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Overview of V2G research techniques

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Abstract:

Nowadays, V2G technology has received a great deal of attention, and this technology not only improves the efficiency of the power grid, avoids the waste of electric energy, helps the grid to store more electric energy, but also largely solves the problem of consuming today's non-renewable resources. In this article, we first introduce the related research and achievements at home and abroad, and then introduce the realization method of V2G technology from two aspects, namely, the management method of electric vehicles and the charging and discharging control strategy. Then the impact of the technology is introduced, mainly from the impact on electric energy, the impact on charging load, the impact on energy storage system, and the impact on the environment. Finally, the article is summarized and suggestions are made.

Keywords: electric vehicle, V2G, charging and discharging control strategy, charging load

1. The concept of V2G

Environmental pollution in today's world has increased, and automobile exhaust pollution accounts for a large part of it, so people have begun to use electric vehicles to alleviate the pollution, electric vehicles compared to traditional cars, not only no longer emit pollutants, but also change the single energy structure of the car, but also more energy-saving. In today's society, more and more electric vehicles are being put into use and connected to the power grid, which brings great pressure on the power grid. People need a new technology to solve this problem, thus the birth of V2G technology, which is also called the two-way energy exchange technology between electric vehicles and the power grid, the core of which is to connect the electric vehicle to the power grid to realize the two-way power, when the load of the power grid is too high, the electric vehicle can be used as a power source to recharge the grid, and when the load is low, it can be used as a back-up power source to store electricity to avoid wastage. Not only that, this technology also benefits EV users, who can earn money by selling electricity when the EVs are idle. A large number of EVs connected to the grid can serve as an excellent reserve energy source to alleviate the pressure on the grid, but they cannot be connected to the grid randomly, as Prof. SaberA [1] proved that charging a large number of EVs will definitely have a serious impact on the grid. Overall, V2G technology can effectively solve the problem of EVs' access to the grid in today's society, and it is worth studying as a popular emerging technology.

2. Current status of domestic and international research

Since V2G was proposed, there are many people to research, practice this technology in the United

States, Europe, Japan and so on in the forefront, China started late, but scientists have not given up efforts. The following is the current status of research and project results at home and abroad.

2.1 Current status of foreign research

The concept of V2G was proposed by Amory Lovins in 1995. In 2005, Willett Kempton of the University of Delaware studied the fundamental issues of V2G: capacity calculation and net benefits, and in the same year, he also studied the implementation issues of V2G: stabilizing the grid and supporting large-scale renewable energy sources . 2008 Google announced a $10 million investment in the development of an electric vehicle project and conducted research on v2g technology. In 2009, the Danish government, the Danish Energy Association, Dong (Denmark) and Siemens (Germany) jointly launched the world's first commercialization of v2g technology on an island, which is one of the largest demonstrations of v2g technology to date. 2012, the University of Delaware started the V2G project, which is the first commercialization of v2g technology using V2G technology. project investigated whether EVs could mitigate the inherent intermittency of renewable electricity by providing FM services to PJM's grid under the conditions of using V2G technology. In 2018, the EV-elocity project was launched in the UK , which aimed to experiment with V2G projects in a range of real-world scenarios. In 2019, Mitsubishi Corporation of Japan and others will carry out a demonstration of the "V2G integration project" in five cities in Japan. In general, foreign countries have been studying V2G technology for a long time, and have carried out a lot of practical projects and accumulated a lot of experience, which is worth learning from our country.

2.2 Current status of domestic research

China's v2g technology started late, in 2009, China put forward the "ten cities, one thousand vehicles" plan , in 2010, the state grid in Shanghai World Expo demonstrated the application of V2G technology in the Expo smart grid. 2010, Yang Jian and others established a V2G system model, which provides a reference for future research. In 2010, Zhang Li and others elaborated the general idea of electric vehicle charging and discharging control strategy, and gave a specific implementation of a V2G charging and discharging control strategy algorithm for a particular region. Since the beginning of 2020, the state has introduced several policies to promote the progress of V2G technology and strongly support local V2G pilot work. For example, Shanghai has had three demonstration zones with more than 100,000 EVs participating. Nowadays, China's V2G technology still has a certain gap compared with the international, we lack top-level design, key technology reserves, and the market environment has to be improved. However, with the strong support of the state, there is still hope to catch up.

3. V2G technology realization method

Because of the wide variety of EVs and their different charging methods, it is difficult to popularize the same implementation method on a large scale. The realization of V2G largely depends on a feasible management approach, and appropriate scheduling, charging and discharging control strategies are also the focus of scientists' research.

3.1 Management approach

According to the different needs of electric vehicles, there are three main categories, centralized, autonomous and replacement battery pack management methods [2].

3.1.1 Centralized

This method is to centralize all electric vehicles in a region, and adopt unified dispatching strategy and charging/discharging control strategy to complete the management of electric vehicles in the region according to the demand of local power grid. This is also the most adopted management method today, and many projects at home and abroad have adopted this management method.

Since this project is adopting a unified charging and discharging strategy and scheduling strategy, and can also centralize the construction of charging sites required for electric vehicles, it can minimize the cost and achieve the best overall results.

3.1.2 Autonomous

Due to the large number of electric vehicles nowadays, which are scattered all over the world, it is difficult to manage them in a uniform way, so people have thought of transferring smart chargers to the cars so that they can be used for V2G technology according to the characteristics of the local grid as well as the demand and the condition of the car itself. Yutaka at the University of Tokyo, Japan, used such an approach to realize smart charging.

The advantage of autonomous is that the car carries a smart charger with it, which is convenient to use and not limited by the environment, time and other factors. However, each electric car can independently and autonomously use V2G technology to access the power grid, not subject to unified scheduling, which increases the difficulty of management and the cost of the car.

3.1.3 Methods of replacing battery packs

This method involves forming a battery replacement sta-

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tion, having the replacement station connected to the grid, storing a large number of batteries in the station and implementing V2G technology through the batteries, and the EVs have to go into the station to be recharged by replacing the batteries.

This approach is similar to the centralized one, but with a different management method, which not only has to manage the charging and discharging of EVs, but also has to ensure that the batteries in the battery replacement station are kept in a fully charged state. Its advantage lies in reducing EV charging time and saving charging steps, which greatly changes the shortcomings of slow charging and short range of EVs nowadays. However, this method not only needs to invest a lot of manpower and financial resources to build the battery replacement station, but also has to unify the charger interface.

3.2 Charge and Discharge Control Strategy

Adopting appropriate charging and discharging control strategies and using corresponding models can accelerate the charging efficiency of EVs and gain more benefits. The control strategies can be mainly categorized into single control strategy, and EV cluster control strategy [3].

3.2.1 Single control strategy

This strategy focuses on individual EV charging and discharging control, which is an important method for analyzing the user's electricity consumption efficiency, charging efficiency, and so on. It can optimize the user charging process based on EV usage, real time electricity price, fuel cost, so that EV charging efficiency can be increased and charging cost can be reduced. For example, Galus M D studied the driving process and energy usage of EVs and developed a model to improve it, and Moura S J [4] and others mainly studied the stochastic nature of user's travel and proposed an energy management scheme using stochastic optimization method, and summarized the effect of different fuel prices on their proposed scheme.

3.2.2 Electric Vehicle Swarm Control Strategy

Electric vehicle swarm also called as aggregato, compared to single control strategy, EV swarm control strategy is more rich in optimization, control methods because it involves a large number of units such as numerous EVs and parking lots etc.Sortomme E[5] reduced the charging losses in the grid by combining charging control of multiple EVs. While Venayagamoorthy G K [6] et al. optimized the V2G technology by particle swarm algorithm with the objective of reducing the charging cost.He Y et al. developed a local optimization model to optimize their predicted charging loads taking into account its stochastic nature.

4. Impact of Electric Vehicles on the Grid

With the increasing number of electric vehicles nowadays, their large-scale access to the power grid will bring non-negligible impacts on the grid, specifically the following four points, 1. Impact on power quality 2. Impact on charging load 3. Impact on energy storage system 4. Impact on the environment.

4.1 Impact on power quality

The impact on electrical energy is mainly reflected in harmonic pollution, voltage drop, and three-phase unbalance. When an electric vehicle is being charged, harmonics are generated when the DC current is constantly changing phases between the AC three phases, which in turn affects the power quality of the distribution network system such as power loss, voltage deviation, frequency, etc., which were then investigated by Clement-Nyns K [7], Wu D [8] and others. Moses P S[9] and others studied the effect of battery charging rate on harmonic losses, voltage ware etc. in electric vehicles. It was shown that there will be significant harmonic losses and transformer overloading when fast charging is used. Zechun Hu analyzed the impact of charging large-scale electric vehicles for power quality of the grid by targeting harmonics and grid voltage. Tian Liting analyzed the electric vehicles for charging will lead to an increase in current harmonics, power quality degradation; and electric vehicles on the grid discharge will inevitably generate harmonics, by the discharge process of boosting, inverting the output voltage harmonic distortion rate is larger, so necessary measures need to be taken to ensure the safe operation of the distribution network. Zhao Chuanli established a model of two-way charger for electric vehicles and analyzed the output voltage harmonics by means of Borrier transform method and proposed effective suppression measures.PapadopoulosP [10] investigated the impact of electric vehicle charging on the voltage of a typical low-voltage distribution network of the United Kingdom under different levels of access and different degrees of aggregation. And Putrus G A [11] concluded that the three-phase unbalance problem will only be manifested in the case of a large number of EV accesses, and EV charging loads should be reasonably distributed among the three phases.

4.2 Impact on charging loads

Charging loads are also an important cause of impact. The nature of charging loads is complex and is characterized by the following.

1. User trips: this mainly refers to the travel time of the

vehicle owner, the length of the trip and the number of trips, and so on. They can reflect the user's charging time as well as the energy needed.
2. User habits: it reflects the user's car habits, charging habits. Their differences will also have an impact on the charging load.
3. Battery characteristics: such as the capacity of the battery and charge/discharge rate, etc., they can reflect the charge/discharge efficiency.
4. Charging facilities: they determine the amount of EV charging and discharging power, and as charging and discharging become widespread in the future, they will also become facilities that can accept two-way flow.
5. The number of electric vehicles: it determines the size of the charging load and reflects the market acceptance of electric vehicles, and is also closely related to the price of the car, the costs incurred in its use, as well as its safety and performance.
To summarize, it can be classified into two aspects, user aspect and EV technology, which have an impact on the load. Of course there are other categorizations, for example, Guo Q categorized the factors into internal and external factors, and used data mining methods to analyze the impacts generated by internal and external factors. And the establishment of appropriate models can effectively study the load. For example, Shao S [12] used a simple analytical model to study the impact of smart charging technology on charging load in multiple scenarios. Zou Wen also established a mathematical model based on real-time electricity price and proposed an algorithm based on dynamic estimation interpolation idea according to the model characteristics. Wang Xifan believes that it can be divided into travel demand based method and charging station charging load probability analysis method. Among them, the method based on travel demand starts from the factors affecting the load and obtains the system charging load through simulation, which can be convenient to analyze the impact caused by different factors on the load. The charging station charging load probability analysis method can study the spatial distribution characteristics of the charging load, which can be good for the planning and construction of charging stations.

4.3 Impact on energy storage systems

Nowadays, electrochemical energy storage technology is developing very rapidly and most of the electric vehicles are using lithium batteries as energy storage components and they are bound to be affected under the application of V2G technology. Over the years, Germany, the United States, Australia and other countries have begun to strongly support the installation of self-consumption battery program. fathabadi H studied a new solar charging station with V2G technology, this charging station can convert solar energy into electricity, which can reduce the pressure on the grid. At present, China's lithium battery development is very rapid, advanced technology, open application prospects, such as optical storage electric vehicle charging stations, demand response charging and so on . The biggest problem of the current battery is that with the increase of the use of time, the battery capacity will decline. But the decline of the battery still has value in other areas, such as communication base stations, data centers and so on. Currently foreign countries in this area is developing rapidly. Among them, Lih W C[13] studied the secondary use technology of retired lithium batteries under V2G technology, and Bräuer S[14] introduced the secondary use of lithium batteries.

4.4 Impact on the environment

Electric vehicles connected to the grid also affect the environment of the city.Zhong X[15] et al. argued that electric vehicles are equivalent to conventional vehicles in terms of environmental and energy advantages.Li Yinvestigated the deployment of electric vehicles in China and examined their impact on environmental, energy issues.Zakariazadeh A proposed a multi objective resource scheduling scheme and develops an EV management model to analyze the impact of EVs on air pollution. The results proved that pollutant emissions can be reduced.Zhao Y studied the greenhouse gas emissions of a supervised fleet of electric trucks and compared them with conventional trucks.
With the popularization of new energy electric vehicles, V2G technology will become the most promising technology. With the features of two-way interoperability, high efficiency and convenience, it can play a role in a series of links such as reducing carbon emissions and integrating renewable energy.
5.Conclusion
This paper discusses the use and impact of V2G technology, and argues that although V2G technology is not widely used at present and there are many technical problems, it will become one of the most important technologies for electric vehicles with the popularization of electric vehicles and the rapid development of other technologies, such as energy storage and charging technology, and it can play an important role in promoting economic development and slowing down the pressure on the power grid.
At present, China's V2G technology is also in the development stage, should consider the economic, environmental and energy factors, vigorously develop key technologies, optimize management methods, and promote the

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development of China's V2G technology and the entire electric vehicle industry.

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