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Financial shortfall for electric vehicles: Economic impacts of Transmission System Operators market designs

Paul Codani [a,*], Yannick Perez [a,b], Marc Petit [a]

[a] Group of Electrical Engineering Paris (GeePs), UMR CNRS 8507, CentraleSupelec, UPSud, UPMC, Gif-sur-Yvette, France
[b] RITM Lab, University of Paris-Sud, Orsay, France

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ABSTRACT

Using electric vehicles as transmission system operator reserve providing units has been demonstrated as being both a feasible and a profitable solution. However, the surveys leading to these conclusions are always conducted either without considering the transmission system operator market rules, or using the existing ones from the local system operator. Nevertheless, such rules have potentially a great impact on the electric vehicles' expected revenues, and they are likely to change within the next few years. This paper aims to assess how these rules impact the ability for electric vehicles to provide power reserves and on their expected remuneration for doing so. First, a list of the most important market rules for this use case is drawn up. Then, a simulation model is developed in order to evaluate the expected revenues for the electric vehicles. Finally, these expected revenues are computed considering various combinations of rules. A loss of revenue for electric vehicles is identified, due to the use of non-optimal rules governing grid services remuneration. Considering the French case, according to the simulation results, this financial shortfall per vehicle and per year ranges from 193 € to 593 €. Market design recommendations for reserve markets are deduced from these results.

1. Introduction

In order to cope with the objectives of reductions in CO_2 emissions in both electricity grids and transportation systems, governments' environmental-friendly policies tend to incentivize the use of alternative fuels for propelling vehicles. Among the possible technical options, plug-in vehicles (EVs) driven by electric motors and powered by electrochemical batteries represent a promising solution. As a consequence, an increasing number of car manufacturers now have plug-in hybrid and fully electric vehicles in their product lines and EV sales are expected to increase significantly within the next few years [1].

However, EV sales are not yet following their expected trend: for instance in December 2015, the EV market share only reached 1.2% in France [2], and the initial forecast of having 2 million EVs on the roads by 2020 has been downgraded to 500,000 [3]. EV sales are increasing slowly for three main reasons: (a) the limited EV driving ranges compared with their equivalent in conventional vehicles; (b) the lack of charging infrastructure; and (c) their relatively high price [4].

One suggested way to deal with the latter issue is to use EVs as distributed storage units when they are plugged-in – in France, this entails more than 95% of the time [5] – turning them into so-called Grid Integrated Vehicles (GIVs). Such a GIV has a means of communication, a controllable charging rate, and, in this case, is able to supply Vehicle-to-Grid power, i.e. to inject power back to the grid. Under these conditions, GIVs participate in the grid system's wide balance between production and demand; they are active components of the smart grids, in which demand becomes more controllable and able to follow the generation patterns.

According to the literature, the most profitable solution is the integration of EVs into Transmission System Operator (TSO)[1] reserves [6] – mainly to provide frequency regulation reserves. In this case, a fleet of GIVs is controlled by and reports to a central aggregator, which is responsible for presenting the fleet as a single entity in the frequency control market.

This solution has been intensively studied in the scientific literature, both from a technical and an economic point of view. Complex multi-objective optimization problems were proposed,

* Corresponding author.
E-mail address: paul.codani@centralesupelec.fr (P. Codani).

[1] In the United States, TSOs are referred to as Independent System Operators (ISOs).

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solving linear [7] or quadratic problems [8]. Economic earnings were evaluated for various areas such as Germany [9] or PJM area in the United Stated [6], sometimes taking battery degradation into account [10]. Similarly, there are several ongoing demonstration projects, in particular in the USA (California, Delaware) and in Europe (Denmark) [11]. These theoretical papers bear little consideration for the rules and regulations of the targeted electricity market: they are either ignored in the case of technical surveys, or considered as given in most economic studies. However, there is a wide diversity of electricity market rules and regulations across the world and even within Europe, mainly because TSOs face different technological and economic challenges, and have different topologies and energy mixes [12]. Moreover, with the liberalization of electricity markets, TSO market rules are likely to evolve within the next few years in order to better support the three main energy policy pillars of the European Union (EU): security of supply, sustainability, and competitiveness.

Thus, in a smart grid environment, electromobility could be a promising solution not only to reduce local air pollution, but also to manage intermittent distributed generation (DG). For instance, reference [13] shows how solar and wind sources could be coupled with EV charging load curves in France at the regional scale. It has also been demonstrated that lowest costs and best voltage profiles were achieved in power distribution networks by combining various DG sources with EVs [14]. Similar conclusions are found at the system-wide scale [15]. However, in order to achieve this potential future, integrated grids require adapted technical and regulatory structures that are not complete yet. Electricity grids, and hence their regulatory frameworks, have a key role to play in facilitating this transformation from vertically integrated systems to the emergence of new actors, services, and storage technologies. In this work, the authors analyze the regulatory changes that are required to align grid needs with grid users' incentives in order to promote the development of electromobility.

More specifically, the authors assess the economic impacts of the implemented market rules and regulations on the expected revenues of a fleet of GIVs providing frequency regulation. In order to do so, the existing frequency regulation rules from six TSOs are reviewed and a 'best combination' of existing rules with respect to this solution studied is presented. Then, a simulation model which was developed in a previous work is implemented [16]. This model is applied for two different sets of market rules; the first one represents the current French rules, while the second one is the aforementioned 'best combination'. The simulation results are used to infer frequency control market design recommendations.

In this paper, the authors work from the perspective of EV car owners; the expected revenues are entirely intended for them. The aggregator is assumed to be a benevolent third party; obviously, in real life, the aggregator should earn something out of these revenues, but addressing business models is beyond the scope of this paper.

The paper is organized as follows. Section 2 presents the survey of the TSO rules. In Section 3, the simulation model is recalled and the data used are described. Section 4 features and discusses the simulation results under two combinations of rules: a best case and the current French rules. Policy considerations are inferred from these results in Section 5.

2. TSO rules survey

Six TSOs are compared by screening their manuals on a list of rules and characteristics that are important for GIV deployment. The six TSOs in question, represented in Fig. 1, are: Energinet.dk (Denmark), RTE (France), ERCOT (Texas, USA), CAISO (California, USA), PJM (North-East, USA), and NGC (UK). The associated regulatory manuals are [17–36].

Based on the findings from this analysis, and on feedback from the GridOnWheels [37] and Nikola [38] demonstration projects, two essential and relevant sets of rules (hereafter called modules) that assemble the critical regulation for enabling the participation of GIV fleets to grid services are identified: the rules presiding over the aggregation of GIVs, and the rules establishing the payment scheme of the services provided by GIVs. The objective of this approach is to finally be able to determine a 'best combination' of frequency control rules for GIV fleets based on the authors' opinions and on the point of views of researchers involved in the aforementioned demonstration projects. The two modules are described in more detail in the two following subsections.

2.1. Module 1: the rules governing the aggregation of electric vehicles

An aggregator[2] has a key role in the organization enabling the provision of TSO services by GIV: it is in charge of presenting a GIV fleet as a one and only body to the TSO. Aggregators are necessary for the following reasons: (a) TSOs are used to treating with large entities, (b) TSOs do not have the information processing abilities to control numerous kW size units; they were thought up for a few multi-MW size power plants, and (c) TSOs count on reliable resources, which is an issue for a unique GIV. Transportation remains the priority for GIV, but from the grid viewpoint, one GIV is likely to unplug at any time. Aggregators are able to deal with these matters by supervising a huge amount of GIVs [39] and presenting a unique, statistically-reliable entity to the TSO.

On the other hand, such GIV coalition should be made possible by TSO rules. Here, three main rules are underlined: the smallest bidding size allowed in the market, the possibility to aggregate across several Distribution System Operators (DSOs), and the technical level of aggregation.

2.1.1. Minimum bidding size

All TSO markets require bids to have a minimum size [40]; throughout this analysis, a spectrum of least bid from 100 kW to 10 MW was observed. As far as GIV aggregations are concerned, this minimum-bidding value leads to a minimum number of GIVs. A substantial minimum bidding value would be a challenge for the development of pilot and early commercial projects, since the GIV fleet in question may miss some vehicles to meet the requirement.

As an example, considering electric vehicle supply equipments (EVSE) of 3 kW, and a GIV availability factor of one third for grid services' markets, 100 GIV would be required to meet a minimum bid value of 100 kW. However, if this minimum was set to 10 MW, 10,000 GIV would then be needed. Comparing these results with those of today's EV sales (there are approximately 50,000 EVs in France [2]) shows that making an aggregation of private electric vehicles in France would be extremely difficult.[3]

Even if EV penetration was more important, a significant minimum bidding value would restrict the variety of possible aggregators: for instance, company fleets would not be admitted as aggregators.

2.1.2. Possibility to aggregate across DSOs

The possibility to aggregate GIV across multiple DSO technical areas is also a major concern for aggregators. GIVs can potentially

[2] An aggregator is typically a third party entity, but different stakeholders could fulfill its role: System Operators, utility companies, car OEMs, etc.

[3] Note that the geographical location of the EVs bears little importance here as the frequency value is the same at each node of the network.