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Analysis and Evaluation of the Social and Economic Benefits of Independent Energy Storage Projects

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Abstract: Against the backdrop of building a new-type power system, independent energy storage, as a critical flexible regulation resource, is developing rapidly. Domestic independent energy storage is still in the early commercialization stage. Policies and market mechanisms vary greatly across regions, leading to obvious regional divergence in business models and revenue performance. Taking Y independent energy storage demonstration project in Chongqing, China, as research case, this paper analyzes the development environment and major business models of independent energy storage, and evaluates the social benefits, economic benefits, and major risks of the project. The research shows that policy mechanisms are a key factor determining the business models and project returns of independent energy storage, and the combination of "capacity leasing + spot market + ancillary services + capacity compensation" is expected to become a mainstream operating model. The economic evaluation of Project Y shows that the project has a certain degree of economic feasibility, with an after-tax financial internal rate of return of 7.75%. Its returns are mainly affected by the charge-discharge price spread and the number of charge-discharge cycles. The research findings provide a reference for the preliminary investment assessment and decision-making of similar independent energy storage projects.

1. Research Background

Driven by China's "Dual Carbon" goals, China's wind power and photovoltaic energy installed capacity have continued to grow rapidly. By the end of 2025, the Renewable Energy installed capacity across the Country had exceeded 1.88 billion kilowatts, with the wind power and photovoltaic energy installed capacity exceeding 1.45 billion kilowatts. The renewable energy has inherently variable and intermittent characteristic. While a high proportion of renewable energy is integrated into the grid, the power system's demand for flexibility resources such as peak load regulation and frequency regulation is constantly increasing. Independent energy storage can participate independently in electricity markets, share capacity, and respond flexibly to dispatch, and has therefore become a key component of the new-type power system.

National Development and Reform Commission and National Energy Administration of the People's Republic of China, have successively issued relevant policies to support the development of storage technologies, such as the "Guidelines to Accelerate the Development of New Energy Storage Technologies" and "The Implementation Plan for the Development of New Energy Storage

Technologies in the '14th Five-Year Plan'"[1]. These policies not only set the target for new energy storage capacity in 2025, but also clarified the market entity status of independent energy storage, encouraged participation in ancillary services and the electricity spot market, and explored capacity pricing mechanisms.

In recent years, the installed capacity of new energy storage in China has grown rapidly. By the end of 2025, the cumulative installed capacity of new energy storage across the country reached 136 million kilowatts. The rapid expansion of independent energy storage projects has also driven the development of the upstream and downstream industrial chains. However, the initial investment scale of independent energy storage projects is large, and the unit cost is still relatively high, and the project return period is long, as a result there is a greater demand on the stability of returns for independent energy storage projects.

Therefore, how to evaluate the commercial value and social economic benefits for independent energy storage projects is an important issue for both project owners and financial institutions to make investment decisions[2]. The existing literature can be summarized as follows. On the one hand, some scholars believe that the capacity leasing is the most stable income source at present, while spot trading and ancillary services are potential growth points in the future by analyzing the value realization paths for both shared energy storage and independent energy storage[3-5]; On the other hand, through empirical research analysis in the typical provinces of China some scholars have further revealed the significant impact on the investment IRR by charge-discharge price spread, the number of dispatches and the price of capacity lease[6-8].

Although these relevant researches provide a better research foundation for the business model and economic analysis of independent energy storage, there is an urgent need for studies which focus on the mainstream mode of "capacity leasing + peak load regulation", comprehensively analyze both social economic benefits and risk evaluation, and are derived from real engineering practice cases. This research takes Project Y of independent energy storage of S Energy Limited Company as an example to conduct macro-environment analysis, business model review, economic benefit calculation and risk identification. This project is one of the first batch demonstration projects of independent energy storage in Chongqing, China, and it is a typical grid-side lithium iron phosphate independent energy storage station. The research findings can provide a reference for the preliminary assessment of similar independent energy storage projects.

2. Overview of the Independent Energy Storage Project

With the rapid development of the new energy industry, the grid peak load regulation is facing increasingly greater challenges. In 2023, the peak load regulation shortfall in Chongqing, China, was approximately 3751MW, and there is an urgent need for the flexible regulation resources to support the safe and stable operation of power grids. Independent energy storage which has advantages such as good performance for peak shaving and valley filling, fast response and flexible layout, thus is an important means to enhance the peak load regulation capacity of power grids[8]. As a traditional energy power enterprise in Chongqing, China, S Energy Limited Company is gradually expanding into emerging business areas such as energy storage, actively laying out independent energy storage on the power grid side, and using the existing factory site and transmission and transformation facilities of a retired thermal power plant in Chongqing, China to invest in the construction of Project Y of independent energy storage.

Project Y of independent energy storage is one of the first batch of independent energy storage demonstration projects and one of municipal-level key projects in Chongqing, China. The construction scale is 200MW/400MWh, covering approximately 3.35 hectares, and the approved total investment is approximately 782 million CNY. This independent energy storage station can provide

approximately 400,000 kWh of electricity in a single full charge and discharge. Based on the calculation of "two charges and two discharges" per day (with approximately 700 times used throughout the year), it can provide approximately 280 million kWh of electricity during peak (or critical-peak) electricity consumption periods.

The energy storage system of this project mainly consists of an energy storage battery system (including energy storage batteries and battery management systems), an energy storage power conversion system (PCS), an on-site voltage boosting system, a collection line, a lightning protection and grounding system, a power supply system, a lighting system, a secondary protection system, a control system, a monitoring system, a communication system, a fire protection system, etc. The overall architecture of the energy storage station is shown in Figure 1.

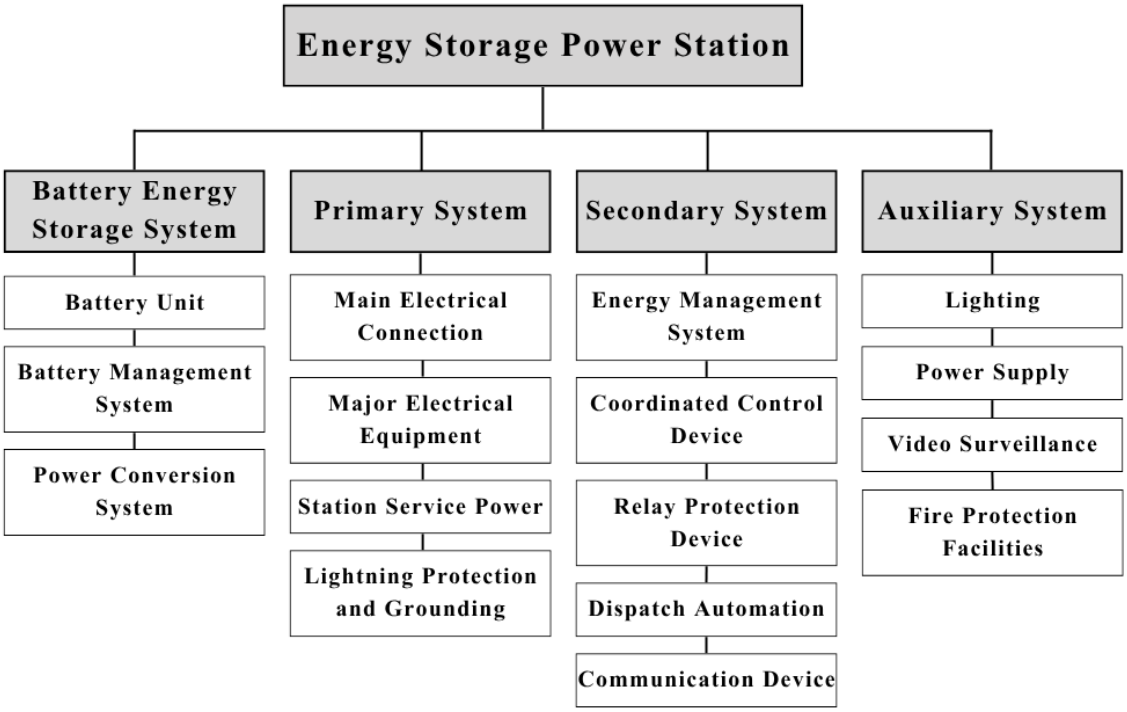

Figure 1: System architecture of the energy storage power station

3. Evaluation of Independent Energy Storage Projects

3.1. Social Benefit Evaluation

During the "14th Five-Year Plan" period, there is a significant peak load regulation shortfall in Chongqing, China. As pumped storage power stations require relatively long construction periods, new pumped storage projects were unlikely to be put into operation in the short term. Independent energy storage facilities can store excess electricity during periods of high demand and release it during periods of low demand, balancing the grid load, effectively reducing the local grid burden, improving the reliability and stability of power supply, enhancing the power supply guarantee for local enterprises and residents. They can also serve as flexible regulation resources for the power system.

China encourages and supports regions, departments and enterprises that meet the conditions to carry out various pilot and demonstration projects for energy storage technologies based on local conditions. As a practical implementation project for energy storage technology, Project Y of independent energy storage aligns with national planning and industrial policies and represents an

innovative approach to promoting the transition from traditional to new growth drivers.

The project has a short construction period, flexible operation, and is effective in peak load regulation. Its construction can help ensure electricity supply in Chongqing, China, enhance the power system's flexibility and regulation capability, and alleviate the actual problem of insufficient peak load regulation capacity of power grids in Chongqing, China, during the “14th Five-Year Plan” period.

In terms of environmental benefits, the lithium iron phosphate battery energy storage system used in this project is an environmentally friendly energy source, which can improve the local environment to a certain extent. Once the energy storage station is put into operation, it will effectively reduce the local coal consumption and emissions of pollutants such as carbon monoxide, sulfur dioxide, and nitrogen oxides, thereby generating environmental benefits.

In addition, the construction and operation of this project will increase local fiscal revenue and create employment opportunities, promote the coordinated development of various local industries such as processing manufacturing, transportation, services, and material supply, and thus effectively stimulate regional economic investment and create new sources of economic growth.

3.2. Economic Benefit Evaluation

The main revenue channels for domestic independent energy storage are divided into four categories: capacity leasing, electricity spot market arbitrage, ancillary services, and capacity compensation, with different regions adopting different combinations depending on local electricity market development[9-10].

(1) Capacity leasing: Following the principle of “who benefits pays”, the energy storage station leases power/capacity to the new energy power plants to meet their storage requirements and earn rental income.

(2) Electricity spot market: Energy storage purchases electricity during low-price periods and sells it during peak periods, generating arbitrage returns from the peak-to-valley price spread. Some provinces allow independent energy storage to participate in spot market trading as an independent entity, but returns from price arbitrage are highly uncertain.

(3) Ancillary service market: It mainly includes peak load regulation, primary frequency regulation, and secondary frequency regulation. In regions without spot markets, peak load compensation is an important source of revenue; once spot markets are established, the peak load regulation function will gradually be integrated into spot prices, and frequency regulation will become the primary source of revenue for ancillary services.

(4) Capacity Compensation: Serves as a safety net for system reserve margins and offsets the fixed investment costs of energy storage.

Project Y of independent energy storage adopts a business model of “capacity leasing + peak load regulation ancillary” services and has a capacity of 200 MW/400 MWh. It is constructed on the site of a retired thermal power plant using a liquid-cooled prefabricated cabin solution with lithium iron phosphate batteries. The operating period is 20 years, with battery cell replacement at the end of the 10th year, and a one-time construction subsidy of 150 CNY/kWh. The main revenue sources are peak-to-valley price arbitrage, capacity leasing, and peak load regulation ancillary services.

Under local supporting policies and market requirement, the operating conditions of Project Y can be assumed as follows: an initial capacity leasing rate of 20% increasing by 5% annually, a first-year overall system efficiency of 82.5% with gradual battery degradation, an average off-peak charging price of 0.1744 CNY/kWh, peak discharge and critical-peak discharge prices are 0.7611 and 0.9133 CNY/kWh, respectively, and a peak load regulation compensation of 0.4 CNY/kWh with 100 dispatches per year.

The economic benefits of Project Y can be evaluated, and the main financial indicators are presented in Table 1.

Table 1: Summary of financial indicators

No.	Item	Unit	Value
1	System Capacity	MW/MWh	200/400
2	Total Project Investment	Ten Thousand CNY	73,454.21
3	Construction Investment	Ten Thousand CNY	72,487.71
4	Interest during Construction	Ten Thousand CNY	966.50
5	Working Capital	Ten Thousand CNY	0.00
6	Total Sales Revenue (Excluding Value-added Tax)	Ten Thousand CNY	190,017.73
7	Total Cost	Ten Thousand CNY	124,146.81
8	Total Sales Tax & Surcharges	Ten Thousand CNY	1,623.94
9	Total Profit	Ten Thousand CNY	70,246.98
10	Project Investment Payback Period (before Tax)	Years	11.23
11	Project Investment Payback Period (after Tax)	Years	12.14
12	Project Investment Financial Internal Rate of Return (Before Tax)	%	9.55
13	Project Investment Financial Internal Rate of Return (after Tax)	%	7.75
14	Project Investment Financial Net Present Value (before Tax)	Ten Thousand CNY	20,277.07
15	Project Investment Financial Net Present Value (after Tax)	Ten Thousand CNY	10,645.27
16	Internal Rate of Return on Equity	%	21.49
17	Net Present Value of Equity	Ten Thousand CNY	19,049.29
18	Return on Investment (ROI)	%	6.18
19	Investment Profit Rate	%	4.89
20	Return on Equity (ROE)	%	18.17
21	Debt-to-Asset Ratio (Maximum)	%	80.26

The economic benefits of Project Y as a whole are quite good. According to the calculation results, the financial internal rate of return (after tax) for the entire project investment is 7.75%, and the investment payback period (after tax) is 12.14 years.

A sensitivity analysis conducted in this paper further indicated that the charge-discharge price spread and the average daily number of charge-discharge cycles had the greatest impact on the return rate, while the peak load regulation compensation price has a relatively smaller impact.

In the scenario of an average daily charging and discharging of 1.5 times, the peak-valley price difference, capacity leasing, and peak load regulation compensation accounted for 61%, 26%, and 13% of total revenue respectively. Without capacity leasing revenue, the project's economic performance would decline significantly.

3.3. Risk Evaluation and Countermeasures

3.3.1. Policy Risk

The location of this project has not yet issued relevant support policies and implementation rules for independent energy storage stations, resulting in significant uncertainty regarding the project’s revenue, primarily in three areas: capacity leasing, peak load regulation compensation, and charging

and discharging rates.

Capacity leasing is entirely market-driven rather than government-priced, and there is significant uncertainty regarding leasing rates. Preliminary research indicates that local leasing quotes are lower than the 125 CNY/kWh used in the project's calculations. There are differences in peak load regulation subsidies and dispatch policies; the compensation standard in the relevant draft for public comment is 0.3 CNY/kWh, which is lower than the 0.4 CNY/kWh used in the project's calculations. The implementation of the user electricity pricing policy has led to an increase in charging costs of approximately 17%.

Therefore, it is necessary to strengthen government coordination and seek policy support. At the same time, the utilization of the energy storage system for charging and discharging should be improved to enhance the project's economic benefits.

3.3.2. Risk of Technological Iteration

With the wide variety of new energy storage technology routes and their rapid evolution, there is a risk that new technology routes could replace lithium-ion technology. This project has selected lithium iron phosphate battery technology, which is currently the most mature option; however, during the operation of the energy storage station, emerging technologies should be closely attuned so that energy storage cells with better technical performance and higher cost-effectiveness can be selected.

3.3.3. Safety Risks During Power Station Operation

Energy storage systems require a large number of battery cells, electrical equipment, and cables; during operation, heat generated by the system may lead to thermal runaway, posing operational safety risks.

This project utilizes lithium iron phosphate batteries certified to UL9540A and is designed, constructed, and operated in strict accordance with the national standard GB/T 42288-2022, Safety Code for Electrochemical Energy Storage Stations. Safety is maximized through zoned management and the design of fire compartments.

4. Conclusion

This paper analyzes the business models, social benefits, economic benefits, and project risks of independent energy storage using Project Y in Chongqing, China as a case study. The study indicates that policy mechanisms have a significant impact on the business models and returns of independent energy storage, and that different regions have developed distinct combinations of business models due to variations in the progress of electricity market development and policy mechanisms. As mechanisms such as the electricity spot market are gradually refined, the combination of "capacity leasing + spot market + ancillary services + capacity compensation" is expected to become a key business model for the long-term development of independent energy storage.

The economic analysis of Project Y shows that the project's financial internal rate of return (after income tax) is 7.75%, and the payback period (after tax) is 12.14 years. Sensitivity analysis reveals that the charge-discharge price spread, average daily charge-discharge cycles, and capacity leasing revenue have relatively large impacts on the project's economic benefits, while the peak load regulation compensation price has a relatively minor impact. At the same time, changes in relevant policy mechanisms and charging and discharging prices increase the uncertainty surrounding the project's returns. Therefore, investment decisions for independent energy storage projects should comprehensively evaluate the project's economic benefits and potential risks in light of the local policy environment, market trading mechanisms, and operational conditions.

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