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Study on Performance of Solar Water Heating System using TRNSYS Software

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Based on the basic principles of thermodynamics and heat and mass transfer, this paper establishes the simulation model of solar hot water system to investigate its performance. The annual thermal performance of solar hot water system is simulated with TRNSYS software as simulation platform. At the same time, under typical weather conditions, the variation of water temperature in the storage tank, the temperature of the inlet and outlet of the collector, the total solar radiation and the change of the heat collection efficiency are analyzed. The establishment of the simulation model of solar hot water system is of guiding significance for setting operating parameters of components and improving the comprehensive performance of solar hot water system. The present study provides theoretical guidance for the operation of the solar hot water system,

1. Introduction

After the introduction of the 13th Five-Year Plan, Energy conservation and emission reduction has attracted wide attention, which makes solar thermal technology has long-term development. Among them, the solar hot water system is the most widely used and the most rapidly developed. At present, through the construction of experimental platform, the performance analysis of solar hot water system is limited by time and space and has a long period. Through constructing test bench, Xu (2014) carried out the annual running test for solar hot water system, air source heat pump hot water system and auxiliary solar air source heat pump hot water system and analysed the performance and economy of the system. But due to the limitation of time and condition, It is impossible to carry out the annual long-term monitoring and analysis of the system, which makes the data less accurate and comprehensive. From the perspective of energy saving, Yang (2007) analyzed all kinds of systems to realize hot water throughout the year. However, due to the complicated relationship between obstruction, placement of collectors, performance of different collectors and other influencing factors, Performance analysis has a certain degree of difficulty.

In recent years, most scholars have focused on the integration of solar hot water systems with high-rise buildings and the monitoring of solar hot water projects. The research of the solar building integrated hot water control system determines whether the promotion and application of solar hot water in urban buildings can be realized. Wang (2012) designed a solar hot water control method based on centralized heating and household thermal storage systems; From the architectural design point of view, the integration method associated with high-rise residential and centralized solar water heating system equipment, as well as the relationship with the later operation and management of the system, etc. Du (2010) proposed relevant design proposals to provide reference for architects to carry out integrated design and application of high-rise residential solar hot water systems; Wei (2012) also studied the collector as a design element to integrate the architectural appearance, structure and heat collection function, so as to combine the solar hot water system with the building; Taking Wuhan as an example, Zhou Xuan (2017) discussed the integrated design and research on solar energy and building interface, discussed the feasibility of using solar energy in high-rise residential buildings in Wuhan, and analyzed the existing problems in the use of solar energy in residential buildings in Wuhan.

At the same time as the development of solar hot water system engineering, there are still problems such as the lack of system operation data, backward measurement and monitoring technology, poor project management and control, and inconsistent performance evaluation indicators, therefore, as part of the solar hot water project, remote monitoring of the project site through wireless/wired methods is also crucial to achieve the

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goals of data collection, project management, and metrology analysis. Feng (2013) first introduced the operating principle of the solar hot water system, and determined the objects and contents to be monitored according to the actual project., then, combining the characteristics of B/S and C/S architectures, a three-tier network architecture for remote monitoring systems was designed; Zhu (2015) has developed a solar hot water remote monitoring system based on OPC communication technology that combines on-site monitoring and remote centralized monitoring capabilities; For the assessment of the operating status and benefits of solar hot water systems, statistical analysis based on relevant standards and real-time, accurate and comprehensive monitoring data is needed, to this end, Zheng (2014) developed a solar water heating system metering monitor to achieve energy metering and monitoring of solar hot water systems.
However, there are few theoretical studies on the performance of solar hot water systems. This article mainly establishes the simulation model of the solar hot water system, analyzes the changing trend of the system parameters under typical operating conditions and the system efficiency, solves the problems caused by the limitations of time and space, helps to optimize the solar hot water system, reduces energy waste and maximizes the benefits.

2. Establishment of simulation model of solar hot water system

Figure 1 is a component integrated image of solar hot water system, used in 7-storey residential buildings with their own hot water supply and bath equipment. The maximum daily water quota is 50 L / (per person per day), hot water temperature is 50 °C.

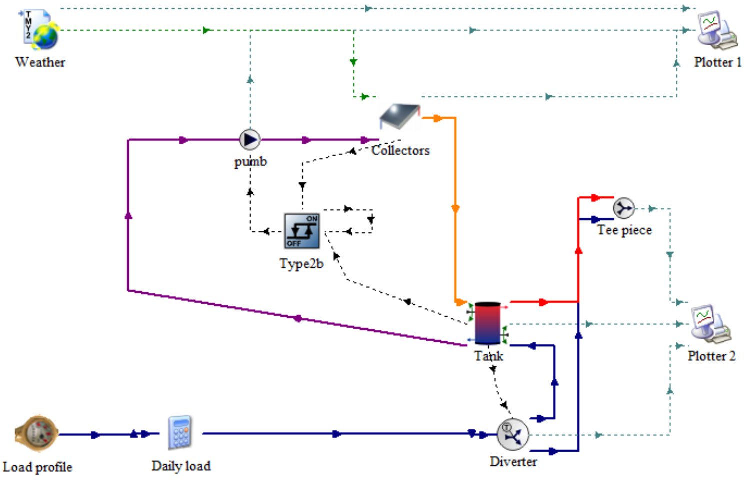

Figure 1: solar hot water system

2.1 The meteorological parameters of the simulation model

The data of Tianjin typical weather year is from the "China Building Thermal Environment Analysis Special Meteorological Data Set", Figures 2 and 3 is a typical meteorological parameter of Tianjin. The average annual temperature is 11.4 to 12.9 °C in Tianjin, the average urban temperature is 12.9 °C. The coldest month is January, the average temperature is -5 to -3 °C; the hottest month is July, the average temperature is 26 to 27 °C.

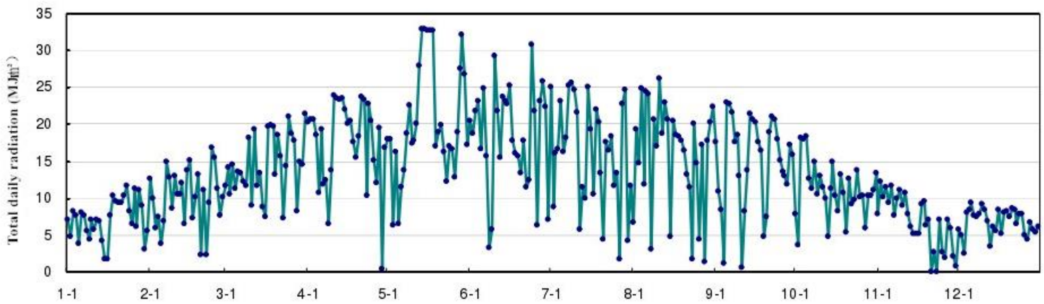

Figure 2: Annual changes in total solar radiation

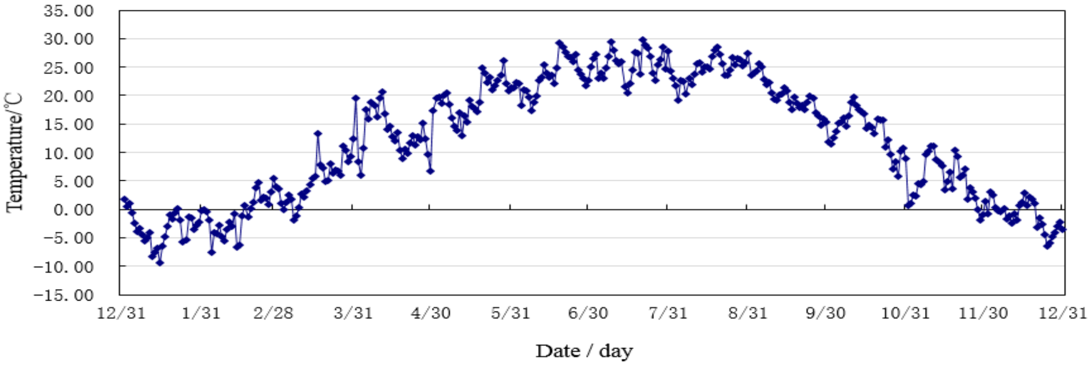

Figure 3: Annual average daily temperature

From the weather parameters, the coldest day is January 15, the hottest day is July 21. Simulate and analysis circumstances of the coldest days and the hottest days.

3. Simulation and analysis under typical operating conditions

For the coldest day in Tianjin on January 15, the hottest day on July 21 to study.

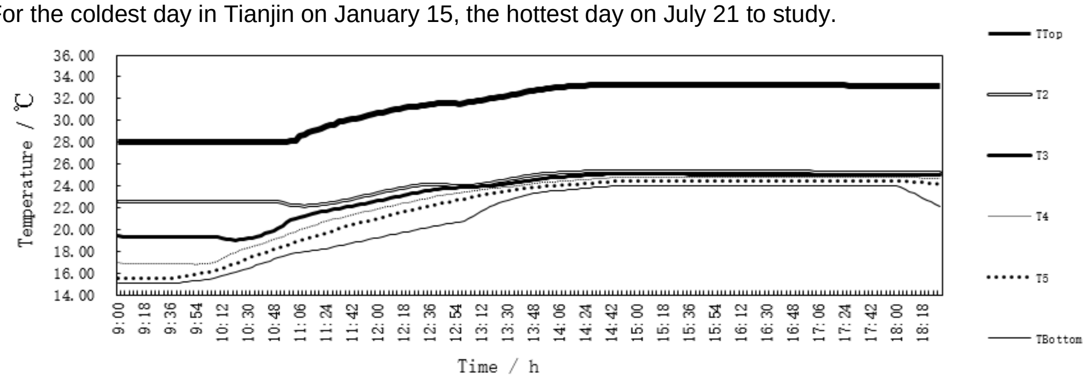

Figure 4: Temperature change in the tank (January 15th)

During the period from 9:30 to 2:00 pm, due to the temperature difference between the top of the tank and the bottom of the tank is greater than 10 °C, the pump starts to run, the water flows into the collector, absorbs the solar radiation energy, obtains the heat, causes the water temperature to rise. The water flowing into the tank is heat exchanged with the lower layer of low temperature water, so that the water temperature inside the tank rises. Due to the reduction of solar radiation, coupled with the difference between the temperature of the bottom and top within 10 °C, the water temperature remained essentially unchanged. At six o'clock in the afternoon, that fact makes the water tank temperature drop which is lower temperatures and existence of temperature difference inside and outside the water tank.

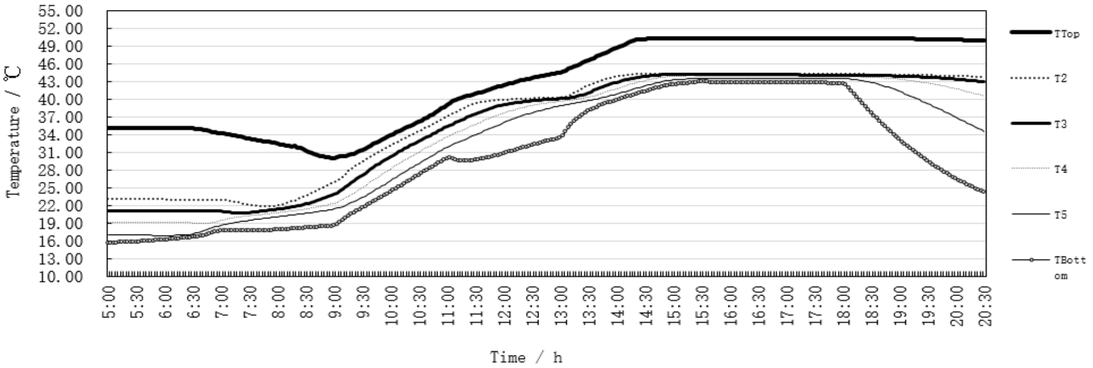

Figure 5: Temperature changes in the tank (July 21th)

As the temperature difference between the bottom and the top of the tank is greater than 10 °C, the pump begins to run, the water at the top of the tank is heat exchanged with the water in the lower part. The water temperature in the lower zone is different depending on the upper and lower positions, and the rate of temperature rise is different. The more slowly flows into the bottom of the tank, the slower the water temperature rises until the temperature difference between these is less than 10 °C. At about nine o'clock, the water temperature inside the tank are rising with the increase in the amount of solar radiation. At about 2 pm, the water temperature at the top of the tank reached 50 °C. At about 6 pm, due to the reduction of solar radiation combined with the decline in ambient temperature, there is a temperature difference between inside and outside the tank, making the water inside the tank begin to decline.

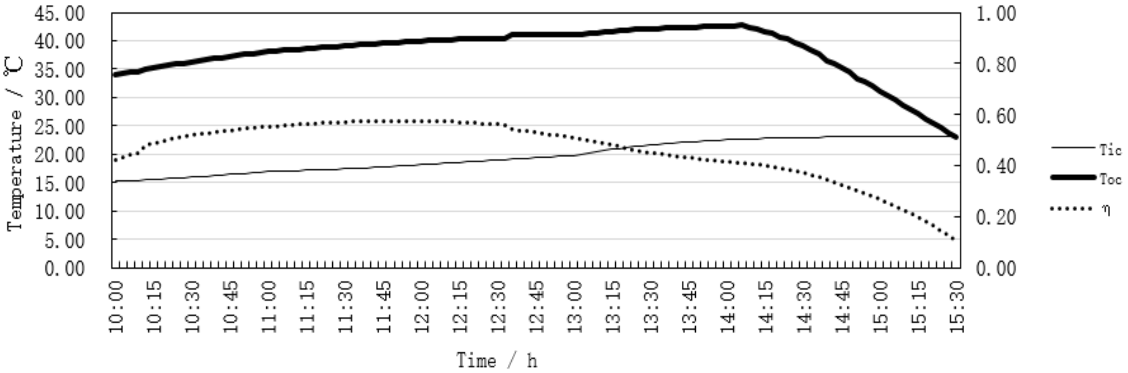

Figure 6: The changes between the temperature of collector inlet and outlet and the heat collection efficiency (January 15th)

The heating efficiency of the 15th is reduced to varying degrees throughout the day. The highest point of heat collection efficiency is at 12 o'clock and the value is around 0.6. The solar collector efficiency is above 0.5 from 10 am to 11 am. At 2 pm, the temperature and collector efficiency of the collector dropped sharply.

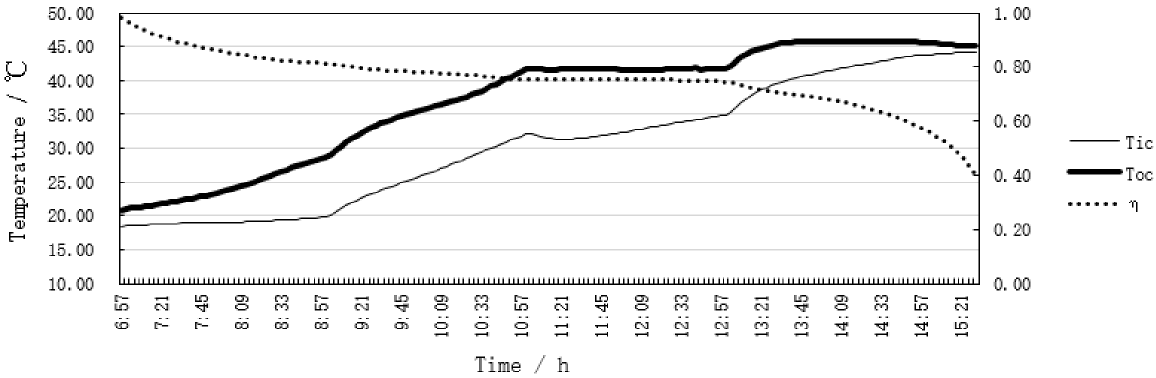

Figure 7: The changes between the temperature of collector inlet and outlet and the heat collection efficiency (July 21st)

The collector efficiency drops faster before eight o'clock. From 8 am to 1 pm, the collector efficiency gently declines, then it dropped sharply until 3:30 pm with the collector outlet temperature decreased. The reason for that is the decrease in the amount of solar radiation and the outlet temperature which the heat loss of the surrounding environment leads to. It indicates that the usefulness of the collector is reduced. So the trend of collector efficiency and collector outlet temperature is basically similar. Collection efficiency is greater than 0.5 before 2:30, which can be very good to meet the user's water needs.

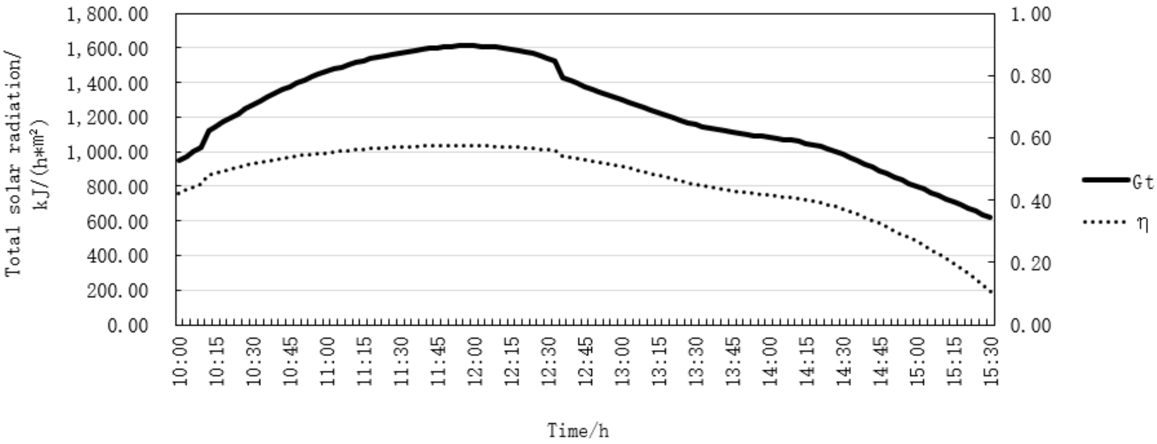

Figure 8: Change in total solar radiation and heat collection efficiency (January 15th)

The collector efficiency is related to the useful energy of the collector and the solar radiation energy that the collector intercepts. Collector efficiency and total solar radiation are reach the maximum at 12:00, the maximum collector efficiency is 0.6, then it reduces with the reduction of solar radiation. The rate of reduction is increasing at half past two. The reason for the decrease is that the reduction of solar radiation on the one hand, but the main aspect is that collector outlet temperature is higher than the ambient temperature, which makes water heat up around the surrounding, as a result, the reduce the range of water's temperature greater than the solar radiation's reduction.

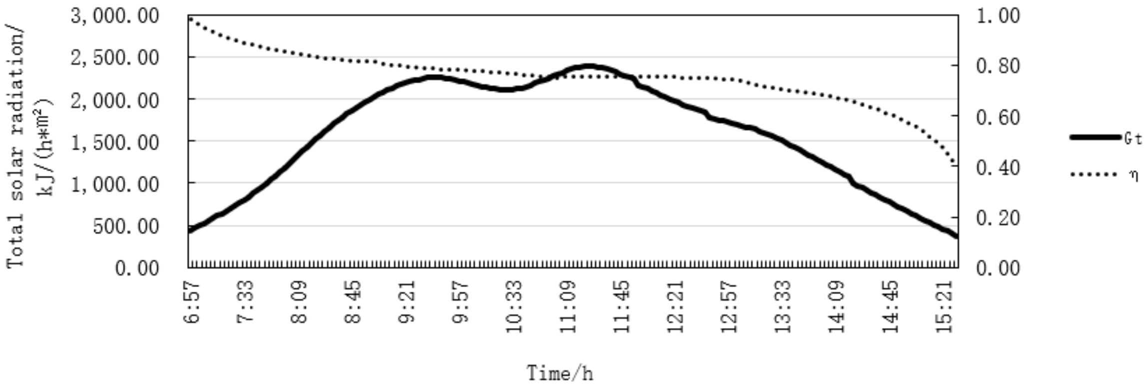

Figure 9: Change in total solar radiation and heat collection efficiency (July 21th)

The collector efficiency decreases with the decrease in solar radiation at 1 pm. The rate of increase is increasing at about 3 pm, because the temperature difference with the surrounding environment dominated. At about 4:30 pm, the rate of decline decreases, and the key effect is the reduction of solar radiation.

4. Conclusions

Based on the basic principles of thermodynamics and heat transfer and mass transfer, the dynamic mathematical model and simulation model of solar hot water system are established. After the simulation analysis of the solar hot water system, the following conclusions are drawn:

(1) The degree of heating of the collector to the water is directly related to the amount of solar radiation obtained.

(2) So the collector to absorb the amount of solar radiation, will affect the outlet temperature of collector. And when the system is forced to circulate, the water will circulate in the system, so, to a certain extent, the amount of solar radiation will also affect the inlet temperature of the collector.

(3) This paper only analyzes the changing trend of each physical quantity in the system. In order to choose the appropriate working condition, it is necessary to optimize the different factors that affect the efficiency of collecting heat, such as collector area, water pump flow and water tank volume.

Acknowledgments

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