USING GRAPH SPECTRA IN NUCLEAR FUEL RELOAD PATTERN OPTIMIZATION

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In the literature several methods for nuclear fuel loading optimization were proposed. They include but are not restricted to linear programming [1], heuristics methods (simulated annealing [2], tabu search [3], neural networks and genetic algorithms [4]), nonlinear optimization [5] and cellular automata [6]. The nuclear fuel loading optimization system Athena is designed primarily for loading optimization in WWER-type reactors but can be used for any reactor zone. The system can design a loading with any possible type of zone symmetry. The system is based on a combination of two approches: the first one uses the physical solver as a black box (a kind of black box optimization) and second one uses identification of the reactor core behaviour by a system of (nonlinear algebraic) equations which are successively optimized directly. The reason is that solving the model obtained by identification is fast and accurate for getting very good estimates of a suitable loading and the physical solver can compute a given loading with the highest possible accuracy (using a longer time of computation). A part of the black box approach is based on an adaptation of the theory of combinatorial landscapes (see [7]). As far as we know this is the first attempt to solve the loading design problem based on a combinatorial theory. The approach is based on finding a suitable topology for the solution space under considerations. In the talk we will present a necessary physical background, suitable mathematical methods for the problem under consideration and connections to spectral graph theory. References [1] Kunsch, P.L., Teghem, J. Jr., Nuclear fuel cycle optimization using multi-objective stochastic linear programming, European Journal of Operational Research, Elsevier, vol. 31(2), pages 240-249, August 1987. [2] D. J. Kropaczek and P. J. Turinsky, "In-Core Nuclear Fuel Management Optimization for PWRs Utilizing Simulated Annealing," Nucl. Tech., 95, 9, 1991. [3] A. Castillo, G. Alonso, L. B. Morales, C. Martín del Campo, J. L. François and E. del Valle, BWR fuel reloads design using a Tabu search technique, Annals of Nuclear Energy Volume 31, Issue 2, January 2004, Pages 151-161 [4] Adem Erdogan, Melih Geckinli,A PWR reload optimisation code (XCore) using artificial neural networks and genetic algorithms Annals of Nuclear Energy, Volume 30, Issue 1, January 2003, Pages 35-53 [5] A. J. Quist, K. Roos, T. Terlaky, R. Van Geemert and E. Hoogenboom, Reloading Nuclear Reactor Fuel Using Mixed-Integer Nonlinear Optimization, Optimization and Engineering, Volume 2, Number 3, September, 2001, Pages 251-276 [6] A. H. Fadaei, S. Setayeshi, A new optimization method based on cellular automata for VVER-1000 nuclear reactor loading pattern, Annals of Nuclear Energy Volume 36, Issue 5, 15 May 2009, Pages 659-667 [7] C. M. Reidys, P. F. Stadler, Combinatorial landscapes, SIAM Review, Volume 44 , Issue 1 (2002), Pages 3 - 54