Optimal Allocation Algorithm of Grid Side Energy Storage Capacity under Large Scale Wind Farm Connection

Junpeng Ma1*, Jianjun Sha2, Feiyan Liu1

1NINGXIA ELECTRIC POWER DESIGN INSTITUTE Co.,Ltd, Yinchuan, Ningxia, 750016, China
2CHINA DEVELOPMENT BANK NINGXIA BRANCH, Yinchuan, Ningxia, 750004, China
a*majunpeng@nxepdi.com.cn

Abstract—For grid energy storage capacity configuration is not reasonable, problems such as instability in crossing the river power fluctuations, are proposed based on a large scale wind power grid side under the condition of energy storage capacity of the optimal allocation algorithm, through the use of large-scale wind farm access method to achieve the optimal design of power grid model, so as to quickly solve the micro grid energy storage capacity planning cost and energy consumption data, according to the results. The operation parameters, energy loss and other numerical values of the model in the power grid are controlled, and according to the calculation results. Finally, the experiment proves that the optimization configuration algorithm of the power grid side energy storage capacity under the large-scale wind farm access has higher practicability and accuracy in the practical application process, and fully meets the research requirements.

1. Introduction
Micro-grid energy storage optimal allocation is a research hotspot. In particular, based on the complementary advantages of super capacitors and batteries, the operating strategy of energy storage equipment is determined by spectrum analysis and probabilistic analysis, and the annual life cost of various types of energy storage equipment is taken into account when the mixed energy storage capacity is allocated[1]. However, the factors of energy storage capacity are not taken into account when the cost of energy storage equipment is calculated, and the operating mode of energy storage system taking into account of fluctuation is calculated according to the output force and load forecast, and the optimal allocation method of energy storage capacity is obtained by establishing the decision-making variables of the planning model[2]. Two optimization methods, emission minimization and lifetime optimization, are used to optimize the configuration of the energy storage system.

2. Optimal Allocation Algorithm for Energy Storage Capacity of Power Grid Side
2.1. Structure of Outer Model of Power Grid Side Energy Storage Capacity
The new characteristics of distributed energy and the appearance of new technology in large-scale distributed access distribution network will have great influence on the planning, operation and analysis of distribution network[3]. At present, the rapid development of a series of intelligent information technology, such as Internet, big data, communication, will become an indispensable
important technology of active distribution network. Key Technologies for Grid Side Storage Structure Based on External Model Structure Shown in the Figure, Mainly Including Basic Technologies and Core Technologies:

![Diagram of key technologies](image)

But the basic technology such as information communication technology, power electronics technology is the foundation of active distribution network, is to achieve other functions of active distribution network support technology. Active network comprehensive planning technology, operation control technology, energy management technology and other core technologies, its core technology is to achieve active distribution network efficient, reliable and safe operation of the technical support. In order to improve the reliability of the inverter, the redundancy design such as the hot and cold backup and the redundancy design of the multi-axle arm are used.

| position | type                        |
|----------|-----------------------------|
| 1        | DC bus current short circuit|
| 2        | The power device has no driving signal |
| 3        | DC bus grounding            |
| 4        | Power open circuit fault    |
| 5        | Inverter output single-phase open circuit |

Integrated planning technology is an active coordination planning method based on the interaction of distributed energy and user load, which integrates the variation characteristics and time distribution of distributed energy and power load to meet planning constraints. The comprehensive planning technology of active distribution network mainly includes the establishment of mathematical model of DG, the prediction of multi-time scaling power, the establishment and prediction of load model, the allocation and optimal management of energy storage system capacity, the evaluation of economic reliability of system, etc.

2.2. Data Processing Algorithm for Energy Storage Layer on Power Grid Side
The smoothing component of wind power output is extracted as grid-connected power, and the fluctuation component is used as energy storage power instruction, which retains the intermittence and volatility. The process of transforming quantitative data into qualitative concepts is called cloud transformation. The cloud transform method is to obtain the local maximum value of the spectrum function f(x) of the sample j as the local maximum value of the cloud model, then establish the cloud
model C (E_x, E_n, H_c) and its distribution function f_{cloud}, then subtract the local maximum value of the f_{cloud} from the original distribution function f(x), and then extrapolate the mathematical expression of the original distribution function f(x) into different granularities of the cloud model C (E_x) as follows: …

\[ f(x) \to \sum_{i=1}^{k} \left( a_i C \left( E_x, E_n, H_c \right) \right) \quad (1) \]

In the formula: \( a_i \) is the distribution frequency of each sub-cloud model; \( k \) is the number of transformed discrete cloud models, that is, the number of clusters automatically determined through the cloud model. Data analysis shows that the stochastic wind velocities in most areas conform to Weibull distribution. According to the historical meteorological data of the scheme area, the random light intensity distribution \( W(k) \), \( K_c \) is +5. At this time, the relationship between light intensity and solar output power can be described as follows:

\[ P_{pv} = \begin{cases} \frac{S}{s_r} & 0 \leq s \leq s_r \\ P_{pv} & s_r < s \end{cases} \quad (2) \]

In the formula, \( P_{pv} \) is the output power at the operating point; \( P_{pv} \) is the standard rated PV output power; \( S \) indicates light intensity. \( s_r \) indicates rated light intensity. The analysis process of smooth control strategy is complicated. In the time dimension, the output power of the power grid is limited to the short-term unit length and the long-term unit time length. It can be expressed in terms of short range unit time \( T_1 \). That is, the period during which the output power of the grid energy storage system changes dramatically, and the long-term unit time can be expressed as \( T_2 \). That is, the power storage system of the power grid output to maintain a stable time period. In conjunction with the above physical quantities, the fluctuation index of energy storage power of grid-connected photovoltaic power grid may be defined as:

\[ Q = \frac{T_1}{\gamma_1 e} + \frac{T_2}{\gamma_2 e} \quad (3) \]

Among them, \( \gamma_1 \) is the current transfer coefficient of the grid-connected photovoltaic node under short-term conditions. \( \gamma_2 \) is the photovoltaic grid-connected node current transfer coefficient under the action of long time unit, \( e \) It is the curvature change condition of the output power wave of the energy storage system. Using this formula, the short-term smoothing characteristics of power grid energy fluctuation can be predicted as follows:

\[ U = \sum_{\alpha=1}^{\infty} \gamma |p - p'| |u - u'| \quad (4) \]

Among them, \( R \) is the physical value of the energy storage resistor of the main circuit of the grid, \( p' \) represent the node mobility coefficient, \( u' \) is the loss of voltage in error range, \( \gamma \) represents a photovoltaic storage condition, \( |D| \) represents the normal wave parameters of energy storage.

2.3. Realization of Optimal Allocation of Energy Storage Capacity in Power Network

Solar energy can be generated by solar power generation, there are two main ways of solar thermal power generation and photovoltaic power generation. It is found that solar thermal power generation is superior to photovoltaic power generation in terms of power quality, power generation reliability and stability. Usually expressed as k. Common energy wave curvature \( \lambda \), along with the extension of
transmission energy storage time, the tendency of deflection accumulation may appear. In the simultaneous formula, the maximum grid-connected PV conditions may be expressed as follows:

\[ a \uparrow = \lambda \left( \frac{U}{\beta k} - l'' \right)^2 \quad (5) \]

Among them, \( \beta_1 \) is the maximum energy storage of PV grid-connected regulation expressed by this method. \( L \) represents the original output vector of the grid fluctuation electron, and \( l' \) represents the actual output vector of the grid fluctuation electron. Can be represented in simultaneous formulas by the control vector adjustment domain:

\[ \{3\} = \left\{ j \cdot \frac{\sum Y_{1}^{2} + Y_{2}^{2}}{\theta \cdot m} \right\} \quad (6) \]

Among them, \( j \) represents the random power fluctuation vector in the control vector regulation domain, \( Y_1 \) represents the utilization coefficient of the photovoltaic grid connection condition, \( Y_2 \) represents the utilization coefficient of the lower limit photovoltaic grid connection condition, \( \theta \) is the PV grid-connected processing parameters represent the grid energy storage system, \( M \) represents the total photovoltaic generation. Based on the charge-discharge characteristics of energy storage system, a management strategy for charging and discharging of energy storage system is proposed and its structure diagram is given.

Fig. 2 Charge and discharge management strategy of power grid energy storage system

In the renewable energy generation system, the energy storage system plays a role in keeping up with the net load. The so-called net load refers to the load value after the power difference from the actual load in the renewable energy generation system, and can also be used as the net load that the distribution network and the energy storage system need to meet. In order to change some unreasonable power consumption habits of residential users, the power consumption time and power consumption under different loads can be optimized and adjusted by optimizing the energy consumption load of individual users, so as to change some unreasonable power consumption habits of residential users and realize the optimal distribution of power consumption load of single users.

3. Analysis of experimental results
Since the volatility of wind resources is greater than that of light radiation, it is difficult to grasp and evaluate the output of distributed wind power generation system. In this paper, kmo-Bartlett double-check method and principal component analysis method are used to predict wind energy. At the same time, taking the summer wind speed monitoring data of a city and a region as an example, the short-term prediction of the summer typical day wind speed is carried out. Among these data, the sampling interval of daily wind speed data is 1 h, and the number of daily sampling points is 24. A total of 6
groups of wind speed data are selected, and each group of wind speed data is the historical wind speed data of a total of 10 days. The double test result table of KMO and Bartlett test results is shown in the table 2.

| Data / group | Kmo test statistics | Concomitant probability of Bartlett sphericity test | Chi square value |
|--------------|---------------------|-----------------------------------------------------|-----------------|
| A            | 0.506               | 0.125                                               | 28.7            |
| B            | 0.635               | 0.028                                               | 35.9            |
| C            | 0.465               | 0.001                                               | 48.6            |
| D            | 0.556               | 0.002                                               | 58.6            |
| E            | 0.863               | 0.000                                               | 69.5            |
| F            | 0.825               | 0.000                                               | 85.2            |

According to the relationship between the simple correlation coefficient and the KMO test variables, the variable data were used as experimental parameters for comparison and control. The indexes of KMO test were shown in the table 3.

| Kmo test statistics | Standard degree                          |
|---------------------|------------------------------------------|
| 9 above             | fit as a pudding for a friar's mouth     |
| 7~9                 | appropriate                              |
| 5~7                 | More appropriate                         |
| 3~5                 | commonly                                 |
| 1~3                 | inappropriate                            |

The measurement of KMO test is that if the test statistics are greater than 0.5, principal component analysis can be performed, and the closer to 1, the more suitable for principal component analysis. When the concomitant probability of bartlett sphericity test is less than the significant level of 0.5, it is suitable for principal component analysis.

For the distributed power output uncertainties and load fluctuation characteristics of probabilistic model, considering the accuracy of the life energy storage system, running condition in the micro grid, for example, energy storage capacity of the micro grid configuration is optimized, and combining the economy and environment protection, energy storage capacity of the micro grid configuration to record, record grid configuration of energy consumption of the comparison result.

![Graph showing comparison results of power grid energy consumption configuration efficiency](image_url)
As shown in the figure, if the optimal allocation rate is achieved, 1.4548 tons of polluting gas will be produced per hour. When the generating capacity is greater than the cumulative load and the system energy storage is insufficient, gas turbine must be used to make up for the shortage of generating capacity. At this time, it is not suitable to use gas turbine because of its high energy consumption and high cost. The service life of the energy storage system in the same region can be predicted accurately by using the two methods of the fixed energy storage life and the accurate calculation of the energy storage life. The daily energy storage capacity of the power grid with different input years is obtained. The following figure shows the comparative analysis curve of the daily power of the power grid:

![Comparison and analysis results of average daily energy storage capacity of the power grid](image)

Fig. 4 Comparison and analysis results of average daily energy storage capacity of the power grid

Through the example simulation analysis, verified the improved harmony search algorithm and the correctness and rationality of the energy storage system to charge and discharge management strategy, make better use of the distributed energy, overcome simple distribution power capacity or the limitation of the capacity of optimizing the allocation of energy storage system, effectively reduce the energy storage system of the investment construction costs, but also can improve the operation parameters of the network.

### 4. Conclusions

This paper considers the requirements of large-scale wind power output fluctuation on the optimal allocation of energy storage system capacity. Based on the energy storage operation curve of wind power output, the characteristics of one-year wind turbine energy storage operation curve are extracted and summarized by using the method of adaptive wavelet packet. At the same time, we take the typical operation curve as the input capacity optimization model, and finally realize the reasonable configuration of the energy storage system.

### References

[1] Ahsbahs T., Nygaard N. G., Newcombe A. (2020), Wind Farm Wakes from SAR and Doppler Radar. Remote Sensing, 12(3):462.

[2] Peng Y., Li Y., Lee K. Y. (2020), Coordinated Control Strategy of PMSG and Cascaded H-Bridge STATCOM in Dispersed Wind Farm for Suppressing Unbalanced Grid Voltage. IEEE Transactions on Sustainable Energy, PP(99):1-1.

[3] Allaerts D., Meyers J. (2019), Sensitivity and feedback of wind-farm-induced gravity waves. Journal of Fluid Mechanics, 862(5):990-1028.

[4] Biswas S., Nayak P. K., PrAdhan G. (2021), A Dual-Time Transform Assisted Intelligent Relaying Scheme for the STATCOM-Compensated Transmission Line Connecting Wind Farm. IEEE Systems Journal, PP(99):1-12.

[5] Durairaj U M., Selvaraj S. (2020) Two-Level Clustering and Routing Algorithms to Prolong the Lifetime of Wind Farm-Based WSN. IEEE Sensors Journal, PP(99):1-1.
[6] Yang R H, Jin J X. (2020), Unified Power Quality Conditioner With Advanced Dual Control for Performance Improvement of DFIG-Based Wind Farm. IEEE Transactions on Sustainable Energy, PP(99):1-1.

[7] Lee G, Kwon D, Moon S I. (2020), DC Current and Voltage Droop Control Method of Hybrid HVDC Systems for an Offshore Wind Farm Connection to Enhance AC Voltage Stability. IEEE Transactions on Energy Conversion, PP(99):1-1.

[8] Lee G, Kwon D, Moon S I. (2020), DC Current and Voltage Droop Control Method of Hybrid HVDC Systems for an Offshore Wind Farm Connection to Enhance AC Voltage Stability. IEEE Transactions on Energy Conversion, PP(99):1-1.

[9] Ghafouri M, Karaagac U, Kocar I. (2021), Analysis and Mitigation of the Communication Delay Impacts on Wind Farm Central SSI Damping Controller. IEEE Access, PP(99):1-1.