

Simulation and energy analysis of distributed electric heating system

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Abstract. Distributed electric heating system assistssolar heating systemby using air-source heat pump. Air-source heat pump as auxiliary heat sourcecan make up the defects of the conventional solar thermal system can provide a 24 - hour high - efficiency work. It has certain practical value and practical significance to reduce emissions and promote building energy efficiency. Using Polysun software the system is simulated and compared with ordinary electric boiler heating system. The simulation results show that upon energy request, 5844.5kW energy is saved and 3135kg carbon - dioxide emissions are reduced and5844.5 kWhfuel and energy consumption is decreased with distributed electric heating system. Theeffect of conserving energy and reducing emissions using distributed electric heating systemis very obvious.

1. Preface

A heavy use of fossil fuels has resulted in two main concerns: fundamentally over their sustainability and their environmental and health impacts. The emissions of harmful gasses and particulates, including CO₂, NO_x, SO_x, etc., which cause considerably serious problems for nature, human beings and the environment. Accordingly, using alternate sources of energy, especially if derived from nature itself, such as; solar, wind and geothermal will be more convenient and a rescue solution from fossil fuels era on the long term. So the use of renewable power increased tremendously for the last few years and expected to grow more in the future. It also asserts that the share of renewable in electricity production is steadily increased [1].

As a typical city in northern China, Tianjin has a relatively long heating period and a large heating load because of cold climate in winter. Heating energy consumption andcoal pollution in Tianjin are both high.The distributed electric heating system assistssolar heating systemby using air-source heat pump. Air-source heat pump as auxiliary heat sourcecan make up the defects of the conventional solar thermal system, so as to provide a 24 - hour high - efficiency work. It has certain practical value and practical significance to reduce emissions and promote building energy efficiency [2-4].

This paper, distributed electric heating system is combined two energy sources solar and air-sourceto develop multi-generation system which provide hot water for heating and the performance of the system is evaluated.



2. System introduction

Distributed electric heating system is made up of solar collector\ water tank\air-source heat pump\electric heater\circulating water pump \radiator and other equipment. Solar collector provides heat to system, and air-source heat pump is supplementary when the solar energy is insufficient provided. In extreme weather conditions, because of frosting in air-source heat pump, system is supplemented by electric heaters. The heat generated by the compressor of air-source heat pump heats the water in tank through the casing, and then the heated water in tank carried toradiateor by circulation pump. Using Polysun software the system is simulated. Distributed electric heating system is shown in figure 1. Design data of hot water quantity demanded is200liters per day. The construction is general multiple dwelling building, and building area is 74.9 square meters. Standard room temperature is 19 °C. 4 group of 1kW radiator is arranged in room. Vacuum tubular solar collector is adopted; a total areaof solar collector is 2.68 square meters. The power of air source heat pump is 10kW, volume of stainless steel heat storage water tank is 800L, and the electric heater is installed in the tank as a supplementary energy [5-6].

According todifferent weather conditions, three different kinds of operation mode are appeared in distributed electric heating system: solar collector is used singly, solar collector is in combination with air source heat pump, and air source heat pump is operated separately. When it is sunny and solar radiation amount is much, solar collector is used singly, and the heat from solar energy is able to supply our energy requirements. At this time air-source heat pump doesn't run. When solar radiationamount is less, because the heat from solar energy isn't able to supply our energy requirements, air-source heat pump is turned onas auxiliary energy andsolar collector is running at the same time. The substantive function of air-source heat pump is to replace electricity auxiliary heater element in solar collector.Solar collector used in combination with air source heat pumpis the major operation state all the year round. In consecutive rainy days, air source heat pump is operated separately which solar radiationamount is little. Based on the analysis above, solar energyis preferred using. Air-source heat pump is operated only when solar radiation amount isn't able to supply hot water requirements.With Distributed electric heating system, low-grade energy in the air ismade full exploitation, reliability and stability under different working conditions is achieved, and good economy is obtained [7-8].

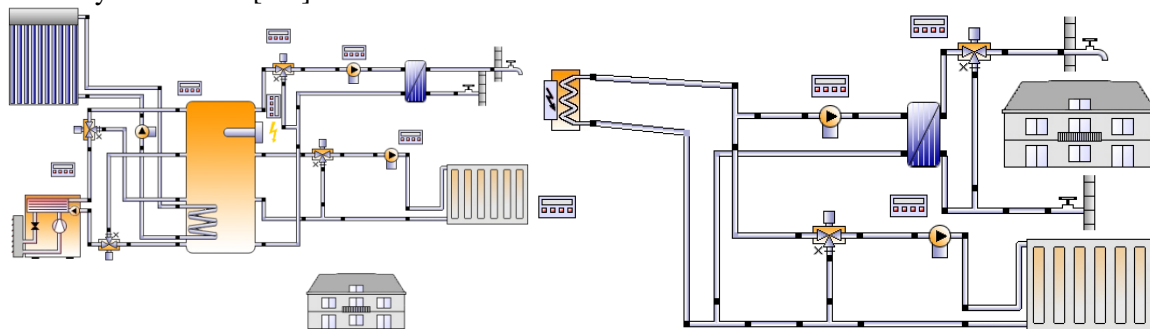


Figure 1.Distributed electric heating system.**Figure 2.** Reference system.

3. System simulation results

For comparison, a reference system is designed with the same designing conditions. The reference system is shown in figure 2. The room condition in reference system is the same as distributed electric heating system. A 12kW electric heating boiler is only used in reference system as heat source. Compare with reference system, the energy consumption and energy-saving of distributed electric heating system are researched.

The generalsimulation results of distributed electric heating system are showed in Table 1. As we know from the table,upon energy request, 5844.5kW energy is saved and 3135kg carbon - dioxide emissions are reduced and5844.4 kWhfuel and energy consumption is decreased with distributed

electric heating system. Compared to ordinary electric boiler heating system, the effect of conserving energy and reducing emissions using distributed electric heating system is very obvious.

Table 1. System overview (annual total).

Primary energy coefficient	0.43
Total energy consumption of heating [Eaux]	3,412.1 kWh
Consumption demand	Meet energy requirements
Energy saving compared with reference system	5,844.5 kWh
Carbon dioxide emission reduction (compared with reference values)	3,135 kg
Total amount of fuel and electricity consumed by distributed electric heating system	3,459.5 kWh
Total amount of fuel and electricity consumed by reference system	9,303.9 kWh

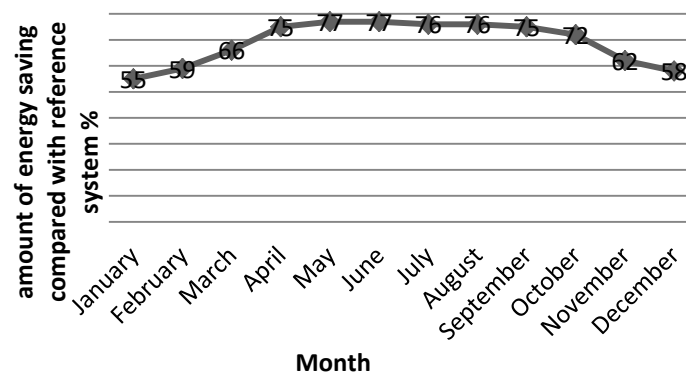


Figure 3. Amount of energy saving compared with reference system (%).

Amount of energy saving of distributed electric heating system by month is showed in Figure 3. The data shows that the effect of energy saving is obvious, the Annual average amount of energy saving is 69%. When solar radiation intensity is high in May and June, energy saving is up to 77%. When amount of solar radiation is small in January, energy saving also can reach 55%.

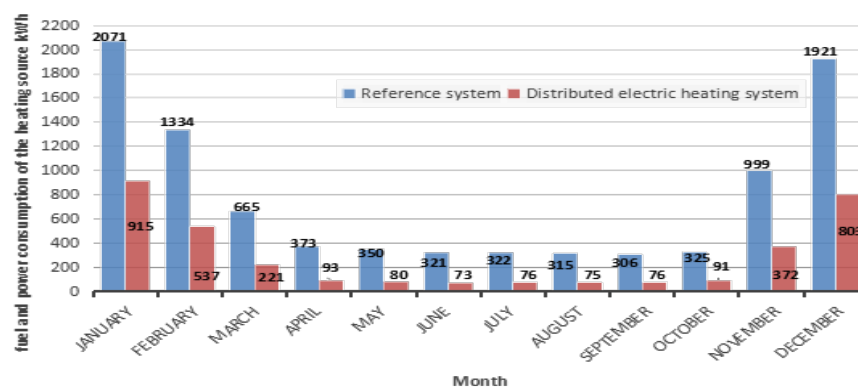


Figure 4. Fuel and power consumption of the heating source.

The fuel and power consumption of the heating source is showed in Figure 4. It can be seen that the energy consumption of distributed electric heating system is obviously smaller than reference system. 5890kWh is saved in annual energy consumption of the heating source. The energy consumption of the distributed electric heating source primarily comes from air-source heat pump. Compared to the use of electric heating in the reference system, the energy consumption of the heating source is the largest in January, which is 1156kWh. In December, the energy consumption of the heating source is the second, also reached 1118kWh. In heating season, the energy demand is large. Energy consumption is very high while simply relying on electric heating.

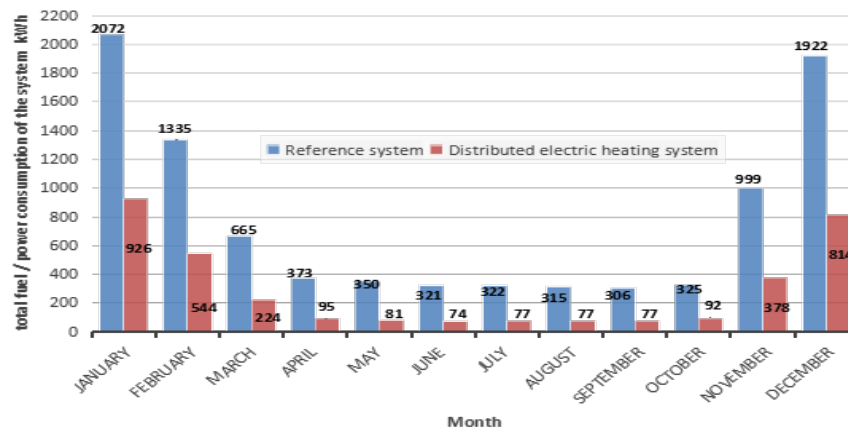


Figure 5. Total fuel/ power consumption of the system.

The total fuel or electricity consumption in the distributed electric heating system is showed in Figure 5. Amount of energy consumption is very high in heating season, which is 2072 kWh. Compared with figure 4, the energy consumption of heating is major contributors in the total energy consumption of the system while the energy consumption of the pump is small. In January, The maximum energy consumption of the pump is 11kWh; and the energy consumption of the pump is 8kWh in December. Because January and December are part of the heating season, Hot water demand is relatively large and the use frequency of the pump is higher in proportion.

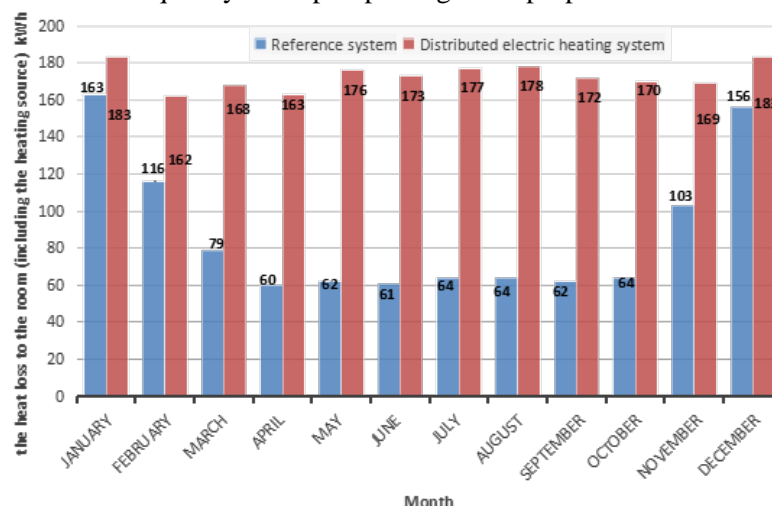


Figure 6. The heat loss to the room (including the heating source).

The heat loss to the room (including the heat loss of the heating source) is showed in Figure 6. According to dates and graph, the heat loss of distributed electric heating system is higher, which the highest heat loss is 183Wh in January and in December. It shows that the heat loss of the heat storage tank is very high. And heat loss in distributed electric heating system is higher than reference system in summer. This shows that temperature of heat storage tank is raised by the high intensity of solar radiation in summer. At the same time the demand for hot water slackens just because it isn't in heating season. Then there are inequalities between supply and demand of hot water. A large number of hot water is wasteful. Thus, How to utilize hot water in summer and reduce heat loss has become an important orientation in future.

4. Conclusion

In this paper, amount of energy saving, fuel and power consumption, total fuel/ power consumption and the heat loss to the room of distributed electric heating system is researched. And compared to ordinary electric boiler heating system, the effect of conserving energy and reducing emissions using distributed electric heating system is very obvious.

Distributed electric heating system is discussed. The system both realize its superiority on using air as a low-grade heat sources for heat pump adequately, and that poor of heat producing capacity of heat pump under low temperature environment is redeemed by solar collector. Distributed electric heating system can improve winter (heating) performance while is a energy saving and environmental protection system.

Acknowledgment

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