Quantifying the participation of electric vehicle fleets in local flexibility tenders

Felipe Gonzalez, Marc Petit, Yannick Perez

CIRED 2020 Berlin Workshop (CIRED 2020)

22-23 September 2020

Theme 1: Integrating New Flexibility Tools and Principles for Planning

Quantifying the participation of electric vehicle fleets in local flexibility tenders

ISSN 2515-0855
doi: 10.1049/oap-cired.2021.0323
www.ietdl.org

Felipe Gonzalez Venegas[1,2] ✉, Marc Petit[1], Yannick Perez[3]

[1]*Université Paris-Saclay, CentraleSupélec, CNRS, Group of Electrical Engineering – Paris, 91192, Gif-sur-Yvette, France*
[2]*Division for Research & Innovations, Groupe PSA, Carrières-sous-Poissy, France*
[3]*Université Paris-Saclay, CentraleSupélec, Laboratoire Génie Industriel, 91190, Gif-sur-Yvette, France*
✉ *E-mail: felipe.gonzalezvenegas@centralesupelec.fr*

Abstract: Distribution system operators are starting to implement market-based mechanisms to use flexibility from distributed energy resources. Flexibility tenders allow distribution system operators to procure flexibility for the medium to long-term, with the first implementations in Europe in the UK since 2018, and a recent pilot in France. This work seeks to quantify the potential participation of electric vehicle aggregators in a flexibility tender, considering the role of market rules and product definitions. The main parameters that affect fleet participation and remuneration are the bidirectional capability (V2G), the reliability of the fleet and the match of availability profiles to the tender requirements.

1 Introduction

Distribution system operators (DSOs) might face significant investments in grid reinforcement to deal with the cross-sector electrification and the integration of renewable energy resources. However, connected and controllable resources, such as electric vehicles (EVs) or battery storage systems, offer the opportunity to provide flexibility to defer costly reinforcements and improve reliability and quality of supply.

To procure flexibility for investment deferral, DSOs require a medium to a long-term vision of the availability and costs of flexibility resources. Indeed, DSOs can face high risks if they rely only on short-term local markets, endangering grid reliability since they have limited options if there is no availability of flexible resources. A solution to mitigate the availability and price risks is to procure flexibility through long-term agreements, which can also provide revenue certainty to flexibility investors [1].

Within this context, UK Power Networks (UKPN) has implemented local flexibility tenders since 2018 in order to contract flexibility for the medium to long-term, in portions of the grid where they expect congestions, reducing their investment costs [2]. The current 2020 tender comprises 62 high-voltage zones and has extended its scope to over 60 low-voltage networks. Similar approaches have been followed by the rest of Great Britain DNOs [3] and by Enedis, France's main DSO, who launched a test implementation in 2019 [4]. Enedis' tender comprises six zones in their medium-voltage grid, with cases ranging from investment deferral to maintenance and post-fault support.

These tenders have been designed for the participation of distributed energy resources. However, the specific rules and requirements on the tender process can still present barriers to entry for operators of demand-side flexibility [5].

The objective of the present work is to analyse and quantify the impact of market rules and product definition of distribution flexibility tenders, on the participation and possible revenue of an EV fleet aggregator. The main parameters reviewed are the availability windows, the minimum bid size and the baseline definition.

2 Methodology

2.1 Main parameters to be reviewed

Previous work [5] proposed a modular framework to identify the main barriers to market design for the entry of demand-side response aggregators, including EVs. This framework is composed of three hierarchical modules, each with a set of parameters that can present a barrier to the optimal participation of flexibility aggregators. This work applied the framework to the UKPN and Enedis flexibility tenders and determined that overall the tenders were designed to allow the participation of small, distributed resources aggregators. However, there were still some barriers in the design of the products and the baseline definition. The present study focuses on the following parameters:

2.1.1 Availability windows: DSO's can define a specific period of the day during which the flexibility should be available for activation. Aggregators can balance their resource availability toward the DSO's needs. Thus, shorter, well-defined windows can provide higher certainty for a type of resource that can provide flexibility. In UKPN's 2020 tender, over 60% of the sites require an 'evening' window (from 1 to 6 h between 4 p.m. and 10 p.m.).

2.1.2 Minimum bid size: This is the minimum amount of flexibility (in kW) that the tender admits. UKPN's tenders consider a minimum bid size of 50 kW for the HV zones, and 10 kW for the LV zones. Enedis' approach considers minimum bids of 500 kW, while also retaining only *full bids* (thus only one tender winner). In both cases, the minimum bid can be attained by aggregating distributed resources. The higher the bid sizes, the less the participation of small aggregators is eased.

2.1.3 Baseline definition: Flexibility is an active adjustment of normal consumption or production patterns or schedules, in response to an external signal, in this case, to a DSO activation. Thus, it is necessary to define a counterfactual baseline upon which a flexibility activation is measured and certified. Thus, baselines methodologies should be adapted to the assets that they attempt to measure.

UKPN's default baseline is calculated as the average consumption or production during the availability window in ten reference days defined by the DSO. This gives a unique, static value for the whole availability window, not a profile.

On the other hand, Enedis proposes various baselines according to the type of asset. In the case of demand-side distributed assets, such as EVs, they propose a half-hourly profile based on a *panel method*. This method computes the baseline with respect to a panel of non-flexible customers with similar characteristics.

2.2 Methodology

To quantify the effect of the three aforementioned parameters on the participation of an EV aggregator in the flexibility tenders, a methodology based on Monte Carlo simulations of EV charging and plug-in behaviour was implemented.

First, a multi-agent simulation of the EV plug-in and charging process is carried out. This module allows us to simulate a high number of EVs fleets, each with a set of stochastic parameters (daily travelled distance and arrival and departure times), and a *probabilistic non-systematic* plug-in behaviour (users may not plug their vehicle every day, or may be absent of their usual charging point), described in [5].

This simulation provides the charging and flexibility profiles of the fleets. The charging profiles allow us to compute the baselines (UKPN's *Unique-value* and Enedis' *30-min profile*), and the flexibility profiles, which represent the amount of flexibility a given fleet can provide to the system at each moment. Given the stochastic nature of the simulation, a fleet can provide different levels of flexibility in each day. To evaluate the amount of *firm* flexibility to bid in the tender, we consider the minimum amount of flexibility that the aggregator can provide with a 95% confidence level.

Finally, we compute the remuneration by evaluating the delivery of flexibility, randomly sampling activation events during the simulated period. If the delivered flexibility is less than what was committed, the payments are reduced proportionally. If the delivered flexibility is <60% of the committed, no payment is done. This emulates the payment de-rating performance factor by UKPN.

3 Case studies

We consider three types of fleets doing uncontrolled overnight charging: a company fleet and two fleets of commuters, one with medium plug-in probability (Commuter MP) and one with high plug-in probability (Commuter HP). The three fleets can provide unidirectional (V1G) and bidirectional (V2G) flexibilities with a 7 kW charger, with 95% efficiency, and have a 40 kWh battery pack.

EVs have stochastic parameters on daily travelled distances and arrival, following a lognormal distribution, and departure times, following normal distributions, as in [6]. The plug-in probability of an EV follows (1) [5], where ξ is the minimum state of charge (SOC) required to complete the next day trips, ρ is the range anxiety factor and ν the probability factor. Their parameter values are shown in Table 1, and an example for the plug-in probability is shown in Fig. 1.

$$P_{\text{plug-in}}(\text{SOC}) = \begin{cases} \text{if SOC} \le \xi \cdot \rho & 1 \\ \text{else} & 1 - \left(\dfrac{\text{SOC} - \xi \cdot \rho}{1 - \xi \cdot \rho}\right)^{\nu} \end{cases} \quad (1)$$

We considered two availability windows: an evening window from 5 p.m. to 8 p.m., and a full-day window. The service is required for 3 months, only during weekdays (60 days per year). During these windows, a 30-min 'downwards flexibility' (demand reduction or injection increase) can be required, though not necessarily activated.

Finally, the possible remuneration can vary greatly according to the tendered zone requirements. We used an equivalent yearly price of 50 € per firm kW tendered, similar to the fixed price proposed for UKPN's low-voltage tenders. This represents an equivalent of 277 €/MWh for the evening availability window (180 h/y) and 35 €/MWh for the full day availability window (1440 h/y). This is within the range of remuneration in the high-voltage UKPN tenders.

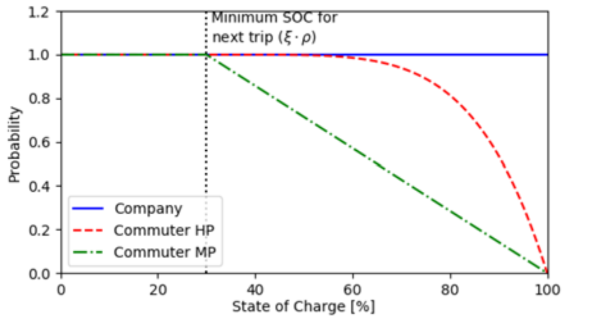

Fig. 1 *Plug-in probability according to SOC at arrival, for a minimum SOC of 35% to complete next day trips*

Table 1 Stochastic parameters of EV fleets

Fleet	Daily distance [μ, σ]	Arrival time [μ, σ]	Departure time [μ, σ]	Plug-in probability [ρ, ν]
company	[80, 10]	[15, 1]	[9, 1]	[1.5, ∞]
commuter HP	[3.43, 0.73]	[17, 2]	[8, 2]	[1.5, 5]
commuter MP	[3.43, 0.73]	[17, 2]	[8, 2]	[1.5, 1]

4 Results

4.1 Average profiles

Fig. 2 shows the average charging and V2G potential profiles for fleets of the size of 20 EVs. Company fleets have higher daily mileage, thus showing a higher peak power demand partially coincidental with the evening window. In addition, they are always plugged-in after trips; thus, having higher V2G potential. On the other hand, commuter's charging process occurs mainly during the evening window, and their lower plug-in reduces the V2G potential ratio (95% for Commuter HP and 67% for Commuter MP), as less EVs are available to deliver flexibility. Additionally, it can be seen that there will be periods of the day where no flexibility can be provided to the system since there are no EVs connected.

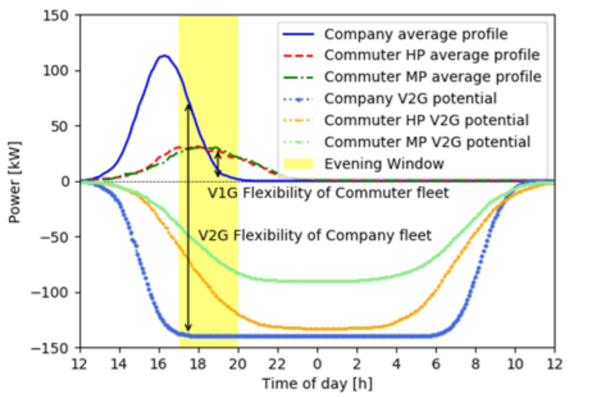

Fig. 2 *Average charging profiles and V2G potential for a 30-min service per fleet (20 EVs), and examples of VxG flexibility levels*

4.2 Baselines

Fig. 3 shows the baselines for the company fleet (these baselines were also computed for the other two fleets): *30-min* forecast, representative of Enedis' baseline, and a *unique-value* for the evening (1.61 kW per EV) and daily (0.9 kW per EV) windows, representative of UKPN's baseline. Such baselines do not capture the actual charging profile of the fleet, thus under-rewarding flexibility in some periods, while rewarding no real flexibility activation (after 20 h, for example). This can create remuneration problems, as flexibility verification will be measured against this baseline, and not against the expected consumption profile. The average flexibility potentials are given in Table 2.

4.3 Minimum bid threshold

By performing a parametric sweep of the fleet size, the minimum size of the fleet to reach the minimum bid size required to be able to participate in the tender is identified (Table 3). Having V2G capability allows smaller fleets to participate in the tender, requiring about one-tenth of the fleet size if only V1G is considered. In addition, allowing reduced minimum bid size allows a great number of participants to enter the tender, as fleets of only 10 (with V2G) to 30 EVs (with V1G) can achieve the threshold of 50 kW. This can be of major importance as these tenders can have limited potential participants, due to the local characteristic of the services.

4.4 Bids and revenues

Each of the simulated fleets will bid a different amount of flexibility on the tenders, and their reliability to provide the service will be reflected in how much they are paid per bid kW. To observe this,

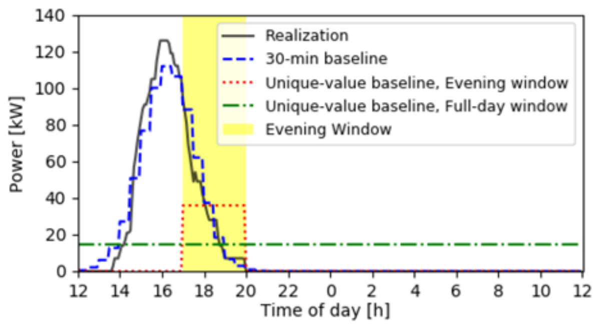

Fig. 3 *30-min and unique-value baselines and a simulated charging profile, for company fleet of 20 EVs*

Table 2 Average flexibility potential, V2G and V1G [kW]

Fleet (20 EVs)	Evening window		Full-day window	
	V2G	V1G	V2G	V1G
company	8.59	1.61	5.73	0.73
commuter HP	5.78	1.45	4.05	0.36
commuter MP	4.24	1.39	2.77	0.34

Table 3 Minimum fleet size to participate in the tender, according to minimum bid threshold

Fleet (V2G/V1G)	Evening window		Full-day window	
	50 kW	500 kW	50 kW	500 kW
company	6/30	59/309	10/69	88/688
commuter HP	9/33	87/346	13/132	124/–
commuter MP	12/34	118/357	18/136	181/–

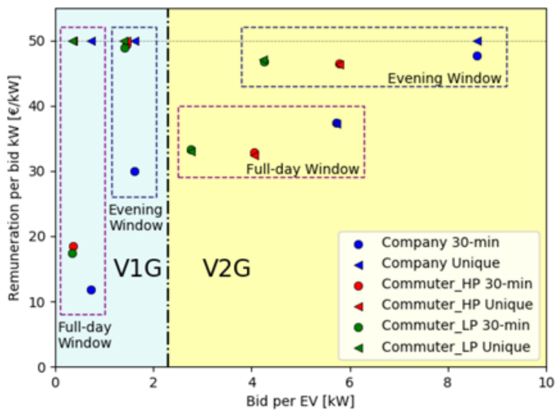

Fig. 4 *Bid per EV and remuneration per bid kW per EV for the three simulated fleets, and two baselines methodologies*

we tested for single-day 30-min activations during either the evening or full-day windows (*unique-value* baseline are chosen accordingly). A flexibility activation that is not fulfilled by the fleet will result in a loss of remuneration proportional to the unserved flexibility, as described in Section 2.

In Fig. 4, bids and remuneration per kW bid are shown for the 24 studied cases. A fleet that can always deliver the committed flexibility, according to the respective baseline, will achieve a 50 €/kW remuneration. The total remuneration per EV per year will be given by the bid per EV [kW] times the remuneration per bid kW [€/kW]. From these results, several observations are drawn:

First, it is necessary to match the availability profiles of the fleets to those required in the tender process. The simulated fleets can provide flexibility for the evening window with high reliability, which is not the case for the full-day window, since there are periods of the day where no flexibility can be provided. This translates into higher bids per EV and higher remunerations for the evening window, both for the V1G and V2G cases, while for the full-day window a loss on remuneration per bid kW is observed, due to reduced reliability of service. Highly reliable fleets, in this case, the company fleet and Commuter HP, obtain a better participation and remuneration per EV than the less reliable Commuter LP.

Second, V1G-only EVs have limited participation in the tenders, being able to bid at most 1.6 kW per EV in the evening window, equivalent to 49–81 €/EV per year (revenue depending on the baseline methodology). Having V2G capability can increase the bid up to 8.6 kW per EV (1.6 kW from demand reduction plus 7 kW of power injection) in the case of highly reliable company fleets for the evening window, equivalent to 409–428 €/EV per year.

Finally, the baseline methodology has limited impact for V2G-capable fleets in the studied case. The main impact is seen in V1G only fleets, where the remuneration obtained by the same flexibility activation (reduction of EV demand) can vary greatly according to the considered baseline. In this case, the unique-value baseline rewards the absence of EV charging as flexibility, even when there would not be any need (see Fig. 2). Therefore, under this baseline, the EV fleets are always remunerated at the maximum level.

5 Conclusion

A methodology to evaluate the potential participation of EV fleets into flexibility tenders was developed and the impact of three main tender design parameters was evaluated.

First, allowing small minimum bids can increase the participation of multiple EV fleets aggregators, allowing increased competition in local flexibility markets. This can be crucial, as these markets can have limited participants. The high minimum bid in the Enedis' case is only explained by their *one-winner* policy, which will need to group several different distributed assets to fulfil the tender requirement.

Second, the potential participation of EV fleets will depend on the match of their availability profiles to those required by the tender. Highly reliable fleets with V2G capability can earn over 400 €/EV/y in favourable tender conditions.

Third, the baseline definition can have a significant impact on the remuneration of the flexibility services, especially for V1G-only fleets, while providing the same physical service. UKPN's *unique-value* baseline provides simple schedules that can over- or under-reward flexibility activation.

Finally, several paths are open for further research, such as the complementarity of flexible DER for full-day availability windows, the optimal bidding of flexibility under availability uncertainty, the effect of penalties for under-delivery on the remuneration profile of EV fleets and the coordination of distribution flexibility with other flexibility services, such as frequency response. Some other countries can also be added to explore other market design alternatives.

6 Acknowledgments

This research benefits from the support of the Chair Armand Peugeot: 'Hybrid Technologies and Economy of Electromobility', led by CentraleSupélec and ESSEC, and sponsored by Groupe PSA.

7 References

1 USEF Foundation: 'The framework explained', 2015
2 UKPN: 'Future smart: flexibility roadmap', 2018
3 'Flexibility in Great Britain', Available at www.energynetworks.org/electricity/futures/flexibility-in-great-britain.html, accessed 20 March 2020
4 Enedis: 'Feuille de route pour la transformation des méthodes de dimensionnement des réseaux et l'intégration des flexibilités', 2020
5 Gonzalez-Venegas, F., Petit, M., Perez, Y.: 'Can DERs fully participate in emerging local flexibility tenders?'. Proc. Int. Conf. EEM, Ljubljana, Slovenia, September 2019
6 Borne, O.: 'Vehicle-to-grid and flexibility for electricity systems: from technical solutions to design of business models'. PhD Thesis, Université Paris Saclay, 2019