Research And Practice Of Dry Wet Combined Cooling For 600 MW Steam Turbine Generator Unit

Jin Shengxiang 2, Wang Lihu 1, Zhang Jinsong 1, Zhang Qi 2, Li Qiyanu 2, Bai Wei1, He Chuan 2, Li Daming 2, Xiao Yu 1

1. Inner Mongolia Daihai Power Generation Company. Inner Mongolia 013700
2. Beijing Jingneng Power Company. Beijing 100025

Abstract: Taking 600MW steam turbine generator set as an example, this paper analyzes the dry wet combined cooling scheme of auxiliary cooling water system, so as to make rational use of local limited water resources.

1. Introduction
Because the cooling system of machine condensing equipment in power plant usually uses wet cooling system, but these systems need a lot of water, and there is a serious lack of water resources in Inner Mongolia. In order to respond to the national requirements, save water resources and promote the application of air cooling technology and circulation technology, this paper analyzes the dry wet combined cooling scheme of auxiliary equipment.

2. Equipment introduction
The research object is 4 × 600MW units of Inner Mongolia Daihai Power Generation Company. the closed water of auxiliary units and cooling water of oil cooler are directly extracted from Daihai Lake water, that is, the closed water cooling adopts the type of open water + plate exchange, and the cooling of oil cooler directly adopts the type of open water. In response to the policy of protecting Daihai Lake Water Resources in Liangcheng County of Inner Mongolia, Daihai Power Generation Company entrusted Fujian Lixin heat exchange equipment manufacturing Co., Ltd. to transform the cooling mode of the original closed water and oil cooler, that is, to eliminate the original open water + plate exchange system and adopt the closed system of dry wet combined cooling tower.

2.1 Evaporative air cooler
Evaporative air cooler is a device that uses water as circulating coolant to absorb system heat and release it into the atmosphere to reduce water temperature. It is widely used in closed circulating cooling water system of blast furnace desalting water.

2.2 Dry wet combined air cooler
- The higher the critical temperature is, the larger the heat exchange area is, the more water-saving the system is, but the greater the investment is;
- The finned tube is suitable for dry and wet operation, with large fin ratio and good heat transfer performance. However, under wet condition, some problems are encountered, such as corrosion of carbon steel pipe (including steel fin or aluminum fin), too small fin spacing, easy fouling and low heat transfer performance. Under the condition of water spray, the resistance increases significantly and the
power consumption increases the finned tubes are arranged in multiple rows, and the first row of tubes is antifreeze, so the finned tubes are not suitable to be used as wet cooling heat transfer elements. The wet cooling heat transfer element is suitable for smooth tube or plate tube heat transfer element.

![Figure 1: Dry wet combined air cooler](image)

3. **Dry wet combined cooling system**

Dry wet combined cooling system is a system that uses dry and wet cooling methods to cool the exhaust gas of steam turbine. Compared with the traditional wet cooling system, the dry and wet combined system has the advantages of saving water resources, and compared with the dry cooling system, the dry and wet cooling system has higher thermal efficiency in hot summer environment. Dry wet composite cooling system usually includes exhaust pipe, air cooling island, surface condenser, condensate pump, mechanical ventilation cooling tower and other equipment. The exhaust gas from the low pressure cylinder of the steam turbine is sent to the air cooling island and surface condenser for cooling at a certain speed. Finally, it condenses in the condenser tube and is discharged by the condensate pump into the regeneration system[1].

The combined cooling system in the same circular tower is called wet cooling system and air cooling system integrated cooling tower. On the air side, dry cooling equipment and wet cooling equipment are connected in parallel, while on the water side, air cooling equipment and wet cooling equipment are connected in series. The split combined cooling system completely separates the wet cooling system from the air cooling system and cools the exhaust gas of the steam turbine respectively. The wet cooling system is only activated when the ambient temperature is high, and the air cooling system is always in operation.

| Name                        | Combined dry wet cooling system | Separate dry wet combined system                                                                 |
|-----------------------------|--------------------------------|--------------------------------------------------------------------------------------------------|
| Operation mode              | Control air volume by louver   | The wet cooling system can be shut down in winter Elimination by shutdown of wet cooling system   |
| Eliminate fog               | Effective                      |                                                                                                  |
| Working environment of air cooled radiator | It is greatly affected by the wet exhaust steam of the wet cooling tower | Not affected by wet and cold exhaust In winter, the shutdown of wet cooling system can be alleviated |
| Antifreeze                  | difficulty                     |                                                                                                  |

The research of dry wet composite cooling system started late. Daizishao power plant in Germany adopted dry wet composite cooling tower, which showed excellent performance in thermal efficiency and water saving. The experimental study on the target cooling method shows that the new combined
cooling method consumes a small amount of water and the heat transfer efficiency is several times higher than that of the traditional air cooling method. Phelps analyzed the water-saving performance of the new design of dry wet composite cooling tower, integrated the dry and wet composite cooling system, Simulated the dry and wet composite cooling tower, and analyzed the feasibility and economy by Rezaei. And Established the calculation model of dry and wet cooling tower and carried out simulation calculation by Asvapousitkul.

In the coal rich and water deficient areas of China, the application of air cooling technology is increasing year by year. However, with the increase of operation time, the performance of air cooling device decreases year by year. The ambient temperature rises in summer and the heat load increases. The increase of back pressure increases the steam consumption of the turbine, the boiler power, the working load of the auxiliary engine and the safe and economic operation of the equipment.

4. Design Scheme
The first phase unit of Inner Mongolia Daihai Power Generation Company has been running normally until it was put into operation. In response to the government's policy of protecting Daihai Lake, it was decided to transform the first-phase wet cooling unit into direct air cooling unit, so as to improve the unit's flow efficiency, reduce the unit's coal consumption for power supply and reduce its emission index.

4.1 Open cooling water system of the original Daihai power Plant

In the original cooling scheme of steam turbine, the heating pipeline is led out from the opening of connecting pipeline of medium and low pressure cylinder, and butterfly valve is installed on the connecting pipeline to realize heat extraction and steam extraction. Generally, the turbine enters the LP cylinder through the connecting pipe at rated load. After heating and extracting steam in winter, the amount of steam entering the low pressure cylinder decreases. Although the circulating water pump has been turned to low speed, the circulating water temperature is still kept at a low level. According to statistics, when heating in winter every year, due to its low water temperature, closed water heat exchanger usually needs less open water to maintain the closed water temperature. At 25 ~ 30 °C, in order to adjust the temperature of closed water users, it is usually necessary to close the inlet and outlet valves of the boiling water side of the water heat exchanger, which not only increases the throttling loss of the valves in the boiling water system. It will also cause serious mismatch between the flow and power of the open pump, resulting in a large amount of power waste[2].
4.2 Dry wet combined closed circulating cooling water system

The 40 ℃ circulating water discharged from each treatment unit is collected and transported to the circulating water station through the return water pipe. It is pressurized by the circulating water pump into the dry wet combined closed cooling tower and passes through the finned heat exchange tube bundle in the tower. After entering the cooling tower, the snake coil is further cooled to 30 degree C by evaporation of spray water, and then sent to various processing equipment for water circulation. The axial flow fan in the cooling tower can enhance the evaporation of water film and improve the heat exchange efficiency. After the water vapor passes through the high efficiency water collector, the droplets are recovered and the saturated wet air is discharged from the tower. In the process of descending, the water that has not evaporated is cooled by air inlet and enters the water collecting tank at the bottom of the tower. After being collected by the water collecting tank, it flows to the spray tank by gravity. After being pressurized by the spray pump, it will continue to spray on the coil surface as cooling water and recycle. When the ambient temperature reaches the design value, stop the external water spraying, and only rely on air cooling to realize the cooling of circulating water.

4.2.1 Zoning management. Considering the large number of cooling towers, in order to operate flexibly in the aspects of system water injection, operation temperature control and anti freezing ventilation, every four closed cooling towers are set as a group for partition management. Each area is a basic snap in. In each area, the entrance, outlet, bypass, circulating water and exhaust, exhaust and spray entrance water of the circulating water can be operated independently and can be controlled by automatic valves.

4.2.2 System water injection and drainage. Before the system is put into operation, the pipeline and cooling tower must be filled with water, and the system needs to be emptied when the equipment is shut down and overhauled. In order to meet the needs of water injection or emptying, a set of water injection and emptying system is set up in the project plan. The system is mainly composed of soft water storage tank, circulating water injection pump, bypass pipe, ventilation pipeline and filling system. Firstly, the soft water is injected into the system pipeline through the injection pump, then the system pipeline is filled, and then the main inlet and outlet valves of each partition unit are opened gradually, and the cooling tower is gradually filled until the whole system is in order. When the system needs to drain, you can open the vent valve towards the inlet and outlet of the diaphragm unit to drain the water from the diaphragm[3].

4.2.3 Spray water design. Due to the large scale of circulating water and the large number of cooling towers, if each cooling tower is equipped with spray pumps, the number of equipment will be more, which is not conducive to cost control and subsequent operation and maintenance. The water spray of cooling tower is changed to centralized water supply, which reduces the number of equipment and
facilitates the water quality detection and management of water spraying. The spray water system is mainly composed of spray water collection box, spray water pump, water supply pipe, dosing device, side filter device and so on. The spray water is collected from the collecting tray of the tower bottom, and the gravity flows into the water collecting tank of the spray. The free space of the cooling tower water collecting tray ensures that the jet water can be collected when the cooling tower is stopped or overhauled, so as to avoid waste. Spray water should be reused as much as possible, and side filter and water stabilizer adding system should be set up. The water spray pump is controlled by frequency conversion.

4.2.4 Steady pressure water supply and exhaust. In order to ensure the stable operation of the whole closed-circuit circulating water system, avoid the volume change caused by the temperature change of circulating water, or reduce the volume caused by the system operation and dripping, in the project plan, the fully automatic stabilized water supplement device (expansion tank) will be used to stabilize the working pressure of the closed system, and its liquid level signal will be used to supplement the leakage caused Water loss. The design of expansion water tank shall comply with the relevant provisions in code for design of industrial circulating cooling water treatment (GB 50050-2007). In addition, each cooling tower's replacement heat pipe bundle is equipped with an automatic exhaust valve at the highest position. The vent from each zone can share the root zone vent stack to ensure that the system can completely vent air during water injection[4].

4.2.5 Anti freezing measures. In winter, the temperature in the north is usually below 0 ℃. The antifreeze problem of cooling tower needs to be considered. The antifreeze agent for dry and wet combined closed cooling towers consists of two parts: one is the spray water system, the other is the internal circulating water system. Therefore, the cooling tower is required to stop the external water spraying when the ambient temperature is lower than 0 ℃, so only the problem of freezing and cracking of heat exchange tube caused by internal circulating water needs to be solved. The specific measures are as follows:

- The cooling water outlet temperature is controlled by starting and stopping fans in the area;
- When the temperature is low in winter, part of the heat exchange tube bundle is enclosed in the partition unit to transfer heat to the rest of the tube bundle and increase the flow rate in the tube;
- Adjust the opening angle of the cooling tower louver to control the amount of dry and cold air, so as to control the temperature of cooling water outlet;
- The system has a special emergency drainage procedure. In case of winter accident, all zones will be drained simultaneously through emergency drainage procedure. The temperature control is set to manual control mode and automatic control mode. When the system is in automatic control mode, all operations can be realized by preset program.

5. Conclusion
In the traditional process, the circulating water mainly depends on the evaporation in the open cooling tower to remove heat and reduce the temperature. Evaporation loss accounts for most of the water consumption of the circulating cooling water system. The closed exchanger is placed in the tower to ensure the cooling effect through the heat exchange of circulating air, spray water and circulating water. When the outdoor temperature is low, spray water to the outside of the pipe can be stopped, and the ambient air is used as the cooling medium to let the cold air sweep through the heat exchange pipe through the mechanical vent, so that the internal high-temperature circulating water can pass through. This effect, especially for the finned tube, greatly improves the heat transfer coefficient of the air side outside the tube, enhances the air cooling effect, reduces evaporation, and has more obvious water saving effect. Because the closed system relies on air cooling instead of partial evaporative cooling to achieve the purpose of water saving. Under the condition of total heat treatment, the higher the air cooling distribution ratio is, the more water saving the system is, but the higher the equipment cost is. Only by increasing the relative humidity of air at the highest temperature in summer, the utilization rate of humidified air coolers produced by GEA, Shuangliang and other companies can reach more than 90%.
To sum up, it is suggested that the dry wet combined cooling system should be used for auxiliary cooling, which is also in line with the basic policy of national energy conservation and emission reduction.

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