Test of flow characteristics and parameter optimization of steam turbine DEH

Du Zhizheng, Zhang Yan, Zhu Baoying
Huadian Electric Power Research Institute Co., Ltd, Hangzhou, Zhejiang, 310000, China.
Corresponding author’s e-mail: 1270180541@qq.com

Abstract: The characteristics of steam turbine high pressure cylinder intake valve directly affect the performance of AGC and primary frequency modulation. In DEH system, the nonlinear characteristics of the high valve flow need to be corrected to ensure a smooth and linear relationship between the integrated valve level instruction and the steam flow of the turbine. When the nonlinear correction of the high valve flow is not correct, there may be nonlinear intervals such as "dead zone", "jump", and "inflection point" between the valve comprehensive opening instruction and the steam turbine flow, The valve integrated opening command mutates the gain of steam turbine flow, causing the valve to be insensitive or oscillating when the valve is in a certain opening range under the coordinated control system of the furnace and machine.

1. Introduction
The steam turbine regulating valve is the main executing mechanism of the DEH system, The deviation of the flow characteristics of the assembly leads to increased throttle loss, insufficient or excessive response load of the primary frequency modulation, slow response of the AGC, and fluctuation of the valve switching load, which eventually affects the safe and stable operation of the unit. The actual flow curve of the valve changes due to the adjustment of the long running and overhaul installation process of the turbine generator set. Therefore, it is necessary to test and correct the valve flow curve of the unit after a long period of operation or overhaul, so that the unit's indicators are optimized[1].

2. Flow characteristic test
2.1 Test condition confirmation
The unit needs to withdraw from the AGC, withdraw from the frequency modulation, and withdraw from the coordinated control state. Estimated test time is approximately 8 hours. Coordinate control steam turbine side must exit the automatic, boiler side is best to exit the automatic, the total fuel volume remains unchanged during the test process[2]. Under special circumstances, the boiler side can be put into automatic, and the priority is to choose the automatic power adjustment method of the furnace. The DEH side is required to cut all two main valve and four high valve of the steam turbine into manual state[3]. During the test process, the main valve remains fully open, the high valve is kept fully open, one is kept fully open, and the other is open from 0% to 100% or from 100% to 0%, Do a four-valve fully open working condition test during valve switching[4].
2.2 Test process
After completing the confirmation and preparation work, start the test.

1. Exit AGC and primary frequency modulation.
2. By modifying the unit's power generation load rating, controlling the power generation load at the test load point and modifying the pressure rating, the high-voltage valve is exactly in a position of 3 fully open and 1 shut, waiting for the unit's power generation load and pre-machine pressure to stabilize[5].
3. Withdraw from the coordinated control method, keep the total fuel quantity on the boiler side unchanged, and keep the main steam flow, superheated steam temperature, and reheated steam temperature as stable as possible[6].
4. DEH side main valve and high valve are all cut into manual control. The main valve instruction is manually increased to a maximum. The high valve is manually opened 3 times and 1 is closed. The full opening should reach the maximum opening of the valve. The valve shall be closed at a minimum opening[7].
5. Operation of the test valve, on the basis of maximum opening, the following opening interval is added to gradually reduce the opening of the test valve, and after the pre-standby pressure and the first-order temperature are stabilized, the test data is recorded until the minimum opening is reached.
6. Operation of the test valve, on the basis of the minimum opening, the above opening interval is added, the opening of the test valve is gradually increased, and the pre-standby pressure and the first-order temperature are stabilized, and the test data are recorded until the maximum opening is reached[8].
7. For different test valves, refer to the valve action sequence and complete all valve tests.
8. After confirming that the system is normal, put in a coordinated control method.
9. Put in AGC and primary frequency[9].

3. Optimization of flow characteristics of regulator valve
The data processing of Valve flow characteristic test for a 600MW unit is introduced in detail. The unit uses four high tone Gates GV1/GV2/GV3 and GV4 to control the main steam flow during normal operation[10]. In the order valve mode, the high-voltage switch door is opened at the same time as GV1 and GV2, then GV3 is opened, and finally GV4 is opened. The main steam pressure on the side of the additional machine is 24.20 MPa and the rated adjustment pressure is 18.69 MPa[11].

3.1 Flow Directive-Drawing of Actual Equivalent Flow Relationship Curve
Q1 is used as the Y item data, and the traffic requirement instruction is used as the X item data to draw the "X, Y scattered point map", and at the same time, the relationship curve between the traffic instruction and the valve flow is drawn under ideal conditions. The contrast curve is shown in Figure2[12]. It can be seen from Figure1 that the deviation between the original single-valve flow instruction and the actual equivalent flow is large, and the maximum deviation value is 10.17%.
3.2 Calculation of ideal valve flow lift function

The valve management logic under the single valve mode of the unit is shown in Figure 2.

![Valve Management Logic under Single Valve Mode](Image)

As can be seen from Figure 2, the traffic instruction needs to be combined by two folding functions before the final valve bit instruction is obtained. When calculating the processing, we keep the single valve back pressure correction function $F_1(X)$ unchanged, and only modify the valve flow generation function $F_2(X)$. The valve flow characteristic function in the original single valve mode and the storage location in the spreadsheet are shown in Table 1[13].

| Line number | S-list | T-list | X-list | Y-list |
|-------------|--------|--------|--------|--------|
| 3           | In     | Out    | In     | Out    |
| 4           | 0      | 0      | 0      | 0      |
| 5           | 72.03  | 60.917 | 0.01   | 2.78   |
| 6           | 81     | 68.99  | 60     | 17.58  |
| 7           | 83     | 71.17  | 85     | 31.1   |
| 8           | 86     | 74.79  | 90     | 35     |
| 9           | 91     | 81.934 | 93     | 39.2   |
| 10          | 100    | 100    | 94     | 41.6   |
| 11          | /      | /      | 95     | 46.3   |
| 12          | /      | /      | 96     | 51.6   |
| 13          | /      | /      | 97     | 56.4   |
| 14          | /      | /      | 98     | 61.2   |
| 15          | /      | /      | 100    | 95     |

The converted equivalent flow $Q_1$ is used as the $F_1(X)$ input, and the calculated back pressure...
corrected flow value Q2 is stored in the N column.

OFFSET function: Returns a reference to the range in a cell or cell range that specifies the number of rows and columns. The reference returned can be a single cell or cell range. You can specify the number of rows and columns to return[14].

TREND function: Construct a linear regression linear equation based on the values of known X sequences and Y sequences, and then calculate the y-value sequence corresponding to the X value sequence based on the constructed straight line equation. That is, the formula 1 operation is equivalent to formula(1) and the calculation result is N2=97.52.

\[
\frac{98.764 - 91}{100 - 91} = \frac{N2 - 81.934}{100 - 81.934}
\]

The Q2 is used as the X data, and the GV valve position instruction is used as the Y data to draw the "X,Y divergence point map" to form the actual single-valve flow lift characteristics, and a new single-valve flow lift function F2(X) is constructed to make F2(X) conform to the actual single-valve lift characteristics[15]. Opposite to the original single-valve flow lift function F2(X), as shown in Figure3.

![Figure3 Comparison of single valve flow lift function](image)

The old and new single valve flow lift functions are shown in Table2.

| In  | Out  | F2(x)-old | In  | Out  | F2(x)-new |
|-----|------|-----------|-----|------|-----------|
| 0   | 0    | 0         | 0   | 0    | 0         |
| 0.01| 2.78 | 0.01      | 2.78| 0.01 | 2.78      |
| 60  | 17.58| 67.19     | 28.09| 28.09| 28.09     |
| 85  | 31.1 | 76.34     | 31.74| 31.74| 31.74     |
| 90  | 35   | 78.24     | 32.9 | 32.9 | 32.9      |
| 93  | 39.2 | 81.91     | 34.8 | 34.8 | 34.8      |
| 94  | 41.6 | 90.2      | 41.56| 41.56| 41.56     |
| 95  | 46.3 | 92.3      | 44.7 | 44.7 | 44.7      |
| 96  | 51.6 | 94.29     | 48.92| 48.92| 48.92     |
| 97  | 56.4 | 97.56     | 59.62| 59.62| 59.62     |
| 98  | 61.2 | 99        | 95  | 95  | 95        |
4. Conclusion
After the valve flow curve optimization test, the operating effect is obvious. The coordination control effect and stability of a unit are improved. All parameters of a frequency modulation test meet the requirements of a frequency modulation test protocol, meet the requirements of fast response to the power grid, and the quality of a unit frequency modulation is greatly improved. Through this valve flow curve optimization test, the effectiveness of the optimization method is verified, and it has good reference value for the same type of unit.

References:
[1] Liu Xinglong, Ju Lincang, Hu ping. (2011) Adjustment for the Flow Characteristic Curve of DEH Valves. Turbine Technology, 53: 288-290.
[2] Liu Kangning. (2012) Test and Calculation for DEH Valve Flux Curve. Techniques of Automation & Applications, 31: 71-74.
[3] Zhang Zhendong, Zhang Congtai. (2017) The Effect of Valve Flowrate Characteristic Curve on Unit Load. Metallurgical Power, 212: 44-46.
[4] Xu Sidun, Lai Jialiang. (2014) Optimization of Value Flow Characteristic Curve for Domestic 600 MW Supercritical Turbines. Power Equipment, 28: 128-132.
[5] Zhao Zheng, Liu Zirui, Yang Yanbo. (2015) Analysis and Optimization on Flow Characteristic Curve in Steam Turbine Valve. Instrumentation, 22: 27-30.
[6] Yuan Yao, Yuan Yanchun, Liu Bo. (2013) Application of 600MW Unit Optimization of Flow Characteristic Curve of High-profile Portal. In: Discussion on the Development of Intelligent Power Station Technology and Proceedings of the 2013 Annual Conference on Power Station Automation. BeiJing. pp. 214-217.
[7] Venanzi S. (2005) A New Technique for Clearance Influence Analysis in Spatial Mechanism. ASME Journal of Mechanical Design, 127: 446-455.
[8] Innoventic. (2002) Kinematic Clearance Sensitivity Analysis of Spatial Structure with Revolute Joints. ASME Journal of Mechanical Design, 12: 52-57.
[9] Shang Xingyu, He Yongjun, Wang Rui. (2017) Flow characteristic optimization for steam turbine valves based on data fitting. Thermal Power Generation, 46: 121-131.
[10] Li Ning, Zhang Yi, Qie Mengjie. (2010) On-site measurement method analysis on turbine timing valve flux characteristic curves. Hebei Electric Power, 29: 18-19.
[11] Li Qianmin, Bai Yihui. (2012) Optimal analysis on flow characteristic of valve in steam turbine. Electric Power Science and Engineering, 28: 47-52.
[12] Xiao Geyuan, Dong Zhanbin Fan Xiaoying. (2012) Experimental study on single valve switching to sequencing valve and valve discharge characteristic curve. Jiangxi Electric Power, 36: 53-56.
[13] Wang Zhonghai, Yan Tao, Wu Yanghui. (2015) Analysis of turbine flow characteristic principle and bias and key points. Turbine Technology, 57: 285-288.
[14] Wang Zhiqie, Chen Houtao, Tang Zhenqi. (2019) Optimization on Characteristic Parameters of Steam Turbine Valve Flow Based on Operating Data. Guangdong Electric Power, 32: 32-36.
[15] Tam S M, Cheng K C. (2000) Genetic algorithm based defect identification system. Expert Systems with Applications, 18: 17-25.