Optimization Study on Direct-expansion Evaporative Condensation Air-conditioning System

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Abstract. This paper introduces the working principle and characteristics of the direct-expansion evaporative condensation air-conditioning system, and analyzes the main factors affecting the cooling efficiency of a building's direct-expansion evaporative condensation air-conditioning system. Based on the conclusion, this paper optimizes the operation strategy and reduces the system energy consumption and provide reference for the design, control and operation of this system in the future.

1. Introduction
Direct-expansion evaporative condensation air-conditioning system has the advantages of energy saving, water saving, land saving, compact structure and low pollution. It is used in special requirements such as high-quality buildings and subway stations, and has achieved good results[1][2][3]. Due to the lack of corresponding management experience, in the actual operation management, the joint operation strategy between the various devices in the air-conditioning system is still lacking, and there is a large potential for energy saving.

This paper analyzes several important factors affecting the efficiency of the refrigeration system by simulating the direct-expansion evaporative condensation air-conditioning system in a building, and optimizes the operation strategy to provide reference for the design, control and operation of the system in the future.

2. Working principle and characteristics
The direct-expansion evaporative condensation air-conditioning system is based on the evaporative condensation technique to change the cooling mode and structure of the air-cooled condenser. The evaporative condenser is mainly based on latent heat exchange and sensible heat exchange, and uses the suction of water to remove the heat of condensation of the air conditioning system. The operating principle is as follows: the water is used to pump the cooling water from the nozzle above the condensation side refrigerant tube group, and the nozzle sprays the cooling water evenly on the refrigerant tube to form a water film. The refrigerant gas in the refrigerant pipe on the condensing side absorbs heat into a liquid state, and some water evaporates after the cooling water absorbs heat, and the rest flows into the water collecting tray for recycling[4]. Its structure is shown in Figure 1.
The evaporative condenser is a high-efficiency condensing device that combines a condenser and a cooling tower. The evaporative condenser can combine the cooling process of the cooling water and condensation process of the condensing agent, omitting the transfer phase of the cooling water from the condenser to the cooling tower. It also has the advantages of energy saving, water saving and compact structure[5].

3. Influencing factors of refrigeration coefficient

In this paper, the analysis is based on a test of the evaporative condensation air-conditioning system at a subway station. The influencing factors of the system are divided into two parts: the evaporator side impact factor and the evaporation condenser influence factor. The determinants on the evaporator side mainly include the air volume and the inlet wet bulb temperature. In view of the small changes in the intake parameters of the main operation of the refrigeration system, the influence of the air volume on the energy efficiency of the system is mainly considered. Factors affecting the sides of the evaporative condenser are spray density, air volume and wet bulb temperature.

3.1. Influence of air volume on system performance

It can be seen from Figure 2 that the power consumption of the compressor with increasing wind speed is gradually reduced, and the compressor energy consumption decreases greatly when the wind speed is lower than 2.4 m/s. When the wind speed exceeds 2.4 m/s, the compressor energy consumption decreases gradually.
It can be seen from Figure 3 that the corresponding system COP increases when the wind speed is increased from 0.4 m/s to 1.6 m/s under this condition, and the system COP gradually decreases as the wind speed continues to increase.

3.2. Spray density pair system performance influence
We set the other conditions unchanged and studied the by changing the cooling water spray density setting. Due to the small power of the system spray pump itself, the influence on the COP is small, it is recommended that the spray pump work under a fixed frequency.

3.3. Influence of Water-Gas ratio on the performance
The ratio of water to gas in direct-expansion evaporative condensation air-conditioning system is studied by changing the frequency setting of induced draft fan, seeing Figure 4 and Figure 5.

3.4. Influence of air wet bulb temperature on system performance
The increase of the temperature of the air wet bulb causes the temperature difference between the saturated water vapor layer on the surface of the evaporating condenser water film and the air to gradually decrease the latent heat transfer power, so that the condensing temperature increases and the system energy efficiency decreases. Therefore, the outdoor wet bulb temperature is also an important input parameter in the optimization program.

4. Operation strategy of refrigeration system
According to the previous study on the coefficient of refrigeration coefficient of the direct-expansion evaporative condensation air-conditioning system, by calculating the total energy consumption of the entire refrigeration system, the operation strategy is shown in Figure 6.
Figure 6. Flow diagram of automatic control of optimization system.

When the system starts running, the induced draft fan, system fan and compressor are illuminated in sequence. The fan operates at the initial frequency and the compressor is set according to the internal return air temperature: when the temperature is higher than 26 °C, the compressor is charged, and the temperature is lower than 24 °C, the compressor is unloaded. When the temperature of the water collecting tray is detected to be too high, the frequency of the induced draft fan increases, and when the temperature of the water collecting tray is too low, the frequency of the induced draft fan decreases. After implementing this strategy, energy consumption is reduced from 6% to 20% compared to the original working conditions.

5. Summary
This paper taking a subway as instance, analyzes the evaporation side air volume, condensation side water-gas ratio, spray density and inlet wet bulb temperature on compressor energy consumption and system COP, and draws the following conclusions:

1) Although the increase of oncoming wind speed and spray density is beneficial to the increase of
compressor energy consumption, the power consumption of fans and pumps is also increasing, and the system COP is first increased and then decreased.

2) After applying the optimization of operated direct-expansion evaporative condensation air-conditioning system operation strategy, the energy consumption is reduced by 6%-20%, which provides reference for the design, control and operation of this system in the future.

Reference

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