Research And Practice Of 600MW Subcritical Steam Turbine Inter Generation Upgrading

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Abstract: This paper introduces the upgrading technical scheme and application of subcritical 600 MW steam turbine. Firstly, the performance and existing problems of 600 MW subcritical unit before modification are analyzed, and the performance and output of steam turbine before modification are determined. Secondly, the performance of 300MW subcritical steam turbine retrofit and the performance guarantee value of each retrofit manufacturer are studied, and the thermal calculation is carried out. At the same time, the performance index of subcritical 600 MW steam turbine after upgrading is analyzed. Finally, according to the channel reconstruction scheme provided by the manufacturer, the optimization design of cold end optimization, last stage blade selection and base foundation reconstruction is proposed.

1.Introduction

With the increasingly fierce competition in the power market, and the pressure of energy conservation and emission reduction is further increased. In the future, the state thermal energy company will still face more and more business pressure and severe development challenges, which puts forward higher requirements for the thermal energy company.

At present, the cross generation upgrading project of 600 MW Subcritical Units in China has been gradually launched. According to the actual operation of 600 MW subcritical unit, there is an obvious gap between the actual operation performance and the design value. The unit performance is relatively backward, and most of the units have been in operation for nearly two review periods. Therefore, it is necessary to carry on the technical transformation to this type of machine. This paper takes Daihai Power Generation Company 600 MW subcritical steam turbine unit as the main research object.

2.Present situation of 1 600 MW steam turbine

The 600MW Subcritical steam turbine of Daihai Power Generation Company is designed and produced by Shanghai steam turbine works using the technology of Westinghouse in 1990s. The high, medium and low pressure flow passage stages of the steam turbine are 58 stages, and the height of the last stage blade is 905mm. The unit is designed with 8-stage regenerative steam extraction, including 3 HP heaters (HP heaters), 1 Deaerator and 4 LP heaters (LP heaters).

2.1Economy

The subcritical heat rate of Daihai Power Generation Company is 7745.5kj / (kW · h) (design back pressure is 4.9kpa), and the efficiency of high, medium and low pressure three cylinders are 88.16%,
91.58% and 89.60%, respectively. According to the commissioning test report of the equipment (see Table 1), the heat rate of the unit is much higher than the design value of 245.3kJ / (kW · h). According to the performance test in 2013, the unit heat rate is higher than the design value of 365.1kJ / (kW · h), and the longer the operation time is, the economic benefits of the unit will decline significantly. Considering that many manufacturers have upgraded their steam turbine design technology and the conversion effect is good, Daihai Power Generation Company decided to carry out technical conversion of the equipment.

|                      | Project | Design value | Examination experiment | Performance test |
|----------------------|---------|--------------|------------------------|------------------|
|                      | Time    | /            | 2006                   | /                |
|                      | Test standard | /            | ASME PTC6-1996       | ASME PTC6-1996   |
|                      | Heat rate kJ / (kW · h) | 7745.5       | 799.08                | 8107             |
|                      | High pressure cylinder Efficiency /% | 88.16        | 87.54                 | 84.87            |
|                      | Medium pressure cylinder efficiency /% | 91.58        | 91.85                 | 90.63            |
|                      | Low pressure cylinder efficiency /% | 89.60        | 84.01                 | 84.45            |

2.2 Existing problems
According to the collected operation data of the unit and the problems found in the maintenance, it is considered that the subcritical 600 MW steam turbine has the following problems.

2.2.1 Serious over temperature. The 600 MW subcritical unit usually has the problem of excessive overheating under the condition of low pressure five stage extraction and six stage extraction. In some units, the five step extraction temperature is about 30 °C higher than the design value, and the six step extraction temperature is about 50 °C higher than the design value, and the overheating is particularly serious. The same type of household equipment (including Westhouse prototype) also has obvious overheating problem during the fifth and sixth stages of extraction, which affects the economy of the equipment.

2.2.2 Excessive cooling steam flow. The 600MW Subcritical unit adopts the design of medium pressure rotor cooling steam, and the design flow is about 7.5t/h under rated working conditions. However, according to the performance test results of several equipment in guohuadao Electrical Appliance Factory, the actual steam flow is about 4 times of the design value, reaching 30t / h, which is far greater than the design value, which affects the economy of the equipment.

2.2.3 High vibration of low pressure cylinder bearing. If the back pressure of the unit is low, the bearing vibration of the low pressure cylinder is too large. When the back pressure is lower than 3kpa and decreases gradually, the vibration of low pressure cylinder bearing will increase gradually. The main reason for the analysis is the design of low pressure bearing pedestal of SAIC subcritical 600 MW unit installed outside the upper cylinder. The deformation of the low pressure outer cylinder is too large, which leads to the problems of static collision and vibration increase of steam turbine motor.

2.2.4 Vibration of control valve and valve stem fracture. The high pressure control valve often fails due to the fracture of valve stem and connecting sleeve pin, and the fracture of LVDT connecting rod [6].

3. Solutions
At present, domestic and foreign steam turbine manufacturers have updated their technologies and
started to use the new generation ultra supercritical million unit technology to design and transform 300 MW and 600 MW units. The overall technical level is much higher than that in the 1990s. However, from the feasibility study on retrofitting the 600MW Subcritical steam turbine of Daikin Power Generation Company, the 600MW Subcritical steam turbine produced by Shanghai steam turbine Co., Ltd. still has no retrofit performance during the start-up of the feasibility study. The determination of heat consumption rate and modified nameplates is the focus of this study [6].

3.1 Heat consumption rate after modification
The latest performances of 11 300MW steam turbines are collected (see Table 2). When the efficiency of high and medium pressure cylinder reaches 86.86% and 92.8% respectively, and the heat consumption rate reaches 7866kj/(kW·h) [5]. It can be seen that the retrofitting technology of 300MW steam turbine is quite advanced.

| Name of power plant | Back pressure (Kpa) | High pressure cylinder Efficiency (%) | Medium pressure cylinder efficiency (%) | Heat rate kJ/(kW·h) |
|---------------------|---------------------|--------------------------------------|----------------------------------------|-------------------|
| PlantA Number 3     | 4.9                 | 85.74                                | 91.89                                  | 7883.0            |
| PlantA Number 4     | 4.9                 | 87.04                                | 91.71                                  | 7888.6            |
| PlantB Number 3     | 4.9                 | 87.34                                | 91.84                                  | 7862.5            |
| PlantB Number 4     | 4.9                 | 86.52                                | 92.88                                  | 7874.4            |
| PlantC Number 1     | 4.9                 | 87.46                                | 93.70                                  | 7878.0            |
| PlantC Number 2     | 4.9                 | 87.36                                | 92.49                                  | 7882.0            |
| PlantD Number 1     | 4.9                 | 85.40                                | 92.93                                  | 7845.6            |
| PlantD Number 2     | 4.9                 | 87.55                                | 93.11                                  | 7840.0            |
| PlantE Number 3     | 4.9                 | 86.20                                | 93.40                                  | 7852.9            |
| PlantE Number 4     | 4.9                 | 87.20                                | 93.70                                  | 7850.8            |
| PlantF Number 3     | 4.9                 | 87.60                                | 93.12                                  | 7868.4            |
| **Average value**   | **4.9**             | **86.86**                            | **92.80**                              | **7866.0**        |

In order to determine the heat consumption rate of the reformed steam turbine, the following works are carried out: (1) based on the performance of 300MW units, the similarities and differences between the subcritical 300MW units and 600MW units are analyzed, and it is concluded that the heat consumption rate of 600MW units should be lower than 30kJ/(kW·h) of 30MW units [4]. (2) The guaranteed values of 600MW steam turbine after transformation provided by Shanghai Steam Turbine Works, All Four Dimension Company and Alstom Company were collected and compared. The guaranteed value of heat consumption rate is basically at the same level. In addition, the thermal balance was checked by the thermal calculation program [5]. Finally, it was determined that the efficiency of high pressure cylinder and medium pressure cylinder of 600MW turbine was 88.5% and 92.5%, respectively, and the heat consumption rate was about 7,840 KJ/(kW·h) (back pressure was 49kpa).

3.2 Low pressure cylinder base reconstruction
The bearing blocks on both sides of the low pressure module should be separated from the cylinder and positioned independently on the foundation. At the same time, the low-pressure module part of the turbine base needs to be added with a foundation (as shown in the light blue part in Figure 1) to meet the needs of bearing landing of the low-pressure module of the steam turbine.

In the construction of low pressure cylinder foundation reconstruction, it is necessary to rearrange the foundation plate and anchor bolt at the low pressure cylinder. In view of the fact that the turbine generator foundation is an organic whole vibration structure, the foundation of the turbine generator needs to be reinforced and reconstructed. For the turbine generator foundation and low-pressure cylinder,
measures such as planting reinforcement and wrapping are adopted to increase the cross-section size of beams and columns, connect the old and new beams and columns into one, and carry out the old and new reinforcement and transformation. In the new and old reinforcement and reconstruction scheme, the reinforcement measures and materials (including structural adhesive) used for vibration members bearing dynamic load should meet the requirements of fatigue resistance in 《Technical Code For Safety Appraisal Of Engineering Structural Reinforcement Materials》 (GB-50728). The following describes the new process and process involved in the design.

3.3 Technical proposal

3.3.1 Removal of pipes and cables around III, IV and V axis base columns. Due to the construction of column cladding steel, it is necessary to remove the cables, pipes, thermal insulation, cooling water device and surrounding protective facilities around the base column of axis III, IV and V. after the construction is completed, all of them need to be restored, as shown in Fig. 2.

3.3.2 Earth excavation for foundation column of axis III and V. Due to the construction of column encased steel, earth excavation should be carried out within 3 m around the original III and V axis base column to - 4.5 m, so as to meet the needs of column cladding steel construction working face, as shown in Fig. 3.
3.3.3 Wall panel cutting of III and V axis base column. After the earthwork excavation is completed, concrete rope saw shall be used to cut the surrounding wall panels, and a drilling machine shall be used to make holes in the wall panels for later construction fixation and hoisting. After the wall panels are removed, they shall be hoisted to the designated place outside the factory, as shown in Figure 4.

3.3.4 Perforation and reinforcement at the side of column base of III, IV and V axes. III, IV, V shaft base four construction surface, in addition to one side for the anchor bolt installation, steel binding, the remaining three sides need to punch, planting bar, eyelet, according to the first figure anchor reinforcement planting bar, bar and position for the old base within the column reinforced effect can be adjusted according to the field situation, need to replace the punches a hole location for many times, after the completion of the bar and then planting bar according to decorate open hole on the steel plate, as shown in figure 5.
3.3.5 Anchor bolt installation. The anchor bolts of III, IV and V axis bases should be punched and installed, and the anchorage depths are 960mm and 1280mm respectively. Special adhesive should be used for application and installation. Before installation, the foundation shall be broken.

3.4 Construction steps of belled anchor bolt

- According to the requirements of engineering design, the type and quality of screw thread steel self-locking bolt are selected.
- Drill a straight hole at the anchor point of the foundation to the depth required by the design; clean the ash in the hole with a blower.
Ream the bottom of the straight hole to the inverted taper hole with the specified bottom diameter by reaming bit (patented product).

Check the bottom diameter of the reamed hole with a hole meter. After meeting the requirements, the open water in the hole can be cleaned. Before grouting, the surface of hole wall shall be kept moist, but no open water shall be left.

The amount of WSJ structural grouting glue is about 2/3 of the hole depth, that is, when the anchor rod is inserted into the hole, a small amount of glue will overflow from the hole.

Insert the locking cone head slightly into the slotted end of the self-locking anchor rod, then put the bolt with cone head into the bottom of the anchor hole, and then press the slotted end of the bolt with hammer or other methods to force the slotting end of the bolt to expand and self lock; the slotting pressure shall not be too large, and the bolt will not continue to extend after encountering pressure. Although 1.5m ~ 3.0m steel bar lap length is reserved in the upper part, the expansion of anchor head of reinforcement will not be affected due to the small hammering force required.\[1\]

Before the final setting of structural adhesive (about 24 hours), the bolt should not be disturbed.

For the anchor rod after construction, the project should be sampled for uplift test after 5 days of age.

3.4.1 Process flow of belled anchor bolt. Measurement and determination of hole position → drilling → bottom reaming → hole cleaning → installation of self-locking anchor rod → grouting → maintenance → test, as shown in Fig. 7.

Figure 7: Process flow of belled anchor bolt

4. Conclusion

- After the improvement of the flow passage, the operation economy of the unit is increased by 4.3%. The efficiency of each cylinder of steam turbine has been improved obviously.

- There is still a certain potential to improve the unit operation economy. Canceling the cooling steam from primary extraction to intermediate pressure cylinder can improve the operation economy of the unit\[1\]; adopting low-pressure steam source (four-stage extraction or cold reheating) as the standby steam source of the shaft seal system can meet the working requirements of the steam seal system of the unit. Using high-quality main steam has high energy consumption and low utilization, which affects the economy of the unit under low load operation\[2\].

- In the process of steam turbine transformation, not only the problems existing in steam turbine should be solved, but also the matching and boundary conditions of main auxiliary machines such as boilers and units should be considered. Through comprehensive analysis and research, we can realize the coordination and optimization of various systems after transformation, avoid the impact of local system compatibility problems on the performance of other systems or equipment, and ensure the optimal operation economy of the unit under different loads.

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