

V2G – An economic gamechanger in E-Mobility?

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Abstract

The Vehicle-2-grid (V2G) technology enabling bidirectional charging between electric vehicles and the energy grid system for frequency regulation and load balancing has the potential of significantly improving the financial viability of electric mobility. However, the full scale deployment and exploitation of V2G technology require an intelligent smart grid system, an integrated communication network and feasible business models, which take the complexity of the energy distribution network into consideration. This paper has identified that the introduction of V2G offers a plethora of potentially beneficial business models, which primarily focus on providing stability services to the energy grid and optimizing the economic benefits of owning an EV. Within these overarching categories, it is likely that several niche business models will emerge, as the current V2G concepts include the integration of intermittent renewable energy into the grid, reduction of peak load, charging optimization and regulation of participating capacity. The market potential of these business models seems to fluctuate, as different studies have yielded considerably different results. A study by Brand et al. (2017) concludes that the current price levels in Germany do not incentivize the provision of grid-stabilizing services, whereas Li et al. (2015) conclude that V2G compatible vehicles can generate a profit of up to \$454.26 a year. This striking difference indicates that the economic viability of V2G business models depends on a range of contingent variables, and further studies enlightening the benefits of several V2G concepts should be conducted.

Keywords: Vehicle-2-grid (V2G), V2G deployment criteria, V2G business model, V2G market potential

1 Introduction

The production and distribution of energy are continuously being improved with the installation of an increasing amount of renewable energy sources, which are constantly pushing the boundaries for energy efficiency. However, as no one is capable of determining when the wind blows and sun shines, and has found an effective way of storing excess energy, the European production of energy is still highly reliant on nonrenewable energy sources. A proposed strategy to accommodate this apparent energy waste is to integrate vehicle-2-grid (V2G) technology into the energy system, and take advantage of the energy storing capacities of electric vehicles. As electric vehicles are used for transportation purposes only 12,1% an

average day, they are available for load balancing and frequency regulation [1], which can be beneficial for both the energy system and EV owner, who will be able to generate a considerable profit by taking advantage of the price elasticity of electricity over the course of the day. However, in order to make the energy grid system ready for the integration of V2G charging and ensuring a positive business case for the vehicle owner, different aspects must be considered. This paper will therefore evaluate different V2G business models, and the market potential of V2G.

2 Technology overview

The V2G technology, essentially, represents an application enabling a bidirectional flow of energy to and from an EV, building a large capacity of instantly available energy storage devices, which can be used for load balancing, peak shaving and frequency regulation [2].

2.1 Central actors in the V2G-system

Aggregators will become central actors in the future energy system, as they can accumulate electric energy from several vehicle fleets for delivery to the distribution responsible (DSO), balance responsible (BRP), and/or overall system responsible (TSO). As there are requirements for minimum bid size for up- and downregulation on several European energy markets, the electric vehicle owner will not be able to deliver power back to the system without the aggregator, who will become a key player in the future energy system [3]

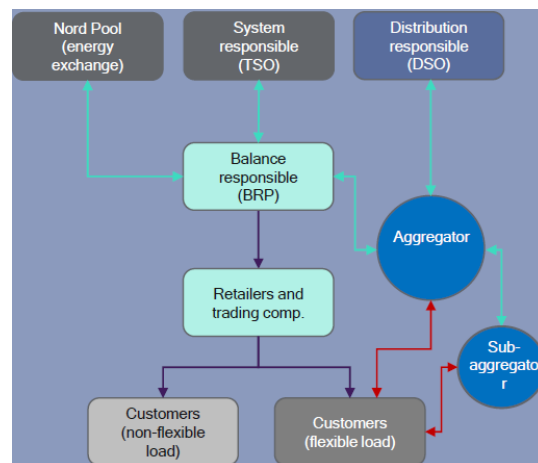


Figure 1: Central actors on the electricity market

3 V2G business models

For reaping the economic benefits of V2G technology, it is necessary to develop and deploy viable business models taking factors such as minimum bid size, participating capacity, state-of-charge (SOC), etc. into consideration [3] [4]. The following section outlines a range of V2G business models, which complies with these measures.

3.1 Frequency regulation

As noted by several studies, “a shallow charge/discharge cycling instead of deep depth of discharge (DoD)” is more suitable for V2G-enabled BEVs, as it can prevent fast battery degradation [5]. Frequency regulation, therefore, represents an ideal V2G business model, as it will have a less negative impact on the battery cycle lifetime without compromising the potential economic benefits that can be generated by

engaging in frequency regulation [5]. Essentially, a frequency regulation strategy entails that the aggregator dispatches the bi-directional charging according to the grid frequency deviation [4].

3.2 Reduction of peak load

The large scale integration of EVs into the energy grid will increase load, which could cause system overload during peak periods. V2G operators could therefore develop a business model dispatching intelligent signals that regulate when the different EVs charge to reduce peak load [4]. If the system is built appropriately, it might be possible to reduce the dimension of the energy distribution network, which could be very economically viable.

4 Market potential

The market potential of V2G technology seems to be dependent on the specific case and a range of decisive variables, as different studies have yielded significantly different results [5] [6] [7]. For instance, a recent study [6] concludes that “the current price levels in Germany do not incentivize the use of EVs to provide grid-stabilizing services”, whereas another [5] conclude that a Nissan Leaf with a battery capacity of 24 kWh can generate a yearly profit between \$318 and \$454.26. However, despite this difference among scientists, the emergence of V2G technology opens up a whole new field of business models with new market actors [4]. As V2G technology involves several complex variables, it is likely that the market will see different business models focusing on aspects such as participating capacity, frequency regulation, load balancing, etc. [4]. Moreover, with the structure of the V2G market, it is likely that new market actors and business models will emerge, as OEMs, charging infrastructure owners and parking garage operators likely will develop innovative concepts with which they can offer ancillary energy services [1] [4] [5] [6] [7].

5 V2G Market Factors

In order to apply the new business models in the field of V2G, the importance of knowing the market place will be the defining factor between success and failure. These new markets will be distinguished by geography, market rules and EV adoption, but already now five central factors that will defined the role of the aggregator, the pricing of the bid and the construction a positive business case can be identified.

5.1 Battery effect

A central element, that has been mentioned often as a barrier towards the implementation of V2G is the potential effect on the battery. Both arguments about longer and shorter lifetime have been placed by parties involved in the development of the services, and recently research has concluded both that it has a negative impact on battery degradation [8] and that it prolongs the lifetime of the battery [9]. The difference between the two research papers connect to the application of the technology, which supports the

conclusion that the aggregator will play a vital role in creating a balanced business case across the value system.

5.2 Value System

The core of the concept of V2G is to utilize a balancing opportunity without making large investments in batteries [1]. This concept should make it possible for an aggregator to offer the energy from the batteries for grid services at a competitive price. The potential economy should however be considered into the context of the value system, where several actors are to share the economic revenue generated by the services. The number of involved parties are, as seen on figure 1, three levels of stakeholders including the BRP, the Aggregator and the Prosumer. Other relevant groups could include Sub-aggregators, Charging point operators and Vehicle OEM's, who all have an interest in the system performance. Some countries – e.g. Finland – are experimenting with allowing the Aggregator to act as a BRP, hence reducing the number of stakeholders in the value chain, increasing the potential revenue for the aggregator. The split between the parties in the value system will be defined by individual offerings of aggregators and BRP's and happen on market terms.

5.3 Services

The commonly mentioned market, when referring the largest V2G potential, is frequency regulation, see section 3.1, where the battery can supply quick, high power and low energy support. Further to this, a large group of potential services for V2G have been identified [10]. Especially the distribution system will be challenged in the future by the combined implementation of photovoltaics and EVs, which will put stress on the low voltage grid on different times of the day. The balancing of the grid on this level will be a potential new market place that will develop with the increase of EVs in larger scale in local areas. This is a relevant topic to consider as a rapid increase in EVs and aggregators will cause market saturation on the frequency regulation market.

5.4 Energy

Energy used for providing V2G services will need to be re-bought, in order to charge the battery, which causes for a simple, yet important, calculation to be done before applying the energy from the battery to the designated service chosen by the aggregator.

$$\sum I_{services} > C_{energy}$$

The sum of potential income (I) from the services provided should surpass the cost (C) needed to refill the battery for all the services delivered. Although a simple equation, this is an element that often has been overlooked, but is critical to take into consideration – especially for the vehicle owner, as they will the entity to whom this expenditure applies.

Previous analyses have shown that in Denmark [11] a potential in buying energy at low prices utilizing it for Vehicle-2-Home can provide a potential saving of 70 € pr. Year/Vehicle and that smart charging can create savings of 60 € pr. Year/Vehicle. The limited size of the potential savings is partly a result of the low deviation in Danish energy prices and partly caused by the fact that the Danish energy taxation system is fixed priced and not a percentage of the energy price and make out a very high percentage of the retail price. When transferring this into a V2G context it is important to consider that energy sold are sold without tax, but the supplementary energy needed after providing a service is bought with taxes.

5.5 Market variables

The market structure for balancing services creates a framework that defines the potential for applying V2G as a technology for grid services. A market structure can be defined by seven variables, which are to be considered when applying V2G and creating bids into the market place [12], see figure 2:

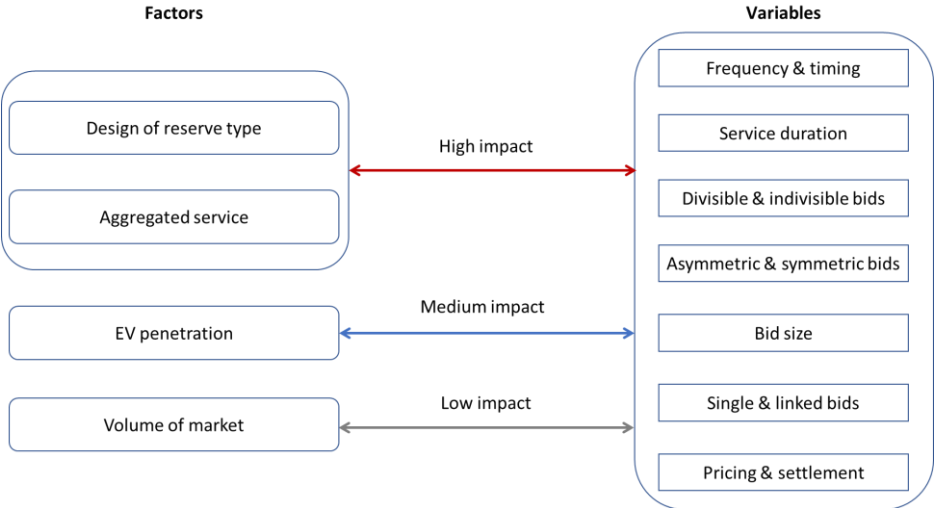


Figure 2: Impact factors and levels for FCR variables

The individual variables are important to consider, when structuring a bid as they each will set limitations or open opportunities for applying a competitive bid. In example, the bid size could delimit V2G aggregators from bidding into the market in the time, where available EVs are low, thereby causing the available power to be equally low, whereas the frequency and timing of the bid could cause for high insecurity in the bid if these are to be applied by a week’s notice.

6 Conclusions

The philosophy of applying the V2G technology as a mean to balance the grid on DSO and TSO level is a logical approach, when considering the future smart grid and in some locations, the technology is already being tested in real-life conditions.

When going through the available research on the area, conclusions on the viability of the technology are inconclusive as the market place and application of the technology will differ from aggregator to

aggregator. Analyses show results from it being a cost bearing system to up to 454,26 \$ in revenue pr. Vehicle.

The paper has identified and described five central market factors to take into consideration when doing the business case study on V2G in a given market. These are:

1. Battery effect
2. Value System
3. Services
4. Energy
5. Market variables

As these factors are still only considered on a theoretical level, no clear equation that sums up the potential can be made, but for companies considering this as a market potential, several scenarios should be considered with different versions of the factors in order to create a full overview of the potential futures the system will be applied into.

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