Research of overshoot phenomenon in frequency control

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Abstract. Frequently overshoot phenomenon is appeared in the regulation of active power of some areas, which is not conducive to the reliability and economy of power grid. The reasons of overshoot are discussed and improvement measures are proposed.

1.   Introduction

The frequency of grid is one of the important indicators to measure the power quality. In China, through Automatic Generation Control (AGC) and development of primary frequency Control resources to keep active power balance of the power grid. In some control area, the improper control mode to pursuit of better control performance lead to overshoot phenomenon.

The overshoot phenomenon can cause the following hazards:

a) Considering from the grid position, when overshoot phenomenon occurring in a control area, in whose connected area Power fluctuations then. So, overshoot phenomenon make it more difficult to control of adjacent areas. At the same time, the intense fluctuations of the power grid frequency also effect the power quality.

b) Considering from the generator unit, executing commands which may cause overshoot can make regulating valve wear and tear, Shorten the service life and increase maintenance costs. Due to units which participate in frequency control need to be at constant pressure operation mode and the pressure loss of main steam should occur in the all levels valve, so power generation efficiency decline.

Therefore, overshoot phenomenon is not good for both reliability and economy of system.

2.   Analysis of reasons

The frequency control process usually is automatic adjustment process. Therefore, the automatic adjustment of the control strategy directly affect the control performance. And the influencing factors that choose control strategy include control performance standard and regulation service compensation mechanism.

Control quality of each control area is evaluated by the control performance standards, which guide and restrain the regional control behavior. Power grid of East China ,as the earliest introduction of control performance standard regional power grid[1], shorten calculation cycle of CPS1 indicators to 10 or 15 minutes. In 2015, the new standards called Balancing Authority ACE Limit(BAAL) are voted. As a short period standard, the target of BAAL is reliability of system and the ACE limit is three times than CPS1[2]. Thus it can be seen that $\varepsilon 1$ in CPS1 is too tight for the limit of short period evaluation standard.

Regulation service is one of ancillary services and its target is reliability. In addition to power cost, AGC units which supply regulating service need to bear additional cost. So there should be corresponding compensation for regulation service. AGC compensation mechanism in China is more like responsibility[3]. All the AGC units obtain the same compensation when they meet the requirement of performance. To put Energy storage battery into regulation service, PJM Issued performance-based regulation compensation mechanism[4]. Which consider capacity payment and performance for frequency control.

In addition, frequency Bias B is studied In the literature [5]. The unreasonable setting method of B can also cause overshoot.

Frequency does not change in an Interconnection as long as there is a balance between resources and customer demand. When there is deviation of supply and demand, it is necessary to adjust active power of AGC unit or other resources ., It usually boils down to an optimization problem to determine the output power of each unit, such as equation (1). The problem needs to consider reliability and economy o whose quantitative requirements are control performance standard and compensation mechanism. The requirements of reliability and economy.

$$object \quad economy \quad or \quad frequency \, deviation$$

$$s.t. \quad control \, performance \, standard \quad\quad\quad\quad\quad\quad\quad\quad\quad (1)$$

$$compensation \, mechanism$$

Reliability require the faster rate of regulation and the smaller frequency deviation. On the contrary, economy require to reduce regulating action. Reliability and economy of power system influences and restricts each other. In China, grid corporation pay the same amount of compensation for all regulation resources, Whether they adjust power more or less. The standard in China is much stricter than the one in North America. and many control areas compare CPS1 value ranking with its conjoint areas. Therefore the control strategies tend to easily cause overshoot.

3.   improvement measures

According to the above mentioned analysis, it can be seen that there are many reasons for overshoot phenomenon. Therefore grid need to make adjustment respectively in order to avoid overshoot phenomenon.

3.1 Frequency bias setting

The way of adjustment should reference standard BAL-003-1 issued by the NERC, whose title is Frequency Response and Frequency Bias Setting (FRS)[7]. B is set by the electric reliability organization (ERO) ，dispatch center in China. Compared with the current methods, the ERO will announce the three-day implementation period for changing the Frequency Bias Setting.

3.2 build regulation market

Refer to the PJM regulation market, auxiliary services trade platform that is based on the market should be built for market participants, they can buy and sell regulation service. Each unit To participate in regulation quotes a price by calculating the corresponding cost, dispatch center get the price ranking. And then according to the forecast it should buy corresponding regulation capacity.

The regulation market is 5 minute real-time market. The regulation capacity procured at this stage will participate in regulation and receive instruction of AGC.

To put Energy storage battery into regulation service, PJM Issued performance-based regulation(PBR) compensation mechanism [4, 5] . the PBR model in PJM have two regulation signal types ,Regulation A(RegA) and Regulation D(RegD). RegA is a low pass filter of PJM Area Control Error (ACE) sent to traditional regulating resources, such as steam and combined cycle units. RegD is a high pass filter of PJM ACE sent to dynamic or fast response regulating resources, such as batteries and flywheels

Resources following the dynamic signal (RegD) will likely move much more than those on the traditional signal (RegA). So, the concept of mileage is introduced, which represents resource's contribution to the ACE deviation correction. Mileage is the absolute sum of movement of the regulation signal in a given time period. For an hour with 8 mileage, a 1 MW assigned resource will move up and down a total of 8 MW.

Regulation Market Clearing Price include Capability Clearing Price (CCP) and Performance Clearing Price (PCP). According to the settlement method, regulation service fee depends on the capacity, performance and mileage.

Under the rules of the regulation market, the cost of overshoot will increase sharply for dispatch center. Firstly, Each generator regulating speed is determined by unit capacity and unit

types. To increase regulating speed have to make more units participated in AGC ,that increase the capacity. Secondly, the concept of mileage represent the contribution to ACE correction ,the mileage will increase sharply if overshoot. Therefore, the rules of regulation market limit the capacity and speed of regulation service, as a result of limiting the overshoot.

3.3 Add constraint of the differential value of ACE in standard

It will be a long time for building regulation market. In the transition stage, overshoot problem should be solved by adding constraint of the differential value of ACE in standard. The differential value of ACE represent change speed of ACE, which is determined by change speed of load and ramp of units' power output. If the speed of ACE is much bigger than the speed of speed of load, it indicates that ramp of power output is significantly larger. Therefore, ramp limit is determined by the historical data of speed change in load, which can effectively restrict overshoot .

In order to the feasibility of the standard, the CPS1 value limit shall be relaxed .This standard should be retired until the regulation market is built. Specific operation method is as follows:

Load fluctuation has different speed in different periods of a day. The limit of the differential value of ACE is set by the speed of the load fluctuation . the examination cycle is a day . If the percentage of the time over the limit of standard is less than the set value , it can be said that performance of control meet the standard. Otherwise, it should be punished. In real-time operation, the dispatcher e can refer to historical data to set the limit value. When disturbance occur, the power unbalance largely . the speed of frequency recovery will not be restricted for follow this standard.

4. Case analysis

Figure 1 is the simulation results of the ACE between two strategy. Maximum of the differential value of ACE is 2.13MW/s in strategy 1, and 0.59MW/s in strategy 2. If the limit value is set as 1MW/s, it is violation in 82% in strategy 1 and 0% in strategy 2 of the period of simulation . So ,the standard of the differential value of ACE makes dispatcher choose the strategy 2 which don't cause overshoot.
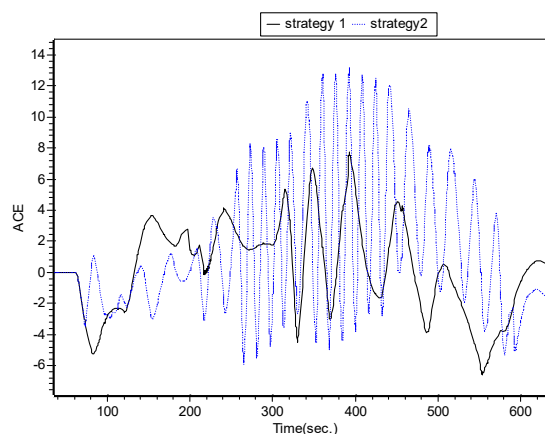

Fig. 1   Simulation calculation of ACE between two strategy in regulation service

5. conclusion

Overshoot in regulation is mainly discussed in the paper. According to analysis of the control performance standard and compensation mechanism of frequency control, the reasons of overshoot are concluded .And then , the corresponding improvement measures are proposed.

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