Research on Investment Economic Evaluation of Flexible Regulating Resources such as Energy Storage in High Proportion New Energy Environment

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Abstract. With a high percentage of new energy scenarios, it has become a trend for flexible resources such as energy storage systems to participate in long-term planning. In this context, it is important to explore how energy storage systems are configured. Therefore, it is necessary to analyse the economics of energy storage and other resources to ensure that investments in energy storage and other resources are economically valuable under different future models. This paper firstly analyses the current situation of a high percentage of new energy in China, and secondly constructs a model for analysing the economics of flexible regulation resources such as energy storage. Under partial data based on the scenery storage project, the economic analysis under four models is derived, including cost and benefit analysis, investment benefit analysis, and break-even point analysis. Finally, the economic evaluation of investment in energy storage projects under different models is summarized based on the calculation results.It is concluded that different scenario models have different economic benefits, and the operation capacity of the four scenarios is higher than that of the existing models.

1. Introduction

According to the National Energy Administration statistics, from 2006 to 2019, China's installed renewable energy capacity increased from 135 GW to 795 GW, nearly five times, and renewable energy power generation increased from 446.9 TWh to 1998.8 TWh, an increase of 3.5 times [1]. The proportion of installed capacity of renewable energy generation is gradually rising, but new energy generation is affected by changes in wind and light natural resources, and there are problems of difficult prediction, difficult control, and difficult scheduling, and large-scale grid connection has an impact on power quality and transient stability of the grid. At the same time, China's energy structure is gradually transforming, and it needs to deal with the challenges brought by the continuous capacity increase of wind power generation and photovoltaic power generation to the power system and the stable operation of the grid [2].

At present, China 's power system mainly provides automatic generation control (AGC) frequency modulation function by traditional thermal power units. Traditional thermal power units are composed of mechanical devices with rotational inertia, and the conversion of primary energy into electrical energy requires a series of complex processes. Therefore, the response speed of traditional thermal power units to active power regulation is slow. Energy storage technology is applied in the field of AGC frequency modulation. [3]Because of its advantages of fast response speed, accurate control and two-way regulation, it has incomparable advantages over traditional thermal power unit frequency modulation in power grid frequency modulation[4].

Compared with the basic requirements of safety, reliability, and economy of power system operation, flexibility has become an important indispensable indicator for measuring the operating characteristics of the system as the penetration rate of new energy sources has increased significantly. With the rapid development of technology, energy storage has become a source of flexibility for power systems that cannot be ignored . Relying on its flexibility, energy storage technology can help solve a series of challenges brought by the current high percentage of new energy background to the power system. Energy storage technology plays a corresponding role in each link of power system generation, transmission, distribution, and use, which is of great significance to ensure the security of the power grid, improve the quality of power, increase the proportion of renewable energy, and improve the efficiency of energy utilization. In this context, the purpose of this paper is to analyze the investment economy of flexible adjustment resources such as energy storage, so as to ensure that energy storage

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investment has a considerable economic value level under current and future conditions.

2. Energy Storage Economic Analysis Model

2.1 Energy storage economic evaluation method

The economic analysis of wind and solar energy storage and storage adopts the technical-economic evaluation method to analyze the initial investment, annual cost, and revenue of energy storage. On this basis, the economic evaluation indexes such as net present value, internal rate of return, and payback period of wind and solar energy storage and storage are measured to draw relevant evaluation conclusions.

2.2 Cost analysis of energy storage

The cost of wind and solar energy storage, including the initial investment of the storage power plant, is apportioned to the annual cost C_1, annual operation, and maintenance fees (including management costs) C_2, annual charging costs C_3, annual financial costs (annual bank loans to be repaid) C_4, annual taxes C_5.

2.3 Analysis of energy storage returns

The annual revenue of wind and solar energy storage includes the revenue of participating in auxiliary services R_1, the annual power generation revenue of the storage power plant R_2, and the equalization to the annual policy subsidy revenue R_3.

2.4 Calculation of economic indicators of energy storage

In this study, the annual cost and annual revenue of the scenic energy storage are analyzed to calculate the annual net revenue; the dynamic payback period is measured to analyze the years required to recover the initial investment of the energy storage project; the economic benefits of the project are measured by calculating the financial net present value and internal rate of return. Considering the time value of money, the three economic evaluation indexes of dynamic payback period, NPV (net present value), and IRR (internal rate of return) are used to evaluate the economics of the energy storage project. The IRR is the discount rate that equates the sum of the present values of a cash flow to zero. If the NPV of a project is zero at a selected discount rate, that rate is the IRR. If the NPV of a project is zero at a selected discount rate, that rate is, by definition, the IRR [5].

3. Economic Analysis of Energy Storage Projects Under Four Modes

3.1 Project basic information and parameters

This paper studies whether the subsequent investment in energy storage has a certain economic value with the development and cost reduction of energy storage technology and the change of business model. It explores the economic situation of energy storage in four modes and provides some reference for the subsequent energy storage investment strategy.[6-8] Therefore, the setting of the basic parameters will be based on the scenic storage project with certain condition adjustments to facilitate the subsequent economic analysis. In addition, with the rapid development of battery energy storage technology, the unit cost level of energy storage has been showing a decreasing trend, so the economic evaluation using the current cost level is more meaningful for future investment strategy. For this reason, this chapter sets 2020 as the construction year and 2021 as the commissioning year and uses the current cost level to calculate the initial investment cost of energy storage, to determine whether the energy storage project has investment value. The specific parameters are set as follows: (1) The capacity of the energy storage project is 19MW/83.5MWh. (2) The first phase capacity of the scenery storage energy storage is 19MW/83.5MWh. The unit cost of about 5500 yuan/kW. The capacity unit cost of about 2000 yuan/kWh measurement. According to the above parameters, the initial investment can be calculated as 271.5 million yuan. The capital of the initial investment is 20%, the loan ratio is 80%, and the loan interest rate is 4.99%. The operation and maintenance overhaul costs are measured at about 2% of the initial investment, so it is measured at 5 million yuan per year. (3) Using the straight-line depreciation method, the depreciable life is the entire operating period, and the benchmark rate of return is i=8%. (4) The discharge tariff is calculated according to the wind turbine feed-in tariff of RMB 0.54/kWh; the charging tariff is calculated according to the average of the PV and wind power feed-in tariffs of RMB 0.456/kW. (5) The loan ratio is 64.94%, the loan interest rate is 5.14%, the repayment period is calculated as 15 years, and the repayment is made in the form of equal principal and interest. The value-added tax rate is calculated at 17%, urban construction, and maintenance tax and education surcharge are 7% and 5%, respectively, the local education surcharge is 3.5%, and corporate income tax is 25%.

3.2 Economic analysis based on the consumption of new energy model

3.2.1 Cost and revenue analysis.

According to the capacity of the scenery storage project is 19MW/83.5MWh, the daily operation of the storage battery is within the range of 10%-90% of its rated capacity, using the abandoned wind energy, the charging electricity price is measured according to 0, the

discharging electricity price is measured according to 0.54 yuan/kwh (including tax), one day charging and discharging, thus we can get the cash flow expenditure of the new energy consumption mode as follows: during the construction period, the project investment cost is 271.5 million yuan, the operation and maintenance cost is 5 million yuan per year, and the debt service is 21,472,600 yuan per year. The cash flow inflow revenue of the new energy consumption model comes from the power generation revenue of 11.8497 million yuan per year.

3.2.2 Investment benefit analysis.

Using the technical-economic evaluation method, the internal rate of return of energy storage, net present value, and dynamic payback period indicators can be measured as follows:

Table 1 Energy storage engineering technology economic evaluation indicators

Indicator	Value	Remarks
Net present value	-205,730,000	yuan
Internal rate of return	-10%	
Static payback period		cannot be recovered within the operation cycle
Dynamic payback period		cannot be recovered within the operation cycle

From Table 1, we can see that the NPV of the project is -205.73 million Yuan, which is less than 0; the IRR is -10%, which is less than the benchmark IRR of 8%, which makes the project infeasible and uneconomic from the perspective of economic evaluation.

3.2.3 Break-even point analysis.

First, the energy storage project needs to ensure that the internal rate of return is greater than or equal to 8% and the net present value is greater than or equal to 0 to ensure that the project is economically feasible. After technical and economic calculations, the discharge price of energy storage needs to be increased to at least 2.01 yuan/kwh (including tax) to ensure that the NPV of the project is greater than or equal to 0 and reach the break-even point of the project. Second, since the economic evaluation of energy storage under the current cost does not consider policy subsidies, and at present, China's energy storage power plants can obtain one-time or annual subsidy income according to national, local, or project policies, which can make energy storage projects turn from losses to profits. After technical and economic calculations, it is necessary to obtain a one-time subsidy of 222,192,900 yuan in 2020 to ensure that the NPV of the project is greater than or equal to 0. Third, after technical and economic calculations, the initial investment of energy storage needs to be reduced to at least 43.35 million yuan, which is 84.03% lower than the original initial investment of 271.5 million yuan, in order to ensure that the NPV of the project is greater than or equal to 0. Currently, the power unit cost is 878.34 Yuan/kW, and the capacity unit cost is 319.4 Yuan/kWh[9-10].

3.3 Economic analysis based on peak-shaving and valley-filling model

3.3.1 Cost and revenue analysis.

Referring to the peak and valley split tariff of Jibei Grid, the peak tariff is 0.7033 yuan/kWh, the valley tariff is 0.3151 yuan/kwh, and the difference between the peak and valley tariff is 0.3882 yuan/kWh. The capacity subsidy is calculated according to the reward of 550 yuan/kW in the central and western regions, and the one-time compensation that the scenery storage power station can get is 10.45 million yuan. According to the capacity of the scenery storage project is 19MW/83.5MWh, the daily operation of the storage battery is within the range of 10%-90% of its rated capacity, and it is charged and discharged once a day, so the daily charging volume is 66.8MWh. The charging tariff is 0.3151RMB/kWh, the feed-in tariff is 0.7033RMB/kwh, and the comprehensive efficiency of charging and discharging of the storage battery is 90%. Then the annual power generation revenue of energy storage is 15,433,100 yuan, and the annual charging cost is 7,682,800 yuan. The cash flow expenses of the peak-shaving and valley-filling model can be obtained as follows: the investment cost of the project during the construction period is 271.5 million yuan, the operation and maintenance cost is 5 million yuan per year, the charging cost is 7,682,800 yuan per year, and the debt service is 21,472,600 yuan per year. The cash flow inflow of the peak-shaving and valley-filling model comes from the generated revenue and peak-shaving subsidy. Among them, the generated revenue is 15,433,100 yuan per year and the peak shaving subsidy is 10,450,000 yuan per year of operation.

3.3.2 Investment benefit analysis.

Using the technical-economic evaluation method, the internal rate of return of energy storage, net present value, and dynamic payback period indicators can be measured as follows.

Table 2 Energy storage engineering technology economic evaluation indicators

Indicator	Value	Remarks
Net present value	-224,950,000	yuan
Internal rate of return	-14.49%	
Static payback period		cannot be recovered within the operation cycle
Dynamic payback period		cannot be recovered within the operation cycle

From Table 2, the NPV of the project is -224.95 million yuan, which is less than 0; the IRR is -14.49%, which is less than the benchmark IRR of 8%, making the project infeasible and uneconomic from the perspective of economic evaluation.

3.3.3 Investment benefit analysis.

After technical and economic calculations, first, the peak electricity price of energy storage needs to be increased to at least 2.30 yuan/kwh (including tax) to ensure that the NPV of the project is greater than or equal to 0. Second, a one-time subsidy of $242,428,000 in 2020 is required to ensure that the project NPV is greater than or equal to zero. Third, the initial investment in energy storage needs to be reduced to at least 22.78 million yuan, which is 91.61% lower than the original initial investment of 271.5 million yuan, in order to ensure that the NPV of the project is greater than or equal to 0. Currently, the power unit cost is 461.52 yuan/kW and the capacity unit cost is 167.82 yuan/kW. The cost of a power unit is 461.52 RMB/kW, and the cost of a capacity unit is 167.82 RMB/kWh.

3.4 Economic analysis based on peaking and frequency regulation auxiliary service model

3.4.1 Cost and revenue analysis. According to the current operation of the scenery storage and energy storage, set from the year of commissioning to use the peaking and frequency regulation auxiliary service mode, the FM mileage compensation is determined by the FM mileage, FM performance index, and mileage settlement price, and its model is:

$$R_{f1} = \sum_{t=1}^{N_f} D_t \times K_{AP} \times \lambda_1 \quad (1)$$

where R_{f1} is the FM mileage compensation; D_t is the FM mileage; K_{AP} is the comprehensive FM performance index of the FM unit on the execution date; λ_1 is the number of days of energy storage and FM operation in a year.

Referring to the transaction price of Guangdong FM mileage compensation is taken as 7 Yuan/MW. The enhancement of the original AGC regulation capacity of thermal power plants by electrochemical energy storage is taken as 2.1. thus, the daily revenue of FM service can be estimated as about 6703.2 Yuan, and the annual revenue of FM service is 2.4467 million Yuan.

The peaking compensation parameter is set according to the charging compensation of 0.05 million yuan/MWH of the standard of Southern Power Grid, and the daily operation of the energy storage battery is within the range of 10%-90% of its rated capacity. Assuming that the daily dispatch is the rated power multiplied by 0.8 factor, and the daily power generation is 53.44MWh, then the annual peaking service revenue is 752.8 million yuan. The storage charging tariff is 0.3151 yuan/kWh, the feed-in tariff is 0.7033 yuan/kWh, and the comprehensive efficiency of storage battery charging and discharging is 90%, then the annual power generation revenue is: 12,346,500 yuan and the annual charging cost is 6,146,200 yuan. The cash flow expenditure of the peaking and frequency regulation auxiliary service model can be obtained as follows: the engineering investment cost during the construction period is 271.5 million yuan, the operation and maintenance cost is 5 million yuan per year, the charging cost is 6,146.2 million yuan per year, and the debt service is 21,472.6 million yuan per year. The cash flow inflow of the peaking and frequency regulation auxiliary service model comes from power generation revenue, frequency regulation subsidy, and peaking subsidy. Among them, the generated revenue is 12,346,500 yuan per year, the frequency regulation subsidy is 2,446,700 yuan, and the peak regulation subsidy is 9,752,800 yuan.

3.4.2 Investment benefit analysis. From Table 3, using the techno-economic evaluation method, the internal rate of return of energy storage, net present value, and dynamic payback period indicators can be measured as follows:

Table 3 Energy storage engineering technology economic evaluation indicators

Indicator	Value	Remarks
Net present value	-147,870,000	yuan
Internal rate of return	-3.26%	
Static payback period		cannot be recovered within the operation cycle
Dynamic payback period		cannot be recovered within the operation cycle

From Table 4, the NPV is -147.87 million yuan, less than 0; the IRR is -3.26%, less than the benchmark IRR of 8%, which makes the project infeasible and uneconomic from the perspective of economic evaluation.

3.4.3 Break-even point analysis. After technical and economic calculations, first, the feed-in tariff of energy storage needs to be increased to at least 2.06 yuan/kwh (including tax) to ensure that the NPV of the project is greater than or equal to 0. Second, a one-time subsidy of 159.722 million yuan is needed in 2020 to ensure that the NPV of the project is greater than or equal to 0. Third, the initial investment in energy storage needs to be reduced to at least 102.99 million yuan, which is 62.07% lower than the original initial Third, the initial investment in energy storage needs to be reduced to at least 102.99-million-yuan, 62.07% lower than the original initial investment of 271.5 million yuan, to ensure that the project NPV is greater than or equal to 0. Currently, the power unit cost is 2086.43 yuan/kW, and the capacity unit cost is 758.7 yuan/kWh.

3.5 Economic Analysis Based on Capacity Tariff Model

3.5.1 Cost and revenue analysis. According to the current operation of wind and solar energy storage and storage, the capacity tariff model is set to be used from the year of commissioning to obtain both capacity and power

revenue. The capacity of the wind and solar storage project is 19MW/83.5MWh, and the capacity tariff is according to the average value of 865.5 Yuan/kW/year, so the annual capacity cost is 16,444,500 Yuan. The power capacity electricity price is measured according to the average value of 0.312 Yuan/kwh, then the annual power revenue is 6,846,500 Yuan. The daily operation of the energy storage battery is within the range of 10%-90% of its rated capacity, and the FGD benchmark coal-fired tariff in North China is 0.3634 Yuan/kwh, and the charging tariff is measured at 75% of the FGD benchmark coal-fired tariff, then the annual power generation cost is 6.6380 million Yuan. The cash flow expenditure of the capacity tariff model can be obtained as follows: the engineering investment cost during the construction period is 271.5 million yuan, the operation and maintenance cost is 5 million yuan per year, the charging cost is 6.6380 million yuan per year, and the debt service payment is 21.472 million yuan per year. The cash flow inflow of the capacity tariff model comes from capacity revenue and power revenue. The capacity revenue is 16,444,500 yuan per year and the electricity revenue is 6,846,500 yuan per year.

3.5.2 Investment benefit analysis. Using the technical-economic evaluation method, the internal rate of return of energy storage, net present value, and dynamic payback period indicators can be measured as follows:

Table 4 Energy storage engineering technology economic evaluation indicators

Indicator	Value	Remarks
Net present value	-172,720,000	yuan
Internal rate of return	-5.84%	
Static payback period		cannot be recovered within the operation cycle
Dynamic payback period		cannot be recovered within the operation cycle

If there is no relevant capacity electricity policy subsidy subsequently, the NPV is -17.272 million yuan, which is less than 0; the IRR is -5.84%, which is less than the benchmark IRR of 8%, making the project infeasible and uneconomic from the perspective of economic evaluation.

3.5.3 Break-even point analysis. After technical and economic calculations, first, the electricity tariff of energy storage needs to be increased to at least 1.56 yuan/kwh (including tax) to ensure that the NPV of the project is greater than or equal to 0. Second, a one-time subsidy of 186,542,100 yuan needs to be obtained in 2020 to ensure that the NPV of the project is greater than or equal to 0. Third, the initial investment in energy storage needs to be reduced to at least 77.38 million yuan, which is 71.5% lower than the original initial investment of Third, the initial investment in energy storage needs to be reduced to at least 77.38-million-yuan, 71.5% lower than the original initial investment of 271.5 million yuan, in order to ensure that the NPV of the project is greater than or equal to 0. Currently, the cost of the power unit is 1567.55 yuan/kW and the cost of the capacity unit is 570.02 yuan/kWh.

4. Economic Evaluation of Energy Storage Investment

Through the evaluation and analysis of the economics of flexible regulation resources such as energy storage, the following conclusions are drawn:

First, the economics of different scenario modes are different, and the operating capacity of all four scenario modes is higher than that of the existing modes. The peak and frequency regulation auxiliary service model has the highest benefit, with an annual increase in revenue of 18.31 million yuan, an increase in net present value of 37.98 million yuan, and an increase in internal rate of return of 2.30% compared with the existing model.

Second, the analysis of the investment income calculation of energy storage shows that although the initial investment is significantly reduced, the NPV and IRR of the projects under the four business models are still negative. Among them, the peak and frequency regulation auxiliary service mode is the least negative, with a net present value of -144.99 million yuan and an internal rate of return of -3%, which cannot be recovered during the operation period of the project, and the project is still uneconomic. Under the existing technical conditions of energy storage and construction costs, the cost of various types of battery energy storage system is still on the high side, investment in energy storage systems do not yet have a significant economic, so it is not yet appropriate to promote battery energy storage technology on a large scale. At this stage of the development of battery energy storage, but also need the support and guidance of the government.

Third, the break-even point analysis shows that if the construction period is considered, such as the Golden Sun and other one-time government subsidies, in order to achieve the break-even of energy storage projects, the least number of subsidies required under the four commercial scenarios is the peak and frequency regulation auxiliary service mode, and the greatest number of subsidies required is the peak-shaving and valley-filling mode. If we do not consider the policy subsidies, from the perspective of improving the price of electricity, in order to achieve the break-even of energy storage projects, the lowest feed-in tariff is the capacity tariff mode and the highest is the peak-shaving and valley-filling mode. From the perspective of reducing the cost of energy storage, in order to achieve the break-even of energy storage projects, the least reduction in the unit cost required under the six commercial scenarios is the peak and frequency regulation auxiliary service mode, and the greatest reduction in the cost required is the peak and valley reduction mode.

5. Conclusions

This article explores four different scenario modes of high-proportion new energy storage and consumption. In addition, it calculates the technical and economic

indicators of each scenario mode during the subsequent operation cycle of wind and solar energy storage, while other boundary conditions remain unchanged. Different scenario models have different economic benefits, and the operational capabilities of the four scenario models are higher than those of the existing models. Although the four modes can greatly improve the operational capacity of energy storage, it has not yet reached the project profitability threshold. Government subsidies and the reduction of energy storage costs are still important ways to achieve the critical profitability of the project.

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