SIMULATION OF ROD EJECTION ACCIDENT BY PARCS CODE

Jitka Matejkova

Doctoral Degree Programme (2), FEEC BUT

E-mail: xmatej50@stud.feec.vutbr.cz

Supervised by: Karel Katovsky

E-mail: katovsky@feec.vutbr.cz

Abstract: This paper describes reactor core model used for simulating REA. The model was designed in PARCS utilizing graphical interface SNAP. The data for model were given from benchmark NEACPR L-335. The PARCS model used integrated thermal hydraulic block for calculation. The results and solution is shown in the paper. Thermal hydraulic calculation can also be provided by external system code TRACE. The PARCS model is prepared to couple with TRACE model for giving more accurate calculation.

Keywords: PARCS, coupling, model

1. INTRODUCTION

The rod ejection accident (REA) is the design basis accident in pressurize water reactor. It is assumed a mechanical failure of the control rod drive mechanism housing that causes control rod assembly ejection from the reactor core in approximately 0.1 s. Analyses of the accident is necessary for getting license to operate nuclear power plant.

Safety analyses are carried by several codes, which are usually developed by a university, operator of nuclear power plant and regulator. The U. S. Nuclear Regulatory Commission (NRC) in collaboration with universities developed some of them. Neutron kinetic code of NRC is Purdue Advanced Reactor Core Simulator (PARCS). The TRAC/RELAP Advanced Computational Engine (TRACE) is thermal-hydraulic code.

In this study, model of REA was utilized in PARCS using Symbolic Nuclear Analysis Package (SNAP). The parameters of model were taken from NEACRP-L-335: 3-D LWR Core Transient Benchmark Specification [2].

2. SIMULATION TOOLS

2.1. PARCS

This code is a reactor core simulator, which solved multi group neutron diffusion and low order transport equations. It can solve problem of pressurize water reactor (PWR), boiling water rector (BWR), Canada Deuterium Uranium (CANDU) and pebble-bed reactor (PBR). PARCS uses nodal approximation, where each fuel assembly is homogenized and the two group flux is calculated in each axial mesh of either the full assembly or a subregion of the assembly. Thermal-hydraulic block is integrated in PARCS and can also be substitute by thermal hydraulic code like TRACE, RELAP5 and others. TRACE/PARCS coupled calculation reduces uncertainties and gives more realistic analysis.

2.2. SNAP

SNAP is a graphical interface design for TRACE, RELAP5, PARCS, MELCOR, CONTAIN, COBRA, FRAPCON-3 and RADTRAD. SNAP allows simplifying the process of performing engineering analysis and is used for visualization of calculation data.

2.3. TRACE

TRACE is designed to analyse loss of coolant accident, operational transient and other at light water reactor, especially PWR and BWR, so it can simulate steady state and transient problem. The code solves heat transfer equation and describes two-phase flow using finite volume numerical methods. TRACE has to be coupled with PARCS for transient with large changing asymmetries in the reactor-core power like REA.

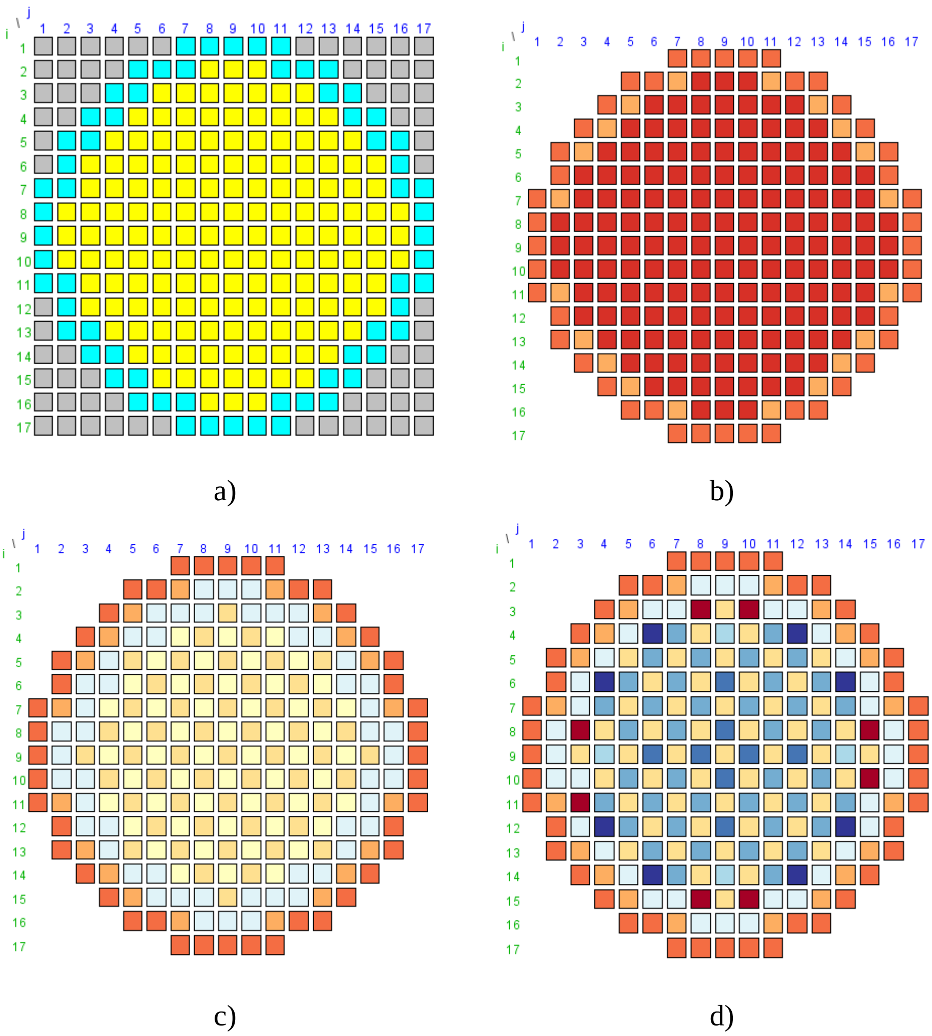


Figure 1: a) Core geometry (yellow – core, blue - reflector), b) Planar region at the top and bottom level, c) Planar region at 2nd level and d) core planar region

3. BENCHMARK NEACPR L-335

Benchmarks are widely used to verify reliability of numerical simulations. Sets of geometric data and measures are included for making model and compering simulation solutions. This benchmark was sponsored by OECD Nuclear Energy Agency and was used for testing three-dimension neutronic codes for light water reactor. The benchmark describe problem of REA at PWR and BWR. The transient PWR problem was measured for hot zero power and full power states for three different cases: rod ejection of central or peripheral assemblies for octant symmetry and rod ejection of peripheral assemblies at full core geometry. The reference PWR reactor core consists of 157 fuel assemblies with Cartesian geometry. Full power state is 2775 MW.

4. MODEL

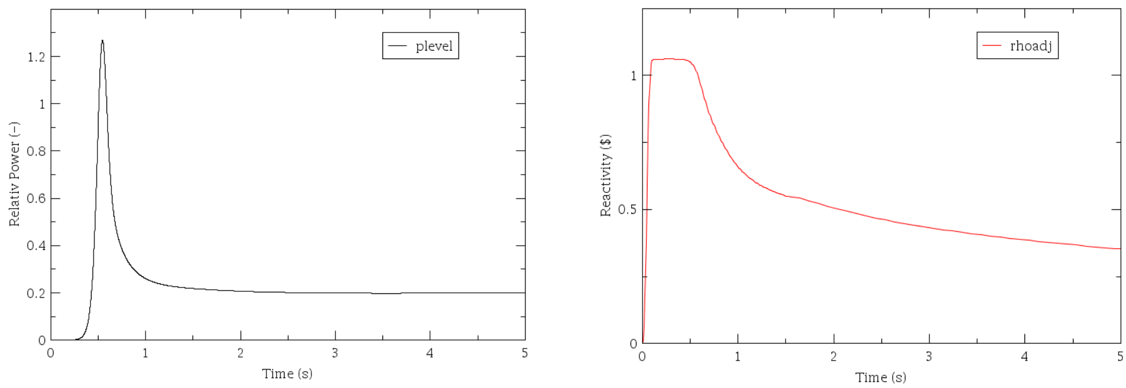
Model was created for octant core symmetry case of benchmark with central rod ejection at hot zero power (2775 W) condition with an ejection time of 0.1 s. It has 157 fuel assemblies and 64 assemblies which represent reflector (Figure 1 a)). The cross section library was taken from benchmark. PARCS solved steady state problem followed by a transient problem during a time of 5 s.

4.1. DESCRIBE OF MODEL

The core symmetry is often used to reduce calculation time. But for coupled calculation it was necessary to make full core symmetry model. Model used an axial mesh of 18 nodes within core. It is used 2 x 2 meshes radially within an assembly. Particular planar regions are presented at Figure 1 b), c), d). Color of the nod indicates identical material behavior, which means the same cross section data.

4.2. SIMULATION SOLUTION

Rapidly increasing power which is shown in Figure 2 a) is caused by control rod ejection. During time of ejection assembly (in our case 0.1 s) reactivity increasing linear. It is shown at Figure 2 b).



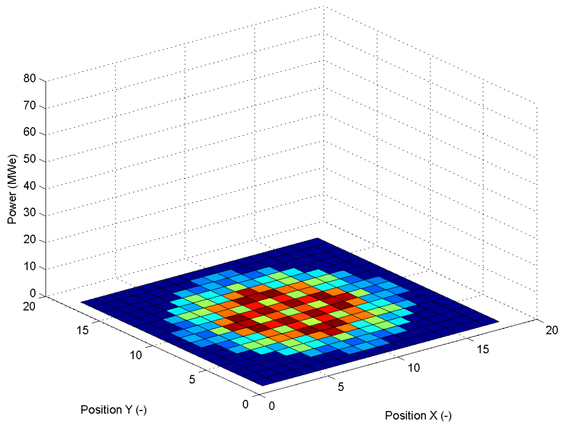
a) b)

Figure 2: Chart of a) relative power depends time, b) reactivity depends time

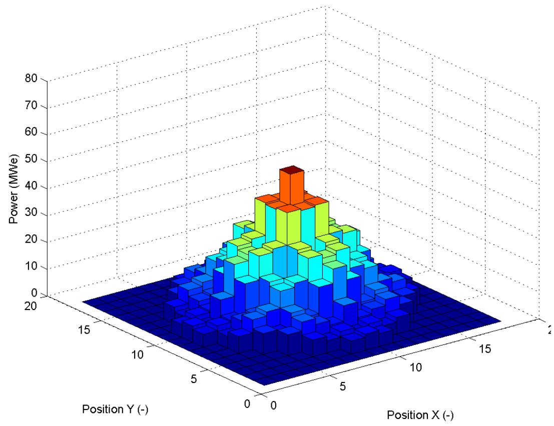
The details of power pulse, namely the peak power, time of peak, Doppler temperature and values at final time are given in Table 1 compare to references solution from lit. [2]. Deviation of power maximum time is the lowest in compare to solutions from benchmark. Also deviation of power maximum, final power and Doppler Temperature are among the lowest value of deviation at benchmark. Power distribution in the core during the transient is shown on Figure 3.

Table 1: Solution of simulation

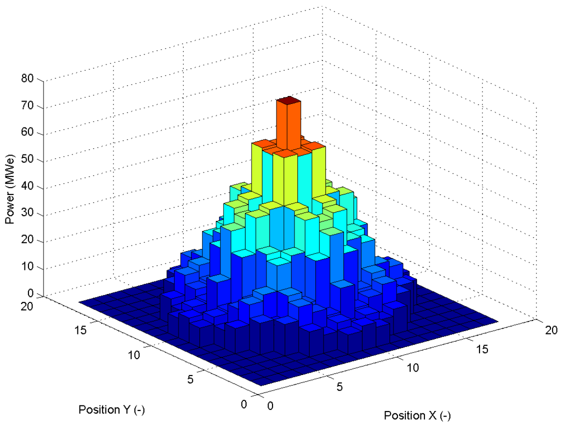
	Time (s)	*Relativ Power (-)*	*T_{Dop} (°C)*
Transient Reference Solution of Power Maximum	0.560	1.179	294.5
PARCS Solution of Power Maximum	0.545	1.26942	295.02
Transient Reference Solution at final time	5	0.196	324.3
PARCS solution at final time	5	0.200	325.24



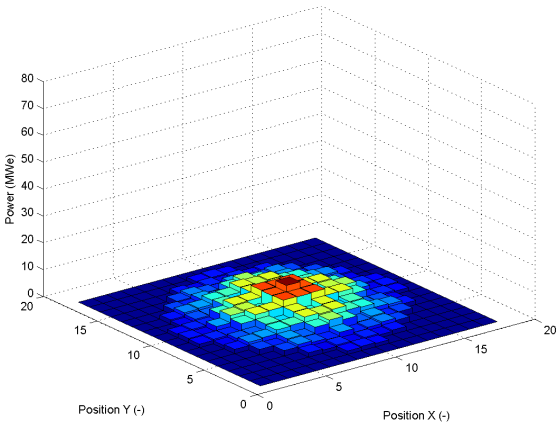
a)



b)



c)



d)

Figure 3: Distribution of relative power at time a) 0 s, b) 0.495, c) 0.545 (peak), d) 5 s.

5. CONCLUSION

The core model was created by PARCS according to data from benchmark L-335. Thermal hydraulic part of solution was solved by thermal hydraulic block integrated in PARCS. The solution of the model simulation is very close to the best simulation solution data of benchmark.

The model has been modified and it is prepared for coupling with TRACE model now. TRACE/PARCS calculation gives higher accuracy solution. The solution of stand-alone calculation will be compared to coupled calculation. Comparison will give answer to the question whether coupled calculation is necessary or stand-alone calculation gives sufficient results.

ACKNOWLEDGEMENT

This research work has been carried out in the Centre for Research and Utilization of Renewable Energy (CVVOZE). Authors gratefully acknowledge financial support from the Ministry of Education, Youth and Sports of the Czech Republic under NPU I programme (project No. LO1210).

REFERENCES

[1] Diamond, D.J.; Bromley, B.P.; Aronson, A.L.: Studies of the Rod Ejection Accident in a PWR, New York 2002

[2] Finnemann, H.; Galati, A.: "NEACRP 3-D LWR Core Transient Benchmark," NEACRPL 335, October 1991, http://www.nea.fr/html/science/docs/1991/

[3] Downar, T.; Xu, Y.; Seker, V.; Hudson, N.: PARCS v3.0: U.S. NRC Core Neutronics Simulator [online]. 2010 [cit. 2015-03-04]. UM-NERS-09-0001. http://pbadupws.nrc.gov/docs/ML1016/ML101610098.pdf

[4] Diamond, D.J.; Aronson, A.; Jo, J.; Avvakumov, A.; Malofeev, V.; Sidorov, V.; Ferraresi, P.; Gouin, C.; Aniel, S.; Royer M.E.: Intercomparison of results for a PWR rod ejection accident. Nuclear Engineering and Design [online]. 2001, vol. 208, issue 2, s. 181-189 [cit. 2015-02-10]. DOI: 10.1016/s0029-5493(01)00375-2.

[5] Noori-Kalkhoran, O.; Minuchehr, A., Akbari-Jeyhouni, R.; Shirani, A. S.; Rahgoshay, M.: Simulation of rod ejection accident in a WWER-1000 Nuclear Reactor by using PARCS code. Annals of Nuclear Energy [online]. 2014, vol. 65, s. 132-140 [cit. 2015-02-10]. DOI: 10.1016/j.anucene.2013.11.003.

[6] Mascary, F.; Vella, G.; Casamassima, V.; Parozzi, F.: Analyses of Trace-parcs Coupling Capability. Nuclear Energy for New Europe 2011 [online]. Ljubljana: Nuclear Society of Slovenia, 2011, ISBN 978-961-6207-32-4. [cit. 2015-02-24]. http://www.djs.si/proc/nene2011/pdf/816.pdf