Simulation and Analysis of Air-Soil Dual Source Heat Pump Energy Consumption in Cold Regions

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Abstract

INTRODUCTION: This paper mainly researches the practical engineering about Simulation of air-soil heat pump system in an office building of Shenyang, China. This system in the winter uses the air source as the main heat source and soil source as the auxiliary heat source for heating, in the summer only uses the soil source heat pump to refrigerate.

METHODS: This paper mainly applies DEST software and TRNSYS software to study engineering air simulated analysis of soil heat pump system and compare with a single heat source. Analyzing the energy consumption of the dual heat sources pump system and its results were compared with the single soil source heat pump system to draw a conclusion.

RESULTS: Analysis of energy consumption of dual-source heat pump system in summer and winter. And energy consumption analysis of single soil source heat pump system in summer and winter.

CONCLUSIONS: In terms of energy consumption, the annual energy consumption of dual heat source heat pump system is 25962.23 kWh. The annual energy consumption of single soil source heat pump system is 45573.78 kWh, saving about 43.03% of energy consumption. The superiority and development prospects of the dual heat source heat pump system is obvious and promising, in the operating cost and conservation area. This project was financially supported by the National science and technology support plan sub-topic (2011BAJ05B01-04).

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1. INTRODUCTION

From the current development status of single heat source, there are advantages and disadvantages on heat pump (Peng Jinmei, Luo Huilong, Cui national 2012). Because the form of single heat pump has some defects, the researchers set about comprehensive utilization of renewable energy, that is there are some problems, when the load of heat pump system deals with the single pump. (Li-bin Z, Huan-guo C, Ying P A N 2014) This study aimed at improvement of the soil source heat pump system, establish the air-soil dual heat source heat pump system and analyze the operating energy consumption, comparing with a single heat source heat pump to analyze its superiority, which can provide the scientific basis for the research and development of dual heat source heat pump system.

2. METHODS

This paper aims at the practical engineering of an office building in shenyang soil - air dual heat source heat pump system simulation research, the total area of land is 3965.62 m2.

The main research methods of this paper include:

(1). Using application of DEST-h (Designer’s Simulation Toolkits) software to establish the simulation model building, choose and set the typical operating conditions, analyze the whole year hourly load calculate results of an office building in Shenyang and create dynamic load file (Zhu D, Hong T, Yan D 2013).

(2). Simulating by the software of TRANSYS (The full name of program simulation system) of the energy consumption of each system, analyze the simulation results compare with the single heat source system.

(3). Analyzing the energy consumption of the dual heat sources pump system and its results were compared with the single soil source heat pump system to draw a conclusion.

3. RESULTS

3.1. The simulation results of DEST

Through running DesT modeling operation and practical calculation for the amount of actual load in one year, real annual cumulative heat quantity is 14611.89kW, the actual total cooling capacity is 11155.33kW, the difference between the actual amount of heating and cooling capacity of the actual is 3456.56kW, accounting for 31% of the actual cooling capacity (Lu Yajun, Ma Zui Liang, Zou Pinghua 2009).

3.2. Analysis of energy consumption of dual-source heat pump system

3.2.1 The principle of dual heat source heat pump system

The principle of Air-soil dual heat source heat pump system diagram as shown in figure 3.2.1. The system consists of solar PV panels 1, photovoltaic panels crosswind machine 2, dual heat source heat pump units 3, buried side circulating pump 4, buried pipe heat exchanger 5, buried side make-up water pressurization system 6, phase change heat storage water tank 7, user side circulating pump 8, the user side make-up water pressurization system 9. In order to connect with the user, the system uses the heat pump units and the heat storage water tank.

The photovoltaic panel side: The dual source heat pump unit 3 connects fan 2 and the hot air of solar photovoltaic panels 1 with air hose. And it constitutes a hot air circulating circuit. The temperature tester is put on the glass curtain wall and the top of facades intermediate cavity, when the cavity temperature reaches the specified temperature, it can control dual heat source heat pump system open or close the air source heat pump mode.

Buried pipe side: The dual heat source heat pump unit 3 connects buried side circulation pump 4 and ground heat exchanger 5 with water supply pipe of buried side. And it constitutes buried pipe side circulating circuit. At the same time, hydrating constant pressure system of buried side 6 connected return pipe in buried side. It can fill water...
and make pressure stable in circulation loop of buried side. In summer buried pipe used fluid circulation to heat the soil and cool the building; whereas in winter, it took heat from the soil. And it operates with air source heat pump to heat the building.

![System schematic of dual-source heat pump](image)

Dual-source heat pump system uses soil source heat pump mode to provide cold for the building in summer; in winter, the air source heat pump mode is dominant, if it does not meet the conditions, we will use the soil source heat pump system to provide heat for the building. And single soil source heat pump system is given priority to with heating, cannot meet the requirement of refrigeration in summer.

### 3.2.2 Simulation analysis of energy consumption of equipment in summer

Figure 3.2.2 shows the hourly variation diagram of energy consumption of dual heat source heat pump system in cold period of summer. The energy consumption of the system contains heat pump unit energy consumption and the water pump energy consumption. Pump energy consumption contains the power consumption of heat pump unit side, the buried tube side and pump users side.
The simulation results show the accumulated heat pump energy consumption is 3088.96 kWh, total energy consumption of the pump is 6020.44 kWh. The total energy consumption of the dual-source heat pump system is 9109.40 kWh after cooling period. The energy consumption curves a linear growth with heat pump units running stable.

3.2.3 Simulation analysis of energy consumption of equipment in winter

By simulating the dual heat source heat pump system operating in the November 1st to March 31st of the following year heating period, the cumulative heat pump energy consumption value is 5387.18 kWh, the cumulative pump energy consumption value is 8954.09 kWh, the cumulative fan energy consumption value is 2511.56 kWh. After the heating period, the device operation energy consumption value total of dual heat source heat pump system is 16852.83 kWh. Figure 3.2.3 shows the change of the equipment system hourly about heating energy consumption in winter.
3.2.4. Analysis and Simulation of annual monthly energy consumption of equipment

Through the simulation and collection of the data, the dual heat sources heat pump system monthly energy consumption data of the equipment in the year is shown in figure 3.2.4. The figure shows the pump power consumption reaches the peak in July, the power consumption is 2180 kWh of month, this is because in the summer cooling period, the system only operates soil source heat pump cooling, in the winter heating period it operates the double source heat pump coupling mode, the energy consumption of the fan partly replaces the energy consumption part of pump, so the pump consumption is the lowest during February heating period. The air source heat pump bear most of the load supply during the winter heating, the fan energy reaches a maximum value in January about 5910 kWh. Heat pump units run in dual mode in winter, in January reached the maximum value about 1810 kWh, the cooling season in July reaches peak valve about 1440 kWh. This paper calculates and simulates monthly energy consumption of equipment for the whole year, which results are shown in figure 3.2.4:

Figure 3.2.5 is annual cumulative energy consumption curve about the dual heat source heat pump system. The data shows that the cumulative energy consumption of circulating water pump is 14974.53kWh, accounted for the major part in the total energy consumption of equipment. The annual total energy consumption of heat pump units is 8476.14kWh, which is about 2~3 times more than the energy consumption of air source heat pump, accounted for the major part of the heat pump energy consumption. Fans cumulative energy consumption is 2511.56kWh.
3.3. Energy consumption analysis of single soil source heat pump system

3.3.1. Simulation analysis of energy consumption of equipment in summer

Figure 3.2.3 shows the change of the equipment system hourly about single equipment of ground source heat pump system. The energy consumption of the single soil source heat pump system contains the heat pump unit energy consumption, water pump energy consumption, compared with the heat pump system without energy consumption of the fan. The water pump energy consumption contains heat pump unit side, the buried tube side and users side pump power consumption. Simulation work condition and load are as the same as the users side. The cumulative heat pump energy consumption is 8659.38 kWh. Total energy consumption of the pump is 7753.83Wh. The combination is 16413.21kWh. Through the simulation work of the single soil source heat pump system running between June 1st and August 31st in cooling period.
3.3.2. Simulation analysis of energy consumption of equipment in winner

The cumulative heat pump energy consumption is 16196.32 kWh, total energy consumption of the pump is 12964.25kWh, the combination is 29160.57kWh By using the TRANSYS to simulate the result of the single soil source heat pump system operation by the end of between November 1st and March 31st after heating period. Figure 3.2.3 shows the change of the equipment system hourly about each equipment of the heat pump system in winter.

3.3.3. Analysis and Simulation of annual monthly energy consumption of equipment

The results of annual monthly energy consumption simulation are shown in figure 3.3.3:
The single soil source heat pump system only runs a ground source heat pump unit, ignore zero data of equipment and stop operation in the transition season. The figure 3.3.4 shows the annual peak value of ground source heat pump during the heating period in January, which monthly energy consumption totaled is $4.91 \times 10^3$ kWh. The lowest value of heat pump system appeared in the early June refrigeration, which is $1.59 \times 10^3$ kWh. The figure 3.4 shows that the total energy consumption of pump is $20718.08$ kWh, the annual accumulative total energy consumption of the heat pump units is $24855.70$ kWh. The combination is $45573.78$ kWh.
4. CONCLUSIONS And DISCUSSION

Table 4.1 The two systems equipment energy consumption comparison table

|                          | Energy consumption of the Heat pump (kWh) | Energy consumption of the pump(kWh) | Energy consumption of the fan(kWh) | Total energy consumption of each season(kWh) | Total annual energy consumption(kWh) |
|-------------------------|------------------------------------------|------------------------------------|----------------------------------|--------------------------------------------|-------------------------------------|
| Double heat source      |                                          |                                    |                                  |                                            |                                     |
| summer                  | 3088.96                                  | 6020.44                            | 0                                | 9109.4                                     | 25962.23                            |
| winter                  | 5387.18                                  | 8954.09                            | 2511.56                          | 16852.83                                   |                                     |
| Soil source             |                                          |                                    |                                  |                                            |                                     |
| summer                  | 8659.38                                  | 7753.83                            | 0                                | 16413.21                                   | 45573.78                            |
| winter                  | 16196.32                                 | 12964.25                           | 0                                | 29160.57                                   |                                     |

The two systems equipment energy consumption comparison is such as shown in table 4.1.

In terms of energy consumption, the annual energy consumption of dual heat source heat pump system is 25962.23 kWh. The annual energy consumption of single soil source heat pump system is 45573.78 kWh, saving about 43.03% of energy consumption. The superiority and development prospects of the dual heat source heat pump system is obvious and promising, in the operating cost and conservation area.

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