Deep reinforcement learning for the optimization of loading plans for NPPs

In collaboration with TRACTABEL (ENGIE) Bruxelles - Belgium

Context of the research

The development of fuel loading plans for Nuclear Power Plants (NPPs) cores is a complex optimization aimed at ensuring operational safety, while maximizing economic performance in terms of cycle length, fuel utilization and discharge burnup. Traditionally, loading plans have been defined by a trial-and-error approach, which is time-consuming and achieves suboptimal solutions.
To address these limitations, metaheuristic optimization techniques, such as simulated annealing and genetic algorithms, were introduced in the 1990s and 2000s. Although these methods have been integrated into modern software tools (e.g., ROSA by NRG), they still suffer from significant computational inefficiencies and do not always guarantee globally optimal solutions.
This thesis aims to develop and apply a methodology based on Reinforcement Learning (RL) to optimize NPPs core loading plans. By leveraging RL, this research seeks to provide more efficient and effective solutions to NPPs core loading to enhance both safety and economic performance.

Objective of the research

The research aims to develop a RL-based methodology for NPPs core loading. The performance of the RL-discovered policy will be compared to those of state-of-the-art optimization methods to highlight advantages and potential improvements. The research activity will include:

- Literature review on reinforcement learning and its application to NPPs loading plans optimization
- Analysis and comparison of available optimization techniques, methodologies and tools
- Definition and development of synthetic and real case studies.
- Environment modeling and implementation of state-of-the-art approaches.
- Application of RL to synthetic and real case studies, and comparison with state-of-the-art approaches;
- Identification of methodological limitations and proposal of directions for future research.

Collaborations

Tractebel, part of the Engie Group, is a leading engineering firm specializing in energy and nuclear safety. The work will be performed in the Laboratory of Analysis of Systems for the Assessment of Reliability, Risk and Resilience (LASAR^3) of Politecnico di Milano in tight collaboration with TRACTABEL in Bruxelles (Belgium), where an internship is foreseen.

For further information, please contact:
Prof. Piero Baraldi, piero.baraldi@polimi.it, 02 2399 6345
Prof. Enrico Zio, enrico.zio@polimi.it, 02 2399 6340