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Provision of regulating- and reserve power by electric vehicle owners in the Dutch market

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HIGHLIGHTS

- Simulation of four EVs participating in the secondary reserve during one year.
- Dutch travel patterns, unbalance prices and loads on urban power distribution.
- EVs show significant benefits by participating in the secondary reserve.
- Providing secondary reserve has little effect on the ability to travel.

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ABSTRACT

Recent years have shown a large increase in electric vehicles (EVs), which could make a significant contribution meeting European, national and municipal energy- and climate goals. However, most EVs are not used for about 90% of the time, which makes their batteries available for other purposes. One of these purposes could be the provision of Regulating- and Reserve Power (RRP) to the transmission system operator, a vehicle-to-grid (V2G) concept. The aim of this paper is to determine the potential value that EVs could generate by providing RRP and identify EV user impacts on the provision of RRP. A model was developed to simulate the potential value of four commonly sold EVs under a baseline charging- and RRP dispatch scheme with three user categories for one year. The model used minutely settlement prices of the Dutch RRP market from 2014 to 2015, along with charging- and driving characteristics of Dutch EV drivers. Results show substantial effects of RRP provision in terms of monetary benefits, battery throughput and state-of-charge (SOC) distribution. Provision of RRP resulted in monetary benefits in the range between €120 and €750 annually per EV owner, depending on EV- and user category. This is accompanied by increased battery throughput and lower SOC distributions. However, the latter has little effect on the assumed trip requirements of the EV user. Subsequently, an assessment was made on the sensitivity of the results for changes in user characteristics and fleet sizes, which offered both favourable prospects and limitations. We conclude that the provision of RRP by EVs in the Netherlands shows promising potential.

1. Introduction

Since its introduction in the Netherlands in 2011 the number of electric vehicles (EVs) has grown to roughly 100,000 in late 2016 [1]. This growth was supported by numerous government policy schemes for electric mobility and charging infrastructure. Most of these electric vehicles are either 100% battery electric vehicles (BEVs), range extended electric vehicles (REVs) or plug-in hybrid electric vehicles (PHEV). While their precise propulsion mechanism differs, all these vehicles can connect to the grid to charge their batteries [2]. However, studies have shown that the time that EVs are parked and connected usually exceeds the time that is required for charging [3–5]. This implies that EVs possess flexibility that can be marketed and since the Dutch government aims to have 1,000,000 EVs on the road in 2025 the amount of flexibility will increase in the coming years [1].

1.1. Markets

There are several markets where EVs could offer their flexibility, namely the Primary Control Reserve (PCR), market for Regulating and Reserve Power (RRP) and the Tertiary Reserve. The purpose

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of the PCR is to restore frequency disruption in the entire, internationally interconnected High-Voltage grid. This means that in case of a disruption somewhere in the interconnected grid, all connected generators react to restore system balance. The market for RRP, also known as the secondary reserve market, is operated by the Dutch TSO Tennet to maintain grid balance in its control area in the Netherlands and part of Germany. The tertiary reserve is called upon in case there is insufficient RRP to restore disruptions.

Of all these markets, the market for RRP is most interesting for several reasons. Firstly, RRP is contracted through market bids that apply for one- or multiple 15-min blocks. These bids can be submitted until one hour before dispatch. These short time spans allow parties to accurately place their bids, contrary to the primary reserve, where a bid must apply for a full week, and tertiary reserve, where bids apply for a quarter or full year. Secondly, the tertiary reserve is characterised by a minimum bid size of 20 MW, high availability requirements and dispatch periods that can take several hours. These criteria make the tertiary reserve unsuitable for participation with EVs. The final argument for choosing the secondary reserve is that fact that the primary reserve only pays a capacity price and does not remunerate the volume of energy delivered. In the market for RRP an energy-only fee is applied.

Participation in the market for RRP is realised through symmetrical products where a party offers capacity to provide RRP up and/or down, in order to correct overconsumption and/or overproduction, respectively. Offers of RRP are bundled and dispatched according to a so-called bid ladder. Fig. 1 shows an example of such a bid ladder, where the left-hand side shows bids for RRP down and the right-hand side for RRP up. Each bid represents one bidding party.

Bids for RRP down contain a price per volume that the bidding party is willing to pay to the TSO for taking power from the system. Note that prices for RRP down can be negative, in which case the bidding party will receive payment from the TSO. Bids for RRP up contain a price per volume that the bidding party is willing to receive from the TSO for adding power to the system. In case of an unbalance the TSO will dispatch these bids in an economically efficient manner, i.e., in decreasing order for RRP down and in increasing order for RRP up. The settlement price that each party eventually receives for each MW h of energy delivered is determined by the highest- or lowest bid for RRP up or down, respectively. Taking Fig. 1 as example, this would require that for 500 MW of RRP up parties 1–5 would receive a settlement price

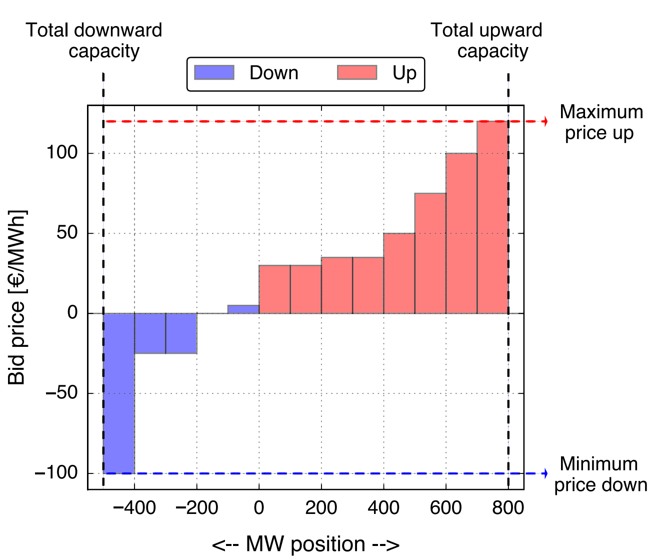

Fig. 1. Illustrative price bid ladder for TenneT, after [6].

of 50 €/MW h. The rationale behind our study is that EV owners can potentially earn money by providing RRP up and save on charging costs by providing RRP down at a price that is lower than the electricity price paid for charging.

Codani and Petit provided a framework to assess the suitability of TSO market design for reserve power provision by EVs [7]. They describe two key sets of rules that are important for the potential of V2G: the rules towards aggregation of distributed energy sources and the rules defining the payment scheme of V2G services. These are described in Table 1 and are compared to the rules employed by the Dutch TSO. This shows that Tennets market design is favourable for RRP provision by EVs, as it complies to rule 3, 4 and 5. Allthough the market design does not fully comply to Rules 1, 2 and 6, these conditions are still relatively favourable. Codani and Petit also used this framework to assess TSOs in Denmark, France and the US. If Tennets market design was included in their analysis it would have been in their top three of most favourable market designs.

1.2. Literature review

The requirement of a symmetrical product means that EVs have to be capable to charge and discharge power from and to the grid. This concept is also known as vehicle-to-grid (V2G) and was first described in [8], who argued that an increasing share of electric mobility comes with a large volume of potential battery capacity available for ancillary services [9]. Since then numerous studies have been conducted on the potential of V2G for balancing power systems and supporting the integration of renewable energy [10]. Many of these studies focus on the dispatch of EVs in the primary reserve where participants usually receive a capacity price which differs from a bid ladder system such as employed by the Dutch TSO [4,5,11,12].

Sortomme and El-Sharkawi conducted their analysis based on 10,000 EVs in Houston, TX and estimated annual revenues between $161 and $635 per EV [13]. In addition, Sortomme and El-Sharkawi pointed out that the mass roll out of public charging facilities under the eVgo network made V2G adoption realistic. In the Netherlands similar developments were seen as municipalities have actively supported the roll out of public charging infrastructure, thereby creating potential for V2G applications. The work of Codani et al. [7], for instance, focused on the primary reserve in France and concluded that under alternative TSO market designs EV owners could potentially earn between €193 and €593 per year, which is in line with the findings of Sortomme and El-Sharkawi.

Some studies have also been conducted related to the secondary reserve. Pavić et al. [14] presented the participation of EVs in the secondary reserve in the UK. Their results show that not only the EV driver, but also the entire system reaps benefits when EVs are used for balancing power systems. This was also concluded by Fernandes et al. [15], who assessed the impact of V2G on power system operation costs in Spain under different scenarios for EV- and renewables penetration. They report savings in reserve costs between €122 and €540 per EV, which would potentially flow back to EV users. Another study found benefits from balancing ranging between £150 and £400 depending on number of EVs and installed wind capacity for the UK [16]. In another study, Jargstorf and Wickert [17] assessed the potential of EVs in the German secondary reserve market and concluded that the average revenues for EV drivers are low (less than €60 per year per EV) due to strict regulations.

1.3. Research aim

The studies mentioned in the literature review acknowledge that EVs can create value by participating in reserve markets. How-