Study on Operation Strategies of Cooling Tower in Ground Source Heat Pump System

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Abstract. The mingled system of ground source heat pump with cooling tower has its advantage in winter cold and summer hot region. Basing on the experiments of a ground source heat pump system assisted with cooling tower in Wuhan, the operation controlling strategies of mingled ground source heat pump system were studied in this paper. And the maximal temperature controlling method was adopted by comparing energy cost of the system and soil temperature changes in different cases. The results show that cooling tower could operate as the single cold source instead of buried tubes when the outlet water temperature in buried tube is lower than 32°C. It will help to increase the operation efficiency and decrease the energy cost of this ground source heat pump system. And it will also release heat accumulation problem of the soil surrounding buried tubes.

1. Introduction
In recent years, ground-coupled heat pump systems are considered as one of the cleanest and most effective heat extraction systems among renewable sources [1, 2]. There are many factors which influence the heat transfer of ground heat exchanger. In winter cold and summer hot region, such as Wuhan in China, the heat extracted from underground soil in winter is greater than that injected in summer. It will lead to underground heat accumulation and efficiency drop for long-term running of this ground source heat pump system. The underground thermal balance is an urgent problem for this system. Systems with cooling towers and buried ground tubes are used to support large ground-coupled heat pumps [3-6].

Basing on the experiments of a ground source heat pump system assisted with cooling tower in Wuhan, this study aimed to mingle ground source heat pump and cooling tower, and optimize this system by proposing intermittent operation strategies of cooling tower while underground soil heat is unbalance between summer and winter. It will increase the operation efficiency of this ground source heat pump system.

2. Intermittent Operation Strategies
The ground source heat pump and cooling tower mingled system has its predominance. The energy cost in this system will be decreased. The energy efficiency ratios (EER) of heat pump unit and whole heat pump system will be increased by the assisted heat ejection of cooling tower. But the key factors are the operation controlling strategies between buried tubes and cooling tower.
The operation controlling strategy of mingled ground source heat pump system is mainly on and off control of cooling tower in different operation conditions. Considering existed ground source heat pump system, the maximal temperature controlling method was adopted in this paper. In this method, cooling tower operation will replace ground heat exchanger when outlet water temperature in buried tubes reaches the set maximal temperature. And cooling tower becomes single cold source in this mingled system.

Different maximal temperatures of outlet water in buried tubes were set for cooling tower single operation. Then different experimental data, such as inlet and outlet water temperatures in buried tubes, were noted. The optimal operation strategy with cooling tower operation instead of ground heat exchanger will be concluded by analyzing these data and EER of this system.

3. Experimental Results and Discussion

In the experiment, testing points 1-60 (or 1-40) represent water temperatures in buried tubes and EER of heat pump unit and whole heat pump system while ground heat exchanger is cold source. And testing points 61-100 (or 41-70) represent water temperatures in buried tubes and EER of heat pump unit and whole heat pump system while cooling tower is the single cold source. The experimental results are showing as figure 1 to figure 6.

Case1, cooling tower operation instead of buried tubes when maximal outlet water temperature in ground heat exchanger is 26°C. While ground heat exchanger is the single cold source, the inlet and outlet water temperatures in buried tubes gradually increase and EER of the system gradually decrease as figure 1 and figure 2 showing. This is because the soil temperature increasing fast at the beginning. Then the temperature difference between buried tubes and surrounding soil drop abruptly. And it leads to the decrease of EER. When the outlet water temperature in buried tube reaches the set maximal temperature 26°C, cooling tower becomes the single cold source instead of buried tubes. Then the inlet and outlet water temperatures in cold source side increase shortly and gradually decrease. And EER of heat pump unit and whole heat pump system drop a little and become stable.

Case 2, cooling tower operation instead of buried tubes when maximal outlet water temperature in ground heat exchanger is 30°C. While ground heat exchanger is the single cold source, the inlet and outlet water temperatures in buried tubes gradually increase and EER of the system drop abruptly at the beginning and then gradually decrease as figure 3 and figure 4 showing. When the outlet water temperature in buried tube reaches the set maximal temperature 30°C, cooling tower becomes the single cold source instead of buried tubes. The inlet and outlet water temperatures in cold source side increase shortly and gradually decrease, and then become stable. The EER of heat pump unit and whole heat pump system increase a
lot and then gradually decrease. This is because the higher heat exchanging efficiency in cooling tower than that in buried heat exchanger surrounding with higher soil temperature at the beginning. But the efficiency of cooling tower will gradually drop down.

![Figure 3. Temperature changes with testing point.](image1)

![Figure 4. EER changes with testing point.](image2)

Case 3, cooling tower operation instead of buried tubes when maximal outlet water temperature in ground heat exchanger is 32°C.

![Figure 5. Temperature changes with testing point.](image3)

![Figure 6. EER changes with testing point.](image4)

While ground heat exchanger is the single cold source, the inlet and outlet water temperatures in buried tubes gradually increase and EER of the system drop abruptly at the beginning and then gradually decrease as figure 5 and figure 6 showing. When the outlet water temperature in buried tube reaches the set maximal temperature 32°C, cooling tower becomes the single cold source instead of buried tubes. The inlet and outlet water temperatures in cold source side increase shortly and then gradually increase. It is different from case 1 and case 2. The ever increasing inlet and outlet water temperatures in cold source side are a disadvantage to the operation of ground source heat pump system. And EER of heat pump unit and whole heat pump system also decrease gradually.

4. Conclusion

The ground source heat pump and cooling tower mingled system has advantage for buildings which have greater cold load in summer than heat load in winter. While cooling tower operates as an
assisting cold source in summer, its operating strategies are very important to the operation of the ground source heat pump system.

Basing on above analysis, we could conclude that cooling tower instead of buried tubes to assume cold load may some extent improve the operation of ground source heat pump system. When the outlet water temperature in buried tube is lower than 32°C, cooling tower could operate as the single cold source instead of buried tubes. After cooling tower is started, the outlet water temperatures in buried tubes gradually decrease. And the decreasing trend of EER of the system will be restrained a little. But while the outlet water temperature in buried tube exceeds 32°C, it will continuously increase if cooling tower operates as the single cold source instead of buried tubes. And EER of the system will also decrease gradually. Obviously, it has disadvantage to the operation of this system. Therefore, while the outlet water temperature in buried tube is higher than 32°C, cooling tower should be shut down. And some other assisting method to eject heat should be adopted.

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