

The Key Issues for China's Electric Vehicles to Participate the Electricity Market

Jing Li*, Xiaofeng Zhang, Gao Zhang, Menghua Fan

State Grid Energy Research Institute Co., Ltd., Beijing, 102200, China

Abstract. At present, China has the world's largest number of electric vehicles, and the total amount of charging power from electric vehicles is growing rapidly. Due to the small scale and high dispersion of a single electric vehicle, however, it is difficult for electric vehicles to participate the electricity market directly and share the dividends of electricity reform in China. Reducing electricity prices through the participation of electricity market can effectively encourage consumers to choose and use electric vehicles. Based on the analysis of the current Chinese electricity market, this paper studies the way in which electric vehicles participate in the electricity market in China, and designs corresponding market participation mechanisms.

1. Introduction

Vigorously developing electric vehicles is an important measure for China to comprehensively strengthen ecological and environmental protection, fight against pollution, ensure energy security, and promote industrial transformation and upgrading. With strong national support, China now has the world's largest electric vehicle industry. Until September 2022, the national ownership of electric vehicles reached 11.49 million, while the national ownership of charging piles during the same period reached 4.315 million. The rapid development of the electric vehicle industry has also led to a significant increase in the charging capacity of electric vehicles. Despite the rapid growth in the total amount of charged electricity, the small scale and high dispersion of electric vehicle users have made it difficult for users to directly participate in the electricity market and share the dividends of electricity reform. On the other hand, due to the characteristics of strong randomness and constrained by travel demand boundaries, electric vehicle charging loads, if not aggregated and guided, may increase the burden on local distribution networks, which is not conducive to the safe and stable operation of the grid.

On March 16, 2015, the State Council of China issued the "Several Opinions on Further Deepening the Reform of the Electric Power System" (referred to as Zhongfa No. 9)^[1], and it initiated a new round of electricity market in China. The document clarifies the key points and paths for deepening the reform of the power system, which are: in accordance with the institutional framework of controlling the middle and opening up both ends, orderly opening up competitive electricity prices outside of transmission and distribution, orderly opening up the distribution of electricity business to social capital, and orderly opening up power generation and consumption plans outside of public welfare and regulation; Promote the relative

independence and standardized operation of trading institutions; Continue to deepen research on regional power grid construction and transmission and distribution systems suitable for China's national conditions; Further strengthen government supervision, enhance overall power planning, and ensure safe and efficient operation as well as reliable power supply.

In terms of the electricity sales market, multiple channels are used to cultivate market entities, allowing eligible high-tech industrial parks or economic and technological development zones to establish electricity sales entities to directly purchase electricity, encouraging social capital to invest in establishing electricity sales entities, and allowing them to purchase electricity from power generation enterprises and sell it to users; Allow users or microgrid systems with distributed power sources to participate in electricity trading; Encourage public service industries such as water supply, gas supply, and heating, as well as energy-saving service companies, to engage in electricity sales business; Allow eligible power generation enterprises to invest and component sales entities to enter the electricity sales market to engage in electricity sales business.

On the user side, fully open up the user side distributed power market. Open up the construction of user side distributed power sources, support enterprises, institutions, communities, and households to invest in the construction of various distributed power sources such as solar energy, wind energy, biomass energy generation, and gas-fired "heat, power, and cooling" cogeneration according to their respective conditions, and allow access to distribution networks and terminal power systems of different voltage levels. Encourage specialized energy service companies to collaborate with users or build distributed power sources through a "contract energy management" model.

In January 2022, the National Development and Reform Commission and the National Energy

* Corresponding author: jingli0120@163.com

Administration issued the "Guiding Opinions on Accelerating the Construction of a National Unified Electricity Market System" (Development, Reform and Reform Commission [2022] No. 118). The document proposes to optimize the overall design of the electricity market, improve the multi-level unified electricity market system, unify trading rules and technical standards, break down market barriers, promote the construction of electricity market mechanisms that adapt to the transformation of energy structure, and accelerate the formation of a unified, open, competitive, safe, efficient, and well governed electricity market. In terms of overall goals, by 2025, the national unified electricity market system will be initially established, and the national market will operate in coordination with provincial (regional, municipal)/regional markets. The integrated design and joint operation of electricity medium and long-term, spot, and auxiliary service markets will be carried out, and the scale of cross provincial and cross regional resource market allocation and green electricity trading will be significantly improved. Market trading and pricing mechanisms that are conducive to the development of new energy, energy storage, and other industries will be initially formed. By 2030, the national unified electricity market system will be basically established to meet the requirements of the new power system. The national market will operate in conjunction with provincial (regional, municipal) / regional markets, and new energy will fully participate in market transactions. Market entities will compete equally and make independent choices, and electricity resources will be further optimized and allocated nationwide.

China's power industry has fully utilized its institutional advantages, continuously improved its institutional mechanisms, and initially established a market framework of "unified market, two-level operation". It has also established a comprehensive market system covering medium and long-term trading, spot trading, auxiliary service trading, capacity guarantee mechanism, and green power trading, continuously stimulating market vitality and achieving significant results, which has strongly supported the rapid development of China's economy and society. At present, the market has become the main way for optimizing the allocation of power resources in China.

The continuous improvement of the electricity market has created conditions for electric vehicles to participate in the market.

2. The experiences of from mature electricity market

Different from China's electricity markets, mature electricity markets, such as those in Northern Europe, the United Kingdom, and the United States, allow all market entities that meet market access requirements, including demand side resources, to participate in the electricity market. As a result, a type of market role has emerged called Load Aggregator (LA), which aggregates a large number of small and medium-sized capacity users with response potential to meet the performance requirements

and access thresholds (such as minimum outage capacity) to participate in the market, thereby representing users to participate in various market competitions and provide various services to obtain benefits. Load aggregators connect the power grid side and the demand side, and can provide demand response (DR) resources with potential product value with opportunities to participate in the electricity market, including the main energy market, auxiliary service market, and capacity market.

Due to its naturally dispersed charging/discharging properties in time and space, electric vehicles are often regarded as demand side resources in mature electricity market with response potential by load aggregators as aggregation objects. The ownership of electric vehicles is owned by users, and aggregators conditionally purchase the scheduling control rights of electric vehicles by signing bilateral charging contracts with users.

Referring to the existing load aggregators in mature market, the user resources for LA aggregation mainly include residential users, as well as large industrial and commercial users, as well as small generators and standby power supplies. Specifically, they can be divided into load reduction, energy storage devices, and distributed power supplies. Among them, load reduction includes air conditioning and lighting systems, and energy storage devices include fixed energy storage such as flywheel energy storage, as well as movable energy storage such as electric vehicles.

In the Australian and European markets, the load aggregators provide users with free installation of intelligent measurement and monitoring equipment. There are two control methods for users ^[2]:

(1) Direct load control

LA obtains jurisdiction over a certain amount of loads by signing a reduction contract with users, and has full control over the loads specified in the contract. It can uniformly control users with similar demand response strategies and compensation standards ^[3].

(2) Develop a scheduling plan in advance

Due to the constraints of users' electricity habits and basic electricity demand, some users cannot be directly controlled to power off. Therefore, the load aggregator needs to formulate a scheduling plan in advance and notify users in advance. Moreover, it must meet the constraints of the number of interruptions, the minimum reduction duration, and the maximum reduction duration of the user. After receiving the notice of reduction, the user shall adjust the electricity consumption and time period in accordance with the contract ^[4].

3. The role of electric vehicles in electricity market

According to the current situation of China's electricity market, there are four kind of roles in the electricity market including: electricity sale companies, users, power generation enterprises, and ancillary service providers. Therefore, electric vehicles or their aggregators need to be one of the market players to participate in the electricity market. Based on the Starting from these five identities, the following will analyse the possibility of electric

vehicles or their aggregators participating in the Chinese electricity market.

3.1. As electricity sale company

According to the analysis of market access conditions for electricity sale companies in different provinces and cities, from the perspective of legal entity, asset size, qualification requirements for employees, business premises and equipment, credit requirements, laws and regulations, charging aggregators all meet or easily meet the relevant requirements of the "Management Measures for Access and Exit of Electricity Sale Companies" (FGJT [2016] No. 2120) jointly issued by the National Development and Reform Commission and the National Energy Administration. There are also no clear provisions in the descriptions of the admission rules for electricity sale companies by the provincial and municipal development and reform commissions that can restrict electricity sale companies from entering the green power trading market. Therefore, from the perspective of current domestic market rules, charging aggregators are suitable to participate in green power transactions as power selling companies.

3.2. As users

By analysing the market access conditions for power users in various provinces and cities, it can be seen that when aggregated electric vehicles participate in power trading as power users, they meet the access requirements of various provinces and cities in terms of national industrial policies, unit energy consumption, environmental protection and emission standards.

From the perspective of access voltage level and power consumption scale, some provinces and cities have special constraints on voltage level requirements and annual power consumption (for example, if the voltage level is above 35 kV, Tianjin requires industrial enterprises with an annual power consumption of 100 million kWh or more; Shanghai requires an annual power consumption of 1 million kWh or more; Jiangxi must have been in operation for more than 2 years, and the annual power consumption exceeds 40 million kWh). Due to the fact that aggregated electric vehicles represent many charging stations with different voltage levels and capacity scales, they may not be able to meet provincial and municipal constraints on voltage levels and annual power consumption when participating in the market as power users.

Some provinces and cities require that "electricity users who implement tiered, differential, and punitive tariffs should not participate in the market." If charging service providers in this region have included users with tiered, differential, and punitive tariffs, they cannot participate in the market.

Therefore, in regions where there are no special requirements for voltage levels, capacity scales, electricity pricing policies, and industrial policies, aggregated electric vehicles can participate in the market as power users. In regions with special restrictions on the above

conditions, it is necessary to consider aggregated electric vehicles participating in the market as other roles.

3.3. As power generation enterprises

By analyzing the market access conditions of power generation enterprises in various provinces and cities, it can be seen that at present, various provinces and cities have provided specific access conditions mainly for hydropower, thermal power, new energy, self-provided power plants, and other entities. Even if electric vehicles will have the operational capability and status of V2G (Vehicle to Grid) technology in the future, neither electric vehicles nor their aggregators will belong to any of the aforementioned power generation enterprises. In addition, from a technical perspective, even if electric vehicles or charging aggregators have the ability to transmit electricity, they are also constrained by user behavior constraints and control methods, making it difficult to fully possess all the technical capabilities of the aforementioned power generation entities. Therefore, it is difficult for charging aggregators to participate in power transactions as defined by current power generation companies.

3.4. As ancillary service providers

From a technical perspective, electric vehicle loads have good interruptible and adjustable potential ^[5]. If information on a wide range of electric vehicles, charging piles, charging stations, and other equipment is collected, analyzed, and aggregated for modeling, it is convenient to achieve unified and coordinated control of a wide range of charging loads, and has a good ability to provide ancillary services. By analyzing the operating rules of ancillary service markets, it can be seen that some regions allow electric power users to serve as ancillary service providers, and they can participate in the ancillary service market in these regions if they meet the access conditions for electric power users in these regions. Some regions have proposed the market role of "independent ancillary service provider" or "third-party ancillary service provider", and encourage independent ancillary service providers to invest in building a certain scale of electric energy storage facilities to participate in the ancillary service market. For these regions, electric vehicles and their integrators can consider participating in the market as "independent ancillary service provider" or "third-party ancillary service provider". In some regions, participants in the ancillary service market are limited to power grid enterprises and thermal power units, limiting the access of electric vehicles.

In summary, under the current China's market access constraints, the electric vehicles or their aggregators can participate in the electricity market as an electricity sale company or power user. However, when it participates in the market as a power user, it may be subject to restrictions from different provinces and cities on access voltage levels, power consumption scale, and local electricity pricing policies. In comparison, based on the current China's electricity market situation, the most suitable

entry point for the electric vehicles or their aggregators to enter the electricity market is the power sale company. When the electric vehicles or their aggregators enter the electricity market as a power sale company, some provinces may be limited by local policies, and the charging load of electric vehicles may temporarily be unable to enter the market as a proxy retail user.

When electric vehicles or their aggregators are limited by local policies and cannot enter the electricity market using the existing local market restrictions, it can refer to the mature electricity market experiences and introduce the new market role of "load aggregator". Under this model, pilot research can be considered in the form of experiments to reduce the resistance to urging government authorities to introduce corresponding market access policies at the initial stage. Based on the pilot approach, from the perspective of accumulating relevant market management and technical practical experience for future demand response resources to participate in the power market, including the energy market, ancillary service market, and capacity market, strive to obtain the approval of the government authorities.

4. Market mechanism for the participation of electric vehicles

Currently, the construction of China's electricity market is accelerating. In order to promote the full utilization of electric vehicle resources and enhance system flexibility, it is necessary to consider the participation mechanism of electric vehicles in the design of the power market. According to the construction path of China's electricity market, the market mechanism for electric vehicles participating in the electricity market is designed in three stages: short term, medium term, and long term.

In the short term, the market will be dominated by medium - and long-term markets, with the pilot spot market gradually advancing. The area where the ancillary service market is independently operated, the electric vehicles can mainly involve in ancillary service transactions and short-term transactions.

In the medium-term, market is still dominated by the medium and long-term transactions, and the provincial spot market gradually promotes the joint optimization of electric energy and ancillary services. The electric vehicles can participate in ancillary service transactions and electric energy transactions.

In the long term, market establishes a complete power market system that includes medium - and long-term, spot, ancillary services, and capacity transactions. Electric vehicles can participate in ancillary services, energy, and capacity transactions.

In addition, electric vehicles can participate in the market only after passing technical tests conducted by power dispatching agencies. Based on the definition and characteristics of electric vehicle technology, the following conditions need to be met for electric vehicles to participate in the electricity market ^[6].

(1) Scale requirements. A customer side electric vehicle group gathered by independent operators.

(2) Characteristic requirements. It has ultra-short term time scale response ability and high flexibility.

(3) Equipment requirements. Rapid demand response suppliers have control centers for electric vehicle clusters and can interact well with the power grid.

5. Conclusion

This paper investigates the participation of electric vehicles in typical mature electricity markets. Based on the summary and reference of practical experience from mature electricity market, the feasibility of China's electric vehicles or their aggregators participating in the market with different roles is studied. The market role for electric vehicles or their aggregators is proposed based on the the characteristics of the current electricity market in China.

At the same time, this paper also investigates the current situation of China's electricity market construction, and based on the development status of electric vehicles and the background of electricity system reform in China, proposes the path and relevant mechanisms for electric vehicles to participate in the electricity market.

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