Research on Energy Storage Configuration Method Based on Wind and Solar Volatility

Shi Xuewei
Wind and Solar Power Energy Storage Demonstration Station Co., LtdState Grid
Hebei Province Wind and Solar Energy Storage Combined Power Generation Technology Innovation Center
Zhangjiakou, China
shixuewei2@126.com

Shi Xuefang
Hebei College of Science and Technology
Baoding, China
1468998271@qq.com

Dong Wenqi
Wind and Solar Power Energy Storage Demonstration Station Co., LtdState Grid
Hebei Province Wind and Solar Energy Storage Combined Power Generation Technology Innovation Center
Zhangjiakou, China
dwq30@163.com

Zang Peng
Wind and Solar Power Energy Storage Demonstration Station Co., LtdState Grid
Hebei Province Wind and Solar Energy Storage Combined Power Generation Technology Innovation Center
Zhangjiakou, China
zp7416@163.com

Jia Hongyan
Wind and Solar Power Energy Storage Demonstration Station Co., LtdState Grid
Hebei Province Wind and Solar Energy Storage Combined Power Generation Technology Innovation Center
Zhangjiakou, China
798123187@qq.com

Wu Jinfang
Wind and Solar Power Energy Storage Demonstration Station Co., LtdState Grid
Hebei Province Wind and Solar Energy Storage Combined Power Generation Technology Innovation Center
Zhangjiakou, China
1558409376@qq.com

Wang Yang
Wind and Solar Power Energy Storage Demonstration Station Co., LtdState Grid
Hebei Province Wind and Solar Energy Storage Combined Power Generation Technology Innovation Center
Zhangjiakou, China
810356384@qq.com

2020 10th International Conference on Power and Energy Systems (ICPES) | 978-1-6654-0494-5/20/$31.00 ©2020 IEEE | DOI: 10.1109/ICPES51309.2020.9349645

***Abstract*—Vigorously developing the new energy has become an important measure for our country's energy strategy adjustment and transformation of the power development mode. However, it provides significant challenges to the grid for their large-scale integration because of their random and volatile characteristics, such as wind power and photovoltaics. The introduction of energy storage devices can improve this situation effectively, to promote the large-scale application of new energy. Based on the historical wind and solar data of the National Wind and Solar Storage and Transportation Demonstration Project, this paper analyzes the 15-minute and 10-minute fluctuation characteristics of wind and solar power generation. It also studies the control method of energy storage system to improve the friendliness of wind and solar power generation, based on the control strategies such as smoothing new energy output fluctuations, tracking planned power generation, peak shaving and valley filling, and participation in system frequency modulation.**

Keywords—Energy storage, wind and solar Volatility, Configuration Method

I. Introduction

Vigorously developing new energy has become the only way to ensure energy security, solve environmental problems, and fulfill its emission reduction commitments of our country. In the past decade, the new energy power generation of our country has developed rapidly, with wind power and photovoltaic grid-connected capacity increasing more than 100 times. According to our country's development plan, by 2030, our new energy will surpass hydropower to become the second main power source, accounting for 33.3% with installed capacity and 15.7% with power generation.

Wind and solar power generation is characterized by volatility, and its large-scale access will have a large impact on the safe and stable operation of the power grid. By adding an energy storage system to wind and solar power generation, we can take advantage of its charging and discharging characteristics to keep the total output active power of the wind and solar combined power generation system relatively stable, reduce power fluctuations, improve power quality, and reduce the impact on the grid.

Located at the junction of Zhangbei and Shangyi counties in Zhangjiakou City, Hebei Province, the National Wind and Solar Storage and Transmission Demonstration Project is currently the largest comprehensive new energy utilization platform demonstration project of the world, integrating wind power, photovoltaic power generation, energy storage, and smart power transmission. The demonstration project has completed 450MW of wind power generation, 100MW of photovoltaic power generation and 33MW of chemical energy storage equipment. The first phase of the project, wind power generation, photovoltaic power generation and energy storage have achieved 100MW, 40MW, and 20MW respectively. Based on the historical data of the first phase of Wind and Solar Power Energy Storage Demonstration Station, this study analyses the wind and solar power volatility in Zhangbei area and proposes the energy storage system capacity configuration technology, when smoothing wind and solar output fluctuations.

II. Analysis of the Wind and Solar Power Output Fluctuation

The 10-minute volatility of wind power, photovoltaic power and wind-solar combined power in the three years from 2017 to 2019 of the wind-solar storage and transmission demonstration project is calculated, as shown in Table I. Wind farms, photovoltaic power stations and wind-solar combined power generation all have a 15-minute volatility of more than 15% and a 10-minute volatility of more than 10%, indicating that wind-solar power generation has certain volatility; From the data in Table 1, which is that the probability that 15-minute volatility is greater than 15% and 15-minute volatility is greater than 10% and 33%, it can be seen that the volatility of photovoltaics is greater than that of wind power at different time scales. The 10-minute volatility of wind and solar combined power generation is greater than 10% is between wind power and photovoltaic. The probability of the 15-minute fluctuation rates is greater than 15% and the probability of that the 10-minute volatility rate is greater than 33% is sometimes lower than that of wind power and photovoltaic itself. It shows that wind and solar have a certain complementary effect.

TABLE I. Statistics of Wind and Solar Power Volatility

	years	Wind energy	Solar energy	Wind and solar combined
Probability of 15-minute volatility is greater than 15%（%）	2017	1.82	8.23	1.59
	2018	1.06	8.47	1.66
	2019	1.25	14.1	3.8
Probability of 10-minute volatility is greater than 10%（%）	2017	2.71	8.87	2.75
	2018	1.68	9.03	2.96
	2019	2.1	14.24	5.11
Probability of 10-minute volatility is greater than 33%（%）	2017	0.1	1.8	0.05
	2018	0.4	2.34	0.01
	2019	0.3	4.43	0.1

III. The Method of Energy Storage Configuration for Smoothing Wind and Solar Output Fluctuations

Based on the understanding of wind and solar output power fluctuations, the energy storage system is configured for the purpose of smoothing wind and solar output fluctuations. The application objectives of the combined wind and solar storage system are summarized as follows: the unit time power fluctuation amount λ_{ws} of the combined output of the wind and solar storage system is less than the limit fluctuation amount λ_{lim} of the wind and solar power allowed by the grid. Here, λ_{lim} is treating the combined output of the wind and solar storage as a thermal power or other controllable Adjustable power supplies of the same nature, without additional addition or operating measures, to ensure the safe and stable operation of the power system, the calculated maximum power change per unit time. As shown in formula (1) ~ formula (3):

$$\lambda_{ws} = \left|\frac{dp_w}{d_t} + \frac{dp_s}{d_t}\right| \tag{1}$$

$$\lambda_{lim} = min\left[\begin{array}{l} \left(\frac{dp_w}{d_t}\right)_{str1+}, \left|\left(\frac{dp_w}{d_t}\right)_{str1-}\right|, \left(\frac{dp_w}{d_t}\right)_{str2+}, \\ \left|\left(\frac{dp_w}{d_t}\right)_{str2-}\right| \ldots \left(\frac{dp_w}{d_t}\right)_{stri+}, \left|\left(\frac{dp_w}{d_t}\right)_{stri-}\right| \end{array}\right] \tag{2}$$

$$\lambda_{ws} \le \lambda_{lim} \tag{3}$$

Among them, p_w represents wind and solar combined power, p_s represents the system charging and discharging power of the energy storage system, $(\frac{dp_w}{d_t})_{stri+}$ represents the allowable wind and solar combined power limit increase speed of the grid under the i-th constraint condition, and $(\frac{dp_w}{d_t})_{stri-}$ represents the power grid under the i-th constraint condition. The allowable wind and solar combined power limit reduces the speed.

In addition, λ_{lim} should also meet the National Standard of the People's Republic of China GB-T-200 "Technology for Connecting Wind Power Plants to Power Systems", as shown in Table II.

TABLE II. Recommended Table of Active Power Variation Limits for Wind Power Plants

Wind power plant installed capacity (MW)	10min maximum active power change limit (MW)	1min maximum active power change limit (MW)
<30	10	3
30-150	Installed capacity /3	Installed capacity /10
>150	50	15

At home and abroad, researches on smoothing wind and solar power fluctuations based on low-pass filters are relatively mature. The basic principle of smoothing wind and solar power fluctuations based on low-pass filters is input wind and solar power data into the low-pass filter, and the output of the filter is smoothed. Wind and solar grid-connected power reference value, the difference between the wind and solar power value and the wind and solar grid-connected power is the power value that the battery energy storage system should handle, where the wind and solar grid-connected power reference value and the battery energy storage system should handle the power value can be expressed Such as formula (4), formula (5).

$$P_{out}(s) = \frac{1}{1+T_s} P_w(s) \tag{4}$$

$$P_b(s) = P_{out}(s) - P_w(s) = -T_s \times P_W(s) \tag{5}$$

$P_w(s)$: The output active power of the wind and solar, $P_{out}(s)$: the total output after smoothing, $P_b(s)$: the output power of the battery, T: the smoothing time constant.

Perform inverse Laplace transform on $P_b(s)$ and integrate in the time domain:

$$B(t) = \int_{t_0}^{t} L^{-1}(P_b(s))dt \tag{6}$$

B(t) represents the energy storage capacity value that needs to be configured in the time period (t-t0). When t takes different values, B(t) represents the different capacity requirements of the energy storage system in different time periods. Theoretically speaking, when calculating the rated capacity of the energy storage system, it is only necessary to take the maximum value of the energy storage capacity demand in a sufficient period of time as the rated capacity of the energy storage system.

Based on the historical data of wind and solar energy in Zhangbei area, a simulation study on the ratio of energy storage capacity is carried out when the energy storage system smooth the fluctuation of scenery. Fig. 1 shows the changes of Pout, the reference value of grid-connected power with different time constant T, and Fig. 2 shows the changes of the capacity of the energy storage system with time constant T.

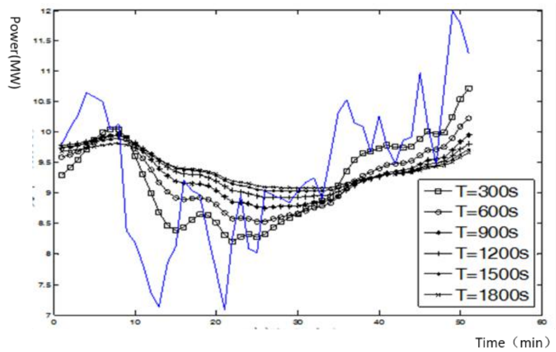

Fig. 1. Variation diagram of grid-connected power reference value Pout with different time constants T

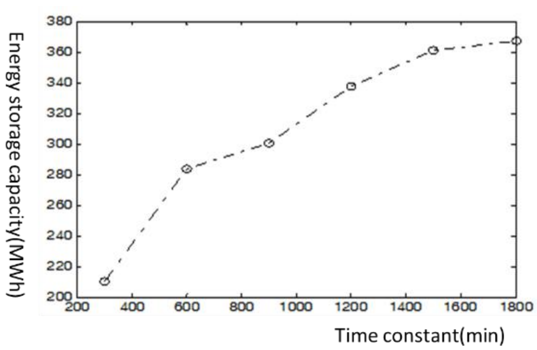

Fig. 2. Variation characteristics of energy storage system capacity with time constant T

As can be seen from the above figure, the smaller the value of the time constant T, the faster the grid-connected power reference value Pout will track the wind and solar output power Pw, and vice versa; the smaller the value of the time constant T, the required rated storage The smaller the energy capacity, the larger the other way around. Therefore, as the time constant of the first-order low-pass filter increases, the energy storage capacity required by the energy storage system to suppress wind and solar power also increases, and there is a nonlinearity between the time constant of the first-order low-pass filter and the energy storage capacity Increasing relationship.

IV. Analysis of Demonstration Project Wind-Solar Storage Ratio

A. *Analysis of Energy Storage Ratio for Smoothing Wind and Solar Fluctuations*

There is a certain degree of complementary characteristics between the wind and solar output, but the fluctuation of the combined output of the wind and solar is still large, and the fluctuation of the combined output can be further smoothed by configuring the battery energy storage system. This section analyzes the ratio of wind and solar energy storage based on historical data from the demonstration project.

According to the typical wind and solar data of the wind and solar storage demonstration project and the above-mentioned smoothing control method, the ratio analysis of the smooth application of energy storage is carried out. The obtained energy storage capacity and volatility are shown in Fig. 3 below. If the wind and solar combined volatility is suppressed to 5%/10 minutes or less, 25MW energy storage is required; if the wind and solar combined volatility is suppressed to 7%/10 minutes or less, 20MW energy storage is required; if the wind and solar combined volatility is reduced To suppress to 10%/10 minutes or less, 15MW energy storage is required; if the wind and solar combined volatility is suppressed to 15%/10 minutes or less, 5MW energy storage is required. Considering the smoothing effect, the configuration of 15MW energy storage can suppress the combined wind and solar volatility to 10%/10 minutes.

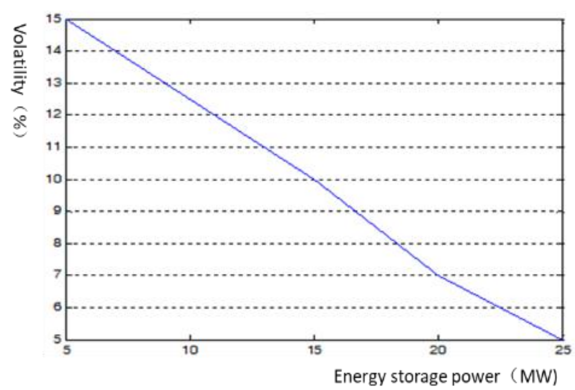

Fig. 3. The relationship between energy storage ratio and volatility when smoothing wind and solar output fluctuations

B. *Analysis of Energy Storage Ratio during Tracking Plan*

Energy storage can improve the day-ahead planning ability of wind power and photovoltaic tracking, thereby enhancing the predictability, the controllability and dispatchability of wind power. The day-ahead forecast for wind power and photovoltaics (96 points a day, each point represents 15 minutes) is used as the day-ahead output planning curve. According to the typical wind and solar power generation data of the demonstration project, in the absence of energy storage, the deviation of the actual output of wind power and the planned curve is shown in Fig. 4.

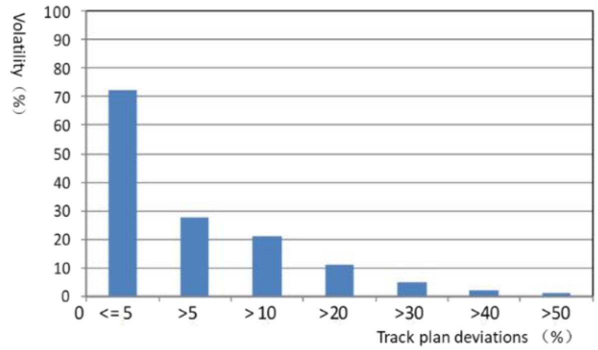

Fig. 4. The probability distribution of the deviation between the actual output of the scenery and the planned output

As shown in Fig. 4, based on the current forecast level, the probability that the actual output deviation of wind and solar is 10% or more is 21%; the probability that the deviation of wind and solar output is 20% or more is 11%; the probability that the deviation of wind and solar output is 30% and above The probability is 5%; the probability of wind-solar output deviation of 40% and above is 2%; the probability of wind-solar output deviation of 50% and above is 1.5%. It can be seen that, without the assistance of energy storage, Wind-solar has a poor ability to track the previous planned output.

As shown in Fig. 5, for 100MW wind power and 40MW photovoltaic, when the energy storage configuration ratio is 7% (and the total energy storage power is 10MW), based on the current forecast level, the probability that the actual wind power output deviation is 10% or more is 11%; the probability of wind-solar output deviation of 20% and above is 1.5%. Has a better improvement.

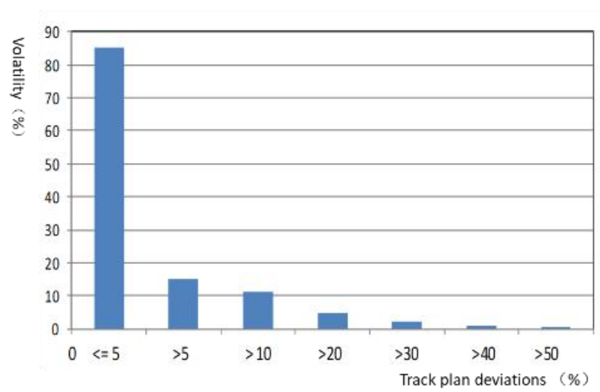

Fig. 5. When the energy storage ratio is 7% (10MW), the probability distribution diagram of deviation between the actual output of wind and solar and the planned output of the day before

As shown in Fig. 6, when the energy storage configuration ratio is 15% (and the total energy storage power is 20MW), based on the current forecast level, the probability that the actual output deviation of wind and solar is 5% or more is 9%, and the actual output deviation of wind and solar is 9%. The probability of 10% and above is 5%; the probability of wind-solar output deviation of 20% and above is 1.5%. Have better ability to improve.

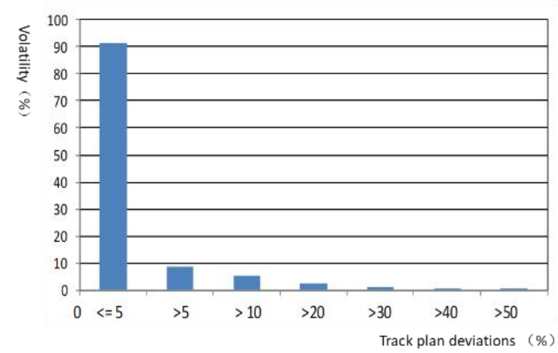

Fig. 6. When the energy storage ratio is 15%, the probability distribution of deviation between the actual output of wind and solar and the previous output plan

As shown in Fig. 7, when the energy storage configuration ratio is 20% (and the total energy storage power is 30MW), based on the current forecast level, the probability that the actual output deviation of wind and solar is 5% or more is 3%, and the actual output deviation of wind and solar is 3%. The probability at 10% and above is 1.5%. The improvement is excellent.

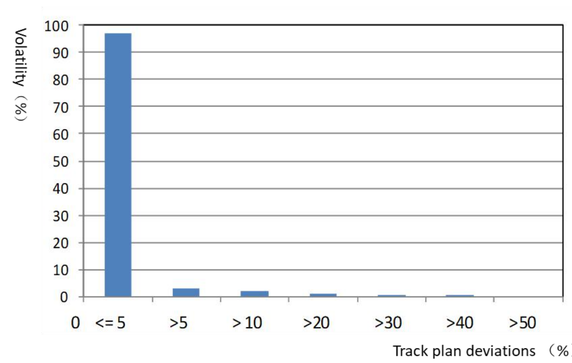

Fig. 7. When the energy storage ratio is 20%, the probability distribution of deviation between the actual output of the wind and solar energy and the previous output plan

V. Conclusion

Based on the historical data of the demonstration project, this study carried out the research of energy storage capacity allocation technology for smoothing wind and solar combined output fluctuations and the analysis of the energy storage system configuration for smoothing wind power fluctuations and tracking planned output. Comprehensive consideration, the energy storage configuration is 15% (20MW).), which has reached a very good effect on smoothing and tracking planned output. Therefore, the 20MW energy storage configuration of the demonstration project (Phase I) fully meets the requirements, which integrates the two functions of smoothing fluctuations and tracking planned output.

References

[1] Optimal control of battery energy storage for wind farm dispatching. Teleke, Sercan, Baran, Mesut E., Bhattacharya, Subhashish, Huang, Alex Q. IEEE Transactions on Energy Conversion. 2010

[2] Control strategies for battery energy storage for wind farm dispatching. Teleke, Sercan, Baran, Mesut E., Huang, Alex Q., Bhattacharya, Subhashish, Anderson, Loren. IEEE Transactions on Energy Conversion. 2009

[3] Modeling of hybridrenewable energy systems. DESHMUKH M K, DESHMUKH S S. Renewable and Sustainable Energy Reviews. 2008

[4] Application of Petri nets for the energy management of a photovoltaic based power station including storage units[J]. Renewable Energy. 2010 (6)

[5] Cooperative control strategy of energy storage system and microsources for stabilizing the microgrid during islanded operation. Kim, Jong-Yul, Jeon, Jin-Hong, Kim, Seul-Ki, Cho, Changhee, Park, June Ho, Kim, Hak-Man, Nam, Kee-Young. IEEE Transactions on Power Electronics. 2010

[6] Optimal sizing of smart grid storage management system in a micro-grid. Bahramirad. S, Daneshi. H. Proceedings of Innovative Smart Grid Technologies (ISGT). 2012