

Research on Distribution Network Side Shared Energy Storage Business Model under Double Carbon Strategy

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Abstract. Under the goal of the national dual carbon strategy, favorable policies related to national and local energy storage appear frequently, and the era of large-scale energy storage comes. Based on the analysis of relevant national energy storage policies, this paper points out that under the single business model of energy storage, its energy storage resources will lead to a large number of idle waste and low economic benefits, and then leads to the necessity of shared energy storage business model. Compared with the traditional single energy storage business model, shared energy storage has wider sources of income and higher return on investment; This paper expounds the characteristics of the multi-agent shared energy storage business model participated by the third party, points out the interest relationship among its subjects, and then analyzes the typical application scenarios and business model of shared energy storage combined with the case of Shandong shared energy storage; Finally, it combs the application technology of shared energy storage, analyzes the bilateral and unilateral transaction interest relationship of shared energy storage, puts forward the transaction mode of standardizing its single and bilateral cost sharing, and then studies the transaction architecture of shared energy storage system for multi-agent users in distribution network.

1. Introduction

In the context of the "dual-carbon" strategic goal and the new power system, the scale of installed energy storage capacity will usher in a substantial increase, and the problem of a large number of idle energy storage resources will also be taken seriously. The construction of shared energy storage in the distribution network can effectively alleviate Grid capacity pressure [1], optimize and integrate the power resources of the distribution network, and conform to the power requirements under the new situation [2]. However, the shared energy storage technology in the distribution network still has the following problems to be solved urgently: the diversification of power subjects, the diversification of operation modes, and the many uncontrollable factors, the extraction of typical application scenarios of shared energy storage and the valuable business operation model has not yet formed [3]; Distributed multi-agent power transactions are frequent under the distribution network, the amount of interactive data information is huge, and there are many unknown factors that threaten information security. A fast, safe and efficient matching transaction mechanism for shared energy storage for different service needs has not been formed yet Therefore, further research on shared energy storage is promising and necessary.

2. Sorting Out Relevant Policies

2.1. National Top-level Design

In June 2020, the National Development and Reform Commission and the National Energy Administration jointly issued the "Basic Rules for Medium- and Long-term Electricity Trading" document clarifying that market entities include various power generation companies, power grid companies, power distribution companies, energy storage companies, etc. On the power generation, transmission and distribution other transactions have been further regulated to further promote the development of market-oriented transactions and transmission and distribution services. At the end of the same year, the "Technical Requirements for Containerized Lithium Battery Energy Storage System Access to DC Distribution Network (Draft for Comment)" proposed by the China Electricity Council stipulated the access conditions and energy storage configuration of the containerized lithium battery energy storage system. At the technical level, the configuration requirements for energy storage on the distribution side have been standardized, which has greatly promoted the development of energy storage on the distribution side and the development of shared energy storage mode on the grid side [4].

The "Guiding Opinions on Accelerating the Development of New Energy Storage (Draft for Comment)" issued by the National Development and Reform Commission in 2021 clarified the development goal of 30 million kilowatts of energy storage to help achieve leapfrog development, emphasize planning and guidance, and further deepen storage in various

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application fields. The energy storage industry has gradually changed from the initial exploration stage to the large-scale development. Table 1 below shows the comparison of goals in different stages of my country's energy storage. Through the comparison, it can be seen that the scale of energy storage development is growing very rapidly, and it is predicted that energy storage will gain Large-scale development [5]. In July of the same year, the National Development and Reform Commission issued the "Notice on Further Improving the Time-of-use Electricity Price Mechanism", which clarified the scope of implementation of time-of-use electricity prices, encouraged industrial and commercial users to use electricity in different time, and at the same time, overall consideration should be given to factors such as local conditions and the proportion of new energy installed

capacity. The peak-valley period is divided scientifically and reasonably, and the peak-valley electricity price gap is generally widened throughout the country. This is conducive to the development of the peak-valley arbitrage business model of energy storage, and promotes the commercial development of shared energy storage on the distribution network side. Power generation companies are encouraged to build energy storage or peak-shaving capacity by themselves, and power generation companies are allowed to purchase energy storage or peak-shaving capacity. This will further promote the development of the energy storage industry from all aspects of the society. The important position of energy plays a role in promoting the formation of a perfect shared energy storage business model [6].

Table 1. Comparison of objectives in different stages of energy storage in China.

Entry	The first stage (2015-2020)	The second stage (2021-2025)
Stage	Energy storage transitions from R&D demonstration to the initial stage of commercialization	Transition to large-scale development in the early stage of commercialization
New type of energy storage installed capacity	/	More than 30 million kilowatts
Demonstration project construction	Build demonstration projects using different types of energy storage under different application scenarios	Energy storage projects are widely promoted
Business model	Initially established	Form a variety of energy storage business models

2.2. Local Policy Promulgation

Under the guidance of national policies, localities have responded to the call and issued relevant energy storage policies to promote the development of the energy storage industry. In June 2020, Jiangsu Province issued the "Notice on Matters concerning Jiangsu Power Grid's 2020-2022 Transmission and Distribution Prices and Sales Electricity Prices" notice clarifying matters related to Jiangsu Grid's 2020-2022 transmission and distribution prices and sales electricity prices. Subsequently, the "Jiangsu Distributed Power Generation Market Transaction and Grid Enterprise Transmission and Distribution Service Tripartite Contract (Demonstration Text)" was issued to identify the three entities of power purchaser (A), power seller (B) and grid operating enterprise (C) It elaborates and divides the rights, obligations, and responsibilities of the three parties, and further regulates the details of the parties involved in the market-oriented transaction. This document is conducive to the formation and improvement of the standardized shared energy storage transaction structure.

At the end of 2020, Shandong Province issued the "Notice on Matters Concerning Shandong Power Grid's Transmission and Distribution Prices and Sales Price for 2020-2022", which not only widened the peak-to-valley electricity price gap, but also matched the supply and demand relationship with the spot market at various times. The development trend is closely linked to further

improve the energy storage's participation in the power market transaction mode; Zhejiang Province also issued the "Notice on Zhejiang Power Grid's 2020-2022 Transmission and Distribution Price and Sales Price Relevant Matters" to reduce the cost basis of large industrial power consumption. In addition, the "Notice on Matters concerning Transmission and Distribution Prices and Sales Prices of Hubei Power Grid 2020-2022" issued by Hubei Province to further reduce the valley section electricity prices and increase the peak-to-valley price difference. Further widening the peak-to-valley electricity price gap. All provinces have successively promulgated relevant policies to promote the development of energy storage and encourage all entities in the society to deploy energy storage devices. The huge increase in the amount of energy storage will inevitably lead to idle and surplus energy storage [7], resulting in a waste of resources. To solve this situation, the formation of a complete shared energy storage model has become an indispensable part of the realization of the national "dual-carbon" strategic goal, which has further promoted the formation and improvement of the shared energy storage business model on the distribution network side.

3. The Business Model of Shared Energy Storage

3.1. Business Model Overview

The shared energy storage business model mainly stems

from the current problems in the energy storage industry such as "low utilization of energy storage devices", "single profit model", and "compulsory support to increase the cost of new energy power plants". Specifically, there are three modes of operation. The first is that the owner of energy storage equipment directly participates in shared energy storage market transactions as an independent market entity [8]; the second is for transactions with the power grid. When the market for energy storage is not finished, Energy storage cannot directly enter the shared pure energy market transaction, but when it can match the grid conditions, it can be directly called by the grid at the electricity price to increase the integration of new energy into the grid [9]; the third is through the organization of shared energy storage suppliers Idle energy storage resources constitute the energy storage resource supply pool, and the demand side publishes energy storage resource information to constitute the energy storage resource demand pool. The fair platform conducts negotiation and bidding and matching supply and demand. Finally, the supply side provides point-to-point services to the demand side. This method increases the number of uses of energy storage and increases the project's rate of return [10].

3.2. Shared Energy Storage Business Model Involving Multiple Entities

With the large-scale development of energy storage, whether it is a business model that directly participates in market transactions or transacts with a direct grid, its source of income is single. Even in places where the peak-to-valley price difference is high, the return on investment of its business model is generally in the range Over seven years, the rate of return on investment is not high. Under the background of the rapid growth in the amount of energy storage, the third business model can better solve the problem of large amounts of idle energy storage resources. In this regard, it is more important to carefully study the shared energy storage business model with multiple market players.

3.2.1. Shared Energy Storage Business Model Involving Multiple Entities.

In the third shared energy storage business model, the interest relationship of multiple market players is involved. As a third party, the integrated energy party can connect multiple stakeholders to expand market-based energy storage transactions and maximize the use of energy storage resources. The specific relationship is shown in figure 1. Relying on a third-party-led multi-stakeholder collaborative operation system, the third party can aggregate distributed energy storage resources for various stakeholders, and use a fair and efficient platform to negotiate bidding and match supply and demand. According to the energy storage needs of users, matching energy storage resource configuration is provided to energy storage users through the power grid, and point-to-point services are provided between users and energy storage resources.

The third party acts as a connected entity to increase the utilization rate of energy storage for all parties in the society; energy storage users release energy storage requirements, form an energy storage resource demand pool based on energy storage requirements, and reasonably share energy storage construction costs according to the principle of "who benefits, who pays" , The benefits obtained by using energy storage are distributed to individual users through a response mechanism; energy storage manufacturers provide energy storage equipment, lease the manufactured energy storage batteries to a third party, and then the third party leases it according to the different needs of different users. Manufacturers provide battery maintenance and repair work and technical supervision; power grid companies mainly perform the duties of providing venues, rapid installation, efficient dispatch, and investment and share benefits. At the same time, benefit from the auxiliary services that energy storage can provide and delaying equipment upgrades.

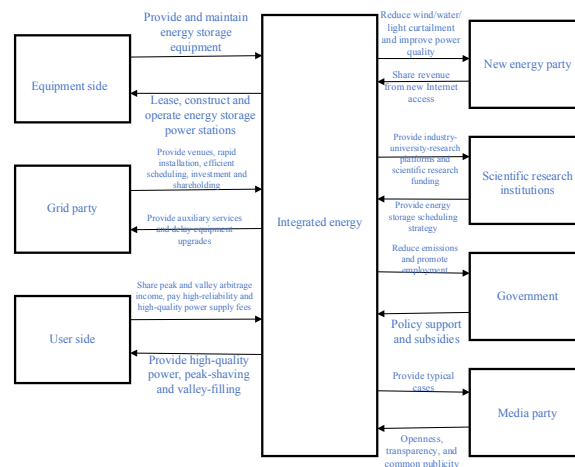


Figure 1. Transaction mode with the participation of a third party.

3.2.2. "Use Lease Instead of Sale" Model of Energy

Storage. Due to the high cost of construction and installation of energy storage, and the high initial costs, a

"Use lease instead of sale" model of energy storage utilization method was established. The system is leased to users, and users can flexibly set energy storage related uses and energy storage system parameters. They only need to pay monthly rent, which can avoid the problem of excessively high initial costs of energy storage project construction, and it can also generate stable cash flow, as the financing basis for developers, greatly promotes the development of energy storage.

In November 2020, Hunan will provide core equipment leasing services to energy storage companies for the four 60MW/120MWh new energy supporting electrochemical energy storage power station projects planned by Hunan for a lease term of 10 years. As the scale of my country's new energy power generation continues to expand, the pressure of use is increasing. Since 2020, many places have clearly included new energy projects with energy storage in the priority support range at the policy level. The successful practice of the Hunan energy storage leasing model is regarded as a "new way" for the commercial development of energy storage. It can improve the utilization rate of energy storage power station and the flexibility of the power system, realize energy storage cost reduction and efficiency increase, and promote the effect of new energy consumption.

3.3. Revenue Model

(1) Distributed Photovoltaic Power Generation Revenue:

If the electricity generated by the distributed photovoltaic power station is higher than the required electricity, there will be surplus electricity, which can be sold to the shared energy storage power station:

$$f_1 = C_{11} * Q_{11} - C_{12} \quad (1)$$

In the formula: f_1 is the economic benefits of distributed photovoltaic power generation. C_{11} , Q_{11} are the electricity price and electricity sold to shared energy storage power stations, respectively. C_{12} is the energy storage usage costs.

(2) Economic benefits of the industrial zone:

The industrial zone purchases electricity from the shared energy storage power station during the peak power consumption of the grid, and the electricity price is lower than the grid electricity price, or uses the shared energy storage power station as a backup power source during power outages to reduce economic losses. The economic benefits of the industrial park are:

$$f_2 = C_{21} * Q_{21} + f^* \quad (2)$$

In the formula: f_2 is the economic benefits of the industrial zone. C_{21} , Q_{21} are the electricity price difference and electricity consumption in the industrial zone during the peak electricity consumption, respectively. f^* is the reduced economic losses.

(3) Economic benefits of the power grid:

Shared energy storage power stations can delay equipment upgrades; the power grid charges the shared

energy storage power stations when power consumption is low; the power grid purchases power from the shared energy storage power stations during peak power consumption to maintain the safe and stable operation of the system. The economic benefits of the power grid are:

$$f_3 = f' + C_{31} * Q_{31} - C_{32} * Q_{32} \quad (3)$$

In the formula: f_3 is the economic benefits of the grid. f' is the cost of delaying equipment upgrades. C_{31} , Q_{31} are the electricity price and electricity sold by the grid to the shared energy storage power station, respectively. C_{32} , Q_{32} are the electricity price and electricity absorbed by the power grid from the shared energy storage power station, respectively.

(4) The economic benefits of shared energy storage power station

The system serves residential areas, commercial areas, industrial areas, user photovoltaic power generation supply areas, built energy storage power stations, etc. The shared energy storage power station buys surplus electricity at low prices from the distributed photovoltaic side; Sell to the grid or industrial zone to get the price difference. Then the economic benefits of shared energy storage power stations are:

$$f_4 = C_{41} * Q_{41} - C_{42} * Q_{42} \quad (4)$$

In the formula: f_4 is the economic benefits of shared energy storage power station. C_{41} , Q_{41} are the shared energy storage discharge price and discharge power, respectively. C_{42} , Q_{42} are the shared energy storage charging service fee and charging power, respectively.

3.4. Case Study on the Development of Shared Energy Storage in Shandong Province

3.4.1. Shandong Energy Development Background.

In order to achieve the goal of "carbon peak and carbon neutralization", Shandong Province has accelerated the transformation of the power industry to green and low-carbon and vigorously promoted the development of clean energy. Its photovoltaic and wind power development is in a leading position in the country. By the end of 2020, the installed capacity of Shandong Province has reached 160 million KW, and the installed capacity of photovoltaic and wind power has reached 22.72 million KW and 17.95 million KW respectively. The proportion of coal power has decreased by 17.7% compared with 2015. With the gradual increase of the scale of new energy, it is necessary to further coordinate all sides of the power system and accelerate the development of energy storage industry, so as to improve the development and utilization level of clean energy and promote the construction of a new power system with new energy as the theme.

3.4.2. Income Analysis of Shandong Energy Storage Project.

Shandong issued the "Implementation The

"Opinions on Conducting Energy Storage Demonstration Applications" states that in principle, new centralized new energy generation projects must be equipped with a corresponding proportion of energy storage, or leased with already built energy storage, with a requirement of more than 10% and a continuous charging time greater than or equal to 2 hours. Support various market entities to invest in the construction and operation of shared energy storage facilities, and encourage wind power and photovoltaic power generation projects to prioritize the lease of shared energy storage facilities, and the leased capacity is deemed to be the energy storage capacity of their counterparts.

Haiyang energy storage power station project of State Power Investment Co., Ltd. was jointly built by Shandong Branch of State Power Investment Co., Ltd. and Shandong Electric Power Engineering Consulting Institute Co., Ltd. The energy storage power station has a capacity of 101MW/202MWh, with a total investment of 438 million yuan. The project can not only participate in the auxiliary service of peak load regulation in Shandong power grid, but also serve as the centralized shared energy storage, Leasing energy storage capacity to new energy enterprises reduces their energy storage costs, and the project has good economic benefits.

4. Shared Energy Storage Transaction Architecture

Traditionally, the distribution network draws on the experience of the transmission side to manage and operate in a centralized manner. However, this model has many problems in the new power system, such as poor economic efficiency, ineffective security assurance, and information asymmetry between the trading parties. With the continuous development of my country's energy

storage industry, more and more distributed power sources can participate in market competition as independent entities. In this context, a more flexible and scientific internal transaction mechanism is required. Nowadays, the distribution network uses blockchain technology, introduces blockchain technology in power transactions, uses alliance chains to reduce the degree of data development to ensure data security, and completes the verification and verification of transaction information in a relatively short period of time through the consensus mechanism of the share authorization certificate. Confirm, and ensure the timeliness of transactions through fair distribution, rewards and punishments, and rapid replacement mechanisms. At the same time, the data information access mechanism, hash algorithm and asymmetric encryption algorithm are introduced to ensure data security.

4.1. Trading Mechanism

In the current practice of shared energy storage, the main transaction modes include bilateral negotiation transaction, market bidding transaction and power grid direct call transaction mechanism. The specific transaction mechanism is as follows:

4.1.1. Bilateral Negotiation Transaction Mechanism.

Bilateral negotiation transaction is a market transaction that can involve multiple market subjects (see figure 2 for details). Both parties can conduct bilateral transactions among power producers, electricity sellers and users, as well as negotiation transactions among power producers, electricity sellers and users. It has strong flexibility and is conducive to promoting the consumption of new energy, Bilateral negotiation transactions are mainly applicable to medium and long-term ancillary service transactions.

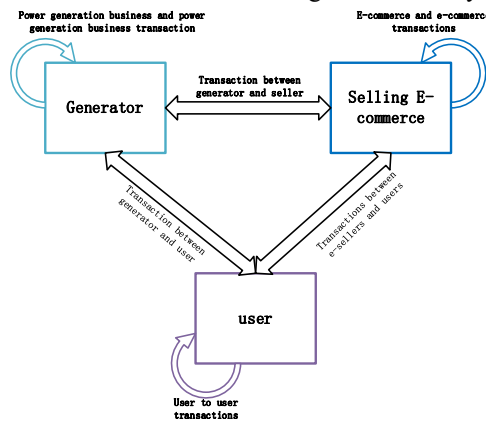


Figure 2. Schematic diagram of bilateral transaction mechanism.

4.1.2. Market Bidding Trading Mechanism. In the market bidding transaction, the energy storage power station and the power plant submit the trading intention including the trading period, trading power, trading price, etc. to the auxiliary service trading platform. After the transaction can be carried out after verification, the seller and the buyer quote respectively, and compare and match the buyer (from high to low) with the seller (from low to

high), When prices intersect, the transaction is concluded. Firstly, the price difference in the quotation is settled sequentially from high to low, until all electricity in the market has been traded, or the prices between the buyer and seller are the same, or there is no available line for the transaction. The average price quoted by both parties is the clearing price, and all the traded electricity shall be settled separately according to their respective clearing price. Market bidding transactions are mainly

applicable to short-term auxiliary service transactions.

4.1.3. Trading Mechanism Directly Invoked by Power Grid. If the energy storage power station still has remaining charging capacity after the bilateral negotiated transaction and the market bidding transaction, when the power grid has peak shaving demand, the dispatching agency can call the energy storage power station to participate in the power grid peak shaving according to the pre-agreed grid call energy storage peak shaving price.

4.2. Transaction Clearing and Settlement Method

The clearing of the shared energy storage peak shaving market needs to comprehensively consider the boundary conditions such as power generation constraints, energy storage rate and energy storage capacity. The settlement of the shared energy storage peak shaving market shall comprehensively consider the daily market clearing results and the actual implementation of market members.

In terms of settlement basis, the energy storage and peak shaving power purchased by wind power and solar power generation enterprises is the new power generation space in the corresponding period of wind power and solar power generation enterprises. According to the bidding ranking before the trading day of energy storage peak shaving (including the ranking of energy storage stations and new energy stations), the dispatching organization automatically matches and trades new energy stations for energy storage stations in turn according to the actual generation surplus capacity of each new energy station calculated, tracks and controls the charging process in real time through AGC system, and records relevant control and charging data as the basis for settlement. During peak load period or low power generation output period of the power grid, AGC system will automatically issue instructions to orderly discharge the energy storage power station, and record real-time control and discharge data as the basis for settlement.

Among them, the cost of shared energy storage auxiliary services is settled on a monthly basis and shared by the proceeds of solar power generation and wind power. If the energy storage and peak shaving resources are not transferred unilaterally, the behavior of charging and discharging by the energy storage power station shall not obtain the peak shaving auxiliary service fee.

4.2.1. Energy Storage Settlement Fee. Energy storage settlement fee is the sum of bilateral settlement fee and unilateral settlement fee. Bilateral settlement fee can be expressed as the product of bilateral transaction discharge and bilateral transaction price of wind power, solar power generation and energy storage power station. Unilateral settlement fee is expressed as the product of power grid auxiliary service call discharge and auxiliary service fee. See the following formula for details:

$$f_{es} = Q_b * p_b + Q_d * p_d \quad (5)$$

Where: Q_b is the discharge capacity of bilateral transactions. p_b is the bilateral transaction price of wind power, solar power generation and energy storage power stations. Q_d refers to the amount of discharged electricity involved in grid auxiliary service call. p_d is the price of participating grid auxiliary services.

4.2.2. Cost Sharing of Energy Storage Bilateral Market-oriented Transactions. It is defined that the payment for bilateral peak shaving of shared energy storage of each wind farm and solar power station is:

$$f_w = Q_b * p_b + \frac{Q_c * L * f_g}{1-L} + (Q_c - Q_b) * f_g \quad (6)$$

Where: f_w pays for bilateral peak shaving of shared energy storage of each wind farm and solar power station. Q_c is the bilateral charging capacity of energy storage. L is the comprehensive line loss rate of the whole network for one year. f_g is the on grid price.

4.2.3. Cost Sharing of Energy Storage Unilateral Invocation. Define the unilateral peak shaving cost of each wind farm and solar power plant shared energy storage as:

$$f_u = Q_d * P * p_d + \frac{Q_u * P * L * p_g}{1-L} + (Q_u - Q_d) * P * p_g \quad (7)$$

Where: f_u pays for the unilateral peak shaving of the shared energy storage of each wind farm and solar power station. P is the apportionment coefficient, that is, the sum of the scalar quantity won by unilateral call / the sum of the bidding electricity quantity of all wind power and solar power unilateral markets. Q_u is the charging power of energy storage unilateral peak shaving.

5. Conclusion

In terms of policies, the state has issued a series of policies in the field of energy storage to promote the development of shared energy storage; In terms of engineering, the demonstration projects of shared energy storage are gradually increasing, which has application prospects; In terms of technology, the technologies involved in the popularization and application of shared energy storage are developing continuously; In terms of economy, the business model and transaction framework of shared energy storage are further discussed.

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