IOP Conference Series: Earth and Environmental Science

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To cite this article: Jun Li *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **295** 042102

IOP Conf. Series: Earth and Environmental Science **295** (2019) 042102 doi:10.1088/1755-1315/295/4/042102

Influence of Delay Analysis and Research on The Thermal Power Unit's PFC Performance

Jun Li[1,2*], DaPeng Liao[3], PengWei Yang[2], Song Gao[1], Bo Lin[1]

[1]State Grid Shandong Electric Power Research Institute, Jinan, China
[2]State Grid East Inner Mongolia Electric Power Research Institute, Hohhot, China
[3]State Grid Shandong Electric Power Company, Jinan, China

[*]Corresponding author's e-mail: lijun_sdu@hotmail.com

Abstract. Primary frequency control(PFC) of thermal power unit is an important means to ensure power supply frequency and safe and stable operation of power grid. Through the analysis and research of the PFC standard of the power grid, combined with the control structure of conventional thermal power units, it is pointed out that the delay and inertia inherent in the unit equipment have a negative impact on the PFC performance. From two directions of field dynamic test and laboratory simulation, existing problems of currently widely used control structures are clearly defined, and the technical means of reducing the influence of delay on PFC are proposed. The practical application results show that the proposed method can effectively reduce the overshoot of the PFC system and ensure that the system recovers quickly and stably.

1. Introduction

With the increasing scale of new energy and the rapid development of UHV power grid, the connections between power grids at all levels are increasingly close, and the requirements for coordination and cooperation between power grids and power units are also increasingly high. Frequency is one of the standards to measure the power supply quality of power grid. The grid-connected generator set participating in the PFC is an important means to ensure the power supply frequency and the safe operation of power grid. For the main part of China's power grid and the main frequency modulation based on that of thermal power unit PFC is mainly by adjusting the DEH (Digital Electric Hydraulic Control System) inlet damper in the system, using the boiler heat storage, rapid response to the requirements of the grid when the grid appear abnormal, to make up for the gap between power load, so as to maintain the stability of power grid frequency.

As an important means of frequency adjustment, PFC needs to be fast and effective. The rapidity of PFC refers to the quick adjustment of unit's output with the change of frequency to ensure timely adjustment of power grid frequency. Since the PFC of the generator directly acts on the turbine's regulating valve, the PFC has a quick response to the change of power grid frequency. Generally speaking, the power of unit is less than 3s[1-3]. Effectiveness of PFC refers to that after the grid frequency crosses the dead zone, the unit output changes rapidly to a certain extent, so as to ensure that the frequency can be significantly and accurately adjusted towards the dead zone. However, due to the inherent delay and inertia of the unit's physical regulating mechanism, the response time, steady-state accuracy and overshoot amplitude of the PFC of the unit are all affected. On the one hand, the stability of the unit operation is reduced, and on the other hand, it is not conducive to the frequency stability of the power grid.

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2. PFC Standard Specification and Control Structure

PFC refers to the capability inherent in the frequency characteristics of the speed regulation system of the unit to automatically adjust the frequency as the frequency changes[4,5].

2.1. PFC Standard Specification

In case of frequency fluctuation of the power grid, it is required that the speed governing droop of thermal units should not be more than 5%, or the PFC integral power contribution index should not be less than the specified percentage value. For example, in some provinces of China this standard is 80%. As required in the Chinese national standard GB/T 30370 Guide of primary frequency control test and performance acceptance for thermal power generating units and other technical specification, the dead band of thermal unit's PFC is 50±0.033Hz[6], the response delay time is no more than 3 seconds, and the stabilization time is less than 1 minute.

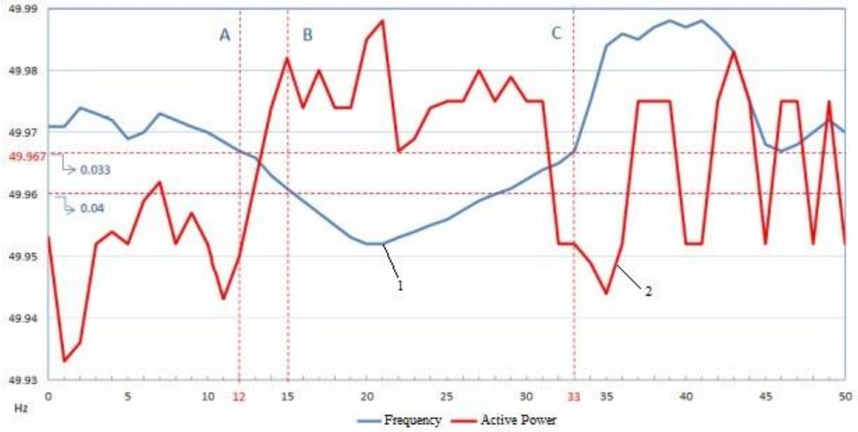

Figure 1. Frequency fluctuation curve

As shown in Figure 1, the blue curve 1 is the power grid's frequency, and the red curve 2 is the unit's active power. When the power grid's frequency is more than dead band (50±0.033Hz) after point A, unit's active power begin to act according to frequency deviation. Point B is the active power change point after frequency more than dead band 3 seconds. At 3 seconds, the unit's active power must have a change. At point C, the power grid's frequency returns to the dead band. It is an effective disturbance when the frequency exceeds the dead band and lasts for no less than 6 seconds, and the maximum frequency deviation reaches 50±0.038Hz.

2.2. Conventional PFC Control Structure

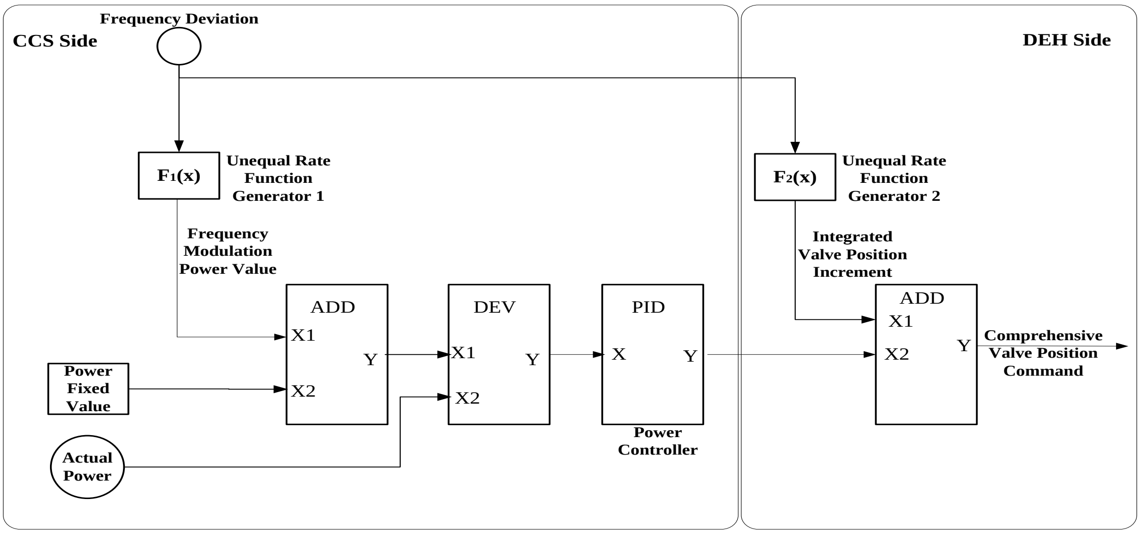

Figure 2. Conventional PFC control structure

The schematic diagram of the realization of PFC function of conventional units in existing technologies is shown in figure 2. As shown in figure 2, PFC System sends the calculated frequency deviation to the coordination control system(CCS) side and the DEH side, respectively. On the CCS side, the frequency deviation passes through the unequal rate function generator 1 to generate the corresponding frequency modulation power value. The frequency modulation power value is superimposed on the unit power fixed value to generate the unit power setting value[7,8].The unit power setting value is compared with the actual power of the unit, and the valve position command signal is generated by the power controller PID calculation.

On the DEH side, the frequency deviation passes through the unequal rate function generator 2 to generate the corresponding integrated valve position increment, which is superimposed on the valve position instruction signal sent by the CCS side to generate the comprehensive valve position command, and it is used to control the steam turbine to adjust the turbine regulating value. Among them, the integrated valve position increment on the DEH side directly affects the turbine regulating value's opening degree, so the DEH side response speed is faster to meet the rapid requirements of the power grid frequency modulation. The CCS side mainly adjusts parameters such as wind, coal and water to ensure that the unit power is stable at the desired target value.

3. Existing Problems and Simulation Analysis

In the PFC process of the thermal power unit, it often occurs in the initial stage of the frequency difference, the active power of the unit is seriously over-adjusted, and the fluctuation is large. The main reason for analyzing the problem is that the unit is generally operated in the DEH+CCS mode. Because there are the inherent delay and inertia of the unit adjustment mechanism, and the time transmission difference existence of DEH and CCS, the reaction speed of the unit is affected.

3.1. Field Test

One 330MW thermal unit with the higher proportion in the current power grid was selected for the PFC disturbance test. The boiler produces 1025t/h sub-critical pressure, intermediate reheat and coal-fired drum furnace for Harbin boiler plant. The steam turbine produces sub-critical, intermediate reheat, and condensing units for the Dongfang steam turbine plant. DCS and DEH are XDPS-400 systems of Xinhua control engineering Co., Ltd. The PFC function is realized by DCS, DEH and NX-PFR intelligent control systems. The primary frequency modulation signal is connected by hard wiring, and the transmission delay can be approximately ignored.

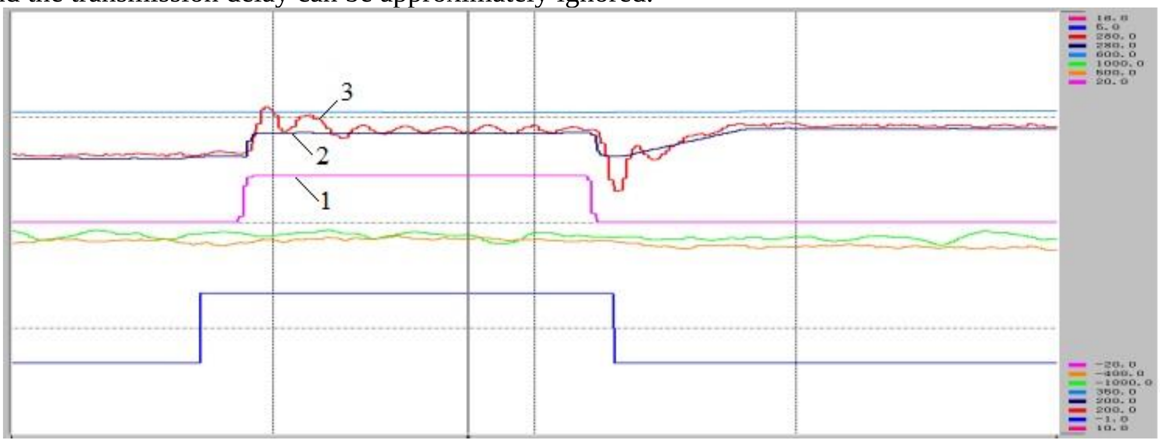

Figure 3. PFC disturbance test curve before transformation

In the figure 3, curve 1 is the frequency deviation, curve 2 is the unit power setting value, curve 2 is the actual power. It can be clearly seen that the load is seriously over-adjusted at the initial stage of the unit's PFC disturbance test, and the system recovery time is longer, and there is a small amplitude oscillation. During the test, the unit power changed after the unit command changed 1.2s, and it increased rapidly. The maximum change was about 170% of the standard compensation, and the overshoot was serious. Moreover, it did not reach a stable state within 60s.

3.2. Simulation

Because the PFC control signal between CCS and DEH is hardwired, the transmission delay can be approximately ignored. Therefore, first of all, it is assumed that the unit is in a manual state, which eliminates the possible time delay of signal transmission between the CCS control system and the DEH control system, and only relies on the function of DEH to realize the PFC. Then, the pure delay of the operation instruction output on the side of DEH and the inertia of the modulation only exist at this time, the transfer function is

$$G(s) = \frac{1}{T_1 s + 1} e^{-\tau_1 s}$$

Where, T_1 is the inertia time, is the delay time.

In the simulation environment, according to the unit field test and actual operation, the inertia time T_1 is set to 1s, and the delay time τ is 0s, 1s, 2s for simulation. It can be clearly seen from the figure that with the increase of delay time, on the one hand, the output response becomes slower, on the other hand, the output stabilization time becomes longer and the overshoot amplitude increases.

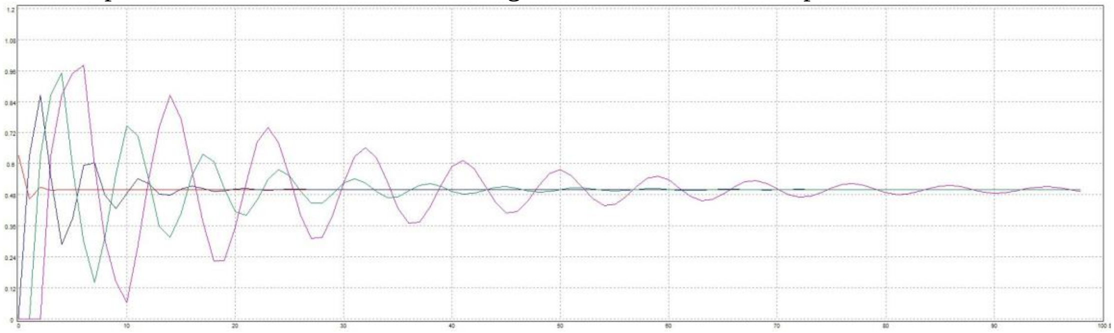

Figure 4. Simulation curve based on different delay time

Comparing the results of actual field tests and simulation calculations, it can be clearly concluded that with the constant control parameters of the system, as the delay time of the unit equipment becomes longer, the overshoot of the unit is larger, and the fluctuation time is longer.

4. Program Design and Application Effect

Since the unit normally operates in DEH+CCS mode, and the CCS side is PID operation, there is output value sent to DEH after calculation. The coordinated actions of DEH side and CCS side should be reasonably matched to ensure that the control quality of both sides will not decline due to delay and inertia. The design idea is that, without changing other control logic and parameters on the CCS side, an inertial link is added, and its transfer function is

$$G(s) = \frac{1}{T_2 s + 1}$$

The inertia time T2 is set to 2s, 3s, 4s and 5s respectively. It can be clearly seen from the figure 5 that as the inertia time increases, the overshoot of the output can be effectively reduced and the system stabilization time can be shortened.

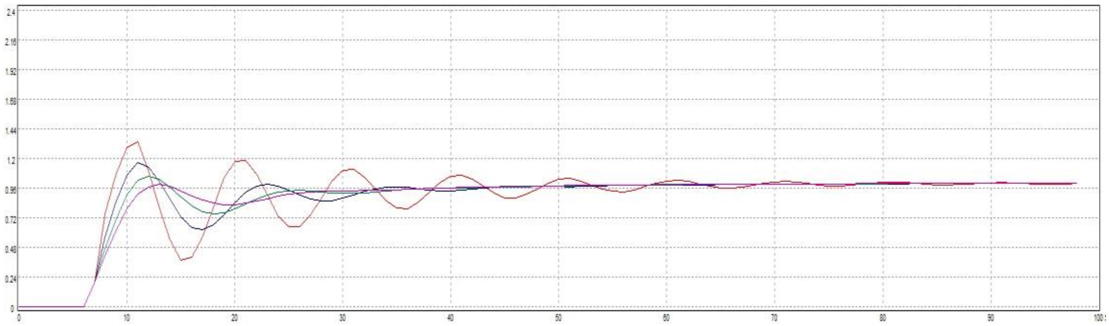

Figure 5. Simulation curve after increase the inertia link

According to the simulation results, an inertial link was added to the actual control system of the power plant. The inertia time was 4s. It can be clearly seen from the figure 6 that the actual control effect was significantly improved, and the indicators such as response time, control precision and attenuation rate all met the specified requirements.

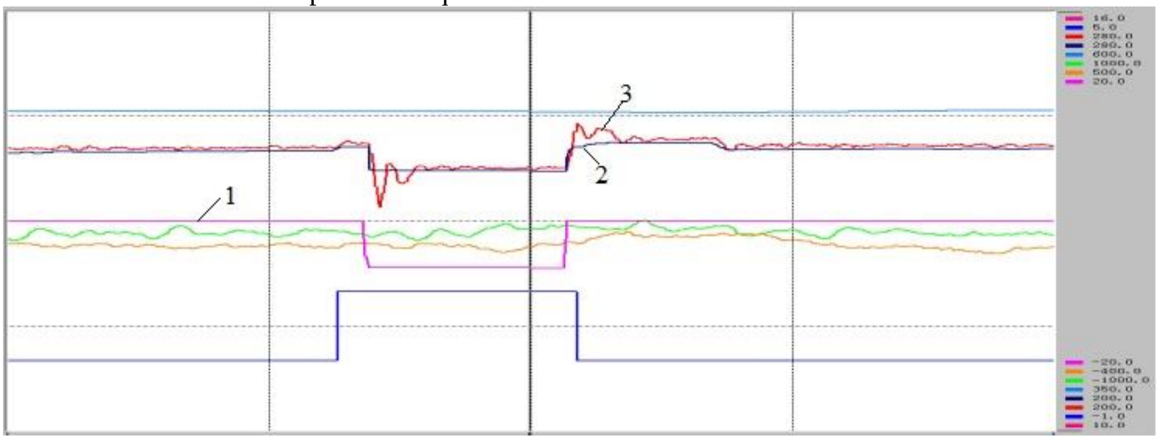

Figure 6. PFC disturbance test curve before transformation

5. Conclusion

China's power industry in large-scale new energy power generation and high voltage long distance power transmission technology keeps a world-leading position.The rapid development of new energy brings great challenges to the frequency control of power grid, and the adjustment of power grid frequency mainly depends on the PFC function of thermal power units. Through the analysis and research of the grid's PFC technology standard of the power grid, combined with the control structure of conventional thermal power units, it is pointed out that the delay and inertia inherent in the unit equipment have a negative impact on the PFC performance. From two directions of field dynamic test and laboratory simulation, existing problems of currently widely used control structures are clearly defined, the technical means of reducing the influence of delay on PFC are proposed. The practical application results show that the proposed method can effectively reduce the overshoot of the PFC system and ensure that the system recovers quickly and stably. It provides one reliable means for thermal power unit to promote the PFC performance.

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