Proposal of PhD Thesis

China Scholarship Council – 2021/2022

Title: Large-scale integration of electric vehicles via decentralized and sustainable energy management considering grid-support services in community integrated energy systems

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1. Context

The energy crisis and environmental issues accelerated the energy transition process to electric vehicles (EV) in the transportation sector. Since vehicles with internal combustible engine (ICE) are responsible of approximately two-third of global oil consumption, countries start developing e-mobility strategies with key policy measures such as banning sales of ICE vehicles (China in 2035, France in 2040). This will lead to have a rapid growth of EVs penetration in the electrical systems in following years, and EVs will eventually be one of the vital components of the future electricity network.

However, a large-scale adoption without appropriate control measures of EVs will drastically increase the load within a short time scale which will lead to require using polluting generators (e.g., diesel, gas) and to be reason jeopardizing the robustness of the power system. As long as the energy required for EVs is supplied by carbon-based energy sources, the targeted carbon reduction objectives cannot be achieved to meet the challenges of sustainability in the electricity grid [1]. Therefore, energy management strategies should be improved by coupling EVs with renewable energy sources and energy storages to increase clean energy usage in the community integrated energy systems (CIES) such as residential smart grids [2].

Moreover, EVs can be interpreted as distributed energy resources (DER) that can be connected to the electricity grid and provide the necessary grid support services by discharging stored energy to the main grid and buildings/homes in the community as vehicle-to-X (V2X) [3]. EVs can provide these complementary services by participating to the electricity market operations through incentivized pricing schemes (e.g., demand response) in order to obtain economical profits as the return of their efforts.

However, although V2X operations are providing highly tempting motivations for increasing EVs penetration in the network, it will be quite difficult for power system operators to directly coordinate a large number of EVs in the manner of efficiency (cost, emission, etc.) and reliability. Instead, it is more viable to let community managers (CM) regulate a limited number of EVs, thus system operators only need to dispatch several CM rather than numerous EVs in the electricity grid. CM can operate

with *centralized* approach in which it is the ultimate decision-makers; or with *decentralized* approach in which EVs are the decision-makers and CM is the coordinator of the game [4].

Accordingly, CM can facilitate the coordination among EVs by providing profitable solutions for end-uses and provide better grid-support services to the main grid. Therefore, this research aims to develop and analyze cost-efficient and reliable management strategies in CIES by concentrating on the large-scale energy scheduling of EVs via CM (or without CM where the group of EVs regulates themselves as a CM) considering various cost and revenue factors (e.g., degradation, carbon emissions, peak shaving etc.) in the optimization problem.

2. Objectives

This research aims to address the energy management problem for large scale integration of EVs in CIES by developing novel battery control strategies and analyzing electricity market participation opportunities. The main objectives of the project are highlighted as below:

- Formulating/solving complex optimization problems on the simulation environment
- Investigating the grid-support options (V2X) by enabling several EVs' battery discharging options: vehicle-to-grid (V2G), vehicle to building (V2B), and vehicle-to-vehicle (V2V)
- Coordinating EVs charging/discharging operations in order to maximize benefit (e.g., cost, emission) without violating the constraints of the grid (e.g., peaks)
- Developing decentralized methods for coordination using game-theory and comparing them with centralized approaches
- Evaluating the impact of the EV number to determine limitations and/or performance of the algorithms on different scale (scalability)

Utilization of community-owned renewable energy sources and energy storage systems is also considered while coordinating EVs operation, hence the maximization of local self-consumption is one of the aspects in the project.

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
- Gathering and analyzing the required data related to electricity market, environmental variables, carbon emissions and EVs for the modeling of the studied system
- Formulation of the objective functions and constraints including V2X options in EVs
- Developing and performing the first simulations solving the formulated optimization problem

Year 2:

- Design and implementation of the decentralized coordination mechanisms using game-theory
- Performance comparison of the decentralized methods with centralized approach
- Analyzing the results with different electricity market structures for investigating additional opportunities for EVs

Year 3:

- Including the impact of the uncertainty on various parameters (consumption generation, EV arrivals/departures) in the optimization problem
- Implementing sensitivity analysis on the performance of the proposed strategies (EV number, community consumption, user-preferences, etc.)
- Determining the possible next steps according to obtained outcomes and the advancement of the scientific community (isolated microgrids, zero-carbon markets, etc.)

Year 4:

- Writing the dissertation
- Preparation for the oral defense

4. Expected contributions

In the end of the project, the research team envisages to provide answers related to the challenges on the decentralization process of the electricity network in the perspective of the integration of EVs in the smart grid. The obtained numerical results will allow to emphasize the advantages/disadvantages of the presented coordination methodologies on multiple aspects: technical, economical, and environmental.

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/or 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:

[1] S. Cheikh-Mohaad, M. Sechilariu, F. Locment, and Y. Krim, "PV-Powered Electric Vehicle Charging Stations: Preliminary Requirements and Feasibility Conditions", *Applied Sciences*, 11, pp. 1770, 2021.

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[3] D. Borge-Diez., D. Icaza, E. Açikkalp, and H. Amaris" "Combined vehicle to building (V2B) and vehicle to home (V2H) strategy to increase electric vehicle market share", *Energy*, vol. 237, pp. 121608, 2021.

[4] B. Celik., R. Roche, D. Bouquain, and A. Miraoui, "Decentralized neighborhood energy management with coordinated smart home energy sharing", *IEEE Transactions on Smart Grid*, 9(6), pp. 6387-6397, 2017.