The Analysis of the Primary Frequency Regulation in Electric Power System

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Abstract. Power system frequency control technology plays an important role in the maintenance of the safe and stable operation of power system, and the primary frequency regulation occupies the important position relied on its own advantages. In order to analyze the primary frequency regulation, the definition of the primary frequency control ability of electric power system is presented here. From the definition, the mathematic expression of the primary frequency control ability in dynamic state is obtained. For engineering applications, the influence of the speed droop coefficient on the primary frequency control in electric power system is illustrated. Besides, for a more intuitive research, the simulation waveforms of the primary frequency regulation are given.

Introduction

With the continuous economic and technological progress, the electric power system is moving in the direction of large-capacity, high-voltage, long-distance transmission. More and more regional power systems become interconnected and the formation of large power system has become a big trend now. On the one hand, it raised the awareness for efforts to control the grid, so that people on the grid control regulation is more convenient, on the other hand, it also makes the stability of the grid becomes more complex, so people have to further enhance the security and stability attention on the power grid. [1-3]

The frequency is one of the most important operating parameters of the power system, and the frequency deviation of the system has a very important impact on the safety and stability on the operation of the power system. Recognized the most important one as the world's three major power quality indicators, the scope of change in frequency in electric power system is related to the lifeline of the country's economic development, and therefore the importance of maintaining frequency stability is even more prominent. [4-6]

According to the reference [7], frequency is an important indicator of the quality of power system and the security situation of power system. If the frequency of the system changes dramatically, exceeding the safe range, the system will run extremely unfavorable, or even result in serious consequences, including Turbine blade cracks, frequency collapse and affecting the quality of production, which will have a bad influence on the industrial production and people's lives.

The above analyses show that, the great frequency deviation of the power system will bring many serious consequences to the power system and the electricity users. When the power system is disturbed, the main objective of power system is that the frequency of the power system can be controlled within a range of requirements to ensure that the power system can operate normally, safely and stably. It is generally through primary frequency regulation and secondary frequency to achieve, so the research on the frequency control in electric power system is essential. [8-9]

The research will be based on the basic structure of the power system and the units' parameters of a certain province. This province is a famous Coal-rich province and its grid structure mainly based on its

thermal power units. Meanwhile, as China's major agricultural province, its agriculture electricity load plays a very important part in the overall proportion of the load. By 2015, this province's total installed capacity is 60920MW, where the total thermal power installed capacity is 49665MW and the hydroelectric generating total installed capacity is 3260MW.

The Calculation of the Primary Frequency regulation ability in Power System

The Mechanism and Mathematical Model of the regulation of frequency in electric power system. Before calculating the primary frequency capability, we must establish the mathematical model first. The primary frequency modulation is all synchronous generators, operating in parallel together in the power system. According to Turbine Regulating System action principle, we can establish a mathematical model of frequency regulation in electric power system.

According to the principle of the reheating steam turbine control system, the mathematical model of the research and analysis of primary frequency regulation is established. Fig.1 is the mathematical model of M synchronous generators in parallel running, where R_i is coefficient of power budget of the units of the perform primary frequency regulation, d_i is speed droop coefficient of generator i, a_i is ratio of the installed capacity of generator i to the installed capacity of electric power systems， $c_{p_{L\Sigma}}$ is the normalized value of the load and c_n is the normalized value of the rotor speed . Besides, the first three modules constitute the transfer function of the generator. This model is for the study of a certain power system and the subsequent studies are based on it.

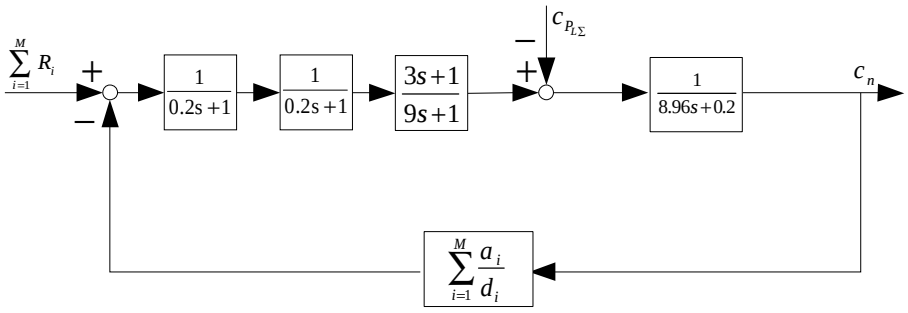

Figure 1 mathematical model of the primary frequency regulation

This research is based on a specific province power system data and the simulation model relies on a provincial power system structure. The establishment of the model is based on the specific data and features of this power system. This simulation model contains all the thermal power plants, hydropower plants and one special high-voltage line in this simulation model. When creating simulation model, we put a step signal with amplitude of 0.130 to replace the high-voltage line, and let this step signal become zero at 500s to simulate the actual situation in the case of interruption of this province at 500s when the high-voltage circuit break.

When setting up the model, we assume that the province's thermal power units are all reheat unit type and the primary frequency modulation circuit is added the dead zone in order to avoid different units operating in different situations.

The concept and the expression of primary frequency regulation ability. According to the reference [10], in order to quantitatively describe the power system response capability to deal with unexpected incidents, we need to use an indicator to measure its primary frequency regulation ability. Primary frequency regulation ability refers to that the power system itself can not rely on the secondary frequency regulation mechanism when the power network frequency is changed and we can observe it's ability to adjust the capacity of the power change automatically.

Under the dynamic grid, the definition of a frequency modulation type is shown as formula 1:

$$PFRA = \frac{\text{Variance of grid load changes}}{\text{Variance of grid frequency changes}} (\text{Within a certain period of time}) \quad (1)$$

Reference variance formula used in analysis of stochastic processes considered in the dynamic case, a calculation expression for the frequency regulation is that:

$$PFRA(dynamic) = \sqrt{\frac{1}{\int_{-\infty}^{+\infty} \left| \frac{W(jw)}{T_{a\Sigma} jw + b_{\Sigma} + G(jw)} \right|^2 dw}} \tag{2}$$

Numerical examples of a specific province. According to the above calculation method, the calculation of the primary frequency regulation ability when the speed droop coefficients are set to different values shows as table 1.

	Different speed droop coefficients		
	$d_1 = 0.06$ $d_2 = 0.06$ $d_3 = 0.06$	$d_1 = 0.04$ $d_2 = 0.05$ $d_3 = 0.06$	$d_1 = 0.04$ $d_2 = 0.04$ $d_3 = 0.04$
$PFRA(dynamic)$	9	10	11

Table.1 the results of primary frequency regulation capability

The above analyses and calculation results show that the smaller the speed droop coefficient on primary frequency regulation, the bigger the primary frequency control ability.

The effect of primary frequency regulation rate on the performance of primary frequency regulation.

The establishment of a simulation model of a certain power system. Based on the above analyses, we can establish the simulation model on the Matlab Simulink platform.

The output waveforms of the simulation model. Change the values of the units in the simulation model so that we can observe and compare the differences between these output waveforms.

(1) The speed droop coefficient is set to $d_1 = 0.04; d_2 = 0.04; d_3 = 0.04$

The output waveform of the frequency deviation in such a situation is shown as figure 1.

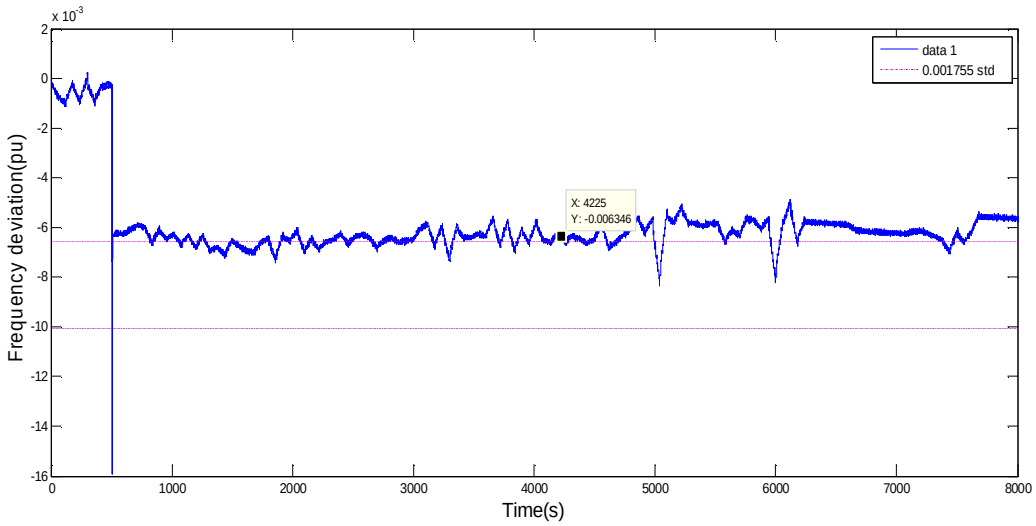

Figure 2 Output waveform under only primary frequency regulation 1

(2) The speed droop coefficient is set to $d_1 = 0.04; d_2 = 0.05; d_3 = 0.06$

The output waveform of the frequency deviation in such a situation is shown as figure 2.

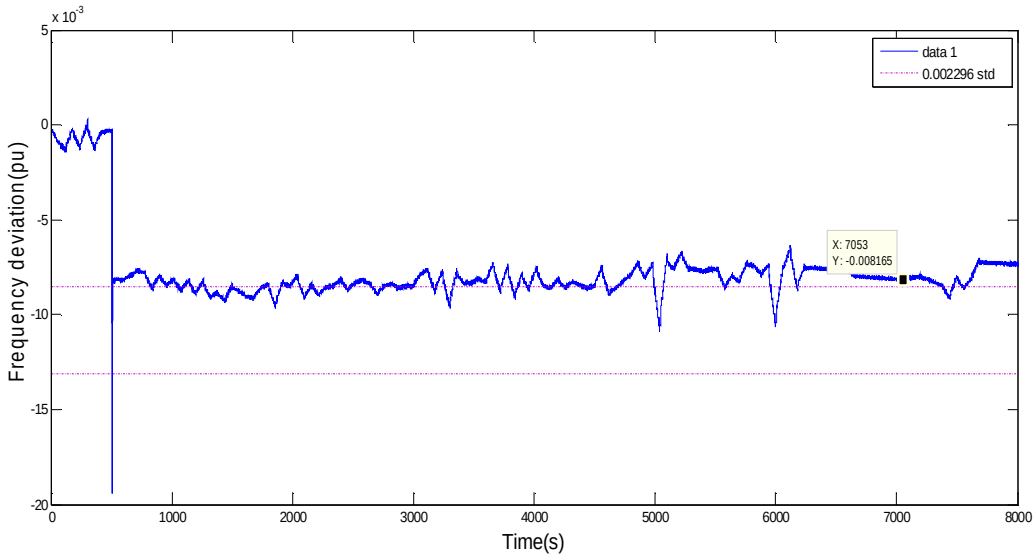

Figure 3 Output waveform under only primary frequency regulation 2

(3) The speed droop coefficient is set to $d_1 = 0.06; d_2 = 0.06; d_3 = 0.06$

The output waveform of the frequency deviation in such a situation is shown as figure 2.

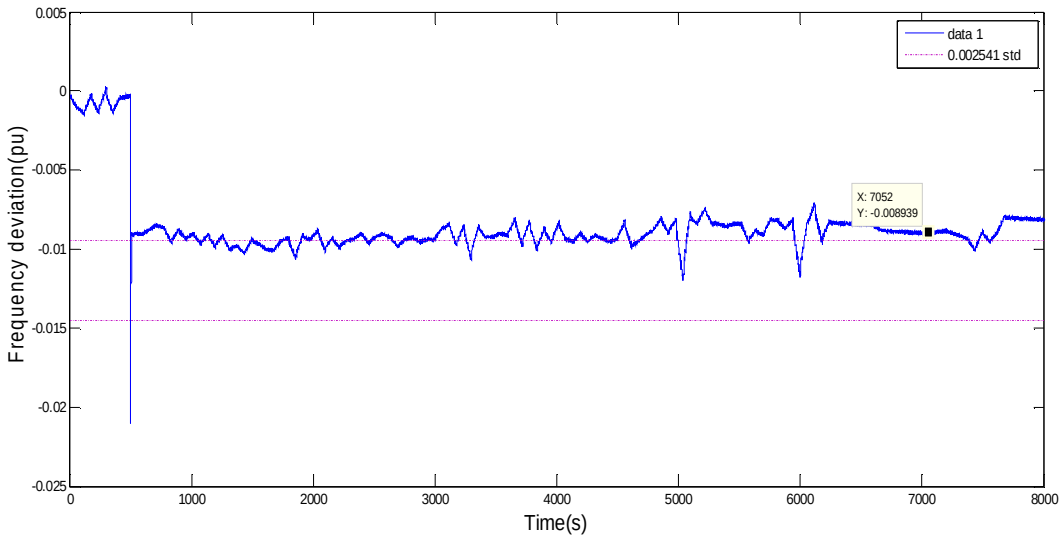

Figure 4 Output waveform under only primary frequency regulation 3

From the waveforms we can see that, the smaller the value of the speed droop coefficient, the better the performance of primary frequency regulation after a big disturbance occurring in this power system.

Conclusions

This paper researches the influence of different sets of speed droop coefficient on primary frequency regulation ability of the power system. The study found that the effects of the changes of the coefficient in the primary frequency regulation are as follows:

The varying speed droop coefficient of the unit directly affects whether the unit can run stably and the speed droop coefficient is an important factor to ensure the stable operation of the power system. It can be seen from the values of the primary frequency regulation ability and the simulation waveforms,

the smaller the setting values of the speed droop coefficient, the better the primary frequency modulation performance.

However, when the unit's speed droop coefficient is set too small, it will lead to unstable operation of the unit. According to this principle, when it comes to the design of the speed droop coefficient, it is necessary to consider the value of the coefficient must cause the entire power system stable, but also ensures that it has sufficient primary frequency regulation ability.

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