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Simulation Analysis of Large-scale Application of Energy Storage System in Power Grid

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Abstract

To study the stability control effect of large-scale distributed battery energy storage system for Tianzhong DC blocking. In the PSASP simulation platform, the flexible DC model is used to replace the battery energy storage model, and the stability control effect of conventional measures and battery energy storage is compared, and the battery energy storage location and corresponding output power are determined. The effect of battery energy storage on the primary frequency modulation of the generator set is studied, and the energy storage control reduces the primary frequency output of the generator. The influence of battery energy storage on grid AGC control is studied. The energy storage control can further improve the effect of generator secondary frequency modulation on grid frequency and tie line power.

Keywords: battery energy storage, clean energy, power grid frequency modulation, peak clipping and valley filling, PSASP technology

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INTRODUCTION

Since the 21st century, the fast-growing industry has faced China's dual challenges of energy crisis and environmental pollution (Li et al. 2018). With the increasingly prominent fossil energy crisis and environmental protection issues, centralized power generation has a single topology and flexible power supply. The characteristics of poor performance, etc., it is difficult to meet the requirements of users for power supply security and reliability. Therefore, countries have turned their attention to distributed generation with renewable energy as the energy source (Hu and Luo 2018), and the development and expansion of the use of new clean energy has become an inevitable choice to solve the energy environment and the reliability of power supply security (Sun et al. 2017). However, natural resources based on wind energy and solar energy are easily affected by many aspects such as environment and climate. Therefore, the power of wind power generation and photovoltaic power generation are intermittent, uncertain and volatility, and will be connected to the distribution network. It has a more serious impact on the power quality of the system (Niu et al. 2018).

In order to smooth the fluctuation of the scenery output and reduce the adverse impact of its access on the power grid, many studies have been done at home and abroad. Such as: grid structure modification (Shen et al. 2015), wind power output prediction, increase reactive power compensation device and configuration energy storage system (Li et al. 2018). Among them, the energy storage device has the ability to set two-way flow and can respond quickly to the energy of the grid (Xiong et al. 2013). By controlling it, the energy storage unit performs rapid energy throughput when power fluctuations occur in the distributed power supply, which can effectively reduce the fluctuation of wind power (Huang et al. 2017, Leou 2012, Ma et al. 2018, Ma et al. 2018). From 2013 to 2018, with the development of energy storage technology and the rapid decline of cost (Wade et al. 2010, Zhen et al. 2011), the advantages of energy storage systems participating in AGC frequency modulation are becoming more and more obvious. Comparing the presence or absence of energy storage in the power grid and simulating it, it is found that energy storage has unparalleled advantages in conventional power generation frequency modulation applications (Alexandre et al. 2007, Hessami and Bowly 2011, Huang et al. 2015).

THE NECESSITY OF ENERGY STORAGE TECHNOLOGY IN HENAN POWER GRID

In 2015, the peak-to-valley difference of the provincial network heavy load day was 16.94 million kilowatts, and the peak-to-valley difference was 33%.

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The midday peak in summer is greater than the evening peak, and the typical peak in winter is greater than the peak in the afternoon. The peak hour is about 6 hours a day, and the trough is about 9 hours. The peak-to-valley difference is increasing year by year.

The problem of "standard low, weak contact, heavy overload and low voltage" in Henan urban and rural distribution network is particularly prominent. The reliability of urban distribution network is low, and the ratio of inter-supply lines is only 61.7%. The problem of heavy overload and "low voltage" in urban distribution network is mainly concentrated in suburban power grids and county power grids with large area such as Xinyang and Shangqiu.

Reasonable arrangement of energy storage systems in the distribution network can effectively improve power supply reliability and power supply quality, solve low voltage problems, and delay investment in distribution networks of 110 kV and below. In addition, since 2012, the macroeconomic situation has continued to slump, the economy has gradually entered a new normal, the downward pressure is increasing, the growth rate of electricity consumption in the whole society has declined, the number of hours of power generation has decreased, and the pressure on peaking of thermal power units has further increased. The installed capacity of new energy sources such as wind power and photovoltaics is increasing day by day, which increases the uncertainty of peak shaving and frequency modulation of the power grid.

The energy storage device can better smooth the volatility and intermittentness of new energy sources. Large-scale energy storage system can also improve the economic operation level of coal-fired units, reduce the rotation standby time, and improve the energy-saving and emission-reduction effect of the unit. The following is a simulation analysis of the large-scale distributed battery energy storage system of Henan Power Grid in the application of Tianzhong DC blocking stability control, generator set primary frequency modulation, grid frequency and tie line power fluctuation (AGC).

BATTERY ENERGY STORAGE APPLICATION SIMULATION

Calculating Boundary Conditions

The simulation model has a total of 16 energy storage systems in Henan Province. The preliminary selection points are: Chunan, Tapu, Jiajia, Cangjie, Boai, Weizhou, Guandu, Zhengzhou, Huiji, Lushan, Jucheng, Xiangfu, Zhuang Zhou, Xiangshan, Baihe, Huadu. The basic method of calculation is to choose the UHV south transmission mode in winter of 2018, the south of the Changnan line to send 5.7/3 million kilowatts, the south section of the Hubei-Yu section to send 5.7/3 million kilowatts, and the middle of the day to be 8 million kilowatts. Henan has a total load of 54 million kilowatts and a total power of 46.3 million kilowatts.

At present, the PSASP simulation platform has not developed a battery energy storage model. This simulation uses a flexible DC model to replace the battery energy storage model. (The two are connected to the system using voltage source converters, and the control characteristics are similar).

Power Grid Stability Control

Comparison of conventional measures and energy storage stability control effects

For the Tianzhong DC blocking, the current grid usually adopts the Three Gorges DC modulation (reduced transmission power) and the Henan power grid load shedding measures to reduce the power shortage of the Central China Power Grid during the fault period, and then control the maximum power of the South South Line to avoid static instability. The battery energy storage has a fast response capability, and can quickly change the working state during the fault period, increase the power, and reduce the power shortage of the power grid. Therefore, the battery energy storage achieves a stable control effect similar to that of the Three Gorges DC modulation and the Henan Power Grid load-cutting measure after the Tianzhong DC blocking.

Figs 1 and **2** shows the south of the Changnan line to send 3 million, Tianzhong DC 8 million rated power operation, after the single pole lock, no stability control measures, three Gorges DC modulation (reduced) 1 million, Henan power grid load 1 million, Henan power grid energy storage The device increases the output by 1 million, and the simulation results of the four working conditions.

It can be seen that DC modulation, load shedding, and energy storage can significantly reduce the maximum power of the long south line after the fault. The efficiency is about 1 to 50,000,000 yuan per 10,000,000. The energy storage control effect is slightly lower than DC modulation and load shedding. The reason is that the three measures adopt different

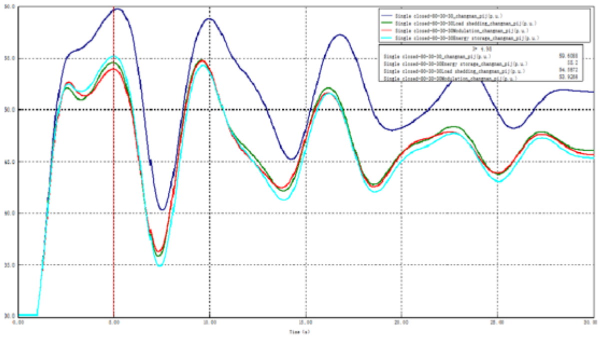

Fig. 1. Long South Line Power Comparison

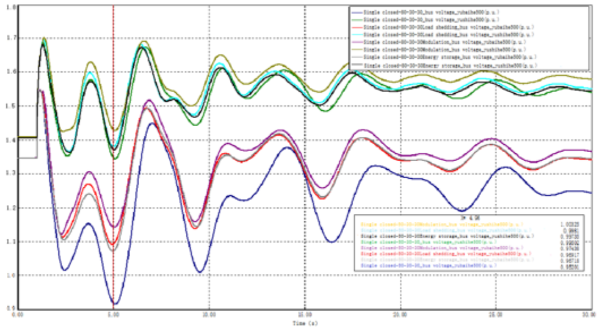

Fig. 2. Comparison of Henan Bus Voltage

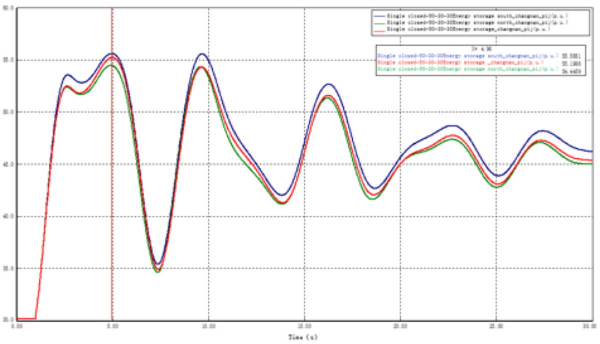

Fig. 3. Long South Line Power Comparison

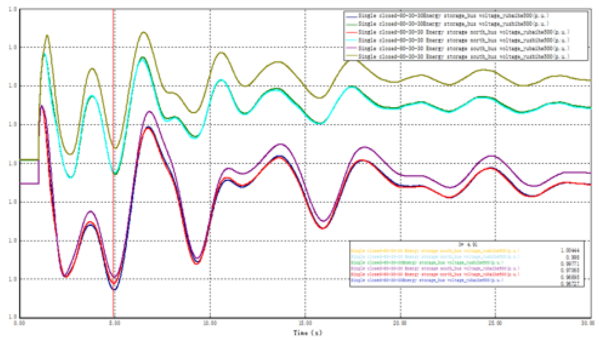

Fig. 4. Comparison of Henan Bus Voltage

dynamic characteristics in the simulation, and the energy storage response rate is slow.

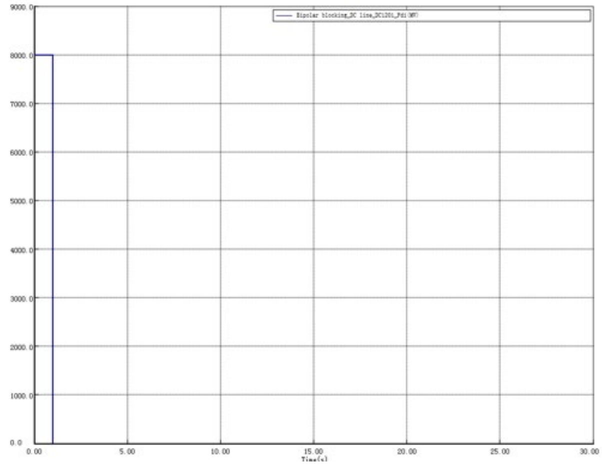

Fig. 5. Tianzhong DC Power Curve (Bipolar Blocking)

Comparison of geographical location on the effect of energy storage stability control

Figs. 3 and **4** shows a comparison of the stability control effects of the Henan Power Grid's energy storage devices installed in Yubei, Yuzhong and Henan, respectively. It can be seen that the energy storage device is installed in the Yubei, Yuzhong, and Henan power grids, and the effect of reducing the maximum power of the long south line and the voltage of the Henan power grid is similar.

Tianzhong DC blocking stability control

(1) 8 million bipolar locking under the energy storage system

Before the Tianzhong DC bipolar lockout, the energy storage system is in a fully charged state, and discharge begins within 200 ms after the lockout. In the initial state, the Changnan line sends 5.7 million kilowatts south, and the Tianzhong DC bipolar lock at 1 s. The fault curve is shown in **Fig. 5**.

After the failure, the energy storage system is set up in five cases: 8 million kilowatts, 7 million kilowatts, 6.7 million kilowatts, 6.6 million kilowatts, and no investment.

The output power of one of the energy storage system's grid points is shown in **Fig. 6**.

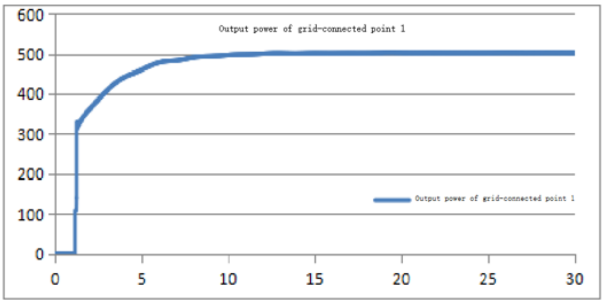

Fig. 6. Active output of one of the energy storage grid points (output 500,000 kilowatts)

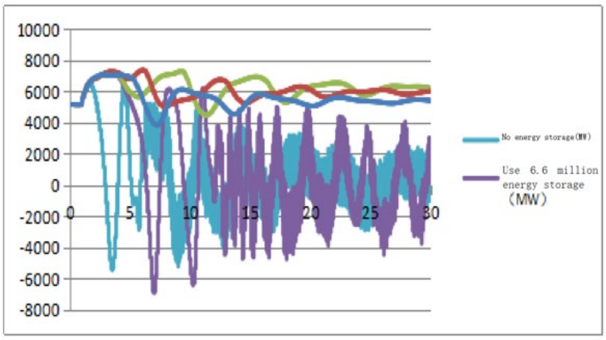

Fig. 7. Comparison of power curve of Changnan line (South transmission mode)

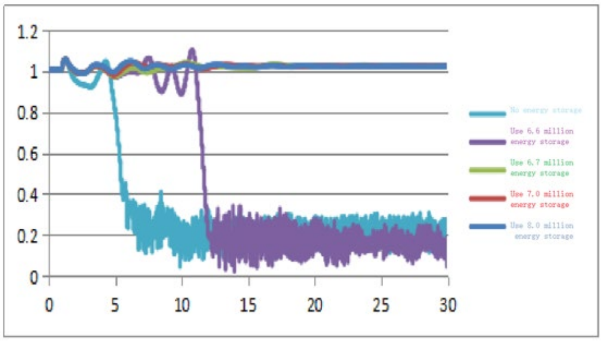

Fig. 8. Comparison of 1000 kV voltage curves at Nanyang Station

The power curve of 8 million kilowatts, 7 million kilowatts, 6.7 million kilowatts, 6.6 million kilowatts and non-returning south line is shown in **Fig. 7**. It can be seen that the system is unstable and the power of the long south line is oscillating without investing energy. The energy storage system invested 6.6 million kilowatts, the system is unstable, and the power of the long south line oscillates. When the energy storage system is invested 6.7 million kilowatts or more, the system is stable, and the minimum fluctuation of 8 million kilowatt hours is invested, which can effectively improve the stability level of the system.

Fig. 8 shows the 1000 kV voltage curve in UHV Nanyang in five cases. It can be seen that the 1000 kV bus voltage of the UHV station is unstable when the

Table 1. Relationship between system stability and energy storage

The energy storage capacity of the system (10,000 kW)	System stability
800	Stability
700	Stability
680	Stability
670	Stability
660	Instability
650	Instability
0	Instability

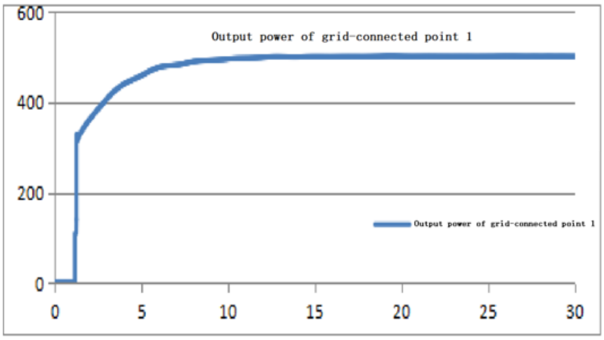

Fig. 9. Active output of one of the energy storage grid points (output 500,000 kilowatts)

energy storage is not applied, the energy storage system is invested 6.6 million kilowatts, and the UHV station is 1000. The kilovolt bus voltage is unstable. When the energy storage system is invested 6.7 million kilowatts or more, the voltage of the 1000 kV busbar of the UHV station is stable.

In summary, the relationship between system stability and energy storage in the case of Tianzhong DC 8 million and bipolar blocking is as shown in **Table 1**.

(2) Tianzhong DC 8 million unipolar locking under the energy storage system

Before the Tianzhong DC single-pole lockout, the energy storage system is in a fully charged state, and discharge begins within 200 ms after the lockout. In the initial state, the Changnan line sent 5.7 million kilowatts south, and the Tianzhong DC single pole was locked at 1s.

After the failure occurred, the energy storage system was set up in five cases: 4 million kilowatts, 3.5 million kilowatts, 2.5 million kilowatts, 2.6 million kilowatts and no investment.

The output power of one of the energy storage system's grid points is shown in **Fig. 9**.

The power curve of the south line of 4 million kilowatts, 3.5 million kilowatts, 2.5 million kilowatts,

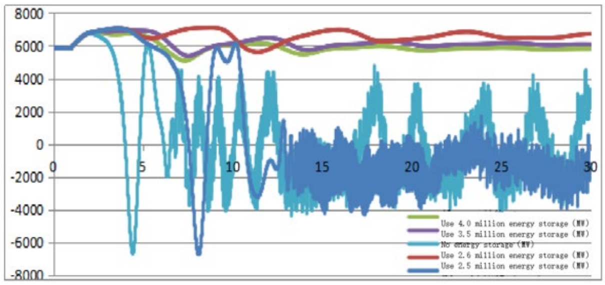

Fig. 10. Comparison of the power curve of the Changnan line

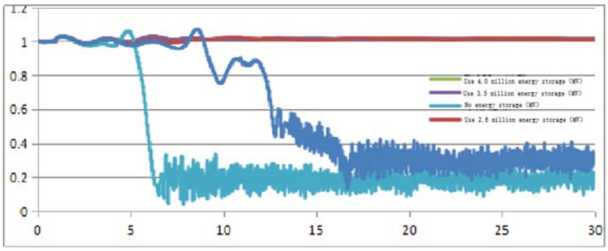

Fig. 11. Comparison of 1000 kV voltage curves at Nanyang Station

Table 2. Relationship between system stability and energy storage

The energy storage capacity of the system (10,000 kW)	System stability
400	Stability
350	Stability
300	Stability
260	Stability
250	Instability
0	Instability

2.6 million kilowatts and non-returning time is shown in **Fig. 10**. It can be seen that the system is unstable and the power of the long south line is oscillating without investing energy. The energy storage system has invested 2.5 million kilowatts, the system is unstable, and the power of the long south line is oscillating. When the energy storage system is invested 2.6 million kilowatts or more, the system is stable, and the minimum fluctuation of 4 million kilowatt hours is invested, which can effectively improve the stability level of the system.

Fig. 11 shows the 1000 kV voltage curve in UHV Nanyang in five cases. It can be seen that the 1000 kV bus voltage of the UHV station is unstable when the energy storage is not applied, the energy storage system is invested 2.5 million kilowatts, and the UHV station is 1000. The kilovolt bus voltage is unstable. When the energy storage system is put into 2.6 million kilowatts and above, the voltage of the 1000 kV busbar of the UHV station is stable.

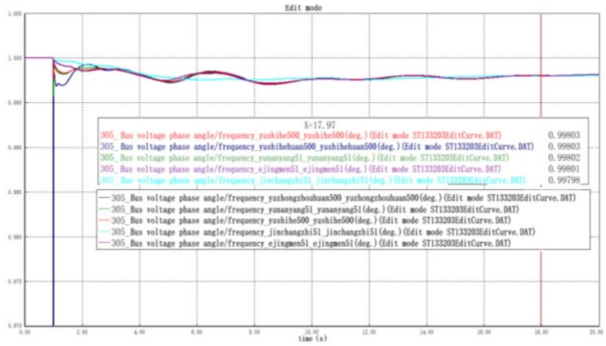

Fig. 12. Frequency simulation of Henan power grid after unipolar blocking

In the case of Tianzhong DC 8 million unipolar blocking, the relationship between system stability and energy storage is as shown in **Table 2**.

In summary, if the Tianzhong DC has bipolar blocking and does not consider the DC modulation, load shedding and other stabilization measures, it needs 6.7 million kilowatts of energy storage system to provide short-term power support. If the unipolar blocking occurs in the DC in the sky, and the stability measures such as DC modulation and load shedding are not considered, a storage power system of about 2.6 million kilowatts is required to provide short-time power support.

ANALYSIS OF THE INFLUENCE OF BATTERY ENERGY STORAGE ON PRIMARY FREQUENCY MODULATION OF GENERATOR SETS

System disturbances (cutting or load shedding, DC blocking) cause frequency deviations in the grid. When the frequency deviation exceeds the primary frequency regulation dead zone of the generator set (2 rev/min), the genset speed control system will automatically adjust the active output. In this simulation, the effect of battery energy storage on the primary frequency modulation of the generator set is studied.

Calculation conditions: 3 million kilowatts in the south of the Changnan line, 3 million kilowatts in the south of the Hubei-Yu section, and 8 million kilowatts in the sky. The single pole is locked.

No Energy Storage

0.5 seconds after the fault, the system frequency is at least about 49.85 Hz, corresponding to the generator speed of 2991 r/min; the generator speed control system increases the force;

20 seconds after the fault, the system frequency tends to be consistent, about 49.90 Hz, corresponding

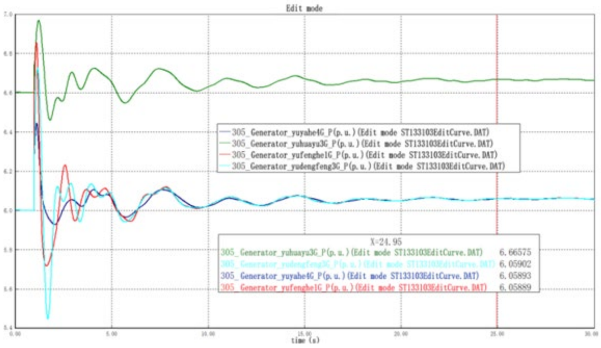

Fig. 13. Simulation of output power of Henan Power Grid unit after unipolar blocking

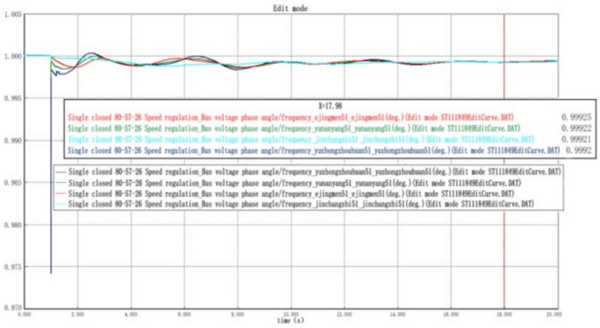

Fig. 14. Frequency simulation of Henan power grid after unipolar blocking

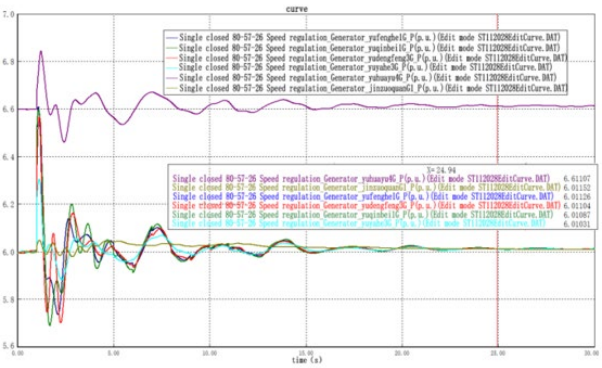

Fig. 15. Simulation of output power of Henan Power Grid unit after unipolar blocking

to the generator speed 2994 r/min; beyond the generator speed control system dead zone, the generator speed control system action.

20 seconds after the failure, a generator set increased its output by about 0.59 million kilowatts.

Energy Storage

After the Tianzhong DC single pole lock, the energy storage system increases the output power by 2.6 million.

0.5 seconds after the fault, the system frequency is about 49.89 Hz, corresponding to the generator speed of 2993.5 r/min; the generator speed control system increases the force;

20 seconds after the fault, the system frequency tends to be consistent, about 49.96 Hz, corresponding to the generator speed of 2997.6 r/min; basically in the dead zone of the generator speed control system, the generator speed control system is in the critical section of motion.

20 seconds after the failure, the Yahe #4 generator increased its output by about 0.1 million kilowatts.

ANALYSIS OF THE INFLUENCE OF BATTERY ENERGY STORAGE ON GRID AGC FUNCTION

The grid AGC control objective is to maintain system frequency and tie line power stability, usually achieved by AGC generator set secondary frequency modulation. However, the genset adjustment process has a certain delay, and it is difficult to guarantee the initial frequency of the fault and the power control effect of the tie line.

Because the distributed battery energy storage system has fast and active power adjustment capability, when the power and capacity are large enough, the distributed battery energy storage system can be used to disturb the initial grid AGC control, and further improve the grid frequency and tie line power adjustment effect.

When the cutting machine is 1 million disturbances, the simulation of the energy storage system is carried out:

In the initial state, Tianzhong DC 5 million, Changnan Line 5.6 million, 1s time North Second Phase #1 machine (1 million machines) fault trip. Consider the system frequency and the external tie line power simulation of Henan Power Grid when investing/not investing 1 million kilowatts of energy storage system.

When investing in 1 million kilowatt energy storage system, the output power of one of the energy storage system's grid points is shown in **Fig. 16**.

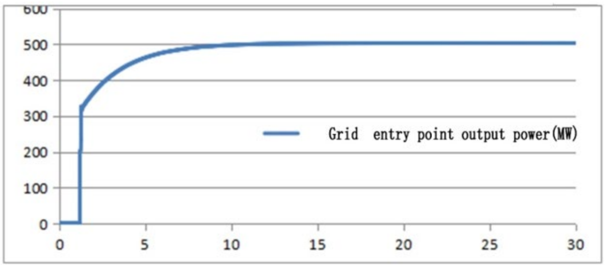

Fig. 16. Active output of one of the energy storage grid points (output 500,000 kilowatts)

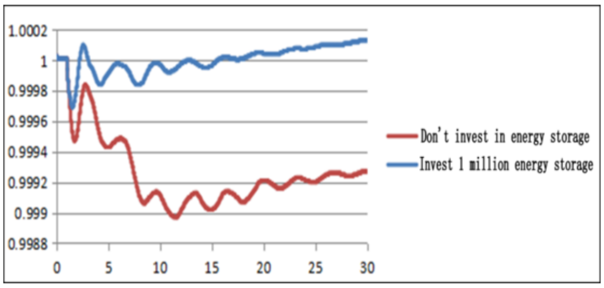

Fig. 17. Comparison of the frequency curve of the 500 kV busbar at Nanyang Station

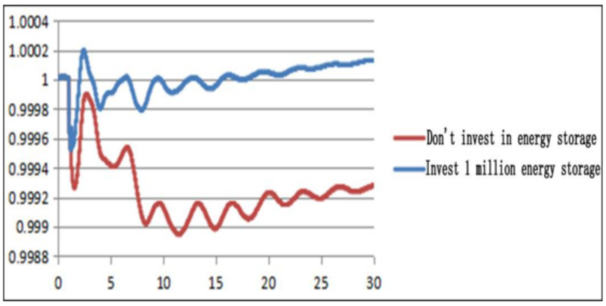

Fig. 18. Comparison of the frequency curve of the 500 kV busbar at Zhongzhou Station

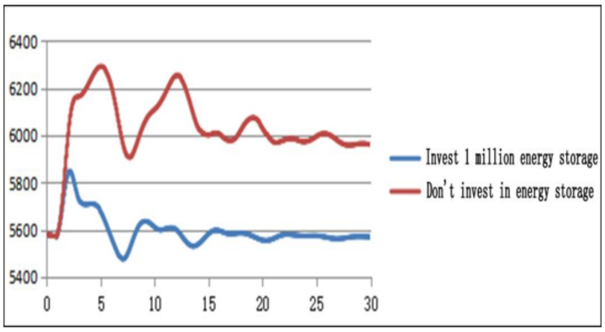

Fig. 19. Comparison of the transmission power curve of the Changnan line

The frequency curve of the 500 kV busbar of Nanyang Station and the 500 kV busbar of Zhongzhou Station is as shown in **Figs. 17** and **18**. It can be seen that the frequency of 500 kV busbar of Nanyang Station and Zhongzhou Station drops without investing in energy storage. Larger. The energy storage system invested 1 million kWh. The frequency of the 500 kV busbar at Nanyang Station and Zhongzhou Station fluctuated less.

The power curve of investing 1 million kilowatts and not investing in the south line is shown in **Fig. 19**. It can be seen that the system is stable without energy storage, and the power of the long south line is stable at around 6 million. The system frequency and tie line power exist in the initial fault. Large deviation.

The energy storage system has a stable investment of 1 million kWh, and the power of the Changnan line is stable at around 5.6 million.

CONCLUSION

(1) The battery energy storage has the fast response capability of active power, and reduces the power amplitude of the long south line after the Tianzhong DC blocking. It can be used for grid stability control after the Tianzhong DC blocking.

(2) The fast response characteristics of the energy storage device can replace the primary frequency modulation of the generator set to a certain extent, and reduce the system frequency transient fluctuation.

(3) The battery energy storage active response function can basically maintain the grid frequency and the tie line power at the initial stage of the fault, and further improve the grid AGC control effect.

(4) Research on large-scale construction of energy storage has improved the level of intelligence of the power grid. Especially for active distribution networks based on distributed energy, the large-scale application of energy storage can provide major technical support. Through the simulation experiments in the paper, the further analysis and verification of the role of energy storage in the microgrid has great reference significance for the application of energy storage in microgrid.

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