PHASE CHANGE STORAGE SOLAR HEAT PUMP HYDRONICS BASED ON CLOUD COMPUTING

by

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In order to understand the solar heat pump heating system, a phase-change storage solar heat pump heating system based on cloud computing is proposed. This paper first introduces the solar heat pump as a phase change energy storage that can change four types of heat depending on the weather conditions and significantly reduce the energy consumption of the system. Second, through the special design of the energy storage capacitor, in addition adjusting the energy distribution of the solar heat pump system, it can also improve the reliability of supply and demand between the solar heat pump system and the building heating system, improve the level of solar energy consumption, but also improve the low temperature of the pump milk temperature, and improve the solar heat up quickly to achieve the goal of improving the overall performance of the heat pump. Finally, this paper takes an urban "electric coal" house as a research object to investigate the hot air efficiency of solar heat pumps. This paper analyzes the daytime solar heat pump mode, the nighttime energy storage mode under extreme conditions, and the air source heat pump mode. And shows the research results that the solar heat pump has good heating efficiency and the highest solar COP. Will be heat pump is 5.28 solar energy average heat pump COP is 2.13. In very bad weather, solar heat pumps work better.

Key words: *solar energy utilization, heat pump, hydronics*

Introduction

Cloud computing is a type of distribution that refers to the *cloud* of the network, where central computing data and processing services are broken down into small programs, and then multiple servers from available systems process and analyze these small programs to produce and return results. At the beginning of cloud computing, it only solves distributed computations and distributed tasks and aggregates the results, so cloud computing is called grid computing. Through this technology, dozens of data can be viewed in a short period of time (two or three minutes) to achieve powerful network services. At this stage, cloud services are not only distributed computing, but also distributed computing, energy consumption, load balancing, traction, network storage, hot backup and virtualization, and other computer technology changes and leaps. Solar heat pumps usually refer to heat pumps that use solar energy as the heating material for the evaporator, as opposed to solar photovoltaic or heat pumps that generate thermal energy. These usually come in two forms: solar heat pumps and solar thermal. Research on solar heat pumps in the country is lagging behind and mainly focuses on two directions: direct solar

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heat pumps and scaling up solar air source heat pumps. Solar energy is passive and low energy. Therefore, it is important to store energy for efficient use of solar energy. During the research, it was found that the hierarchical heat transfer storage has reliable power, low heat transfer characteristics and good reliability. Foreign countries have studied the effects of different levels of transfer agents, such as hydrated nitrates and phosphates. German researchers have pointed out that paraffin, hydrated salts and salt inclusions are the best phase transfer agents for energy storage below 100 °C. Research on the theory and application of phase shift energy storage in the country began in the 1980's. Major research in the field of phase change materials initially focused on hydrated inorganic salts such as sodium sulfate decahydrate, followed by paraffin and calcium chloride hexahydrate. Currently, solar heat pump heat storage technology has matured, and researchers have developed many systems, including integrated solar heat pump water heaters that use paraffin as a medium. A new type of integrated solar heat pump water heater that uses paraffin as an energy storage material for heat collection, energy conservation and evaporation. New types of solar energy storage/evaporation/collector, integrated solar heat pump for hot water*, etc.*

Solar heat pumps have three main functions: heating, storage heating, partial heating, heating, and direct heating:

– *Heat and heat storage models*. When the sun’s radiation is strong, the solar collector will absorb the solar energy and send it to the evaporator. As the temperature of the solar evaporator continues to rise, heat from the heat pipe is transferred to the energy storage. From now on, the phase shifter in the energy storage will harvest solar energy from the liquid phase shifter.
– *Semi-heating and heating modes*. When the solar energy is insufficient, the temperature near the evaporator will decrease and the phase change data in the energy storage tank will be increased by the latent heat released from the liquid phase change.
– *Heat and heat mode*. When the solar energy is not in use, a phase switch in the energy storage system captures the solar energy generated by the liquid phase and converts it into latent heat, providing heat to the pump.

Screen heat storage and phase transfer heat are two types of heat storage in solar heat pumps. Sensible heat stores more energy by increasing the temperature of the product. The advantage of this type is that it is simple and mature, but it has problems such as low equipment and high heat. In addition, the size of the heater and the inability to control the heat output limit its use. The principle of phase change heat is to store and release heat during phase change by absorbing heat and releasing the phase change material. Its advantages are high energy storage value, small volume change, temperature constant during endothermic and exothermic processes, and easy to control. So it has good applications. At present, there are two main problems in the research of phase switch equipment:

– Selection of different phase switch equipment according to physical, lifetime and reliability, which can affect heat storage capacity and thermal phase change rate. save.
– The main research of thermophysical problems is the design and control of heat, and the development of heat is the key to the development of energy saving [1, 2].

Literature review

With the increase in population and public housing, the use of heating is increasing every year. According to this study, China’s domestic electricity consumption accounts for 30% of the total energy consumption, and hot water production accounts for 20%. Hot research technology in recent years. Heat pump heating with solar photo-thermal technology, when it comes to electricity, we can separate our energy and make it efficient on a small scale. In addition, energy storage technology plays an important role in gathering insufficient solar and wind energy, Smaysim *et al*. [3]. The use of energy storage technology can solve the problem of thermal energy consumption, the demand is insufficient. He *et al*. [4] use the paraffin phase to store energy, transfer heat to salt water heat, and increase heating time and efficiency.

The author of the solar heat pump based on phase change energy storage uses solar energy as the heating material, high phase change latent heat value, stable phase change point characteristics, and specially designed energy storage capacitor for energy storage. Storing energy during the day, using *free* heat at night, reducing energy consumption and improving the use of solar energy. It not only compensates for the shortcomings of solar heat pumps, improves their efficiency, reduces fossil fuel consumption, saves energy and protects the environment, but also increases the use of solar energy and air [5, 6].

Methods

System principle and control

The schematic diagram of the solar pump based on phase shift energy storage is shown in fig. 1. As shown in fig. 1, the solar pump usually has a solar collector evaporator, compressor, air fin heater, energy storage capacitor, electric expansion valve, water pump, and heating terminal. The solar pump uses the phase change of the inorganic phase to transfer heat to achieve heat release and storage. When the Sun is good, the cooling liquid absorbs heat in the solar collector evaporator or air fin heat exchanger to heat and cool the oil. The refrigerant undergoes adiabatic compression by the compressor and superheats at low temperature. The oil cooler stores energy by releasing heat from the condenser and liquid. Part of the sweat is used for internal heat, while the other part is stored in the transition period of energy storage. The cold water is used by electric expansion, then heated by solar water evaporators or fan fins, recycled, and the cycle repeats. At night, the energy storage capacitors continue to release heat to warm the interior. In rainy and snowy weather, the solar pump helps heat. When the data is lost, the power storage capacitor works to stabilize, quickly defrost, and stabilize the temperature of the electronic equipment without heating.

The role of the energy storage capacitor during the whole process, on the one hand, the energy storage capacitor plays the role of controlling the energy distribution of the solar pump and solving the problem difference between the solar energy consumption and the actual demand. Converting excess electricity into heating at night and reducing electricity use at night. On the other hand, the energy storage capacitor, when working properly, can store excess heat from the solar pump and act as a carrier to control the distribution of electricity. It acts as a low temperature sensor for the defrost pump and solves the problems of slow defrost, unstable operation of the solar pump, and efficient and stable operation of the solar bright pump [7].

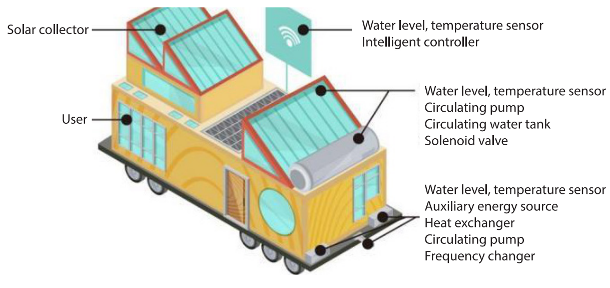

Figure 1. Schematic diagram of a solar heat pump system with phase change energy storage

Experimental platform

The writer uses a *coal for electricity* building in a city with an area of 80 m^2 and a floor height of 2.9 m as research material. In winter, the temperature in the house for heating is 18 °C, and the sun from 8:30 a. m. to 16:30 p. m. The end of the heat is radiant floor heating. After calculating the hourly load, the total heat load from 8:30 a. m. to 16:30 p. m. is 130.33 MJ. The total heat from 0.30 a. m. to 8:30 a. m. tomorrow is 340.66 MJ. In this experiment, the solar pump power measurement equipment includes WHP19460DCC rotor compressor, 24 flat plate solar evaporators, finned tube heat exchanger with 9.30 m^2 air space, electric expansion valve, and energy storage capacitor. Among them, the energy storage capacitor has a latent heat of 252.8 kJ/kg, a density of 1950 kg, and there is a 48 °C inorganic phase change energy storage product $Ca(NO_3)_2$ made by a certain company. The solar pump test equipment includes TBQ-2L solar irradiator, MIK5000A paperless recorder, JK-16U multi-channel monitor, Tianyi LWY-25C turbine flow meter, DSSD331 three-phase three-wire power meter, HC2- S temperature and humidity sensor. The accuracy of the temperature and humidity is +0.9% RH/0.2 °C.

Experiment and result analysis

To analyze the efficiency of the solar pump, the author analyzed the type of solar pump, the type of night energy storage, and the type of cloud milk electric pump.

Experimental data processing

The formula for the heating capacity, Q_{PCM}, of the phase change energy storage in the energy storage capacitor is:

$$Q_{\mathrm{PCM}} = km_{\mathrm{PCM}}\left[\left(T_t - T_{m2}c_s + \frac{\lambda}{\rho}\right) + (T_{m1} - T_t)C_L\right] \tag{1}$$

The calculation formula for the energy efficiency ratio COP of a solar heat pump system:

$$COP = \frac{Q_s}{W_s} \tag{2}$$

The calculation formula for the volumek, V, of the heat storage tank:

$$V = \frac{Q}{Cp(t_1 - t_0)} \tag{3}$$

The calculation formula for the mass, Q_m, of consumed standard coal:

$$Q_m = \frac{Q_j}{q_m \eta_m} \tag{4}$$

where Q_j [MJ] is the heating capacity of the solar heat pump, Q_m [MJkg^{-1}] – the calorific value of standard coal, taken as 30.3, and η_m – the thermal efficiency of coal-fired boilers, take 66% [8].

Experimental results

Solar heat pump mode. Figure 2 shows the difference between COP and solar pump temperature. It can be seen from fig. 2 that the change in ESD of the solar pump is the main factor in changing the power of the solar fire during the daytime operation of the solar pump mother's milk 4.6~5.3. Between 12:30 p. m, and 13:30 p. m. the maximum COP of the solar pump is 5.28 and 24.9 compared to the heater, so saving energy is very important. The room temperature increases from 15-22.6 °C, meeting the heating needs.

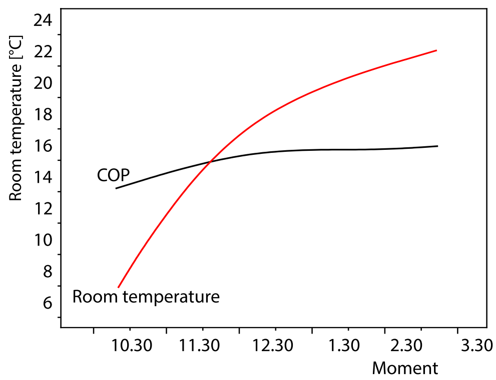

Figure 2. Changes in COP and indoor temperature over time in a solar heat pump system

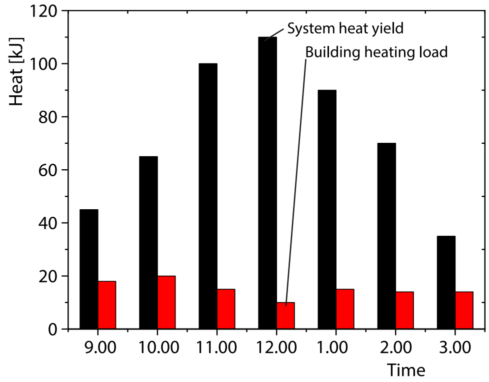

Figure 3. Changes in heat output of solar heat pumps over time during the day

The variation of solar heat pump heat over time during the day is shown in fig. 3.

The effective heating capacity of the solar heat pump (557.18 MJ) is lower than that of the milk heating of the solar heat pump (623.45 MJ) when the Sun is shining well during the day. The reasons for the energy imbalance are:

– The thermal efficiency of the energy storage capacitor is 0.92, and a part of the heat is discharged by the sunlight heat pump during the heat storage operation.
– During the heating process, heat is released from the water pipe of the solar heat pump.
– During the test, there was a measurement error. 31.5 of the effective heat of the solar heat pump is stored for internal heating and the remaining 69.6 is stored in the energy storage capacitor.

In summary, an energy storage capacitor collects excess solar energy when heating a house.

Energy storage mode. The difference between the temperature of the energy storage capacitor at night and the previous temperature is shown in fig. 4.

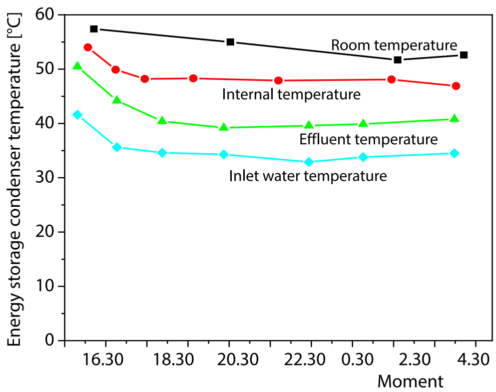

Figure 4. At night, various temperature parameters of the energy storage condenser and indoor temperature vary with

Figure 4 shows the phase change of energy storage in the energy storage capacitor until 18:30 p. m. (48 °C temperature change), the temperature change is very stable until 6: Day after 30. The average outlet temperature of the energy storage capacitor is 43 °C, the average inlet temperature of the energy storage capacitor is 38.4 °C, the temperature of the power supply and return water is different, the capacitor is so 6 °C. The night output of the energy storage capacitor is 352.489 MJ, which is 92.3 of the daytime thermal capacity.

As shown in fig. 4, the indoor temperature is above 19 °C in the first stage of heating. The temperature inside the house first rises, then gradually decreases, and then gradually stabilizes. The average indoor temperature of the heating system is about 22 °C. The analysis shows that the heat released from the energy storage capacitor during heat release exceeds the heat demand of the room heater, which means that the heat released from the energy storage capacitor does not correspond to the total load of the heating unit. This not only makes the internal temperature too cold and creates waste heat, but also causes the heating time on the energy storage capacitor to increase. In response to this problem, the author installed a solar heat pump temperature sensor. When the temperature in the room reaches the set level, the water supply to the user is cut off. When the indoor temperature is below the set point, the water is returned to connect the solar pump heating time.

*Solar heat pump and energy storage defrosting mod*e. During continuous rain and snow, when the solar energy is not enough to operate the solar pump, the working mode of the solar pump will change to the breast type of heat pump. For the water droplet formation problem, the author proposes a new energy storage defrosting method based on the energy storage capacitor, which uses the energy storage capacitor as the defrost temperature. This type of air source heat pump does not use internal heat to stabilize, reduce defrosting time and stabilize the temperature of the house. Between 0:30 a. m. and 2:30 a. m., the outside temperature is low and the relative humidity is high, so the thermal efficiency of the heat pump is low. Figure 5 shows the difference between the thermal capacity of the solar heat pump and the indoor temperature.

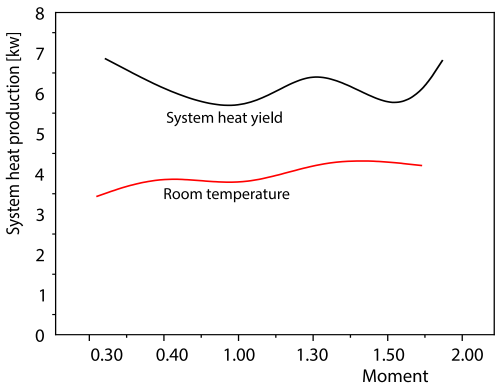

Figure 5. Changes in heating capacity and indoor temperature of a solar heat pump system over time

Figure 5 shows that the heating capacity of the solar heat pump fluctuates regularly, and the maximum natural heat of the system capacity is about 35, which is caused by the formation of droplets in the system. The temperature inside the room is around 18 °C and the temperature changes very little. This is because the energy-saving defrost mode enables fast defrosting and quick heating of the solar heat pump system. The average COP of solar heat pumps is 2.13. Performance results show that solar heat pumps perform better in extreme weather conditions.

Energy storage effect

An energy storage capacitor not only acts as a heat exchanger, but also stores excess energy. Figure 6 is a schematic diagram of an energy storage capacitor device.

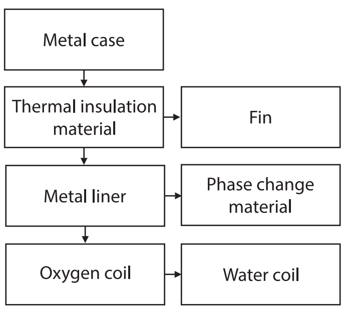

Figure 6. Schematic diagram of energy storage condenser device

As shown in fig. 6, the left side of the energy storage capacitor is connected to the fluorine coil, while the right side is connected to the water coil. Both are exchangeable, and the remainder is filled with the inorganic phase. In the same thermal storage, the volume of phase change energy storage is 0.696 m^3, and the weight of phase change energy storage is 1.35 tons. Compared to the heating box, the volume of phase change energy storage is reduced by 92.4 and the weight of phase change energy storage is reduced by 84.5. In summary, the phase change energy storage has good heating capacity, the temperature change of the liquid phase of the phase change energy storage is stable, easy to control and control, and reach the desired was hot [9, 10].

Conclusion

In order to achieve the advantages of solar energy, air source and phase change energy storage, the solar pump as phase change energy storage will reduce the environmental dependence of the solar pump. On a sunny day, the average power of the solar pump is 4.93. The average COP of the solar pump for rainy and snowy days is 2.13. The answer is that the general characteristics of the solar pump are better, it is better to combine the heat with the heat below, and it should be increased in the area north side. Energy storage capacitor can control energy. Solar heat pumps work well during the day, up to COP 5.18 for solar heat pumps. At night, through poorly designed capacitors, energy storage is done as *free* heat, further reducing energy consumption. In extreme weather conditions, the energy storage capacitor can act as a low temperature heat source for the heat pump, enabling rapid defrosting.

References

[1] Xue, D., *et al*., Prediction of Structural Mechanical Properties of Energy-Saving Materials for Solar Photovoltaic Photo-Thermal System Based on Deep Learning, *Thermal Science*, *27* (2023), 2A, pp. 1109-1116
[2] Ilgaz, R., Yumruta, R., Heating Performance of Swimming Pool Incorporated Solar Assisted Heat Pump and Underground Thermal Energy Storage Tank: A Case Study, *International Journal of Energy Research*, *46* (2022), 2, 1008
[3] Smaisim, G. F., *et al.*, Investigation and Optimization of Solar Collector and Geothermal Pump Hybrid System for Cogeneration of Heat and Power with Exergy-Economic Approach, *Clean Energy*, *41* (2023), 3, 3
[4] He, X., *et al.*, Effects of Particle Size and Concentration of Magnesium Oxide on The Lubricating Performance of a Chloride Molten Salt for Concentrating Solar Power, *ACS Sustainable Chemistry and Engineering*, *419* (2022), 14, 74
[5] Anarbaev, A., Koroly, M., Autonomous Hybrid Solar-Heat Pump for System Heat-Cooling in Buildings, *IOP Conference Series: Materials Science and Engineering*, *1030* (2021), 1, 012178
[6] Lu, J., *et al*., Solar Heat Pump Configurations for Water Heating System in China, *Applied Thermal Engineering*, *1* (2021), 8, 7
[7] Gu, X., *et al*., Experimental and Theoretical Assessment of a Solar Assisted Heat Pump System for in-Bin Grain Drying: A Comprehensive Case Study, *Renewable Energy*, *1* (2022), 8, 1
[8] Wang, Z., *et al*., Structural Optimization Design and Heat Transfer Characteristics of Multi-Degree-of-Freedom Spiral Plate Type Agricultural Machinery Equipment Heat Exchanger, *Thermal Science*, *23* (2019), 5A, pp. 2525-2533
[9] Kadir, B., Bedri, Y., Simulation Study of Solar-Source Heat Pump System with Sensible Energy Storage, *Journal of Thermal Analysis and Calorimetry*, *14* (2021), 4, 146
[10] Feng, X., Reliability Optimization Design of Intelligent Mechanical Structure for Waste Heat Recovery, *Thermal Science*, *27* (2023), 2A, pp. 1083-1090

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