

Multi-energy optimization for industry decarbonization

Expected start-up Fall 2022

Context of the thesis

The recent conclusions issued by the International Energy Agency to achieve the goal of carbon neutrality by 2050 highlight the need for massive investment in clean energy and energy systems (electricity, gas and thermal). The decarbonation of the industrial sector is one of the important levers and that is why France has integrated it in its fourth Program of Investments for the Future (PIA4) via a priority research program (PEPR). The thesis is part of the PEPR ACT-4-IE project (A systemic and Territorial approach to decarbonize activity areas with Industrial Ecology) whose objective is to develop a systemic approach to decarbonize industrial areas by promoting local multi-flow symbioses. This project involves several complementary academic partners: the Chemical Engineering Laboratory (LGC), the Environmental and Food Process Engineering Laboratory (GEPEA), the Grenoble Electrical Engineering Laboratory (G2Elab), the Lorraine Research Laboratory in Computer Science and Applications (LORIA) and IFP Energies nouvelles (IFPEN).

Keywords : multi-systems, multi-flows, system modeling, optimization, industrial eco-park

Objectives and structure of the thesis

The objective of the thesis is to develop a multi-energy planning methodology via a constrained multi-objective systemic optimization allowing to define optimal decarbonization strategies for the industry and the energy systems to which it is connected (power system, heat system and possibly gas system). These strategies will consist in defining (i) the optimal technological choices specific to the various energy vectors and the interfacing technologies such as, for example, heat pumps and electrolyzers; (ii) the energy flow management mode allowing to optimize the exploitation of the industrial site(s); (iii) (depending on the progress of the other points) the architecture and the electrical distribution mode of the site or even of the system to which it is connected (AC versus DC).

To meet these objectives, the thesis work will involve several steps:

- **A bibliographic study** to define the existing and future use cases, their spatial and temporal perimeter and the digital and optimization tools used. We can cite the following examples (non-exhaustive list):
 - *Flexibility use cases* (from the industrial site scale to the territorial scale) :
 - maximizing the flexibility (in terms of electrical power able to be curtailed) available at any time for participation in the generation/consumption balance of the systems (short term),
 - postponement of investment in the power system to which the industrial plant is connected (medium-long term).
 - *Use case of multi-energy and multi-objective optimization of systems exchanges*. The objectives of the optimization can cover, for example, the issues of management, reliability, quality of service...
 - *Integration of renewable energy and storage technologies for local symbiosis*.

- **Use of adapted KPIs (Key Performance Indicators)** defined in partnership with the other members of the project: costs, reliability of the overall system, environmental and societal impacts, etc.
- **Modeling and mathematical formulation of the problem according to the time horizon and the use cases:** choice of the models used (of the various energy systems as well as their interactions, their components, existing and future technologies, etc.), objective functions and constraints. Given the high degree of uncertainty on the development of technologies and on the future production and consumption of uses, a reflection will have to be carried out on the methods to take into account the uncertainties (approaches by scenarios, probabilistic, sensitivity analysis etc.). This reflection will have a direct impact on the optimization tools that will be developed later.
- **Development of optimization tools:** a literature review on optimization methods will allow the selection of the most suitable method(s) for the multi-energy planning problem. A compromise will have to be found between computation time and robustness of the results. The analysis will cover the different families of optimization methods and their possible combinations.
- **Application to industrial sites/territorial areas:** the planning tools developed will be tested and adapted in relation to the industrial sites/territorial areas selected by the project partners. The interest of the developed models will be confronted to the classical reference cases of the literature (e.g. MILP) in order to quantify the benefits and impacts.

Required knowledge

- Modeling and operation of electrical and thermal systems (component models, load flow equations, stability etc.)
- Knowledge in optimization and mathematical language programming would be a plus or to be acquired at the beginning of the thesis
- Mastery of Matlab or Python

Skills required

- Taste for research
- Good level of French and English
- Ability to work in a team

Location of work

The PhD student will be mainly based at G2Elab in Grenoble with frequent travels to GEPEA in Nantes. Travel is also expected in connection with the project (plenary sessions, seminars and conferences).

Type of visa for non-European candidates : Passeport talent-chercheur

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