Optimization and application of flow characteristics of steam turbine valve based on big data

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Abstract. In order to adapt to the demand of power grid, improve the flexibility level of coal power units, and tap the potential of deep peak-regulation of units, it is necessary to study the valve flow characteristics. The linearity of steam turbine valve flow characteristics is also one of the important factors affecting the quality of AGC and primary frequency regulation. According to the valve flow principle, through the test of steam turbine valve flow characteristic, the calculation function of steam turbine valve flow characteristic, the correction flow characteristic linearity of steam turbine valve flow characteristic linearity, therefore, the AGC control performance and the frequency modulation quality have been improved. Meanwhile, the ability of participating in the depth peak regulation has been enhanced, and the safety, the stability and the economical have been better.

1. Introduction

The flow characteristics of steam turbine valve refer to the steam turbine of the opening of the tone and the corresponding relation of steam flow through the valve. When the unit change load and participate in primary frequency, if the linearity of valve flow characteristic is bigger, it may lead to change load suddenly or slowly. And also, it influences the safe and economic of operation. Through the test of steam turbine valve flow characteristic, the calculation function of steam turbine valve flow characteristic, the correction flow characteristic linearity of steam turbine valve flow characteristic linearity, therefore, the AGC control performance and the frequency modulation quality have been improved. Meanwhile, the ability of participating in the depth peak regulation has been enhanced, and the safety, the stability and the economical have been better.

2. Experiment

2.1. Unit overview
No. 2 steam turbine of Yangxi power plant is N600-24.2/566/566 supercritical, primary and intermediate reheat, three-cylinder, four-row steam turbine, uniaxial, double-back pressure, condensing steam turbine produced by Shanghai steam turbine co., LTD. The unit consists of 2 high pressure main valves (TV), 4 high pressure main regulating valves (GV) and 4 medium pressure regulating valves (IV). In the sequential valve mode, the high-voltage valve opening sequence is GV1/GV2, GV3 and GV4. SYMPHONY decentralized control system produced by ABB is adopted in DCS system and DEH system of unit 2 in Yangxi power plant.

2.2. Test principle
In the flow analysis of DEH, the actual flow of each GV valve is calculated according to formula (1)
according to the test record data. In the formula, $Q_{\text{eq}}$ - equivalent actual flow is corresponding to the load setting value (valve position mode) of DEH (0 ~ 100 ECR %).

$$Q = \frac{P_{\text{im}}}{P_t} \times \frac{P_{\text{tr}} - \%}{P_{\text{imr}}}$$

(1)

$P_{\text{im}}$ – the pressure of regulating stage;

$P_{\text{imr}}$ – the pressure of rated regulating level;

$P_{\text{tr}}$ – the main steam pressure at rated load;

$P_{t}$ – the test pressure under different loads (stable test pressure is required during the test).

2.3. Datas collection

It is necessary to collect flow characteristic data under single-valve operation mode and sequential valve operation mode, and set up data recording points of DEH load setting, DEH load reference, unit power, regulating stage pressure, main steam pressure, main steam temperature, re-heater temperature, $gv_1$-$gv_4$ opening instruction and $gv_1$-$gv_4$ opening feedback at 1-second interval on the engineer station. The valve position reference instructions collected in the test are 5 seconds adjacent to each other, and the variation of the collected amount is greater than 0.04%.

3. Check and analyze the original flow characteristics

According to the collected test data of valve characteristics in the single-valve mode, the relationship between the DEH flow demand instruction (REF) and the actual equivalent flow (0~100% after calculation) in the single-valve mode is shown in figure 1. As can be seen from figure 1, under the single-valve mode, the original DEH load instruction - valve flow characteristic has a maximum deviation of +15.565% compared with the ideal valve characteristic, and the lower the load is, the greater the deviation is. According to the collected test data of valve characteristics in the sequential valve mode, the relationship between the DEH flow demand instruction (REF) and the actual equivalent flow (0~100% after calculation) in the sequential valve mode is shown in figure 2. It can be seen from figure 2 that, under the sequential valve mode, the original DEH load instruction - valve flow characteristic has a maximum deviation of +4.145% and -3.681% compared with the ideal valve characteristic, and there are abrupt changes near 61%, 76%, 87%, 57% and 76% of the flow reference.

![Figure 1](load_valve_under_original_single_valve_model.png)  
**Figure 1** load - valve under the original single valve model.

![Figure 2](load_valve_under_original_sequence_valve_model.png)  
**Figure 2** load - valve under original sequence valve model.

4. Optimized valve flow characteristics

Through the analysis and calculation of the collected test data, the current unit flow characteristics are
obtained, and the local non-linearity is more than 2%, the existing valve curve needs to be modified, so that the turbine valve flow characteristic function is consistent with the actual. In the single-valve control logic, the steam turbine 4 high-pressure regulating valves (Gv1-Gv4) corresponding to the valve command function are the same, and by the combination of single valve flow coefficient and valve flow lift function. In sequential valve control logic, valve instruction is composed of multiple valve flow coefficient, overlap degree function and valve flow lift function, in which the multiple valve flow coefficient function and overlap degree function are 1:1 linear functions. In this way, each high pressure regulating valve of the steam turbine USES only one valve flow characteristic function. Through the analysis and calculation of the test data, the valve characteristic curve of GV4 in the sequential valve mode is consistent with the original, no need to modify, retain the original data.

Figure 3. Comparisons of flow-valve relationship curve under the single valve model.

Figure 4. Comparisons of flow-valve relationship curve under the sequence valve model.

5. Check and analyze valve characteristics after optimized adjustment
Firstly, we had to do the tests of loading up and down under the single valve model, after modifying the flow characteristic function of the single valve model. In the whole process of loading up and down, the load adjustment was stable, and the GV1 ~ GV4 valve operation was stable, as shown in figure 5 and figure 6. Secondly, the switch test from single valve to sequence valve was carried out. During the valve switching process, the load was stable. Finally, after modifying the flow characteristic function of the sequential valve, the 450MW 308MW variable load test under the sequential valve mode was carried out. During the entire variable load process, the load adjustment was stable and the valve action was stable, as shown in Figure. 7. After the optimization and adjustment, the data collected from the valve calibration test of the unit are analyzed to obtain the actual valve flow characteristics of DEH. The load instruction has a good linear relationship with the valve flow, and the error is within 2.0%.

![Figure 5. single valve load drop curve](image)

![Figure 6. single valve load curve.](image)
Figure 7. variable load curve under sequential valves.

6. Conclusion
After the valve characteristic curve has been adjusted, the linearity of load command-flow characteristic is better in the single-valve model or in the sequential valve model. The deviation from ideal load command-flow characteristic is within 2%, without obvious inflection point. As shown in figure 8, in the single-valve mode, the deviation from the ideal load instruction-flow characteristic is +1.505% and -1.994%. As shown in figure 9, in the sequential valve mode, the deviation from the ideal load instruction-flow characteristic is +1.471% and -1.998%. And also, the unit load and pressure are always steady, no obvious flow turning point in the process of switching. The quality of the AGC and primary frequency has been improved validity. The power plant has more abilities to participate in the depth of load peak and runs more economically, more safely and more stably.

Figure 8. load - valve under the optimized single valve model.  
Figure 9. load - valve under the optimized sequence valve model.

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