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Optimization and promotion of automatic generation control strategy under large-scale wind power

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Abstract. With the increasing proportion of wind power in power grid system, the frequency control ability of power grid system were weakened. The security and stability control of power grid is facing great challenges. The research of frequency control for thermal power need to be further strengthened. The characteristics of wind power and automatic generation control (AGC) strategy were analyzed and studied, the optimization method and system design of unit's AGC were pointed out. Under the premise of ensuring safety and economy, the proposed approaches can fully used the load control capacity of thermal power generation and effectively improved the frequency characteristics of the power system.

1. Introduction

Since the 21st century, wind power, photovoltaic power generation and other new energy generation have gradually become important development issues. With the limitation of the energy resources and the requirements of environmental protection, new energy access is increasing. Because China's new energy distribution and the load distribution are in the opposite direction, at the same time, considering the characteristics of the randomness, uncertainty, volatility in the new energy, new energy still need a certain number of conventional units, to take on the regulation of power grid frequency requirements. In addition, when a large-scale new energy is connected to the power grid system, it will also bring some adverse effects to the system's safe and stable operation^[1-3].

Due to the obvious characteristics of day and night variability of natural wind, wind power has the characteristics of anti-peaking^[4-6]. When electricity load is at a low level at night, wind energy resources are often relatively abundant, and wind power output is relatively large. However, power grid peak shaving mainly depends on thermal power generation units and pumped-storage power stations. When unit worked in depth adjustment of peak, coal consumption is too high, and load tracking capability is also poor. Especially during the heating season in northern winter, heating units must maintain normal output and cannot participate in peak adjustment. When the power generation scale exceeds the range that the power grid can withstand, the power grid can only restrict the wind farm unit from suspending power generation, and the wind power should not be used.

2. Characteristics of Wind Power

Wind power is the most effective form of exploitation and utilization of wind, wind power as a renewable energy compared with conventional energy has its own advantages, such as abundant wind



resources, and can solve the problem of environment pollution brought by the fossil fuels, is a kind of clean energy, can effectively reduce the harmful gas emissions^[7,8]. However, due to some other characteristics of wind power itself, these characteristics have brought some negative impacts to the power grid.

2.1. Randomness

Wind power as a kind of unpredictable natural resources, its capacity influenced by air density, humidity, topographical features and other aspects. The randomness of wind energy leads to great difficulty in wind power prediction, which makes it difficult for the normal operation of operators.

2.2. Uncontrollability

The big or small of wind speed cannot be changed. Although pitch angle is adjusted to control the output of wind fans, but, because of the provisions of the present national policy, to avoid wind waste, wind power combined to the grid generally worked in full condition, so, wind power control is difficult with the change of wind speed uncertainty.

2.3. Volatility

Volatility of wind power is mainly manifested in the change of wind in a short period of time, due to the wind speed change rapidly in a short time, the fan output also follow the change in a short time. The small amplitude fluctuations can be inhibition by the system unit itself characteristic, while the larger fluctuation amplitude needs to take some measures to deal with.

Because of the above characteristics of wind power, when the wind power is connected to the grid, it will have a certain impact on the safe operation of the system. Due to the unpredictability of the wind power combined to the grid output, it will cause a certain impact on the stability of the system frequency. At this moment, adequate and effective frequency reserve is used to cope with the frequency drop. At the same time, due to the anti-peaking feature of wind power, it is necessary to provide some additional spinning reserve requirements for the uncertainty of wind power output, to eliminate the due to the increase or decrease of wind power potential safety hazard. Therefore, after the wind power is connected to the grid, according to its impact on the system's various indicators, a reasonable arrangement of the system spinning reserve becomes the key to system economic dispatch and safe operation.

3. AGC Performance Evaluation Standard

The traditional frequency modulation behaviour of power system can be divided into primary frequency control (PFC) and AGC by time scale. PFC is differential control, there is static frequency deviation. AGC is no difference adjustment, and ultimately achieve balance between supply and demand.

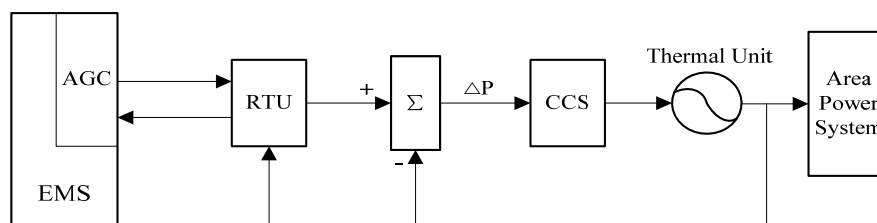


Figure 1. Control schematic diagram of a single thermal power unit

Traditional AGC in the power plant control structure is shown as figure 1. The standalone AGC commands from energy manage system(EMS) will be sent to remote terminal unit(RTU) of power plant side, then by the RTU via I/O hard-wired to send to unit coordinated control system (CCS), to complete the adjustment task of unit's AGC system.

3.1. Unit's AGC Control Performance Evaluation Standard

According to the rules of regional dispatch center, the unit's AGC operation must to be according to the scheduling curve, it put forward higher requirements on the unit control system. The variable load of AGC is the test of the whole control system. How to on the basis of existing equipment, optimize the unit's control strategy, realize the load control requirements, and ensure stable operation of the unit, is a problem that must be considered.

3.1.1. Adjustment rate. According to the requirement of regional dispatch center, the rate 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%.

3.1.2. Adjustment accuracy. 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.

3.1.3. Response time. Response time 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.

3.2. Grid's AGC Control Performance Evaluation Standard

The Grid's AGC control performance evaluation standard are mainly adopted by North American Electric Reliability Council for A1, A2 and CPS1, CPS2 standards^[9-11]. Generally speaking, the CPS1 and CPS2 standards are more favourable for ensuring the frequency quality of the power grid, and are conducive to the mutual support of the power between regions in the accident.

CPS1 and CPS2 standards were formally implemented in 1998, and its contents are as follows.

Requirements of CPS1 is

$$AVG_{period}[ACE_{AVE-min} \times \Delta F_{AVE-min} / (10B_i)] \leq \varepsilon_1^2$$

In the formula, $AVG_{period}[]$ is the average of the values in parentheses. $ACE_{AVE-min}$ is the average of 1 minute ACE, which requires every 2s to be sampled once, and 30 values are averaged. $\Delta F_{AVE-min}$ is the average of one minute frequency deviation, which requires 1s to be sampled once, and 60 values are averaged. B_i is the deviation coefficient of the control region. ε_1 is the control target value which the mean square root of the interconnection power grid for the average annual frequency deviation of 1 minute, which is the uniform amount of the whole grid, such as 0.03Hz. The physical significance of $ACE_{AVE-min} \times \Delta F_{AVE-min}$ is, when the value is negative, the control region is represented by the low frequency but too much output or the high frequency but too small output in the 1min process. When the value is positive, the control region is represented by the low frequency but too small output or the high frequency but too much output in the 1minute process.

The statistical formula of the CPS1 index for a period of time is

$$K_{CPS1} = (2 - K_{CF}) \times 100\%$$

$$K_{CF} = \sum[ACE_{AVE-min} \times \Delta F_{AVE-min} / (10B_i)] / n / \varepsilon_1^2 = \sum[ACE_{AVE-min} \times \Delta F_{AVE-min}] / n / (10B_i \times \varepsilon_1^2)$$

In the above statistical formula, there are two key points, $K_{CPS1} = 100\%$ and $K_{CPS1} = 200\%$.

When $K_{CPS1} \geq 200\%$, or $K_{CF} \leq 0$, it must be

$$\sum[ACE_{AVE-min} \times \Delta F_{AVE-min}] \leq 0$$

This indicates that during this period, ACE is helpful to the frequency quality of the interconnected power grid.

When $100\% \leq K_{CPS1} < 200\%$, or $0 < K_{CF} \leq 1$, it must be

$$\begin{aligned} \sum[ACE_{AVE-min} \times \Delta F_{AVE-min}] &\geq 0 \\ \sum[ACE_{AVE-min} \times \Delta F_{AVE-min}] / n / (10B_i) &\leq \varepsilon_1^2 \end{aligned}$$

This indicates that ACE has an adverse effect on the frequency quality of the power grid, but not exceeding the allowable level.

When $K_{CPS1} < 100\%$, or $K_{CF} > 1$, it must be

$$\begin{aligned} \sum[ACE_{AVE-min} \times \Delta F_{AVE-min}] &\geq 0 \\ \sum[ACE_{AVE-min} \times \Delta F_{AVE-min}] / n / (10B_i) &> \varepsilon_1^2 \end{aligned}$$

This indicates that ACE has an adverse effect on the frequency quality of the power grid and exceeds the allowable range. The standard requires that the average ACE of 10 minutes must be controlled within the specified range L10.

$$L_{10} = 1.65\varepsilon_{10} \times \text{sqrt}[(10B_i) \times (10B_g)]$$

In the formula, B_i is the frequency deviation coefficient of the control region, and B_g is the frequency deviation coefficient of the whole interconnected power grid. ε_{10} is the control target value which the mean square root of the interconnection power grid for the average annual frequency deviation of 10 minute.

According to the CPS standard, the evaluation of contribution to the frequency quality of the power grid in each control area is very clear. It is particularly beneficial to support other control areas in the event of an accident in a control area and to give full play to the superiority of the large power grid.

4. Influence of wind power on AGC

According to the daily curve, the change of total wind power generation caused the change of regional control deviation, and then affected the load target value of the AGC function unit.

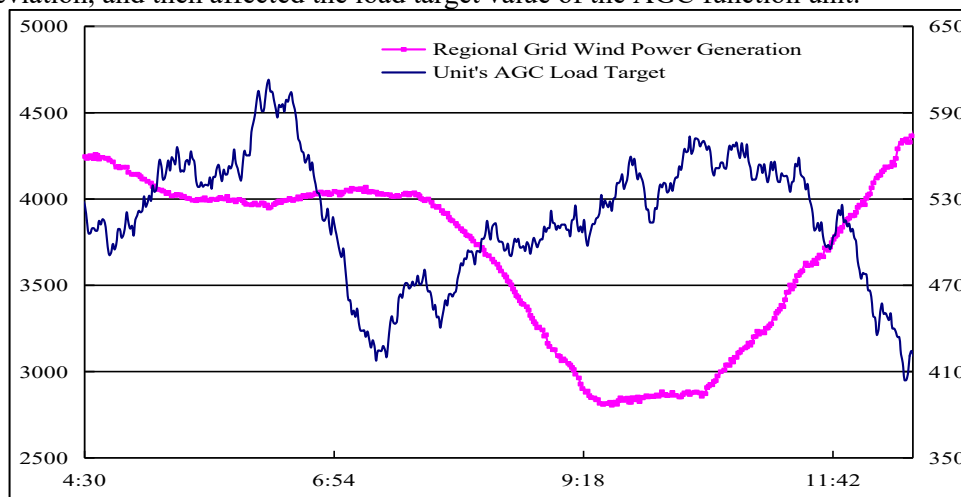


Figure 2. The curve of regional grid wind power generation and unit's AGC load target

When the wind power changes greatly due to changes in the environmental climate, the Region Control Deviation (ACE) at the dispatching end of the regional power grid will also become a large difference, and the AGC mode of units in the power grid will be adjusted to adjust the load, in order to make the grid frequency back to normal 50Hz.

The certain period of time of regional grid wind power generation and unit's AGC load target curve is shown in figure 2. The time interval in the curve is 1min. When the wind power generation changes significantly, the AGC load target changes in the opposite direction to promote ACE to 0. Therefore, it

is necessary to adjust the AGC control of the unit according to the change of wind power, and change the regulation rate of the unit so as to ensure that the grid frequency fluctuates within a certain range.

5. AGC optimization control strategy

One dynamic adjustment method based on ACE for AGC is designed. The basic idea of design is, when the power shortage accident occurs in the power grid, whether the regional control deviation value exceeds the preset range value, and whether the main steam pressure deviation value exceeds the set range is determined.

5.1. Unit's AGC Optimal Control Design Based on ACE

If the unit area control deviation value exceeds the ACE setting range and the main steam pressure deviation value does not exceed the pressure setting range, the artificial acceleration load adjustment shall be carried out. If the unit area control deviation value does not exceed the ACE setting range, the load will be adjusted normally.

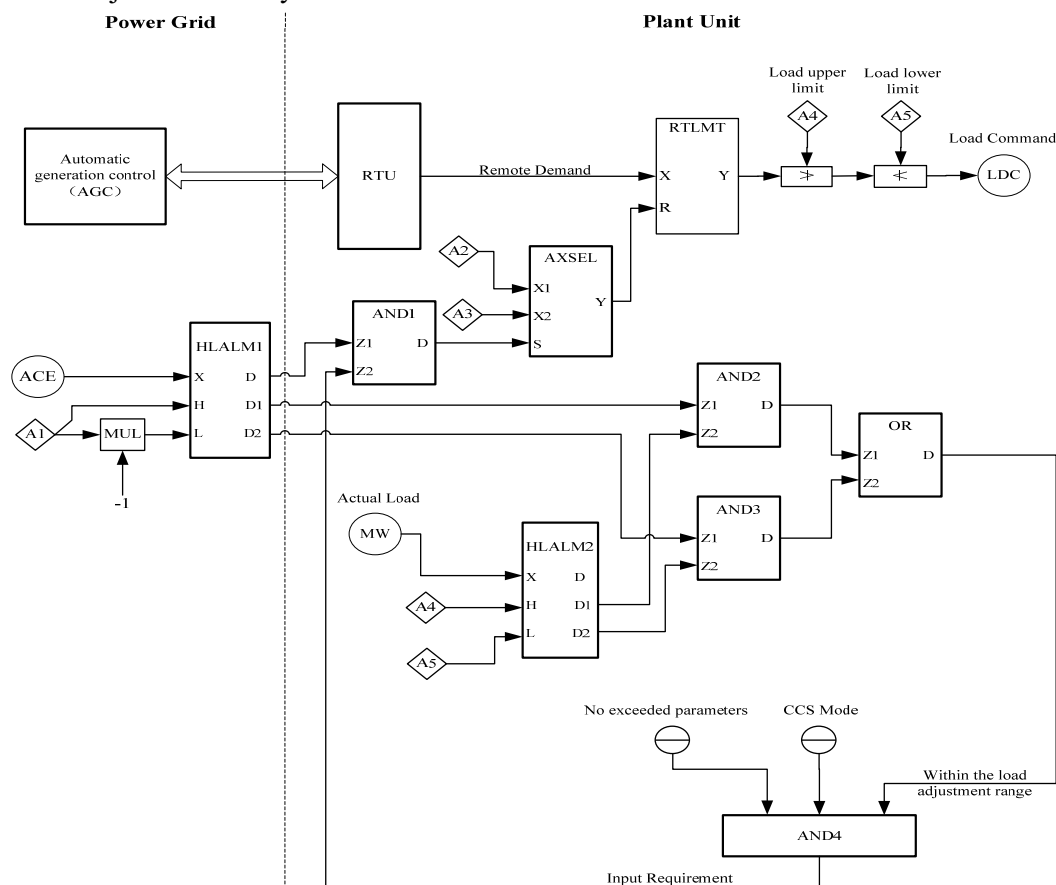


Figure 3. Optimal control schematic diagram of unit's AGC

As shown in figure 3, when the wind power fluctuates greatly and the power grid produces a large power gap, the emergency mode input signal of the power grid is sent to the unit, so that the unit enters the rapid adjustment mode. If the main steam pressure deviation within the prescribed scope, i.e. not beyond the high and low limit alarm module HLALM's height limit, the rate of load adjusting was increased until the emergency mode input signal disappear. If the main steam pressure deviation value is not within the prescribed scope, beyond the HLALM's limit range, so the unit maintain normal load adjustment, rapid emergency load adjustment will not be involved.

5.2. Practical Application

The size of ACE caused by the changes of wind power determines whether the AGC adjustment rate speeds up and achieves coordinated action of the grid and the unit to ensure the stability of the grid frequency.

According to the regulations for the grid-connected operation and management of power plants in the North China region, the general adjustment rate of thermal power unit is 1.5% of the rated active power. Take one 300MW unit as an example, according to the regulations, the adjustment rate is 4.5MW/min that is the standard regulation rate of the unit's normal operation. The value of HLALM are set from -0.6 to 0.6. When the wind power changes dramatically and rapidly, the ACE will inevitably change. The normal regulation range of ACE in this region is -200 to 200MW, so the value of A1 is 200.

After test verification, when the unit is changing at the rate of 8MW/min in a short time, the main parameters such as steam pressure can be controlled within the standard range, so the corresponding dynamic adjustment rate is set to 8MW/min, much larger than the standard 4.5MW/min.

Through optimization and transformation, the supply and demand balance ability of regional grid load is improved, and the overall frequency index is significantly improved.

6. Conclusion

The paper introduced the characteristics of wind power and AGC, analyzed the relationship between them, and put forward the optimization method of unit's AGC. By dynamically adjusting the adjustment rate of the AGC according to the ACE size, an effective compensation for wind power fluctuations can be achieved. Under the premise of ensuring safety and economy, the proposed approaches can fully use the load control capacity of thermal power generation and effectively improved the frequency characteristics of the power system.

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