Nuclear Services / Engineering Services

Fuel Movement Planning Optimization Technology

Background

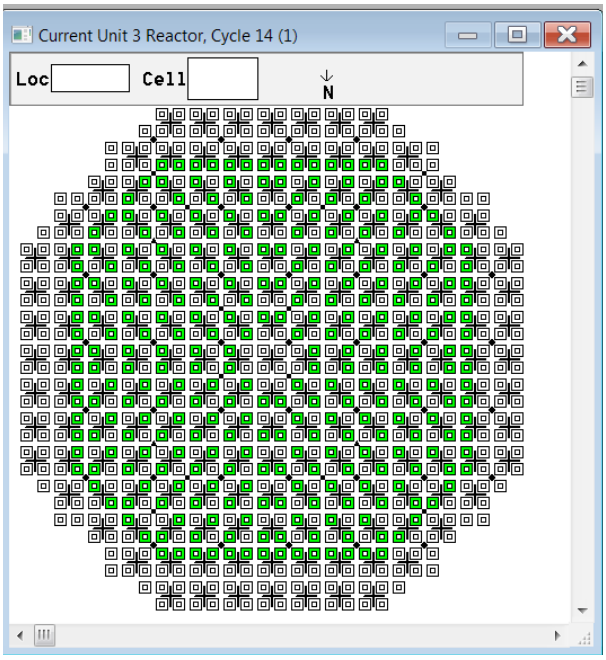
Westinghouse's computer-based ShuffleWorks® system helps utilities plan and monitor fuel/component movement activities more efficiently, resulting in reduced operation and maintenance costs. The ShuffleWorks system is designed to meet fuel-movement planning and monitoring requirements of pressurized water reactors and boiling water reactors. The ShuffleWorks system encompasses 20 years of utility expertise in one computer-based package. In addition, Westinghouse has explored applying simulated annealing optimization technology to enhance the ShuffleWorks system's "expert" approach to planning and to further reduce in-core fuel movement time.

Description

Saving an hour or more of refueling time at a nuclear reactor translates into substantial cost savings to the utility. A recent Westinghouse technology innovation project evaluated how to optimize in-core shuffle planning using simulated annealing methods. The goal of the Westinghouse innovation project is to leverage the extensive ShuffleWorks system customer base to test and quantify the benefit of optimization techniques over the current heuristic or "expert knowledge" approach for planning in-core fuel shuffles.

Simulated Annealing Overview

Simulated annealing is an optimization methodology particularly useful for finding relative optimal values in complex systems. The basic process is to increase the entropy of a given system, allowing it to "settle" into a lower energy threshold. This process occurs repetitively, potentially millions of times, with different randomizations of the system states each time.



ShuffleWorks system screen map of a reactor core

Applicability of Simulated Annealing to Fuel-movement Planning

In fuel-movement planning, engineers take an end-of-cycle core map and produce a sequence of fuel-movement steps to reconfigure the fuel assemblies into the beginning-of-cycle core pattern. This is considered to be a problem of high computational complexity and, therefore, is difficult to solve with the deterministic methods that apply "expert" logic. Traditionally, the ShuffleWorks system has taken a deterministic approach to produce high-quality step sequences optimized for both the shortest fuel-movement travel distance and the fewest fuel-movement steps. Using the simulated annealing methodology, Westinghouse has been able to join the ShuffleWorks system's high-quality deterministic approach with probabilistic methods that perform more exhaustive searching across potential shuffle-step sequences. During this search, Westinghouse technology detects the qualitative differences of the various shuffles and selects the best option.

Westinghouse

Westinghouse Simulated Annealing Innovation Project

Westinghouse has developed a simulated annealing software prototype code that interfaces with the ShuffleWorks system. In its testing phase, Westinghouse demonstrated that both the ShuffleWorks system's expert planning method and the simulated annealing optimization planning method can produce above-average in-core shuffles. In some cases, the simulated annealing prototype produced in-core shuffle efficiency improvements of 1 to 2 percent when compared with shuffles produced with the base product. Data from the innovation project indicate that, with additional tuning of fuel-movement planning parameters and longer computer run times, an improvement of up to 5 percent could potentially be achieved over heuristic in-core shuffles.

Westinghouse Simulated Annealing Service

To augment our fuel data management ShuffleWorks product, Westinghouse is offering this simulated annealing technology as a value-added service. We are also willing to explore the application of this methodology to pool capacity management and cask-loading applications. We can work with customers that are interested in this optimization technology.

Benefits

- Cost Benefit: Reduced in-core shuffle outage time
- Deliverable: A ShuffleWorks-compatible, in-core fuel-movement sequence with improved shuffle efficiency

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