Acta Technica 62 (2017), No. 6A, 201–210

Research on power smoothing control for new micro-grid energy storage system

Zhang Xudong [1, 2]

Abstract. Aiming at the new micro grid access of renewable energy caused by the large capacity battery energy storage system output power fluctuation and strong uncertainty, put forward a new system of power smoothing control method of a new type of large capacity storage battery based on micro. The basic structure of the new micro-grid is introduced. According to the micro-grid composed of solar power supply device and large capacity battery energy storage device, the method of power smoothing control is expounded, and the detailed structure sketch of the new micro-grid is given. The first order low-pass filter is used to process the output signal of photovoltaic power generation, and the power reference signal of large capacity battery energy storage system is obtained. By adjusting the active power output of the stored energy in real time, the fluctuation component of the active frequency band of the active power output of the regenerative energy is supplemented, so that the rate of success can be smoothly controlled. The correction factor is introduced to achieve the regulation of SOC status and power commands. The experimental results show that the proposed method can achieve smooth transition of output power, the feasibility is strong, the battery charge and discharge depth is greatly improved, and the demand for battery capacity is low.

Key words. New micro-grid; large capacity; battery energy storage system; smoothing control.

1. Introduction

At present, renewable energies such as solar energy and wind energy are widely concerned. The renewable energy power generation technology is increasingly mature. Many new micro-grids made of renewable energy are used in real life [1, 2]. Because of the large variation of power generation of renewable energy and uncertainty, the new micro-grid project is mostly equipped with energy storage system [3]. The energy storage system in the micro-grid can greatly reduce the variation of the output power of the renewable energy power generation and contribute to the stable

[1] North China Electric Power University, Beijing 102206, China
[2] Corresponding Author, e-mail: zxddl@163.com

operation of the new micro-grid. Under normal circumstances, the new micro-grid energy storage system is divided into electrochemical battery energy storage, physical energy storage, capacitive energy storage and other means, the most widely used large-capacity battery energy storage, and low cost [4]. Therefore, it is very important to study the power smoothing control method of the new micro-grid high-capacity battery energy storage system.

In this paper, an effective power smoothing control method is proposed for the new micro-grid high-capacity battery energy storage system, which not only reduces the power variation range, but also can prevent overcharge and over discharge of the battery to a certain extent and increase the service life of the battery. The effectiveness of the proposed method is verified by experiments

2. Power smoothing control method based on new micro-grid for large capacity storage battery

2.1. New micro-grid structure

The new micro-grid consists of various distributed power supplies. Its structure is shown in Figure 1, which includes not only photovoltaic, wind energy and battery energy storage systems, but also switches, control and protection devices [5]. For renewable energy such as photovoltaic and wind power which random volatility and uncertainty, they must be combined with the battery energy storage system whether they are combined into a large grid transmission power or supply power to the load independently Constitute a complete system.

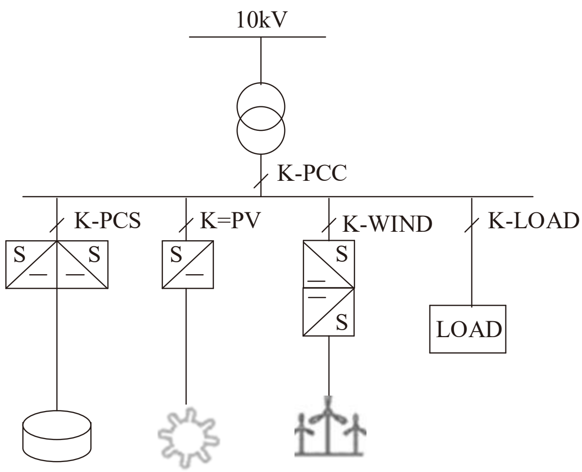


Fig. 1. A new type of micro-grid consisting of distributed power supplies

2.2. Large-capacity battery energy storage system power smooth control method

This section relies on the real-time adjustment output active power of energy storage systems, The fluctuation component of the frequency band of the active power output from the regenerative energy source is added in order to complete the large-capacity battery energy storage system power smooth control. The power smoothing control method is described by a micro-grid formed by a solar power supply device and a large-capacity battery energy storage device. Figure 2 shows a detailed structural diagram of the new micro-grid. As can be seen from Figure 2, the energy will be connected to the AC bus through the corresponding inverter. The factors used to describe the output power of photovoltaic power generation and affect its size are mainly temperature and light intensity; the PQ control is used in the large-capacity battery energy storage inverters, used to describe the output power of the energy storage system which along with the previous active power scheduling signal changes. The function of the monitoring equipment is to obtain the active power of the photovoltaic generation, meanwhile output the reference signal of the large-capacity battery, and transmit the control information to the energy storage inverter.

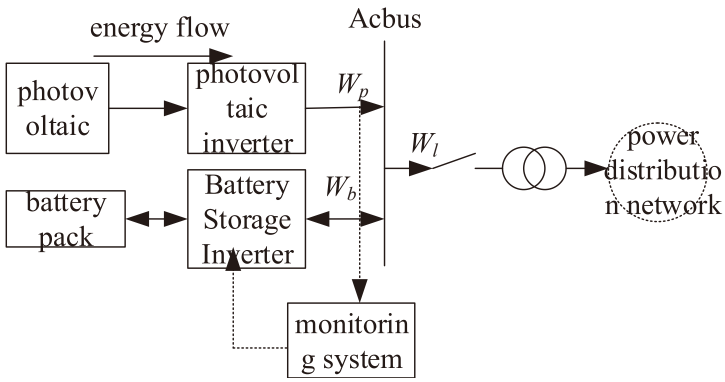


Fig. 2. Schematic diagram of micro-grid system

Through the law of conservation of energy to determine the relationship between the incoming line powers into the new micro-grid, the formula is described as follows:

$$W_p + W_b - W_r = 0 \tag{1}$$

Among them, W_r shows the power of the new micro-grid communication line. If positive, it means that the battery discharge process at this time; if it is negative, it means that the battery charging process. In the power control of the new micro-grid high-capacity battery energy storage system, the first-order low-pass filter is used to process the photovoltaic power output signal W_p to make sure the active power reference signal W_{pr}, and then use W_{pr} minus W_p. so as to find the reference signal W_r of the power of the large-capacity battery energy storage system. The low-pass filtering process uses a first-order Butterworth filter, the formula is described as follows:

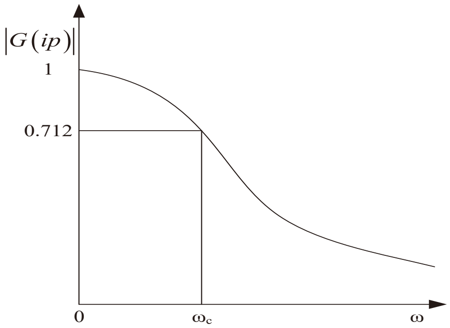


Fig. 3. Potter diagram of first order filter

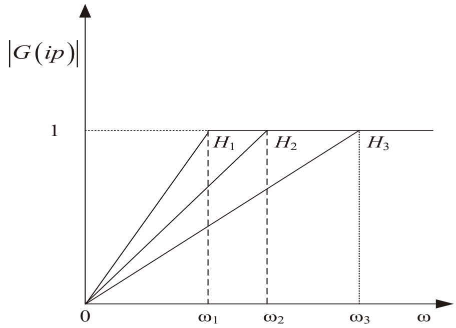


Fig. 4. Output power function Potter diagram of battery energy storage system

As can be seen from Figure 3, the Butterworth low-pass filter amplitude-frequency function is a decreasing curve, when the angular frequency $\omega = 0$, the maximum value of amplitude is 1; when the angular frequency reaches the cut-off frequency ω_c, the amplitude is 0.712.

The relationship between the various variables of the power smoothing control method of:

$$W_{pr}(k) = \frac{1}{1+kH} \cdot W_p(k) \tag{2}$$

$$W_r(k) = W_{pr}(k) - W_p(k) = -\frac{kH}{1+kH} \cdot W_p(k) \tag{3}$$

It can be seen from Figure 4 that the power smoothing control time constant is equal H_1. For a component with an angular frequency greater than ω_1, its output active power has an amplitude equal to 1, which means that large-capacity battery energy storage can supplement all the active power components with an angular frequency greater than ω_1. In figure4, $\omega_1 < \omega_2 < \omega_3$, $H_1 > H_2 > H_3$ the larger the time constant is, the smaller the angular frequency is. The larger the frequency range of the large-capacity battery energy storage system complements the larger the output power of the large-capacity battery energy storage system. Set $k = \frac{d}{dt}$, after the difference calculated:

$$W_{pr}(a) = \frac{t_d}{H}\left[W_p(a) - W_{pr}(a-1)\right] + W_{pr}(a) \tag{4}$$

$$W_r(a+1) = W_{pr}(a) - W_p(a) \tag{5}$$

In the formula, t_d represents the calculation period; $W_{pr}(a-1)$ refers to the reference value of the photovoltaic power generation $W_{pr}(a)$ immediately before. For the actual situation, t_d has been determined in advance as a known quantity. Therefore, the reference signal $W_r\,(a+1)$ of the output power of the large-capacity battery energy storage system at the next moment is only controlled by the power smoothing time coefficient H and the active power $W_p\,(a)$ of the photovoltaic influences.

2.3. SOC regulator design

The charging and discharging processes of the new micro-grid high-capacity battery energy storage system need to take into account the state of charge of the battery (SOC) and the power command at same times. Throughout the control process, system needs to introduce a correction factor and let multiply by correction factor. in order to achieve the status of SOC and power instruction adjustment. According to the characteristics of high-capacity battery, through the following strategies for large-capacity battery energy storage system charge and discharge adjustments: When the SOC value is relatively large, it indicates that the energy storage is close to saturation, and the discharge can be fully realized. Therefore, it is necessary to ensure the minimum charge or non-charge. When the SOC value is relatively small, it shows that the energy storage is not sufficient and the full charge can be achieved, and the minimum or the minimum discharge should be ensured. The SOC regulators given in this section are described by the graph, see Figure 5.

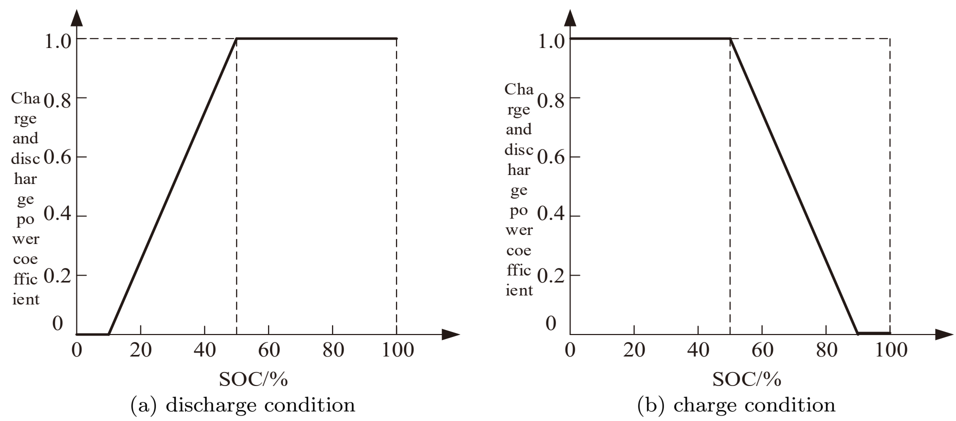


Fig. 5. Power correction factor under charge discharge state

When the high-capacity battery is in the discharged state, when the SOC value is less than 10%, the power adjustment coefficient is 0, so that the battery discharge power is 0, of which 10% is the minimum depth of discharge. When the SOC value is higher than 10%.The power adjustment coefficient gradually increases from 0 to 1, and in the case of SOC value exceeding 50%, the power adjustment coefficient is 1, and the large-capacity battery energy storage system can discharge according to the power required for smooth control, of which 50% is the most Excellent adjustment value.

When the new micro-grid high-capacity battery energy storage system is in a charged state, when the SOC exceeds 90%, the power adjustment coefficient is 0, so that the battery charging power is 0, of which 90% is the highest charging depth. When the SOC value is higher than 50% and lower than 90%, the power adjustment coefficient gradually changes from 0 to 1. When the SOC value is lower than 50%, the power adjustment coefficient is 0, and the large-capacity battery energy storage system can be based on the requirement of smooth control Power charging.

3. Experimental analyses

3.1. control smoothness test

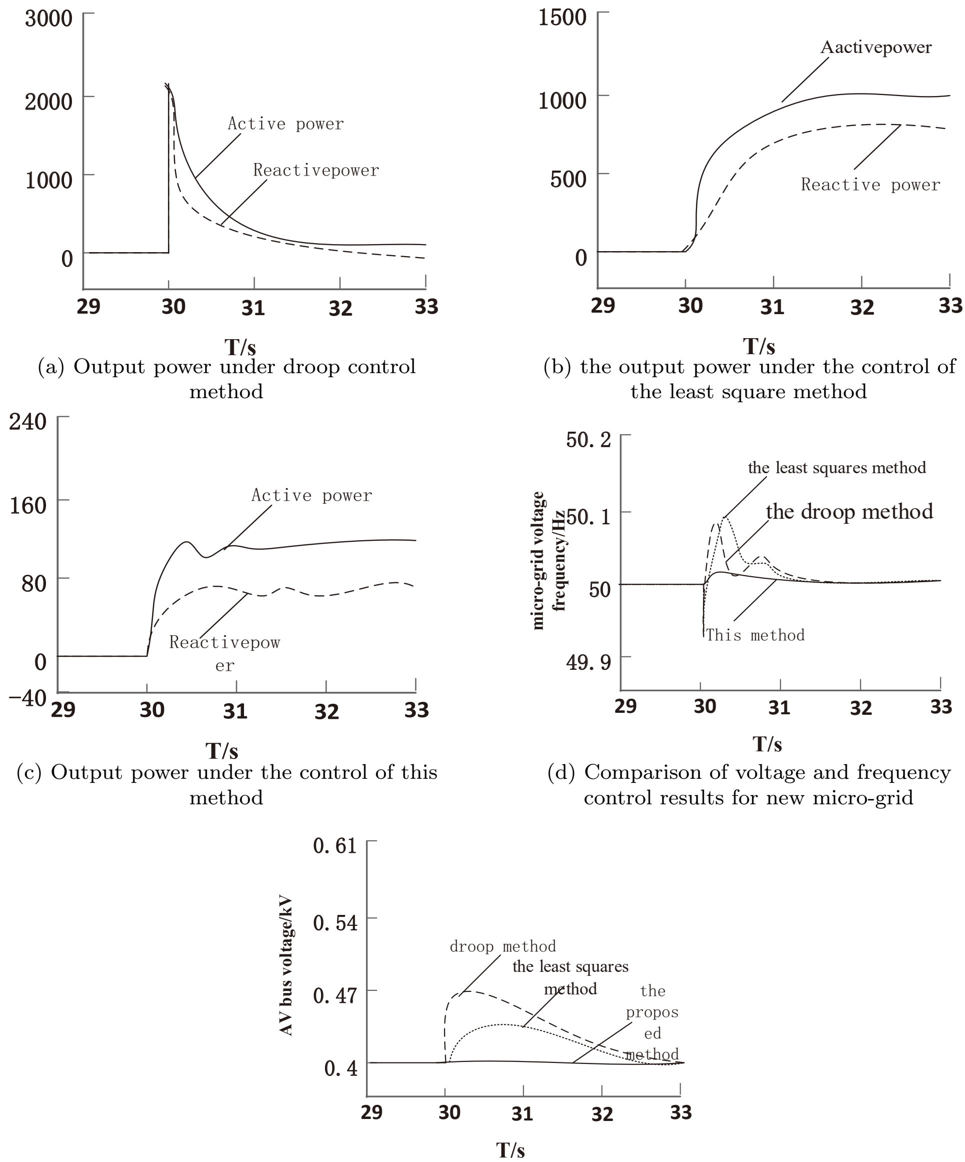
In order to verify the effectiveness of the proposed control method, in the process of experiment, we need to verify the effectiveness of the method, the least squares method and the droop control method, and verify the smooth switching between the control methods. Because of the need to analyze the shift in the new micro-grid working model, the experiment assumes that external conditions such as wind speed, light and the like remain unchanged. The new micro-grid related parameters are described in Table 1.

Table 1. Partial parameters of micro-grid

parameter name	numerical value
The wind generating set outputs active power and reactive power	550 kW, −120 kvar
Photovoltaic power generation system output active power, reactive power	350 kW, 60 kvar
The battery output active power and reactive power	250 kW, 60 kvar
The micro grid has active power and reactive load	1200 kW, 400 kvar
Fan parallel compensation capacitor	400 kvar
network voltage	40 kV
The rated voltage of the micro-grid AC bus	0.5 kV

This section mainly verifies the smooth control effect of this method. In the initial stage of the experiment, the new micro-grid was studied in the grid-connected operation mode. That is, for the large-capacity battery energy storage system, PQ control was selected before 30 s. The current output active power and reactive power are both zero. After 30 s, the new micro-grid high-capacity battery energy storage system was controlled by this method, the least squares method and the droop control method respectively. The new micro-grid frequency was fixed at 60Hz and the voltage was kept at 0.5 kV. The result use figs 7 to describe.

Analysis of Figure 6 shows that before 30 s, the new micro-grid high-capacity battery energy storage system is controlled by the PQ control method, and the output active power and reactive power are the same as the reference values, and both are zero. After the conversion to this method, the least squares method and the droop method control, although the final steady state values are consistent under the control of the three methods, the power output fluctuates significantly when using the least square method and the droop method control, The method shows



(a) Output power under droop control method

(b) the output power under the control of the least square method

(c) Output power under the control of this method

(d) Comparison of voltage and frequency control results for new micro-grid

(e) Comparison of AC bus voltage control results

Fig. 6. Comparison of control results between the three methods

that this method can make the output power achieve a smooth transition. After switching to the control of the three methods, the new micro-grid high-capacity battery frequency and voltage in a period of time after a steady state, are stable at a given value, and compared the control curve of the three methods shows that the use of this paper can control the new micro-grid Large-capacity battery frequency and voltage fluctuations in the smaller changes, verify the effectiveness of the method of control.

3.2. Comparisons with other control methods of performance

This section mainly analyzes the change of charge and discharge capacity under our method, the least square method and the droop method. The SOC curve formed under the control of the three methods is illustrated in FIG. 9

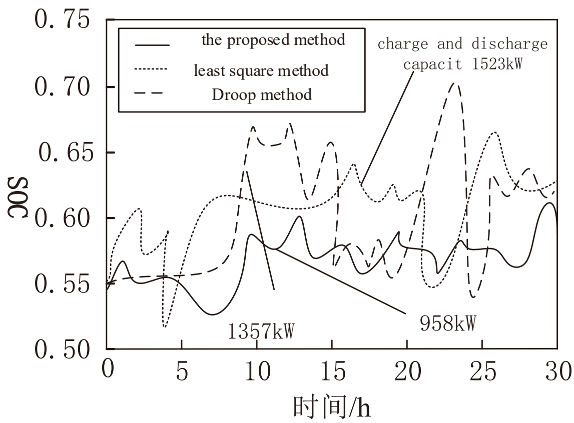


Fig. 7. Comparison results of SOC curves of different methods

Analysis of Figure 7 shows that the difference between the highest SOC and the lowest SOC under the control of the least squares method is about 15.7%, and the difference between the highest SOC and the lowest SOC under the droop method is about 18.2%, while the value is decreased during the control of this method about 7.6%. This paper shows that the demand for battery capacity of this method is greatly reduced compared with the traditional method. In addition, the statistics, the least squares method in the entire control process of battery charge and discharge and the sum of 1523 kWH, droop method in the entire control process of battery charge and discharge and the sum of 1357 kWH, and this method in the entire control The total amount of charge and discharge of the battery in the process is 958 kWH, which shows that the method in this paper has greatly improved the depth of charge and discharge compared with the two traditional methods.

4. Conclusion

This paper proposes a new power smoothing control method based on the new micro-grid high-capacity battery energy storage system. On the renewable energy output active power within the band frequency components to supplement, in order to complete the power smooth control. After the method of this article control, the voltage is stable at the maximum power point in a short time, and the output current voltage is constant. Compared with other methods, the SOC dropped to about 7.6%, and the total amount of charge and discharge of the battery in the whole control process was 958 kWH. This shows that after the method is processed, the output power is kept steady, the power supply status of the battery energy storage system is good, and the demand for the battery capacity is greatly reduced, greatly improving the depth of battery charging and discharging. Although good results have been obtained in the above control process, the control stability of this method will be greatly reduced under the interference, which is also a problem to be further solved.

References

[1] Liu Y., Li Y. D., Chen X. H.: *Integrated Design and Control Strategy of Energy Storage System in Micro-Grid.* Electric Power Construction *37* (2016), No. 8, 141–148.

[2] Feng X. Z., Hu J. H., Sang B. Y., etc.: *Power optimization control strategies of zinc bromine flow battery energy storage systemin photovoltaic/battery micro-grid.* Chinese Journal of Power Sources *40* 2016, No. 7, 1385–1382.

[3] Wu M. R., Tao S., Xiao X. N.: *Study on control method of smooth switchover for micro-grid based on master-slave control.* Modern Electric Power *32* 2015, No. 1, 1–70.

[4] Jing W., Lai C. H., Wong S. H. W, et al.: *Battery-super capacitor hybrid energy storage system in standalone DC microgrids: areview.* Renewable Power Generation *11* 2016, No. 4, 461–469.

[5] Bahmani-Firouzi B., Azizipanah R.: *Optimal sizing of battery energy storage for micro-grid operation management using a new improved bat algorithm* . International Journal of Electrical Power & Energy Systems *56* (2014), No. 3, 42–54.

Received November 16, 2017