Optimal Configuration of energy Storage in New Energy Stations Considering Battery Life Cycle

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Optimal Configuration of energy Storage in New Energy Stations Considering Battery Life Cycle

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Abstract: In order to analyze the energy storage benefits and their impact on new energy stations throughout their entire life cycle, a new energy station energy storage optimization method considering the power supply life cycle is proposed. Firstly, based on the operational characteristics of energy storage in new energy stations, a revenue model and a cost model are established for the energy storage system; Secondly, by taking the constraints of each energy output in the new energy station into account, with the goal of maximizing investment return, an objective function is established by considering the entire life cycle of the battery, and the improved Grey wolf optimization algorithm is used to solve the objective function; Finally, the configuration of 10MW/20MWh energy storage is used as an example to verify the proposed method. The results show that the optimized new energy station has significantly improved the phenomenon of wind and light abandonment, and the net income of energy storage has been increased.

Keywords: full life cycle; new energy stations; energy storage optimization; IGWOA

0 Introduction

With the proposal of the "dual carbon" goal, the energy structure will accelerate adjustment, and the proportion of new energy generation, mainly wind and photovoltaic, in the power system will further increase. However, its randomness and volatility pose some challenges to the safe operation of the power system. To improve the stability of the power system, it is necessary to comprehensively consider the characteristics of new energy sources such as wind and solar power, and configure energy storage systems to ensure the normal supply of electricity.

As a collection of new energy power generation, new energy stations bear the important task of stable operation and safety control of new energy power generation, and be the platform support for realizing the new power system. At present, research about new energy stations has achieved fruitful results. Reference [8] studied the electricity pricing mechanism for new energy stations considering the market environment; Reference [9] proposed a collaborative planning method which considers new energy civilian stations and demand response to determine the optimal location, equipment capacity, and demand response configuration of new energy stations. References [10]-[12] proposed different control methods for new energy stations to improve the voltage quality during electric vehicle charging and the power grid energy quality; Reference [13] proposed a new probabilistic mixed integer linear programming method for determining the optimal capacity and type of new energy stations to minimize energy costs; Reference [14] designed a new DC fast charging station for electric vehicles using the characteristics of new energy stations, effectively solving the various control strategy requirements for charging stations connected to distributed networks. Reference [15] optimized new energy stations containing hydrogen refueling stations based on the potential and load demand of renewable energy to improve the efficiency of renewable energy centers; Reference [16] proposed a prediction method based on user feature analysis to accurately predict the repurchase behavior of users in new energy civilian stations, which facilitates energy scheduling in new energy stations; On the basis of energy sharing in new energy stations, reference [17] proposed the concept of flexible energy storage power stations, and used a two-layer optimization model method to fully release the energy storage capacity in new energy stations. It should be noted that the above literature has conducted research on different aspects of new energy stations, but rarely mentions the joint
control of new energy stations and energy storage stations, and has not conducted in-depth research and analysis on the role and impact of energy storage.

The configuration of energy storage in new energy stations can effectively improve the operational efficiency of new energy stations, promote the consumption of new energy, and ensure the normal and stable operation of new energy stations. Currently, research on energy storage is also a hot topic\cite{18}-\cite{23}. Reference [24] proposed a time-domain protection algorithm for battery energy storage system transmission lines based on current trajectory coefficients to ensure the normal operation of the energy storage system; Reference [25] studied the optimal scale and site selection schemes for battery energy storage and photovoltaic power generation to improve the resilience of the power system and evaluate the reliability of extreme events on power and energy storage capacity. Reference [26] proposed a new cost model for large-scale battery energy storage power stations and analyzed the economic feasibility of battery energy storage and nuclear power joint peak shaving; Reference [27] installed battery energy storage systems in solar photovoltaic power plants, improving the utilization efficiency of voltage source converters and shortening the recovery period; Reference [28] comprehensively analyzed the battery energy storage systems of multiple rooftop grid connected solar photovoltaic power stations to improve energy security and grid resilience; Reference [29] aims to minimize the cost of power exchange and the penalty cost of voltage deviation between distribution and transmission networks, and proposed an optimized scheduling model for distributed battery storage power stations considering peak shaving to improve voltage distribution in the distribution network; Reference [30] studied the energy storage problem of smart grids using fog calculation methods; Reference [31] used real data to study the optimization design of photovoltaic systems with battery energy storage systems, in order to determine the optimal size of photovoltaic panels, the optimal capacity of energy storage systems, and the optimal charging/discharging time; Reference [32] analyzed the performance of shared bicycle station photovoltaic cell systems and proposed multiple improvement strategies to enhance energy independence, sustainability, and system reliability; Reference [33] proposed a medium voltage direct current microgrid monitoring system based on photovoltaic, battery, green hydrogen system, and electric vehicle charging station, which realizes the sale of energy to the grid to maintain power balance and obtain economic benefits in the microgrid; Reference [34] utilized the Gorilla Troop Optimizer (GTO) algorithm to achieve efficient operation of battery storage systems, electric vehicle charging stations, and renewable energy connected to distribution systems. It is worth mentioning that the research on energy storage issues mentioned above mostly focuses on the participation of energy storage in peak shaving, energy storage system design, and energy storage optimization control, which not consider the energy storage life cycle and energy storage configuration issues.

Based on the above analysis, this paper studies the optimization problem of energy storage in new energy stations under the full life cycle of batteries. By constructing a profit model and a cost model of the energy storage system in new energy stations, an objective function with the maximum investment return rate under the full life cycle of energy storage is established. The improved Grey wolf optimization algorithm (IGWOA) is used to solve the objective function. Finally, the effectiveness and correctness of the proposed method are verified through case analysis.

1 Establishment of energy storage system model

The establishment of an energy storage system model is related to the revenue of new energy stations. This paper starts from the energy storage revenue model and energy storage cost model, and refines the energy storage system model. Among them, the energy storage revenue model mainly includes the annual revenue model for normal operation of energy storage, national policy revenue model, delayed expansion and renovation revenue model, and carbon trading revenue model. The energy storage cost model mainly includes investment cost model, maintenance cost model, battery replacement cost model, and penalty cost model.

1.1 Energy storage revenue model
There are various energy storage revenue models, mainly involving the total revenue generated by the energy storage system. This paper establishes an annual energy storage revenue model on an annual basis, which can be specifically divided into:

1. Annual revenue model for normal operation of energy storage

The annual revenue model for normal operation of energy storage is based on an annual basis. In order to improve the revenue brought by energy storage operation, energy storage charging and discharging during periods of low grid access electricity price, which can be specifically divided into:

(1) Annual revenue model for normal operation of energy storage

The annual revenue model for normal operation of energy storage is based on an annual basis. This annual revenue model can be established as follows:

\[
f_1 = \sum_{j=1}^{365} \sum_{t=1}^{24} \left[ (r_{j,t,d} P_{j,t,d} - r_{j,t,c} P_{j,t,c}) \Delta t \right],
\]

(1) where \( r_{j,t,d,} \) and \( r_{j,t,c} \) are the discharge and charge price of energy storage in \( t \) time period on the \( j \)-th day of the year, respectively, \( P_{j,t,d} \) and \( P_{j,t,c} \) are the discharge and charge power of energy storage, \( \Delta t \) is the time interval.

2. National policy revenue model

According to the relevant policies issued by the country, the excess electricity in new energy stations is sold to the power grid to generate profits. The model is:

\[
f_2 = \sum_{j=1}^{365} \sum_{t=1}^{24} \left[ r_{j,t,b} \Delta P_{j,t} \right],
\]

(2) where \( r_{j,t,b} \) is the subsidy electricity prices in \( t \) time period on the \( j \)-th day of the year, \( \Delta P_{j,t} \) is the remaining power of the system, \( P_{j,t,w}, P_{j,t,v}, P_{j,t,g} \) and \( P_{j,t,l} \) are the wind power output, photovoltaic output, generator output, and load demand, respectively.

3. Delayed expansion and renovation revenue model

The use of energy storage charging and discharging can effectively alleviate the large-scale expansion and renovation of equipment, thereby reducing investment costs and delaying the benefits of expansion and renovation. The model is:

\[
f_3 = C_0 \left[ 1 - \left( \frac{1 + i_0}{1 + E_0} \right)^n \right],
\]

(4) where \( C_0 \) is the the upgrading and expanding cost in \( t \) time period on the \( j \)-th day of the year, \( i_0 \) and \( E_0 \) are inflation rate and discount rate, respectively, \( n_\delta \) is the period of expansion and renovation , \( \alpha \) and \( \beta \) are the annual load growth rate and energy storage peak shaving rate, respectively.

4. Carbon trading revenue model

After configuring energy storage in new energy station, using energy storage for charging and discharging can effectively reduce the system's purchase of electricity from the grid, thereby reducing carbon emissions. This model can be expressed as:

\[
f_4 = \sum_{j=1}^{365} \sum_{t=1}^{24} \left( r_{j,t,z} Q_{j,t,z} \right),
\]

(6) where \( r_{j,t,z} \) is the carbon trading price in \( t \) time period on the \( j \)-th day of the year, \( Q_{j,t,z} \) is the less electricity purchased from the grid.

1.2 Energy storage cost model

(1) Energy storage investment cost model

The investment cost of energy storage is a one-time investment cost in the construction of energy storage systems, which is related to the discharge and charging power of energy storage as well as the energy storage capacity. The model is:

\[
C_1 = \left( C_{11} P_{11} + C_{12} Q_{12} \right) \frac{E_0 (1 + E_0)^n}{(1 + E_0)^n - 1},
\]

(7) where \( C_{11} \) is the unit power cost of energy storage, \( P_{11} \) is the rated power of energy storage, \( C_{12} \) is the unit capacity cost of energy storage, \( P_{12} \) is the rated energy storage capacity, \( n \) is the operating period of energy storage.

(2) Energy storage maintenance cost model

The energy storage system needs regular maintenance during daily operation, and its model can be represented as:
\[ C_2 = C_{21}Q_{21}, \quad (8) \]

where \( C_{21} \) is the operation and maintenance cost per unit capacity of energy storage, \( Q_{21} \) is the annual operation and maintenance capacity of energy storage.

(3) Battery replacement cost model

To ensure the normal operation of energy storage, it is necessary to monitor its status and replace individual batteries that do not meet the requirements. The cost model for replacement is:

\[ C_3 = \gamma C_{12}Q_{11}, \quad (9) \]

where \( \gamma \) is the battery replacement rate.

(4) Energy storage penalty cost model

Due to the uncertainty and volatility of wind and photovoltaic power generation, the combined output of the system in new energy stations cannot meet the load demand, and sometimes there may be waste of wind and solar resources, leading to the phenomenon of wind and solar abandonment. These situations will be punished to a certain extent, and the model can be expressed as:

\[ C_4 = C_{41}Q_{41} + C_{42}Q_{42} \]
\[ Q_{41} = \sum_{j=1}^{365} \sum_{t=1}^{24} \left[ \text{sign}(-\Delta P_{j,t}) (-\Delta P_{j,t}) \Delta t \right] \]
\[ Q_{42} = \sum_{j=1}^{365} \sum_{t=1}^{24} \left[ \text{sign}(\Delta R_{j,t}) \Delta R_{j,t} \Delta t \right] \]
\[ \Delta R_{j,t} = P_{j,t,w} + P_{j,t,v} + P_{j,t,d} - P_{j,t,c} - P_{j,t,l} \]

where \( C_{41} \) is the unit purchase cost of electricity, \( Q_{41} \) is the electricity purchased from the power grid, \( Q_{42} \) is the total amount of wind and light abandoned, \( \text{sign}(x) \) is a sign function, if \( x>0 \), the return value is 1; if \( x \leq 0 \), the return value is 0.

2 System constraints

New energy stations include renewable energy sources such as wind power and photovoltaic, gas turbine power generation, and energy storage system charging and discharging. During the normal operation of new energy stations, each equipment must meet its own constraints.

(1) System power balance constraints

At any time during the operation of a new energy station, it is desired to achieve a balance between system power supply and demand, which can be expressed as:

\[ P_{j,t,w} + P_{j,t,v} + P_{j,t,g} + P_{j,t,d} = P_{j,t,c} + P_{j,t,l}, \quad (11) \]

(2) New energy generation output constraints

\[ P_{j,t,w} \in \left[ P_{j,t,w \min}, \ P_{j,t,w \max} \right], \quad (12) \]
\[ P_{j,t,v} \in \left[ P_{j,t,v \min}, \ P_{j,t,v \max} \right], \quad (13) \]
\[ P_{j,t,wesc} + P_{j,t,wg} \leq P_{j,t,w}, \quad (14) \]
\[ P_{j,t,vesc} + P_{j,t,vg} \leq P_{j,t,v}, \quad (15) \]

where \( P_{j,t,w \min} \) and \( P_{j,t,w \max} \) are the lower and upper limits of wind power output in \( t \) time period on the \( j \)-th day of the year, respectively, \( P_{j,t,v \min} \) and \( P_{j,t,v \max} \) are the lower and upper limits of photovoltaic output, respectively, \( P_{j,t,wesc} \) and \( P_{j,t,wg} \) are the wind power charging power to the energy storage and to the grid, respectively, \( P_{j,t,vesc} \) and \( P_{j,t,vg} \) are the photovoltaic charging power to the energy storage and to the grid, respectively.

(3) Gas turbine output constraints

\[ P_{j,t,g} \in \left[ P_{j,t,g \min}, \ P_{j,t,g \max} \right], \quad (16) \]

where \( P_{j,t,g \min} \) and \( P_{j,t,g \max} \) are the lower and upper limits of the generator output in \( t \) time period on the \( j \)-th day of the year, respectively.

(4) Energy storage charging and discharging constraints

\[ P_{j,t,c} \in \left[ P_{j,t,c \min}, \ P_{j,t,c \max} \right], \quad (17) \]
\[ P_{j,t,d} \in \left[ P_{j,t,d \min}, \ P_{j,t,d \max} \right], \quad (18) \]

where \( P_{j,t,c \min} \) and \( P_{j,t,c \max} \) are the lower and upper limits of the energy storage charging power, respectively, \( P_{j,t,d \min} \) and \( P_{j,t,d \max} \) are the lower and upper limits of the energy storage discharge power, respectively.

(5) State of Charge Constraints for Energy Storage

\[ SOC_{j,t} = (1 - \eta_s) SOC_{j,t-1} + \eta_c P_{j,t,c} - \frac{P_{j,t,d}}{\eta_d}, \quad (19) \]
\[ SOC_{j,t} \in \left[ SOC_{j,t,\min}, \ SOC_{j,t,\max} \right], \quad (20) \]

where \( SOC_{j,t} \) is the energy storage state in \( t \) time period on the \( j \)-th day of the year, \( \eta_s \) is the energy storage loss coefficient, \( \eta_c \) and \( \eta_d \) are the charging and
discharging efficiency, respectively, $S_{j,t,\text{min}}$ and $S_{j,t,\text{max}}$ are the lower and upper limits of the energy storage state, respectively.

Within a scheduling cycle, the initial state of energy storage remains the same, i.e.:

$$SOC_{j,0} = SOC_{j,T},$$  \hspace{1cm} (21)

### 3 Construction and solution of 3 objective functions

On the basis of comprehensively considering the total benefits and costs of energy storage systems, this paper constructs an objective function with the goal of maximizing investment return rate throughout the entire life cycle of energy storage systems, which can be expressed as:

$$F = \frac{11}{1} \times \frac{E_{\text{EEf}}(1 + E_{1})^{n}}{(1 + E_{1})^{n} - 1},$$  \hspace{1cm} (22)

where $F$ is the return rate on investment, $f$ is the net revenue of the battery throughout its entire life cycle, $E_{1}$ is the expected rate of return, $n$ is the operating years of energy storage.

According to the previous model, $f$ can be expressed as:

$$f = \sum_{i=1}^{n} f_{i,k} - \sum_{s=1}^{4} C_{i,s},$$  \hspace{1cm} (23)

where $f_{i,k}$ is the $k$-th benefit brought by energy storage in the $i$-th year, $C_{i,s}$ is the $s$-th cost of energy storage operation in the $i$-th year.

The constraint conditions that need to be met are equations (11) - (21).

The Grey Wolf Optimization Algorithm (GWOA) simulates the predatory behavior of gray wolf populations and achieves optimization goals based on the mechanism of wolf group cooperation. This algorithm has strong optimization ability and fast convergence speed, and is widely used in the engineering field.

In GWOA, a pack of gray wolves will first surround their prey, and the mathematical model for this behavior can be expressed as:

$$D = \left| CX_{\alpha} (t) - x(t) \right|,$$  \hspace{1cm} (24)

where $X_{\alpha}(t)$ is the prey position, $x(t)$ is the current gray wolf position, $C$ is the synergy coefficient.

The formula for updating the position of the gray wolf population is:

$$x(t+1) = X_{\alpha} (t) - AD,$$  \hspace{1cm} (25)

where $A = 2ar_{1} - a$, $C = 2r_{2}$, $a = 2 - 2t/T$. $a$ is the convergence factor, with values of [0,2], $r_{1}$ and $r_{2}$ are random vectors between [0,1], $t$ is the current number of iterations, $T$ is the maximum number of iterations.

During the hunting process, it is assumed that the optimal grey wolf is $\alpha$. The second best is $\beta$. The third best is $\sigma$. The remaining gray wolves are $\omega$, utilize $\alpha$, $\beta$ and $\sigma$ updating the position of all gray wolves, that is:

$$D_{\alpha} = C_{1}X_{\alpha} (t) - x(t),$$  \hspace{1cm} (26)

$$D_{\beta} = C_{2}X_{\beta} (t) - x(t),$$

$$D_{\sigma} = C_{3}X_{\sigma} (t) - x(t),$$

$$x_{1} = \left| X_{\alpha} - A_{1}D_{\alpha} \right|,$$

$$x_{2} = \left| X_{\beta} - A_{2}D_{\beta} \right|,$$

$$x_{3} = \left| X_{\sigma} - A_{3}D_{\sigma} \right|,$$

$$x(t+1) = \frac{x_{1} + x_{2} + x_{3}}{3},$$  \hspace{1cm} (28)

where $D_{\alpha}, D_{\beta}$ and $D_{\sigma}$ are the distance from $\omega$ to $\alpha$ layer wolf pack, $\omega$ to $\beta$ layer wolf pack, $\omega$ to $\sigma$ layer wolf pack, respectively, $x_{1}, x_{2}$ and $x_{3}$ are the influence affected by $\alpha$ layer wolf pack, $\beta$ layer wolf pack, and $\sigma$ layer wolf pack, respectively, $\omega$ is the position that individual gray wolves need to adjust.

GWOA has better optimization performance, but due to the limitations of the algorithm's iterative mechanism, it does not consider the diversity of problems and is prone to falling into local optima. This article improves the algorithm from two aspects.

1. Improvement of convergence factor

In GWOA, the convergence factor varies linearly with the number of iterations, and the convergence speed is slow, which affects the algorithm's running speed. This article uses a nonlinear fast convergence
method to improve the convergence factor, which not only enhances the algorithm’s search ability but also accelerates the convergence speed. The improvement of the convergence factor can be expressed as:

\[ a = a_i - \frac{a_f - a_0}{1 - e^{-\frac{t}{T}}} \]  (29)

where \( a_0 \) and \( a_f \) are the initial and final values of the nonlinear factor \( a \), respectively, \( k \) is the adjustment factor, with values \([1, 5]\).

(2) Position adjustment improvement

Set the fitness value of individual i of the current wolf as \( k_i \). By comparing with the average fitness value \( K \) of the population, and dynamically adjust the individual fitness value based on the comparison results. The adjustment strategy is:

\[
x_i'(t+1) = \begin{cases} 
\left( \frac{x_1 + x_2 + x_3}{3} \right), & k_i > K \\
\left( \frac{D_\alpha/k_\alpha + D_\beta/k_\beta + D_\delta/k_\delta}{1/k_\alpha + 1/k_\beta + 1/k_\delta} \right), & k_i \leq K 
\end{cases} 
\]  (30)

where \( k_\alpha, k_\beta \) and \( k_\delta \) are the fitness value of \( \alpha, \beta \) and \( \delta \) wolves, respectively.

The optimization process of improving the grey wolf optimization algorithm (IGWOA) can be expressed as:

1. Obtain basic data of various operating equipment in the new energy station.
2. Initialize settings, including \( r_1, r_2, a_0, a_f, k, T, X_p(0), x(0), P_{j,t,0}(0), P_{j,t,0}(0), \) etc.
3. Calculate the fitness value of individual gray wolves and select the top three excellent individuals.
4. Calculate the average fitness value of the population.
5. Use equation (29) to update the convergence factor.
6. Use equation (30) to adjust the three optimal individual positions of the wolf pack.
7. Use equations (24)-(28) to update the individual positions of wolf packs.
8. Whether the end condition is met, if so, end the iteration and obtain the result; If not, return to step 3 for iteration.

4 Example analysis

In this section, the validity and correctness of the proposed method are verified by simulation analysis and revenue analysis.

4.1 Simulation analysis

This subsection takes an energy station in Henan as the research object to simulate and verify the proposed method. The energy storage system in this new energy station owns a capacity of 10KW/20MWh, a charging power of 10MW, and a charging and discharging efficiency of 0.95. The lower and upper limits of the energy storage state are 0.1 and 0.9, respectively. The initial state is 0.5, the battery replacement rate is 5%, the self loss rate is 0.1%, and the expected rate of return is 8%. The time-of-use electricity price information is shown in Table 1.

<table>
<thead>
<tr>
<th>Time period</th>
<th>Time</th>
<th>Price(Yuan•(KWh)^-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak load period</td>
<td>9: 00-12: 00</td>
<td>0.746</td>
</tr>
<tr>
<td></td>
<td>18: 00-21: 00</td>
<td>0.726</td>
</tr>
<tr>
<td>Usual load period</td>
<td>5: 00-9: 00</td>
<td>0.586</td>
</tr>
<tr>
<td></td>
<td>12: 00-18: 00</td>
<td>0.586</td>
</tr>
<tr>
<td>Low load period</td>
<td>0: 00-5: 00</td>
<td>0.372</td>
</tr>
<tr>
<td></td>
<td>21: 00-24: 00</td>
<td>0.372</td>
</tr>
</tbody>
</table>

The typical daily wind power, photovoltaic and load curves in the region are shown in Figure 1. It can be seen that wind power generation has significant fluctuations, with the maximum wind power of 63MW at 10:00 pm and the minimum wind power of 28MW at 1:00 pm, with an average power of 46.458MW. Photovoltaic power generation is concentrated from 6:00 pm to 7:00 pm, with an average power generation of 10.375MW. The load has certain fluctuations, with a maximum load power of 65MW at 9:00 pm, a minimum load of 51MW at 4 hours, and an average power of 59.375MW.
After configuring a capacity of 10MW/20MWh for energy storage, the energy storage charging and discharging power is shown in Figure 2. During the low load period from 1:00 am to 4:00 am in the morning, the energy storage is charged during this period. The load has increased from 5:00 am to 9:00 am, and the wind power output fluctuates, resulting in changes in energy storage between charging and discharging. During peak periods of electricity prices from 10:00 am to 12:00 am and 6:00 pm to 9:00 pm, energy storage is used for discharge; At other times, energy storage can be used for charging.

After optimization, the energy output of new energy station is shown in Figure 3. It can be seen that at any time of the day, the system energy supply and demand reach equilibrium. When the output of the new energy source exceeds the load demand, the gas turbine begins to generate electricity. When the total output still cannot meet the load, the energy storage system will release electricity for energy supplementation to ensure a balance between supply and demand of the system.

The comparison of wind and photovoltaic power before and after optimization is shown in Figure 4. It can be seen that after optimization, the maximum amount of wind and photovoltaic power curtailment does not exceed 3MW, indicating a significant improvement in this phenomenon and once again proving the effectiveness of the proposed method.

According to the energy storage charging and discharging power curve, the energy storage SOC curve is shown in Figure 5. The curve is periodic for 24 hours a day. The rising SOC curve in the figure represents the energy storage charging process, while
the falling SOC curve represents the energy storage discharging process. Each point in the curve satisfies the upper and lower limits of SOC.

4.2 Revenue analysis

Based on the typical daily energy storage SOC curve and data from a certain year in the region, the annual energy storage SOC curve can be plotted. Referring to the relationship between the depth of battery discharge and the number of cycles shown in Table 2, while considering battery self-loss rate and replacement rate, the operating years and remaining capacity can be simulated using the first year's energy storage capacity as a reference. The results are shown in Figure 6.

Table 2 The relationship between the depth of battery discharge and the number of cycles

<table>
<thead>
<tr>
<th>Discharge depth</th>
<th>Cycle numbers</th>
<th>Discharge depth</th>
<th>Cycle numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>400</td>
<td>0.5</td>
<td>1350</td>
</tr>
<tr>
<td>0.9</td>
<td>600</td>
<td>0.4</td>
<td>1600</td>
</tr>
<tr>
<td>0.8</td>
<td>650</td>
<td>0.3</td>
<td>2000</td>
</tr>
<tr>
<td>0.7</td>
<td>950</td>
<td>0.2</td>
<td>3000</td>
</tr>
<tr>
<td>0.6</td>
<td>1100</td>
<td>0.1</td>
<td>4000</td>
</tr>
</tbody>
</table>

Analysis shows that when 10MW/20MWh energy storage is configured, the energy storage capacity decreases year by year with the increase of operating years. By the 17th year, the energy storage capacity is slightly higher than the rated capacity by 20%, indicating that the operating period of energy storage is 17 years.

Based on the information in Figure 6 and Table 2, the net revenue of energy storage were calculated, and the simulation result is shown in Figure 7. From the perspective of the entire life cycle of the energy storage system, when the new energy station is equipped with an energy storage system, the total energy storage revenue in the first 6 years is negative, which indicates that the profits brought by the energy storage system are less than the costs incurred in this stage. Starting from the 7th year, the net revenues of energy storage starts to be positive, indicating that the total profits brought by the energy storage system thereafter is positive. This revenues reaches the maximum in the 13th year after the allocation of energy storage, and then decreases until the end of the life of the energy storage system.

5 Conclusion

In this paper, an optimization method for energy storage of new energy station considering the life cycle of power supply is proposed in order to achieve the maximum benefit of energy storage under the whole life cycle. Firstly, establish the annual revenue model for normal operation of energy storage, national policy revenue model, delayed expansion and renovation revenue model, and carbon trading revenue model, as well as investment cost model, maintenance cost model, battery replacement cost model, and penalty cost model. Secondly, by considering the full life cycle of batteries, establish an objective function with the maximum investment return rate as the objective function. Finally, the IGOOA was used to solve the objective function, and the proposed method was validated through simulation analysis and profit analysis. The energy storage capacity configuration scheme was obtained, which increased the net profit of energy storage.

Reference:


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