Optimization and Improvement of AGC Performance Assessment Method Under the New Situation of Power Grid

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Abstract. With the gradual increase in the proportion of intermittent renewable energy, the standby capacity required by the system will increase accordingly, extensive attention is paid to the research on optimal control of thermal power units with automatic generation control (AGC) in power grid. Through the analysis of the current grid AGC control strategy, assessment indicators, rewards and punishments assessment, it is pointed out that the existing quotation is unreasonable, and the unit selection strategy is not conducive to the stable operation of the power grid, etc.. The AGC performance index based on the grid and source adjustment rate is proposed. The assessment method is good for the fairness of the AGC assessment and the safe and stable operation of the grid.

1. Introduction

The high proportion of intermittent renewable energy is connected to the grid, and the uncertainty of its output will have a series of impacts and challenges on the safe and stable operation of the power system[1]. With the permeability increasing, the problem of abundance is particularly acute. Compared with Europe and the United States, which have a higher proportion of flexible adjustment units such as pumping and gas, China’s flexible power supply ratio is low (the ratio of pumping and gas power supply is only 6%), which seriously affects the effective consumption of renewable energy. The nature of wind power and photovoltaic power generation is intermittent, which makes it difficult to quickly improve its prediction accuracy[2]. According to the forecast results, the risk of organizing electric power production will exist for a long time, especially in the Chinese power system dominated by coal-fired power, this problem is more prominent[3]. The thermal power unit starts slowly and has the minimum technical output constraint. It relies on its balance of wind power, photovoltaic and other new energy generation fluctuations. If the thermal power is too much, the wind will be abandoned, which will cause huge clean energy resources. At the same time, if the coal-fired power unit is turned on or the adjustment rate is insufficient, the adjustment will not keep up with the rapid fluctuation of the renewable energy, which will cause the risk of power outage[4]. Therefore, how to properly configure the power-on capacity of the thermal power units and control the regulation rate of the thermal power units is the key to coordinate the reliable, economical and clean operation requirements of the power system in the new era.

In the 13th Five-Year Plan for Electric Power Development (2016-2020) issued by the National Development and Reform Commission and the National Energy Administration, it is clearly proposed to strengthen the flexibility transformation of thermal power units, especially the rapid start-stop capability to improve the peaking capacity of the system. Therefore, optimizing the configuration and
adjustment capability of thermal power units is an effective way to achieve high proportion of renewable energy access. At the same time, how to adopt an effective AGC evaluation system and establish a reasonable compensation mechanism are important concerns for promoting the healthy and orderly development of AGC.

2. AGC Control and Assessment

Because of the large-scale grid connection of intermittent low-carbon power sources, the frequency characteristics of power systems tend to be complicated. The high frequency component of the interconnection system area control error (ACE) is increased. The AGC instructions sent to the unit controllers under the AGC system have more stringent requirements on the delay and slope climbing rate in response to the frequency modulation source [5].

2.1. AGC Control Strategy

Each provincial control area should improve the AGC’s adjustment capability to ensure that there are enough AGC units to adjust the capacity and the speed [6], and maintain the ACE of the control area near 0, and avoid active disturbances in the area to the UHV tie line, which is the basis for UHV tie line power control. In recent years, many scholars have conducted in-depth research on the new AGC technology and successfully applied it in engineering practice [7-11], such as coordinated control of thermal power units and advanced AGC control by ultra-short-term load prediction, which can effectively improve the control ability of AGC and effectively control the power of UHV tie-line.

The total regulation response rate of regional power grid system refers to the sum of unit regulation response rate invested in AGC, including rising and falling directions. It is an important indicator to measure AGC capability, and will give an alarm when it is insufficient. The formula is described as follows:

\[ R_{UP} = \sum R_{UPi} \]  \hspace{1cm} (1)

\[ R_{DN} = \sum R_{DNi} \]  \hspace{1cm} (2)

Where, \( R_{UP} \) is the regulating response rate in the rising direction of the system, \( R_{UPi} \) is the regulating response rate in the rising direction of unit i, \( R_{DN} \) is the regulating response rate in the descending direction of the system, \( R_{DNi} \) is the regulating response rate in the descending direction of unit i.

As shown in Figure 1, the power supply reference point of the thermal power unit in the power grid is determined by the dispatch control center through the ultra-short-term load and wind power forecasting information in the planning process. The basis point and participation factor of each unit are the results of the planned output optimization, and the rolling optimization is performed every 15
minutes and remains unchanged during the time period. At the same time, the ACE value is allocated to the unit in AGC mode according to certain strategy, and the AGC unit will eliminate this part of power deviation, so as to ensure the stability of the power grid frequency. Since AGC is included in the auxiliary service transaction in the power market, and the order of unit input is determined by the bidding mechanism, the number of unit in AGC mode is limited within a certain period of time.

2.2. AGC Assessment Indicators and Compensation
The north China regional power grid evaluates and compensates the thermal power units providing AGC services with comprehensive performance index $K_p$.

$$K_p = K_1 \times K_2 \times K_3$$  \hspace{1cm} (3)

In the formula (3), $K_1$ is the unit’s adjustment rate, $K_2$ is the unit’s adjustment accuracy, $K_3$ is the unit’s response time.

$$K_1 = 2 - \frac{v_a}{v_b}$$  \hspace{1cm} (4)

Where, $v_a$ is the standard load regulation rate on unit side, $v_b$ is the actual load regulation rate on unit side.

![Figure 2. Typical AGC unit set point control process](image)

As shown in Figure 2, it is a set point control process of a typical AGC unit. According to the requirement of Dispatch center, $K_1$ of pulverizing system and drum boiler unit is 1.5% of unit’s rated active power, thermal power units with intermediate storage pulverizing system is 2% of unit’s rated active power, circulating fluidized bed coal-fired units is 1%, super-critical once-through boiler unit is 1.0%. The adjustment accuracy $K_2$ is described by the integral mean value of the output and the command difference after the unit is stabilized. It is the difference between the actual output of unit and the set point of EMS when unit work stably after a response, permissible deviation is 1% of unit's rated active power. Response time $K_3$ refers to, after the EMS system send commands, on the basis of the original output point, the time that the output of generating unit reliably adjust to across adjusting dead zone to need. AGC response time of thermal power unit should be less than 1 minute.

3. Existing Problems
There must be an appropriate number of AGC units in the grid that operate in accordance with real-time grid control commands to control system frequency and inter-area exchange of power. Of course, after implementing the electricity market, AGC must provide corresponding economic compensation as an important auxiliary service. If the adjustment capacity of the unit AGC is restricted, which is not conducive to the sustainable and healthy development of the power grid.
Taking one provincial power grid in the North China Power Grid as an example, according to the requirements of the local energy supervision and management department, the selection of the frequency-providing service provider and the frequency modulation price adopt the market-oriented operation mode. Among them, the main terms include: the quotation interval 0~4 yuan/MW, according to the original quotation results to select the winning unit, the marginal unit quotation as the entire network unified settlement price. According to the information published on the website of the provincial energy supervision department, the total amount of AGC monthly compensation is shown in the Figure 3. From the analysis of the rules and the results of the operation, the province’s AGC market has the following problems.

First, the frequency modulation market is highly volatile. The total amount of compensation for the month ranges from 1 million yuan to 20 million yuan, with a difference of nearly 20 times.

Second, the lowest clearing price was only 0.1 yuan/MW, and the monthly compensation for the unit with the highest compensation in that month was only 50,000 yuan.

Third, the assessment results only consider the quotation, and do not consider the adjustment effect, and the unit with better adjustment effect is insufficiently stimulated.

In short, when the lower limit of the quotation is 0 yuan/MW, and there is no strict penalty mechanism for the unit with poor frequency modulation performance, it is easy to cause the problem that the 0 yuan unit wins the bid and the unit with poor frequency modulation performance is overloaded. Therefore, when the compensation amount is too low and the frequency modulation compensation fluctuates widely, the willingness of the unit’s AGC service will be reduced accordingly, and it is almost impossible to attract investment and construction of energy storage.

4. Optimization of Performance Indicators

For the setting of AGC indicators, firstly, it is necessary to effectively ensure the grid power shortage, and it can quickly supplement the shortage. Secondly, it is necessary to fully mobilize the enthusiasm of the unit, tap the frequency modulation potential of the unit, and ensure that its compensation is guaranteed while accelerating the quality of its power regulation.

From the actual operation results, the $K_3$ index difference between different units is small. The $K_3$ indicator is mainly affected by the valve flow characteristics and can be optimally adjusted through experiments. The $K_1$ is currently restricted, with an upper limit of 1.2, which artificially limits the ability of the unit to adjust quickly. Therefore, one weighting calculation method based on the comprehensive improvement of the network source adjustment rate is proposed.

$$K_p = K_1 \times K_2 \times K_3 + (v^*_n - v_n)$$  \hspace{1cm} (5)

In the formula, $K_1$ is the unit’s unlimited adjustment rate, it can be obtained by formula (6). $v^*_n$ is the actual load regulation rate on grid side, $v_n$ is the standard load regulation rate on unit side.
\[ K'_1 = \frac{v_c}{v_b} \]  

(6)

The faster adjustment rate of the unit in actual operation, the corresponding \( K'_1 \) value in the AGC is also large, and the \( K'_p \) will also be improved.

After the technical transformation of the unit, the AGC rapid adjustment test application can be submitted to the power grid according to the process. The power grid shall issue AGC load instruction at the rate \( v'_b \) higher than the standard rate \( v'_n \). If the test pass, the assessment index \( K'_p \) shall be calculated according to the formula(5). Only when the regulation rate of both the grid side and the unit side was improved, the regression of ACE can be effectively promoted, which is conducive to the stability of the grid.

5. Conclusion
With the gradual increase in the proportion of intermittent renewable energy, the standby capacity required by the system will increase accordingly, extensive attention is paid to the research on optimal control of thermal power units with automatic generation control (AGC) in power grid. Through the analysis of the current grid AGC control strategy, assessment indicators, rewards and punishments assessment, it is pointed out that the existing quotation is unreasonable, and the unit selection strategy is not conducive to the stable operation of the power grid, etc. The AGC performance index based on the grid and source adjustment rate is proposed. The assessment method is good for the fairness of the AGC assessment, and it can effectively improved the power of the AGC optimization, ensured the safe and stable operation of the grid.

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