Optimal two-stage dispatching strategy of multi-element integrated power station considering demand response characteristics

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Abstract. In order to analyze the influence of the storage power station on the regional distribution network under the background of multi-element integration, and reduce the negative impact of charging and discharging load on the power network, based on the general model of multiple integration, considering the demand response characteristics, the load model of data centre, the model of energy storage station and the model of distributed new energy are established. The whole life cycle economic benefit model of energy storage system is established considering the energy storage arbitrage income, the government electricity price subsidy income, the delay of power network upgrading and the whole life cycle cost. Based on the two-stage optimization model, a “Maximum net profit-minimum fluctuation” charging and discharging strategy model is established for the energy storage power plant under the background of multi-element integration. The objective of this method is to minimize the load fluctuation in the distribution network based on the maximum net income of the energy storage system. Finally, the simulation results show the effectiveness of the proposed method.

1. Introduction

Substation resources are the most abundant available resources for power grid enterprises. In order to carry out the strategy of “Three types and two networks” and combine the advantages of internal energy storage and external resources, the State Grid Corporation of China actively explores a new construction mode of “Multi-station integration” of substations, energy storage stations and data centre stations. Under the background of the shortage of land resources, the increase of power consumption and the difficulty in the location of substations, the new mode of multi-station fusion substations brings together many kinds of resources, which can optimize the allocation of urban resources and improve the efficiency of data sensing, analysis and calculation, on-site digestion of load [1,2]. At the same time, the distributed power supply has also entered a period of rapid development, and will form a large-scale, large-scale, high-density “Wide-area distributed power supply”, however, most of the typical distributed power sources, such as photovoltaic and wind power, have randomness, which is caused by the uncertainty of natural environment and belongs to uncontrollable power source [3–6]. The randomness and fluctuation of distributed renewable energy will bring great pressure to the operation of distribution network.

Energy storage systems can play an important role in smoothing intermittent power fluctuations, peak shaving, valley filling, improving voltage quality and providing backup power supply by virtue of their fast power regulation as well as the characteristics of both supply and storage capacity, it is the key for active distribution network to realize flexible regulation of distributed energy with wide access and
optimal operation of network, its configuration will directly affect the ability of active distribution network for distributed energy management and the economy of network operation [7-8]. At present, domestic and foreign research on energy storage and optimal allocation of distributed generation has achieved more results, there are two main categories: one is the single planning of storage power plants and distributed generation, for example, site selection and capacity determination of energy storage power stations [9], planning of electric vehicle in distribution network [10,11], distribution network planning considering distributed generation; The other is the joint planning of storage power station or distributed power supply and distribution network [12], for example, the joint planning of distributed generation, storage power station and distribution network is considered [13], joint planning of energy storage and electric vehicles [14,15]. For the first kind of research, reference [16] considers voltage deviation, network loss, load shedding and other factors, establishes a multi-objective programming model to obtain the optimal position and capacity of the energy storage system; literature [17] establishes a mixed integer nonlinear model, and uses genetic algorithm to solve the position and capacity of the distributed power supply. For the second kind of research, literature [18] according to the characteristics of photovoltaic system-energy storage combined operation, a combined allocation method of photovoltaic and energy storage capacity is proposed; In the literature [19], a mixed integer linear programming model was established to minimize the investment and operation cost of the distribution network including charging stations, and the branch-and-bound method was applied to solve the planning scheme of charging stations and distribution networks.

The main contributions of this article are as follows:

- Based on the general model of multi-element integrated, the load model of data centre, the model of energy storage power station and the output model of distributed new energy are established.
- The whole life cycle economic benefit model of the energy storage system is established by considering the energy storage arbitrage income, the government electricity price subsidy income, the delay of power network upgrade and the whole life cycle cost.
- The goal of the first stage is to maximize the total net profit of the storage battery system in the whole life cycle of the distribution network, and the goal function of the second stage is to minimize the load fluctuation, a two-stage optimization function is established to study the configuration of storage battery and the optimization of charge/discharge value in each period in distribution network.

2. Component Model Based on Demand Response Characteristics

2.1. Data Center Model

Energy efficiency in data centres is often measured by power usage effectiveness (PUE), PUE is defined as the ratio of the total power consumption of a data centre to the power consumption of IT equipment. Obviously, the PUE is greater than 1 because the power consumption of the data centre is the sum of the power consumption of the air conditioning system and the IT equipment. Let PUE be the PUE of data centre c. \( P_{idle}^c \) and \( P_{peak}^c \) represent the idle power and peak power of data centre c. Let \( d_{c,t} \) be the workload of data centre c; \( P_{c,t} \) represents the total power consumption of data centre c at time t. There are:

\[
P_{c,t} = \alpha_c + \beta_c \left( d_{c,t} + \pi_{c,t} \right), \forall c, t
\]

\[
\alpha_c = C_c \left( P_{idle}^c + (PUE_c - 1)P_{peak}^c \right)
\]

\[
\beta_c = P_{peak}^c - P_{idle}^c
\]

2.2. Charging and Discharging Model of Energy Storage Power Station

The residual energy (RE) of an internal energy storage power station s with two continuous time gaps \( \Delta t \) is described in equation (4).
where $S_{s,t}$ is residual capacity of energy storage system $s$ at time $t$; $\eta^c_s$ and $\eta^d_s$ are charge and discharge efficiency of battery; $P^c_{s,t}$ and $P^d_{s,t}$ are charging and discharging power of energy storage system $s$ at time $t$; $\Delta t$ is unit time of energy storage charge and discharge; $P_{s,t}$ is the power of energy storage system $s$ at time $t$ is positive when charging and negative when discharging.

The remaining capacity and charging and discharging power constraints of the energy storage system are as follows:

\begin{align}
S_{s,t}^{\min} & \leq S_{s,t} \leq S_{s,t}^{\max} \\
0 & \leq P^c_{s,t} \leq P^c_{s,t}^{\max} u^c_{s,t} \\
0 & \leq P^d_{s,t} \leq P^d_{s,t}^{\max} \cdot (1 - u^c_{s,t})
\end{align}

where $S_{s,t}^{\min}$ and $S_{s,t}^{\max}$ are the upper and lower bounds of the residual capacity of the energy storage system $s$; $P^c_{s,t}^{\max}$ and $P^d_{s,t}^{\max}$ are maximum charge and discharge power of energy storage system; To avoid simultaneous charging and discharging of the energy storage system, it is specified that $u^c_{s,t}$ is a binary indicator and 1 is the charging state.

2.3. Renewable Energy Model

2.3.1. Wind Power Model

In the wind power generation system, the main function of wind turbine is to convert wind energy into mechanical energy. The blade and runner of wind turbine are modeled by blade element theory.

\begin{equation}
P_{w,t} = \frac{1}{2} \rho \eta_w S_w v_t^3
\end{equation}

where $\rho$ is air density; $\eta_w$: coefficient of wind energy utilization; $S_w$ is the area swept by the blades; $v_t$ is for actual wind speed.

Wind speed has a significant impact on fan output, wind power generation has a strong randomness and instability. Based on the actual wind speed data from the In-dependent Power System Operator in Ontario, Canada, the power curves of a single wind turbine can be calculated using formula (9).

2.3.2. Photovoltaic Generation Model

According to the principle of photovoltaics, the output power of photovoltaic power generation is affected by the device temperature $T_{s,t}$ and is related to the light intensity $E_t$, the area $S_c$ of the Solar Array Plate and the photoelectric conversion efficiency $\eta_{c,t}$, as follows:

\begin{equation}
P_{p,v,t} = T_{c,t} E_t S_c \eta_{c,t}
\end{equation}

The equipment temperature $T_{c,t}$ is related to the external temperature $T_{a,t}$. In order to determine the equipment temperature, the standard operating state temperature is obtained here, that is, the standard temperature of the solar cell array panel under fixed conditions (temperature 20°C, wind speed 1 m/s, irradiance 0.8 kW/m²), usually 45°C. According to the model, the temperature of the equipment is:

\begin{equation}
T_{c,t} = T_{a,t} + \frac{T_{a,t} - 20}{0.8}
\end{equation}

where $T_{a,t}$ is standard operating temperature.

The light intensity $E_t$ and external temperature $T_{a,t}$ use Ontario actual data, combined with (10) and (11) to plot the PV power curve per unit area.
3. Economic Benefit Model of Energy Storage Power Station Based on Life Cycle

The net benefit of the distribution network storage power station is the difference between the total benefit and the total cost, the total revenue can be summarized as the following three aspects: the battery life cycle “Low storage high hair” arbitrage revenue, government electricity price subsidy revenue, to delay the benefits of grid upgrading. The total cost is: Battery fixed investment costs and operation and maintenance costs.

Under the condition of power market, the electricity price is lower in the low load period and higher in the peak load period. By controlling the storage energy to charge in the low load period and discharge to the grid in the peak period, the arbitrage can be realized. Then the storage energy “Low storage high development” arbitrage income for:

$$B_t = \sum_{i=1}^{T} [P_{c,i}u_{d,i}^e - P_{c,i}u_{s,i}^e]p_{e,i}$$

$$f_1 = \sum_{i=1}^{T} B_t D (1 + i)^y$$

where $B_t$ is the arbitrage for the current day of storage; $t$ is the time period; $T$ is the total number of sessions; $P_{c,i}^e$ and $P_{c,i}^d$ are the charge power and discharge power of the storage battery at $t$ time respectively; $u_{d,i}$ and $u_{s,i}$ are the charge and discharge state variables in $t$ period of storage battery, respectively; $P_{c,i}$ is the price of electricity in $t$ period; $Y$ is the battery life; $Y$ is the battery life; $D$ is the number of days in a year that the battery is used; $i$ is the rate of inflation; $d_r$ is the discount rate.

At present, due to the high cost of energy storage equipment, in order to promote the development of energy storage industry, the United States, Japan and other countries have a series of policies. China first mentioned the development of energy storage in the amendment of renewable energy law in 2010, but there is no specific industry support policy. In addition to the improvement of relevant laws and regulations, government financial subsidies and other economic incentives have a significant effect. There are two forms of government subsidy: one is construction investment subsidy, the other is electricity price subsidy. In this paper, if the electricity price subsidy is used, the subsidy income of BESS is:

$$B_2 = \sum_{i=1}^{T} P_{c,i}U_{d,i}^e P_{FIT,e}$$

$$f_2 = \sum_{i=1}^{T} B_t D (1 + i)^y$$

where $B_2$ is the subsidy income for the current day of energy storage; $P_{FIT,e}$ is an additional government subsidy for electricity prices.
When the load of a line in distribution network increases year by year and exceeds the capacity, it is necessary to upgrade the distribution network. The traditional method of distribution network upgrade is to add or replace transformers or to retrofit distribution lines, and the cost of such upgrade is high. BESS installed near the load side can reduce the cost of grid investment and construction by reducing peak load and filling valley to achieve peak load regulation. If the annual growth rate of load is $\tau$ and the peak-shaving rate of energy storage is $\lambda$, the number of years when BESS can delay the grid upgrade is:

$$\Delta n = \frac{\log_{10}(1 + \lambda)}{\log_{10}(1 + \tau)}$$

The benefit of delaying the grid upgrade:

$$B_3 = C_{inv}[1 - (1 + i_r)^{-\Delta n}]$$

$$f_3 = B_3$$

where $\Delta n$ is the number of years to delay the grid upgrade; $C_{inv}$ is construction costs of grid upgrades.

The life cycle cost of battery mainly includes fixed investment cost and operation and maintenance cost. The fixed investment cost is related to the rated capacity and the rated charge-discharge power, which are independent of each other in forming the investment cost of energy storage, can be expressed as:

$$C_1 = C_p \bar{P} + C_e \bar{E}$$

$$f_1 = C_1$$

where $C_1$ is fixed investment cost of storage battery; $C_p$ is the cost of unit charge and discharge power of storage battery; $\bar{P}$ is rated charge and discharge power of storage battery; $C_e$ is cost per unit capacity of storage battery; $\bar{E}$ is rated capacity of battery.

The operation and maintenance cost of BESS is mainly related to the rated power of storage battery:

$$C_2 = C_m \bar{P}$$

$$f_2 = \sum_{y=1}^{Y} C_y \left(\frac{1 + i_r}{1 + d_r}\right)^y$$

where $C_2$ is current annual operating and maintenance cost of storage battery; $C_m$ is annual operating and maintenance cost per unit charge and discharge power of storage battery.

4. Overall Strategy of Two-stage Optimization Model

4.1. Influence of Energy Storage Station on Distribution Network Planning

The storage power station is a new type of load in the receiving distribution network, which can reduce the peak value of the absorbed power from the main network, smooth the load curve, improve the utilization ratio of the power equipment, and promote the utilization of the distributed renewable energy, reduced investment in grid upgrading and expansion, therefore, is often used as an absorption measure in conjunction with distributed new energy sources to connect the grid. The location and capacity of storage power station in distribution network should be considered: not only the access location of storage, but also the power and capacity of storage. Conventional distribution network expansion planning only considers peak load level, so it is difficult to determine the amount of electricity stored in the energy storage system. In the first stage, the capacity of the storage power station is determined by minimizing the total life cycle cost of the storage energy. In the second stage, the capacity of the storage power station is determined based on the optimization results of the first stage, considering the optimal strategy of energy storage and distributed new energy in the day, the optimal storage capacity allocation and charging and discharging strategy are determined.
4.2. Influence of Renewable Energy Generation on Distribution Network Planning

The new type of renewable energy in the form of distributed power supply can reduce system losses, voltage fluctuations and reduce grid operating costs and investment in upgrading and expansion. The output of distributed new energy is affected by wind power, light intensity, temperature and humidity, which leads to serious fluctuation and uncertainty of its output, users will first choose a new power source, resulting in smaller load data, power capacity expansion, higher deviation value [20]. When large-scale new energy sources are connected to distribution network, the similarity of historical load curves will change to some extent, and the accuracy of load forecasting will decrease. The distributed power supply and energy storage system can be used to suppress the real-time power fluctuation of the distribution system, which can increase the power supply capacity and improve the reliability of the system.

4.3. Overall Strategy for Joint Optimization

A unified optimization model can be established for joint planning of storage power station and distributed generation, but the problem is very complex and the model is difficult to be solved directly. Especially for the power of charging and discharging at different time and the energy coupling at different time, the scale of the problem increases rapidly with the number of scenarios considered and the number of consecutive time periods. Therefore, this paper adopts the idea of phased planning as shown in Figure 3. In the first stage of planning, the optimal capacity and charge and discharge power of the energy storage power station are first determined, and in the second stage, the strategy of the first stage is used for joint optimization of the energy storage power station and new energy, so as to determine the optimal charge and discharge strategy of the energy storage power station.

5. Two-stage Optimization Model

5.1. First-stage Optimization Model

The objective of optimization in this stage is to maximize the total return over the life cycle, that is, to maximize the difference between the total return and the total cost. The objective function is:

$$\max F_1 = f_1 + f_2 + f_3 - f_4 - f_5$$

(23)

where $f_1$ is arbitrage of “Low storage and high incidence” in the life cycle of storage battery; $f_2$ is government revenue from electricity price subsidies; $f_3$ is the benefits of delaying the grid upgrade; $f_4$ and $f_5$ are fixed investment cost and operation and maintenance cost of storage battery.

The model constraints are as follows:
\[
\begin{align*}
S_{s,t} &= S_{s,t-1} + (\eta_t^e \cdot P_{s,t}^e - 1/\eta_t^d \cdot P_{s,t}^d) \cdot \Delta t \\
P_{s,t} &= \eta_t^c \cdot P_{s,t}^c - 1/\eta_t^d \cdot P_{s,t}^d \\
S_{s,t}^{min} &\leq S_{s,t} \leq S_{s,t}^{max} \\
0 &\leq P_{s,t}^d \leq P_{s,t}^{d,max}u_{s,t} \\
0 &\leq P_{s,t}^d \leq P_{s,t}^{d,max} \cdot (1 - u_{s,t})
\end{align*}
\]  

(24)

In addition, in order to ensure that the energy can be recycled during the discharge cycle of the energy storage battery, the energy storage power station satisfies the conservation of energy in one charge-discharge cycle, that is, the equation constraint

\[
\sum_{t=1}^{T} [P_{s,t}^d - P_{s,t}^e \eta] = 0
\]

(25)

where \(\eta\) is BESS energy efficiency, for batteries with different mediums, \(\eta\) varies.

5.2. Second-stage Optimization Model

In the context of time-of-use pricing, on the one hand, because the low price period will last for several hours, it is possible to achieve the maximum total revenue under different energy storage capacity and different charging and discharging strategies, but with the full life cycle economic benefit model of energy storage, can not achieve global optimization; On the other hand, the energy storage charging and discharging strategy is obtained from the first-stage optimization model, which often leads to a new peak load in the period of low price. The new peak load will even exceed the original peak load, which is unacceptable to the grid companies. Aiming at this problem, this paper presents the second-stage optimization problem. In order to minimize the global peak-valley difference and maximize the benefits associated with it, the storage power station minimizes the local peak-valley difference during the current control period.

The goal is to minimize peak-valley differences:

\[
\begin{align*}
\min F_2 &= \sum_{t=1}^{T} \left[(P_{load,t} + P_{s,t} + P_{c,t} + P_{w,t} + P_{pv,t})
\right.

\left. - \frac{1}{m} \sum_{t=1}^{m} (P_{load,t} + P_{s,t} + P_{c,t} + P_{w,t} + P_{pv,t})\right] ^2
\end{align*}
\]

(26)

where \(P_{load,t}\) is the load of distribution network at time \(t\) is studied; \(T\) is number of load measuring points in a day, in this paper, a measuring point is set for 15 min and \(T=96\); Let the current measurement point be \(t = m\), then when \(1 \leq t \leq m\), \(P_{load,t}\), \(P_{s,t}\), \(P_{c,t}\), \(P_{w,t}\), \(P_{pv,t}\) are respectively the known actual load at time \(t\), known stored energy charge-discharge load, known power consumption of data center \(c\), wind power output and photovoltaic output; when \(m+1 \leq t \leq T\), \(P_{load,t}\) is \(t\) time forecast load; \(P_{s,t}\) is the charge and discharge power of energy storage system \(s\) between time \(t\) and time \(t+1\); \(P_{c,t}\) is the power consumption of data center \(c\) between time \(t\) and time \(t+1\); \(P_{w,t}\) is the output of wind power between time \(t\) and \(t+1\); \(P_{pv,t}\) is the photovoltaic output between time \(t\) and \(t+1\).

In order not to affect the basic income of the energy storage power station, the maximum income constraint obtained from the first-stage optimization model will be considered in the second-stage optimization model. The addition of this constraint condition may lead to the deterioration of the overall income of the energy storage power station, but when it is difficult to quantify the income related to the local peak-valley difference, considering this constraint condition, a satisfactory solution can be obtained, which is no less than that of the first stage, so this constraint is still included in the discussion.

Optimal revenue constraint:

\[
C_1 + C_2 + C_3 - C_4 - C_5 = F_{max}
\]

(27)
where $F_{\text{1max}}$ is the minimum operating cost calculated by the first-stage model. This constraint ensures that the solution of the second-stage optimization model must satisfy the first-stage optimal benefit.

The other constraints of the second-stage optimization are: Formula (4)–(8)

6. Case Study

6.1. Introduction of Relevant Parameters

In this paper, a feeder from a regional distribution network is selected as the re-search object for the optimal configuration of the energy storage system of the active distribution network, and the effectiveness of the research model and method is illustrated by it. The example system is shown in Figure 4.

![Figure 4. Energy storage optimization configuration example system.](image)

As shown in Fig. 4, the transformer used in this paper for the optimal configuration of the energy storage system of the active distribution network has a capacity of 10000kVA and is a 33-node feeder with two renewable power generation units, of which the parameter configuration of two renewable power generation units and the relevant parameters of the battery energy storage system are shown in Table 1. It is known that the construction cost of the power grid upgrade is 300,000 USD, the inflation rate is 1.5%, the discount rate is 9%, the annual load growth rate is 1.5%, the additional electricity price subsidy from the government is 2.75 USD/ MW.h, and the energy storage plant operates for 250 days every year.

| Name                  | Unit     | Quantity       |
|-----------------------|----------|----------------|
| Renewable Energy      |          |                |
| photovoltaic generation | kW      | 500(peak value) |
| wind power generation | kW       | 500(peak value) |
| $C_r$                 | USD/kW   | 250            |
| $C_c$                 | USD/kWh  | 190            |
| $C_m$                 | USD/kW   | 9              |
| $\eta$                | %        | 80             |
| $T$                   | a        | 15             |

In order to meet the requirements of smart grid, many distribution networks have measurement terminals in many places to collect and upload operation data. Normally, the measurement terminal collects the data every 15 minutes and uploads it to the data centre of the Power Supply Bureau. Figure 5 below shows the typical daily load measurement data of a regional distribution network, presenting a basic pattern of one trough and two peaks, with the highest point appearing around 20:00 in a day. According to the TOU price system shown in Table 2 below, the arbitrage return of "low storage and high release" of the energy storage system is calculated. The scheduling period of the energy storage system is from 0:00 to 24:00, and the whole scheduling cycle is divided into 96 periods, each of which is 15 minutes in length.
Figure 5. Typical daily load curve of a regional power grid.

Table 2. Time of use tariff

| Time of day       | Time of use tariff (dollar/kwh) |
|-------------------|---------------------------------|
| 23:00-07:00       | 0.37                            |
| 07:00-10:00       | 0.67                            |
| 10:00-15:00       | 1.12                            |
| 15:00-18:00       | 0.67                            |
| 18:00-21:00       | 1.12                            |
| 21:00-23:00       | 0.67                            |

6.2. Analysis of Calculation Results

In order to ensure that the energy storage system connected to the power grid does not cause a big impact on the upper power grid and considering the construction and installation costs of the energy storage system, the total capacity of the energy storage system should not be more than 25% of the upper transformer capacity; Second, for complete Intermittent energy source, the total capacity of the storage system shall not be less than the sum of the capacities of the Intermittent energy source minus the minimum load of the feeder, and therefore the total capacity limit of the storage system shall not be less than 1.5 MWh, not more than 2.5 MWh. In this paper, the energy storage capacity is set to 1.5 MWh, 2 MWh and 2.5 MWh, respectively, and the optimal scheduling strategy of energy storage is obtained as shown in Figure 6 below. The two-stage target values are shown in Table 3 below.

Figure 6. Charging and discharging strategy optimization results of energy storage system under different capacities.

Table 3. Two stage target values of energy storage system under different capacities

| Capacity  | Full life cycle net income | Load standard deviation |
|-----------|-----------------------------|-------------------------|
| 1.5MWh    | 68318                       | 404.09                  |
| 2MWh      | 66243                       | 372.12                  |
| 2.5MWh    | 62471                       | 341.11                  |

From the above results, it can be seen that the larger the storage capacity, the smaller the load standard deviation, that is, the smaller the load fluctuation. But because of the objective factors such as the cost of land and the cost of energy storage devices, energy storage investors will not blindly pursue the
maximization of energy storage capacity, according to the first stage of the life cycle net income calculation results can be seen when the storage capacity of 1.5 MW. H has the largest life cycle, and with the increase of energy storage capacity, the life cycle return decreases gradually. This is due to the limited development of energy storage technology, energy storage devices high fixed investment costs, but the annual rate of return on investment is smaller. Therefore, considering the two-stage optimization goal, 2MW.h is the optimal capacity allocation of the regional distribution network.

For the determination of the initial state of energy storage, the existing research takes into account the balance of the storage capacity between the beginning and the end of the whole scheduling cycle, and the initial state is set as a constant, so that the reasonable initial state can maximize the use of the peak cutting and valley filling effect of energy storage, improve the reliability of system operation. Under the same energy storage capacity, the two-stage optimization results of different initial states are compared without changing other factors. The optimization results of the charge state curves of the energy storage system under different initial states are shown in Figure 7 below. Under the same storage capacity, the fixed investment cost is the same, so the optimal initial state can be determined from the angle of arbitrage income, life cycle and equilibrium load fluctuation. The results show that the ability of balancing the fluctuation of new energy load is the greatest when the initial charge state of energy storage is 0.1. Combined with the fitting result of storage life cycle and charge-discharge depth, storage energy deep-charging and deep-drawing cycle can reduce the battery life, and 0.1 initial charge state can easily lead storage energy into deep-charging and deep-drawing cycle and increase the use cost. In this paper, the storage capacity is 2 MW.h and the initial charge state is constant 0.2. Using the above two-stage optimization model, the optimal scheduling results of charging and discharging of the energy storage system are obtained as follows: 8, the charging power of the energy storage system is less than 0, greater than 0 is the discharge power.

![Figure 7. SOC curve comparison of energy storage in different initial states.](image)

![Figure 8. Calculation results of optimal charging and discharging strategy of energy storage system.](image)

7. Conclusions

It is found that the energy storage power station plays multiple functions in multi-station fusion. The optimal operation strategy is as follows: On the one hand, the optimal operation strategy of the energy storage system is determined by the time-of-use price, the battery life and the load characteristics of distributed renewable energy. On the other hand, the configuration of the energy storage system is a
decision-making problem in a long time frame. With the existing technology and investment cost, the fixed investment cost of the energy storage device is still high, but the annual return rate of investment is small. In this paper, a charge-discharge strategy model of “Maximum return-minimum fluctuation” is established, which considers the life cycle return of the battery, the impact of energy storage systems and distributed new energy systems on regional distribution networks can be minimized.

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