Centrum výzkumu Řež s.r.o.
Research Centre Rez

PRACTICAL ACQUIRING OF PARCS CODE FOR 3D ANALYSES OF NEUTRONIC BEHAVIOR OF VVER1000/V320

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Introduction

In response to the Fukushima accident the Research Centre Rez plans to simulate accident scenarios of NPP Temelin and NPP Dukovany analyzed in the stress tests ordered by the European Commission to all European NPPs. The aim of the presented work is to prepare a model of the core of VVER1000/V320 reactor applicable for 3D modeling of neutron kinetics in selected design and beyond design basis accidents for a future coupling with RELAP or TRACE.

1. Calculation scheme

TRITON

In particular the TRITON Module is used for the generation of cross-sections useful for PARCS code. It is a control module in computation code **SCALE 6.1.2**. It is using several computational sequences like CENTRM, NEWT, BONAMI, etc., that are depending on user's requirements. TRITON performs 2-D calculations for square and hexagonal geometry of the fuel assembly. Its main computational features are cross-section calculation and isotopic compositions of the fuel assembly.

PARCS

PARCS 3.2 is a three-dimensional (3D) reactor core simulator which solves the steady-state and time-dependent, multi-group neutron diffusion and low order transport equations in orthogonal and non-orthogonal geometries. PARCS is coupled directly to the thermal-hydraulics system code **TRACE** which provides the temperature and flow field information to PARCS during the transient calculations via the few group cross sections. PARCS is available as a standalone code for performing calculations which do not require coupling to TRACE or **RELAP5**. A separate code module, **GENPMAXS**, is used to process the cross sections generated by lattice physics codes, such as TRITON (SCALE 6.1.2), HELIOS, or CASMO into the **PMAXS** format that can be read by PARCS. Calculation scheme is shows on Fig. 1.

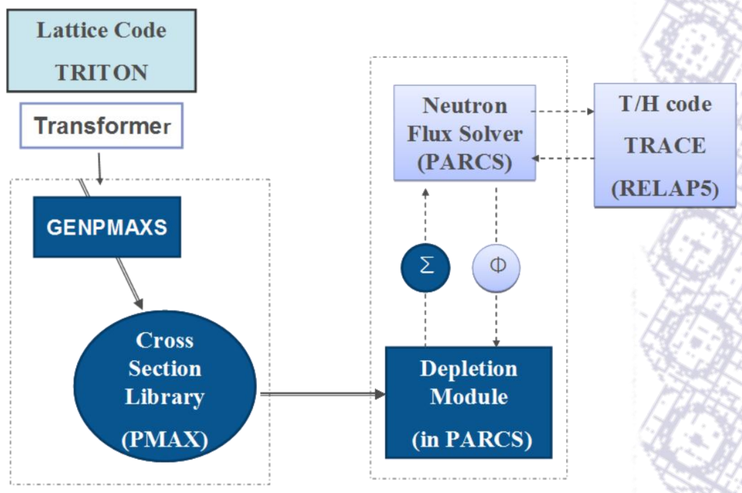

Fig.1 Calculation scheme

2. Fuel Assemblies Description

There are six types of fuel assemblies with different enrichment as shown in the Tab. 1. In the first step was necessary to define chemical parameters of fuel such as density, temperature and enrichment. After these parameters we defined cladding, which consist of 99% Zr and 1% Nb. Moderator comprised from main an additional materials. The main material is water (H2O) with density of 0,73 g/cm3, temperature 575 K and the additional material is boron with 1065 ppm. Inside the fuel pellets we considered the central hole filled with helium. As next step we defined geometrical parameters of fuel assembly and fuel pellets.

	Fuel 1 %	Fuel 2 %	Fuel Gd %	Gd amount %	Gd Rod Number
A200	2.0	-	-	-	-
A130	1.3	-	-	-	-
A40E6	4.0	-	3.3	5	6
A30E9	3.0	-	2.4	5	9
P36E9	3.6	3.3	3.3	5	9
P40E9	4.0	3.6	3.3	5	9

Tab. 1 Fuel enrichment description

The inputs are shown in Fig. 2 and Fig. 3. Fuel assembly consists from nine nodes and each node has power level that depends on the active length power distribution.

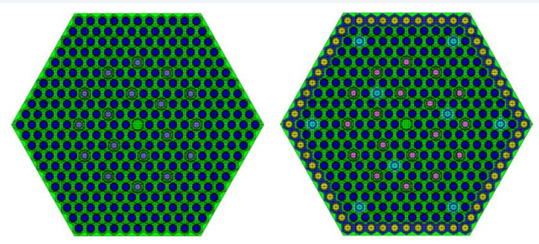

Fig. 2 Inputs of A130/A200 (left) and inputs of P36E9/P40E9 (right)

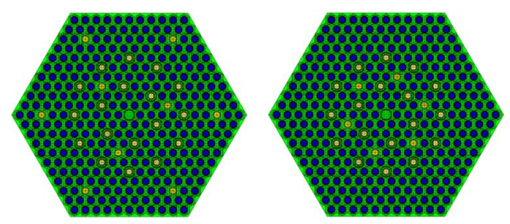

Fig. 3 Input of A40E9 (left) and input of A30E6 (right)

3. Core Description

Core input is composed of several data blocks. These blocks contain the general data as core initial power, control bank position and calculation options for 3D or 1D solution of the transport equation or if the calculation is steady-state or transient. The option for specifying cross sections of different materials is included in the XSEC block, where the user can put beta (delayed neutron fraction) and lambda (delayed neutron precursor decay constant) cross-sections for each energy group and for each assembly used inside the core. All of the data above are used in the geometry block, where the radial and axial configuration is specified. The hexagonal VVER core can be written in different symmetries as 1/12, 1/6, 1/3 and the full core. Along with the assembly configuration, it is also possible to set the configuration of control rod clusters. The VVER 1000 input is replaced and filled from the Fig. 4 in order to have the full core in 360° geometry.

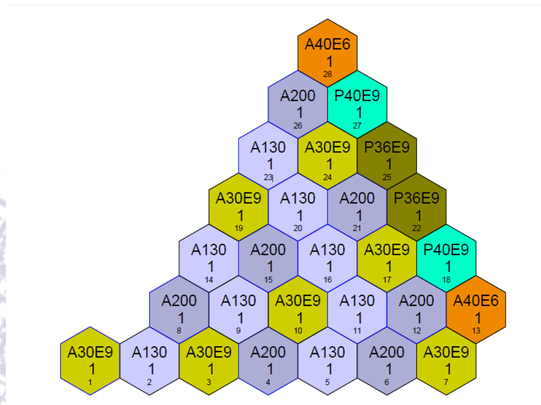

Fig. 4 VVER 1000 Core Sketch

4. Analyses Results

The analyses substantially are divided in two phases:

1. The analyses with SCALE code of the single assembly neutron property (k_{inf}, rates, cross-sections, ...) and the homogenization and collapse in two groups for PARCS input.
2. The analyses of the results of PARCS of the most important parameter as k_{eff}, power profile (axial and radial) and others.

The first phase is the most important and takes some computational time due to the complexity of the model, the homogenization of entire assembly in 2 groups cross sections starting from 238 groups. It is chosen 0.25 eV as boundary between the 2 groups in order to devise the Thermal flux from Fast/Epithermal flux and results are described in the Tab. 2 and in the Fig. 5. The Fig. 5 refers to the assembly P40E9 and it has been chosen due to the presence of the two different type of fuel and the Gd burnable poison.

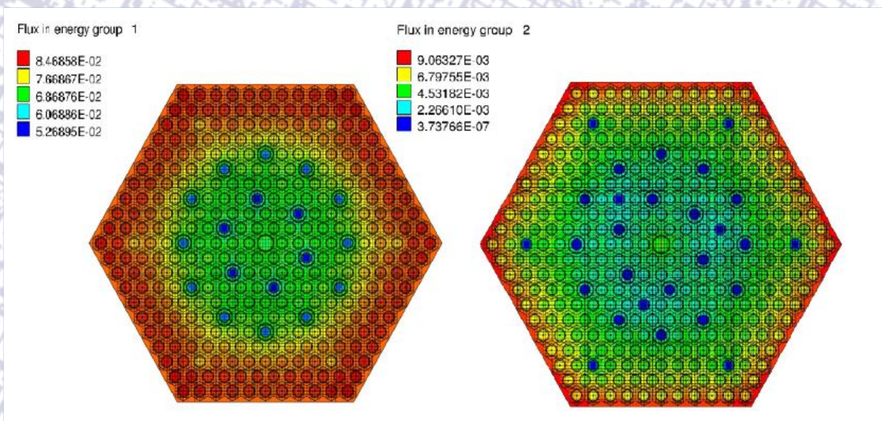

Fig. 5 Flux of Assembly P40E9 in arbitrary unit

As shown in Fig. 6, and Fig. 7, the flux shape is symmetrical according to the solution of Boltzmann equation. In particular, the Fig. 6 and Fig. 7 reference to the middle of the core, where the calculation shown the peak factor of axial power distribution (Fig. 8). The axial power distribution (Fig. 9) is symmetrical due to the lack of control rods.

Ass. Name	k_{inf}
A200	1.05141973
A130	0.897668481
A40E6	1.2031641
A30E9	1.08878469
P36E9	1.06773758
P40E9	1.10006011

Tab. 2 SCALE k_{inf} results without Control Rod

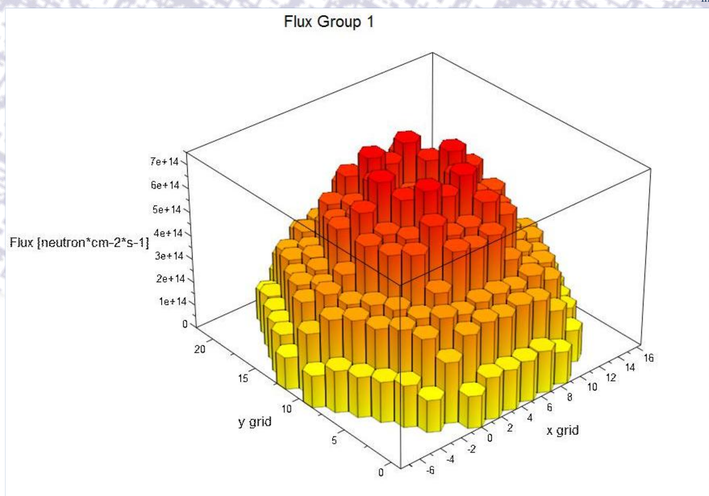

Fig. 6 Fast-Epithermal flux distribution as function of Assemblies positions (Group 1)

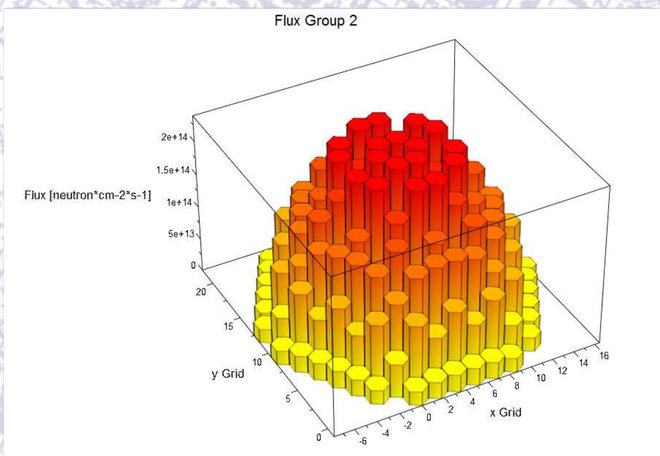

Fig. 7 Thermal flux distribution as function of Assemblies positions (Group2)

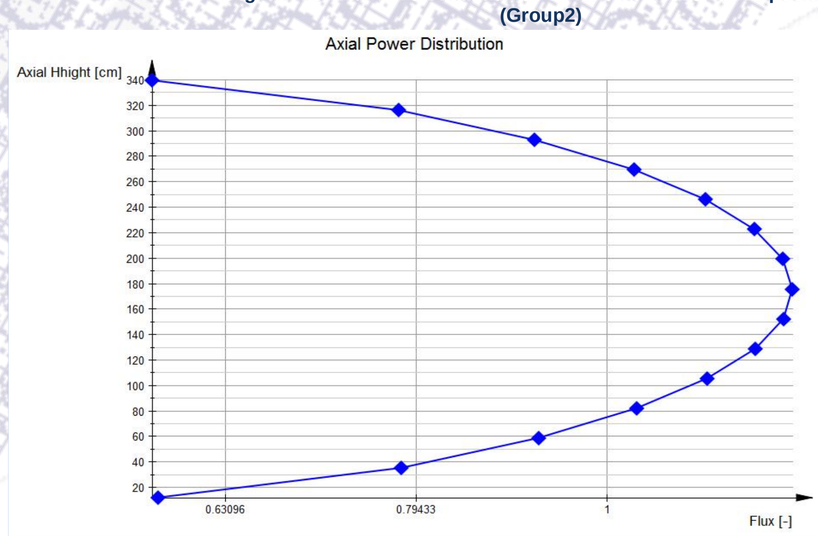

Fig. 8 Axial Power distribution

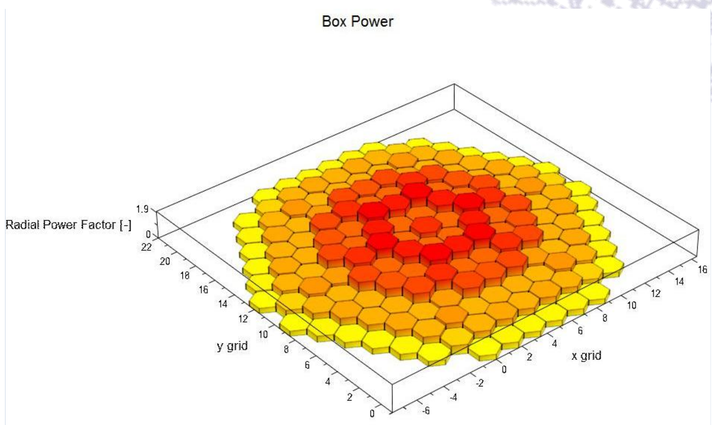

Fig. 9 Power factor as function of Assemblies positions

Conclusion

In the presented work a model of the VVER1000/V320 core has been proven applicable for 3D modeling of neutron kinetics in selected design and beyond design basis accidents in order to couple with the thermo-hydraulic system codes, such as RELAP5 or TRACE. The model based on SCALE 6.1.2/TRITON simulations datasets is prepared in PARCS 3.2 using homogenized cross-sections libraries based on ENDF/B-VII.0 in 2 groups able to calculate neutronic and other core parameters of the VVER reactors.

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