ATLANTIS PRESS

Advances in Engineering Research, volume 185

2nd International Conference on Electrical and Electronic Engineering (EEE 2019)

Application Effect Analysis of Energy Storage Technology in Power System

Lei YU, Xin-yan ZHANG*, Yang YU and Jia-jun ZHANG

College of Electrical Engineering, Xinjiang University, Urumqi, China

*Corresponding author

Keywords: New energy, Technology of ES, Stabilizing fluctuation, Frequency modulation.

Abstract. With the deterioration of environmental and energy problems, the demand for large amounts of new energy interconnection has become increasingly strong. However, the fluctuation of new energy will impact the stability of power grid. This paper describes the development and application status of energy storage(ES) technology , and simulates the effects of technology of ES on suppressing wind power fluctuation and participating in regional power grid frequency modulation. It concludes that the application of technology of ES in power system has great value and significance, and prospects the application of large-scale ES in the days to come.

Introduction

With the increasingly serious environmental pollution and energy problems, the extensive use of new energy is imminent. Owing to the fluctuation and nondeterminacy of wind power and photovoltaic output, the peak-shaving and frequency-modulation pressure is increased, which leads to the decline of voltage quality in power grid [1]. Take wind power as an example, by the end of 2017, China's newly installed wind power units are located in the world's wind power installed capacity first, from the market share point of view, China also occupies an important share of the wind power market. In recent years, through vigorous research in our country, the cost of wind power generation is decreasing, the technology level is becoming more and more mature, and the economic benefits are increasing. However, the rapid fluctuation of wind power causes great hidden danger to the safety and stability of the system and endangers Endangering the safety of the whole power system and its users. The output characteristics of the energy storage system(ESS) are: (1) fast response, which can complete the power output task in milliseconds; (2) precise control, which can maintain stable output at any power point; (3) bi-directional regulation capability, which can exist in the form of load during charging and power supply during discharging[2].

Applying technology of ES to suppress fluctuations, participating in frequency modulation, voltage support, peak shaving, reactive power support of reserve capacity, alleviating line congestion, delaying expansion and upgrading of transmission and distribution capacity and serving as DC power supply of substation can alleviate a series of problems brought about by new energy grid connection[3,4].

Utilization of ESS in Restraining Wind Power Fluctuation

Closely cooperating the ESS with the fluctuating distributed generation of new energy, using the fast charging and discharging characteristics of the ESS to suppress the power fluctuations beyond the standard, these new energy sources can provide stable power according to human needs.

Generation of Error Fluctuation in New Energy Generation

The rapid fluctuation of new energy generation will be harshly affected on the frequency reliability of power grid. Taking wind power as an example, the dispatching of wind power in our country is to arrange the generation plan on the basis of the wind power forecast curve of the power system dispatching agency. Thus the accuracy of planning depends entirely on the accuracy of wind power prediction [5]. Although the accuracy of wind power prediction is improving, uncertainty still exists[6].

The real-time power data of existing wind farms are collected at a time interval of 1 minute, while the predicted power data of dispatching agencies are collected at a time interval of 15 minutes. In order to unify the time interval of the two methods for 1 minute and to facilitate the calculation of errors, linear interpolation method is used to determine the predicted power data of the first minute (i=0,1,... 15). Figure 1 shows the predicted and actual wind power of a wind farm with rated power of 150 MW in December in Shandong Province.

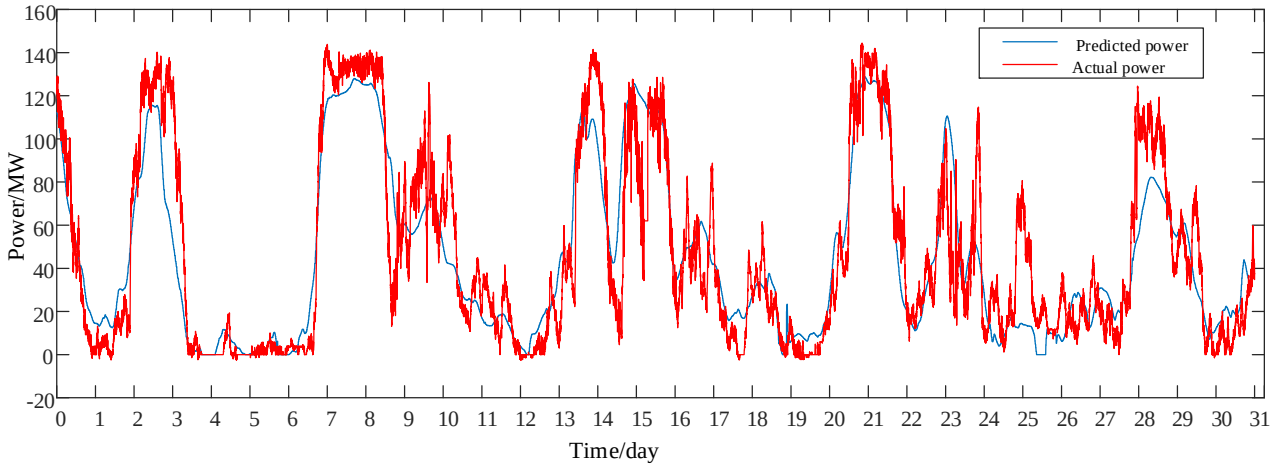

Figure 1. Wind power forecasting power and actual power wave form

As can be seen from Figure 1, although the trend of predicted power is similar to the curve of actual output power, errors are common. The error of wind power forecasting power is equal to the difference between wind power forecasting power and actual power. According to the accuracy and qualification rate of wind farm power generation forecasting, the max error of daily forecasting curve provided by relevant departments is not more than 25%. Figure 2 shows the error curve of wind power prediction.

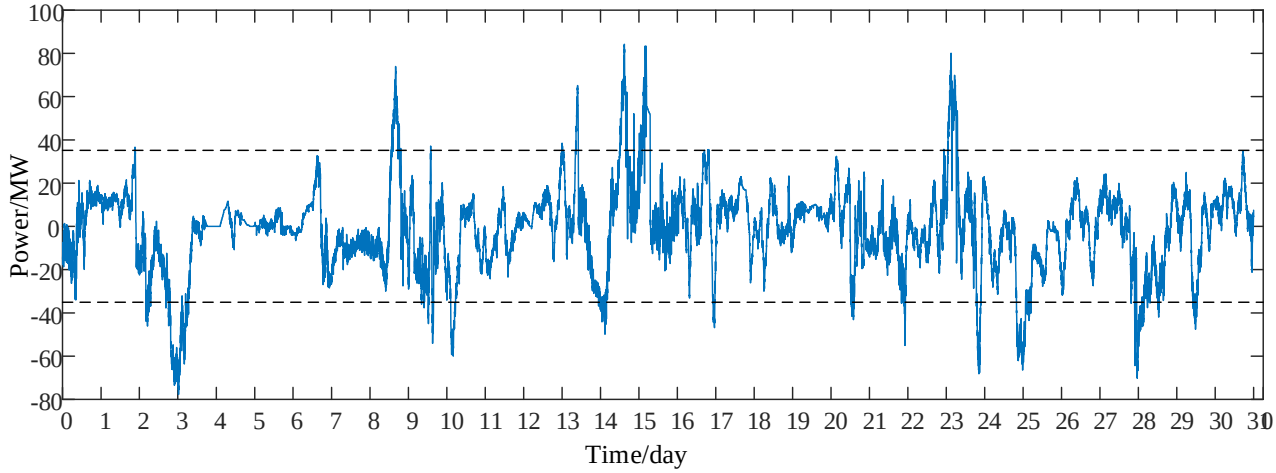

Figure 2. Wind Power Prediction Error Curve

In Figure 2, the allowable range of prediction errors is between the two dotted lines, while the part outside the two dotted lines will impact the stability of the regional power grid because the errors are larger than the prescribed range.

Analysis of the Effect of ESS on Suppressing Wind Power Fluctuation

The ESS has flexible and fast power throughput capability. The ESS is used as the power buffer medium to suppress the fluctuation before the wind power is connected to the grid, so that the wind power integration can meet the relevant regulations of wind park access to the power system in China.

When the power fluctuation of the wind park is positive, the ESS acts as a load to charge the ESS. When the power fluctuation of the wind park is negative, the ESS acts as a power source to discharge and fill up the power shortage of the wind park, so as to achieve the effect of suppressing the

fluctuation of wind power. Structural sketch of wind power fluctuation suppression for ESS [7] is shown in Figure 3.

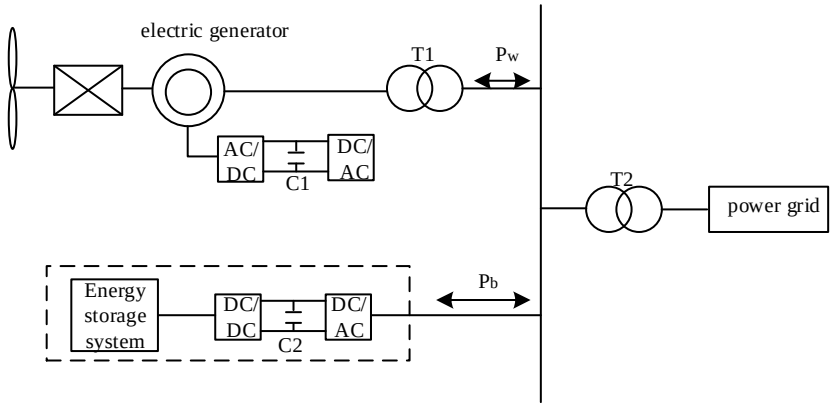

Figure 3. Wind power fluctuation suppression structure of ESS

Taking a 40 MW wind farm in Shandong Province as an example, the power prediction error of the wind farm in December is shown in Figure 2, and it after the ESS suppresses the fluctuation is shown in Figuer 4.

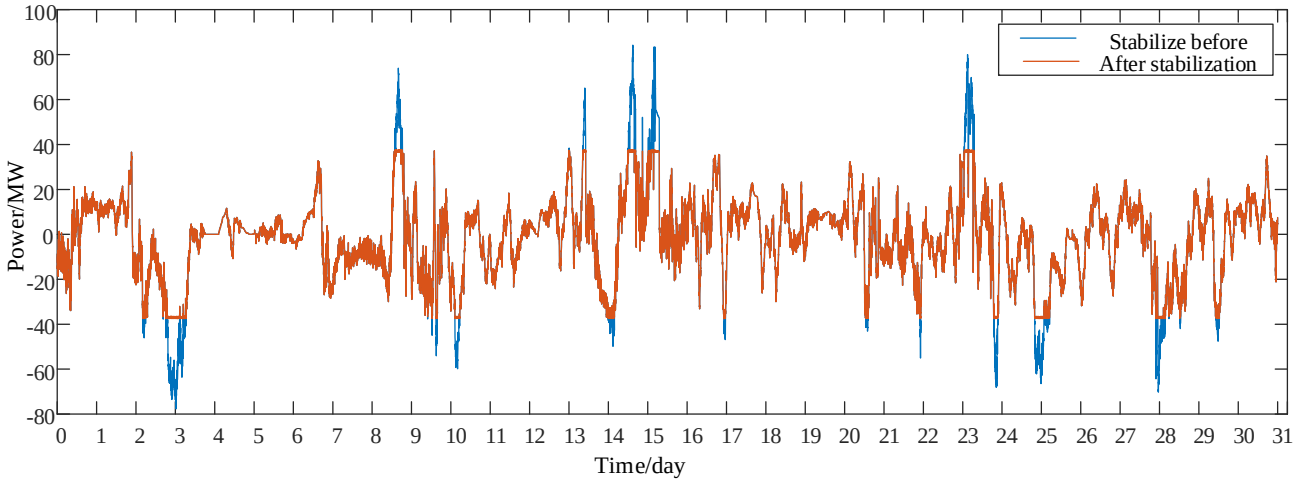

Figure 4. Power Error Curve of ESS after Stabilization

From the Figure 4, the power fluctuation of wind farm can be adjusted to standard requirements through the ESS.

Application of ESS in Frequency Adjustment

Research Status of ESS Participating in Power Grid Frequency Modulation

For the sake of mitigate the negative impact of grid-connected intermittent power supply on grid stability, energy storage, which has the advantage of fast response in participating in grid frequency modulation, will be used as a new auxiliary frequency modulation method. At present, energy storage is mainly involved in fast frequency modulation characteristics, ES charging and discharging strategies, ES configuration types and ES economy[8]. On the generation side, the charging and discharging strategy of ES to improve the frequency modulation performance of power plant can achieve the frequency modulation effect and improve the stability of power system [9]. But the current research seldom combines with the latest frequency modulation policy to allocate energy storage output. On the distribution side, according to the frequency modulation characteristics and frequency control characteristics of energy storage participation, the influence of key parameters on the primary frequency modulation characteristics of battery energy storage is analyzed[10,12]. On the basis of the research on the primary frequency modulation characteristics of energy storage participation, energy storage capacity allocation is realized from the perspective of technical economy, timing and depth of

energy storage battery participation in primary frequency modulation [13]. The effect is different. Lithium-ion batteries are mostly used to provide primary frequency modulation service for traditional generators because of their fast response characteristics. Supercapacitors are generally used as primary frequency modulation auxiliary equipment to better guarantee the frequency quality of the system.

Effect Analysis of ESS Participating in Power Grid Frequency Regulation Research

For the sake of verify the effect of ESS participating in grid frequency modulation, a regional equivalent model including energy storage battery is built as shown in Figure 5.

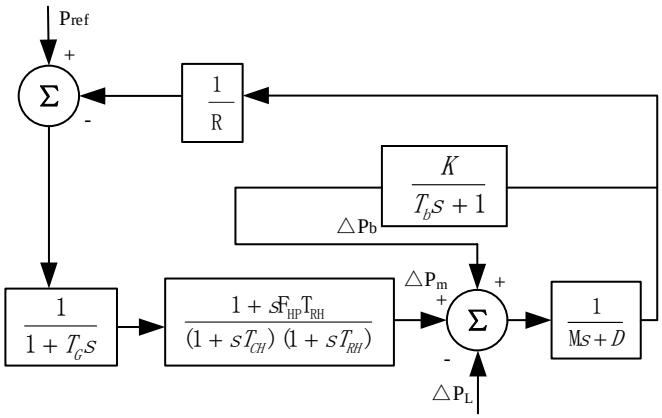

Figure 5. Equivalent Model of ESS Participating in Regional Power Grid frequency modulation

Among them, R is the speed adjustment rate of governor; K is the unit regulating power of ES battery; Pref is the given value of secondary frequency modulation; ΔP_L is the fluctuation of load power; ΔP_b is the output of energy storage power source; ΔP_m is the output of traditional power source; T_G, T_{CH} and T_{RH} are the time constant of traditional power supply governor, steam turbine and reheater, and T_b is the time constant of energy storage battery. For reheater gain, M and D are inertia time constants and load damping coefficients respectively, and S is Laplace operator.

The equivalent model in Figure 5 is used to analyze the step disturbance. After adding the step disturbance of 0.085 to the system, the frequency deviation of energy storage participating in frequency modulation is compared with that of non-ESS in Figure 6.

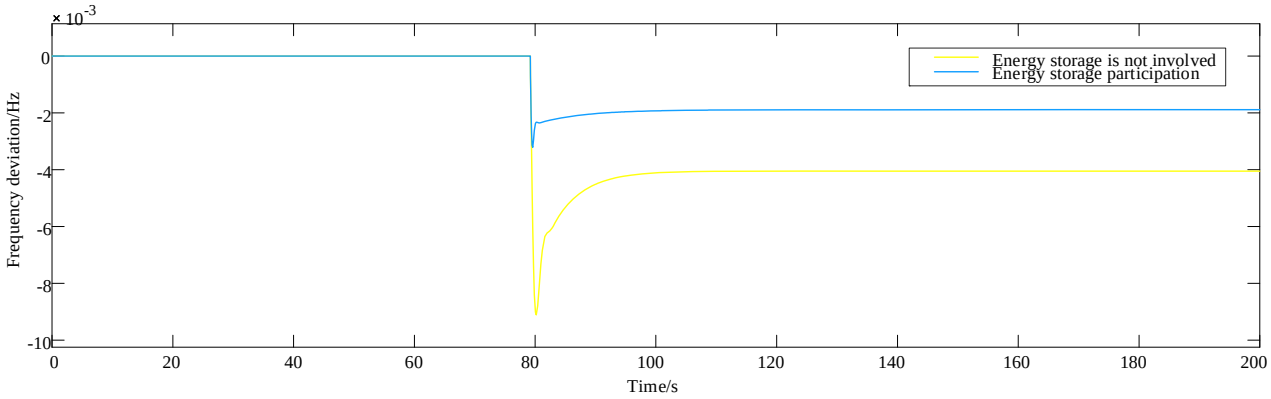

Figure 6. System Frequency Deviation under Step Disturbance

From the frequency deviation curve in Figure 6, it can be seen that when step disturbance occurs, the frequency drop without adding ESS is obviously larger than that after adding ESS, and the frequency rise speed of adding ESS is better than that without adding ESS. So the participation of ESS in grid frequency modulation has significant advantages for system stability.

Summary and Prospect

This paper demonstrates the application value and advantages of technology of ES in power system through practical comparison in two aspects: suppressing wind power fluctuation and participating in regional power grid frequency modulation. Adding energy storage to the power grid to participate in frequency modulation can increase the quality of system frequency, improve the security level of power grid operation, clear up the diversity between day and night load peaks and valleys, increase the utilization rate of power equipment, reduce the cost of power supply, and promote the utilization of renewable energy such as wind energy and solar energy.

At present, our country attaches great importance to technology of ES, technology of ES is improving day by day, but the application of large-scale energy storage power plants is less. Large-scale battery technology of ES is an effective means to improve the grid-connected absorptive capacity of clean energy generation and the flexibility of power system planning and operation dispatch. The grid-connected operation of large-scale BES power stations will certainly change the power and load characteristics of the grid. Combining with the actual situation of the specific power grid, it will become an important research direction in the field of power system analysis and control to study the comprehensive application scenario of large-scale ES power plants in the power system and their theoretical methods and practical technologies in planning, dispatching control and operation and maintenance management.

Acknowledgement

This research was financially supported by the National Science Foundation(51667018).

References

[1] G.G.Yan, Y.B.Wang, C.Zhong, Electric Power Construction, J. 37(2016) 55-60.

[2] D.Y.Chen, L.Z.Zhang, S.Wang, Power System Automation, J. Ei.37(2013) 9-13.

[3] Z.Zheng, Z.Y.Yang, W.H.Li, Electric Power Automation Equipment, J. 37(2017) 92-100.

[4] L.Wang, H.Liu, H.M.Wang, Power generation and air conditioning, J. 33(2012) 14-18.

[5] G.X.Xu, L.Guo, G.F.Zhang, Shaanxi electric power, J. 40(2012) 17-20.

[6] Z.Wang, W.S.Wang, C.Liu, Power grid technology, J.Ei. 37(2013) 242-247.

[7] W.J.Liu, S.J.Li, J.Y.Hang, Electrical Appliances and Energy Efficiency Management Technology, J. 16(2018) 41-47.

[8] Y.Lei, N.N.Ma, J.T.Kang, Electric Power Automation Equipment, J. 37(2017) 227-233.

[9] L.J.Chen, Y.X.Jiang, C.Wang, Electric Power Automation Equipment, J. 37(2017) 52-59.

[10] J.Hang, Y.Cao, Automation of Electric Power Systems, J. 39(2015) 20-24.

[11] X.R.Li, J.Y.Hang, P.Q.Li, High Voltage Technology, J.Ei. 41(2015) 2135-2141.

[12] T.H.Jin, C.Mo, K.Y.Shin, Journal of Sustainable Development of Energy. J, 4(2016) 392-407.

[13] J.Y.Hang, X.R.Li, M.Chang, Transactions of China Electrotechnical Society, J.32(2017)112-121.