Assessment of the Impact of Electric Vehicles on Iberian Day-ahead Electricity Market

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Abstract— **Electric vehicles (EVs) could become a controllable grid load by using demand side management techniques, but this requires an information and communications technology (ICT) infrastructure and aggregator agents, to coordinate the EV charging process. To determine the opportunity cost of aggregators, it is necessary to analyze the extra charges in the electricity market, due to the EV charging demand. The EV energy consumption is modeled following agent-based techniques, and the data used corresponds to the Iberian day-ahead market and Spanish mobility needs in 2012. The simulation results show that EVs would significantly influence the electricity price on the day-ahead market, depending on the EV charging behavior.**

Keywords— Electric vehicles, day-ahead market, demand side management, EV demand

I. INTRODUCTION

The transportation sector is responsible for around a quarter of EU greenhouse gas emissions, and amount of emissions from transportation have increased with 36% between 1990 and 2007 [1]. Demand for transportation fuels will continue to increase along with carbon dioxide emissions, unless there is a shift in the transportation sector. Most of the EU member states are now establishing clear deployment goals for increasing and stimulating a larger penetration of EVs which include plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), and fuel-cell electric vehicles (FCEVs).

Wide use of EVs will have an impact on electricity loads and could accelerate the overstretching of the power system, if steps are not taken to prevent this. Big amounts of EVs would add a considerable amount of additional load on the power system if the charging of EVs is uncontrolled, as the start of the uncontrolled charging process at home would coincide with the residential evening peak load. With controlled charging, this influence can be decreased by shifting the charging to times when the consumption is low [2] − [5]. Some papers showed that a penetration of 30% EVs is possible without any significant impact on distribution networks, if some form of coordinated charging is implemented [6]. Charging of EVs is more flexible than traditional loads, because the majority of EVs is driving a relatively low distance and is standing still for a significantly long time, typically overnight [6]. To utilize this flexibility, appropriate algorithms for charging control and management can and must be designed [8]-[10]. This control will be performed by EVs aggregators which will offer new financial contracts specific for aggregated EVs loads.

Smart grid technologies and demand side management (DSM) have been proposed as a technical solution to make demand more flexible and able to adapt to power generation and increase system efficiency, stability and reliability. DSM has been regarded as one of the most effective and efficient ways to solve problems associated with renewable energy integration into power system [11]. Shifting of load in certain optimal ways can contribute to various goals such as peak shaving and valley filling [7]. Responsive loads are one part of a DSM approach, which can offer different incentives and benefits to consumers in response to their flexibility, i.e. demand response (DR) [12]. DR is a cost effective technique and can be achieved by either price based or incentive based programs [8]. The power grid has limited storage capabilities, so electricity generation and transmission must be continuously managed to match fluctuating demand [13]. Conventionally, this balance is maintained by power plants that remain on stand-by, ready to respond at desirable moment. DR programs can change consumption behavior by shifting loads to off-peak periods and participate in balancing of demand and supply [14]. Albadi and El-Saadany presented an overview of new flexible resources and defined DR programs and how electricity consumers can participate in those programs [13]. Others provided an overview of the evolution of the DR program and analysis of current opportunities [15]. Cappers et al. summarized the contribution of DR resources in the U.S., with the focus on performance of incentive-based DR programs in organized markets [16]. Kim and Shcherbakova examined central structural and behavioral obstacles to success of DR programs and defined some potential solutions which could greatly improve the functionality and success in the future [17]. Ma and Alcadi

assessed the realizable potential of DR for ancillary services (AS) in terms of economic value and implementation [18]. Some authors proposed and explored a distributed direct load control approach for the large-scale residential DR [19] and others investigated DR programs for residential appliances [20]-[21], or electric heaters [22]–[23]. Venkatesan et al. developed a model for DR to calculate the effect on the voltage profiles [24], and others developed a model to assess the impact on both voltage profiles and grid losses of an electric distribution network [25] - [26].

The most costly part of the electricity demand is the one that occurs during the peak periods. Ultimate objective of DR programs is to reduce peak demand and programs are implemented so consumers can make decisions based on the information of price from the market. High price periods creates the opportunity for using electric vehicles with the vehicle-to-grid (V2G) services to provide required flexibility to the power system. V2G is the concept under which the power system can receive power from parked EVs. V2G services could be sold in an organized market as AS (regulation or spinning reserve), or as energy sales to the grid (peak power). The Federal Energy Regulatory Commission (FERC) reported a total potential DR contribution of about 37,500 MW in 2012 in the US [27]. A total of 66 GW were under some form of control, making up 9 % of total US national capacity in 2012. Response and the average estimated peak clipping was 8-11 % while average estimated peak clipping in Europe in the same time was 6-13 % [28].

Because of the plans of implementing smart grid technologies, some policy makers are anticipating that DR will be able to play a much bigger role in electricity markets in the near future [15]. Increased availability of DSM over the next 10 years will reduce peak demands, contribute to the deferral of new generating capacity, or improve operator flexibility in day-ahead or real-time time operations [28]. Ma, Callaway and Hiskens concluded that if 30 % of conventional vehicles in the US were replaced by PHEVs, the total charging load would be around 140 GW, which accounts for 18 % of the US summer peak load of 780 GW [29].

One of the most important challenges in the smart grid context is the employment of the necessary ICT infrastructure [30]. Authors proposed multi-agent system for various implementation, from calculating best solution for DSM program of PHEVs [31] to managing a power distribution system with PHEVs in smart grids [32]. Smart grid technology also enables bidirectional communication between the power system and the power consumer (EV owner or EV aggregator), so consumers can make decisions based on the information delivered to them. This communication infrastructure and protocols will greatly enhance DR capabilities of the whole system [33].

Fig. 1 shows schematic of proposed agent system with EVs. It consists of: transmission system operators (TSO or ISO), distribution system operator (DSO), aggregation agent and EVs (customers). Existing and new agents in the electricity sector are also discussed in [13]. It has to be mentioned that this paper is about conventional, restructured and deregulated electricity market. Customers are agents that are consuming

real purchased energy as producers are producing. EV owners can chose whether they want to be directly connected with the supplier or in some cases through an EV aggregator. If EV owners decide to provide V2G services, they need to be aggregated by a market agent since the regulation doesn't allow market participation of small loads [34].

EV aggregation agents play an important role as a commercial middlemen between EV owners and electricity markets. Some of the authors are referring to the aggregation agent as charging service provider (CSP) or virtual power plant (VPP), but their role is the same [26],[35]. This agent is seen as a large source of generation or load (aggregated EV load), which could provide auxiliary services such as spinning and regulating reserve (V2G services). EV aggregator is controlling EVs consumption and needs to forecast the effective consumption from the EV under contract so specialized forecasting algorithms are needed. Aggregators can be managed for example to maximize energy trading profits [11], or to minimize charging costs [12]-[13]. Brooks proposed the development of a V2G aggregator, and others studied different optimization approaches to support aggregator participation in day-ahead and secondary reserve markets [36] – [38].
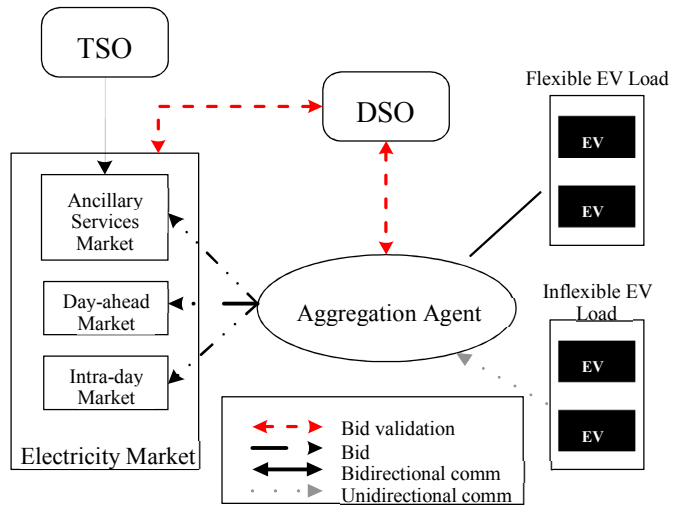

Fig. 1 Schematic of proposed agent system [34]

Distribution system operators (DSOs) are the owners and operators of the distribution grid in the case when the distribution system is legally unbundled from generation, transmission, and particularly from supply and retail. It has the purpose of physically distributing energy to the final customers.

Independent system Operators (ISOs) or transmission system operators (TSOs) are agents which are responsible for keeping a secure system operation at a regional or national transmission level. TSOs like DSOs cannot trade energy, but it has to manage transmission system with a goal of covering errors from the wrong assumption of production and consumption from market participators. They procures system services, operational reserves and frequency regulation from market participants (spinning reserve generators or EVs).

With the expected mass adoption of EVs in the coming years, as reported by the IEA [3], the impact of EVs charging demand on prices of electric market has to be taken into account. Therefore the impact of charge scheduling of EVs on the day-ahead electricity market prices in different scenarios is investigated in this paper.

II. ECONOMICS AND POWER MARKETS OF EV

This section explains several market and EV aggregator participation in them. Kempton and Tomić [38] first defined the vehicle to grid (V2G) concept under which the electric network can receive power from parked EVs (bidirectional power-flow and communication). Under the V2G framework, aggregator agents can also provide controllable load and AS, such as operating reserve or regulation. Significant capital costs of EV batteries may not be justified for mobility reasons alone, but there may be a potential extra income from tariffs and AS. V2G services would provide economical compensation for battery usage to EV owners and stimulate a larger interaction of EVs with the power system. V2G could economically makes sense, because the storage system is purchased for the transportation function, yet it is idle for more than 94.80 % of time [11] at which they could provide auxiliary service.

Power markets relevant for V2G are: base load power, peak power, spinning reserves, and regulation markets. However, the depreciation cost of the increased number of charge/discharge cycles should be taken into account to correctly assess the economic viability of V2G.

- **Base load power market.**

The base load power market is for the power that has to be provided continuously during the whole day. Base load power is usually sold through long term contracts for steady production at a relatively low price per kW and it is typically provided by large nuclear, coal fired, hydroelectric and gas turbine combined cycle power plants. EVs are not suitable for base load power, because they have very continuous energy capacities, and most EVs are just consumers of electrical power [13].

- **Peak power**

The term "peak power" doesn't refer to a specific power market, and it is used to refer to the highest cost hours of the year, when there is exceptionally high demand (hot summer afternoon), and almost all generators are online and working. This power is typically provided by open and combined-cycle gas generators that can be switched on and off within a shorter time span. The cycle duration can be up to 3 - 5 hours, which is possible for V2G technology, but the battery capacities might limit the amount of power that can be economically provided. EVs can overcome this energy-storage limit if power was drawn sequentially from a series of vehicles [13].

- **Ancillary services.**

The primary function of AS is to maintain the reliability and stability of the power system. In practice, transmission outages, fluctuations and even failures are causing mismatches of power generation and load consumption, so there is a need for AS. Markets that are frequently known as ancillary services are regulation, spinning and non-spinning reserve. The AS market is within day-ahead and intraday markets that are discussed in this paper. In this type of services, revenue derives from "capacity payment" and "energy payment". The former is for the capacity that is contracted for the contracted time duration, whether being used or not, and energy payment is for the actual energy that is produced (kWh). In the V2G concept, capacity is paid only if vehicles are parked and available (plugged-in, enough fuel or charge and have confirmed contract for the hour on market).

AS account for 5-10 % of electricity costs, or about 12 billion dollar per year in the U.S. with 80 % of that cost going to regulation [38]. EVs with V2G services are extremely competitive for this service. AS market (A/S) can be separated on two parts: spinning reserve and regulation.

I. Spinning reserve

Spinning reserve is additional generating capacity (generators) synchronized with the power system that can provide power quickly, depending on the request of the grid operator. This request is given when there is an unplanned event in the system, such as loss of generation, or some kind of failure. Spinning reserves are rarely used, 10-20 times a year for durations from 10 minutes to an hour. Kempton et al. [38] concluded that EVs with V2G are well suited for providing spinning reserves, because they can react quickly and would get paid as "spinning" for many hours. As spinning reserves time is longer, fueled vehicles gain advantage over battery vehicles because they generally have more energy storage capacity [39].Regulation

II. Regulation

The TSO is responsible for maintaining the balance between production and consumption in the delivery hour, and in case of unbalances it has to compensate by activating regulation power from AS. Regulation is also referred to as automatic generation control (AGC) or frequency control, and it is used to regulate frequency and voltage on the grid by matching instantaneous generation to load demand. To provide this service and to participate in regulation market, the participants (EVs) must respond to a frequent real-time AGC signal sent by the TSO every 2-4 seconds [39]. AGC is controlled automatically by direct connection from grid operator and it is called more often (400 times per day) to run for shorter durations, typically for a few minutes at a time [39]. EV battery systems are especially suited for regulation power, because of their quick response capabilities in the order of milliseconds, and the characteristic of short periods of regulation [40]. Bessa and Matos proposed a scenario in which plug-in vehicles alone could provide all of the regulation in are TSO control area, and it was proved that the potential value per vehicle is much greater when selling regulation [41].

- **Storage**

Kempton and Tomić [42] presented storage and backup power of EV as one part of V2G services that can help accommodate high penetration of renewable energy (50%) and compensate forecasting errors. Storage would be provided by battery vehicles or plug-in hybrids and backup power by hybrid running motor generator or fuel-cell vehicles. Such a

service could be important to accommodate a high penetration rate of renewable energy, because a large volume of storage capacity or back-up generation is needed to cover short periods with low wind and sun.

Some of the authors are considering the use of EV batteries to store grid electricity generated at off-peak hours for off-vehicle use during peak hours, i.e., arbitrage [43]. Most important fact in that case is the volatility of the prices because higher volatility offers more opportunities for storage system to buy and sell electricity with profit. Pesch and Stenzel studied the German day-ahead market and they showed that volatility of the prices has been decreasing in the last years, especially because of peak shaving effect of PVs [44]. They concluded that batteries are still too expensive to be profitable in energy storage service, but an increase of volatility could change this situation. They also assumed that an increasing number of renewables could increase volatility. Peterson and Whitacre [43] showed that vehicle owners are not likely to receive sufficient incentives to be motivated for the large scale use of EV batteries for grid energy storage.

Calderaro et al. proposed a study on the energy storage systems (ESS) sizing, in order to offer a peak shaving ancillary services to DSO in order to support the distributed network during the peak demand period [45]. The results shows that by means of an appropriate ESS sizing it is possible to obtain feasible solutions that represent a good compromise between size and cost. In this way the DSO can defer infrastructure investments using the power production of RESs when required and paying for the given service [45].

- **Day-ahead market**

Electricity prices in Europe are set on a daily basis for twenty-four hours of the following day in what is called the Daily market or Day-ahead market. The price and volume of energy over a specific hour are determined by the point at which the supply and demand curves meet, according to the marginal pricing model adopted by the EU, based on the algorithm approved for all European markets (EUPHEMIA). This algorithm and market coupling platform are now being used in Spain, Portugal and other 15 countries.

This section describes the participation of an aggregator agent in the Iberian market with the present market rules [36]. The Iberian market (Portugal and Spain) is organized through several markets, where each day is divided in 24 hours. The day-ahead market is the first which is going to be resolved and cleared. Gomaz and Momber gave detail information about daily and intraday electricity market operating rules [46]. Bessa and Matos [34] proposed a procedure that can be followed by an aggregator for participating in the day-ahead market, as illustrated in (Fig. 2). At time step "t_0" the EV aggregator forecasts: the total EV electrical energy load, the total battery SOC, and the number of EV plugged in each hour of the next day. At "t_1" the EV aggregator forecasts the spot and balancing prices for the day ahead market, and at "t_2" aggregator defines the hourly bids for buying and selling electrical energy in the day-ahead and ancillary service market. At 12:00, the market operator closes the period for reception and validation of the sale and purchase bids placed by the market agents. At 13:00, all results of the day-ahead

market are confirmed by the market players and market operators, and the result is available to all market participants.

Sale and purchase bids are either price dependent or price independent. Usually sale bids will be price dependent and purchase bids independent because most of the consumers don't respond to the price signal. If we take into consideration that EVs are flexible loads, EV aggregation agents can chose to start charging at the assumed less expensive hours of the day, if the business model has the goal of minimizing the costs of the aggregator. The EV aggregator's main problem is to estimate the lowest prices on the market and to purchase power accordingly, while taking into account charging demand and when vehicles are plugged in. This problem is even complicated by the fact that the price is dependent of demand. A significant load increase would increase prices. This problem is also present in the ancillary market (V2G), because if an hour with high prices is expected, it may not make economic sense to EV aggregator to discharge all vehicles simultaneously, since all extra power would cause electricity prices to drop significantly.

Aggregators would need to define number of vehicles, amount of electrical energy to buy and sell. Based on the forecast, aggregators also needs to define the periods where it is possible to manage charging by moving it from one hour to other without jeopardizing owners desired battery state of charge (SOC).
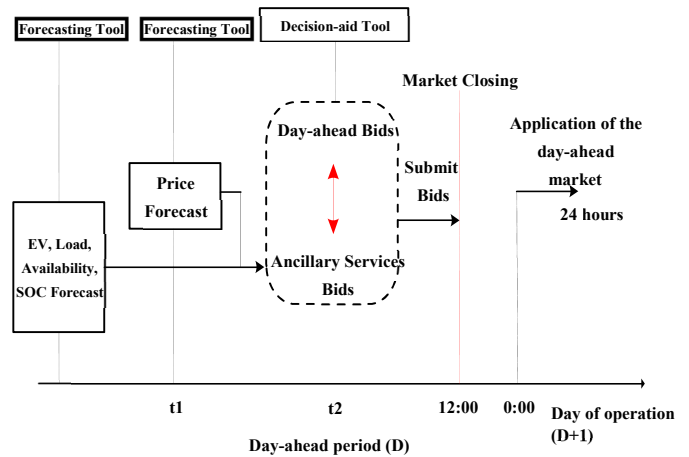

Fig. 2 Timeline of day-ahead market and aggregator market bidding [37]

Aggregators in the day-ahead market must roughly estimate the load that can be later corrected in the intraday market. Gonzalez and Anderson introduced a day-ahead scheduling that minimize costs and avoid network asset overloading, and they proved that aggregated EV fleets can significantly contribute to regulation reserve [47]. Bessa and Matos also studied different optimization problems for supporting the participation of an EV aggregation agent in the day-ahead and secondary reserve market [34]. Balram et al. studied the impact of charge scheduling of a large number of EVs on the day-ahead electric market price [3]. They proposed joint and aggregated scheduling models, and proved that for low penetration rate of EVs, simple scheduling methods without large increase in the market price can be used. In the

case of higher penetration levels of 20, 50, and 100 %, advanced scheduling methods are needed as they proposed.

III. IMPACT OF EV PENETRATION ON ELECTRICITY PRICE IN IBERIAN DAY-AHEAD MARKET

With the aim of assessing the regulations, to stimulate EV participation on energy markets, the impact of EV energy demand on the day-ahead market is investigated. The day-ahead market is the most important market in terms of energy negotiated. Moreover, it is compulsory to participate to have access to the other markets. The hourly data of 2012 for the Iberian day-ahead market are used, and the EV charging demand will be added, accordingly to [6]. Fig. 3 illustrates the dealings between the supply curve and demand curve, giving the marginal price for each MWh joined, and the agreed total energy. This figure also shows how the energy price (λ_t) increases with 469 MWh (+1.91%) due to EVs (P_t), resulting in a price increase from 17.07 to 31 EUR/MWh (+81.61%) and a total energy cost (Producer utility and producer surplus) increase from 419.19 to 775.81 MEUR (+85.07%). This price increase is based on the supply curve, because the supply curves are related to the generation costs and the demand curves are more related to commercial strategies. Moreover, supply curves are very elastic and therefore, the price increases significantly with a limited demand increase.
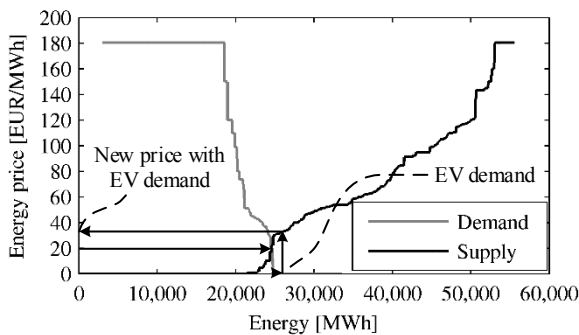

Fig. 3 Curves of supply and demand on energy. March 9th of 2012 for hour 24 of Iberian day-ahead market.

The EV charging used in this study is modeled with Agent-based techniques following the same approach to the one found in [6]. A set of agents has been defined with different attributes, each one being an autonomous software entity. These attributes determine the way the agent behaves in the given scenario, and how they interact with the environment and other agents [11]-[13]. The main reason this methodology is used, is the fact that it has been previously tested in mobility related applications [48], and it enables to test a wide range of different agents and attributes.

The case study simulates the EV users charging behavior of 10% of Spanish vehicles (1,094,944 vehicles). They consume 6,874.7 MWh/day, 6.2786 kWh/day for each vehicle. Each vehicle drives 3.1 displacements/day [49] and 25.91 km/disp. [50] on average. The charging maximum power is 3.7 kW following Mode 1 IEC 61851.

In Fig. 4, it is illustrated how the EVs consume charging energy during a week. In this case, it is considered that EV

drivers charge at the end of each trip in public stations, at the workplace, and at home. The higher energy consumption occurs when the drivers arrive at home and charge their EV. The peak demand before noon each working day occurs when the drivers arrive at the workplace. The EV consumption at weekend days is lower than during weekdays, because the number of displacements is lower.

The model developed to simulate the day-ahead market does not consider the grid constraints, the complex supply offers, and all the EV consumption is purchased in the day-ahead market to reduce extra charges in the intra-day and technical markets. Furthermore, the deviation corresponding to the forecasting errors and their corresponding extra charges are not considered here.
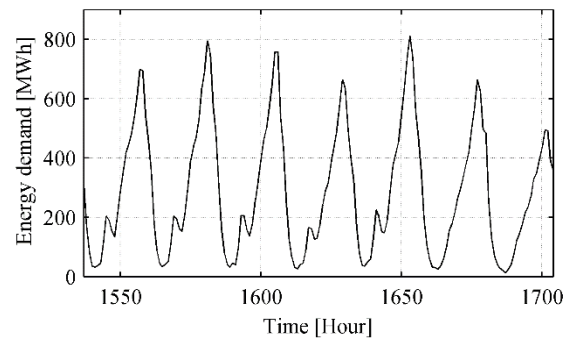

Fig. 4 EV charging demand in a week

$$C = \sum_t \lambda_t \cdot P_t \qquad (1)$$

$$\bar{\lambda} = \frac{\sum_t \lambda_t \cdot P_t}{\sum_t P_t} \qquad (2)$$

TABLE I.   IMPACT OF EV IN IBERIA DAY-AHEAD MARKET

	Average price() [EUR/MWh]	Annual energy [TWh]	Annual cost (C) [MEUR]
Without EV	23.62	245.42	5797.2
With EV	25.44	247.93	6307.9
Variation	7.71%	1.02%	8.81%

The total energy purchased in the market with EVs is shown in Fig. 5, and it shows the seasonal variation during the year. During winter the consumption is higher due to lower temperatures and during summer the energy consumption increases due to higher temperatures and the air conditioners. The EV consumption is not different between summer and winter, because there is no data available about this.

The day-head market energy prices are shown in Fig. 6. The variations have increased, and after the 2,000th and 6,000th hour, the prices decrease due to high renewable electricity production [51]. Furthermore, the EV consumption does not avoid the zero value hours but they are reduced from 3.12 % to 0.39 % of hours.

The duration curve of energy and prices are shown in Fig. 7 and Fig. 8 respectively. Corresponding to the energy duration curve, the EV consumption occurs in the first 5,000

hours with higher energy demand. The maximum demand increases from 43,276 to 44,003 MWh (+1.68%) with EVs, and the total energy increase is also limited (+1.02%).
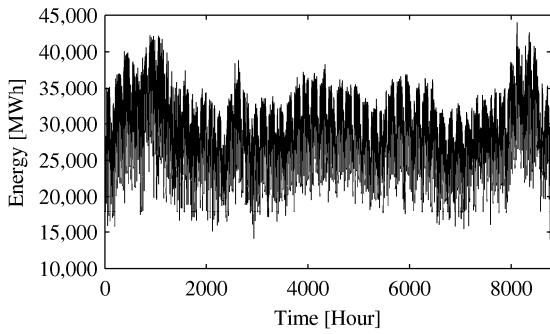

Fig. 5 Energy purchased in the Iberian day-ahead market in 2012 with EV
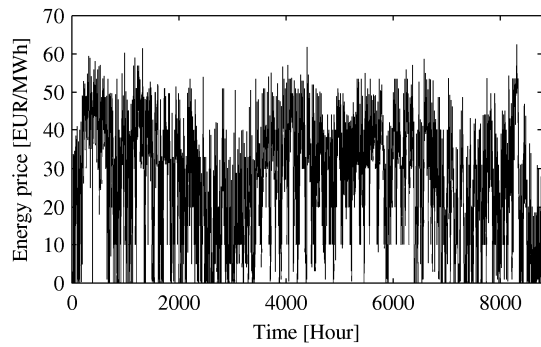
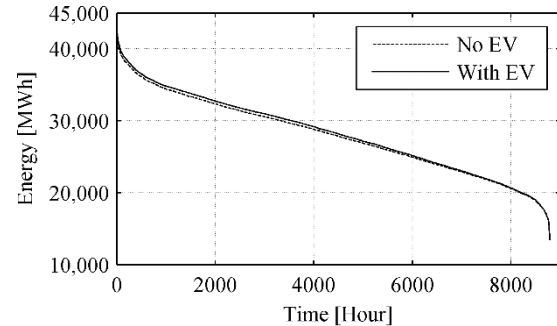

Fig. 6 Day-head market energy prices in 2012.

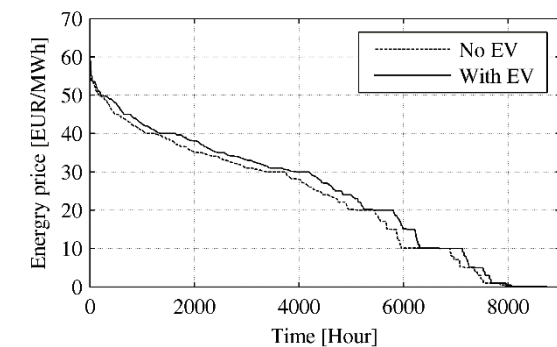Fig. 7 Energy purchased duration curve in day-ahead market in 2012

Fig. 8 Duration curve of day-ahead market energy price

In contrast, the energy price increase is more significant, due to the shape of the day-ahead supply curves, as shown in Fig. 8. The limited energy demand increase of 1.02 %

provokes a price increase of 7.71 %. Furthermore, the energy price increases for all hours according to the generator offers. The maximum price increases with 1.03 % due to EVs, from 61.86 to 62.5 EUR/MWh.

To show the impact of EVs in the day-ahead market in more detail, the analysis is focused in the 11th week of 2012, starting on March 5th of 2012, as shown in Fig. 9. This week exposes different consequences, because the wind production during this week was higher than normal operation, reaching 12,475 MW at 14:00 in March 8th, and having a market share of 37.3 % at 0:00 on March 5th.

Fig. 9 also illustrates that there are hours with zero prices, even with EVs. Moreover, the difference in prices with and without EV are shown in black bars, and the highest variations do not necessarily occur in the hours with highest energy increase. It is also linked with the total amount of energy purchased. This figure also shows the differences between the energy purchased with and without EV.
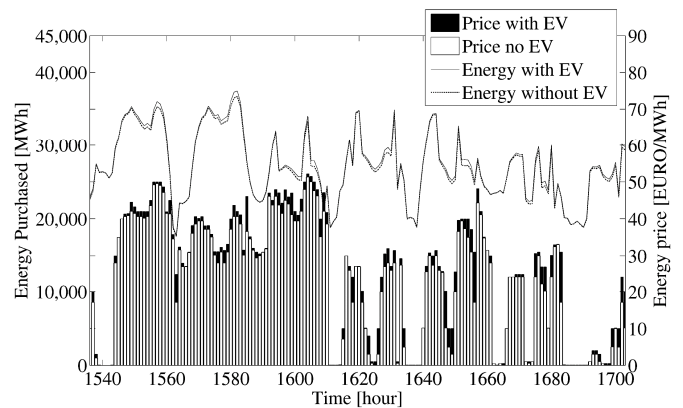

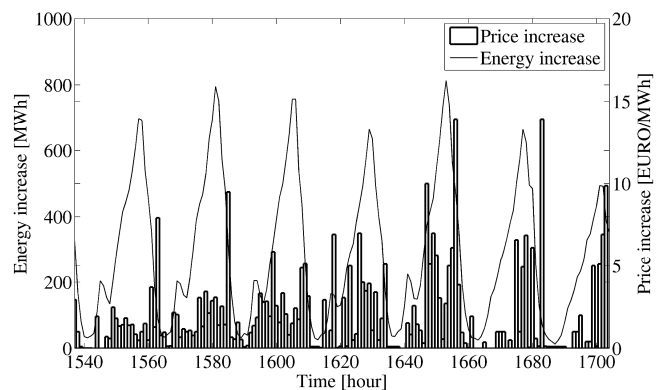Fig. 9 Energy and price of the 11th week of 2012

Fig. 10 Energy and price increases of the 11th week of 2012

Fig. 10 illustrates the EV charging demand which corresponds to the increased energy demand in the day-ahead market. Furthermore, it is compared with the price increase. The first two days show a certain level of directly proportional relation between the energy and price, because when the energy demand increases, the price also increases. Nevertheless, this relation is lower in the third and fourth day and clearly disappears in the last three days of the week, because in the Spanish power system, the consumption on

Fridays, Saturdays, and Sundays is lower than during the rest of the week.

IV. CONCLUSIONS

This paper exposes the advantages of using electric vehicles as an alternative for conventional vehicles, and their relation with electricity market. One conclusion is that the vehicle-to-grid (V2G) concept, under which electric vehicles (EVs) can participate in an organized market as ancillary service provider or as energy supplier to the grid, has a bright future, more specifically for spinning reserve and regulation.

Moreover, the use of EVs will have an impact on the electricity market. Simulations exposed in the paper have shown that of EVs would influence the price at the day-ahead electricity market, depending on the EV penetration rate. The electricity price in the Iberian day-ahead market could increase significantly due to the high elasticity of the supply curves. According to that, there is a considerable opportunity cost for aggregators to implement controlled EV charging strategies.

REFERENCES

[1] European Comission, Energy department related to renewable energies http://ec.europa.eu/energy/renewables/targets_en.htm

[2] M. Gonzalez Vaya, G. Andersson, "Locational Marginal Pricing based Smart Charging of Plug-In Hybrid Vehicle Fleets", ETH Zürich, Smart Energy Strategies Conference 2011, 21-23 September 2011, Zurich, Switzerland

[3] P. Balram, L. Anh, T. Bertling, L. Tjernberg, "Effects of plug-in electric vehicle charge scheduling on the day-ahead electricity market price," Innovative Smart Grid Technologies 2012, 3rd IEEE PES International Conference and Exhibition on ,October. 2012.

[4] D. Steen, "Scheduling charging for optimal distribution systems planning and operation", International Conference on Electricity Distribution CIRED, Frankfurt, June 2011.

[5] S. Shao, M. Pipattanasomporn. S. Rahman, "Grid Integration of Electric Vehicles and Demand Response With Customer Choice", IEEE transactions on smart grid, vol. 3, no. 1, March 2012

[6] P. Olivella-Rosell, "Demand modeling of normal and fast charge of EVs for the study of impact to the distribution networks (Modelado de la demanda de carga lenta y rápida de vehículos eléctricos para el estudio de impacto en la red de distribución)", Master Thesis, Universitat Politècnica de Catalunya, 2013

[7] W. Kempton, J. Tomić, "Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy", Journal of Power Sources, Volume 144, Issue 1, 1 June 2005.

[8] D. Wu, D.C. Aliprantis, L. Ying, "Load Scheduling and Dispatch for Aggregators of Plug-In Electric Vehicles," IEEE transactions on smart grid, vol.3, no.1, March 2012.

[9] K. Schneider, C. Gerkensmeyer, M. Kintner-Meyer, M. Fletcher, "Impact assessment of plug-in hybrid electric vehicles on pacific northwest distribution systems," IEEE Power and Energy General Meeting, Pittsburgh, 2008.

[10] Rashid A. Waraich a,⇑, Matthias D. Galus b, Christoph Dobler a, Michael Balmer, Göran Andersson b, Kay W. Axhausen, Plug-in hybrid electric vehicles and smart grids: Investigations based on a microsimulation, Transportation Research Part C 28 (2013) 74–86

[11] S. Huang, D. Infield, "The potential of domestic electric vehicles to contribute to Power System Operation through vehicle to grid technology," Universities Power Engineering Conference (UPEC), 2009 Proceedings of the 44th International , pp.1,5, Sept. 2009

[12] M. Muratori, B. Schuelke-Leech, G. Rizzoni, "Role of residential demand response in modern electricity markets", Renewable and Sustainable Energy Reviews, Volume 33, May 2014, p - 546-553

[13] M.H. Albadi, E.F. El-Saadany, "A summary of demand response in electricity markets" Electric Power Systems Research, Volume 78, Issue 11, November 2008.

[14] S. Gottwalt, W. Ketter, C. Block, J. Collins, C. Weinhardt, "Demand side management—A simulation of household behavior under variable prices", Energy Policy, Volume 39, Issue 12, December 2011, Pages 8163–8174

[15] R. Walawalkar, S. Fernands, N. Thakur, K. Reddy Chevva, "Evolution and current status of demand response (DR) in electricity markets: Insights from PJM and NYISO", Energy, Volume 35, Issue 4, April 2010.

[16] P. Cappers, C. Goldman, D. Kathan, "Demand response in U.S. electricity markets: Empirical evidence", Energy 35 (2010) 1526–1535

[17] J.H. Kim, A. Shcherbakova, "Common failures of demand response", Energy 36 (2011) 873

[18] O. Ma, N. Alkadi, P. Cappers, P- Denholm, J. Dudley, S. Goli, M. Hummon, S. kiliccote, J. MacDonald, N. Matson, D. Olsen, C. Rose, M.D.Sohn, M.Starke, B.Kirby, M. O'Malley, "Demand Response for Ancillary Services" Smart Grid, IEEE Transactions on , vol.4, no.4, pp.1988,1995, Dec. 2013.

[19] C. Chen, J. Wang, S. Kishore, "A Distributed Direct Load Control Approach for Large-Scale Residential Demand Response" Power Systems, IEEE Transactions on , vol.29, no.5, pp.2219,2228, Sept. 2014

[20] C. Vivekananthan, Y. Mishra, G. Ledwich, F. Li, "Demand Response for Residential Appliances via Customer Reward Scheme", Smart Grid, IEEE Transactions on , vol.5, no.2, pp.809,820, March 2014.

[21] V. Hamidi, F. Li, F. Robinskon, "Demand response in the UK's domestic sector", Electric Power Systems Research, Volume 79, Issue 12, December 2009.

[22] T. Ericson, Direct load control of residential water heaters , Energy Policy 37 (2009) 3502–3512

[23] H. Sæle and Ove S. Grande, "Demand Response From Household Customers: Experiences From a Pilot Study in Norway" Smart Grid, IEEE Transactions on , vol.2, no.1, pp.102,109, March 2011

[24] N. Venkatesan, J. Solanki, S. Khushalani Solanki, "Demand Response Model and its Effects on Voltage Profile of a Distribution System", Power and Energy Society General Meeting, 2011 IEEE , vol., no., pp.1,7, 24-29 July 2011

[25] N. Venkatesan, J. Solanki, S. Khushalani Solanki, "Residential Demand Response model and impact on voltage profile and losses of an electric distribution network", Applied Energy, Volume 96, August 2012

[26] O. Sundström, C. Binding – "Flexible Charging Optimization for Electric Vehicles Considering Distribution Grid Constraints", IEEE Transactions on Smart grid, vol. 3, no. 1, March 2012

[27] P. Martini , DR 2.0 A Future of Customer Response, Newport Consulting Prepared for the Association for Demand Response and Smart Grid, July 2013

[28] J. Stromback, "Demand Response Barriers and Opportunities in Europe", Smart Energy Demand Coalition JCR Demand Response Workshop, October 15th, 2013

[29] Z. Ma, D. Callaway, and I. Hiskens, "Decentralized charging control for large populations of plug-in electric vehicles: Application of the nash certainty equivalence principle," in Proc. IEEE Int. Conf. Control Appl., 2010.

[30] P. Vrba, V. Mařík, P. Siano, P. Leitão, G. Zhabelova, T. Strasser, "A Review of Agent and Service-Oriented Concepts Applied to Intelligent Energy Systems," Industrial Informatics, IEEE Transactions on , vol.10, no.3, Aug 2014.

[31] S. Vandael, N. Bouck, T. Holvoet, G. Deconinck, "Decentralized demand side management of plug-in hybrid vehicles in a Smart Grid" Proceedings of the First International Workshop on Agent Technologies for Energy Systems, May 2010.

[32]   T. Logenthiran, D. Srinivasan, "Multi-agent system for managing a power distribution system with plug-in hybrid electrical vehicles in smart grid," PES International Conference on Innovative SmartGrid Technologies-India (ISGT '11), Kollam, India, December 2011.

[33]   Z.Fan, "A Distributed Demand Response Algorithm and Its Application to PHEV Charging in Smart Grids", IEEE Transactions on smart grid, vol. 3, no. 3, September 2012.

[34]   R.J.Bessa, M.A.Mato, "Global against divided optimization for the participation of an EV aggregator in the day-ahead electricity market, Part 1 Theory" Electric Power Systems Research, Volume 95, February 2013.

[35]   K.Young, C. Wang, L.Y.Wang, K.Strunz, "Electric Vehicle Integration into Modern Power Networks. Chapter 2: Electric Vehicle Battery Technologies" 2013.

[36]   A. Brooks, E. Lu, D. Reicher, C. Spirakis, and B. Weihl – "Using Real-Time Control of Demand to Help Balance Generation and Load", IEEE power & energy magazine, may/june 2010

[37]   R.J. Bessa, M.A. Matos, "The role of an aggregator agent for EV in the electricity market", 7th Mediterranean Conference and Exhibition on , vol., no., pp.1,9, 7-10 Nov. 2010.

[38]   W. Kempton, J.Tomić, "Vehicle-to-grid power fundamentals: Calculating capacity and net revenue", Journal of Power Sources, Volume 144, Issue 1, 1 June 2005

[39]   J. Torriti, M. G. Hassan, M. Leach, "Demand response experience in Europe: Policies, programmes and implementation", Energy 35 (2010) 1575-1583

[40]   http://www.chargepoint.com/

[41]   Bessa, R.J.; Matos, M.A.; Soares, F.J.; Lopes, J.A.P., "Optimized Bidding of a EV Aggregation Agent in the Electricity Market," Smart Grid, IEEE Transactions on , vol.3, no.1, pp.443,452, March 2012.

[42]   W. Kempton,V. Udo, K. Huber, K. Komara,S. Letendre, S. Baker, D. Brunner and N. Pearre, "A test of Vehicle –to – grid (V2G) for energy storage and frequency regulation in the PJM system"

[43]   Scott B.Peterson, J.F.Whitacre, Jay Apt, "The economics of using plug-in hybrid electric vehicle battery pack for grid storage," Journal of Power Sources 2010, p 2377-2384

[44]   T. Pesch, P.Stenzel, "Analysis of the market conditions for storage in the German day-ahead and secondary control market", Institute of Energy and Climate Research -Systems Analysis and Technology Evaluation (IEK-STE), Forschungszentrum Jiilich, Germany

[45]   Calderaro, V.; Galdi, V.; Graber, G.; Graditi, G.; Lamberti, F., "Impact assessment of energy storage and electric vehicles on smart grids," Electric Power Quality and Supply Reliability Conference (PQ), 2014 , vol., no., pp.15,18, 11-13 June 2014

[46]   Tomas Gomez, San Roman and Ilan Momber, "Regulatory framework and business models for charging plug –in electric vehicles: Infrastructure, agents, and commercial relationships," Energy Policy, Volume 39, Issue 10, October 2011.

[47]   Marina Gonzalez Vaya, Goran Andersson – "Combined Smart Charging and Frequency Regulation for Fleets of Plug-in Electric Vehicles"

[48]   E. ElBanhawy, R. Dalton, E. M. Thompson and R. Kotter, "A Heuristic Apporach for Investigating the Integration of Electric Mobility Charging Infrastructure in Metropolitan," in 2nd International symposium on Environment Friendly Energies and Applications, 2012.

[49]   Spanish Ministry of Infrastructure, "MOVILIA 2006 Project" 2006

[50]   Observatorio Cetelem, "Cetelem observer 2012. The electric vehicle and the Europeans (El observador Cetelem 2012. El coche eléctrico y los europeos)" 2012

[51]   Spanish Transmission System Operator, "Annual report about the power system 2012 (Red Eléctrica de España REE, "Informe del Sistema Eléctrico español 2012)"