Overview of V2G Optimal Dispatching Technology

Litian Deng(✉)

Electrical and Electronic Engineering, University of Bristol, Chongqing 401120, China
1577900246@qq.com

Abstract. Starting with an interpretation of the concept of v2g, this paper first analyzed the development background of v2g from such two aspects as the global market and energy, based on which the concept of "optimal scheduling" was introduced. Then, the key factors required by optimal scheduling were summarized, including scheduling assessment standards and real-time optimization management, and reviewed studies of optimal scheduling at home and abroad to explore its feasibility. Finally, this paper provided insights on network security, enterprise management and application agreement, three aspects not involved in the study, observed the market conditions based on statistical charts and proposed a series of suggestions based on the real situation.

Keywords: Scheduling Assessment Criteria · Real-Time Optimal Management · Real Situation Consideration

1 Introduction

This paper aims to popularize the concept of V2G dispatching technology by summarizing the research results of the technology and to analyze comprehensively the future development trend of V2G technology according to the current tough problems. This paper not only reviews the previous research but also includes the author's insights about the current situation of the V2G technology, intending to enhance the understanding of the insiders of relevant industries and thus contribute to the more favorable development of the electric vehicle market and new energy market.

2 V2G Mode

With the continuous rise of fuel prices and the growing concerns over the deteriorating environment, many countries, with the United States as the forerunner, set to include their electrified transportation systems in their long-term development plans. Especially, electric vehicles (EVs) have become the top priority of the plans worthy of development because they are closely linked to people's lives. As EV's share of the car market surges, so does the power grid load. Today's disorder in EV charging modes incurs the occurrence of peak times. In other words, the simultaneous connection of huge numbers of EVs to

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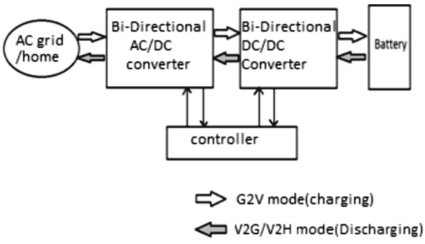

Fig. 1. V2G Bi-directional energy transfer process

the power grid leads to a surging load of the power grid, more transmission losses of the power grid, and thus higher electricity prices. The development of EVs is hindered by a series of chain reactions aforesaid. In response to the problem, V2G mode has been proposed, which conceptually enables EVs to not only garner energy from the power grid but also feed electric energy back to the grid, realizing a bi-directional energy flow. Its core concept is to use the energy storage of a large number of EVs as a cushion between the grid and renewable energy. [1].

The European Union, the United States, and other countries have underpinned V2G-related research in terms of policies and technologies. In 2020, the American company Nuvve projected a transformation of V2G technology from a concept to commercialization. Also, China has witnessed a boom in EV industry in recent years thanks to favorable policies. The National Energy Administration published the project "Research on the Bi-directional Interactive Terminals between electric Vehicles and The Power Grid and The Intelligent Charging and Discharging Control System of Electric Vehicles". [2] However, since EVs are still in their initial development phase suffering from such practical problems with the selection of EV batteries, selection of power generation facilities in the power grid, and grid-connection communication, and distribution of charging piles [Fig. 1], V2G technology has yet to see large-scale application worldwide for the time being. Therefore, the promotion of V2G technology among these countries is only in the conceptual research stage.

3 Concept of Optimal Dispatching

Taking account of the current extremely heavy load of the power grid caused by the disordered charging modes, V2G optimal dispatching emerges as a systematic management method that will be employed to adjust the load of the power grid on the level of EV users with a view to realizing ordered charging and discharging control. As the V2G sector currently lacks a mainstay of massive entities, most of the optimal dispatching research depends on algorithm simulation, thereby obtaining load curves and grid node performance. As a part of the task, grid transmission losses, actual cost, along with some factors that can lead to different simulation curves, should be considered. The optimal dispatching technology is able to allow power companies to achieve a more stable and efficient power grid without adjustment or with minor adjustments to the structure and performance of the grid.

3.1 Real-Time Optimal Management

Power companies can apply a real-time optimal management mode that enables EV users to better experience the interactive V2G mode. Specifically speaking, they can regulate user behaviors through time-of-use electricity rates. When the grid load is too high, EVs feed electricity into the power grid; when the grid load is too low, EVs store the surplus electricity of the power grid. The real-time fluctuation of electricity rates should result in a certain amount of return or loss for users, facilitating the better application of new energy through economic behavior. To get a good effect, power companies should first monitor the normal load of the power grid, and the load under disordered and orderly charging so as to figure out the adjustment range of the load. Secondly, power companies should summarize the users' charging rules, electricity quality varying with load, and time-of-use electricity rates, analyze how to achieve the balance between charging efficiency and social economy, and ultimately summarize the workable planning and dispatching of the power grid.

Disordered Charging.
The calculation of EV charging load requires a real vehicle as the model, and the built-in performance of the vehicle is used as the benchmark for the statistics. Yang Xiuru et al. from Anhui Polytechnic University just applied the Monte Carlo method, and made use of a large number of random samples to build a mathematical model. [Fig. 2] The more samples were used, the more typical the actual result would be. Although the charging behaviors of EVs were highly uncertain, EVs have regularity in daily running. Accordingly, the EVs' regularity and the normal power grid loads were considered in the simulation to obtain the result: disordered charging elevates the grid load to a higher peak. [3].

Ordered Charging.
There are many methods of ordered charging, so it is necessary to figure out an appropriate optimization path through mathematical methods. Yang Xiuru et al. from Anhui

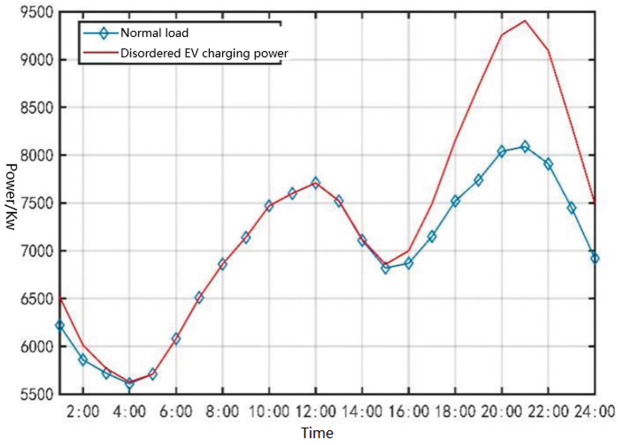

Fig. 2. Impact of disordered charging on the power grid

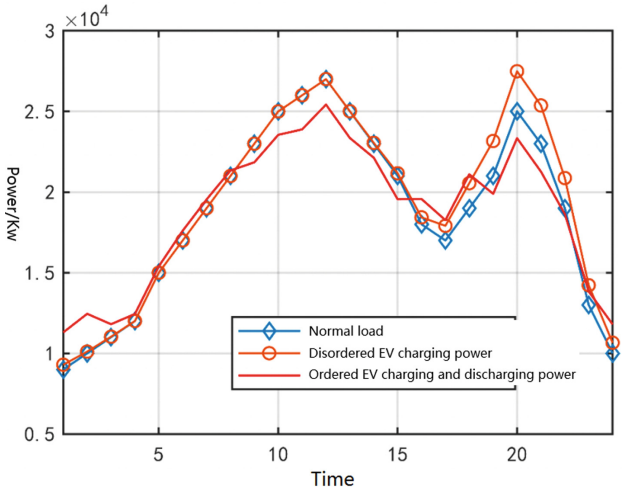

Fig. 3. Optimization effect of ordered charge and discharge

Polytechnic University applied multi-objective particle swarm optimization (MOPSO) algorithm and other intelligent solutions for the optimization to obtain a solution set (Pareto solution), and thereby generated an ordered EV charging and discharging load model that is able to realize the peak-cutting and valley-filling function. [Fig. 3] [3].

Feasibility Analysis.
This research used 500 EVs as samples for the statistical analysis, and saw an evident effect resulting from the change. The ordered charging method, also called the method of time-of-use electricity rates, not only mitigated the risk of an elevated peak of the power grid, but also filled the grid load during the valley time, so that the grid load tended towards a more stable condition. However, the practicability of the data-based calculation method cannot be verified because of the failure to gain a large-scale investment. Therefore, the work now is only in the phase of the simulation. In reality, the sample size should be larger, and user habits, regulations and rules, regional differences, and other factors might indirectly affect and change the result.

3.2 Evaluation Criteria for Power Dispatching

Power dispatching is aimed to better balance the grid load, but given diverse realistic factors, the evaluation criteria should not only include the stability of the grid load, but also consider the economic effect, environmental effect and social effect, and more aspects. Multiple evaluation criteria should be used to regulate and optimize the dispatching so that V2G technology can be implemented from a realistic perspective. The performance in meeting the indexes of the evaluation criteria also can further verify the effectiveness and shortcomings of the V2G optimal dispatching strategy. [4].

Optimization Through Indexes

In the literature "Multi-index Evaluation Method for the V2G Dispatching Optimization Strategy of Electric Vehicles", Zheng Xin et al. simulated the constrained state and particularly, the constrained state of a balanced power system, during EV grid connection by setting an array of target parameters included in the V2G technology, and thus obtain a multi-index evaluation process for V2G dispatching. [Fig. 4] Besides, they simulated the typical load curves under the conditions combining the charging piles with the functioning of the time-of-use electricity rates to obtain the maximum benefit, the maximum stability, and the maximum consumption of the time-of-use electricity rate mechanism. Accordingly, the conclusion was that different regions saw varied impacts on the V2G economic effect. Because those regions developed varied dispatching criteria and tapped into the problem factors affecting the dispatching in order to achieve the stable operation of the power grid and balance the economic effect of various social parties. [5].

Feasibility Analysis

In this study, functions were created to calculate more specific commercial economic indexes while considering charging piles, parking fees, and other factors varying from region to region. If actually ordered large-scale discharging is needed, it is very difficult to find a solution to obtaining reasonable dispatching effect meeting various targets and standards effectively and promptly among different regions. Even if a result is achieved following an enormous amount of calculation, the dispatching effect cannot be ensured. In other words, changing the electricity price or other prices cannot affect other industries. [6].

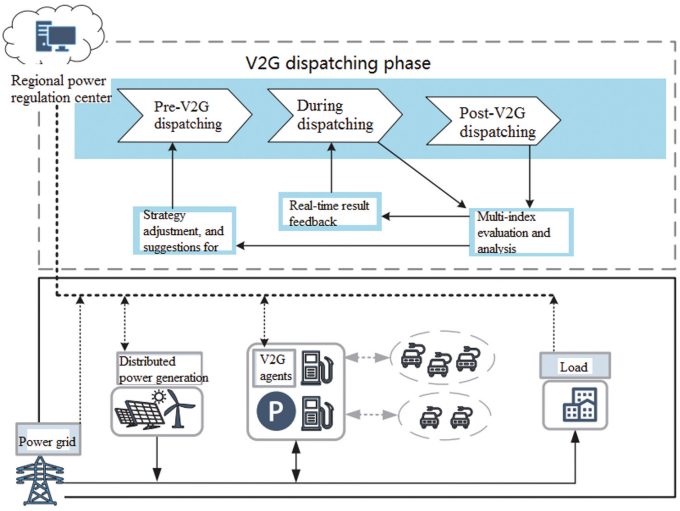

Fig. 4. Strategy for dispatching technology

4 Development Bottleneck

4.1 Network

The essence of ordered V2G charging and discharging is the bi-directional energy flow. To meet this condition, the connection between EVs and the power grid entails the promotion of intellectualization. Power companies intend to acquire information via a network, including states of EVs, real-time grid load, real-time electricity price, and performance of charging piles, among others. That will rely on the capacity, transmission speed, and stability of the network. But given the development situation of the network, it is very difficult to promote the V2G concept. Moreover, if the whole power grid is connected to the network, any security problem with the network will incur a huge loss. The three prerequisites for realizing the V2G concept—the security, stability, and speed of the network are immature as of today.

4.2 Management of Enterprises and Individuals

If the V2G mode is launched, the issue facing enterprises and EV owners is whether they willingly accept the benefits of the mode. The reason is that according to current research, the service lives of EV batteries will be shortened if EVs are connected to the power grid and transmit electricity to the grid. From these individuals' perspectives, causing a reduction in battery life should diminish the benefit of the V2G mode. In addition, the process of electricity transmission to the power grid requires time and effort, so it cannot be ensured that in reality, many EV owners are willing to or have enough time to do so. From the perspective of enterprises, they might care less about subjective factors, and more about other aspects instead. Taking utility providers as an example, implementing V2G mode can help them to more closely cater to the green policies, and enjoy preferential policy treatment. Given the trend of decarbonization of electricity production at the source, the enterprises will be bound to opt for what the policy is supporting as long as the overall interest balance can be achieved, even if electricity transmission to the power grid will lead to shorter battery life. However, this assumption is given without considering battery manufacturers. As it is impossible for the power grid to offer different connecting and dispatching schemes fitting to every single battery model, only those battery manufacturers that possess core technology of battery materials or have a dominant role are able to easily collaborate with the power grid. Such a restriction also applies among countries.

4.3 Formulation of Agreement

To address the issue of battery life reduction and launch the V2G mode, it is imperative to correspondingly adjust the remuneration for electricity transmission to the power grid. However, a single-minded elevation of remuneration will convert the purposes of the power users and even power companies, and thus lead to the same result—a deteriorated imbalance of power grid load. Consequently, a binding agreement then becomes a major issue to be solved. It is pretty difficult for different battery manufacturers to sign different specific agreements with the power grid should these manufacturers have no benchmark

of the dominant technology in place. Compared with ordered charging technology, two-way complex interactions relating to the V2G mode, the legal constraints of all parties, and the cooperation under the condition of assured interests are more intricate and uncontrollable.

5 Conclusion

Electric vehicles are surely a major project under development, and renewable energy is an integral part of the long-term political guideline. The proposal for the V2G technology should be nonnegligible in the sense of industrial growth and economic development because the launch of the V2G technology marks the entry of the world into the era of information and intelligence. Meanwhile, what should not be underestimated is the difficulty in promoting the V2G technology. If underestimated, there will be tremendous problems and an unlikely guarantee that a massive investment can lead to an ideal output. Taking into account the current situation of V2G technology, it is advisable to shift from the subject —the power grid. For example, Tesla's Powerwall is a mini energy storage device. As a preliminary step, conducting small-scale tests among individuals and enterprises should be more practical. Insiders of the industry need not worry about the dilemma of the V2G technology at all because the technology is a forward-looking project and thus ascertaining where the problems are should be perceived as a kind of progress at least. [7, 8].

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