

# Solution of the 3D Neutron Diffusion Benchmark by FEM

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**Abstract.** The objective is to analyze the neutron diffusion benchmark developed by the Atomic Energy Research community for verification of best-estimate neutronics codes. The 3D benchmark of Schulz models a VVER-1000 core in steady state. The assemblies are homogeneous, represented by given diffusion theory parameters. There are seven material compositions including four enrichments, burnable absorber, control rods and a reflector. The finite element method on tetrahedron computational grids is used to solve the three-dimensional neutron problem. The software has been developed using the engineering and scientific library FEniCS. The matrix spectral problem is solved using a scalable and flexible toolkit SLEPc. The solution accuracy of the benchmark is analyzed by condensing the computational grid and varying the degree of the finite elements.

## 1 Introduction

The physical processes in a nuclear reactor [1] depend on the distribution of the neutron flux, whose mathematical description is based on the neutron-transport equation [2, 3]. The equation, describing the process is of integro-differential form and the required distribution of neutrons flux depends on time, energy, spatial and angular variables. As a rule, simplified forms of the neutron transport equation are used for practical computations of nuclear reactors. The system of equations obtained by the multigroup diffusion approach is often used for reactor analysis [4, 5] and is applied in most engineering calculation codes.

The processes in a nuclear reactor are essentially non-stationary. The stationary state of neutron flux, which is related to the critical state of the reactor, is characterized by local balance between the neutron generation and absorption. This boundary state is usually described by the solution of a spectral problem (Lambda Modes problem,  $\lambda$ -eigenvalue problem) provided that the fundamental eigenvalue (the maximal eigenvalue) that is called  $k$ -effective of the reactor core, is equal to unity. In this case, the stationary neutron flux is a corresponding eigenfunction. Computations of  $k$ -effective of the reactor using the Lambda Modes problem are obligatory for reactor design calculations.

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