Optimization of Primary Frequency Regulation of 650MW Thermal Power Plant

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Abstract. Wind power and photovoltaic power generation are developing rapidly, and installed capacity accounts for an increasing proportion of the power system. However, most new energy power stations are not equipped with energy storage equipment. Wind power and photovoltaic power generation do not yet have primary frequency modulation capabilities. For a long time in the future, the participation of thermal power generation in primary frequency modulation will still be the main method of primary frequency modulation in my country. The primary frequency regulation capacity of the combined heat and power unit often fails to meet the requirements due to heating. This article takes a 650MW thermal power heating unit as an example, and optimizes the primary frequency regulation of the unit. After optimization, the primary frequency regulation capacity of the unit is greatly improved. The optimization method in this paper has certain guiding significance for the optimization of primary frequency regulation of other heating units.

1. Introduction
As of the end of 2020, China's full-caliber power generation installed capacity was 2.09 billion kilowatts, of which thermal power installed capacity was 1.23 billion kilowatts, grid-connected wind power was 220 million kilowatts, and grid-connected solar power installed capacity was 220 million kilowatts.

At present, since most new energy power stations are not equipped with energy storage equipment, wind power and photovoltaic power generation do not yet have primary frequency modulation capabilities. Thermal power generation will still be the main force of primary frequency modulation in my country for a long time to come. The installed capacity of combined heat and power in my country accounts for 37.6% of the total installed capacity of thermal power. The primary frequency adjustment capacity of the combined heat and power unit often does not meet the requirements due to heating. Therefore, it is necessary to optimize the primary frequency adjustment of the heat supply unit.

This article takes a 650MW thermal power heating unit as an example, and optimizes the frequency adjustment of the unit.

2. Problem analysis
supercritical extraction steam heating unit with a maximum continuous evaporation of 1950t/h and a maximum external heating flow of 650t/h.
Figure 1. Primary frequency modulation response curve of heating unit.

1- Load order, 2- Active power, 3- Extraction steam heating flow, 4- Master valve position command.

Figure 1 is the primary frequency regulation action curve of the unit. Before the primary frequency regulation action, the unit load command is 443MW, the active power is 442.7MW, the unit undertakes external heating flow of 600t/h, and the integrated valve position command is 91%. After the primary frequency regulation action, the load command becomes 458MW, the active power increases slowly, and the gate opens instantly. When the heat supply unit of this unit has a large amount of heat, and the unit is not at full load, the steam turbine valve is fully opened, and the unit loses the ability to adjust the load upward.

"GB/T 30370-2013 Thermal Power Generating Unit Primary Frequency Modulation Test and Performance Acceptance Guidelines" stipulates that when the grid frequency change exceeds the unit primary frequency modulation dead zone, the response lag time of the unit should be less than 3 seconds, and the coal-fired unit reaches 75% of the target load The time should be no more than 15 seconds, the time to reach 90% of the target load should be no more than 30 seconds, and the stabilization time should be less than 1 minute.

The primary frequency modulation action curve of this unit obviously does not meet the requirements.

The extraction steam heating unit extracts part of the steam from the intermediate pressure cylinder for heating. Since the steam used for heating cannot be fully converted into electrical load, the primary frequency regulation capability of the extraction steam heating unit is still better than that even when the gate is not fully opened. The non-heating unit is poor.

3. Optimization method

3.1. Extraction butterfly valve compensation primary frequency modulation

It can be seen from Figure 2 that the heat supply steam source of this unit is the medium-pressure cylinder with three extractions, and the maximum heat supply flow is 650t/h. The steam extracted from the heat supply does not completely perform work in the steam turbine, which has a certain influence on the primary frequency regulation of the unit.

Primary frequency regulation is a process in which the unit uses boiler heat storage to quickly respond to work. The unit mainly relies on the work of the high-pressure cylinder to provide the power generation load required for primary frequency regulation. Therefore, the main factor restricting the primary frequency regulation capability of the heating unit is that the heat supply is so large that the regulating door is fully opened and the unit loses its load regulation ability.
Figure 2. Unit extraction steam heating system diagram.
1-Medium pressure cylinder, 2-Low pressure cylinder, 3-Steam extraction and heating butterfly valve, 4-Heating network heat exchanger, 5-Heating network backwater, 6-Heating network circulating water pump, 7-Heating network drainage.

The heating network system has sufficient heat storage, and closing the heating pressure regulating valve has little effect on the heating network in a short time. Under normal conditions, the duration of a frequency modulation is relatively short. During this period, reducing the amount of extraction steam will have little effect on the pressure and temperature of the entire heating system. By closing the heating extraction butterfly valve to improve the heating unit One-time frequency modulation capability is feasible.

The primary frequency regulation optimization of the heating unit can be divided into two parts, the optimization when the unit regulating door is fully opened and the optimization when the unit regulating door is not fully opened. When the heat supply of the unit is large, the regulating valve is fully opened when the unit is under full load, and the unit loses its primary frequency regulation ability. At this time, the opening of the extraction steam heating regulating valve can only be turned off, and the heat network energy storage is used to enhance unit load regulation ability.

Figure 3 is a logic diagram of using the heating butterfly valve to enhance the unit's primary frequency regulation capability. When the unit's regulating door is fully opened and the grid frequency is lower than the reference frequency, the unit's load regulation capacity is enhanced by closing the extraction steam heating regulating door.

3.2 Heating load-electric load signal conversion
Due to the need of the unit to extract part of the steam from the exhaust steam of the medium pressure cylinder for the heating load, this part of the steam does not perform work, which will inevitably cause
a mismatch between the generating load of the unit and the boiler load. At this time, if the coordinated control is still based on the original load command, it will inevitably cause an imbalance between the energy of the boiler and the energy required by the steam turbine, which will lead to the imbalance of the unit load, pressure, temperature and other parameters. Therefore, the extraction steam heating flow is converted into the power generation load is very necessary.

The increased heating load-generation load conversion logic is shown in Figure 4. The pressure of the regulating stage calculates the conversion coefficient through two conversion functions, and the conversion coefficient is multiplied by the filtered heating flow to get the converted power generation load. The power generation load after the heat load conversion is superimposed on the main control of the boiler to realize the matching of the coordinated control of the steam turbine and the boiler.

![Figure 4. Heating load-generation load signal conversion logic.](image)

### 3.3 The theoretical load adjustment of primary frequency modulation is multiplied by the amplification factor

The primary frequency modulation control mode of the unit in the conventional coordinated control mode is DEH+DCS, that is, the difference between the rated speed (frequency) in the DEH and the turbine speed (grid frequency) is calculated by a certain function and the valve is directly actuated. DCS adjusts and compensates to ensure the unit load meets the requirements of the grid. The primary frequency regulation on the DEH side quickly responds to the load through the direct action of the valve. The action of the valve will cause the main steam pressure to change. After the main steam pressure changes, the DCS side compensates the change of the main steam pressure by controlling air, coal, and water.

The action of a unit frequency adjustment can be divided into the following two situations:

**Situation 1:** After the DEH action, if the load change exceeds the load change range required by the primary frequency regulation, the boiler adjusts in the opposite direction.

**Situation 2:** After DEH is activated, if the load change is less than the load change required by the primary frequency regulation, the boiler will adjust in the same direction.

According to the existing standard, overshoot is allowed for one frequency modulation, so the first case is the optimal adjustment process. According to statistics, unqualified primary frequency regulation is often the second case. For a 650MW unit, the maximum load change range of primary frequency control is 6% of the rated load. After DEH actuates the gate, the load change is less than the load change required by the primary frequency control, which requires fast boiler adjustment, but the boiler side adjustment is slow, causing the unit's primary frequency adjustment to not meet the requirements.
Figure 5. Optimized primary frequency modulation control logic.

Figure 5 is the optimized primary frequency modulation logic. A1 is the amplification factor on the DCS side, which is 1.3, and A2 is the amplification factor on the DEH side, which is 1.15. F(x) is a frequency modulation function, as shown in Figure 6.

The frequency difference of the power grid is calculated by the primary frequency modulation function to calculate the primary frequency modulation load compensation amount. The primary frequency modulation load compensation amount is multiplied by A2 on the DEH side, and the amplified load compensation amount is multiplied by the standard unit coefficient A3. A3 is 0.154, and A3 compensates the load. The quantity standard is a valve position command for a frequency modulation compensation, and the compensated valve position command directly acts on the regulating door. Increase the magnification factor A2 on the basis of the original logic, which can ensure that the unit's actions under any circumstances meet the requirements.

The DCS side primary frequency modulation load compensation amount is multiplied by the amplification factor, and the load command is added to generate the primary frequency modulation load command. After the primary frequency modulation, the difference between the load command and the active power is PID calculation to generate the steam turbine main control command, and the DCS side is multiplied by the amplification factor A1 can speed up the adjustment speed of the boiler, making the coordinated control of the unit faster and more accurate.
Figure 6. F(x) polyline function.

4. Optimization effect

Figure 7 is the optimized primary frequency modulation test curve. Before the test, the unit load is 443MW, the heating flow is 500t/h, and the regulating valve is in the fully open position. After the test starts, the steam extraction and heating butterfly valve is quickly closed, and the extraction flow is 500t/h. When h drops to 400t/h, the unit load increases rapidly, which meets the requirements in "GB/T 30370-2013 Primary Frequency Modulation Test and Performance Acceptance Guidelines for Thermal Power Generating Units".

5. Conclusion

This article takes a 650MW thermal power heating unit as an example, and optimizes the primary frequency regulation of the unit. After optimization, the primary frequency regulation capability of the unit is greatly improved. The optimization method in this article has certain guiding significance for the primary frequency regulation optimization of other heating units.

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Figure 7. Optimized primary frequency modulation curve.