Artificial Intelligence and blockchain for decentralized energy management in an energy community of smart buildings

Abstract:

Local energy communities (LECs) comprise prosumers cooperating for the satisfaction of their energy needs. Prosumers are community members that can both produce and consume energy. LECs facilitate the integration of renewables and provide the potential for reducing energy costs. Peer-to-peer (P2P) energy trading allows direct energy exchange between members of a local energy community. The surplus of energy from renewables is traded to meet a local consumption demand so that costs and revenues stay within community avoiding transmission losses and stress on the grid. This PhD proposal aims at using Artificial intelligence and blockchain to design a smart peer-to-peer market for local energy communities where prosumers are rational and self-interested agents acting selfishly in an attempt to optimize their trades. The market design aims to ensure self-consumption of locally produced energy and provides incentives for balancing supply and demand within community. The proposed design will be investigated in comparison with existing ones (centralized and decentralized management) using theoretical analysis and simulations. The comparison will consider the environmental impact of the digital solutions developed and the use of AI to try to minimize it.

Keywords: Energy community, Energy management, Peer-to-Peer, Artificial Intelligence, Blockchain, Deep learning, Multi-agent systems

Required skills:

Training level: Master 2 or Engineer fifth year. Strong capability of coding using Python and Matlab
Good knowledge on micro-grids and renewable energy systems.

Research context:

SMART Control Systems (SCS) Team of the Smart Systems and Energies department (Junia, HEI Lille) exploits the latest mathematical theories and advanced technologies such artificial intelligence for the optimal design, control and operation of multi-energy systems. It brings together transdisciplinary activities with experts in the fields of micro-grids, optimization and control, and data analysis.

This thesis project is an extension of Matthieu STEPHANT's thesis : "Optimization of self-consumption in a renewable energy community via a blockchain". In his PhD, Matthieu presents a distributive method of optimizing exchanges, based on game theory. To implement this approach in a concrete way, Matthieu proposes to use blockchain technology, which constitutes both a communication network and a distributed database. This technology has the potential to automate optimization operations while ensuring complete decentralization.

As perspectives, it is important to compare game theory with other techniques such as deep learning or multi-agent systems. In addition, it is required to well forecast electric consumption and production. Finally, it is crucial to study the interaction between AI and blockchain and to assess the energy cost of such a solution.

Localization: HEI-Lille (Junia), 13 Rue de Toul 59000, France/ L2EP laboratory/ Smart Control Systems Junia team.

Duration: 3 years

Supervisors: Kahina HASSAM OUARI, Benoit ROBYNS and Dhaker ABBES **(Dr.Ing. HdR PhD director)**

Supervisors' presentation:

- **Prof. Dhaker ABBES, PhD Director:** Electrical and Control Engineer since 2007 and has a doctorate in Electrical Engineering since 2012 from ENSIP Poitiers in France, with a confirmed specialty in renewable energy, micro-grids and optimization of complex energy systems. He is a full professor (HDR : "Habilité à Diriger des Recherches") and co-head of Energy, Electrical and Automated Systems (ESEA) field in the engineering school Junia. He is also a member of electrical networks team in the L2EP Laboratory and head of Smart Control Systems (SCS) Research team in Junia. He is author or co-author of many scientific publications in journals and national and international conferences and of two books. He is also an invited teacher in ISEC Coimbra (Portugal) and the Polytechnic University of Bucharest (Romania) and has many close collaborations with several other local and international schools (ECL Lille, France, EIGSI La Rochelle, EILCO Côte d'Opale, ENIM and ENIS Tunisia, TEI of Kavala in Greece, etc.). Moreover, he is a reviewer in several scientific journals (IET, MATCOM, Applied Energy, etc.) and member of the scientific committee of the international conferences STA (International conference on Sciences and Techniques of Automatic control & computer engineering) and ICSC (International Conference on Systems and Control).
- **Prof. Benoit ROBYNS , PhD Co-director :** received the Ingénieur Civil Electricien and Docteur en Sciences Appliquées degrees from the Catholic University of Louvain, Louvain-la-Neuve, Belgium, in 1987 and 1993, respectively, and the Habilitation à Diriger des Recherches degree from the Université des Sciences et Technologies de Lille, Lille, France, in 2000.
  From 1988 to 1995, he was an Assistant in the Laboratory of Electrotechnics and Instrumentation, Faculty of Applied Sciences, Catholic University of Louvain. Since 1995, he has been with the Ecole des Hautes Etudes d'Ingénieur, Lille, where he was Director of Research from 2006 to 2019. He is currently deputy scientific director of the engineering school Junia. Since 2015, he is Vice President Energetic and Social Transition of Catholic University of Lille.
  Since 2003, he is head of the Power Systems Team of the Laboratory of Electrotechnics and Power Electronics of Lille (L2EP). He is the author or coauthor of 250 papers and 5 books in the fields of digital control of electric machines, renewable energies, distributed generation, storage systems, and power systems (Published in French, English and one in Chinese).

- **Dr. Kahina HASSAM-OUARI, PhD Supervisor:** Assistant professor at HEI, Junia Lille, has a doctorate on computer science since 2011 from University of Bretagne, France. Specialist on data analysis, tools development and blockchain. She contributes on the supervision of Matthieu STEPHANT PhD Thesis. Many scientific publications in journals and national and international conferences.

Context and goals:

With the insertion of renewable energy sources into distribution networks, new patterns of energy consumption and exchange are developing. This is the case with renewable energy communities, in which producers and consumers share locally produced electricity, with the aim of improving self-consumption by enhancing and aggregating the flexibility of users. The large-scale deployment of these operations requires the establishment of energy management methods to coordinate the actions of participants and therefore optimize energy exchanges.

To answer this problem and extending previous work [1] [2] [3], this thesis will investigate a distributive method of optimizing exchanges based on artificial intelligence (deep learning and multi-agent systems) [4]. In addition, blockchain technology will be deployed to automate optimization operations while ensuring complete decentralization [5]. Indeed, blockchain is a vector of acceleration and reliability of AI, particularly in energy exchanges with the concept of "Smart Contract". Proposed method will be investigated in comparison with existing ones (centralized management with fuzzy logic and decentralized management with game theory [6]) using theoretical analysis and simulations. The comparison will consider the environmental impact of the digital solutions developed and the use of AI to try to minimize it.

References

- [1] Matthieu STEPHANT; Dhaker Abbes; Kahina Hassam-Ouari; Antoine Labrunie; Benoît Robyns, “Distributed optimization of energy profiles to improve photovoltaic self-consumption on a local energy community” , Simulation Modelling Practice and Theory, 2020.

- [2] Matthieu Stephant, Kahina Hassam-Ouari, Dhaker Abbes, Antoine Labrunie et Benoît Robyns, Distributed optimization of power profiles on a local energy community using blockchain. In : 2020 5th International Conference on Smart and Sustainable Technologies (SpliTech). IEEE, 2020. p. 1-6.

- [3] Matthieu Stephant, Kahina Hassam-Ouari, Dhaker Abbes, Antoine Labrunie, Benoît Robyns, “A survey on energy management and blockchain for collective self-consumption”, 7th International Conference on Systems and Control (ICSC'18), October 24, 2018 to Friday October 26, 2018, Universitat Politècnica de València, Spain.

- [4] Benoît Robyns, Arnaud Davigny, et Christophe Saudemont, “Methodologies for supervision of hybrid energy sources based on storage systems–a survey”, Mathematics and Computers in Simulation, 2013, vol. 91, p. 52-71.

- [5] Matthieu Stephant, Dhaker Abbes, Kahina Hassam-Ouari, Antoine Labrunie, Benoît Robyns, “Increasing photovoltaic self-consumption with game theory and blockchain” EAI Endorsed Transactions on Energy Web, 10/2020.

- [6] Benoit Durillon, Arnaud Davigny, Sabine Kazmierczak et al. “Decentralized neighbourhood energy management considering residential profiles and welfare for grid load smoothing”, Sustainable Cities and Society, 2020, vol. 63, p. 102464.

The thesis schedule:

This project will run over a period of the thesis (36 months)
Step 1: Modeling of the energy community (duration 4 months) :

- *Configuration definition*
- *Components modeling*
- *Data collection*
- *Consumption and production assessment.*

In this step, deep learning will be used to provide an extremely reliable forecast, hour by hour, of the energy consumption of the buildings within the energy community in the coming weeks and to analyze the behavior and preferences of the inhabitants, and generate models of action.

Stage 2: AI and Blockchain for peer-to-peer market design (12 months) :
In this phase, we proceed with the design of the peer-to-peer market for the local energy community based on AI (deep learning, fuzzy logic, multi-agent systems, etc.) and blockchain.

Step 3: Validation of the prosed solution (12 months) :
This step is crucial, it consist on the comparison of the proposed solution based on AI with existing solutions especially in terms of energy impact and on the answer to these questions:
Does AI go beyond game theory? Does it allow predicting the parameters that characterize the behaviors and wishes of users / actors? Could AI make it possible to reduce the energy consumption of the blockchain?

Step 4: Development of an ergonomic tool for the deployment of the solution (4 months):
A software layer will be developed to allow an ergonomic operation of the solution.

Step 5: thesis document writing in parallel with step 4 (6 months).

Motivation for the program *AI_Engineering_PhD@Lille:*

The objective of this thesis is in complete cohesion with the power plant program.

Our primary motivation is to offer the AI tool for energy management in energy communities and for multi-energy systems. Artificial intelligence (AI) is at the heart of the latest innovations in smart buildings. It allows to act with the behavior and consumption of residents, but also to master the energy of the building, or to apply a predictive maintenance. AI can also be applied at the scale of a district, then to the city, in order to choose the right investments to save energy.

It is an interdisciplinary project bringing together several disciplines (Computer Science, control and electrical engineering).

Finally, this thesis will try to answer to these questions: Does AI go beyond game theory? Does it allow predicting the parameters that characterize the behaviors and wishes of users / actors? Could AI make it possible to reduce the energy consumption of the blockchain?