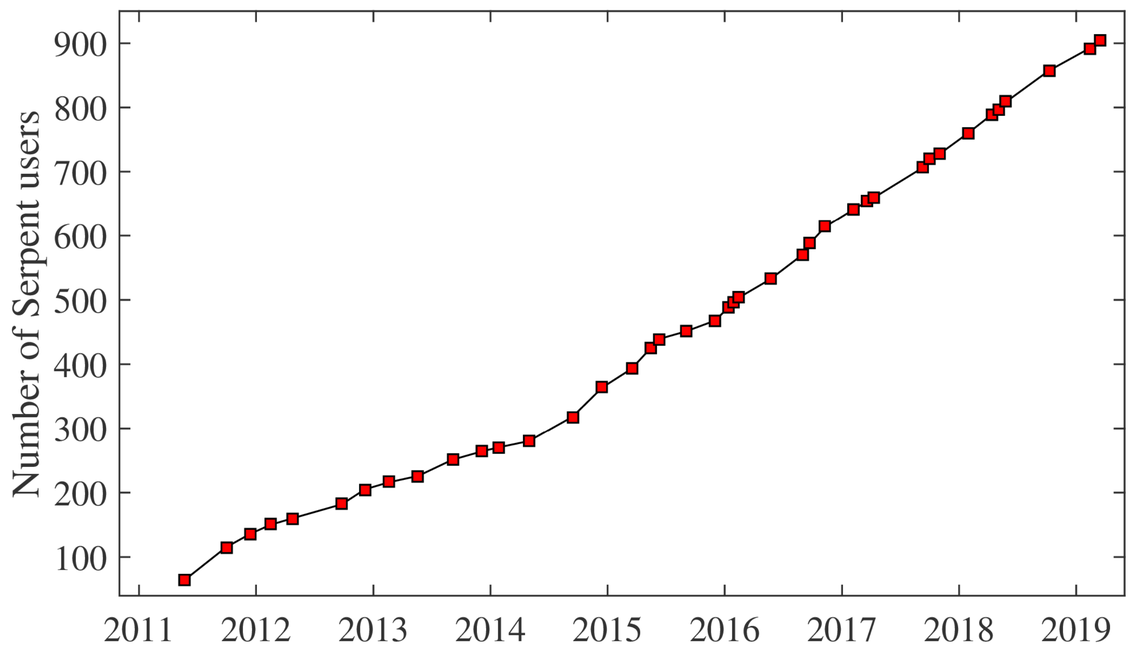

Figure 2. *Number of registered Serpent users since the beginning of the KÄÄRME project (predecessor of MONSOON) in SAFIR2014.*

Highlights

- **The MONSOON project continued the development of the Serpent Monte Carlo code.**
- **Methodology used for producing group constants for nodal diffusion codes was finalized and verified.**
- **Development of a new nodal solver "Ants" was started as part of the "Kraken" computational framework.**
- **Serpent user community grew to more than 900 users in 200 organizations in 42 countries around the world.**

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