Analysis of Combined FM Application in Thermal Power Plant of Energy Storage System

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Abstract. With the increasingly strict assessment of grid AGC, the energy storage system's participation in AGC FM technology has ushered in a good development opportunity. This paper introduces the application status, basic principle and application effect of the largest energy storage system put into power plant in China. This paper analyzes the performance index and economic benefits of the integrated frequency modulation before and after the energy storage system put into operation.

1 Introduction

New energy sources such as wind power and photovoltaic power have been incorporated into the power grid on a large scale recently, power generation characteristics of which directly affect the stability of power system operation. Winter is the wind power generation season, when thermal power units enter the heating stage, which reduces the power grid frequency modulation capacity to a certain extent. There is a serious wind abandon problem. With the increasing expansion of installed wind power capacity, once the demand for AGC FM auxiliary service cannot be met by the power grid, it will not only seriously restrict the effective development and utilization of wind power and other new energy, but also seriously affect the benefits of auxiliary service for thermal power units [1].

1.1 The significance of the energy storage system participating in AGC FM

Automatic power generation control (AGC) realizes the control of power grid frequency and power of tie lines by adjusting the active power output of units in the power grid in real time, so as to solve the problem of active power imbalance with random characteristics in regional power grid in a short time scale of minutes or seconds. At present, AGC FM function is mainly provided by hydro-power, gas and thermal power units. The conversion of primary energy into electric energy will go through a series of complex processes. At present, the AGC frequency modulation performance of thermal power units, as the main force, has a large gap with the regulation expectation of the power grid, which is manifested by such phenomena as regulation delay and deviation (over and under regulation). The perfect energy storage system that suits the grid AGC frequency modulation within the scope of the rated power not only can provide precision output in 1 s and more than 99%,
but also can realize its comprehensive response ability completely and satisfy demand in AGC FM time scale power transformation, namely reverse to adjust, and adjust the deviation and adjust the delay problems[2].

1.2 Calculation method of AGC performance index of Guangdong power gride

The operation of power generation unit that responses to AGC command can be evaluated and measured from three aspects, adjustment rate, response time and adjustment precision, namely.

Regulation speed \( (k_1) \) is the rate at which a generation unit responds to AGC control instructions. \( k_1 \) is equal to the measured rate of generating unit divided by the average standard regulation rate of AGC generation units in the FM resource distribution area(p.u.). The maximum value of \( k_1 \) is temporarily not more than 5 to avoid overregulation or overshoot when the generating unit responds to AGC control instruction.

Response time \( (k_2) \) is the time delay for the generation unit responds to AGC control instructions. \( k_2 \) is equal to 1 minus the value that response delay time of generation unit divided by 5minutes. The response delay time of generation unit refers to the delay time between the AGC action of generation unit and the AGC command received by generation unit.

Adjust accuracy \( (k_3) \) is the accuracy of generating unit response to AGC control instructions. \( k_3 \) is equal to 1 minus the value generation unit adjustment error divided by generation unit adjustment allows for errors. The adjustment error of power generation unit refers to the deviation between the actual output value and the control instruction value after the power generation unit responds to the AGC control instruction. The allowable adjustment error of power generation unit is 1.5% of its rated output.

Integrated frequency modulation performance index \( (k) \) refers to the comprehensive performance of the generation unit in response to AGC control instructions. The formula is as followed,

\[
k = 0.25 \times (2 \times k_1 + k_2 + k_3)
\]

The arithmetic average value of the comprehensive FM performance index \( k \) of power generation unit in different time cycles corresponds to comprehensive FM performance index \( k \) in the statistical cycle.

FM mileage \( (D) \) is the absolute value of the difference between the actual output value at the end of each response to the AGC FM control instruction and the output value at the time when the regulation instruction is issued. The total FM mileage in a certain period is the sum of the adjusted mileage of the generation unit responding to the AGC control instruction in that period [3].

2 Example analysis

2.1 System introducton

The energy storage frequency modulation project of the power plant is the largest one in China. This project adopts lithium iron phosphate battery with the capacity of 30MW/15MW•h energy storage auxiliary frequency modulation system. When the energy system participates in frequency modulation, the maximum output can be 30MW and last for 0.5 hours. According to the access conditions, the energy storage system is connected to the 110kV photovoltaic substation in the form of one tow two to adjust the power interval
of the 10kV equipment unit, which does not affect the normal operation of the original equipment in the power plant. The specific access method is shown in figure 1. With an investment of 120 million yuan, the project adopts container layout, modular design, and covers an area of about 1500 square meters with a high integration degree. The battery section consists of 15 30-foot containers, each with a battery capacity of 995kW•h. The power part consists of 15 30-foot containers, each of which is 2MW with 10kV output. The central control part is composed of a 30-foot container. The high voltage electrical part is composed of a 30-foot container. The battery system has reliable security. First, the three-level BMS architecture can monitor the operation status information of each cell. Second, the battery uses iron phosphate lithium battery, the stability is good, the heat will not produce oxygen, with the fire system can eliminate the danger. Third, the system has passed the CSA\TUV certification, and it will not explode in the case of impact, acupuncture, short circuit, high temperature, etc. Forth, when the battery exceeds 60℃, the system shuts down, eliminating the risk of thermal runaway. It took more than one year from the project beginning of construction to the completion of 30 days of continuous trial operation.

![Figure 1. Schematic diagram of the energy storage system.](image)

2.2 Data analysis

After the energy storage system is connected to the thermal power unit, the energy storage combined frequency modulation system has the characteristics of high response time, high response speed and high precision in output control. Fig. 2 shows the response process of tracking AGC frequency modulation of power grid when load is increased. After the power grid AGC command is issued to the power plant, the unit's power response time is particularly slow (which \(k_2=0.6\)) due to the inertia of the previous load reduction., while combined power depends on the energy storage system to increase output response immediately (\(k_2=0.92\)). The response speed of combined power is much higher than that of unit power. \(k_1, k_3, k\) of the unit power are 0.75, 0.7 and 0.67, respectively. \(k_1, k_3, k\) of the combined power are 1.81, 0.91 and 1.36, respectively. The energy storage combined frequency modulation system greatly improves \(k\).
Fig. 2. Tracking the grid AGC FM response process when load is increased.

Fig. 3 shows the tracking process of AGC FM response of power grid when load is reduced. After the power grid AGC command is issued to the power plant, the unit's power response time is relatively slow \( k_2 = 0.65 \), while combined power depends on the energy storage system to increase output response immediately \( k_2 = 0.95 \). The response speed of combined power is much higher than that of unit power. \( k_1, k_3, k \) of the unit power are 0.81, 0.71 and 0.74, respectively. \( k_1, k_3, k \) of the combined power are 1.2, 0.92 and 1.41, respectively. The energy storage combined frequency modulation system greatly improves \( k \).

Fig. 3. Tracking the grid AGC FM response process when load is reduced.

Energy storage combined with FM 24-hour data is shown in Fig. 4. Compared with a single thermal power unit, the energy storage combined frequency modulation system has obvious advantages in the regulation rate, response speed and response accuracy of AGC frequency modulation instruction of the power grid.
Figure 4. The energy storage system tracks the grid AGC FM response process on November 20, 2019.

The average $k$ of the unit is about 0.6 before the energy storage system is put into operation. The average of $k$ is about 1.3 after the energy storage system is put into operation. $k$ improves significantly, which can be seen in Table 1. In terms of economic income, the average daily income of energy storage combined with FM is 100,000 yuan. For example, under the circumstance of winning the bid 24 hours a day, the highest historical income is 270,000 yuan, and the economic income is obvious.

Table 1. $k$ comparison of comprehensive FM performance index before and after energy storage invested.

<table>
<thead>
<tr>
<th>Time</th>
<th>November 18, 2019</th>
<th>November 19, 2019</th>
<th>November 20, 2019</th>
</tr>
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<tbody>
<tr>
<td>Before</td>
<td>0.58</td>
<td>0.63</td>
<td>0.61</td>
</tr>
<tr>
<td>After</td>
<td>1.41</td>
<td>1.32</td>
<td>1.22</td>
</tr>
</tbody>
</table>

3 Conclusions

Power plant energy storage project and unit joint operation, significantly improve the power plant generator AGC regulation performance, which not only greatly improve $k$ and create considerable economic benefits, but also provide emergency security unit power, to ensure the safety of equipment. The energy storage system makes the load regulation of the power grid more accurate and fast, realizing the win-win situation between the power grid and the power plants.

References