A Research on Primary Frequency Control Strategy

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Abstract. There are the overshoot phenomena of the active power regulation in some regions, which goes against the reliability and the economics of the power system. The Strategy of primary frequency control is not reasonable for regulation. The influence of current primary frequency control strategy is discussed. A new strategy considering cooperation of AGC is proposed. Simulation results show that the strategy in this paper can effectively reduce the overshoot phenomenon.

Introduction
There are the overshoot phenomena of the active power regulation in some regions, which goes against the reliability and the economics of the power system. In general, the frequency control are almost the automatic adjustments. As a result, the control strategy directly determines the performance. Overshoot phenomena are always of short time scale, and the automatic adjustment will consist of the automatic generation control (AGC) and the primary frequency control.

Among the frequency control research, the majority only consider the control strategies of AGC [1], while the researches of the primary frequency control nowadays are separated in power plants side and the grid side. The side of power plants focuses on adjusting the coordinated control system to satisfy the requirements of primary frequency control from the power grid, or discovering more frequency control resources [2]. Whereas the grid side tends to the management of primary frequency control [3]. Although the coordination between primary frequency control and AGC lacks the theoretical analysis, it could be seen in more practices [4].

Primary Frequency Control Strategy Analysis
The definition of primary frequency control is mainly based on the admitted time scales, however there are different views on the task of primary frequency control.

In Chinese power grid, the primary frequency control is widely used in regulation services, affecting the quality of frequency together with the AGC. However, the current primary frequency control and AGC are nearly independent.

The Requirements of Primary Frequency Control in China
There are usually two kinds of views about the definition of primary frequency control. The one is defined according to the change trend of the load. The primary frequency control is the adjustments of generators to modify the load variation with the fast frequency change, short time cycle, and small amplitude. This definition is widely used in Chinese power grid, and is applied to the regulation. The other one is determined by NERC, and it is that the whole system must be able to control to frequency and arrest excursions during disturbances [5].

A technic file "management of primary frequency generator sets" from a Chinese regional grid indicates that the response time of primary frequency control should be less than 3s. Also the speed change rate should be less than 5%, and the dead zone is 0.033 Hz. In conclusion, the requirements of primary frequency control includes the shorter response delay, and faster ramping speed in the recovery phase after the dead zone.

The technical requirements are necessary for the recovery of frequency after the emergency. However, they are not suitable for the common fluctuations of load. Due to the separated managements between the plant and the grid, the implementation of both primary frequency
control and AGC is done by the power plant side. To meet the requirements of the ramping speed, the adjustment speed of frequency control units is generally set to a fixed value (such as 5% of frequency control speed changes). And none unit is permitted to adjust the speed according to the frequency deviation. Therefore, the ramping speed of active power in the grid is proportional to the unit capacity of participation in the frequency control. The more units involved, the faster speed is.

Unified limit to the dead zone will cause that the frequency control units are involved all or none. In the actual operation, the dead zone limits of AGC and primary frequency control are almost the same. So primary frequency control will be ahead of AGC adjustment. As a result, primary frequency control will determine the regulation at the beginning of the disturbance.

**The Influence of Primary Frequency Control to Overshoot**

The steam turbines and boiler are usually built as the one-order inertia models, so the problem can be simplified as the response to the inertial system under the closed-loop control. In the condition of the reasonable control, inertia coefficients decided the response speed and effect.

![Figure 1](image)

Figure 1. Step response of Inertial system on the basis of closed loop control system.

Figure 1 shows the step response to the inertial system under the closed-loop control. Where $y_1$ is the maximum dynamic deviation, and the percentage of $y_1$ to the steady-state change is called the *overshoot*. And $Tr$ represents the rising time, which reflects the adjustment speed of the control system. The inertia coefficients of the system, and the adjustment speed of the actuator, influence the quantity of overshoot. The two factors will be analyzed below.

1. The inertia coefficient of the system. The inertia coefficient is related to the characteristics of units, such as the mechanical inertia of steam turbine is less than the hydro turbine, less than the burning inertia of boiler. It is reflected on the adjustment ways that the response speed of primary frequency control of steam turbine is faster than the AGC or primary frequency control of hydro turbine. The latter is also faster than the AGC of coal-fired units. These ways belong to the inherent nature of the units in control areas, and will not be changed in a short time of period.

2. The adjustment speed of the active power. In the grid, the adjustment speed of active power is equal to the sum of all participants in primary frequency control. And i the speed of each unit for frequency control is a fixed value. Therefore the adjustment speed of active power is only determined by the number of frequency control units or the total capacity of the units.

And unified dead zone and values close to the dead zone of AGC, result in the grid frequency adjustment with maximum ramping speed. The control strategies of AGC include changing the ramping speed of active power in grid by adjusting the number of participation units, which however lags behind the primary frequency control. So the faster ramping speed, the greater amount of overshoot.
The Cooperation of AGC and Primary Frequency Control

It is general to differentiate the function of primary frequency control according to the dead zone. One part participate in regulation services. The other part play the role of power reserves for the emergencies. The units involved in the regulation could gradually increase the quantity of frequency control units through setting the piecewise death zone as the frequency deviation grows. The detail setting method of dead zone should be fit for the AGC strategy. And the AGC control strategy widely used in China is described as the [1].

The regional regulation power \( P_R \) formulated as

\[
\begin{align*}
\dot{P}_N &= \dot{P}_p + \dot{P}_I + \dot{P}_{CPS} \\
\dot{P}_p &= -G_p \cdot E_{ACE} \\
\dot{P}_I &= -G_I \cdot I_{ACE} \\
\dot{P}_{CPS} &= -10 \cdot G_{CPS} \cdot \Delta F
\end{align*}
\]

(1)

Where \( E_{ACE} \) is the filtered ACE value, \( I_{ACE} \) is the integral value of ACE at the current time (10 min), for MWh, and \( G_p, G_I, G_{CPS} \) are respectively proportional, integral and frequency gain coefficient from the experience.

According to the value of the regional regulation power \( P_R \), the control zones of AGC could be divided into dead zone, normal control zone, sub-emergency control zone and emergency control area, in which the thresholds are \( P_D, P_A, P_E \), as shown in Figure 2.

Figure 2. Regulation power and AGC control region.

There will be a different number of units involved in adjust the allocation of power in different AGC control zone. The greater the absolute value of adjustment power is, the more units will participate. So the ways for units to adjust power and AGC control zones could be associated as: (1) O (off-regulated) represents none of adjustment power in any circumstances; (2) R (regulated) represents unconditional adjustment power in any need; (3) A (assistant) represents adjustment power of emergency or sub-emergency; (4) E (emergency) represents the power only in emergency zone.

To cooperate with the AGC strategy, the piecewise dead zone of primary frequency control are set as follows: (1) the dead zone of R model is set to \( f_D \); (2) A model is set to \( f_A \); (3) E model is set to the \( f_E \); (4) O model is set to \( f_E \), for that it is likely to have the ability of primary frequency control when units are not involved.

\[
\begin{align*}
f_D &= \frac{P_D}{G_{DP}} \\
f_A &= \frac{P_A}{G_{PA}} \\
f_E &= \frac{P_E}{G_{PE}}
\end{align*}
\]

(2)

Where \( G_{DP}, G_{PA}, G_{PE} \) are respectively the proportional gain coefficients of control zones. Because the frequency deviation and the ACE will fall in a small range, the integral \( P_I \) and the CPS standard component \( P_{CPS} \) have small proportion in (1). Then the piecewise calculation of the dead zone only considers the influence of the proportional components. In this setting, the units assigned to adjust by AGC, will also participate in primary frequency control. While other units will not in primary frequency control or the AGC process. The piecewise dead zone of primary frequency control above could reduce ramping speed in the regulation to limit the overshoot, which avoids the repeat control of most units.
The Numerical Results

Figure 3. Simulation calculation of frequency deviation between two strategies in regulation service.

The performance of frequency deviation of two kinds of control strategies above is shown as Figure 3. It is obvious that the adjusted strategy has better performance. The common strategy of primary frequency control is not cooperated with the AGC control strategy, and that results in the large overshoot. However after the adjustment, the frequency and amplitude of the fluctuation of frequency deviation are significantly reduced, and the economics is greatly improved, so is the stability of the power grid operation. In a word, it will significantly improve the overshoot above.

Conclusion

The influence of current primary frequency control strategy is discussed in the paper. And then a new strategy is proposed which is considering about cooperation of AGC. At last, the effect of this method is verified by simulation.

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Reference


