Short communication

Power Distribution Correlation with Fuel Assembly Neighbors of VVER 1000 Reactor

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Abstract

Power distribution of full core VVER-1000 reactor with different enrichment has been calculated from MCNP simulation and this relative power value has been correlated with the coordination number of each fuel assembly site. The correlation values give the quantitative relation with the power generation at each fuel assembly with the neighboring assemblies. Such characterization of fission distribution will aid the power distribution prediction and hence in-core fuel management of the reactor.

Keywords: Power distribution, MCNP, VVER, coordination number

1. Introduction

A number of papers can be found where power distribution of PWR is available for different core configurations with different fuel enrichment; here we have attempted to characterize the power distribution for VVER type reactor which can be used to take decisions regarding in-core fuel management. Power peaking factor and reactivity of the core is considered very frequently to define the objective function for the core management problem [1]. Both these parameters depend on neutron flux and fuel distribution in the core. The relative neutron flux at any location inside the reactor core depends on the number of neighboring fuel elements [2]. Hence the power distribution is supposed to be proportional to the number of surrounding fuel loading as well as the loading itself. Here we have tried to quantify the assumed characteristics. The technical data of the reactor is based on the IAEA benchmark entitled “In-core fuel management code package validation for WWERs”, IAEA-TECDOC-847 [3].

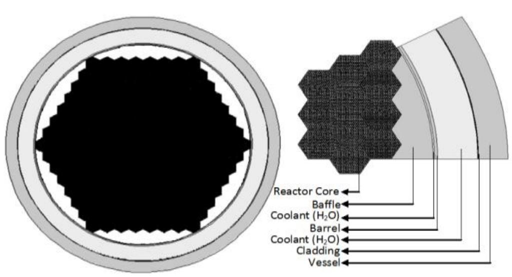

Fig. 1: MCNP model of VVER-1000 full core

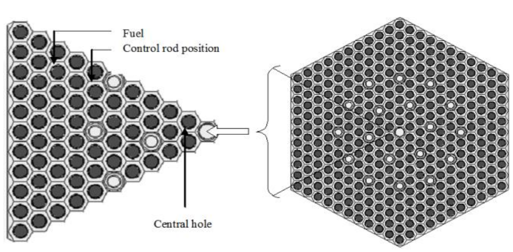

Fig. 2: MCNP model of VVER-1000 fuel assembly

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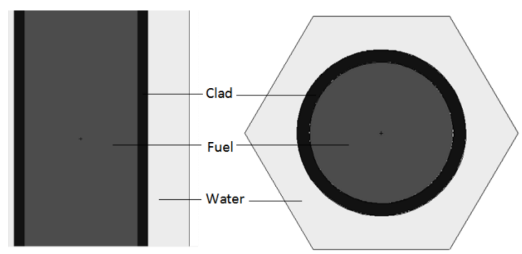


Fig. 3: MCNP model of single fuel cell of VVER-1000

2. VVER Reactor and MCNP Model

VVER-1000 is a pressurized water reactor of Russian design with hexagonal fuel assemblies. The single assembly contains lattice of 312 fuel pins with 18 control rod clusters (CRCs) and a central instrumentation channel. This is water cooled water moderated reactor. The full core model of VVER-1000 has been prepared for the MCNP code; the calculations have been done using the code MCNP5 [4], version 1.60 with nuclear cross-section data library based on ENDF/B-VII [5]. For sufficient statistical convergence of Monte Carlo simulation, calculations performed with 11×10^6 neutron histories in total, skipping 1×10^6 histories. Skipping initial neutron histories foster the convergence of calculation results. The model benchmark has been reported for the fuel assembly in an earlier paper [6]. The full core model has been shown in Fig. 1. Fuel and other elements modeled in the assembly are shown in Figs. 2-3. The assembly is a hexagonal lattice with a pitch of 1.275 cm. The core consists of 163 hexagonal assemblies with 23.6 cm lattice pitch. We have included six additional fuel assemblies at the outer six corners of the VVER full core as shown in Fig. 1, differing from that of the IAEA document [3]. This has been done to keep the symmetry of the outer ring like those of the inner rings. The core geometry surrounded by core baffle, coolant (H_2O), cladding and vessel respectively.

3. Results and Discussion

On the basis of the benchmark specification Monte Carlo calculations were carried out. First we have obtained power distribution for a core of homogeneous enrichment i.e. 2%.

To compare the power distribution for different simulation all the values are divided by the value obtained by summing up the power density values at each fuel assembly locations [7], i.e. normalized to unit total power. In this core we can directly check the influence of surrounding fuel loadings. We have plotted the scatter graph of assembly wise power distribution vs number of surrounding assemblies gradually increasing the number of neighboring rings. The maximum number of next neighbor ring is considered to be the 7^{th} with respect to the reference fuel assembly. We defined the number of influential neighboring assembly as the coordination number, i.e. the effective number of nearest neighbors. The correlation between the power density distribution and coordination number has been computed. We find the highest correlation up to sixth neighboring ring fuels.

Coordination number is settled based on the highest correlation value. The same has been confirmed for the core with 3% enriched fuel loading. Due to the six fold symmetry of the core we have investigated only the one sixth of the core. The correlations are shown in the scatter plot (Fig. 4) with linear fitting and correlation coefficient value. In the figure only 5^{th} to 7^{th} ring neighbor are shown due to the poor correlation for lower ring numbers. A computer program was written in QBASIC to count the number of neighboring fuels for our investigated hexagonal core. Having settled quantitatively the neighboring fuel influence, power distribution prediction needs to know the influence of fuel loading at individual site. This investigation is left for future work. Further detail can be studied for variant fuel loading and core configurations in the future.

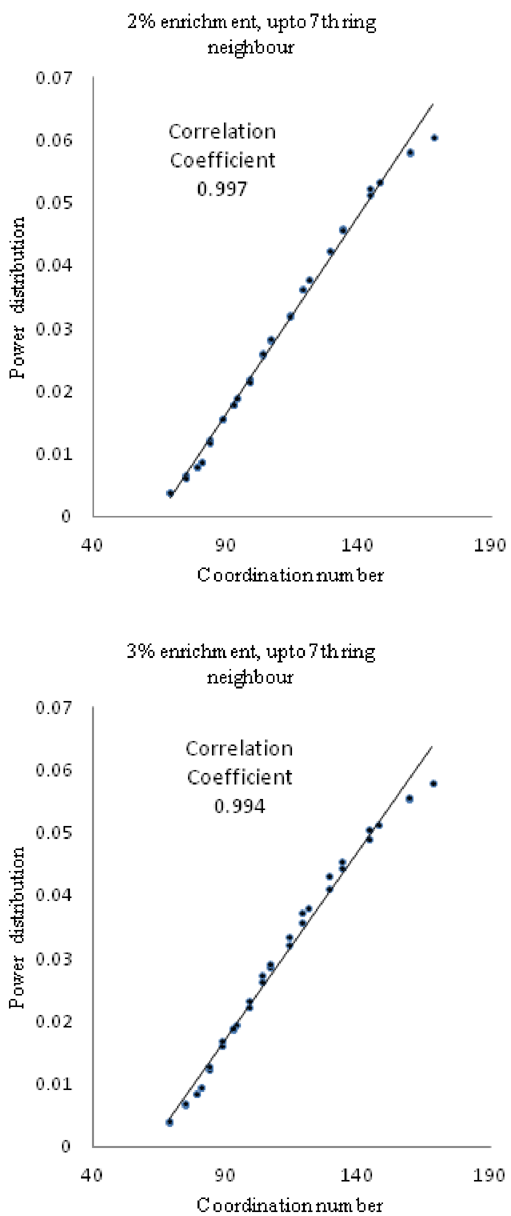


Fig. 4a: Power distribution vs coordination number scatter plot with linear fit and correlation coefficient (up to 7th ring neighbor)

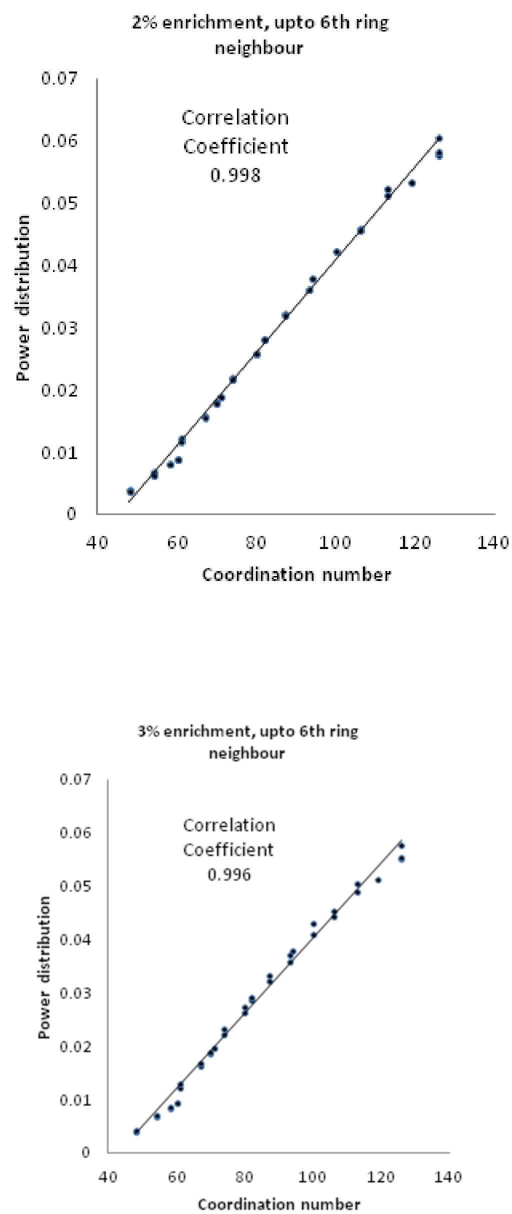
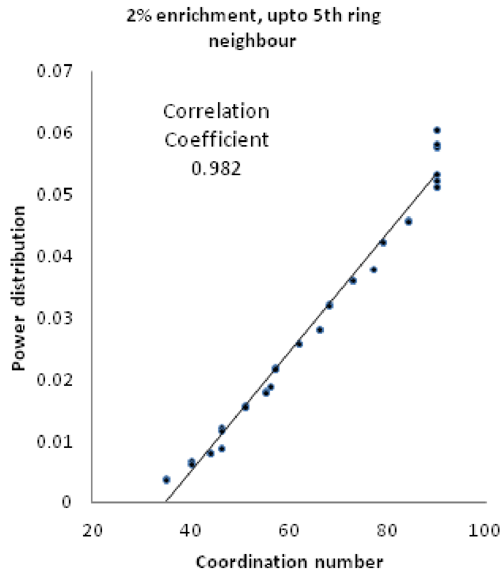


Fig. 4b: Power distribution vs coordination number scatter plot with linear fit and correlation coefficient (up to 6th ring neighbor)



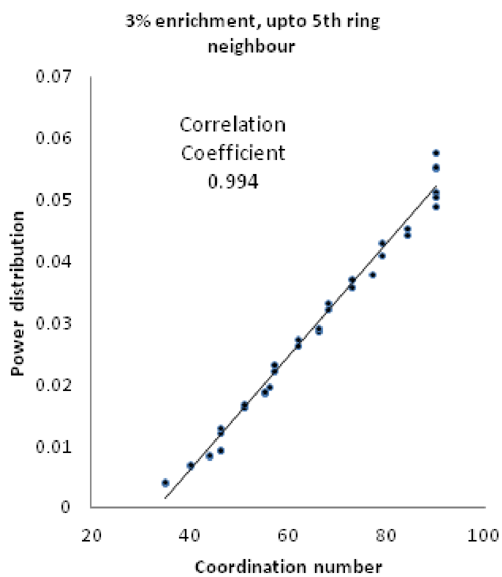


Fig 4c: Power distribution vs coordination number scatter plot with linear fit and correlation coefficient (up to 5th ring neighbor)

4. Conclusion

Relative power values at each fuel assembly site of VVER reactor has been found to be correlated with the coordination number. This coordination number of each fuel assembly site can be limited by the highest correlation coefficient value. The relative power value at each fuel assembly site is found to be dependent on the fuel loading at the neighboring assemblies. Such characterization of power distribution will aid the in-core fuel management of nuclear reactor.

References

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