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This paper studies an incentive contract term "Time Interval for V2G" (TI) for V2G participation. Based on previous studies and data collected from a V2G contract preference survey in China, consumers' preferences are analyzed by the approach of conjoint analysis, which is equipped with the part-worth utility model, the relative importance weight model and simulation packages. Though empirical analysis, "Time Interval for V2G" is proved to offer incentive for V2G participation in this paper and this contract term weighs more to consumers with regular jobs than those with non-regular jobs, when it comes to drawing up a V2G contract.

Declaration of authorship

I certify that the thesis at hand was made without unauthorized help and that I only used the tools denoted. All statements literally or logically taken from publications are marked as quotes.

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1. Introduction

Electric-drive vehicles (EDVs) have been gaining popularity in recent years. Concurrent to the dramatic increase of development in this field, researchers are bringing up the concept of vehicle-to-grid (V2G) (Emadi, 2005) to harness the power of EDVs to the fullest. The basic concept of vehicle-to-grid is that EDVs provide power to the grid while a vehicle is parked (Kempton, et al., 2005a). On one hand, EDVs- with their connected batteries, fuel cells, or hybrid drivetrain- can be considered as mobile reserve power to the grid; on the other hand, researches show that most vehicles are parked for an average of 95 percent of the time (Pearre et al., 2011), making them potentially available for V2G while staying idle in the parking lot. By means of being equipped with appropriate connection and signal devices, EDVs can receive orders from the power grid and are able to fulfill different tasks by charging or discharging from the grid- a V2G activity thus occurs.

Although V2G is still in experimental stage, it has already revealed its advantages. For the whole electricity industry, V2G, with its decentralized characteristics, is a useful supplement to centralized power generation. It has the potential to be utilized for ancillary services- spinning reserves and regulations. For customers, V2G activities, through their contribution to the power grid, generate revenue. The payment of participating in V2G can help customers lower the capital cost of purchasing a V2G-capable EDVs while compensating for the inconvenience that V2G activities may bring about. It is also worth noting that V2G may have environmental benefits. According to previous studies, using V2G-capable EDVs to support large scale renewable energy by stabilizing the grid is possible. In tandem with wind or solar energy, V2G-capable EDVs charge during the periods of high output and discharge when low output occurs (Kempton W., Tomic, J., 2005b).

The idea of V2G seems quite appealing. However, will ordinary consumers really embrace the idea and participate in the V2G activities? George R. Parsons focused on this research question in his paper "Willingness to Pay for Vehicle to Grid (V2G) Electric Vehicles and Their Contact Terms". By using a stated preference survey among U.S households and adopting a latent class random utility model, he found that consumers are extremely sensitive to V2G restrictions such as "Minimum Guaranteed Driving Range (MDR)" (the minimum distance one can still drive with his EDV after each time running a V2G

activity), "Required Plug-in Time per Day (RPT)" (the minimum time per day one's EDV is required to be plugged into the grid for V2G activity). He then simulated several pre-specified contracts in return for annual cash payments, but ascertained that V2G participation was uncompetitive under current market conditions.

To improve the undesirable result and increase the participation of V2G, measurements should be taken to reduce the level of reluctance to participate. One possible settlement is to introduce new factors to existing models and analysis, testing whether they help improve the performance. In this paper, a new contract term "Time Interval for V2G" is introduced to study the V2G participation other than George R. Parsons' previous study. The so-called "Time Interval for V2G" represents the time interval of grid call for V2G activities. Three degrees of this term are assumed in the new model: "V2G all day available", "V2G not available between 7am-10am on weekdays" and "V2G available neither between 7am-10am nor between 5pm-8pm on weekdays". The idea behind this term and its degrees is that the better the usage patterns of individual drivers are catered to, the more appealing V2G activities become. For instance, if it is convinced that consumers value different time intervals of a day differently, (say the time interval 7am-10am may be valued more than 10am-12am, because consumers are unwilling to sacrifice the use of vehicles during rush hours for working [7am-10am, 5pm-8pm], whereas they consider office hours [10am-12am] as useless), then a customized V2G contract, which only takes up the majority of the "useless" time, could be better accepted by consumers due to mitigating the inconvenience that V2G activities cause.

Two major research questions are put forward in this paper: firstly, does the additional term "Time interval for V2G" really work to offer incentive for V2G participation? Secondly, if it does work, how important can it be in the matter of V2G participation?

To help answer these two questions, a V2G contract preference survey was administered in China. Based on face-to-face interviews and internet investigation, a total of 198 usable questionnaires were collected from 17th September 2014 to 4th November 2014. The survey included three parts: part one (see Figure 1) collects personal characteristics of all the respondents; part two (see Figure 2) introduces basic knowledge about V2G and defines four contract

terms for V2G in the study: "Time Interval for V2G", "Annual Cash Back Payment (ACB)", MDR and RPT; part three (see Figure 3) demonstrates nine V2G contracts designed with four above-mentioned contract terms respectively. In this part, respondents are asked to rate all these contracts based on their preferences.

A method called fractional factorial design (Hair et al., 2006) is introduced to help select a suitable fraction- in our case the nine designed V2G contracts- of all possible combinations of contract terms. With four V2G contract terms associated with three levels respectively, there are (3 x 3 x 3 x 3) 81 possible combinations of contract terms, which means there are 81 V2G contracts in total for respondents to rate. If we adopt all the 81 possible contracts in the survey, it is obvious that such large number of choices would confuse all the respondents. In order to shrink the total number of presented contracts while representing main effect of each term, we should find a representative subset of the possible combinations. Using orthogonal arrays, orthogonal fractional factorial design is a way to realize such a subset. Moreover, the methodology of conjoint analysis is applied to analyze data in the survey. This method is nowadays widely used to measure consumers' preferences by combining part-worth utilities for each attribute ("attribute" refers to contract term in our survey). It also provides a systematic way to estimate the importance of each attribute to the respondents or their subgroups. It is also worth noting that the two above-mentioned methodologies are realized by programming via IBM SPSS 19.0 in this paper.

With the help of SPSS, a part-worth utility model (Harrison et al., 1998) was devised and the relative importance weights of each attribute were calculated. To further study the effect of the attribute "Time interval for V2G", I compared the response of two subgroups of respondents, namely respondents with regular nine-to-five jobs and those with non-regular working patterns. Finally, three simulation V2G contracts were run by SPSS to predict the preference.

This paper is organized as follows. Section two and section three introduce the concept of V2G and the methodology of conjoint analysis respectively. Section four demonstrates the survey design. Following that, we run the empirical analysis in section five. Section six presents the related works. The last section assesses and concludes the paper.

2. The concept of V2G

Vehicle-to-grid (V2G) describes a way in which EDVs work as mobile electricity storage devices for the power grid. With their capacity, EDVs can discharge when the grid needs power and charge during the grid's low-demand period. As a promising technology, it is not just a theory or tentative idea. Several pilot tests have already been run in the United States, such as MIT's V2G study of Staples delivery company in 2012 (De Los Rios et al., 2012) and the application of the first vehicle-to-grid aggregation system, which was developed by Southwest Research Institute (SwRI) and qualified by the Electric Reliability Council of Texas (ERCOT) in the beginning of 2014.

In light of the classic paper from Kempton (Kempton et al., 2005a), EDVs, which participate in V2G activities, have the positive characteristics of quick response times, low standby costs, and low capital cost per kW. However, they also hold the drawbacks of limited energy storage, short device lifetimes, and high energy costs per kWh in comparison with large power stations. Taking the advantages and disadvantages of EDVs into consideration, Kempton assessed the four possible opportunities of V2G respectively: base-load power, peak power, spinning reserve and regulation. Base-load power supply is paid by provision of power. It demands that power providers should be available around the clock and offer large-scale energy. It is not competitive for EDVs to participate because it hits all aforementioned weaknesses of EDVs. As the second V2G opportunity, peak power supply is also paid by provision of power. As the name suggests, it refers to power provision during the period of consumption peak in the grid. This peak period can last up to five hours and thus challenges EDVs at the aspect of limited energy storage. Other than base-load power supply and peak power supply, spinning reserve is paid by EDVs' capacity and the amount of time EDVs are waiting for. Spinning reserve indicates the extra generating capacity, which is able to response to the grid demand in a short interval of time when disruption or instability in the power grid occurs. It satisfies the advantages of EDVs by means of quick response and is appealing to EDV owners owing to the way of payment. Same as spinning reserve, regulation is paid by EDVs' capacity. Regulation refers to real-time frequency control by keeping the balance between power generation and load. It exploits the quick response strength of EDVs while luring EDV owners to take part in V2G activities through financial incentives. In electricity industry, spinning reserve