Agent-coordinated Virtual Power Plants of Electric Vehicles

(Extended Abstract)

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ABSTRACT

Challenges with energy provision due to intermittent renewable energy sources can be addressed with information systems in smart energy markets. One specific solution is virtual power plants (VPP) of electric vehicles (EV). The operation of the VPP is agent controlled, so that cars are charged when market prices on the wholesale market signal excess capacity and turn into a power plant when market prices signal a need for additional energy supply. We show that due to a low utilization of EVs, its storage in idle status can be used by owners of large EV fleets to trade energy on the electricity wholesale market. We scrutinize and evaluate a trading strategy under different scenarios of battery cost developments for large EV fleets owners in the simulation platform Power TAC against the triple bottom line (people, planet, profit). Findings indicate that people pay lower electricity prices under widespread adoption of VPPs of EVs. In addition to that results show a decrease in CO_2 emissions for the planet. Finally profits for fleet owners of EV parks are boosted, which decreases with growing market adoption.

Categories and Subject Descriptors

H.4.2 [**Information Systems Applications**]: Decision Support Systems

General Terms

Economics; Performance; Human Factors; Measurement

Keywords

Innovative Applications; Smart Grid; Agents; Electric Vehicles; Virtual Power Plant

1. INTRODUCTION

A growing support for sustainability has set in motion a move towards renewable energy sources and ultimately a low carbon economy. The EU for instance wants to increase its share of renewable energy sources to 20% by 2020. This, however, also bears challenges that need to be addressed for a smooth transition. The inability to predict and alter the output of solar and windpower plants under the absence of storage leads to imbalances in the generation and consumption of electricity destabilizing the electric grid. Smart grids are an approach to solve this problem with the help of information systems and computing power. Previous research has studied the effect of static battery storage on future energy systems. We extend this research with an analysis of the storage capacity of Electric Vehicles (EV) that is shared for driving and balancing. Our contribution lies in the uncertainty of availability of storage by including driving profiles. In this respect we study a large fleet owner of EV that has the critical mass to participate in wholesale trading with the help of the Power TAC simulation. This fleet owner leases the cars to consumers and when the cars are idle he uses them as virtual power plants that generate and consume electricity in accordance with market requirements. The fleet owner exploits and benefits from an electricity arbitrage opportunity that could not previously be exploited due to unavailability of storage, which has a positive effect on the triple bottom line: lower electricity prices for people, lower emissions for the planet, and profits for the fleet owner.

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2. PROSUMER BUSINESS MODEL

EV's unique properties with large storage capacity that is quickly scalable make them particularly interesting for smart grid storage solutions. Current research focuses on smart charging that alleviates the strain that a large amount of uncoordinated charging EV have on the electric grid [5] and have addressed the concept of Vehicle-2-Grid (V2G) by making energy from the EV available to the grid [4], [6]. This way consumers not only use energy for charging but also produce energy for the grid and become *prosumers*. In this research we investigate how large fleet owners of EV can aggregate this storage capacity in form of VPPs to actively trade energy in the electricity wholesale market. To ensure that the driving needs of individual EV drivers are not compromised we employ intelligent software agents. These software agents combine information on driving patterns with price signals from the electricity wholesale market and based on that make decision to charge, or discharge EV in the fleet as agent assisted decision support [1]. The fleet owner makes additional arbitrage profits by buying energy at low prices

Figure 1: Overview Business Model.

to charge EVs and sell that energy at higher prices on the market at a later point in time. For an overview of the business model see Figure 1.

3. RESEARCH DESIGN

Based on driving profiles of EV and electricity market data we determine an agent based trading strategy for EV fleet owners. This trading strategy assumes the economic market properties of demand and supply in which fleet owners are not price takers, but have an influence on the electricity price with their trading behavior. This causes a reciprocal effect between price and VPP, which is why apply a non-linear algorithm to solve the agents decision problem. We use a monte carlo simulation for this purpose. Agents purchase and sell electricity via the day ahead market and future contracts to charge cars, while integrating driving and expected driving behavior, to maximize the arbitrage price difference. We take charging inefficiencies and battery depreciation cost according to estimated future scenarios into account. The driving pattern information are extracted from driving panel data of the Dutch Statistical Institute (CBS). The wholesale market data is obtained from the Power Trading Agent (Power TAC) competition [2]. The applicability of the Power TAC simulation to future developments in the electricity sector has been established in prior research [2],[3]. A simulation is most appropriate tool to validate our analysis as the infrastructure and scale for EV does not yet exist. We simulate the trading strategy in the Power TAC environment and compare it to a situation without VPP of EV. The impact on the triple bottom line of the availability of VPPs is discussed in the next section.

4. TRIPLE BOTTOM LINE

The results of the simulation disclose benefits for people, planet, and fleet owner profits. For fleet owners the simulation suggests that the price differences on the wholesale market support the proposed VPP of EV in terms of **profits**. The agents manage to procure electricity at a sufficiently low price that they are able to store and resell later while offsetting efficiency losses and storage costs. However, the profits for the fleet owners decreases with growing competition. The market reaches a saturation point when approximately half of all vehicles are involved in a VPP. The benefit for **people** and society at large is a decrease in electricity prices. The trading behavior of the VPP agents stabilize the price in the wholsale market by using and making energy available to the grid when the marked needs it. With this the trading strategy reduces the average to peak ratio which has the effect that the overall price for electricity is reduced. This translates into a small electricity bill reduction at the saturation level but increases under higher levels of competition among VPPs. Last but not least there is a positive externality of the trading strategy for the **planet**. As peak demand in electricity is met with more carbon intensive generation capacity than average demand, the trading strategy reduces CO_2 emissions. As a side effect of charging electricity when its cheap on the market, it also has a relatively low carbon content. If this electricity is then made available at higher prices (at which electricity has a higher carbon content) we are able to replace carbon intensive generation capacity with VPPs. This is reinforced by different price elasticities, charging at low prices has a lower price effect than discharging at a higher price. At the saturation point CO_2 emissions are reduced.

5. CONCLUSION

Storage capacity of EV can be effectively used when aggregated to a VPP by large fleet owners to balance the grid. This has positive effects on the triple bottom line: people, planet, profits. For large fleet owners our research entails that they have to be aware that there is a first mover advantage, that subsidies might be attainable from energy providers for this business model, and that carbon emission reductions should be certified as carbon allowances. Finally the VPP of EV idea and its contribution towards a low carbon economy should be utilized to position the fleet owner as an environmentally friendly company.

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