MILP optimization model for collective self-consumption network design

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1 Introduction

The introduction of renewable energies such as solar and wind power into the energy mix is changing the distribution network. Governments are increasingly promoting local energy consumption initiatives due to the rise of local production sources. Even though collective self-consumption is seen as a solution for managing energy loads, the establishment of collective self-consumption micro-grids involving multiple actors across territories remains uncommon. Most of the proposed optimization frameworks found in literature, whether they employ mixed-integer linear programming (MILP) models [1, 2], agent-based models [5, 3] or heuristics [4], commonly assume predefined actors within a self-consumption micro-grid. Our proposal aims to address this gap by introducing a MILP model for the comprehensive design of collective self-consumption micro-grids involving both selecting actors and determining energy exchanges.

2 Collective self-consumption micro-grid design model

To model the problem of selecting actors within the self-consumption network, we utilized the network flow illustrated in Figure 1. Each actor is represented by a node whose edges depict energy exchanges between actors and with the national grid. Based on production (P_i) and consumption (C_i) data, the models defines for each actor its participation in a self-consumption micro-grid (x_i) the quantity of energy shared with other collective self-consumption micro-grid members (e_{ij}) and the amount of energy exchanged with the national grid (r_i, f_i).

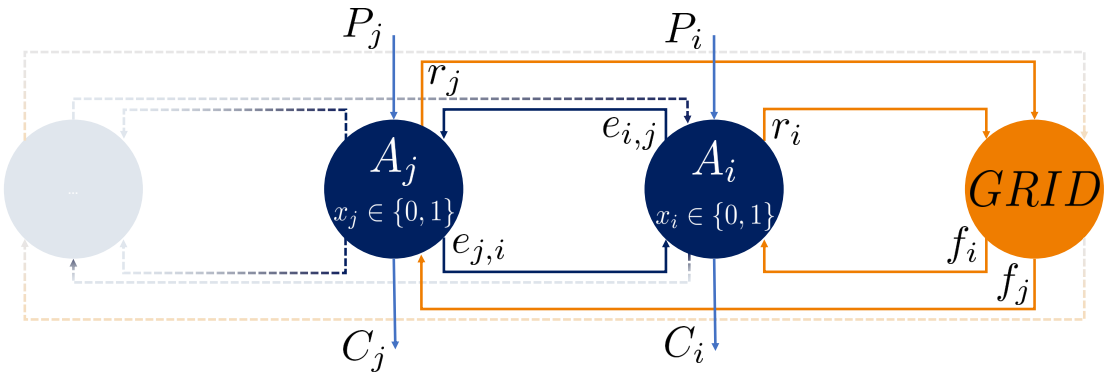

FIG. 1: Network flow representation of the self-consumption micro-grid design problem

2.1 Considering multiple micro-grids optimization and larger time scale

The first version of the proposed model tries to identify the optimal collective self-consumption micro-grid focusing on economic and self-consumption objectives. However, considering a broader geographical area and legal distance constraints among actors within a single micro-grid, it becomes important to entertain the possibility of creating multiple self-consumption micro-grids. To address this, we extended and reformulated the base model using Dantzig-Wolfe decomposition, enabling the design of multiple micro-grids within a feasible computational time frame.

Similarly, as the production and consumption profiles of actors exhibit temporal variations, it becomes pertinent to design micro-grids while considering longer time scales, spanning at least a year. To address this with reasonable resolution time, we propose a Benders decomposition, aimed at reformulating the problem and enabling more comprehensive optimizations that better represent the system dynamics.

2.2 Application and evaluation

The proposed model have been applied in the context of a multiple plant implantation project, considering 4 plants and 4 associated consumers. Initially, this real world use case served to validate the model's efficacy concerning energy exchanges. Notably, the inclusion of the eight actors in the self-consumption micro-grid was established prior to the optimization phase. Subsequent studies involved simulated instances to further test the model's performance on larger-scale problems, specifically evaluating its ability to design multiple micro-grids.

3 Conclusion and Perspectives

While the proposed model identifies the optimal design of self-consumption micro-grids for a defined group of potential members, it leaves the determination of the inside micro-grid selling price pending. To address this, a possible extension of this work involves a secondary optimization model. This subsequent model, leveraging the design outcomes, aims to ascertain the most suitable inside micro-grid selling price. This determination should be based on previously determined actor configuration while adapting to various legal and economic contexts.

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