The Economic Value of Independent Energy Storage Power Stations Participating in the Electricity Market

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Abstract. Under the "dual carbon" goal, the proportion of new energy generation in new power systems is increasing, and the volatility and uncertainty of power output are also becoming more significant. Energy storage, as a flexible resource, can effectively compensate for the shortcomings of new energy generation. Therefore, the country has continuously introduced policies to encourage the development of independent energy storage and mandatory new energy allocation and storage. But as the scale of energy storage capacity continues to expand, the drawbacks of energy storage power stations are gradually exposed: high costs, difficult to recover, and other issues. This article establishes a full life cycle cost and benefit model for independent energy storage power stations based on relevant policies, current status of the power system, and trading rules of the power market. A typical electrochemical energy storage power station in Shandong is selected, and its economic value is analyzed by calculating its cost and benefit status after operation. Finally, it is suggested that the construction of energy storage facilities should actively switch to independent energy storage and that independent energy storage facilities should actively participate in auxiliary services.

Keyword: Independent energy storage, Electricity market, Economic value

1 Introduction

In order to achieve the goals of "carbon peaking" and "carbon neutrality", China needs to build a new type of power system with new energy as the main body, and further increase the development of renewable energy during the 14th Five Year Plan period. The rapid development of renewable energy poses significant challenges to the balance of the power system: the randomness, volatility, and uncertainty of power output are becoming increasingly prominent [1-3]. Energy storage systems are favored by various sectors of society due to their ability to greatly enhance the flexibility of the power grid, promote the consumption of intermittent renewable energy, and improve the stability of the power grid. Currently, the country has introduced a series of policies to encourage the development of energy storage and made development plans. The importance of energy storage and its role in new power systems are becoming increasingly prominent. The policy explicitly proposes that the installed capacity of energy storage should reach 30GW by 2025, and at the same time, energy storage should be transformed from a current policy driven approach to a market-oriented approach,

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guiding the market-oriented development of energy storage. However, when the development of new energy storage is in full swing, the problems of energy storage power stations are also exposed: the cost of new energy storage power stations remains high, the utilization rate of energy storage is not high, and the cost mitigation mechanism is not clear enough. This has seriously dampened the enthusiasm of investment entities and restricted the application of new energy storage in new power systems, especially in the construction of energy storage power stations.

Energy storage can play an important role in suppressing renewable energy fluctuations, peak shaving and valley filling, improving power supply reliability, peak shaving and frequency regulation in the power system [4,5]. As an important flexibility resource, it can provide various services such as peak shaving, frequency regulation, backup, black start, and demand response support for grid operation [6]. It is one of the main means to improve the flexibility, economy, and security of traditional power systems [7]. Energy storage stations can be divided into independent energy storage stations and auxiliary energy storage stations according to application scenarios, and the economic efficiency of auxiliary energy storage is significantly lower than that of independent energy storage. Independent energy storage refers to an energy storage power station that, as an independent market entity, directly signs a grid connection agreement with a power grid company, promises to belong to the management of the power grid company, and signs contracts with relevant parties such as power grid enterprises and related power generation enterprises or power users according to their access location, stipulating the rights and obligations of all parties [8]; Allocated energy storage refers to energy storage power stations that are dispatched by new energy sources in order to obtain grid connection qualifications and do not have the conditions for direct control. Compared with independent energy storage, distributed energy storage has not entered the electricity market, lacks a market-oriented profit model, and cannot enjoy the dividends of the electricity market. The enthusiasm and initiative to participate in grid dispatching are low [9-11], the specific differences are shown in Table 1. In the first half of this year, independent energy storage can basically achieve one charge and one discharge per day, with a utilization hour of 533 hours. However, the utilization hour of auxiliary energy storage is 192 hours, only one-third of the independent energy storage, and the utilization hour is not high. The difference between new energy allocation and independent energy storage is shown in the table below. Faced with such problems, Shandong Province has taken the lead in encouraging the conversion of auxiliary energy storage to independent energy storage. As of September 2023, the independent energy storage scale in Shandong Province was 1.976 million kilowatts, accounting for 70%, and the auxiliary energy storage scale was 854000 kilowatts, accounting for 30%.

Table 1. The difference between new energy distribution and independent energy storage

Difference	Supporting energy storage	Independent energy storage
Main body	New energy power generation projects	Independent entities connected to the grid and receiving power grid calls
Independent legal person	Yes	No
Income method	Mainly used to obtain grid connection qualification for wind and solar power	Participate in the electricity market, profit through auxiliary

	plants, as well as to reduce wind and solar power waste and reduce power generation deviation assessment	services and peak valley arbitrage, and also rent out capacity.
Utilization rate	Low	Higher

Based on this, this article selects independent energy storage power stations in Shandong Province to participate in the electricity market as an example to calculate their economic value. Based on the analysis results, some development suggestions are proposed for the main body of energy storage power stations.

2 Current situation of energy storage participating in the electricity market

With the continuous acceleration of the construction of China's new power system, the framework of China's electricity market is also gradually improving. The electricity market in China is mainly composed of several sub markets. In terms of time, the electricity market can be divided into medium to long term markets and spot markets, specifically including annual, quarterly, monthly, daily and real-time markets; In terms of product types, it can be divided into capacity market, energy market, auxiliary service market (which can be subdivided into various markets such as frequency regulation and peak shaving), and financial transmission rights market.

2.1 Participation of energy storage in the electricity market

In the electricity energy market, independent energy storage stations, due to their charging and discharging characteristics, can purchase electricity at a lower price as demanders during low grid load periods, and operate the stored power as suppliers during peak grid load periods, while also serving as power sources and users to earn profits from peak and valley electricity prices. The unified trading rules for the electricity energy market in China have not yet been formed. Most provinces generally adopt the trading rule of "generation side reporting quantity quotation, electricity side reporting quantity not quotation", and determine the operating mode of spot market prices based on the clearing of node marginal electricity prices. Therefore, during day-ahead trading, energy storage power stations need to submit their declared electricity and declared prices for each time period to the trading center. The trading center will clear the electricity based on the received electricity quotation and declared quantity, with the goal of minimizing power generation costs, and obtain the clearing prices for each time period on the day of operation and the winning bids of each market owner.

2.2 Participation of energy storage in the auxiliary service market

Energy storage frequency modulation has good performance such as fast climbing speed, fast response speed, accurate tracking, and strong short-term power throughput. The auxiliary service effect of energy storage is better than other flexible resources [12]. With the development of new energy storage technologies in China, the cost of energy storage participating in auxiliary services is also decreasing year by year. Therefore, the share of energy storage in the frequency modulation auxiliary service market is gradually increasing. In the frequency modulation auxiliary service market, energy storage stations need to synchronously declare frequency modulation quotations and frequency modulation capacity/mileage in the daily electricity market declaration process. The trading center achieves centralized clearing of the FM market based on the received information and the system FM demand on the operating day, and obtains the winning capacity, winning mileage, and clearing price of the FM auxiliary service market for each time period. The trading mode of energy storage participating in peak shaving market is daily declaration and intraday call. Energy storage stations that are willing to participate in centralized trading in the electricity peak shaving service market and meet the requirements shall declare the intended price and daily electricity consumption curve during the trading period to the market trading institution, including the trading period and the electricity consumption power per period. According to the operation needs of the power grid, the power dispatch agency will sequentially call from low to high prices based on the previous bidding results within the day (if the quotation is the same, it will be called in proportion to the declared deep peak shaving electricity), and the market clearing price will be the last energy storage quotation actually called on the day. Peak shaving compensation will be carried out for the energy storage based on the charging amount and clearing price of the energy storage.

3 Methodology

3.1 Cost model for energy storage power plants

The related costs incurred during the construction and use of energy storage systems mainly include investment costs, operation and maintenance costs, and financial costs, among which investment costs include civil engineering costs, battery procurement costs, related equipment costs, battery selection components, etc; Operation and maintenance costs include labor costs, maintenance costs, return and disposal costs, etc; Financial costs mainly refer to the interest expenses incurred by energy storage plants due to loans.

3.1.1. Initial investment cost.

The initial investment cost refers to the one-time investment required for the project implementation. The initial investment cost of the electrochemical energy storage system mainly includes civil engineering costs, battery procurement costs, container and other related equipment procurement costs, and battery testing/screening/assembly costs. The total initial investment cost can be expressed as equation (1):

$$C_1 = C_i + C_e + C_o + C_e^{'} \tag{1}$$

Among them, C_i represents the cost of civil engineering, C_e represents the cost of battery acquisition, C_o represents the cost of purchasing relevant equipment, C_e' represents the cost of battery testing and screening. The cost of land leasing is calculated based on the actual local land price standard, and the price of containers is calculated according to the standard container market price.

Civil cost. At present, the container construction form of electrochemical energy storage systems is a relatively simple and cost-effective way, and the civil construction cost here mainly refers to the land leasing cost and container cost. The cost of civil engineering can be expressed as equation (2):

$$C_i = S \cdot p_{td} + p_{jz} \cdot n_{jz} \tag{2}$$

Among them, S represents the land lease area, p_{td} represents the rental price of local land; p_{jz} represents the unit price of the container; n_{jz} represents the number of containers.

Battery acquisition cost. The purchase cost of a battery depends on three factors: battery configuration capacity, battery price, and whether the battery needs to be replaced. When determining the purchasing capacity of batteries, in addition to the rated capacity, a certain proportion of batteries need to be configured as spare parts for maintenance and backup during on-site operation. The ratio of rated capacity to backup capacity is generally 9:1. Assuming that the rated capacity of the battery energy storage system is 3MW/9MWh, consisting of six 500kW modules with a rated operating rate of 0.3C, the 500kW module needs to be equipped with a battery pack energy of 0.5MW * 3h. Each 500kW module contains 10 clusters of 50kW branches, including 6 parallel 192 series of battery cells with a capacity of 3.2V-50Ah. The remaining capacity of the battery retirement interface is 80% of the factory rated capacity. When configuring the capacity of the new battery energy storage system, considering the absence of capacity degradation and screening rate, the subsequent failure rate is low, and the purchased capacity is set at 10MWh.

After determining the configuration capacity of the energy storage battery, the purchase price of the battery can be expressed as equation (3):

$$C_e = p_e \times P_i \tag{3}$$

Among them, p_e represents the unit capacity battery price, p_i Configuration represents the initial configuration capacity of an electrochemical energy storage system.

The operating life of energy storage projects is generally designed to be 20 years, and the battery life is generally unable to reach this level. Therefore, there is a problem of the battery needing to be replaced at the end of its service life during the operation period. According to the research results of equipment manufacturers, the service life of lithium-ion batteries is approximately 8-10 years. It is assumed that the service life of lithium-ion batteries is 10 years, and the battery system needs to be replaced at the beginning of the 11th year; The service life of lead-acid batteries is 5 years, and the batteries need to be replaced in the 6th, 11th, and 16th years, respectively. The price for the replacement year is 80% of the previous battery purchase price. The cost of battery replacement is expressed as equation (4):

$$C_e = p_e^{'} \times P_m \tag{4}$$

Among them, p_e' represents the replacement cost per unit battery, P_m represents the rated capacity of the energy storage system.

Related equipment costs. The energy storage system mainly consists of related equipment such as power distribution equipment, battery boxes, battery cabinets, and monitoring systems. The cost of related equipment can be expressed as equation (5):

$$C_o = C_{de} + C_{bb} + C_{bc} + C_{mo} \tag{5}$$

The distribution equipment includes isolation transformers, energy storage converters, energy conversion systems, and battery management systems. The cost of related equipment can be further expressed as equation (6):

$$C_o = p_{IT} \times q_{IT} \times P_m + p_{PCS} \times q_{PCS} \times P_m + p_{BMS} \times q_{BMS} \times P_m + p_{bb} \times q_{bb} \times P_m + p_{bc} \times q_{bc} \times P_m + C_{mo} \quad (6)$$

Among them, p_{IT}、 p_{PCS}、 p_{BMS}、 p_{bb}、 p_{bc} represent the unit prices of isolation transformers, energy storage converters, energy conversion systems, battery boxes, and battery cabinets; q_{IT}, q_{PCS}, q_{BMS}, q_{bb}, q_{bc} The battery cabinets represent the number of corresponding equipment required per unit power; C_{mo} represents the cost of monitoring systems. The specific related costs are shown in Table 2.

Table 2. Related equipment costs

Equipment		Component/Unit	Value
Related equipment costs	Equipment cost	Unit price of isolation transformer, 10000 yuan/unit	8.9
		Number of isolation transformers per unit capacity, set	2
		Unit price of energy storage converter, 10000 yuan/set	20
		Number of energy storage converters per unit capacity, set	2
		BMS unit price, 10000 yuan/unit	20
		Number of BMS per unit capacity, set	2
	Battery box cost	Cost of a single battery box, 10000 yuan/piece	0.1
		Number of battery boxes per unit capacity, units	360
	Battery cabinet cost	Cost of a single battery cabinet, 10000yuan/cluster	1.7
		Number of battery cabinets per unit capacity, cluster	20
	Cost of monitoring system	Cost of monitoring system, 10000 yuan	75

3.1.2. Operation and maintenance costs.

The operation and maintenance cost refers to the daily expenditure costs of human, material, and financial resources required to maintain the normal operation of the battery energy storage system in the daily operation process. The operation and maintenance costs are mainly related to the scale of the energy storage system, the convenience of related supporting facilities, and the number of maintenance personnel, including labor costs during daily use, maintenance costs, and disposal costs for the retirement of the energy storage system.

Labor costs. The labor cost includes wages, benefits, and corresponding subsidies for the maintenance workers of the energy storage system. Labor costs can be expressed as equation (7):

$$C_2 = P_m \times a \times W_a \quad (7)$$

Among them, P_m represents the rated capacity of the battery energy storage system; a represents the number of operation and maintenance personnel for a unit power energy storage system; W_a represents the salary of operation and maintenance personnel.

Maintenance cost. The main cost of equipment maintenance is the cost of technical workers inspecting, repairing and replacing energy storage facilities such as batteries, BMS, and PCS when they fail. The cost of equipment maintenance can be expressed as equation (8):

$$C_3 = P_m \times p_m \tag{8}$$

Among them, P_m represents the rated capacity of the battery energy storage system, p_m represents the annual equipment maintenance cost per unit capacity.

Cost of return and disposal. Mainly including the cost of decommissioning (demolition, etc.) of energy storage equipment such as batteries, calculated at a fixed rate of 5% based on the initial investment in batteries. The cost of return disposal can be expressed as equation (9):

$$C_4 = 5\% P_{BEST} Q \tag{9}$$

Among them, P_{BEST} represents the battery price, and Q represents the total battery capacity of the power station.

3.1.3. Financial costs

Financial costs refer to the financing expenses incurred by enterprises in the production and operation process to raise funds. Financial costs generally include interest generated by bank loans, bond issuance, and other financing measures. The financial costs of energy storage power stations mainly consider the interest and period generated by long-term bank loans, can be expressed as equation (10):

$$C_5 = I \cdot r \cdot t \tag{10}$$

Among them, I represents the amount of the energy storage plant loan, and t represents the loan term.

3.2 Revenue Model for Energy Storage Power Stations

3.2.1 Peak valley arbitrage benefits

The electricity load curve in China shows a pattern of high daytime and low nighttime, and with the increase of electricity demand, the contradiction between electricity supply and demand becomes increasingly prominent. In order to alleviate conflicts, encourage and increase electricity consumption, and reduce electricity consumption during the day, the government has introduced a "peak valley electricity price" policy. In this way, the leverage of electricity prices can be effectively utilized to suppress the rapid growth of electricity consumption during peak periods and increase electricity consumption during low periods. Energy storage devices can charge during low electricity prices and discharge during peak electricity prices based on the "peak valley electricity price" to achieve peak valley differential benefits. The benefits can be expressed as equation (11):

$$R_1 = \mathrm{n}\left(\eta_{\mathrm{dis}} P_{\mathrm{dis}} T_{\mathrm{dis}} \rho_{\mathrm{dis}} - \eta_{\mathrm{ch}} P_{\mathrm{ch}} T_{\mathrm{ch}} \rho_{\mathrm{ch}}\right) \tag{11}$$

Among them, R_1represents peak valley arbitrage returns, n represents the number of charges and discharges within a year, η_{ch} represents the efficiency of the energy storage device during charging, P_{ch} represents the power of the energy storage device during charging, ρ_{ch}represents the valley time electricity price, η_{dis} represents the efficiency of the energy storage device during discharge, P_{dis} represents the power of the energy storage device during discharge, T_{dis} represents the duration of discharge, ρ_{dis} represents peak hour electricity price.

3.2.2 Capacity leasing benefits

Energy storage power stations can earn certain profits by renting energy storage capacity to new energy power plants. The benefits can be expressed as equation (12):

$$R_2 = k_{gx} P_m \tag{12}$$

Among them, R_2 represents the leasing of energy storage plant capacity, k_{gx} represents the subsidy coefficient for shared leasing, P_m represents the capacity of the energy storage power station (default capacity is fully rented after the power station is in operation)

3.2.3 Auxiliary service benefits

With the gradual improvement of the national auxiliary service market, the participation mechanism of energy storage power stations in various regions is constantly improving, and the types of auxiliary services that power stations participate in are becoming more diverse, and the business model is becoming clearer. The benefits can be expressed as equation (13):

$$R_3 = W_1 + W_2 + W_3 \tag{13}$$

Among them, W_1 represents subsidy for participating in peak shaving services for energy storage power stations, W_2 represents the compensation received by the energy storage station for participating in frequency modulation services, W_3 represents the compensation received by the energy storage power station for participating in voltage regulation services.

Peak shaving service. Participating in peak shaving service revenue storage power stations can not only generate revenue through electricity price differences. In addition, by participating in peak shaving services, corresponding peak shaving compensation benefits can also be obtained. The peak shaving compensation income is expressed as equation (14):

$$W_1 = n_f \beta_b \alpha_{cf} P_{cf} T \tag{14}$$

Among them, n_f is the number of times participating in peak shaving, β_b is the peak shaving subsidy rate, α_{cf} is the charge discharge efficiency, P_{cf} is the charging and discharging capacity, and T is the average duration of charging and discharging.

FM service. The benefits of energy storage power stations participating in frequency regulation include capacity compensation and electricity compensation, and the benefits obtained in the frequency regulation market can be expressed as equation (15):

$$W_2 = \eta n_f k_f P_m \tag{15}$$

Among them, n_f is the number of times participating in peak shaving, k_f represents the compensation coefficient of the frequency modulation service.

Voltage regulation service. The many advantages of energy storage help to promote voltage stability in the power grid and ensure the safety of the power grid system. The participation of energy storage in power grid scheduling stabilizes the load and transmission voltage, thereby receiving subsidies. The benefits of voltage regulation mainly depend on the voltage regulation capacity and participation frequency, The benefits can be expressed as equation (16).

$$W_3 = \eta n_V k_V P_m \tag{16}$$

Among them, n_V is the number of times to participate in voltage regulation, k_V represents the compensation coefficient of the voltage regulation service.

3.2.4. Capacity subsidy benefits. The benefits can be expressed as equation (17):

$$R_4 = \sum_{i=1}^{n} n_i k_{gt} P_m \tag{17}$$

Among them, R_4 represents the capacity subsidy benefits obtained by the energy storage power station, n_i represents the i-th charging and discharging, k_{gt} represents the capacity subsidy electricity price obtained by energy storage power stations.

3.3 Economic analysis

3.3.1 Internal rate of return analysis

The internal rate of return (IRR) is the discount rate when the net present value of the project is equal to zero, when the total annual capital inflow is equal to the total annual capital outflow, and when the net present value is equal to zero. It is used to measure the expected future rate of return of the investment, and is a dynamic evaluation index reflecting the profitability of systematic investment projects. The calculation of the internal rate of return excludes external factors such as the risk-free interest rate, inflation rate and various financial risks, and can be expressed as equation (18):

$$\sum_{y=0}^{Y} \frac{CI_y - CO_y}{\left(1+IRR\right)^y} = 0 \tag{18}$$

Among them, CI_y represents the net cash inflow from the energy storage plant in year y， CO_y represents the net cash outflow of the energy storage plant in year y.

3.3.2 Levelized cost modeling

Levelized energy storage costs allow for a more intuitive comparison of the differences in full life cycle costs of various energy storage technologies. Metrics such as depth of discharge and charge/discharge multiplier are also included in the LCOS analysis in some studies, but these factors are not considered due to the lack of complete data for each type of energy storage technology. It can be expressed as equation (19)-(21):

$$LCOS_{s,i} = \frac{Capital_i \times CRF + Capital_i \times a + \rho_{ch} \times P_m \times Cyc}{Cap_{strong} \times Cyc \times \eta_i \times \left(1 - Deg_i\right)} \tag{19}$$

$$CRF = \frac{D \times (1+D)^n}{(1+D)^n - 1)} \tag{20}$$

$$n = \min\left(\frac{L_{cycle}}{Cyc}, \mathrm{L}_{calendar,r}\right) \tag{21}$$

Among them, $Capacity$ represents the energy storage investment cost in year i, CRF represents the capital recovery factor, Cyc the annual cycling frequency of energy storage, η_i represents the energy storage charge/discharge conversion efficiency in year i, Deg_i the annual capacity decay rate of energy storage in year i, D represents the discount rate, n represents the actual operational life of the energy storage project, represents year i energy storage cycle life, $L_{calendar,i}$ represents the ith year of energy storage calendar life.

4 Case study

This paper selects a lithium iron phosphate energy storage power station in Shandong Province that has been put into operation as an example, and analyzes its costs and benefits. The scale of the energy storage power station is 100MW/200MWh, the total area of the power station is 14,000 square meters, 37 sets of new lithium iron phosphate battery energy storage units, 1 electric integrated prefabricated cabin, and the use of the original power plant bus intervals to connect to the power grid. According to Shandong Province power market recently clearing rules, independent energy storage projects can participate in the FM auxiliary market, provide FM auxiliary services independent energy storage facilities do not participate in the electric energy market clearing, and FM unit revenue is less than the spot trading arbitrage, at this stage, independent energy storage are not considered to participate in FM auxiliary

The initial investment cost of the independent energy storage power station is 433 million Yuan including 20% own funds and 80% loan funds, with a full life cycle of 20 years, and a unit battery cost of 900 Yuan/kwh. The land cost of the energy storage power station is 20 million Yuan, the procurement cost of the battery and related equipment is 370 million Yuan, the unit investment cost is 0.185 million Yuan/kwh, and the construction cost is 43 million Yuan. The annual operation and maintenance cost during the operation cycle of the energy storage power station is 8 million Yuan, and the battery replacement cost is 11,800. the annual interest rate of the loan is 4.65%, and the loan period is 8 years (excluding the construction period), and the total financial cost of the energy storage power station during the full operation cycle is 72,480,000 Yuan. The Specific cost data are shown in Table 3.

Table 3. Cost during the operation cycle of the power plant

Cost		Value (Ten thousand Yuan)
	land cost	2000
Initial Investment	Equipment acquisition	37000
	Construction	4300
	Labor and overhaul costs	16000
Operation and Maintenance	Battery Replacement Costs	11800
	recycling industry	1494
Finance	Loan interest	7248

Power station revenue analysis: the power station can realize 200 times in a year full power full time to complete the single charging and single discharging, charging in the valley time, discharging at peak time, charging electricity price of 0.202 Yuan / kWh, discharging electricity price of 0.546 Yuan / kWh, energy storage charging and discharging efficiency of 80%, so the power station annually to participate in the peak and valley price difference revenue of 9,392,000 Yuan. Leasing price in Shandong Province is 300 Yuan/kw, the power station can realize full capacity leasing, annual capacity leasing revenue is 33 million Yuan. The capacity compensation of Shandong Province energy storage demonstration project will be about Yuan 60/kw-per-year, and the annual capacity compensation gain of the power station will be 6 million Yuan. The specific gains are shown in Table 4.

Table 4. Revenue situation of various business models of energy storage power stations

Revenue model	Value(Ten thousand Yuan)
Peak valley arbitrage	939.2
Capacity leasing	3000
Capacity subsidy	600

Economic analysis of stand-alone energy storage: The average annual effective number of cycles of the plant is 200, the annual benchmark discount rate is 6%, and the internal rate of return of the stand-alone energy storage plant is 1.53%; the levelized kWh cost of the energy storage plant is Yuan 1.66/kWh.

5 Conclusion

As the most promising flexible resource, new energy storage has broad application prospects. However, due to the high cost and unclear cost diversion mechanism, the enthusiasm of investment entities, especially the new energy power plants on the power side, has been affected, resulting in a low utilization rate of energy storage power plants. Among them, the utilization rate of new energy distribution and storage is only one-third of that of independent energy storage. The issuance of the "Notice on Carrying out the Pilot Work of Converting Energy Storage from Auxiliary Construction to Independent Energy Storage in Shandong Province" and the continuous expansion of the scale of energy storage participation in the auxiliary service market have led to clearer profits, more diversified business models, and increasing economic value of energy storage power stations. This helps to increase the enthusiasm of energy storage investors, the utilization rate of energy storage, and promote the consumption of new energy, enhancing the social benefits that new energy storage can bring. Based on the analysis results of the example, the following suggestions are proposed:

(1) The allocation and construction of energy storage should actively transform into independent energy storage, participate in the electricity market as a separate legal entity, increase profit channels, and increase economic value in promoting the consumption of new energy and reducing wind and solar waste.

(2) The original independent energy storage power station needs to be more involved in auxiliary services. From the examples, it can be seen that the benefits in the electricity spot market and capacity market are quickly reaching bottlenecks, while the auxiliary service market still has great potential. Independent energy storage power stations can actively declare to the dispatch and participate in power grid dispatch, especially in peak shaving and frequency regulation. Increasing the number of participation in auxiliary services can significantly increase the economic value of independent energy storage plants.

(3) Improve the mechanism for market entities to participate in the electricity market and improve market price settlement rules. At present, the subsidy benefits obtained by power stations account for a large proportion of the benefits of energy storage power stations. The pressure of larger subsidies will make it difficult to manage costs and dispatch the power grid, and improve a unified power market system, including the electricity energy market, capacity market, and auxiliary service market. Lower costs through reasonable market prices and mechanisms, and mobilize the enthusiasm of energy storage power stations in a market driven manner.

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