32nd Electric Vehicle Symposium (EVS32)
Lyon, France, May 19 - 22, 2019

The road toward electric vehicles as flexibility providers for distribution systems. A techno-economic review.

Felipe Gonzalez Venegas[1,2], Marc Petit[2], Yannick Perez[3,4]

[1]*Felipe Gonzalez Venegas (corresponding author) Groupe PSA, 212 Boulevard Pelletier, 78955 Carrières-sous-Poissy, France. felipe.gonzalezvenegas@mpsa.com*

[2]*GeePs | Group of electrical engineering - Paris, CNRS, CentraleSupélec, Univ. Paris-Sud, Université Paris-Saclay, Sorbonne Université, 3 & 11 rue Joliot-Curie, Plateau de Moulon 91192 Gif-sur-Yvette CEDEX, France*

[3]*LGI – Laboratoire de Génie Industriel, CentraleSupélec, 9 rue Joliot-Curie, Plateau de Moulon 91192 Gif-sur-Yvette CEDEX, France*

[4]*RITM-Université Paris Sud, Faculté Jean Monnet, 54, Boulevard Desgranges, 92330, Sceaux, France*

Summary

Massive integration of electric vehicles into power systems will pose significant challenges, in particular to distribution grids. Nevertheless, EVs can be a source of flexibility for grid operation and planning.

In this work, we systematically identified the key technical and economic aspects for the proactive integration of EVs into distribution electricity grids as providers of flexibility services. While technical aspects have been widely addressed in literature, economic aspects present further uncertainties, coming the absence of frameworks for local flexibility procurement, uncertain viable business models and the evolution of roles and responsibilities of DSOs.

Keywords: Smart grid, V2G (Vehicle to Grid), Smart Charging

1 Introduction

Distribution system operators (DSO) face a challenging environment, coming from the integration of distributed renewable energy sources (DRES), novel schemes to empower prosumers and the uptake of other distributed energy resources (DER), such as demand response programs, batteries and electric vehicles (EVs) [1]. In particular, EV market is rapidly growing, with worldwide sales increasing by 64% in 2018, a trend that is expected to continue [2]. The massive integration of EVs into electricity networks will pose serious challenges, in particular to distribution grids where they are connected. However, EVs can present benefits to the power systems, as they can provide flexibility services by controlling the charging process (smart charge), and even act as distributed storage systems by using the Vehicle-to-Grid technology (V2G), and more generally V2X technology. This works seeks to analyze the key aspects to consider regarding the provision of flexibility services to distribution grids by EVs. By adapting a methodological analysis framework, we were able to identify the associated main technical and economic barriers, as well as emerging opportunities that consider the latest developments on the exploitation of flexibility at the local level.

The remainder of the work presents the motivation for using EV flexibility at the local level, followed by the methodological analysis framework. Then, we present the detailed analysis of the technical, economic and social elements. Finally, we conclude by summarizing the key barriers to exploit EV flexibility at the local level and recent developments in Europe.

2 Analytical Framework

The integration of EVs is one of many challenges that electricity systems are facing, and EVs could affect them both at the local (distribution systems) and global (system-wide) level.

At the local level, EVs will affect the operation and planning of distribution networks. Their impacts can be categorized in load and voltage issues. Additional load by EVs increases active power losses and can create congestion in the distribution grid [3]. Overloading of transformers and can cause equipment degradation and failure and lifespan reduction. On the other hand, voltage issues refer to the quality of voltage delivered to final users. EV charging can create voltage drops and phase-unbalances outside the grid requirements. These impacts depend on several factors including EV penetration rate, grid topology, user behaviour and tariff schemes [4]. To deal with these issues, DSOs would need to invest in infrastructure reinforcements, upgrading transformers or lines to alleviate congestion or to keep the voltage between the required boundaries.

Even though EVs can present impacts to the distribution grids, they present great flexibility potential. In fact, EVs are idle over 80% of the time, and the average daily consumption can be charged in 2.5 hours with a standard 3.7 kVA home charger [5]. This leaves margins for controlling the charging process of the vehicle (smart charge) and even use it as a storage system, being able to give back power to the grid (V2G). In the case of distribution grids, EV flexibility can be exploited to defer or avoid costly reinforcements. The project My Electric Avenue estimated that by 2050 one third of low voltage grids in the UK would need reinforcements (with an EV diffusion between 40-70%), but a simple coordination system could generate up to £2.2 billion in investment savings [6].

In the present work we adapted an analysis framework presented in [7] to systematically identify the aspects to be addressed for a proactive integration of EVs into distribution systems. For this, we reviewed the scientific literature and the results and recommendations of main European demonstrator projects in the subject of smart grids and on electric vehicle grid integration (VGI). The proposed framework allowed us to identify the main technical, economic and social aspects to take into account to exploit EV flexibility, which is shown in Fig. 1.

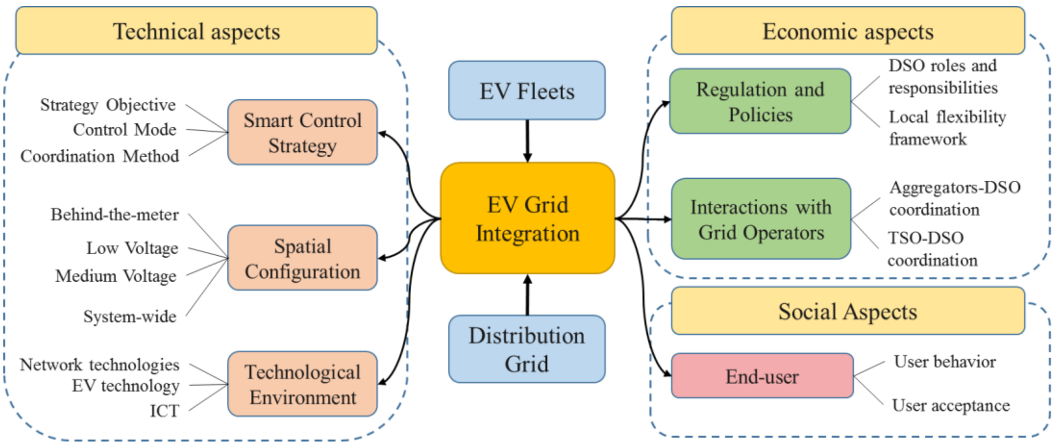

Figure 1: The analytical framework

3 Technical aspects

3.1 Control charging strategy

They are related to the technological environment necessary to make use of electric vehicle flexibility. Its main aspect refers to the charging control strategy. Several EV smart control strategies have been proposed in the literature with different objectives and coordination methods. These strategies are applied in a given spatial configuration of the electrical grid, from a low voltage district network to a regional (medium voltage) or national level (transmission level, wholesale markets), within a given technological environment, that can include DRES (PV, wind), EV technology (fast charging, V2G, reactive power provision) and information and communication technology (ICT) standards and requirements.

3.2 Definition of grid services

EV flexibility services can be proposed at various levels of the electricity system, as shown in Table 1. On one end, EV flexibility can be used to benefit directly the end-user in a behind-the-meter fashion, with the objective of reducing its energy bill or providing security of supply (vehicle-to-home and vehicle-to building). On the other end, EV fleets can provide system-wide services such as frequency regulation and energy portfolio management. In between, EV fleets can provide flexibility at the distribution level to solve local constraints (congestion or voltage issues), as well as other services such as phase balancing (in low voltage grids) and load shaping services (peak-shaving or valley filling). These services have been studied in various demonstrator projects in Europe. In particular, the technical flexibility potential of EV fleets has been proven for highly complex services such as frequency regulation. Most notably, in the Parker project an EVs provided frequency containment regulation in the Danish market, using commercially available EVs and V2G technology [8]. Regarding the distribution level, the projects My Electric Avenue and Electric Nation have proposed coordination mechanisms of EV charging in residential neighbourhoods to manage local grid congestion [6]. Additionally, the FlexPower project [9] has tested variable capacity contracts for public charging points (see 4.2.3) , and the BienVEnu project has tested the capability of a local EV fleet – controlled by a local EMS – to reduce its charging power in reaction to a local DSO signal [10]

Table 1: EV flexibility services by

Level	User	Service
Behind-the-meter	End-user	Electricity bill optimization
Local	**DSO**	**Local congestion management (MV or LV grid)** **Voltage Regulation and/or reactive power reserve** Phase balancing (LV grids) Load shaping
System-wide	TSO BRP	Frequency regulation Portfolio optimization

However, there still exist technical barriers that need to be overcome, which come from the lack of both (i) real-time monitoring of distribution grids and the communication standards, and (ii) requirements of EV capabilities. In the latter case, many studies have proposed the use of bidirectional chargers, even with reactive power compensation capabilities. However, these chargers are still not a mature technology and they still need improvements for the reduction of costs and losses [11].

3.3 Battery aging issues

In addition, battery degradation can represent a major impediment for V2G-based services, as V2G-induced additional battery cycling can reduce the battery's expected life. Battery degradation is a complex process, ruled principally by two behaviours: calendar aging, and cycling aging. Though calendar aging is seen as the major factor in battery aging, V2G might significantly reduce battery life if not used properly [12]. Studies have shown that frequency regulation services or services with low number of activations (ex. 20 activations per year) have little to no effect on battery aging [13]. However, the effects of distribution flexibility services in battery aging still need to be studied, as frequency services are more related to power reserve, while distribution services will involve energy provision, and their frequency of activation still needs to be studied.

3.4 ICT issues

Finally, the development of grid services require advanced metering, control and transactional communication that involve several agents: EVs, charging stations, aggregators, DSOs, Transmission system operators (TSO), and other market players. Increased observability in the distribution grids and widely accepted communication protocols and standards that support the necessary information exchanges (such as V2G support) are required to enable the provision of flexibility. Smart meter rollout in most of European countries [3] and new communication protocols, such as future ISO 15118 for EV-EVSE communication, will help overcome these barriers.

4 Economic Aspects

Understanding economic and regulatory aspects is crucial for a successful EV integration and the development of robust business models on flexibility services. These are related to the evolution of policy and regulation that will allow and encourage flexibility provision at the local level, not only from EVs but from other types of DERs as well, and the interactions between stakeholders, namely DSO with aggregators as service providers and with TSO.

4.1 DSO evolving roles and responsibilities

Historically, the DSOs operated radial grids with unidirectional power flows, from the transmission grid to end-users, where main concerns, congestion and voltage issues, were addressed by investing in grid reinforcements, through a “fit-and-forget” approach. A regulatory framework that remunerates DSOs based on their total costs, inciting them to invest in costly infrastructure to solve grid issues, reinforces this [3].

However, the surge of DERS and digitalization, are making DSO's roles and responsibilities to evolve towards an active management of distribution system operation [14]. With this approach flexibility management at the local level can avoid costly reinforcements and have a more efficient use of existing assets. Regulatory frameworks for DSOs need to evolve to incite cost efficiency, quality of service and innovation [15], enabling smart and flexible solutions.

In recent years, European regulators have had increasing interest in the use of flexibility at the distribution level. A major step forward was the EC Clean Energy Package that explicitly stated the need for DSOs to procure flexibility [16].

4.2 Flexibility Frameworks

Currently EV flexibility is exploited in existing markets for system-wide ancillary services. Existing commercial applications can be found for energy portfolio management [17] and system balancing (i.e. frequency regulation services) [18] [19]. However, currently there are no widespread mechanisms for accessing flexibility at the distribution level.

In particular, the frameworks for flexibility procurement by DSOs can be divided in the following categories, according to CEER [20]:

4.2.1 Rule-based

This approach uses rules and grid codes to impose flexibility requirements. Reactive power compensation by charging infrastructure has been proposed as a grid requirement in [21] to provide voltage support. However, this measure may pose an unfair requirement on electricity vehicles against other flexibility resources.

4.2.2 Network Tariffs

This mechanism provides an indirect value for flexibility, as it provides incentives to encourage end-users to adapt their consumption. These tariffs can reflect the costs of distribution system, giving incentives for the development of different forms of demand side response mechanisms.

The most common studied tariffs are Time-of-Use or Peak/Off-Peak tariffs. Though these tariffs provide the incentives to shift EV load from peak to off-peak hours, they can create local congestion or voltage issues due to synchronisation of the EV charging process during the beginning of the off-peak period [21]. In addition, these tariffs are usually set according to system-wide criteria (peak tariff coinciding with system-wide peak load), and not according to local grid requirements (peak load in a local distribution grid may not coincide with global peak load).

More complex tariff structures have been analysed in the literature, such as dynamic day-ahead tariffs [22] or Distribution Locational Marginal Prices (DLMP) [23], having positive results in simulations but may have difficult practical implementation. Complex tariffs may present issues on transparency and stability of end-user tariffs [24], and in the case of DLMP, they may go against the equalization principle that exist in some European countries (*principe de péréquation* in France).

4.2.3 Smart Connection Agreements

In this case, DSO and customer may reach an agreement for the provision of flexibility. They may take the form of interruptible contracts, where customers can be curtailed at the DSO's request, for example in case of congestion on the local distribution grid, or variable capacity contracts, where customers have reduced capacity connections during certain periods of the day. These contracts can benefit customers with lower connection costs and delays but may preclude their access to local or system-wide flexibility markets.

Smart connection agreements have been used for the connection of renewable generation in several parts of the world, and a similar approach may be used for the connection of new EV charging points. In the case of variable capacity contracts, they were tested in the FlexPower project in Amsterdam, where public charging points have a reduced capacity during peak hours but benefit from an increased one the rest of the day. This leads to a better utilisation of grid assets and faster EV charging for customers during off-peak hours [9].

4.2.4 Market-based

In this approach, DSOs explicitly procure flexibility services from a market, either by long-term bilateral contracts or via a short-term market platform. This approach is preferred by regulators [20].

Bilateral contracts can enable the procurement of flexibility for medium to long-term horizon. In this case, DSOs identify flexibility requirements that will enable to defer or avoid costly reinforcements and procure flexibility, rewarding the availability and activation of it. This type of contract can be signed between DSOs and flexibility providers after a tender process or through over-the-counter contracts, if there are no sufficient conditions for the formation of a liquid market.

This approach has been taken by UKPN, the London area DSO, who adopted a "flexibility first" policy towards all new investments in medium and high voltage (over 10 kV). They have identified grid sections where the use of flexibility during certain critical periods (in winter, during peak load) could help defer reinforcements, and have subsequently organized a tender process to procure flexibility from DERs. Currently, the 2018/2019 tender process will seek to procure up to 206 MW of flexibility to be used during the winter season of 2019-2020 (6 month ahead tender) and 2020-2021 (18 month ahead tender), and their Flexibility Roadmap [25] establishes the contracting of short-term flexibility during 2019. French DSO Enedis is following a similar approach, launching a consultation to develop their own local flexibility auction process [26]

Mechanisms to trade flexibility within a short time frame (day-ahead or intraday) have been proposed in the literature and various demonstrator projects (IDE4L [27], INVADE [28] and Interflex [29]), in particular in the form of flexibility market platforms. In these projects, different flexibility sources can participate to provide services to various stakeholders, such as DSOs, TSOs or Balancing Responsible Parties (BRP).

Another market-based solution are peer-to-peer local energy markets, such as those proposed in the projects EMPOWER and GRID-FRIENDS. These solutions are based on a neighbourhood-scale smart grid, where end-customers can trade energy products between themselves, helping balancing the grid a local level.

Having a market-based approach arises the issue of product definition and procurement. For this reason, flexibility products should be defined, in particular the power (active or reactive), duration and location requirements. These market products should enable the participation of different flexibility sources, not only EV, but all kinds of DER.

Nevertheless, market-based approaches might not be suited for all distribution-level services, as small size markets may lack sufficient competition and can suffer from high transactional costs, for example at the low voltage level. This can be especially true for neighbourhood-scale local energy markets.

Table 2 resumes the four frameworks for flexibility procurement, with their main benefits and risks.

Table 2: Frameworks enabling DSO access to flexibility

Framework	Value	Examples	Benefits	Risks
Rule-based	No value	Reactive power compensation	Useful where no market solutions	Technology bias Inefficiency
Network Tariffs	Indirect	Peak/Off-Peak Dynamic Pricing, DLMP	Incentives for all users	Don't solve local issues Equalization principle
Connection Agreements	Direct	Interruptible Connections Variable Capacity Connection	Fast connection process Lower connection costs	May preclude access to flexibility markets
Market based		Bilateral Contracts Local flexibility platforms Local Energy Markets	Preferred by regulators Competitive and transparent Foster innovation	Reduced size of local markets

4.3 Interactions between stakeholders

This aspect relates to how the different stakeholders interact along the flexibility value chain. On one side, there is the interaction between providers and customers of the flexibility, in this case EV users and DSOs respectively. In particular, whether there is direct interaction between DSO and EV users or through an aggregator of flexibility services. On the other hand, there is the interaction between two possible customers of flexibility, in this case DSOs and TSOs, and how their level of coordination and cooperation affect the use of local flexibility.

The SmartNet project studied DSO-TSO coordination, analysing five possible coordination schemes. Different schemes appeared according to the cooperation level of both entities, their role and responsibility definition and the level of integration of markets (centralized or decentralized). In particular, higher coordination schemes are necessary for the participation of DER, such as EV fleets, to both global and local flexibility markets [30].

5 Social Aspects

Social aspects of EV as flexibility sources for electricity grids are often overlooked or misrepresented in academic studies and demonstration projects, but are key for the success of its deployment [11].

On one hand, to evaluate impacts and flexibility potential of EVs it is necessary to have good knowledge on user behaviour. This refers mainly to how EVs are used (driving patterns) and how much and where they are charged (charging patterns). On the other hand, mobility is and will continue to be the primary purpose of electric vehicles. Flexibility services should be designed to meet driving requirements and work should be done to increase end-user awareness, to ensure user acceptance. Demonstrator projects of great utility, as they provide insight into real end-user data [4] and raise awareness of flexibility solutions [31].

6 Conclusions

The massive integration of EV into electricity grids will pose serious challenges, in particular to distribution grids. However, they present a great opportunity for active management of the grid, by using smart charging and V2G. Exploiting EV flexibility has value for distribution grids as it can defer or avoid costly reinforcements and provide a more efficient use of existing assets.

EV flexibility has been proven technically, and technology is rapidly advancing to overcome technical barriers on EV charging technology, ICT protocols and observability.

For this reason, the main barriers that arise for the provision of distribution flexibility services by EV fleets are economic and institutional. These barriers are the need for DSOs roles and responsibilities to evolve from a “fit-and-forget” towards an active management approach, and the lack of frameworks to procure flexibility at the distribution level.

However, significant advances have been made in recent years. There has been an increasing interest from regulators on the local management of flexibilities by DSOs, the development of local energy communities and increased DSO-TSO coordination. Mechanisms that enable DSO to access flexibility are emerging, most notably with the local flexibility auctions in the UK. Also, technical and economic aspects have been addressed by several European demonstrator projects in the last five years, demonstrating new technical solutions for distributed flexibility, including EVs, while analysing and proposing new frameworks for flexibility procurement.

Acknowledgments

The authors benefit from the support of the Chair "PSA Peugeot Citroën Automobile: Hybrid technologies and Economy of Electromobility", led by CentraleSupélec and ESSEC and sponsored by Groupe PSA.

References

[1] E. Rivero, M. Sebastian-Viana, J. Stromsather and A. Ulian, "The evolvDSO Project: Key Services for the evolution of DSO's roles," in *23rd International Conference on Electricity Distribution*, Lyon, 2015.

[2] EV Volumes, “Global EV Sales for 2018 – Final Results,” 2019. [Online]. Available: http://www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/. [Accessed 12 3 2019].

[3] K. Knezović, M. Marinelli, A. Zecchino, P. B. Andersen and C. Traeholt, "Supporting involvement of electric vehicles in distribution grids: Lowering the barriers for a proactive integration," *Energy,* vol. 134, pp. 458-468, 9 2017.

[4] M. Neaimeh, R. Wardle, A. M. Jenkins, J. Yi, G. Hill, P. F. Lyons, Y. Hübner, P. T. Blythe and P. C. Taylor, "A probabilistic approach to combining smart meter and electric vehicle charging data to investigate distribution network impacts," *Applied Energy,* vol. 157, pp. 688-698, 1 11 2015.

[5] A. Wargers, J. Kula, F. Ortiz De Obregon and D. Rubio, "Smart charging: integrating a large widespread of electric cars in electricity distribution grids," 2018.

[6] EA Technology, "My Electric Avenue Project Close-Down Report," 2016.

[7] Q. Hoarau and Y. Perez, "Interactions between electric mobility and photovoltaic generation: A review," *Renewable and Sustainable Energy Reviews,* vol. 94, pp. 510-522, 1 10 2018.

[8] Nissan International, “Nissan, Enel and Nuvve Operate World's First Fully Commercial Vehicle-to-Grid Hub in Denmark,” 29 August 2016. [Online].

[9] Amsterdam Smart City, "Flexpower Amsterdam," 2018. [Online]. Available: https://amsterdamsmartcity.com/projects/flexpower-amsterdam.

[10] M. Petit and M. Hennebel, “EV smart charging in collective residential buildings: the BienVEnu project,” in *IEEE PowerTech Conference,* Milan, 2019.

[11] Everoze and EVConsult, "V2G Global Roadtrip: Around the world in 50 projects. Lessons learned from fifty international vehicle-to-grid projects," 2018.

[12] K. Uddin, M. Dubarry and M. B. Glick, "The viability of vehicle-to-grid operations from a battery technology and policy perspective," *Energy Policy,* vol. 113, 2018.

[13] D. Wang, J. Coignard, T. Zeng, C. Zhang and S. Saxena, “Quantifying electric vehicle battery degradation from driving vs. vehicle-to-grid services,” *Journal of Power Sources,* no. 332, pp. 193-203, 2016.

[14] EURELECTRIC, "Active distribution system management," 2013.

[15] Council of European Energy Regulators, "Incentives Schemes for Regulating Distribution System Operators, including for innovation A CEER Conclusions Paper," 2018.

[16] European Commission, "Proposal for a Regulation of the European Parliament and the Council on the internal market for electricity," Brussels, 2016.

[17] Jedlix, "The first Smart Charging app | Jedlix," [Online]. Available: https://www.jedlix.com/en/.

[18] "Nuvve Operate World's First Fully Commercial Vehicle-to-Grid Hub in Denmark | NUVVE Corp," [Online]. Available: http://nuvve.com/portfolio/nissan-enel-and-nuvve-operate-worlds-first-fully-commercial-vehicle-to-grid-hub-in-denmark/.

[19] "PSA GridMotion Project | NUVVE Corp," 2017. [Online]. Available: http://nuvve.com/portfolio/gridmotion-project-reducing-electric-vehicle-usage-cost-thanks-to-smart-charging-process/.

[20] Council of European Energy Regulators, "Distribution Systems Working Group Flexibility Use at Distribution Level A CEER Conclusions Paper," 2018.

[21] N. Leemput, F. Geth, J. Van Roy, J. Büscher and J. Driesen, "Reactive power support in residential LV distribution grids through electric vehicle charging," *Sustainable Energy, Grids and Networks,* vol. 3, pp. 24-35, 9 2015.

[22] N. O'Connell, Q. Wu, J. Østergaard, A. H. Nielsen, S. T. Cha and Y. Ding, "Day-ahead tariffs for the alleviation of distribution grid congestion from electric vehicles," *Electric Power Systems Research,* vol. 92, pp. 106-114, 1 11 2012.

[23] R. Li, Q. Wu and S. S. Oren, "Distribution Locational Marginal Pricing for Optimal Electric Vehicle Charging Management," *IEEE Transactions on Power Systems,* vol. 29, no. 1, pp. 203-211, 1 2014.

[24] C. Eid, P. Codani, Y. Perez, J. Reneses and R. Hakvoort, "Managing electric flexibility from Distributed Energy Resources: A review of incentives for market design," *Renewable and Sustainable Energy Reviews,* vol. 64, pp. 237-247, 1 10 2016.

[25] UKPN, "Flexibility Roadmap," 2018.

[26] Enedis, *Les Flexibilités Locales sur le Réseau Public de Distribution d"Electricité: Appel à Contributions,* 2018.

[27] IDE4L Project, "Deliverable 6.1 Optimal scheduling tools for day-ahead operation and intraday adjustment," 2015.

[28] S. O. Ottesen, P. Olivella-Rossell, P. Llloret and A. Hentunen, "Invade Project D5.3 Simplified Battery operation and control algorithm," 2017.

[29] Interflex Project, "D7.1 D7.2 District architecture requirements, tested innovations and use case planning," 2018.

[30] H. Gerard, E. I. Rivero Puente and D. Six, "Coordination between transmission and distribution system operators in the electricity sector: A conceptual framework," *Utilities Policy,* vol. 50, pp. 40-48, 1 2 2018.

[31] J. Kester, L. Noel, G. Zarazua de Rubes and B. K. Sovacool, "Promoting Vehicle to Grid (V2G) in the Nordic region: Expert advice on policy mechanisms for accelerated diffusion," *Energy Policy,* vol. 116, pp. 422-432, 2018.

Authors

Felipe Gonzalez Venegas was born in Santiago, Chile. He followed a double degree program, obtaining a Ms. Sc. degree in Engineering from Ecole Centrale Paris and Electrical Engineering from Universidad de Chile in 2016. He has worked as technical consultant in the Chilean power sector and is currently pursuing the Ph.D. degree in electrical engineering at GeePs-CentraleSupélec, France in collaboration with Groupe PSA.

His current research interests includes the integration of electric vehicles into electricity networks, smart grids and energy transition.

Marc Petit was born in 1972 and is a former student of the Ecole Normale Superieure de Cachan (France). He took his PhD thesis in 2002 in electrical engineering. Since 2003 he is assistant/associate professor in CentraleSupelec in the Power and Energy Systems Department where he currently manages the power system group. Since November 2011, he is co-head of the Armand Peugeot research chair on Electromobility. His research interests are on smart grids, demand response, power system protection and HVDC supergrids.

Yannick Perez was born in 1971 and took his Master's degree and PhD in economics at University La Sorbonne in France. Since October 2008, he is chief economic advisor of the Loyola de Palacio Chair on European Energy Policy at the European University Institute. Since September 2011, he is also associated Professor of Economics in CentraleSupélec, France. In February 2012, he joined the Armand Peugeot research chair on Electromobility as Senior Research Fellow.

His main research interest in on Market Design.