Automatic control of steam turbine two-valve mode under low load condition of coal-fired unit

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Abstract. In order to meet the requirements of deep peak regulation and rapid load change, coal-fired power stations are often under low load condition. Under low load conditions, there are serious throttling loss and poor economy of GV(Governor Valve). Here, based on the DEH sequence valve control of steam turbine, we innovatively propose the two valve operation mode and write the two valve mode control logic, which can automatically switch between the sequence valve and the two valve mode according to the valve flow command. On the premise of ensuring the stable operation of the unit, the purpose of reducing the throttle loss of the turbine can be achieved during the low load and peak regulation of the unit, and the fuel cost can be saved about 970,000 yuan per year. The control method is simple, reliable and practical, and can be widely used in thermal power units involved in peak regulation.

1. Introduction
Pulverized coal fired boiler in power plant at the present stage (40%) below the rated load and low load (20% ~ 30% rated load) under the runtime, the unit and the operating mode of each auxiliary significantly deviate from the design value, the power supply coal consumption rate, plant utilization rate and the index economy of steam turbine heat consumption rate will be greatly reduced, the efficiency of units will be greatly reduced.

Recently, due to the combination of rising international commodity prices, easing global liquidity and market expectations, domestic coal and natural gas prices have risen more than expected, leading to a sharp rise in power generation costs. How to further reduce the cost of coal-fired generating units under the condition of meeting the requirements of deep peak regulation and rapid load change is particularly important. Combined with the practical experience of field work and the experience of domestic and foreign scholars, we summarizes the big throttling loss when the unit runs under low load and puts forward corresponding measures, in order to provide some support for the development of high flexibility coal-fired power generation technology that can meet the requirements of deep peak regulation and rapid load change.

2. Achievement implementation background and existing technology problems

2.1. Implementation background
Most steam turbines of thermal power units are controlled by digital electric hydraulic DEH provides valve management and single-valve/sequential valve switching function.
In the single-valve mode, the GV keeps the same opening, and the steam intake of the turbine is conducive to the steam turbine body being subjected to uniform force and heating, but the throttle is serious at low load and the economy is poor. In order valve mode, the GV is opened in a certain sequence, which can reduce the throttling loss caused by excessively low opening of the regulating door and improve the economy of the unit \[1\]. However, due to the wear and tear caused by the unit running for a long time and the differences brought by the overhaul and renovation process, the flow rate of the valve is different from the designed flow rate characteristic curve. It is necessary to optimize the flow rate characteristic of THE DEH valve and calculate the valve flow rate characteristic curve that suits the actual situation of the unit \[2\]. Under the sequential valve mode, the load disturbance is smaller, the main steam temperature, pressure and other parameters are more stable, the watt temperature and vibration of the turbine are improved to a certain extent, and the capacity of variable load and primary frequency modulation of the unit is enhanced, and the operation economy and control stability of the unit are improved.

At present, in order to improve the efficiency of steam turbine, the flow characteristic curve of high-pressure gate is optimized mainly through flow characteristic test of valve. The problems such as slow primary frequency regulation response, slow load adjustment, large load fluctuation, large valve swing, etc. are solved, and the overlap degree of valve adjustment is modified to reduce throttle loss of the gate adjustment substantially under the mode of sequential valve, reduce coal consumption and achieve the purpose of energy saving \[3\]. This technology is to put forward a two-valve management mode on the basis of optimization of flow characteristic test of regulating valve. In a certain flow range, the valve management of DEH system is in two-valve mode. According to the new flow characteristic curve, the third valve is closed to further reduce the throttle loss of steam turbine. When the flow command exceeds the management range of two-valve mode, then the original flow characteristic curve is executed.

2.2. Problems with existing technology
At present, in the operation of most steam turbine generator units, the DEH system adopts the sequential valve control mode, and opens each valve in sequence according to the pre calculated valve flow characteristic curve and overlap \[4\]. The overlap degree of the valve means that the next valve will be opened in advance before the previous valve is fully opened. The amount of early opening is the overlap degree. If the next valve is opened after the previous valve is fully opened, the characteristic line of total lift and flow of the valve will be a tortuous line, which is not allowed in actual operation. Large overlap is beneficial to the stability of unit control, but too large overlap increases the throttling loss of valves and reduces the economy of the unit. Although the sequence valve can reduce the throttling loss, the economy of the unit is still affected due to the existence of overlap. Especially during the low load and peak load regulation of the unit, the throttling loss will increase greatly \[5\].

3. Innovation points and basis of achievements
The innovation of this achievement is to introduce the two valve operation mode and write the two valve mode control logic based on the DEH sequence valve control of steam turbine, which can automatically switch between the sequence valve and the two valve mode according to the valve flow command. After field observation and test, the parameters in the control algorithm of piecewise linear function generator are properly adjusted, which can reduce the throttling loss of steam turbine during low load and peak shaving on the premise of ensuring the stable operation of the unit.

4. Implementation steps and design process
In normal operation, the unit is in CCS coordination mode, DEH is in remote control state, receives CCS remote control instruction, and then through the valve flow characteristic curve, transforms into corresponding valve opening instruction signal. When the valve flow instruction is within 60%~70% \[6\], the two-valve mode operation, GV1, GV2 to execute the optimized flow characteristic curve, while forcibly closing GV3, reduce throttling loss, when the flow instruction is not in the above range,
execute the original valve flow characteristic curve. The control logic configuration is carried out in the steam turbine DEH control system, and the control function is realized by piecewise linear function generator, high and low limit monitoring algorithm and corresponding logic function block. The specific implementation steps mainly include two parts, the input and cut control logic function configuration in the two valve mode and the high valve control logic function configuration in the two valve operation mode.

The two-valve operation mode of steam turbine under low load conditions reduces the throttling loss of steam turbine and further optimizes the valve control logic on the basis of sequential valves, which is mainly composed of the following two function modules.

4.1. Input and cut-off control logic of two valve mode.
The three conditions of turbine brake, generator grid connection and DEH valve in sequential valve mode are the prerequisite conditions for allowing input in two-valve mode. When these conditions are met, the operator can manually input the two-valve mode when the comprehensive flow instruction is lower than 60.9%. The whole input in two-valve mode can be realized through the self-holding function of RS trigger. You can also manually exit the two-valve mode at any time as required. When the flow instruction exceeds 60.9%, the control logic automatically switches to the two-valve running state; When the flow instruction is greater than 69.9%, the two valves will be automatically quit. The control logic configuration of this functional module is shown in Figure 1.

Figure 1: SAMA diagram of two valve mode input and cut-off control logic
4.2. GV control logic in two-valve operation mode

After the two-valve mode is put into operation, the control system automatically switches to the two-valve mode when the operation conditions of the two valves are met. The opening of GV1 and GV2 is controlled according to the re-optimized two-valve curve to meet the load requirements of the unit. At the same time, GV3 is forced to close to reduce the throttling loss. When the two-valve operation mode exits, the original sequence valve curve is automatically executed and each valve is gradually opened. The control logic configuration of this function module is shown in Figure 2.

![Figure 2: SAMA diagram of high tone door control logic](image)

5. Practical application and popularization

The control method and logic adopted in this achievement have strong adaptability and reliability after long-term field test, which makes this achievement especially suitable for the automatic control of reducing throttling loss of steam turbine unit under low load conditions. The control logic compiled in this achievement adopts general logic function blocks for configuration, which is simple to write and has strong readability. Engineers and technicians can realize their functions through various brands of distributed control system (DCS), programmable controller (PLC) and other computer control equipment, which brings great convenience to use. In the process of use, combined with the actual situation of the equipment, three valve, four valve and five valve control theory can also be introduced, so this achievement also has wide applicability.

6. Conclusions

The control method in this paper was applied to the boiler equipment of the company’s four 300MW Coal-fired Units from February 2020 to January 2021. Up to now, it has been running stably for more than one year. According to the statistics of relevant departments, the coal consumption can be reduced by about 3 g/kWh at most in the low load stage, and the annual power generation of the unit is 2 billion per year, and the unit price of standard coal is 650 yuan/ton, If the power generation under
low load operation is calculated as one quarter of the total power generation, the fuel cost can be saved by about 970000 yuan. During low load and peak load regulation, this method effectively solves the problem of large throttling loss, and greatly reduces the throttling loss of high-speed regulating valve under the mode of sequence valve. It has made outstanding contributions to tapping the potential and increasing efficiency of thermal power units, and greatly increased the competitiveness of thermal power units.

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