Design of Electric Carbon Coordination Trading Mode of Vehicle-to-Grid Subjects under the Background of Carbon Neutrality

Zhiwei Ying1, Aifeng Zhang2, Yong Wang2, Shanshan Shang3*, Xin Du4,5, Yue Xi3, and Dunnan Liu3

1State Grid Shanghai Electric Power Company, Shanghai, 200122, China
2School of Economics and Management, North China Electric Power University, Beijing, 102206, China
3State Grid Chongqing Electric Power Company, Chongqing, 400014, China
4State Grid Electric Power Research Institute Co., Ltd., Nanjing, 211106, Jiangsu Province, China
5Beijing Kedong Electric Power Control System Co., Ltd., Beijing, 100194, China
*Corresponding author’s e-mail: sss1771415@163.com

Abstract. Under the goal of carbon peak and carbon neutral, it is of far-reaching significance to focus on the coordinated trading mode design of the Vehicle-to-Grid subjects in the electricity market and carbon market. However, there are few researches on the Vehicle-to-Grid subjects participating in the trading mode of electric carbon market by predecessors. Therefore, this paper, by combing the basic connotation of the Vehicle-to-Grid subjects, designs the trading mode of the Vehicle-to-Grid subjects in the electricity market and the carbon market, and further discusses how to get through the coordinated trading mode of the Vehicle-to-Grid subjects in the electric carbon market. In this way, relevant suggestions are given to strengthen the technical support of the Internet of Vehicles platform and improve the market trading mechanism.

1. Introduction
China's total carbon emissions now rank first in the world. Carbon emissions mainly come from two industries: transportation industry and power industry. On the one hand, the carbon emissions of the transportation industry will continue to increase for some time in the future, so we should vigorously develop clean public transportation and zero-emission vehicles to promote energy conservation and emission reduction of transportation. On the other hand, the power industry is a key hub for the upstream and downstream of the carbon emission industry. In order to ensure the realization of the goal of "carbon peak, carbon neutral", the power industry should build a diversified clean energy supply system, promote energy efficiency of the whole society and improve the level of terminal electrification.

With the increasing ownership of new energy vehicles, the randomness and simultaneity of the load characteristics of electric vehicles will bring new demands to the operation of the power grid. However, it is difficult for a single EV owner to effectively participate in electricity market transactions, realize demand side response and promote the optimal allocation of resources. The Internet of Vehicles platform...
gathers multiple subjects, which can participate in the trading of the electricity market and the carbon market by virtue of fast and efficient information advantages, and achieve scale effect and gain benefits.

To sum up, this paper first studies the basic connotation of the Vehicle-to-Grid subjects, and then designs the trading mode of the Vehicle-to-Grid subjects to participate in the electricity market and carbon market, so as to improve the consumption of renewable energy and stimulate the vitality of Internet of Vehicles to participate in market transactions. Finally, the paper analyzes the coordinated trading mode of the Vehicle-to-Grid subjects in the electricity market and carbon market, and gives relevant suggestions.

2. The basic connotation of the Vehicle-to-Grid subjects

Generally speaking, Vehicle-to-Grid (V2G) is a mode of Vehicle-to-X (V2X). Under V2G, there are generally three main subjects: EV owners, charging load aggregators and charging facility operators. In the context of carbon neutrality, charging facility operators can purchase new energy electricity for EV users based on the Internet of Vehicles platform as electricity users, actively promote the transaction of green electricity market, and realize the consumption of green energy. Although Internet of vehicles platform gathers a large number of electric vehicle users, the owners of electric vehicles, as scattered power users, have the problem of information asymmetry when they participate in market transactions. When a large number of power users are connected to the grid, which have a great negative impact on the safe and stable operation of the system and are not conducive to the absorption of new energy. Therefore, charging load aggregators emerge at the right moment. Compared with decentralized power users participating in market transactions, charging load aggregators can promote the consumption of wind power, photovoltaic and other energy sources by aggregating users' electricity and trading with renewable energy generators, so as to replace oil with electricity and reduce carbon emissions.

3. The Vehicle-to-Grid subjects in the electric power market transaction mode

3.1 The basic pattern

In order to ensure the safe and economic operation of the power grid, the power grid control center makes the power generation plan of each unit by forecasting the user load in advance. However, with the continuous increase of the proportion of renewable energy installed, it is difficult to meet the needs of safe and economic operation of power grid through generation planning and dispatching instructions, so the requirements for flexible regulation ability of power system are increasing day by day. There is the problem of information occlusion in the participation of single decentralized electric vehicle users in the electricity market, which cannot form scale effect. Therefore, under the V2G, load aggregators of car network can aggregate agents, guide the orderly charging and discharging of electric vehicles to deeply combine the peak and valley distribution of local grid load, wind-solar power generation characteristics and travel conditions of electric vehicles, and formulate reasonable charge-discharge timing sequence, so as to promote the coordinated development of electric vehicles and renewable energy, thus forming a good complementary in time distribution with the safe and economic operation requirements of the power grid. Scheduling optimization characteristics of load aggregators in Internet of Vehicles include three dimensions: natural aggregation, economic incentives, and operation coordination.

3.2 The market types

3.2.1. Electricity trading.

Due to the low power demand of a single internal entity, it is unable to participate in the power wholesale market, so it has no bargaining power and competition conditions. Load aggregators, through the collection of internal demands of a large number of users, form a cooperation mode similar to that of electricity sales companies, which enter the wholesale market and participate in the quotation. The load
aggregator makes a professional quotation based on its familiarity with the electricity market transactions and the corresponding volume, so as to fight for the price difference for the internal subject, and increases the income of the load aggregator as a whole and the internal subject through a reasonable agent mode. In a carbon-neutral context, load aggregators and charging facility operators in the Internet of Vehicles can actively participate in the green electricity trading market and absorb renewable energy. Its basic returns are as follows:

$$\text{The income of the V2G subjects} = (C_d + C_a) \times \alpha$$  \hspace{1cm} (1)

$$\text{Users' benefit of electric vehicles} = (C_d + C_a) \times \alpha \times \beta$$  \hspace{1cm} (2)

$C_d$ is the trading spread. $C_a$ is the internal agency fee of the V2G subjects. $\alpha < 1, \beta < 1$

3.2.2. Demand response.
A large number of electric vehicle resources are aggregated based on the Internet of Vehicles platform, and the response capacity is greatly improved. The selection of response mode of EV participation can be designed according to the principle of maximum benefit. Therefore, electric vehicle aggregation participation has obvious advantages in electric vehicle participation response transactions. Firstly, internet of vehicles platform calculates the load curve and predicts the load baseline trend. Secondly, by considering the response capacity of EV resources owned by the platform, the adjustable range of EV aggregated resources is determined. Thirdly, report capacity and price in the electric vehicle participation response market. Finally, electric vehicles participate in response by means of intelligent operation control platform or information transmitter-user response.

3.2.3. Ancillary services.
The Internet of Vehicles platform measures the capacity, adjustable range and adjustable time of the aggregated electric vehicle resources aggregated by load aggregators to obtain the callable capacity of the aggregated electric vehicle resources participating in peak shaving or standby service. Then, in the
ancillary service market quotation, sign different time period, adjustment ability and price ancillary service contract. Finally, after receiving the auxiliary service scheduling instruction, the charging and discharging of electric vehicles can be adjusted and controlled in time to participate in the auxiliary service by means of intelligent device control or information transmission - user response, etc. The aggregated electric vehicle resources have higher market participation ability and system reliability, which will effectively improve the demand side income and the stability of the power system.

4. The Vehicle-to-Grid subjects participate in the carbon market trading mode
In the process of energy transformation, the carbon emission credits allocated to thermal power plants are usually in short supply. From the perspective of production and operation, there are three ways to choose: buying carbon credits, using clean technology to reduce carbon emissions, or paying a penalty for exceeding emissions. New energy plants themselves use clean energy and produce no carbon emissions, so they can sell CCERS (voluntary emission reductions) on the carbon market.

There are usually two methods of carbon trading quota allocation for power producers: historical method and baseline method. The trading mechanism in this paper uses the base line method based on power generation to determine the carbon quota. Suppose that the carbon quota obtained by the thermal power plant at time $t$ is as follows:

$$D_{f,t} = \varepsilon P_{f,t}$$

$P_{f,t}$ is the active power output of the thermal power plant at time $t$, $D_{f,t}$ is the carbon quota of the thermal power plant at time $t$, and $\varepsilon$ is the carbon quota allocation coefficient.

$$C_{f,t} = \gamma \ast (B_{f,t} \cdot P_{f,t} - D_{f,t})$$

is the cost of purchasing carbon quota for thermal power units at time $t$, $\gamma$ is the price of carbon quota, and $B_{f}$ is the carbon emission coefficient per unit electric quantity of thermal power units. If $C_{f,t} > 0$, thermal power plants need to buy carbon emission credits in the carbon emission trading market, otherwise they can sell carbon emission credits. For the internal trading mechanism of the Internet of Vehicles platform, after using new energy, the users of electric vehicles can obtain the corresponding carbon quota for their reduced carbon emissions compared with the ordinary fuel vehicles.

$$D_{ev,t} = P_{ev,t} \cdot \Delta t \cdot M_{ev} \cdot B_{oil}$$

$D_{ev,t}$ is the carbon quota of EV users at time $t$. $P_{ev,t}$ is the charging load of EV users at time $t$. $\Delta t$ is the period of time traveled by the electric vehicle user. $M_{ev}$ is the mileage of an electric vehicle in a period of time. $B_{oil}$ is the carbon emissions of oil-powered vehicles.

The Internet of Vehicles platform uses big data to make statistical analysis of the carbon emissions of EV users. The load aggregator acts as the agent to sell the excess carbon emissions to thermal power plants and other enterprises in the carbon emission market, so as to obtain profits, and feedback the earnings to EV users after charging a certain proportion of the agency time. This revenue also amounts to a subsidy for electric cars using renewable energy.
5. Coordinated trading mode of electric carbon as the Vehicle-to-Grid subjects

5.1 Power coordinating
Under the current market environment, for charging load users, the assessment and restriction of carbon quota policies will not be directly applied to micro users, but the price signal of carbon emission market will be transferred to the electricity price of users through electricity trading. At the same time, charging load users will be limited by the renewable energy quota system and will have to participate in the green certificate exchange market to meet the assessment conditions. As mentioned in the previous section, the carbon quota for electric vehicles is determined by the carbon emissions of the players in the game, and the corresponding amount of carbon emissions will affect the amount of electricity required by electric vehicles. On the premise that electricity is determined by carbon, it is necessary to establish a coordination mechanism between green certificate trading of charging load aggregators, carbon emission right trading and electricity market trading, so as to provide more efficient services on the basis of reducing the cost of electricity for users.

5.2 Price coordination
From the perspective of commodity attributes, The Vehicle-to-Grid subjects participate in the electricity market transaction, which is aimed at the physical entity of electric energy. The electric power users get the electric energy and pay the energy cost. Carbon market trading is about trading energy derivatives that target environmental benefits. Internet of vehicles represents electric vehicle users to obtain carbon emission rights through trading and selling CCERS. Internet of vehicles platforms collect agency fees through smart aggregation. Power generation companies also avoid fines by buying carbon credits.

6. Conclusion
Under the background of carbon neutrality, the coordinated trading of Vehicle-to-Grid subjects in the electricity market and carbon market is conducive to strengthening the power grid, absorbing green energy and improving the trading efficiency of the market. On the basis of the predecessors, this paper further designs the trading mode of the Vehicle-to-Grid subjects in the electricity market and innovates the transaction mode of the Vehicle-to-Grid subjects in the carbon market. A good transaction mode
depends on the full cooperation of the Vehicle-to-Grid subjects. Therefore, the platform of the Internet of Vehicles should strengthen the construction of the load aggregator operation system, mobilize the demand side response, and improve the efficiency of internal cooperation transaction. Secondly, the Internet of Vehicles platform should improve the top-level design, accelerate the implementation of relevant laws, regulations and policies and open up the electricity market and carbon trading market.

This work was supported by State Grid Company Science and Technology Project (5100-202040443A-0-0-00).

Reference

[1] D.N. Liu, M.G. Liu, W. Wang, X.F. Peng, C.Xu, J.Wang, The operation mode and key technology of charging load aggregator participating in green certificate trading [J]. Automation of power system, 44(10):1-9(2020)

[2] J.L. He, S.Xu, C.X. Mi, T.Yu, Renewable energy quota system, green power certificate and carbon trading mechanism under the background of power spot [J]. Chinese and foreign energy, 25(10):19-25(2020)

[3] Z.Chen, Y.Lu, Q.Xing, X.Chen, Z.Y. Leng, Power System Scheduling Analysis Considering Carbon Allocation of Electric Vehicles [J]. Automation of Power Systems, (16):44-51(2019)

[4] J.W.Hou, S.T.Liao, Pricing Strategy and EV Charging Management for Electric Vehicle Dealers in Commercial Area under Green Electricity Trading Mode [J]. Electrical Appliances and Energy Efficiency Management Technology, (01):70-76(2021)

[5] L.H.Zhang, G.Y.Dai, Q.Y.Nie, Z.H.Tong, Economic dispatching model of virtual power plant with power consumption behavior under carbon trading mechanism [J]. Power System Protection and Control, 48(24):154-163(2020)