Analysis of various types of new energy storage revenue models in China

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Abstract: In the current environment of China's vigorous development of energy storage, it is essential to carry out research on the benefits and economic evaluation of new energy storage. This paper establishes a framework for analyzing the revenue models of various types of energy storage under different scenarios. The framework complements the lack of previous studies on energy storage regulation under power generation systems such as wind power and coal power. In addition, a variety of scenarios were developed for the application of energy storage in the spot market, secondary service market, capacity market and user-side trading market. The results show that the case study energy storage plant has the highest revenue in the spot market, followed by the capacity market, and relatively low revenue in the secondary service market, while the leasing service can also bring a lot of revenue for the energy storage plant and thus become one of the more promising energy storage revenue models in the future.

1. Introduction

In 2017-2020, the power grid responded to the decision of the Energy Bureau and the Development and Reform Commission to reduce the rate of wind and light abandonment, and fully utilized the adaptive consumption of new energy resources in the power system resources, so as to reduce the rate of wind and light abandonment to 2%. At the same time, the pressure on the power grid is highlighted, some provinces began to require the power side configuration of energy storage. According to the national energy bureau statistics, from 2012 to 2022, the domestic new energy storage installed compound growth rate of up to 95%. 2022 domestic new energy storage installed capacity will reach 7.3GW, a year-on-year growth of nearly 200%. From the domestic energy storage installed type distribution, renewable energy distributed energy storage and independent energy storage installed proportion of 45% and 44%, respectively, the proportion of installed FM energy storage is only 1%, industrial and commercial household side energy storage installed proportion of 10%. China's current type of energy storage is still mostly used for supporting new energy installations in front of the meter energy storage installations.

Since 2021, the state has released a number of documents to promote the development of the energy storage industry, and the energy storage industry has thus ushered in a historic development opportunity. The Guiding Opinions proposed that by 2025, the installed capacity of clean energy storage will reach more than 30 million kilowatts, and at the same time, it is necessary to improve the incentive mechanism for new energy and energy storage projects, and to put forward policies to guarantee the grid scale consumption. The vast majority of provinces in China have strict construction requirements for energy storage facilities related to wind power and photovoltaic power stations. Under the stimulation of the mandatory energy storage policy, China's energy storage industry demand has surged and the industry is developing rapidly.

It can be seen that in the context of China's vigorous development of energy storage, it is crucial to strengthen the research on the benefits and economic evaluation of energy storage. Literature [1] proposes two kinds of revenue models and specific quantitative measurement methods for reducing power loss and participating in peaking auxiliary services. Literature [2] proposed the revenue models of "wind farm + energy storage" and "photovoltaic power station + energy storage", and used time series production simulation to calculate the power generation of "wind farm + energy storage" and "photovoltaic power station + energy storage", and as well as analyzed the economy and operation mode of the new energy field station. Literature [2] proposed a modeling and evaluation method for the economic benefits of energy storage, taking into account the reduction of unit losses and deferred investment returns. Literature [3] proposed an energy storage capacity fixing method based on new energy side storage for grid peaking capacity. Literature [4] established an investment return analysis model to statistically analyze the cash flow of the whole life cycle of the PV energy storage system based on the investment of the PV energy storage system, the system power

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generation, the enterprise electricity load curve, the electricity price and other revenue influencing factors. Literature [5] established a user multi-time demand response model and a comprehensive demand response model, and took the annual revenue and PV consumption rate as the optimization objective of collaborative energy scheduling of PV energy storage system. Literature [6,7] constructed a two-stage economic allocation model based on portfolio theory, which solved the problem of optimal allocation of user-side economic capacity, while considering the markets that user-side energy storage can participate in, the revenue, and the risks it may face. Literature [8] studied the current problems of high energy storage costs and unclear revenue models, respectively, and established an economic return model from the perspective of investors and comprehensive social returns, and capacity allocation with optimal economic indicators, and breakeven and sensitivity analysis of important projects affecting the economic benefits of energy storage.

In addition to conducting research related to the benefits of energy storage, specific studies addressing the functional role of energy storage in clean power generation systems and sorting out the various types of energy storage operation are also crucial. Literature [9] has studied and analyzed the application of lithium-ion batteries, flywheels, compressed air, and supercapacitors in gas-fired generating units. Literature [10] describes an energy management strategy that minimizes battery aging in electric vehicles through a combination of batteries and ultracapacitors. Literature [11] proposed a nonlinear coordinated power allocation strategy based on the state of charge (SOCs) of supercapacitors. Literature [12] describes the functional role of energy storage in the power system and proposes an optimal allocation method of energy storage system (ESS) by combining with the actual demand of power grid..

Comprehensive the above literature, this paper analyzes the revenue model of various types of energy storage, and establishes the revenue model of different types of energy storage, selects the typical and reasonable basic data, and conducts specific measurements on the revenue of energy storage under different markets, so as to quantify the comprehensive revenue of various types of new energy storage in China, and to provide references for the future research on the economics of new energy storage and the formulation of development strategies.

2. The application of various types of energy storage scenarios and its revenue model analysis

2.1. Coal side distribution and storage and its revenue model

The growth of new coal-fired power projects nationwide is larger in 2022. 27.35 million kilowatts of installed coal-fired power generation capacity will be put into operation (including trial operation) throughout the year, mainly in Inner Mongolia, Shanxi, Anhui and Jiangxi provinces; 96.26 million kilowatts of installed coal-fired power generation capacity will get started, mainly in Inner Mongolia, Guangdong, Jiangsu and Hunan; the newly approved installed coal-fired power generation capacity will achieve 86.55 million kilowatts, 4.7 times of that in 2021, with Guangdong and Anhui being the provinces with the most newly approved Guangdong and Anhui are the provinces with the most newly approved capacity; 54.39 million kilowatts of in-stalled coal-fired power generation is in planning status, mainly in Hubei, Shaanxi and Jiangsu.

In 2022, the growth of new coal-fired power generation projects across the country will be large. In the whole year, 27.35 million kilowatts of coal-fired power generation capacity will be put into operation (including trial operation), mainly concentrated in Inner Mongolia, Shanxi, Anhui, Jiangxi and other provinces; 96.26 million kilowatts of new coal-fired power generation capacity will be built, mainly concentrated in Inner Mongolia, Guangdong, Jiangsu, Hunan and other provinces; the newly-approved installed capacity of coal-fired power generation will reach 86.55 million kilowatts, which will be 4.7 times of that of 2021, of which Guangdong and Anhui are the provinces with the most newly-approved capacity. Newly approved coal-fired power generation capacity will reach 86.55 million kilowatts, 4.7 times that of 2021, with Guangdong and Anhui being the provinces with the most newly approved installed capacity.

2.1.1. Benefit of saving unit spare capacity

Electricity loads vary at different times of the day, so coal power units need to take on a peaking role. The actual power generation of a coal power unit directly reflects the supply capacity of the peak load, while the lower flexibility of coal power units prevents them from reaching full capacity, which affects the economy of the overall unit operation. Energy storage can be used to reduce load peaks by charging during low load hours and discharging during peak hours. And the substitution effect of energy storage can release the capacity of coal power units, thus improving the utilization rate and economy of the units.

2.1.2. Benefit of load tracking to reduce unit creep

Load tracking is the dynamic adjustment of the slowly changing and continuously varying load to achieve real-time balance. The variable load can be subdivided into basic load and climbing load according to the actual situation of generator operation, and load tracking is mainly employed to climbing load. By adjusting the magnitude of energy storage output, the climbing rate of conventional energy units are able to be reduced, allowing them to transition to the dispatch command level as smoothly as possible. Load tracking has high requirements for discharge response time, requiring corresponding time at the minute level.
2.1.3. Benefits of participating in the frequency regulation market

Conventional units (thermal power and hydropower) usually respond to AGC signals to regulate the energy imbalance of the grid in a short period of time, but its volatility and randomness make the energy imbalance of the grid in a short period of time to aggravate, and the traditional energy is usually slower in frequency regulation, and there is a certain lag in responding to the instructions of the grid scheduling. Energy storage and fire power plants collectively participate in the AGC FM market offer, FM ancillary services market clearing in accordance with the "cost-effective priority, time priority, on-demand scheduling" principle, according to the market players FM service sorting from low to high, until the winning party FM regulation rate total to meet the grid FM regulation of the winning party FM service maximum declared price as the FM service clearing price. The compensation for FM auxiliary services is measured and settled in units of units or energy storage facilities, and the compensation and shared costs are counted on a daily basis and settled on a monthly basis. The role of energy storage on the generation of each unit is shown in Table 1 below.

The regulation of the load component is generally AGC, which requires fast charging and discharging in a short time, and the use of electrochemical energy storage requires a large charging and discharging multiplier. The load component of the system frequency regulation changes in a cycle of minutes and seconds, requiring a high response speed, generally second response. FM energy storage is mainly installed on the thermal power plant side to assist the thermal power plant to provide secondary FM auxiliary services. When the thermal power units participating in the secondary FM are limited by the climbing rate and cannot accurately track the dispatching FM instruction, the AGC capability of the thermal power units can be improved through high-speed response energy storage, so as to obtain more AGC compensation benefits.

Thermal power energy storage equipment is typically 250 kW or more in power and generates revenue by increasing power generation or providing ancillary services. By adding electrochemical energy storage equipment, thermal power plants can improve the comprehensive FM performance indicators (measuring the FM frequency, FM time and FM accuracy) of the units, so that the units can undertake more FM tasks. The general configuration of FM service energy storage duration is only 0.5 hours, which reduces the investment in electrochemical energy storage, and energy storage power stations that entered the FM field earlier can recover the cost in about 2 years. Auxiliary service compensation funds mainly from the apportionment between power generation enterprises, the past annual national auxiliary service market size of 15 billion yuan, and AGC FM accounted for nearly 30%, about 4.5 billion yuan.

There are two joint energy storage FM plants in Shandong, namely Huadian International Laicheng Power Plant and Datang Linqing Thermal Power, equipped with 9MW/4.5MWh and 9MW/9MWh energy storage devices respectively. With the addition of energy storage, the combined value and regulation mileage of the thermal power units have increased significantly, which improves the FM compensation benefit of the thermal power units. After the commissioning of the energy storage power plant of Huadian International Laicheng Power Plant at the end of December 2021, the monthly FM compensation revenue of the power plant increased significantly, with an average monthly compensation revenue of RMB 7,396 billion in January-June 2022; and after the commissioning of the energy storage power plant of Datang Linqing Thermal Power Plant in April 2022, the average monthly compensation revenue in May-June 2022 increased to RMB 5,233,000. From July 2021 to June 2022, the total monthly compensation in the FM auxiliary service market in Shandong Province increased from RMB26 million to RMB135 million per month.

2.2. Centralized scenery power side distribution and storage and its revenue model

At present, a number of domestic provinces require new energy enterprises to configure a certain percentage of energy storage, in order to improve the volatility of electricity, tracking power generation plans, peak shaving and valley filling, power storage to reduce the abandoned light and wind, while enhancing the new energy frequency regulation and voltage regulation capabilities.

And the energy storage system has a flexible four-quadrant operation capability, which can smooth the new energy output and maintain voltage stability, which is conducive to the friendly grid connection of new energy. At the same time, energy storage device and distributed photovoltaic system composed of user-side photovoltaic energy storage system, can be in the photovoltaic power generation peak period, storage of surplus on-line power, smoothing photovoltaic power generation fluctuations,
and in the night time peak tariff hours to release the power, reduce the user peak tariff expenditures, increase the user’s income, and its profit comes from the user's peak tariffs and Internet access to the difference in tariffs of the surplus power. Compared with wind power, photovoltaic and other intermittent energy sources, energy storage power generation costs are lower than thermal power, so it has a greater advantage in terms of operating income.

2.2.1. Cost analysis of scenery energy storage

The cost of wind and solar energy storage system is mostly composed of primary investment cost and O&M cost, while the primary investment cost is mainly made up of power cost and capacity cost, specific analysis of the cost components of the centralized wind and solar power side distribution and storage system are as follows:

(1) Investment cost

Assuming that the equipment replacement cost during the normal use period is not considered, the investment cost mainly contains battery equipment cost (mainly battery pack and battery pack management system) and non-battery equipment cost (including AC side transformer and circuit breaker rectifier/inverter system).

The investment cost $C_1$ can be expressed as:

$$C_1 = (C_E + C_p) \times E$$  \hspace{1cm} (1)

Where: $C_E$ is the unit cost of battery facility, $C_p$ is the unit cost of non-battery facility, $E$ is the rated capacity.

(2) O&M cost

The annual O&M cost of is related to its operation condition, which includes the personnel salary, insurance, repair cost and other operation cost. The annual O&M cost $C_2$ can be expressed as:

$$C_2 = C_o \times Q \times \left[1 + (n - 1)i\right]$$  \hspace{1cm} (2)

Where: $Q$ denotes the O&M rate, $n$ denotes the operating life, and $i$ denotes the annual growth rate of O&M cost, which is generally 2%.

The cycle life of is another crucial parameter in its cost analysis. The cycle life is the number of thorough charge/discharge cycles of the battery when the nominal capacity is reduced to 80% of the initial rated capacity of the energy storage battery. The dominant factors that influence the cycle life include temperature extremes, overcharge and discharge, depth of discharge, DOD and charge and discharge rate. The cycle life is a function of the depth of charge and discharge when operating under benchmark charge and discharge current, voltage, and all kinds of condition. The life years $n$ can be expressed as:

$$n = \frac{T_{life}}{L_{year}}$$  \hspace{1cm} (3)

Where: $T_{life}$ indicates the cycle life under the corresponding DOD; $L_{year}$ indicates times of charge/discharge cycles per year.

Assuming that the equipment replacement cost during the normal service life is not considered, for the purpose of analysis, the linear method is used to cost share the total investment cost over its life time and superimpose it with the annual operation and maintenance cost to attain the annual value of the cost $AC$, which is calculated by the formula:

$$AC = (C_E + C_p) \times E \times \frac{1}{n} + C_o \times Q \times \left[1 + (n - 1)i\right]$$  \hspace{1cm} (4)

2.2.2. Revenue analysis of scenery energy storage

The scenery energy storage system revenue mainly includes the revenue from wind and light abandonment, frequency regulation auxiliary services, the carbon market emission reduction, and the green power in the green certificate market.

(1) Abandoned wind and abandoned light revenue

Some provinces in China require new energy power plants to distribute an assured percentage of energy storage devices for diminishing the rate of wind and light abandonment. Take wind power station configuration energy storage as an example, wind power station can continue to generate electricity at night as the load is low, energy storage power station can be charged at low load, its charging cost can be regarded as zero, and discharged at peak load hours when the electricity price is higher. Therefore, the revenue generated to consume the abandoned wind and light $R_1$ can be expressed as follows:

$$R_1 = N \times E \times DOD \times P_d$$  \hspace{1cm} (5)

Where: $N$ is the number of days of operation of the energy storage plant, $E$ is the rated capacity, $DOD$ is the depth of discharge, $P_d$ is the price of discharge.

(2) Frequency regulation auxiliary service revenue

The compensation method of FM auxiliary services in China's regional power grids largely refers to the U.S. PJM auxiliary services market. The revenue of FM service contains two parts: capacity compensation and mileage revenue, and the annual average revenue of FM service of energy storage power plant $R_2$ is:

$$R_2 = P \times \frac{t_{ct}}{t_{mt}} \times Y_c \times 12 + N \times \sum_{i=1}^{o} L \times Y_m \times K$$  \hspace{1cm} (6)

Where: $P$ denotes the rated power of the energy storage, $t_{ct}$ denotes the time of the month when the energy storage is put into operation, $t_{mt}$ denotes the time of the month, $o$ represents the number of calls per day, $L$ represents the FM mileage offered by the first call in...
the same direction as the command, $K$ denotes the FM performance factor, $Y_c$ denotes the unit capacity compensation of the monthly energy storage, and $Y_m$ denotes the FM mileage compensation.

(3) Carbon market emission reduction revenue

After the configuration of the energy storage system, it’ll supersede the conventional coal-fired units to provide electricity, reduce the emission of greenhouse gases and pollutants, attain carbon quotas, and participate in the carbon market to obtain emission reduction revenue. The annual emission reduction revenue obtained by the energy storage power plant participating in the carbon market $R_3$ is:

$$ R_3 = N \times E \times DOD \times P_{CO_2} \times F $$

Where: $P_{CO_2}$ is the carbon price in the carbon market and $E_f$ is the carbon emission factor of coal power.

(4) Green certificate market green power revenue

China has been implementing green certificate trading since 2017, and scenic energy storage power plants can submit information and proof to the National Renewable Energy Management Center to apply for green certificates; then sell green certificates to other market players through the green certificate market to obtain green power revenue. The annual green power revenue obtained from the participation of energy storage power plants in the green certificate market $R_4$ is:

$$ R_4 = \frac{N \times E \times DOD \times P_{ge}}{1000} $$

Where: $P_{ge}$ is the green card price.

2.2.3. Economic analysis of scenic energy storage

The scenic energy storage system revenue mainly includes the revenue from wind and light abandonment, frequency regulation auxiliary services, the carbon market emission reduction, and the green power in the green certificate market.

(1) Basic data

The scenic energy storage system set up in this section can be profited by participating in the power market, the FM accessory service market, the carbon trading market, and the green certificate market, with the following calculation conditions:

Energy storage capacity:

The installed capacity of photovoltaic and wind power at the site in 2023 is 22.06 million kilowatts. In this section of the economic calculation, the capacity of the configured energy storage system is 100MW/200MWh, the life span is set to 8 years, and the annual operating days are set to 350 days.

Spot market peak hour tariff:

The peak hours of the site are 9:00-11:00 and 15:00-17:00 every day. The spot market price change curve of a typical day is selected, and the average market price of the spot market peak hours is calculated to be 0.384 yuan/kWh, and the discharge price is taken as 0.384 yuan/kWh.

Construction cost of the energy storage system:

The energy storage system selected in this section uses lithium iron phosphate batteries that can be charged and discharged quickly, with high power and long life. The latest unit cost bid price of the energy storage system is between RMB 1600/kWh and RMB 2000/kWh, and the construction cost unit cost selected in this section is RMB 1800/kWh, of which: construction project cost is RMB 126/kWh, accounting for 78% of the static investment; battery equipment purchase cost is RMB 1404/kWh, accounting for 5% of the static investment; installation project cost is RMB 90/kWh, accounting for 5% of the static investment; other costs are 180 RMB/kWh, accounting for 10% of the static investment.

O&M cost of energy storage system:

The O&M cost of different types of electrochemical energy storage equipment varies. The annual O&M cost of lithium-ion battery accounts for about 2% of its investment and construction cost. Among them, repair costs account for about 1.5% of its investment and construction costs, insurance costs account for about 0.25% of its investment and construction costs, and other operating costs account for about 0.25% of its investment and construction costs, all with an annual growth rate of 2%. The wage expense of the energy storage plant with rated capacity of 200MWh is set at 1.5 million yuan/year, and the annual growth rate is set at 5%.

Parameters affiliated to the intervention of energy storage systems in various markets:

In the auxiliary service market, energy storage mainly participates in AGC frequency adjustment service, assuming that its capacity compensation is 240 Yuan/MWh*month, and the compensation for calling mileage is 3 RMB/MW, assuming that it calls a full mileage within 15 minutes, which is 100MW, and the number of calls is 96 times per day. In the carbon market, the carbon price is set to RMB40/ton, and the carbon emission factor of coal power is 800g/kWh. In the green certificate market, the green certificate price is set to 175 Yuan/kWh.

The specific parameters involved in the scenic energy storage economics measurement are displayed in Table 2:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Numerical value</th>
<th>Unit</th>
<th>Parameter</th>
<th>Numerical value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit price of battery equipment</td>
<td>1404</td>
<td>Yuan/kWh</td>
<td>Rated power</td>
<td>100</td>
<td>MW</td>
</tr>
<tr>
<td>Unit price of non-battery equipment</td>
<td>396</td>
<td>Yuan/kWh</td>
<td>Capacity compensation</td>
<td>240</td>
<td>Yuan/MWh*month</td>
</tr>
</tbody>
</table>
(2) Calculation example analysis

Based on the above parameters, the economic is measured. From the investor's perspective, as long as the capacity rate of the energy storage system is 1, the scenic energy storage gains from participating in the energy spot market to consume abandoned wind and light are 26.88 million yuan/year, the gains from participating in the FM auxiliary service market are 15.12 million yuan/year, the gains from participating in the carbon market are 11.025 million yuan/year. The economic analysis of the whole life cycle is shown in Table 3:

| Table 3. Scenic energy storage whole life cycle economic analysis (million yuan). |
|---|---|---|---|---|---|---|---|---|---|
| **Construction Period** |  |  |  |  |  |  |  |  |  |
| **Year** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| **Rated Capacity Rate** | 100% | 100% | 97.5% | 95% | 92.5% | 90% | 87.5% | 85% | 82.5% |
| Abandoned wind and abandoned light revenue | 2419.2 | 2358.72 | 2298.24 | 2237.76 | 2177.28 | 2116.8 | 2056.32 | 1995.84 | 1935.36 |
| FM auxiliary service revenue | 1814.4 | 1814.4 | 1814.4 | 1814.4 | 1814.4 | 1814.4 | 1814.4 | 1814.4 | 1814.4 |
| Carbon market emission reduction revenue | 201.6 | 196.56 | 191.52 | 186.48 | 181.44 | 176.4 | 171.36 | 166.32 | 161.28 |
| Emission reduction revenue from green certificate market | 1102.5 | 1074.94 | 1047.38 | 1019.81 | 992.25 | 964.69 | 937.13 | 909.56 | 881.98 |
| Operating income (tax included) | 5537.7 | 5444.62 | 5351.54 | 5258.45 | 5165.37 | 5072.29 | 4979.21 | 4886.12 | 4793.04 |
| Government subsidies | 2000 | 1800 | 1700 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cash inflow | 6900.62 | 6618.25 | 6435.87 | 6183.49 | 5931.11 | 5678.73 | 5426.35 | 5173.97 | 4921.59 |
| Value-added tax and surtax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Net cash flow before income tax | -36200 | 6035.71 | 5731.54 | 5526.71 | 5321.88 | 5117.05 | 4912.22 | 4707.39 | 4502.56 |
| Accumulated net cash flows before income taxes | -36200 | -2974.71 | -2428.77 | -1882.82 | -1336.88 | -790.94 | -244.01 | -788.08 | -1222.15 |
| Adjustment for income taxes | 0 | 239.25 | 210.50 | 181.59 | 152.51 | 123.25 | 94.10 | 64.70 | 35.29 |
| Net cash flow after income tax | -36200 | 3736.46 | 3511.04 | 3285.63 | 3060.21 | 2834.76 | 2609.31 | 2383.87 | 2158.42 |
| Accumulated net cash flow after income tax | -36200 | -2974.71 | -2428.77 | -1882.82 | -1336.88 | -790.94 | -244.01 | -788.08 | -1222.15 |

In the economic evaluation, the internal rate of return, payback period, total investment return, and net capital profit margin are selected as the economic effect evaluation indexes. The economic effect evaluation is displayed in Table 4:

| Table 4. Evaluation of the economic effect of scenic energy storage. |
|---|---|---|---|
| Economic evaluation indicators | Numerical value | Economic evaluation indicators | Numerical value |
| IRR (before tax) | 2.03% | IRR (after tax) | 1.38% |
| Payback period (before tax) | 8.61 Years | Payback period (after tax) | 8.73 Years |
| Total Return on Investment | 1.30% | Net Capital Profit Margin | 0.59% |

As can be seen from Table 4, the scenic energy storage project has poor economics and the internal rate of return is lower than the standard discount rate, but the capital recovery can be completed within the operation period. Further, the peak tariff of power spot market, mileage compensation unit price of AGC FM, carbon price and green certificate price are selected as the sensitivity analysis factors, and the after-tax internal rate of return is considered as the analysis index to carry out the sensitivity analysis of scenic energy storage, and the results are shown in Table 5 below:

| Table 5. Sensitivity analysis table for scenic energy storage. |
|---|---|---|---|
| Uncertainties | Rate of change (%) | After-tax internal rate of return (%) | Change in internal rate of return (%) | Sensitivity factor |
| Basic Plan | 0 | 1.38 | | |
As can be seen from Figure 1 above, the peak tariff and the unit price of AGC FM mileage compensation in the power spot market are sensitive factors for the economics and should be focused on, while the impact of carbon price and green certificate price on the economics of scenic energy storage is relatively small.

### 2.3. Independent shared energy storage and its revenue model

Shared energy storage is invested, operated and maintained by a third party or manufacturer, and the power and capacity of the storage system is leased to the target user, and the lessee is charged rent referring to the principle of "who benefits and who pays". Before 2015, the total cost of auxiliary services in China accounted for less than 1.5% of the total electricity bill, the current ratio has risen to 2.5%, and the power auxiliary services cost ratio will continue to rise.

In 2022, there are already 11 provinces with new energy storage power plants participating in the peaking accessory service market, with an installed capacity of 1.123 million kW, trading 170 million kilowatt hours of electricity, and an average clearing price of 0.42 yuan/kWh. 2025 and 2030, the whole society's electricity consumption is expected to reach 9.5 trillion kilowatt hours and 11 trillion kilowatt hours, and the national average sales price of 0.6 yuan/kW is calculated. Auxiliary service fee accounts for 3% of the cost of electricity consumption of the whole society, it is estimated that the auxiliary service market size will reach 171 billion yuan, 198 billion yuan.

Independent energy storage revenue model can be roughly divided into: shared leasing, spot arbitrage, auxiliary services, capacity tariff.

#### 2.3.1. Electric energy spot market revenue

According to the national daily maximum load of 1.1 billion kilowatts, the minimum load of 800 million kilowatts calculation, the peak and valley difference is only 300 million kilowatts, if 150 million kilowatts of which will be filled with energy storage will lead to a decline in the peak and valley difference, the enterprise earns the price difference will also decline. Some provinces in the spot market construction of the initial period, the ceiling price control is more strict, although this move is conducive to ensuring the smooth operation of the market, but if the ceiling price is obviously low, will not be able to play the role of investment incentives for energy storage. 2022 In May, the General Office of the National Development and Reform Commission (NDRC)
and the Comprehensive Department of the National Energy Administration (NEA) issued the Notice on Further Promoting the Participation of New Energy Storage in Electricity Markets and Dispatch Utilization, mentioning that the new type of energy storage can participate in the electricity market as an independent storage, and that an independent power station will send electricity to the grid, and its compliant charging power will not bear the transmission and distribution tariffs and governmental funds, and other additional costs, and the electricity tariff will be reduced by about 0.1-0.2 yuan/kWh.

In the case where energy storage participates in the spot market for peak-valley arbitrage, based on a sample of 67 consecutive days of spot trading in Shandong Province in 2022, it can be seen that the maximum peak-valley spread in the spot market spans a wide range, with a minimum value of less than RMB 100/MWh and a maximum value of more than RMB 1,500/MWh, with an average value of RMB 674/MWh. High electricity prices of more than RMB 1,000/MWh are characterized by a typical sharp spike, with a duration of less than a quarter to half an hour. The duration is less than a quarter hour to half an hour, while the duration of the high tariff period that reaches the hourly level corresponds to a tariff range of RMB 600/MWh, so the configuration of hourly peaking energy storage plants cannot be effectively discharged during the highest tariff period, which will greatly cut down on the revenue of new energy storage. The energy storage power station does not need to bear transmission and distribution tariffs and additional costs, can reduce the charging cost, and further expand the single energy storage intervenes in the spot market revenue. With charging tariff of 0.1 yuan / (kWh), discharge tariff of 0.5 yuan / kWh, capacity charge of 0.02 yuan / kWh, charging and discharging efficiency of 85%, the annual number of 360 times of charging and discharging as the basis for calculating the 100MW/200MWh standalone energy storage power station annual spot market revenue can reach 21.96 million yuan.

Shandong power spot market as an example, Shandong May 1, 15 real-time power spot trading price is negative, May 2, 17 real-time power spot trading price is negative, two days within 48 hours of the real-time spot price of negative time period reached 32 hours. 20:00 May 1 to May 2, 17:00, the negative price lasted for 22 hours. May 1 all-day real-time power spot trading price, the average price is - 0.01302 yuan/kWh. For energy storage, the negative price means a significant reduction in charging costs, but ultimately whether it can be profitable, but also depends on the price difference. From the point of view of time-sharing tariffs, the highest price difference on May 1, 2022 was 0.42609 yuan/kWh, and the highest price difference on May 2 was 0.58408 yuan/kWh, and the price difference did not change significantly. Negative tariffs appear frequently, to the new energy generation has brought the impact, but to the photovoltaic + energy storage, distributed photovoltaic + energy storage to bring opportunities for development. 2022 Shanxi spot market peak and valley spread average of about 0.6 yuan / kwh, to 100,000 kilowatts of independent energy storage project for calculation, if 4 hours to recharge and discharge once, recharge and discharge once can earn 240,000 yuan. In addition to the maintenance time, a year by 250 days of operation days, a year can be 60 million yuan of spot market revenue.

2.3.2. Auxiliary service market revenue

According to the existing mechanisms at home and abroad, the electricity market is generally categorized into the energy market and the secondary services market. In the FM market, energy storage power stations must bid on the same platform as generating units. Common new energy storage auxiliary services in the form of new energy storage is mainly peak and frequency regulation (primary FM, secondary FM), the specific amount of revenue varies from province to province, mostly in the form of compensation according to the peak power charge, the price ranges from 0.15 yuan / kWh (Shandong) to 0.8 yuan / kWh (Ningxia). In Guangdong, for example, 3% of the peak load size is distributed over a single duration of no more than 4 hours, with no more than 30 occurrences throughout the year and a cumulative duration of no more than 50 hours. FM is mostly based on FM mileage compensation, and the price is RMB 0.1-15/MW according to the degree of the unit's response to AGC's FM instruction, some provinces have adopted a market-oriented approach to FM auxiliary service offerings and cost sharing. The FM market in Shandong, Shanxi, Fujian, Guangdong and other provinces has entered into operation or trial run. At present, the installed capacity of new energy in Shanxi has reached 40 million kilowatts, and the demand for FM can reach 800-1000 times per day, with a demand mileage of about 120 MW per FM. According to the existing FM market offer, if energy storage participates in the FM market, it can gain about 5.5 million yuan. In addition to one FM, energy storage also has spot market gains.

2.3.3. Capacity market revenue

There is great uncertainty in the utilization hours of energy storage, and it is difficult to maintain its economy by relying on electricity prices alone, so capacity tariffs are needed to stabilize the overall economy of energy storage. In March 2012, Shandong Province's Notice on Capacity Compensation Tariffs for the Electricity Spot Market proposed that, before the operation of the capacity market, the cost of capacity compensation for the generating units participating in the electricity spot market would be collected from the user side, with a tariff standard of per kW 0.0991 yuan (including tax) per kW. The policy has been implemented since May 1, 2022, and is valid until December 31, 2026. Capacity tariff compensation is available for energy storage. It is estimated that the annual capacity compensation revenue of 100MW/200MWh independent energy storage power station can reach RMB43.41 million (calculated on 365 days).
2.3.4. Leasing or sharing of electricity savings proceeds

Revenues are shared between the energy storage developer and owner, with the customer paying a percentage or a certain amount of the energy savings to the owner of the storage asset. Typically, the lease payment is based on the developer's fixed investment costs and thus the amount is essentially fixed, whereas the shared revenue model is usually based on a percentage of the revenue that varies based on how much electricity is saved each month, and so it varies in amount. The shared revenue savings model is less common among individual residential customers and is mostly applied to commercial and industrial customers. When the shared revenue model is used on an individual basis, the contract term is typically 10 years or more. The leasing model, on the other hand, generally has a short-term trend, with a contract period of 2 to 4 years, and also supports monthly leases, so it is more flexible for users.

For example, a capacity of 100MW/200MWh independent energy storage power station, according to the investment of 420 million yuan, 30% of the project capital, internal rate of return of 8% of the indicators for calculation, the annual income needs to reach 64 million yuan to recover the cost; and independent energy storage power station can be leased to the capacity of wind power, photovoltaic enterprises, wind and photovoltaic power enterprises to obtain access to the indicators, so that the enterprise still owns the system of independent. Therefore, the enterprise still owns the independent operation right and income right of the system. Independent energy storage capacity leasing costs using market bidding, set the maximum price and minimum guaranteed price, the general lease transaction price of about 330 yuan / kW. At present, the capacity leasing rate of independent energy storage power stations in Shandong Province is only about 20%. If all the capacity can be leased, the annual capacity leasing income of 100MW/200MWh independent energy storage power station can reach RMB 33 million, so the leasing transaction mode is also a more profitable option for independent energy storage power station.

Independent energy storage power plants can simultaneously carry out three modes of shared leasing, spot arbitrage and capacity tariff compensation. For example, for a 100MW/200MWh stand-alone energy storage plant in Shandong, it is estimated that the annual income from spot arbitrage will be about 20 million yuan, the income from shared leasing will be about 30 million yuan, and the income from capacity tariff will be about 6 million yuan. Based on a total investment of about 450 million yuan and a financing cost of 4.65%, the project can realize a return on capital of more than 8%.

In addition, Qinghai, Ningxia, Hubei, Shaanxi and Shanxi have successively introduced policies favorable to the application of shared energy storage power stations. The compensation standard for energy storage peaking in Qinghai Province is 0.5 yuan/kWh, and the number of annual utilization hours is not less than 540 hours; the compensation price for peaking service of the pilot energy storage project in Ningxia in 2022 and 2023 is 0.8 yuan/kWh, and the number of annual call-ups is not less than 300; Hubei and Shaanxi have committed that the energy storage leasing can be regarded as a new energy storage quota; Shanxi has made it clear that the shared energy storage power station can participate in the market of peak shifting and frequency regulation. Many of the above policies have also brought a strong development boost for shared energy storage power plants.

3. Conclusion

Considering the current development situation of new energy storage systems in China and the lack of research on revenue models, this study takes China's new energy storage systems as the main research object, practically analyzes the revenue models of multiple types of energy storage systems, and based on a large amount of reliable actual data, measures the revenues of energy storage systems under different markets. Through the above research we can get the following conclusions:

(1) Under the electricity spot market, the peaking tariff and the unit price of AGC FM mileage compensation are sensitive factors affecting the economics of energy storage systems, which should be focused on in future related studies, while the carbon price and the price of green certificates have a relatively small impact on the economics of new types of energy storage.

(2) The results show that energy storage plants have the highest returns in the spot market, followed by the capacity market, and relatively low returns in the ancillary services market, while leasing services can also bring a lot of revenue for energy storage plants, becoming a more promising one of the future revenue models for energy storage plants.

References


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