Research And Practice On Transformation Of 600 MW Turbine Tubular Cooling Unit Into Direct Air Cooling Unit

Jin Shengxiang 1, Wang Liuhu 1, Zhang Jinsong 1, Zhang Qi 2, li Qianyu 2, Bai Wei 1, He Chuan 2, Zhou Yong 3, li Daming 2, Xiao Yu 1

1. Inner Mongolia Daihai Power Generation Company. Inner Mongolia 013700
2. Beijing Jingneng Power Company. Beijing 100025
3. Shanghai Electric Group Company, Shanghai 200002

Abstract: In response to the government's policy of protecting Daihai Lake, this paper discusses the possible problems in the technical practice of air cooling transformation of Inner Mongolia Daihai Power Generation Company, including the transformation of steam turbine body, auxiliary system of steam turbine body, transformation of thermal system and auxiliary equipment, layout of steam turbine room, etc. The results show that the operation is stable and the energy saving effect is remarkable.

1. Introduction

With the increasingly stringent requirements for energy conservation and emission reduction of thermal power generation enterprises, comprehensive upgrading and transformation of coal-fired units has become a new trend to improve the utilization efficiency of energy resources and promote the transformation and development of the power industry [1]. Daihai phase I project, as the first comprehensive upgrading unit from wet cooling to air cooling in China, has created a precedent in the industry. The scope of the steam turbine renovation work is large, involving many transformation systems, and the process is complex, so the engineering difficulty is no less than that of the new unit. The reconstruction project has no precedent to learn from and no experience to follow. The main work of the transformation is divided into two stages: old equipment removal (protective demolition of the old part) and new equipment installation stage.

2. Transformation process

2.1 Transformation of turbine body

In the daihai Phase I reconstruction project, the steam turbine was transformed from the original subcritical four-cylinder four-row steam wet cooling unit to the subcritical efficient four-cylinder four-row air cooling unit. Due to the large increase of steam inlet temperature of the steam turbine and the change from wet cooling to air cooling, on the premise that the foundation of the high and middle pressure cylinder remains unchanged, the turbine itself, including all the large and small components of the high, middle and low pressure modules, the flow blades and baffles, and all bearings, shall be redesigned.

2.1.1 High and medium voltage modules

- The inlet parameters are increased from 16.7 MPA / 538 ℃ / 538 ℃ to 16.7 MPA / 596 ℃ / 596 ℃,
and the inlet temperature is directly close to 600 °C. The high and medium pressure modules of steam turbine must meet the requirements of new parameters. Different from the previous flow-through transformation, the components and materials of high-pressure module and medium pressure module in this project are completely replaced, and the influence of inlet steam temperature rise on thermal expansion of each component of the unit shall be considered.

- The energy carried by the main steam increases with the increase of inlet steam temperature and enthalpy. If the structure design of steam turbine before modification is adopted, it is difficult for the unit to meet the design requirements in terms of overspeed condition and sealing performance. In order to reduce the volume time constant, the high and medium pressure modules adopt the structure of direct connection between the inlet valve and the cylinder, and cancel the steam conduit between the valve and the cylinder.
- In order to keep the high and medium pressure cylinder part of the existing civil engine base, the span of high and medium pressure modules should be kept unchanged. In addition, in the design of the specific module, it is also necessary to consider matching with the original 1 # and 2# bearing pedestal.

![Figure 1: Turbine high and medium pressure modules](image)

2.1.2 Low voltage module

- The low pressure module is changed from wet cooling to air cooling, and the cylinder is separated from the bearing seat. The back pressure of air cooling unit is high and changes frequently. The last stage blade is also changed to air cooling 740mm last stage blade. The low pressure module will be completely replaced, including bearing pedestal and embedded parts of foundation. Due to the different sliding pin systems of air cooling and wet cooling units, higher requirements are put forward for differential expansion design of the whole unit.
- At present, the low-pressure module is designed under the ultra supercritical unit system. The low-pressure outer cylinder is rigidly connected with the exhaust device and does not participate in the expansion of the sliding pin system; the low-pressure inner cylinder is axially supported on the bearing pedestal; the flow passage adopts the mode of 2 * 6 + 2 * 2, the first five stages are AIBT integral flow passage platform completely new design, and the last two stages are 740mm standard last stage group. See Fig. 2 for details Block scheme [2].
2.2 Auxiliary system reform of turbine body

- Replace all steam turbine drain systems.
  - The first, second, third, fourth, fifth, and sixth stages of the turbine shall all be replaced.
- The shaft seal steam supply system cancels the original main steam supply line, retains the shaft seal steam supply bus temperature reducer, and increases the shaft seal overflow by one line to no. 7 low addition; The original shaft sealing steam supply safety valve is retained, but the interface position is changed from the front of the temperature reducer before modification to the back of the temperature reducer; The shaft sealing heater can be used after accounting. in addition, the valve and pipeline of the shaft sealing system (including the shaft sealing overflow) are all replaced.
  - Replace all valves and pipes in the low-pressure cylinder water spraying, diffusing water spraying and three-stage temperature and pressure reducing steam and water reducing system.
  - The lubricating oil system shall replace the main oil pump - the oil turbine and the oil pipeline inside the oil tank, the rest of the oil tank and the oil cooler shall be retained, in addition, the oil pipeline set above the operating layer of the machine base shall be replaced. High and medium pressure module bearing shaft jacking tubing is added to the shaft jacking oil system [3].
  - Remove the condenser and replace the exhaust device.
  - Replace No. 6, 7 and 8 low-pressure heaters and keep No. 5 low-pressure heater in combination with the transformation of waste heat utilization of condensate flue gas.

1.3 Transformation of the thermal system and its auxiliary machines

2.2.1 Main steam, reheated steam and bypass system

- The main steam pipeline retains the original "2-1-1" connection mode. In order to prevent temperature deviation, the main steam pipeline is connected out of the header center. In addition, the raw materials of the main steam and the bypass steam pipeline cannot meet the requirements of the design temperature due to the increased parameters, so they are all replaced.
  - For the sake of the safe operation of the unit, the deviation of steam temperature caused by the uneven heating on both sides of the boiler is reduced due to the large increase of engineering parameters. Reheated (cold section) steam pipe and reheated (hot section) steam pipe are changed from the original "2-1-1" connection mode to "2-1-2" connection mode. In addition, in order to meet the requirements of parameter improvement, all the steam pipes of the reheating system were replaced.
  - Maintain the two-stage series hydraulic bypass system of high and low pressure. Replace the high and low pressure bypass valves of the turbine after parameter modification. Old hydraulic oil station; High pressure bypass water stop valve, low pressure bypass water control valve and water spray stop valve are upgraded with old valve body.
2.2.2 Water supply system. Two steam driven feed water pumps with 50% BMCR capacity and one electric starting standby feed water pump with 30% BMCR capacity are still used in the water supply system. The steam feed pump is arranged in the operation layer, which is different from that of the booster pump. The main renovation and accounting items of water supply system are as follows:

- After the No.1 high pressure heater, an external steam cooler was added to No.3 high pressure heater, and the feed water temperature was increased from 280.4 ℃ to 284.8 ℃ under VWO condition;
- In order to improve the flue gas temperature at SCR inlet under low load, the boiler is equipped with graded economizer. The high-pressure water supply is changed to the inlet of the primary classification economizer after the boiler;
- In order to avoid the steam temperature deviation caused by uneven heating on both sides of the boiler, the interface of the primary economizer at the side of the high-pressure feed water boiler is changed from one side to two sides.
- After the steam turbine is changed from wet cooling to air cooling, the exhaust steam of the feed pump turbine is directly discharged into the exhaust device of the main engine instead of being discharged into the condenser.
- The design and layout shall be provided by the flue gas waste heat manufacturer, and the interface shall be reserved by the design institute.
- Calculation of feed pump turbine. The original feed water pump turbine is a wet cooling small turbine, and each unit is equipped with two 50% capacity feed pump turbines. The original design of feed pump turbine has low back pressure and long last stage blade. After the project is changed into an air-cooled unit, the exhaust steam of the small turbine is directly discharged into the large turbine, and the back pressure is correspondingly increased. The efficiency of the original small turbine will be greatly reduced when it operates at high back pressure. In addition, the small steam turbine has been operating for many years, and the efficiency has been reduced a lot, so the situation may be more serious. In addition, the last stage blade is longer, and the limit back pressure of the original small turbine is 28kpa, which can not fully adapt to the higher back pressure condition after changing from wet cooling to air cooling. According to the calculation of the small turbine manufacturer (Hangqi), it is suggested that the flow path of the small turbine should be modified, and the blade more suitable for air cooling and high back pressure operation will significantly improve the economy. After negotiation with the power plant, the small steam turbine will not be replaced for the time being, but the operation of the small steam turbine needs to be closely monitored during the operation, and the back pressure operation shall be reduced if necessary.
- According to the calculation, the original feed water pump set can meet the operation needs after the transformation after the head of the booster pump is restored to the original design head.

2.2.3 Drainage system of high pressure heater

- Add a No. 3 high-plus external steam cooler;
  - Considering safety factors, it is necessary to carry out local transformation for No. 1 high plus and No. 2 high plus. No. 1 high plus to replace the steam pipe, No. 2 high plus to replace the short barrel body;
  - Considering the poor operation condition of No. 3 high plus before the transformation, there are problems such as large pipe blocking rate, large difference at the lower end, and frequent opening of accident drainage, etc., plus the addition of no. 3 high plus external steam cooler, No. 3 high plus is completely replaced in this transformation;
  - Except for the newly added No. 3 high plus external steam cooler, No. 1, 2 and 3 high plus drain, drain and bleed valves and pipelines do not need to be replaced after accounting. Considering that the equipment has been in operation for many years and the setting pressure of the safety valve needs to be returned to the factory, all high plus safety valves should be replaced;
2.2.4 Turbine extraction system. After revamping, the steam turbine also adopts eight stage non-adjustment steam extraction and adds an external steam cooler of No. 3 high pressure heater. After calculation, the first and fourth section of the steam extraction pipes can be used, and all the other stages of the steam extraction pipes are replaced.

2.2.5 Drainage system of low-pressure heater
- Keep no. 5 low pressure heater and replace No. 6, 7 and 8 low pressure heater.
- In addition to no. 5 low plus normal and accident drain, all other low plus normal and accident drain pipes and valves should be replaced. The drain and vent valves and piping of the low pressure heater can be used to replace all safety valves in accordance with the high pressure heater.
- The deaerator and its water and air discharge pipe valves are all retained.

2.2.6 Closed circulating cooling water system. After the upgrading and transformation of large unit from wet cooling to air cooling, the circulating water system of large turbine and open circulating cooling water system of auxiliary machine are cancelled, and the cooling water system of auxiliary machine is changed to large closed water system, that is, all equipment cooling water in the plant is cooled by the evaporation cooling tower of hydraulic engineering, and the water quality is desalted water.

After the transformation, the water supply of the closed circulating cooling water system comes from the dry wet combined cooling tower outside the main power house. The cooling water is led out from the hydraulic cooling water supply pipe outside the main power house. After boosting by the auxiliary circulating water pump set at 0 m in the steam turbine room, it is sent to the heat exchange equipment. The cooling water return water is connected to the hydraulic cooling water return pipe outside the main power house and passes through the dry wet combined cooling tower After cooling, it enters the cooling water supply system for recycling[4].

2.2.7 Condensate system. Before the transformation of the project, each unit is equipped with 2 × 100% capacity condensate pump, one for operation and one for standby. Before this transformation, Daihai phase I project has completed the frequency conversion transformation of condensate pump. In addition to the following changes, most of the condensate system of the upgrading project remains the same.
- In view of the change from wet cooling to air cooling, a grade iron remover is added in the chemical fine treatment;
- According to the calculation of Shanghai steam turbine works, the desuperheating water of drain flash tank and three-stage pressure reducing desuperheater and low-pressure cylinder water spray system supplied by all steam turbine plants were replaced;
- In this reconstruction project, a new condensate flue gas waste heat utilization system will be set up. After the condensate from the inlet and outlet of No. 6 low pressure heater is mixed, it will go to the flue gas waste heat utilization device to recover part of the flue gas heat, and then return to the outlet of No. 5 low pressure heater. The higher exhaust heat is used to heat part of condensate water to reduce the steam extraction amount of regenerative system and coal consumption, so as to reduce the emission of harmful substances and improve the economic efficiency of the whole plant. The manufacturer of flue gas waste heat utilization is responsible for the construction drawing design and construction of this part of the system, and the design institute reserves the interface; the specific system is detailed in the boiler part.
- The heating system of condensate water heater is newly added in the reconstruction project. The manufacturer of flue gas waste heat utilization is also responsible for the construction drawing design and construction, and the design institute reserves the interface; the specific system is shown in the boiler part.
- Add condensate pipe system from air-cooled condenser to exhaust device.
- After calculation, the flow and head of the original condensate pump can meet the operation needs of the unit after transformation.
2.2.8 Vacuum system. The characteristics of air cooling unit are that the volume of vacuum system is larger than that of wet cooling unit and the air leakage is large. The capacity of vacuum pump equipped with original wet cooling unit is small and the pressure is low, which can not meet the demand of vacuum system of air cooling unit. Therefore, two sets of 100% capacity water ring vacuum pump units are newly installed in each unit to meet the requirements of air cooling unit vacuum pumping. It was confirmed that the original steam side vacuum pumps of all the original wet cooling units were removed, and one vacuum breaking valve was shared by two exhaust device shells.

2.3 Layout of steam turbine room
The whole frame structure of the steam turbine room is reserved in this reconstruction, and only partial equipment is removed and added, and some ditches are backfilled and supplemented to meet the needs of this transformation [5]. Two 80 / 30t bridge cranes are installed in the original steam turbine room with the lifting height of 26m, which can meet the maintenance needs of the newly replaced steam turbine and other auxiliary equipment.

3. Transformation results
After transformation, unit 2 of Daihai phase I passed the inspection successfully on April 18, 2019, and unit 1 successfully passed the inspection on June 26. The comparison before and after transformation is shown in Table 1.

| Project                              | Before transformation | Design value after reconstruction |
|--------------------------------------|-----------------------|-----------------------------------|
| Rated power of unit                  | 630MW                 | 630MW                             |
| Heat consumption under rated condition | 7731.5kJ/kWh         | 7899.6kJ/kWh                      |
| Turbine efficiency under rated condition | 46.56%             | 45.57%                            |
| Rated back pressure                  | 4.5kPa                | 10.5kPa                           |
| High pressure cylinder efficiency    | 88.11%                | ≥89.95%                           |
| Medium pressure cylinder efficiency  | 92.19%                | ≥92.38%                           |
| Low pressure cylinder efficiency     | 88.69%                | ≥90.25%                           |

It can be seen from the above table that the transformation has achieved the expected effect with remarkable environmental and economic benefits.

4. Summary
The transformation of 600 MW steam turbine tube cooling unit into direct air cooling unit can effectively reduce the power generation cost and improve the economic benefits of enterprises. In operation, it can significantly reduce energy consumption, save coal resources, improve energy utilization, reduce pollutant emissions, improve urban environmental quality, and set an example for the country to achieve the goal of energy conservation and emission reduction.
Reference

[1] Yu Xiaodong. (2019) Method and benefit analysis of transforming water cooling unit into air cooling unit [J]. China Hi tech, (05): 59-60

[2] Zhang Huimei. (2018) Research on high back pressure retrofit of 300MW wet cooling condensing unit in Jinqiao thermal power plant [D]. North China Electric Power University

[3] Liu Ji, Fu Xiliang, Zhao Zhihong, Zheng Lei, Duan Dongwei, Xugang. (2016) Performance evaluation of 600MW air cooling unit with peak condenser [J]. Energy research and utilization, (03): 27-30 + 35

[4] Wang Yongsheng. (2016) Reconstruction of air cooling peak cooling system of 600MW unit in Huaneng Shangan Power Plant [D]. North China Electric Power University

[5] Lu Peng. (2014) Analysis of air cooling reconstruction project of 600MW unit in Zhangshan power generation company [D]. North China Electric Power University