Trading Model and Development Path of Demand-Side Resource Aggregators

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Abstract. With the accelerating process of re-electrification, the high-proportion access of new energy and the rapid development of flexible demand-side resources, it is of great significance to fully tap demand-side resources, and explore the trading mode and market mechanism of a wide range of load aggregators participating in the operation of the power system. This paper studies the trading mode and development path of load aggregators participating in the electricity market, which can guide the demand-sides resources to participate in the power grid regulation, and link the demand-side resources’ flexibility value with the power system’s regulation demand. At the same time, the uncertainty and randomness of the load-side resources will be reduced, and the system regulating performance and renewable energy consumption capacity will be improved.

1. Introduction
In recent years, China's energy revolution has been in a strategic transition period to accelerate the construction of a clean, low-carbon, safe and efficient energy system. The power supply side has gradually formed a diversified supply system. It is predicted that the total non-fossil energy demand will account for 36% of the total primary energy demand by 2035, and will be more than half by 2050[1]. With the accelerating process of re-electrification and the high proportion of new energy sources, the flexible demand-side resources represented by electric vehicles are developing rapidly. Large-scale and disorderly demand-side resource usage will have an impact on the operation of the power system. The balance pressure has increased significantly, and traditional grid balance adjustment methods based on deep peak shaving of thermal power have been unable to meet the needs of the rapid development of new energy grids. Therefore, it is urgent to tap the potential of flexible charging loads such as electric vehicles to participate in the regulation and mobilize them to actively participate in the grid Regulate operation [2].

At present, the domestic power industry still has certain constraints on demand-side resources. Electricity prices are strictly controlled. The widely used orderly electricity measures have effectively dealt with the shortage of power supply through administrative instructions. However, it is still a big problem that a large number of demand response resources are idle. At the same time, China's power industry is a highly special and complex field. While improving the efficiency of resource allocation and utilization, it is also necessary to take the safety of electricity and rationality of price of residents, agriculture and important public utilities into account to ensure the stable operation of the power grid,
as well as energy conservation and emission reduction, so as to ensure the important goal of renewable energy development. Therefore, it is of great significance to fully tap the demand-side resources and explore the trading mode and market mechanism of extensive load aggregators participating in power system operation.

This paper mainly studies the trading mode and development path of load aggregators participating in the power market, guiding demand-side resources to participate in grid regulation, and linking the value of demand-side resource flexibility with the power system regulation demand, so as to reduce the uncertainty and randomness of the load side resources, and at the same time improve the capacity of renewable energy consumption.

2. The development of demand-side resources participating in electricity trading

2.1. Definition of Load Aggregator
Demand response technology is one of the core technologies of the smart grid. The application of demand response technology can fully mine load-side resources and realize the comprehensive optimization of resource allocation. However, in general, the current mining of load regulation capabilities is not deep enough, and the users’ response to the system is not active enough. A new kind of specialized demand response provider-load aggregator appeared in developed countries. Load aggregator is an independent organization that integrates users’ demand response and provides it to market buyers. It not only provides opportunities for small and medium loads to participate in market regulation, but also fully explores load resources through professional technical means and provides auxiliary service products required by the market[3]. The operation framework of load aggregators is shown in Figure 1.

![Figure 1. Operation framework of load aggregator](image)

2.2. Development status of demand-side resources participating in power trading

2.2.1. Energy storage.
At present, the United States, the United Kingdom, Australia, and Germany are all FM market areas where energy storage applications are relatively active. The U.S. PJM regional power market is the most mature FM market for energy storage applications. Based on costs and effects, the FM capacity price and FM effect price are formed, and it has complete FM auxiliary service bidding rules and a pay-per-effect settlement method. Energy storage mainly provides fixed frequency modulation response and enhanced frequency modulation response in the ancillary service market in the UK, and adjusting frequency modulation and emergency frequency modulation In the Australian. Energy storage facilities
in Germany mainly participate in the FCR market to obtain revenue, and use the method of auction and unified clearing price to pay the revenue.

At this stage, various local ancillary service markets have basically affirmed the identity of energy storage in participating in ancillary services, but in practical applications, there are still problems of unreasonable sustainable benefit sharing, lacking a fair competitive market environment, and unsustainable compensation mechanisms.

2.2.2. Electric Vehicle.
The concept of electric vehicle energy storage was put forward by scholars as early as the 1990s, and was gradually demonstrated by subsequent studies in terms of technical feasibility, economy, operating mode, and standard specifications. Limited by the limited number of early electric vehicles and the high battery cost, foreign electric vehicle energy storage has been in the stage of technology research and development and demonstration. From a practical point of view, electric vehicles participate in market transactions mainly through two modes: auxiliary frequency modulation and demand response.

2.2.3. Virtual power plant.
Since the concept of virtual power plant was put forward in 1997, it has attracted wide attention from many countries in Europe, North America and Australia. The virtual power plant can "series" distributed photovoltaic, energy storage equipment, heat storage boiler and controllable load, so as to maximize the overall energy supply benefit of cold, heat and electricity. The virtual power plant can monitor flexible controllable loads such as central air-conditioning and electric vehicles, environmental parameters, and distributed energy output in real time. It can automatically adjust and optimize response quality around user and system requirements, reduce investment in power supply and grid construction, and create a good and comfortable environment. At the same time of living environment, realize the win-win of user and system, technology and business model.

3. Demand-side resource aggregation operation model
The load aggregator is a commercial organization that serves users to participate in the power market, and effective management has a positive effect on changing load characteristics and promoting system safety and stability. As an intermediary between users and the grid, load aggregators participate in power market transactions by integrating user resources. The operating mechanism is shown in Figure 2.

![Figure 2. Operation mechanism of load aggregator](image)

3.1. The relationship between load aggregators and users
The resources managed by load aggregators include energy storage equipment and backup power sources in addition to the controllable loads in residential, commercial and industrial users. The load aggregator analyzes the potential of users to participate in demand response at various times, fully grasps the controllable power of different equipment and the cost of electrical equipment to participate in
response, and considers the impact of user equipment physical characteristics and users’ willingness to participate in demand response.

3.2. The relationship between load aggregators and the market
The controllable load resources aggregated by load aggregators can provide services including active power balancing and system peak shaving[4]. The ways for load aggregators to participate in the market include bilateral transactions and spot market bidding. Bilateral transaction means that load aggregators sign bilateral contracts with electricity selling companies and power generation companies in advance, directly send instructions to load aggregators when they need to make load adjustment, and finally pay load aggregators according to the contract situation.

3.3. Comparison of load aggregators with other power system participants
Power generation companies can sell electricity through the spot market in addition to signing contracts with electricity sales companies. The responsibility of the electricity sales company is to buy electricity from generators and sell electricity to users. The most important feature of a power distribution company is that it has its own power distribution network, and can serve as a power sales company, a power grid security operation manager, or a power sales company that includes load aggregation services in the future. Load aggregators can also serve as power sales companies in the future, but they need to provide power distribution companies with the cost of grid usage.

4. Operation mechanism of load aggregator
The construction of the power Internet of Things will greatly promote the acquisition of power terminal data and the value-added business driven by data, and promote the intensive, intelligent and automated management of the entire power business through the cyber-physical social system. With the access of a large number of distributed power sources and flexible loads, an energy management system with load aggregators as nodes will provide safety guarantees and operational support for the power system.

Based on the characteristics of load aggregators’ scheduling optimization, this paper focuses on analyzing the scheduling optimization mechanism of load aggregators under the power Internet of Things from three progressive dimensions: natural polymerization, economic incentive, and operation coordination. The control means show an increasing trend, and the control mechanism also gradually changes from intelligent to manual decision-making.

4.1. Aggregation mechanism: user combination peak shift effect
Load aggregators are an effective aggregation of a variety of distributed energy sources such as electric vehicles, flexible loads, and energy storage. Through the combination of user subjects with different load characteristics, using the complementary effects of each load on the characteristic values of daily load rate, daily peak-valley difference rate, daily maximum utilization time, etc.. Artificial intelligence technology is introduced to cluster load curves, which can form a load aggregator that stabilizes the fluctuations of internal entities to a certain extent.

4.2. Incentive mechanism: differentiated contracts based on user flexibility
On the basis of the peak shift effect of the user portfolio, economic means need to be introduced to influence user behavior, and the final manifestation is the differentiated contract signed by the load aggregator and different users. Only when the marginal cost equals the marginal utility, the optimal allocation of resources can be achieved. Therefore, the signing of differentiated contracts needs to be based on the price elasticity of different types of users to maximize economic leverage.

4.3. Operation mechanism: joint operation with energy storage
Due to the user's own load characteristics and restrictions on adjustability, individual load aggregators will inevitably have deviations in the direct electricity trading and ancillary service markets. For load aggregators, by signing cooperation agreements with other operators or energy storage equipment to
form a load aggregator operation alliance, they will further optimize their control capabilities. The increase in benefits or the reduction in costs brought about by the increase in regulation and control capabilities can be reasonably distributed among the various entities.

5. Market trading strategies of load aggregators
Research on the trading strategies of load aggregators from the electricity energy market and electricity derivatives market, as shown in Figure 3.

5.1. Electric Energy Market Trading Strategy

5.1.1. Agent power purchase mode

5.1.1.1. Model body
In the load aggregator agent power purchase is divided into two markets, the first-level market load aggregator enters the wholesale market as an agent to purchase electricity. The buyer is the load aggregator, while the seller is the power generation enterprise, trading institution, power grid enterprise or each independent power selling entity. The secondary market load aggregator performs the agency contract with the internal subject, the buyer is the internal user participating in the load aggregator, and the seller is the load aggregator.

5.1.1.2. Service effect
Through the integration of internal demand, the load aggregator carries a large amount of electricity demand into the power trading market to fight for the profit of the power plant in the bidding, and realize the overall income of the load aggregator. And through the fixed price, the winning bid price commission, the guarantee + commission, and the proportion of the market settlement average price, etc., they can carry out reasonable profit distribution and increase the income of internal entities.

5.1.1.3. Income model
Cost: the investment and construction cost of the load aggregator; the operation and maintenance cost of the load aggregator; and the cost of outsourcing electricity.
Benefits: bidding profits obtained by participating in the power market; agency fees for internal loads obtained; profit distribution under different agency modes.

5.1.2. Ancillary service market transactions

5.1.2.1. Mode body
Load aggregators participate in power market ancillary services. Market members include market operation agencies, load aggregator operators, and load aggregator internal resources. Market operation
agencies include power dispatch control centers and power trading centers; Load aggregator operators integrate internal resources, participating in the ancillary service market as a whole.

5.1.2.2 Service effect
Load aggregators gain profits by participating in the auxiliary service market. After the load aggregator aggregates agents of various entities, it participates in the market quotation as an auxiliary service provider. After the transaction center clears, the load aggregator aggregates internal resources to follow market instructions and finally participates in wholesale market settlement. Through coordinated control and optimization, the impact of distributed resource grid connection on the large power grid is greatly reduced, the scheduling difficulty caused by the growth of distributed resources is reduced, and the stability of system operation is improved.

5.1.2.3 Income model
Costs: investment and construction costs; user compensation costs of participating in auxiliary service; external power purchase costs; internal power purchase costs.
Benefits: peak shaving income; reserve income.

5.1.3 Electricity demand response transactions

5.1.3.1 Mode body
The operating subject of the power demand response transaction is the load aggregator operator, and the participants are the internal photovoltaic power plants, commercial buildings and energy storage equipment of the load aggregator. Load aggregator operators integrate internal resources and participate in demand response transactions as a whole[5].

5.1.3.2 Service effect
The load aggregator aggregates the adjustable power resources of each customer into a controllable aggregate, adjusts it actively according to the operation needs of the large grid and its own conditions, and realizes "demand elasticity, supply and demand coordination", so that the energy utilization efficiency of customers and even society can reach Optimization, to provide better guarantee for the safe operation of the power grid and the energy consumption of the situation. By participating in demand response transactions, load aggregators obtain demand response compensation from large power grids, and then distribute income according to the contribution of internal members. The surplus can continue to invest in the construction of load aggregators.

5.1.3.3 Income model
Costs: investment and construction costs; user compensation costs of participating in demand response.
Benefits: participation in external demand response compensation benefits.

5.2 Electricity Derivatives Market Trading Strategy
Charging load aggregators do not have the assessment conditions or the obligation to purchase green certificates in the renewable energy quota system and green certificate trading market. The green certificate transaction within the aggregate takes place between charging load users, and the renewable energy quota will assess the power usage of the above-mentioned power users, thereby encouraging users to participate in green certificate transactions.

The charging load aggregator green certificate transaction model can be divided into two levels. Within the charging load aggregator, through innovative platform transaction models and products, green certificate transactions within the platform can be realized, and the green certificate transaction circulation between users on the platform can more conveniently achieve the performance of renewable energy quotas.
Outside the charging load aggregator, taking into account the organization of charging load users to participate in market transactions through load integration, on the other hand, charging load aggregators can act for small users to conduct green certificate agency transactions. In the case of oversupply of the green certificate market in the aggregate, the green certificate will have a surplus. In this case, the charging load aggregator can purchase the green certificates through the green certificate trading platform; When the supply of the green certificate market in the body is less than demand, the green certificate is not enough to meet the needs of users. The charging load aggregator can purchase corresponding green certificates from the green certificate market by predicting user needs, based on the green certificate trading market in the charging load aggregate, Through diversified product packages, green certificates are sold to realize user performance.

6. Conclusion
This paper focuses on issues related to demand-side resource gathering participation in power trading business models, and analyzes future energy aggregators' participation in power spot transactions and other various trading models. At present, many research and practical work have been carried out on the construction of load aggregators and their participation in power market transactions at home and abroad. Under China’s clean energy development system, load aggregators provide flexible adjustment resources for power system operation through adjustable load integration, and meet the requirements of power system operation and development. At the same time, the rapid development of adjustable loads such as electric vehicles, flexible loads, and energy storage, and the innovation and application of information technology such as "Big Cloud and Things, Smart Side", provide support for large-scale and distributed micro-load integrated control operations.

At this stage, in order to improve the participation of charging load aggregators in the power market, auxiliary service market and capacity market, it is necessary to integrate charging load aggregation resources and strengthen market access services; integrate charging load aggregation resources; improve transaction procedures and strengthen collaboration among internal businesses.

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