Automatic Analysis Method for Cause of Disqualification in Remote Test of The Primary Frequency Regulation

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Abstract. In this paper, the factors affecting the correct operation rate of primary frequency modulation are analyzed in the light of the primary frequency modulation test of thermal power generating set and the assessment index of primary frequency modulation of power grid. Furthermore, effective solutions and countermeasures are put forward to make the unit meet the technical requirements and performance requirements of primary frequency modulation operation under various working conditions, and meet the requirements of safe operation of power grid and production of the unit.

1. Introduction
During the grid-connected operation of each unit, the frequency of the power grid will change under the influence of external load changes. The regulating system of each unit will participate in the regulating function to change the load of each unit so as to balance it with the external load. At the same time, it will try its best to reduce the variation of power grid frequency. The primary frequency modulation response is quick and can correct the frequency of power grid quickly, which is an important means to ensure the safe operation of power grid. At present, the proportion of thermal power in Shandong power grid is smaller and smaller, and there are more and more DC furnace units, while the frequency modulation capacity of some additional parts, such as nuclear power, UHV input power, wind power, is limited. Therefore, accurate prediction of the primary frequency modulation compensation capacity in a period of time in the future can provide strong support for the safe and stable operation of the power grid. At present, Shandong Power Grid connects the data of all grid-connected units to the provincial tuning system for unified management, which can realize the online remote primary frequency modulation test. The network source information platform obtains the data related to the test and automatically generates the remote primary frequency modulation test report. After the test starts, the provincial tuning system selects participating test units, issues the frequency modulation test preparation signal, and issues the test frequency difference instruction after 15s. The unit receives the test frequency difference instruction and performs a frequency modulation action. After 1 minute, the experiment will be finished, and the end signal of the frequency modulation test will be sent out to restore the test frequency difference. The first frequency modulation operation of the unit is over, and the test is over. The remote test greatly saves time and manpower, and can master the corresponding frequency modulation ability of the unit in time.

2. Influence factors of primary frequency modulation action
There are many factors affecting the primary frequency modulation response, such as data deviation, main steam temperature, main steam pressure, main control instruction, valve flow characteristics and
extraction flow, etc. When the main parameters of the unit, such as the main steam pressure and main steam temperature, obviously exceed the allowable range of the unit, the control strategy of the unit itself will be protected to limit the increase of the output of the primary frequency modulation. According to the linear correspondence between the current opening position of the turbine modulator and the opening of the turbine modulator and the active power, the primary frequency modulation output of the unit is limited by the maximum opening of the actual output of the modulator. In addition, the increase of steam extraction flow of heating unit in heating season will affect the work of steam turbine, thus affecting the operation ability of primary frequency modulation. In the summary of many experimental data, it is found that there are a lot of reasons leading to the unqualified primary frequency modulation test are regular to follow, relatively clear and easy to be judged through the data. Therefore, the corresponding algorithm is used to automatically identify and judge these reasons leading to the unqualified primary frequency modulation test, so as to improve the speed of experimental data analysis.

3. Automatic analysis of the unqualified primary frequency modulation of the source information platform

According to “GB/T 30370-2013 Guidelines for Primary Frequency Modulation Test and Performance Acceptance of Thermal Power Generating Sets” when the grid frequency change over unit primary frequency control dead zone, the unit response lag time should be less than 3 seconds, coal-fired units achieve 75% load time should be no greater than 15 seconds, achieve 90% load time should not more than 30 seconds, stable time should be less than 1 minute. The source information platform statistics remote primary frequency modulation tests, judge whether the test is qualified or not according to the acceptance criteria, classify the tests according to the causes of nonconformity. It can be basically divided into the following categories: nonconformity caused by data quality problems, nonconformity caused by control mode, nonconformity caused by insufficient modulation margin and nonconformity caused by difference in linearity of flow characteristic curve.

3.1. Data quality problem

The data quality is the foundation, only when the data is accurate can the analysis result be reliable. However, due to data communication delay, data packet loss, wiring errors, etc., the data density is not enough and the data is not accurate. When the test results are judged according to the test standards, unqualified experimental results will occur. In the case of insufficient data density or missing data, such as a number of data density in 3 seconds, or missing data for longer than a long time, there will be a 3-second response and a 15-second response the calculation results may not meet the requirements of the procedure, leading to nonconformity. If the measuring point data is misconnected and the telemetry value is wrong, the calculation of the frequency modulation instruction will be affected; if the frequency modulation instruction is wrong, the calculation of the primary frequency modulation response will be wrong.

When analyzing the cause of nonconformity, the platform will automatically analyze the density of data, the missing data and the accuracy of telemetry, etc., and give Suggestions for the problems analyzed.

![Figure 1. Results of A unit #3 primary frequency modulation test.](image)
3.2. Control mode problem
When the unit operates normally in CCS mode, the active power follows the load instruction. When the unit operates in TF or BF mode, the load instruction tracks the active power. Take TF mode as an example. When the speed difference is -6 RPM, the unit runs in TF mode with the turbine automatic, boiler manual and turbine controlled pressure. When the primary frequency modulation action, the DEH side speed difference is directly added to the turbine valve. Due to the existence of the operation cycle of the controller on the DCS side, the final result is added to the modulator later than that on the DEH side. Therefore, the response sequence of the modulator to primary frequency modulation is that the modulator is opened first. After opening the modulator, the main steam pressure decreases, resulting in the change of the output value of the DCS side controller. Then, the output of the main control instruction is turned off until the pressure is restored. The active power output increases when the modulator is opened, and then decreases with the decrease of the modulator opening. Therefore, it is very easy to fail to meet the requirements of 45 seconds and 60 seconds during the descent, resulting in unqualified test. At this point, the platform will automatically judge the running state of the unit and determine whether the running state leads to the unqualified unit.

The figure below shows the results of a remote test of frequency modulation in B unit, with a frequency difference of -0.1Hz. It can be seen from the experimental results that the load instruction tracks the active power. When the frequency modulation command is issued, the modulator should be opened first, the output should be increased, the pressure should be decreased, the DCS side should adjust the pressure, the main control command should be decreased, and the adjustment process should be completed until the main steam pressure is restored before the experiment. Therefore, the active power of the experiment increased rapidly at the beginning and then decreased, reaching only 69.52% of the theoretical value in 30 seconds and 9.05% of the theoretical value in 60 seconds.

![Figure 2. Results of B unit primary frequency modulation test.](image)

### Table 1. Primary frequency modulation index of B unit.

| Time (s) | Theoretical frequency modulation | Actual compensation | The proportion |
|----------|-----------------------------------|---------------------|----------------|
| 0        | 8.4                               | 0.78                | / 21.19%       |
| 3        | 8.4                               | 6.35                | 75.60%         |
| 15       | 8.4                               | 5.84                | 69.52%         |
| 30       | 8.4                               | 0.76                | 9.05%          |

3.3. Insufficient modulation margin
In the sliding pressure operation mode of many units, the pressure setting of some power plants is low, or due to heating and steam extraction and other reasons, resulting in the turbine regulator in the state of full open or nearly full open, the capacity to lift the load of the turbine is reduced. The rated output of some units is close to the maximum output of the unit. Near the rated output of the unit, the
regulator of the turbine is close to full operation or the boiler has reached the maximum output, resulting in the fact that there is no frequency modulation margin of increasing direction of the unit. When the primary frequency modulation occurs, the platform judges whether the main control instruction reaches 100%. When the main control instruction reaches 100% but the unit output still fails to meet the requirements, it can determine whether the insufficient modulator margin has an impact on the primary frequency modulation ability.

Take Unit #1 of C unit as an example. Before the occurrence of primary frequency modulation, the modulator opening has reached 95%, and after the occurrence of primary frequency modulation, the modulator opening directly reaches 100%. The modulator is fully open, but the output of the unit still cannot meet the requirements of regulations.

![Figure 3. Results of C unit primary frequency modulation test.](image)

| Theoretical frequency modulation | 0 | 9.3 | 9.3 | 9.3 | 9.3 |
|----------------------------------|---|-----|-----|-----|-----|
| Actual compensation              | 0 | 5   | 6.9 | 6.58| 5.93|
| The proportion                   | / | 53.76% | 74.19% | 70.75% | 63.76% |

### Table 2. Primary frequency modulation index of C unit.

3.4. **Flow characteristic problem**

In the actual operation of the unit, the sensitivity and flow characteristics of the turbine regulator vary with the variation of operating conditions. For example, during the operation of the turbine for a period of time in the production process, or during the major and minor repair of the unit, or during the through-flow transformation of the turbine, the flow characteristics of the regulator will change after the regulator is dismantled and overhauled. Poor linearity of modulator opening and flow or deviation from control parameters of original modulator, resulting in sudden change and retention of unit flow, etc., resulting in modulator jitter, slow load response or oscillation. The desired effect cannot be achieved simply by adjusting PID parameters, which seriously affects the performance of primary frequency modulation of the unit. The judgment method of flow characteristics has explained in detail in “A Multivariate State Estimation Technique and Multilayer Forward Neural Network Framework on Steam Turbine Valve Flow Curve Simulation” “Application of Multi-layer Forward Neural Network based Piecewise Linear Regression in Simulation of Steam Turbine Valve Flow Curve” how to use big data to analyze the valve flow characteristics, get the valve flow curve, and judge the deviation between the actual flow curve and the set flow curve. In the remote test of primary frequency modulation, when the index of the valve flow characteristic curve is adjusted at this opening, and the index is higher than the specified value, it is considered that the linearity of the valve flow characteristic curve at this opening is not enough.
4. Suggestions to deal with the unqualified causes of primary frequency modulation of the network source information platform

In view of the above reasons for nonconformity, the network source information platform gives processing Suggestions according to their data characteristics.

4.1. Recommendations for Data quality

Data quality problems can be analyzed from three aspects: sub-station, transmission channel and master station. Due to the different DCS systems adopted by each power plant, the data collection methods of the sub-stations are also different. Some units upload data every second, while some units upload data only when the data changes. Moreover, the dead zone of data changes is set, resulting in serious data shortage. There are some unit's measuring point connection error. In this case, the access measurement points need to be checked, and the data acquisition frequency and precision need to be executed in accordance with the relevant provisions. Data acquisition frequency and precision should be in accordance with the relevant provisions. Data transmission channel should be kept unblocked to avoid data delay. Master site data should be saved to the database timely and accurately to prevent packet loss. Network source information platform according to the data quality problems received classified tips to strengthen data quality management, data governance recommendations.

4.2. Recommendations for Control mode

According to the requirements of “GB/T 30370-2013 Guidelines for Primary Frequency Modulation Test and Performance Acceptance of Thermal Power Generating Sets”, CCS should be put into a frequency modulation test. According to the disqualification caused by this kind of problem, it is suggested that the unit should be put into CCS mode during normal operation.

4.3. Recommendations for insufficient modulation margin

When the regulator margin is insufficient due to sliding pressure mode or heating and steam extraction, the pressure needs to be corrected accordingly. The source information platform will automatically give qualitative Suggestions for the pressure increase.

4.4. Recommendations for flow characteristics issues

Based on the data analysis of valve flow characteristics, the grid source information platform draws the actual curve and the theoretical curve. According to the judgment results, the platform automatically gives the direction of regional level qualitative regulation with poor valve flow characteristics.

5. Conclusion

Automatic analysis of the results of primary frequency modulation can improve the analysis efficiency, but due to the differences between DCS and equipment of the unit, the reasons affecting primary frequency modulation are also different. Currently, it is difficult to cover all the reasons, which need to be gradually improved in the future work process.

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