Proposal of PhD Thesis

China Scholarship Council – 2021/2022

Title: Grid-impact anticipated aggregator-oriented energy management in the residential distribution grid with renewable energy sources and energy storages

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1. Context

According to directive EU 2019/944 (on common rules for the internal market for electricity), an independent aggregator is defined as "a market participant engaged in aggregation who is not affiliated to the customer's suppliers". In this perspective, aggregators are relatively new independent market entities in the smart grid that are placed between grid operators (e.g., distribution system operators) and the end-users that possess ability to provide beneficial services for the both side of electricity network [1, 2]. In that manner, due to nature of the electricity market, small entities such as consumers/prosumers are not able to take part directly in the market operations. However, with the help of the aggregation, aggregators can participate in the electricity market on behalf of the energy community and offer end-users economical, efficient and clean energy utilization opportunities. This will eventually be beneficial for the distribution system operators (DSO) since aggregators can increase the grid flexibility by motivating customers to modify their electricity profiles in the distribution grid for better congestion management [3].

Under the objectives of decarbonization and decentralization of the electricity grid, the high penetration of low-carbon technologies such as distributed energy sources (DER), in the form of intermitted renewable energy sources (RES) and energy storage systems (ESS), impacts the grid stability in terms of voltage violation and congestion [4]. Therefore, aggregators are likely to play vital role in the near future by facilitating the integration of DERs while enabling decentralized grid control without jeopardizing the distribution grid stability. In practice, aggregators contract with the individual demand site customers and aggregate load (demand response management) and supply (generation management) to operate together as single grid entity such as virtual power plant (VPP) operator to DSO. Accordingly, they are able to help DSO to procure balancing services more cost-efficiently and manage their local constraints and obtain a better overview of flexibility at lower voltage levels while reducing electricity bills and increasing renewable self-consumption for end-users [5].

Therefore, aggregators can execute multiple tasks such as identifying flexibility potential in the distribution grid by negotiating with customers and aid DSO by matching flexibility to specific services (e.g., demand response) for a reliable service provision with the help of control and communication

systems. Therefore, this research aims to develop aggregator-oriented energy management algorithms for offering profitable energy utilization options to residential customers while anticipating the impact of the proposed strategies on distribution grid via coordinating with DSO. In the developed methods, the optimization problem will be formulated by considering flexibility of the consumption, the distributed RES and ESS penetration on customers side, and distribution grid constraints using one of the test systems (IEEE busbar, European LV test feeder, etc.) in order to verify the absence of possible congestion issue.

2. Objectives

The main objective of this research is to develop/present efficient and reliable energy management methodologies by investigating the grid impacts of the aggregators in the distribution network. The proposed algorithms will consider the grid constraints in the strategies by performing load flow analysis on a test system (e.g., IEEE busbar) for congestion management in the distribution network. The rest of the research perspectives are highlighted as below:

- Building (co)simulation platform in order to solve optimization problems as well as performing load flow analysis in the distribution network
- Formulating multi-level optimization problems for well-being of end-users (economical, comfort) and DSO (congestion)
- Increasing the utilization of local energy resources via distributed RES for decreasing emissions on the electricity utilization
- Coordinating the control/management of distributed resources in the residential grid (as VPP operator) and provide flexibility on grid operation for DSO
- Investigating the opportunities of integration of multiple aggregators in the distribution grid via co-operation and/or competition
- Evaluating the performance of the developed methods using sustainability metrics on annual simulations

3. Research plan

The anticipated roadmap of the thesis is presented as follows:

Year 1:

- Performing literature review in the domain focusing on published articles in last five years
- Collecting the necessary data for modeling residential customers, RES (e.g., photovoltaics) generation, ESS (e.g., battery) utilization, and distribution system modeling
- Modeling of the distribution grid using one of the test systems for performing load flow simulations
- Formulating the objective functions and constraints that aim to maximize profits of end-users without overloading the grid

Year 2:

- (*starting from the end of first year program*) Developing (co)simulation platform for solving optimization problem and realizing load flow analysis for economic and technical analysis
- Implementation of the algorithms on the developed (co)simulation platform and analyze the results for detecting possible non-anticipated impacts

- Building/Performing multi-level optimization problems where aggregator coordinates the grid operations on two side of the grid with the anticipations
- Analyzing the simulation results using sustainability metrics on annual simulations taking into account seasonal variations

Year 3:

- Investigating the multi-objectives (emissions, comfort, etc.) on the energy management problem by investigating pareto-front solutions
- Extending the built model by integrating multiple aggregators on different busbar of the same distribution grid
- Realizing simulations for analyzing the interaction among aggregators for determining possible coordination opportunities for better energy management
- Determining the possible next steps according to obtained outcomes and the advancement of the scientific community (isolated microgrids, peer-to-peer trading etc.)

Year 4:

- Writing the dissertation
- Preparation for the oral defense

4. Expected contributions

In the end of this project, the research team aims to contribute to the literature by addressing to challenges related to aggregators integration in smart grid by coordinating the grid operations via DSO (at the upper level) and end-users (at lover level) in the distribution network. The simulation results will help to build efficient and reliable business models for aggregators by anticipating the impacts of the developed methods on both sides of the network.

5. Requirements

The expected background of Ph.D. candidates is listed as follows:

- Master's degree on electrical engineering
- Solid knowledge on renewable energy sources and energy storage systems
- Computer programming via Matlab and one of the programming languages (e.g., Python, C++)
- Preliminary knowledge on decision-making tools (e.g., optimization)
- Good communication and writing skills in English

The Ph.D. candidates should possess certain autonomy and scientific curiosity during their research. Following documents should be provided by the candidates to apply for the position: CV, motivation letter, transcripts (master and/or bachelor's degree), and list of references or recommendation letters.

References:

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