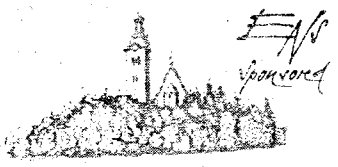
4th Regional Meeting
Nuclear Energy in Central Europe
September 7-10, 1997, Bled, Slovenia



Generation of the Reactivity Coefficient Library in the CORD-2 System

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ABSTRACT - *Reactivity coefficient method, used in the CORD-2 package to cover the Xenon and power feedback effects has been refined and incorporated into the GNOMER diffusion code. Reactivity coefficient library was generated for the NPP Krško and tested on a typical fuel cycle. Results show that the method is very fast and accurate, suitable even for the most demanding design calculations.*

1. Introduction

The CORD-2 package/1/ developed at our institute has been verified for design calculations of PWR cores. It consists mainly of two basic reactor physics codes WIMS/2/ and GNOMER/3/. The first one is used for lattice cell calculations and the second one for the multigroup multidimensional diffusion calculations.

Since the system was designed to be flexible and as accurate as possible, it does not rely on macroscopic cross sections library. Instead, the concept of an isotopic composition library was adopted. For each problem to be solved, only cell isotopic composition is retrieved from a precomputed library. Everything else (cell cross sections determination, assembly cross section homogenization, global diffusion calculation) is performed on a case by case basis. In this standard sequence of calculation, Xenon and power feedback effects are mainly calculated by the WIMS code. Only small local perturbations to accurately account for thermohydraulic and neutronic coupling are covered by the reactivity coefficient method, applied in the diffusion code GNOMER.

The concept proved to be successful for typical design calculations of reload cores, where only a relatively limited number of cases need to be examined. However, for some specific problems, such as loading pattern determination, 3-D dynamic and kinetic problems, efficiency of the system is not sufficient to be practical. In such cases, the power feedback effects are modeled entirely within GNOMER on a nodal basis. To achieve the required accuracy, the reactivity coefficient method was refined and incorporated into GNOMER and the reactivity coefficient library.

2. Reactivity model

Reactivity coefficient library consists of data which describe reactivity changes due to the following effects:

- Moderator temperature (T_M)
- Fuel temperature (T_F)
- Boron concentration (C_B)
- Xenon (Xe)

All coefficients are also tabulated as a function of burnup (Bu). For the moment only one type of the fuel (with average characteristics) is considered, but the expansion to the multiregion concept is straightforward.

Reactivity changes are approximated by:

$$\Delta\rho_B = \int_{C_B^1}^{C_B^2} \frac{\partial\rho(C_B, T_M^1, Bu)}{\partial C_B} dC_B$$

$$\Delta\rho_M = \int_{T_M^1}^{T_M^2} \frac{\partial\rho(T_M, C_B^2, Bu)}{\partial T_M} dT_M$$

$$\Delta\rho_F = \int_{T_F^1}^{T_F^2} \frac{\partial\rho(T_F, Bu)}{\partial T_F} dT_F$$

$$\Delta\rho_{Xe} = \int_0^{Xe^2} \frac{\partial\rho(Xe, C_B^2, Bu)}{\partial Xe} dXe - \int_0^{Xe^1} \frac{\partial\rho(Xe, C_B^1, Bu)}{\partial Xe} dXe$$

3. Spectral corrections

Preliminary calculations have shown that correct accounting of reactivity (K_∞) is not sufficient for the desired accuracy. If sufficiently large differences in the core conditions are present, the change in the infinite neutron spectrum and in the leakage have to be considered. For that purpose in the two energy group approximation, selected cross sections are corrected with the following factors:

Spectral factor	Affected cross sections
C_{spect}	Σ_{tr1}, Σ_{a1}, Σ_{12}, $\nu\Sigma_{f1}$, Σ_{f1}
C_{dif}	Σ_{tr1}, Σ_{tr2}
C_{12}	Σ_{12}
C_{frac}	Σ_{a1}, Σ_{a2}

After spectral corrections (C_{spect}, C_{dif}, C_{12}), the absorption cross sections are modified to reproduce correctly the K_∞ in such manner that the fast to thermal absorption increment ratio equals to C_{frac}. All spectral correction factors C are fitting parameters generated to match the observed differences in cross sections when core conditions change.

4. Results

Reactivity coefficient method was tested on a typical cycle of the Krško NPP. The coefficient library was prepared for the average fuel (average enrichment, average initial mass of U, average fresh IFBA rods number etc.) with no control rods. Cross sections were generated for the hot zero power (HZP) and hot full power (HFP) conditions with the standard CORD-2 sequence of calculations. HFP conditions are simulated with the reactivity coefficient method from HZP cross sections and compared with the reference explicit HFP calculation. Results for beginning of cycle (BOC), middle of cycle (MOC) and end of cycle (EOC) are shown in Table 1 and Figures 1-3. Calculations were performed for all rods out (ARO) and D-bank fully inserted configurations.

Table 1: Simulation of the HFP conditions from HZP cross sections with the reactivity coefficient method.

Condition	$\Delta C_B^{critical}$ (ppm)	ΔD_{worth} (ppm)	εD_{worth} (%)	max $\Delta P_{assembly}$ (%)
BOC ARO	-6			0.32
D-IN	-2	-4	3.2	1.37
MOC ARO	-2			0.36
D-IN	+2	-4	3.3	1.43
EOC ARO	-12			0.35
D-IN	-9	-3	2.5	1.49

Results show excellent agreement for the ARO configuration. Errors are within the accuracy of the GNOMER diffusion code and are well bellow the accuracy of the CORD package itself. Even for such extreme cases as total insertion of control bank at HFP conditions, reactivity agreement is good. However, relatively large discrepancies in the local power distribution near the control rods position (Figure 3) indicate that a modified coefficient library would be necessary in the case when strong absorbers (control rods, large number of IFBA rods in an assembly) are present if full accuracy is to be attained. We believe that such sophistication is not necessary for the moment.

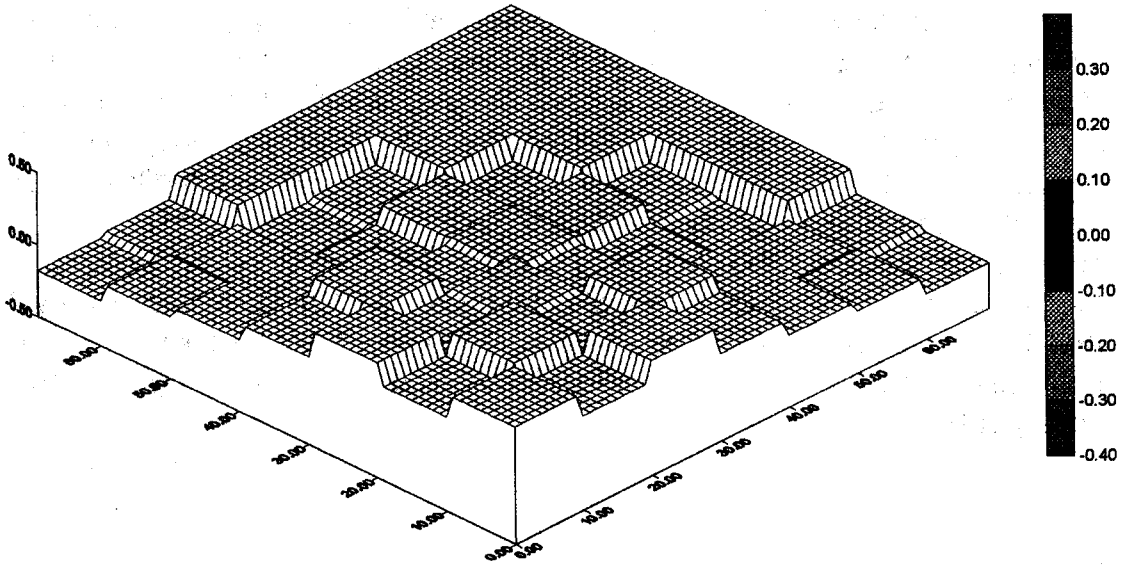

Figure 1: Power distribution errors (in % with maximum 0.32%) of the reactivity coefficient method for the BOL, ARO conditions.

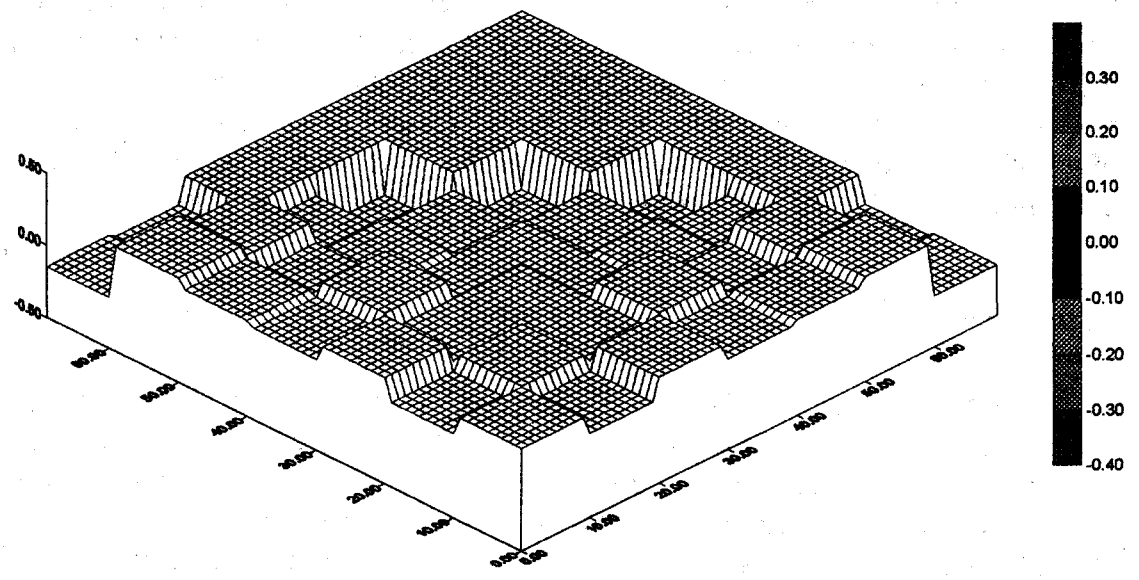

Figure 2: Power distribution errors (in % with maximum 0.35%) of the reactivity coefficient method for the EOL, ARO conditions.

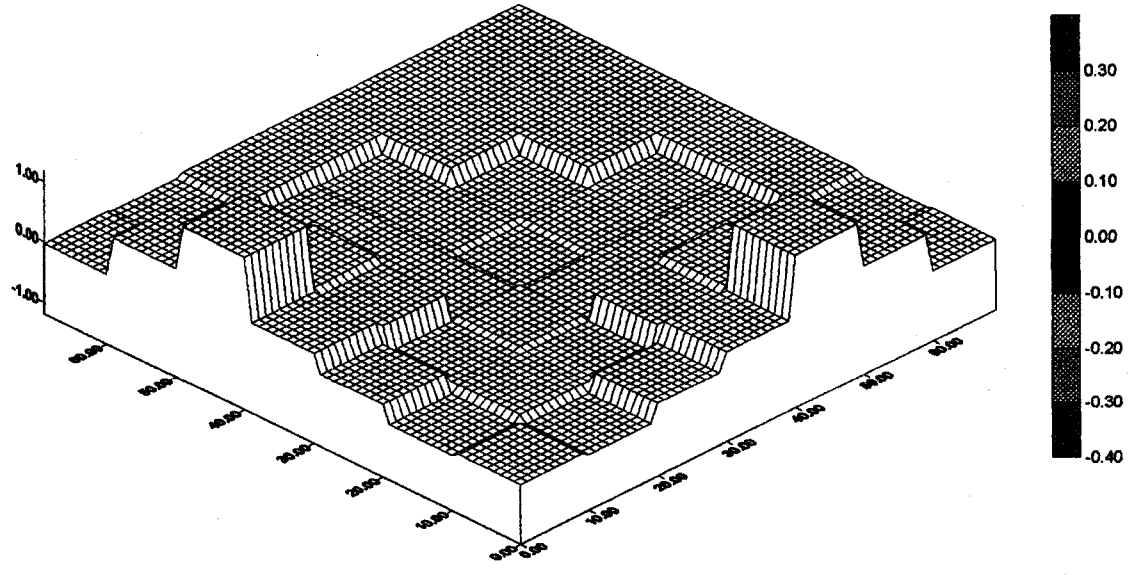

Figure 3: Power distribution errors (in % with maximum 1.37%) of the reactivity coefficient method for the BOL, D-in conditions.

5. Conclusion

Refined reactivity coefficient method incorporated into the CORD-2 package was found to be a powerful tool in the simulation of thermohydraulic and Xenon feedback effects. The method is very fast and its accuracy is sufficient even for the design calculations. Library of coefficients can be prepared in advance and needs to be changed only when substantial differences in fuel characteristics are introduced.

References

/1/ A.Trkov, M.Ravnik: *CORD-2 Package for PWR Nuclear Core Design Calculations,* Proceedings of the International Conference on Reactor Physics and Reactor Computations, Tel-Aviv, 23-26.Jan.1994, Ben-Gurion University of the Negev Press, (1994).

/2/ A.R.Askew, F.J.Fyers, P.B.Kemshell, A *General Description of the Code WIMS*, J.Br.Nucl.Energy Soc., 5, p.564, (1966).

/3/ A.Trkov: *GNOMER - Multigroup 3-Dimensional Neutron Diffusion Nodal Code with Thermohydraulic Feedbacks*, Institute Jozef Stefan, Ljubljana, Slovenia, IJS-DP-6688, Rev.1, Mar.1994.