Université Gustave Eiffel

Research Internship Proposal

Modeling and Control of Electro-Thermal Smart Grids for Smart Cities

Supervisors:

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Keywords: MicroGrid, SmartGrid, Heat network, Combined Heat and Power, Modeling, Control.

I. Context and description

Under the increasing pressure of political and climatic challenges to reduce global carbon emissions, as required by COP21 and the Paris Agreement, a major transformation of lifestyles, production methods, and urban planning practices has now become essential. Reinventing cities for sustainability and resilience is essential to optimize energy consumption and integrate new technologies. The electricity sector is rapidly evolving with renewable energy sources (RES) [1], distributed generation (DG), and electric vehicles (EVs). SmartGrids, key to the future power grid, integrate DG units like EVs and energy storage systems [2] using intelligent forecasting, ICT, and control infrastructures

At the same time, about 40% of the electricity consumption of businesses and homes is dedicated to heating and air conditioning. Furthermore, the electrical and thermal dynamics differ significantly, with thermal inertia offering a form of natural storage compared to electricity. Few studies examine combined electrical and thermal models. Notable examples include the series of works such as [3] and [4], which introduce the concept of the Energy Hub. Each Energy Hub comprises three basic elements: connections, power converters, and storage. This framework enables the development of a model for the Energy Hub and the associated electrical and thermal distribution networks through a system of non-linear equations. Other studies, such as [5] and [6] (focused on railway stations), propose an analysis of these combined networks. These analyses are performed in stages, initially evaluating the electrical and thermal power flows separately and then together, forming a combined state vector of high order. The general system is then linearized (as in [7]), and the analysis is conducted through time-based solutions of its Jacobian matrix using a Newton-Raphson algorithm. More recently, [8] has developed a combined model and analysis that facilitates the calculation of an Optimal Power Flow to minimize system costs and losses while adhering to power flow constraints.

This internship will first focus on modeling the electro-thermal smart grid. Then, control and management algorithms will be developed and investigated at the neighborhood scale. This task is challenging due to the size and complexity of these networks and the diverse range of dynamics involved, including electrical, thermal, and potentially mechanical systems. Finally, simulations will be conducted to validate the proposed model and demonstrate the effectiveness of the control method.

II. Work plan

The objective of this internship is to develop a model and control/management algorithm for an electro-thermal smart grid at the neighborhood level, inspired by the recent work in [9], and to validate the proposed system through simulations and/or real experiments. The concept is very innovative and challenging, because even if very logical, it is also quite complex. The algorithms will be developed based on these new elements and should enable the seamless integration of RES and EVs into existing networks. This integration will leverage the flexibility provided by the coordinated management of multiple energy vectors and potentially incorporate distributed information and weather forecasts. It is crucial to highlight that the ultimate objective is to empirically validate the efficiency, performance, and accuracy of the proposed methodologies. The steps of this internship are as follows:

1. Review the literature on electrical and thermal modeling and control approaches.
2. Develop a comprehensive mathematical model integrating electrical, thermal, and mechanical dynamics.
3. Design control and management algorithms.
4. Perform validation of the proposed model and control method through simulations.

III. Required skills

The required skills include strong motivation and a background in one of the main fields of this work: control, mathematics, power systems, or thermal system. Expertise in numerical tools like MATLAB/Simulink/Simscape and multi-scale modeling will be appreciated. The work can be conducted in English or French, depending on the candidate's language skills.

IV. Internship information

Duration: 6 months (Starting from February/March 2025)

Location: Université Gustave Eiffel, Campus Marne-la-Vallée, bâtiment Bienvenüe, 5 Boulevard Descartes, Champs-sur-Marne F-77454 Marne-la-Vallée Cedex 2, France

Gratification: Legal rate, approximately 550€/month for 6 months.

How to Apply: Please send your most recent transcripts, CV, and motivation letter to : asma.achnib@univ-eiffel.fr and gilney.damm@univ-eiffel.fr.

V. References

[1] Cochran, J., Mai, T., & Bazilian, M. (2014). Meta-analysis of high penetration renewable energy scenarios. Renewable and Sustainable Energy Reviews, 29, 246-253.

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