A multi-agent system for energy trading between prosumers

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Abstract. Local energy communities are identified as a promising approach to efficiently integrate distributed generation whereas keeping costs down for prosumers. In this context, we propose a multi-agent system to collectively optimise the energy flows of a local community of prosumers. The novelty and strength of our approach resides in the use of decentralised decision making algorithms, based on the alternating direction method of multipliers, to orchestrate the demand and supply of a large number of homes. Our preliminary results show how the proposed approach can significantly increase the self-consumption level of the community while significantly reducing the energy bills of its members.

Keywords: multi-agent systems, distributed optimisation, local energy exchange, alternating direction method of multipliers, prosumer community.

1 Introduction

Smaller commercial and residential customers account for between one-third and one-half of the total electricity consumption in many markets and represent the greatest need and opportunity for demand response [3]. Furthermore, more and more consumers are becoming *prosumers* (i.e. producing their own energies with renewable green technologies such as solar energy) and the trend is expected to continue with all new construction being able to produce energy on-site.[3] However, since distribution networks are traditionally not designed to cope with large amounts of generation, increasing distributed generation (DG) is expected to create congestion and voltage problems if not properly handled. In this context, *local energy communities* (LECs) are identified as a promising approach to integrate DG whereas maintaining energy security and keeping costs down for consumers [7]. In such communities, prosumers can locally trade their excess of energy, reducing in this way the transmission losses which occurs over long distances and making the system as a whole more efficient. Indeed, we can already find across EU some real examples of successful LECs, as for example the EWS Schönau[4] in Germany, or the *REScoop 20-20-20* project[5] in Belgium.

[3] The EU Parliament's Committee on Industry, Research, and Energy declared that all buildings built after 2018 will be able to produce their own energy on-site.
[4] https://www.ews-schoenau.de/ews/international/
[5] https://rescoop.eu/

S. Omatu et al. (eds.), *Distributed Computing and Artificial Intelligence, 14th International Conference*, Advances in Intelligent Systems and Computing 620, DOI 10.1007/978-3-319-62410-5_10

Nevertheless several research challenges remain to be addressed before the widespread of these local energy communities can take place. First, it is crucial for the success of such communities to provide prosumers with *individual incentives* to reward their participation. For example, recent studies stated that 51% of people interviewed would be motivated to get involved in community energy if they could save money in their energy bill [4]. However, more traditional approaches for trading locally produced energy have focused on optimizing the overall system, generating solutions that may result in weak financial incentives of some prosumers [1, 9]. Second, prosumers will only be comfortable sharing their data if they are confident that these are stored securely and exchange in a way that safeguards their *privacy*. Last but not least, the distribution level of next generation electric grids will include a large number of active devices, whose control and scheduling significantly increases the complexity of the corresponding energy management problem compared to traditional grids [2, 6]. Consequently, traditional approaches that commonly solve this problem in a centralised fashion will become computationally impractical due to its lack of *scalability*.

In this paper we address these challenges by proposing a Multi-Agent System (MAS) to collectively optimise the energy flows of a local community of prosumers. The decentralised decision making is based on the Alternative Direction Method of Multipliers (ADMM) algorithm. As we show in Section 3, the ADMM protocol enables a multi-period local market, where the preferences of the prosumers and their cost structures are reflected in their private utility functions and the interactions between them take place through price signals. Concretely, this paper makes the following contributions:

1. We model the local energy exchange problem by means of an energy cooperative network.
2. We distribute this cooperative network among different agents and we use the ADMM algorithm as a coordination mechanism among these agents.
3. We empirically evaluate our approach via simulations. Our results show how the proposed approach can significantly increase the self-consumption of the community of prosumers whereas appreciably reducing their energy bill.

This paper is structured as follows. We first give, in Section 2, some background on energy coordination networks and the ADMM algorithm. Afterwards (Section 3) we present the MAS local energy exchange model. Finally, we validate the proposed approach in simulation (Section 4), to later conclude in Section 5.

2 Background

2.1 Energy coordination networks

A cooperation network [8] is composed of a set of actors, A, a set of nets, N, and a set of terminals, T. A terminal is a connection point, a connection between one actor and one net. This is depicted in Fig. 1 where nets are represented by grey dashed rectangles, terminals are represented by lines and actors by circles. In an *energy coordination network*, a net is an agent that represents a virtual