Available online at www.sciencedirect.com

ScienceDirect

Applied Mathematics and Computation 187 (2007) 977–988

APPLIED MATHEMATICS AND COMPUTATION

www.elsevier.com/locate/amc

Application of a genetic algorithm to the fuel reload optimization for a research reactor

Binh Quang Do *, Lan Phuoc Nguyen

Centre for Nuclear Techniques, 217 Nguyen Trai St., District 1, Hochiminh City, Viet Nam

Abstract

This article presents results from an application of a genetic algorithm (GA) to the fuel reload optimization for a research reactor. In this work, we proposed an improved model of the problem and a new coding procedure for the GA to automatically search for optimal fuel loading patterns most suitable for the research reactor. The model consists of an objective function, which maximizes the effective multiplication factor and minimizes the power peaking factor, and operational and safety constraints. The new coding procedure is used to handle a constraint on the limited number of fuel shuffles in a refueling operation. The GA works with an elitist selection based on the elitism strategy and the roulette wheel spin method, a modified one-point crossover and a simple mutation. A computer program was developed in FORTRAN 90 running on a Pentium III personal computer to perform illustrative calculations for a research reactor type TRIGA MARK II. Results from illustrative calculations show that the GA can successfully search for the optimal loading patterns, which can be employed to establish a simple refueling scheme for the reactor with a limited number of fuel shuffles in a practical refueling operation.
© 2006 Elsevier Inc. All rights reserved.

Keywords: Genetic algorithm; Elitism strategy; Loading pattern; Optimization; Reactor calculation

1. Introduction

For nearly four decades research into the problem of in-core fuel management optimization has increasingly developed, resulting in a perspective progress. Many research works have been expansively performed since 1980 [1–17]. Recent research works have been usually based on stochastic methods like GA [6–12], simulated annealing method [13–16], simple tabu method [17], etc. as well as combinations of these methods with heuristic rules [7,10,14]. Turinsky [18] overviewed the development of nuclear fuel management optimization capabilities for PWRs and BWRs ranging from the employment of experience-based rules to the usage of mathematical approaches. However, many of them have focused on power reactors while a very few applied to research reactors.

* Corresponding author.
E-mail address: doquangbinh2005@yahoo.com (B.Q. Do).

0096-3003/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.amc.2006.09.024

It is reckoned that the application of optimization methods to finding optimal fuel loading patterns (LP) for research reactors has not yet attractive. One of the reasons is that the optimal LPs resulting from an automatic optimization search based on mathematical approaches often require the exchange of all the fuel bundles over the core. This requires an automatic refueling machine to perform practical refueling. However, automatic refueling machines have not been usually equipped at research reactor centers, so reactor managers prefer simple refueling schemes with a small number of fuel shuffles resulting from traditional experience-based rules. As a result, the preparation of refueling schemes for research reactors reveals a practical requirement that the fuel LPs for research reactors should satisfy a constraint on the limited number of fuel shuffles.

This work tried to apply a GA to automatically search for the optimal fuel LPs for a research reactor. A principal objective of the fuel reload optimization problem is to extend cycle length of the reactor. This requires the maximization of the effective multiplication factor k_{eff}. In addition, in order to reduce the risk the power peaking factor (PPF) should be reduced as low as possible, hence another objective of the problem is the minimization of the PPF. These objectives are considered as competing and conflicting with each other because any attempt at maximization of reactivity will be limited by the PPF constraint [2]. Therefore, the fuel reload optimization problem for research reactors is a multi-objective optimization problem that both maximizes the effective multiplication factor k_{eff} and minimizes the PPF while satisfying operational and safety constraints. In order to handle the constraint on the limited number of fuel shuffles the GA needs a suitable coding procedure for transforming LPs into chromosomes. In the following, the model of the problem is presented in Section 2; Section 3 describes the proposed GA; Section 4 briefly introduces a computer program coded for this purpose; results from illustrative calculations for a research reactor type TRIGA MARK II are presented and discussed in Section 5; and the final section is conclusions.

2. Model of the problem

Decision variable of the reload optimization problem is a fuel LP that is just the core configuration consisting of fresh and burnt fuel at the beginning of cycle (BOC). Objective of the problem aims at finding the optimal LPs that maximize the k_{eff} and minimize the PPF. For such a bi-objective optimization, the objective function can be set up according to the weighting method [19] as follows:

$$F = \alpha(k_{eff} - 1) + \beta(\mathrm{PPF}^0 - \mathrm{PPF}), \qquad (1)$$

where PPF^0 is an input factor that is chosen so that the PPF is always lower than it, α is the weighting factor for k_{eff} and β is the weighting factor for the PPF, α and β are positive coefficients and are considered as a measure of the k_{eff} and PPF significance, respectively.

Constraints include operational and safety parameters

$$k_{min} \leqslant k_{eff} \leqslant k_{max}, \qquad (2)$$

$$\mathrm{PPF} \leqslant \mathrm{PPF}_{max}, \qquad (3)$$

$$\mathrm{BU} \leqslant \mathrm{BU}_{max}, \qquad (4)$$

$$N_{FS} \leqslant N_{max}, \qquad (5)$$

where k_{min} and k_{max} are the limits of k_{eff}, PPF_{max} is the maximum power peaking factor, BU_{max} is the maximum fuel burn-up, N_{FS} is the number of fuel shuffles issued from the core configuration at the end of cycle (EOC), and N_{max} is the limit on the number of fuel shuffles. A fuel shuffle in this study is a binary exchange of two fuel bundles in the reactor core at the beginning of cycle (BOC), i.e. the core configuration produced after replacement of the discharge fuel bundles by fresh fuel. One of the two shuffled bundles is a fresh fuel bundle at fixed positions and another is a certain spent fuel bundle remained in the core. The fixed core positions are the positions of discharge fuel bundles; however, they can be defined by users for some specific purposes.

Eqs. (2) and (3) are reactivity and thermal limits. Constraint (4) defines the set of burnt bundles remained in the reactor core for the next cycle. A constraint on the limited number of fuel shuffles in a refueling operation is introduced in this model by Eq. (5). This constraint gives rise from practical operation of the research

Download English Version:

https://daneshyari.com/en/article/4636373

Download Persian Version:

https://daneshyari.com/article/4636373

Daneshyari.com