Post-doctoral research position - January 2023

Title: Operational Optimization of Innovative Heating and Cooling Urban Network

This post-doctoral research position will take place in Le Bourget du Lac (73, France) in the Laboratory of Energy Systems for Territories (LSET), which is part of the LITEN Institute within the French Alternative Energies and Atomic Commission (CEA). It will be performed in collaboration with the LOCIE laboratory (CNRS / University Savoie Mont-Blanc)[1].

Context:

Due to their inherent ability to integrate renewable and waste energies efficiently [1], urban thermal networks are key systems for any policies aiming at limiting global warming [2]. With the increase in space cooling demands, expected to be multiplied by 1.6 from 2016 to 2050 in Europe [3], urban areas energy systems must evolve. Even though individual reversible heat pumps present some advantages (modularity, resilience to variations of heat to cold demand ratio), a generalization of their development induces numerous issues: low efficiency of air as thermodynamic source, increased stress on the electrical grid, enhancement of urban heat island phenomenon, architectural integration, etc. In this context and in the frame of smart energy systems development, i.e. systems taking advantage of positive synergies between energy carriers, the concept of 5th generation district heating and cooling systems has been introduced (5GDHC) [4]. The latter concept is generally presented as an extension of older generations district heating networks (1G to 4G, [1]). 5GDHC systems are able to ensure heat and cold demands with high spatial and temporal variability by making use of a set of hydraulic pumps and a network operating close to ambient temperature, which offers a high quality thermodynamic source to a set of distributed thermodynamic machines (heat pumps and/or chillers) [5].

This new type of urban network presents a multi-dimensional complexity (design, sizing, control) with a high potential for innovation. The main objective here is to address the operational control optimization aspect by proposing, implementing and testing innovative control of 5GHC system in a virtual environment.

State-Of-the-Art:

From an industrial point of view, about 40 systems currently exist in Europe [4] E.ON is a major player with i) its solution off-the-shelve E.ON ectogrid™, ii) its research center based at Aachen university (very active in the 5GDHC field), and iii) a dozen of patent since 2017.

From an academic point of view, the activity in the field of optimization of 5GDHC systems is exponential since 2016. Using a simple simulator and logic based control laws, Revesz et al. [6] concluded that a detailed modeling of thermo-hydraulic was necessary at both the simulator and the controller levels

[1] https://www.univ-smb.fr/locie/

in order to tackle properly the problematic. Different authors addressed the problem using model-based controller. Wirtz et al. [7] used a MILP (Mixed Integer Linear Program) only model with discretized level of temperatures. Hering et al. [8] used a MIQCP (Mixed Integer Quadratically Constrained Program) to tackle the non-linearity associated with the thermo-hydraulic. Bunning et al. [9] used a 2-stage controller combining a non-linear pre-calculation of the optimal temperature trajectory followed by a multi agent control of the different production units. These different approaches emphasized the need of controlling the temperature in the different lines to enhance the efficiency of the thermodynamic machine dynamically rather than having a floating temperature

Objectives

Our team is active in the field of optimal control of district heating networks and exergetic analysis throughout research projects conducted with industrial partners relying on both experimental and numerical means. The latter projects led to scientific publications ([10], [11] and [12]) and development of dedicated tool (see next Section).

Compared to the state-of-the-art, the proposed project goal is to go further by including in the controller:

- The optimization of the temperature in different points of the lines,
- The optimization of the flow rate / differential pressure of the distributed hydraulic pumps to pressurize one line or the other at appropriate moments,
- An exergo-economic based approach to tackle properly the thermal/electrical coupling.

The objectives for this 24-months postdoctoral project are:

- To model a simple yet generic 5GDHC circular network within DistrictLab-H, the modeling and simulation environment developed in our lab for district heating systems;
- To formulate/implement a model based controller of this 5GDHC network using an exergo-economic approach within PEGASE, the cosimulation/optimization platform of our lab;
- To realize a proof of concept of the model based controller (2^{nd} objective) on the built simulator (1^{st} objective) and compare it with state-of-the art common controllers of this type of system;
- To disseminate the result through participations to international conferences and publications in high impact factors journal papers;
- To protect the innovation through patent redaction.

The postdoctoral researcher will have an access i) to state-of-the art tools allowing to program, verify and validate operational optimization strategies for complex thermal grids and ii) to the computer clusters of CEA Grenoble research center.

Qualifications and experience:

- PhD in Optimization and / or Simulation
- Strong interest / background for the energy sector
- Knowledge of C++/Python programming

Language skills:

As an international research center, we are particularly keen to ensure that we attract applicants from France and abroad yet, proficiency in French or English is required.

How to apply:

Please submit your application with a CV, a motivation letter, a list of publications and the names of 3 references, including one from your present work place.

Miscellaneous:

Where?: CEA INES in Le Bourget du Lac	**When?**: from January 2023, 24 months
Benefits?: Refer to general employment conditions in CEA	**Contact for application and further information:** nicolas.lamaison@cea.fr

References:

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