SMR-DISP-2023B

Call for applications for a M2 research internship

Optimizing a nuclear power scenario

Supervision:
Matthieu GUILLOT, Khaled HADJ-HAMOU, Kévin TIREL

University: Lyon 2
Research laboratory: DISP laboratory

Required profile:
Master 2 or equivalent in computer science, optimization or operational research

Funding: around 600€ per month

Internship period: February to July 2023

Required skills:
modeling, optimization, linear programming, Python, LP solvers (Cplex, Gurobi)

Key words: optimization, modeling, linear programming, operational research

Background & motivation:

In the context of the fight against climate change, the decarbonization of energy production is a central issue. Over the past century, France has opted to rely heavily on nuclear power generation, which has enabled it to achieve low CO2 emissions. The long-term management of a nuclear plant is a difficult chellenge, as it is subject to many uncertainties: how many reactors will be deployed in the future? What type of reactor will be preferred? What strategy should be adopted for nuclear materials management?

The "electronuclear scenario" is one of the tools we have at our disposal to deal with these uncertainties. It involves the dynamic simulation of a nuclear plant from the point of view of material flows. More precisely, the entire fuel cycle is modeled, from the extraction of natural resources, through fuel fabrication processes, irradiation of the fuel in the reactor, cooling of the irradiated fuel, recycling of materials and, finally, waste production. Scenario simulation is based on scientific computing tools that enable fine modeling of core irradiation and material evolution over time. At the end of the scenario simulation, it is possible to access the various material flows that have taken place over the duration of the simulation, as well as the evolution of the various inventories monitored (masses of spent fuel stored, mass of plutonium present in the fleet, mass of waste generated and stored, etc.). In particular, physical or technological limits can be highlighted through scenario simulation. For example, a shortage of material to feed a reactor can be detected, thereby jeopardizing the evolution of the plant under study. Alternatively, quantifying the flows to be processed over time can provide indications for future plant sizing.

Problem description:

In this study, we are interested in the modeling and optimization of an electronuclear scenario. A set of irradiated fuels from existing reactors is available. These fuels are classified according to their composition. Each year, a certain quantity of material is taken from each type of irradiated fuel. After reprocessing in dedicated plants, it is possible to extract the plutonium isotopes that will be used as fuel raw material. This new fuel can only be manufactured if the composition of the raw material is appropriate, and will be used to power a nuclear reactor.

Our problem consists in sizing reprocessing plants to extract the right quantity of irradiated fuel of each type at each time step considered over a given time horizon (typically 100 years), in order to respect two hard constraints: on the one hand, we need to ensure that the stock of raw material is never empty; and on the other, we need to guarantee that the composition of the raw material actually allows the manufacture of new fuel.

In this Master2 project, we propose to model the selection of spent fuel quantities and the movement of fuel through different states as a linear program, initially simplifying the steps inducing non-linear constraints.

Candidate profile:

The candidate should have a good knowledge of computer science, optimization and operations research. He/she should be able to model the electronuclear scenario optimization problem as a linear program and solve it using dedicated solvers (CPLEX, GUROBI). In addition, good development skills in Python are required in order to process real data, interface with the linear programming solver, and analyze the results obtained.

Finally, the candidate should be curious and interested in nuclear physics and its applications, since results will have to be analyzed from a physical point of view. Knowledge in this field is not required, but candidates should be open to further training.

Continuation in thesis:

This subject will be pursued through the funding of a doctoral thesis by CEA, on the Cadarache site. This will be an opportunity for the candidate to build on the work done in the Master2 internship, by modeling more realistically the most complex aspects of fuel movements and transformations in all their forms. This work will subsequently be used to study the robustness and resilience of nuclear power scenarios in the face of uncertainties about the future of the nuclear plant.

Submit your application by November 30, 2023, by sending an email to Matthieu GUILLOT (matthieu.guillot@univ-lyon2.fr), . Kévin TIREL (kevin.tirel@cea.fr) and Khaled HADJ-HAMOU (khaled.hadj-hamou@insa-lyon.fr) Precise the job offer reference (SMR-DISP-2023B) and attach a file composed of CV and motivation letter.