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Research and Application of Remote Intelligent Monitoring System for Air Energy Heat Pump Hot Water Unit

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Abstract: Air energy heat pump hot water technology is one of the most promising new energy technologies. According to the principle of reverse circulation, a small amount of electric energy is used to drive and refrigerant is used as carrier to transport energy from low heat source air to hot water. Production of high-quality domestic hot water and heating hot water. This paper deeply studies the data communication mode and control technology of air energy heat pump hot water unit, and analyzes the influence of water temperature setting and defrosting control method on the heating performance of air energy heat pump hot water unit. The results show that the closer the water temperature setting is to the actual water temperature demand, the higher the heating performance of the unit, the better the energy saving effect, the more accurate the determination of the frosting condition of the evaporator, the smaller the thawing loss and the higher the energy efficiency.

1. Introduction

With the improvement of health care consciousness and living standard of residents in China, the proportion of hot water used in the field of household and commercial services has increased, and the demand for domestic sanitation water has increased, water heater has become an indispensable condition in life. With the aggravation of the world energy supply shortage and the sustainable development of China, the air energy water heater called the "fourth generation water heater" has begun to attract public attention.

The research and application of remote intelligent monitoring system for air energy heat pump hot water unit has attracted the interest of many experts and has been studied by many teams. For example, some teams found that at present, the development of technology and the improvement of manufacturing technology have greatly improved the product quality of the fresh air heat pump hot water unit and ensured the safety and reliability of the unit. Under the same electricity consumption, the heating effect of air heat pump hot water unit is 2-3 times that of electric water heater [1]. In recent years, high performance heat pump has been studied and popularized in Europe. Heat pump transfers heat energy to low temperature environment by consuming a small amount of electric energy, and releases the energy consumed and the heat transferred to high temperature environment through the operation of refrigeration system. Therefore, the heat pump system can consume part of the electric energy to "obtain" the multi-part heat energy, which can be used to make hot water or air conditioning for winter heating. The types of heat sources from the heat source are: ground source type, water source type, air source type [2, 3]. Heat pump is paid more and more attention because of the advantages of no pollution and renewable energy. The "heat pump water heater" shown in Gu's name is to use heat pump as a hot water device. Unlike electric water heater, it has the advantages of energy saving, environmental protection and safe use. It may cause leakage of electricity when used [4]. In the face of serious consumption of resources, shortage of domestic resources and serious pollution of traditional resources, the government is actively developing clean, efficient, safe and sustainable new energy sources, replacing traditional petrochemical resources, optimizing the energy consumption structure of our country, controlling the use of some highly polluted petrochemical products, and relying on scientific and technological progress to continuously improve energy efficiency [5]. At the same time, traditional energy enterprises are actively encouraged to use new technologies to improve the quality of petrochemical energy products, and small and medium-sized new energy enterprises are encouraged to actively seek and develop new energy sources. The government will increase investment in clean energy, such as hydropower, wind, solar, thermal, biological, tidal and nuclear energy [6]. The air source heat pump water heater uses the air as the heat source, absorbs the heat in the air through the refrigeration system, and finally heats the water with the obtained heat. The air source heat pump water heater consists of compressor, condenser, expansion valve and evaporator [7]. Based on the inverse carnot principle, the process of energy conversion is that the electric energy is converted into the mechanical energy of the compressor, and the mechanical energy of the compressor is converted into heat energy through the refrigeration system. The principle of the air source heat pump water heater is that the compressor compresses the refrigerant into a liquid at high temperature and high pressure, condenses through the condenser and becomes a liquid at low temperature and high pressure. Refrigerants at low temperature and high pressure flow into the evaporator to quickly absorb energy evaporation in the air and eventually enter the compressor again to complete a refrigeration cycle [8]. Although their research results are very rich, but there are still some shortcomings.

In this paper, a fuzzy control algorithm is proposed to realize the water temperature setting and thawing operation of the remote intelligent control unit, thus replacing the traditional manual control method. According to the laboratory view, the fuzzy control model is established, the water temperature is determined according to the change of outdoor ambient temperature and outdoor ambient temperature, and the frost degree of the unit is determined according to the outdoor ambient temperature and defrosting interval.

2. Method

2.1. Principle of Heat Pump Hot Water Heater

Pumps are everywhere in everyday life, people are no stranger to this, like ordinary pumps and air pumps, they all have one feature, that is, fluid media can be pumped to higher potential energy, essentially, it is a mechanical device that increases the position or pressure of the medium. Heat pumps consume only a small amount of electricity, can absorb a lot of free heat from low temperature heat sources in the environment, to water and heat the hot water, taking the typical working parameters of heat pump hot water device as an example, at 10 ℃ ambient air temperature, at 45 ℃, the heat pump consumes only one kilowatt, electric absorption 3.5 part low temperature thermal QL, the last generation 4.545 ℃ heat QH produce hot water. The flow chart of air energy heat pump hot water machine system is shown in Figure 1:

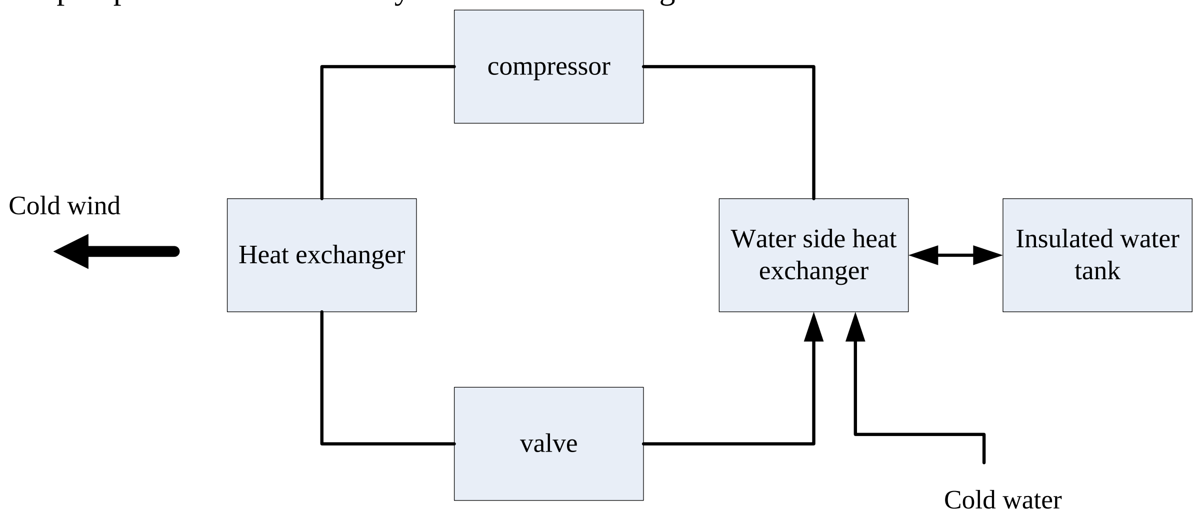

Figure 1: Operating principle of the heat pump and hot water machine

According to the principle of heat pump hot water device, with reference to the first law of thermodynamics, the three parameters satisfying the law of conservation of energy, heat QH(heat pump, heat and water for heat), QL(heat pump, heat absorption of low temperature heat source), Wc(electric energy consumed by heat pump are shown in formula (1)[9].

$$Q_H = Q_L + W_C \tag{1}$$

Heat pump hot water unit performance coefficient, also known as heat coefficient, is the heat efficiency or energy efficiency index of heat pump hot water unit. The calculation method is the ratio of heat energy obtained by hot water to electric energy consumed by compressor, usually expressed in COP. It is defined as:

$$COP = \frac{Q_H}{W_C} \tag{2}$$

Combination (2) provides:

$$COP = \frac{Q_H}{W_C} = \frac{Q_L + W_C}{W_C} = 1 + \frac{Q_L}{W_C} > 1 \tag{3}$$

According to formula (3), the COP value of heat pump is always greater than 1, so the thermal efficiency of heat pump hot water device must be greater than 100. actually, the COP value of heat pump is usually 3.0-8.0, that is, the thermal efficiency of heat pump hot water device is usually 300% to 800%, while the efficiency of gas water heater and electric water heater is generally less than 100, the conversion efficiency of solar water heater is 300. Therefore, using heat pump hot water device can save a lot of electric energy.

2.2. Basic Fuzzy Control Structure

The input of the system can be one or more. Because the input is clear, the input should be blurred into fuzzy quantity, fuzzy reasoning based on fuzzy rules, fuzzy control and accurate control of the controlled object. Fuzzy control is also required to be converted to clarity. This step is called inverse fuzzification and finally clarity. When converting input clarity to blur, it first needs to be discrete, and the actual range of changes in clarity is [x, y],then we first convert to variables using formula (4), so you can divide [-3, 3] continuous changes into seven levels, each of which corresponds to a fuzzy set, in fuzzy language, that is {nb, nm, ns,z,ps,pm,pb}.Therefore, any accurate quantity between [-3] can be expressed by fuzzy quantity, and the discrete accurate quantity is related to the fuzzy quantity expressed in fuzzy language [10-12].

$$b = 6[a-(x+y)/2]/(y-x) \quad (4)$$

The control variable obtained by fuzzy rules is fuzzy quantity, which can not directly control the control object. It is necessary to use anti-fuzzy method to transform fuzzy control quantity into clear quantity [13]. In order to give full play to the decision effect of fuzzy reasoning, the most widely used inverse fuzzy method is barycenter method. It is essentially weighted average method, its formula is (5).

$$Z_0 = \frac{\sum_{i=1}^{n} \mu C(Z_i) \cdot Z_i}{\sum_{i=1}^{n} \mu C(Z_i)} \quad (5)$$

2.3. Determination of Membership Functions and Fuzzy Rules

Since the possible frosting temperature range is small, the basic range E outdoor ambient temperature is [-8 ℃, 8 ℃], and the fuzzy domain is X={-2,-1,0,1,2}. The conversion formula is shown in (4). Fuzzy set is divided into 5 files, indicating outdoor ambient temperature, fuzzy language is low, low, moderate, high, high, called {NS,Z,NB,PS,PB}.The fuzzy set is divided into 5 files.

$$X = \frac{E}{4} \quad (6)$$

The thawing interval time T the basic domain is [0min, 30min], the fuzzy domain is Y={-3,-2,-1,0,1,2,3}, and the conversion formula is shown in formula (7). A fuzzy set is divided into seven files, indicating the length of the thawing time: very short, short, slightly medium, slightly longer, longer, very long, described {NM, NS, Z, PS, PM, PB}in fuzzy language.

$$Y = \frac{T-15}{5} \quad (7)$$

The basic domains of frost R are [0%, 100%], Z={-2,-1,0,1,2}, and the conversion formula is shown in (8). Fuzzy sets are divided into into five files, representing the frosting degree of the unit: micro frosting, mild frosting, moderate frosting, icing, severe frosting, describing the fuzzy language {NB, NS, Z, PS, PB}respectively.

$$Z = \frac{R-50}{25} \quad (8)$$

2.4. Development of Refrigerants

Currently, China market air heat pump hot water unit product export temperature about 55 ℃, winter due to low ambient temperature, heat pump water heater outlet temperature is low, low energy efficiency. Because the effluent temperature and energy efficiency of air heat pump hot water unit are greatly affected by the physical characteristics of working fluid, so in the development of air-energy heat pump water heaters, quality selection becomes extremely important. Improper job selection, heat pump water heaters are hard to get higher discharge temperatures, meanwhile, also low COP, therefore, selecting suitable refrigerants to improve energy efficiency of low temperature heat pump water heaters in winter, it has become one of the important research and development topics of heat pump water heater. Research on carbon dioxide heat pump water heaters, at 0 ℃ ambient temperature, when the water temperature rises from 9 ℃ to 60 ℃, the average total power of the carbon dioxide heat pump water heater prototype is 4.3. Notice, at the same time, carbon dioxide hot water pump water heater has good working performance at high temperature. H.Z.Abou - Ziyan by assessing meteorological data in Cairo, compared with conventional heat pumps, R134a thermodynamic performance is 22% higher than R404a, SAHP systems provide better features than traditional systems, SAHP system heats air from the collector, then flow to the evaporator, the method of passing the condenser is feasible [14-15]. R134a, through use the system increases the performance factor of the heat pump by 50%, save 21% of the collection area, and the prototype works at 90 ℃ of water, the flow characteristics and thermodynamic characteristics of R32,R22,R407C,R410A four refrigerants were compared with those of Rao Rong Water of Guangdong Meimei HVAC Equipment Co. Ltd. The conclusion is that, R32 is the best refrigerant for air energy heat pump hot water unit at present.

3. Experiment

3.1. Experimental Data Sources

This paper studies the theory and specific technology of the performance test system of air source heat pump water heater. On the basis of mastering the relevant knowledge of thermal performance test, the performance test system of air source heat pump water heater is studied according to the industry test standard and national standard.

3.2. Experimental Design

According to the above theory, the scheme of fuzzy PID control system for water temperature is put forward, and the traditional wired transmission signal is changed to radio frequency transmission.

4. Result

4.1. Effect of Water Temperature on Unit Heating Performance

Experiments show that, the higher the water temperature of the air heat pump hot water unit, that is, the greater the temperature difference between the hot and cold ends, heating performance of the unit is lower than COP value, the main reason is, the higher the temperature, the higher the condensation temperature, which reduces the heat, compressor energy consumption will increase, the lower the ambient temperature, and the greater the influence of water temperature on the COP value of the unit. As shown in Figure 2, the effect of water temperature on the heating performance of fresh air heat pump hot water unit is very obvious, and when the ambient temperature E fixed, as the temperature rises, a significant decrease in unit COP, the overall slope remains basically the same, close to linear variation. A set of data E25 ℃ ambient temperature, when the water temperature U increased from 12 ℃ to 48 ℃, from 6.5 to 2.4, a reduction of 63 per cent in unit COP, because the higher the temperature, and the more unit COP falls, therefore, the water temperature should be controlled as much as possible, that is, the water tank outlet temperature setting should not be too high, to ensure efficient operation of the unit, to save more electricity.

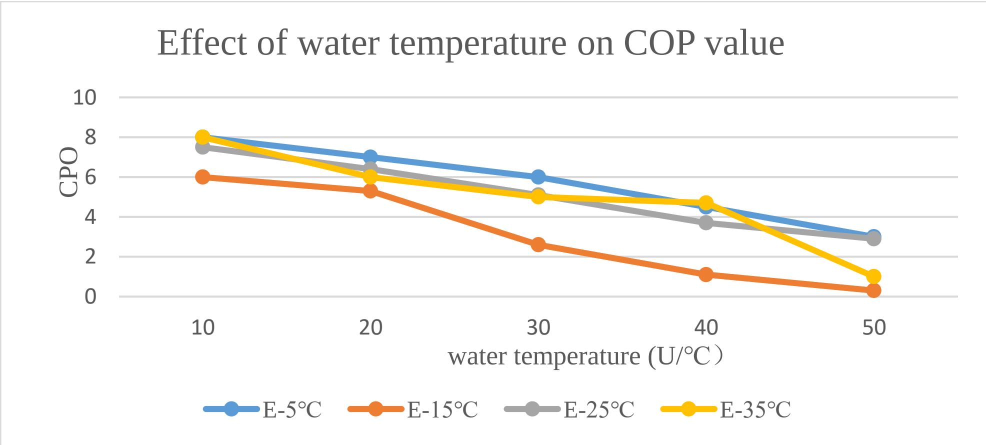

Figure 2: Effect of water temperature on COP value

Taking the air energy heat pump hot water unit as the object, there are usually two ways to make hot water: one is that the water temperature is only equal to the hot water temperature required by the user; the other is that the set water temperature is higher than the required hot water temperature. For air energy heat pump hot water unit, the heating performance of these two hot water production methods is obviously different.

4.2. Fuzzy Control Lab VIEW Implementation

After blurring the input variables, the output fuzzy variables are obtained by fuzzy reasoning according to the fuzzy rules. The output fuzzy variables need to be inversely fuzzified to obtain accurate output variables. Many inverse fuzzy algorithms are provided for fuzzy control designer. This paper uses the medium and small maximum gravity center method to carry on the fuzzy reasoning, the output fuzzy variable is anti-fuzzy, in the laboratory view background program interface, loads the set fuzzy control system, if the file imports the outdoor temperature measurement value E, calculates the average temperature change EC, carries on the fuzzy processing as shown in Table 1.

Table 1: Input and output variables simulation test

E(℃)	U(℃)	EC(℃)	-6	-3	0	3	6
5			51	50	49	46	43
15			51	49	46	43	41
25			50	47	44	42	41
35			47	44	42	41	41

4.3. Data Split Display

After checking, send data to the appropriate host or display controller, and on the front panel, first, it is necessary to determine which unit the frame data belongs to from the source address and destination address. Under the communications protocol, the source and destination addresses are the third and fourth bytes of the data frame, so intercept these two bytes, and converted to digital format. If the source address of destination address 0 is h, FFh indicates that frame data is sent and broadcast by the host; if the source address is h,01Addressh,00, the frame data is sent from 1; if the source address is FFh,0Addressh,00, the frame data is transmitted by the line controller on the data bus. According to the data controller → the program uses a stacked sequential structure, host → the order in which the data frame belongs determines the number of units, and split the data into unit display panel. The data message contains 28 bytes, each byte represents the unit's different parameter information, therefore, the operation and processing of each byte in the program are also different. Take the first byte of the data message, as shown in Table 2, this byte represents native mode, eight bits represent eight Boolean variables, the front panel corresponds to 8 status indicators, reservation 6, so the front panel does not show.

Table 2: Datagram format

Octet	Meaning		Data content	
1	Native mode of operation	Bit7	1: Manual operation	0: voluntarily
		Bit6	Obligate	
		Bit5	1:Anti-freezing knot	0: no
		Bit4	1: Defrosting operation	0: no
		Bit3	1: Shut down	0: no
		Bit2	1: Pump mode	0: no
		Bit1	1: Heating mode	0: no
		Bit0	1: Refrigeration mode	0: no

After segmenting each byte in the data message through the above procedure, it is sent to the front panel module to which it belongs, such as local operation mode, port output state, fault state, protection state diagram, etc. Finally, all the contents together constitute the host display panel. The display panel of each slave and line controller in the lab view is also composed of ways.

4.4. Analysis of the Effects of Ambient and Backwater Temperatures on Power Consumption

In order to clearly analyze the heating performance of air energy heat pump hot water unit under working conditions, we understand it more intuitively and facilitate the evaluation of its performance. We use a series of experiments to represent the change of total power consumption. When the air energy heat pump hot water unit operates at different ambient temperatures, its energy consumption may be affected by Figure 3. It is not difficult to find that the power consumption curve of heat pump unit will move upward with the increase of ambient temperature. In other words, the influence factor of ambient temperature on the backwater power consumption of heat pump unit will increase with the increase of backwater temperature of heat pump unit. Specifically, when the backwater temperature reaches 50 ℃, the ambient temperature is 0 ℃, and the total power of the heat pump unit reaches 244.3 kW, at the same backwater temperature, when the ambient temperature rises to 35 ℃, the total power consumed by the heat pump unit decreases to 68. Therefore, the change of ambient temperature will make the consumption power of air heat pump hot water unit change obviously.

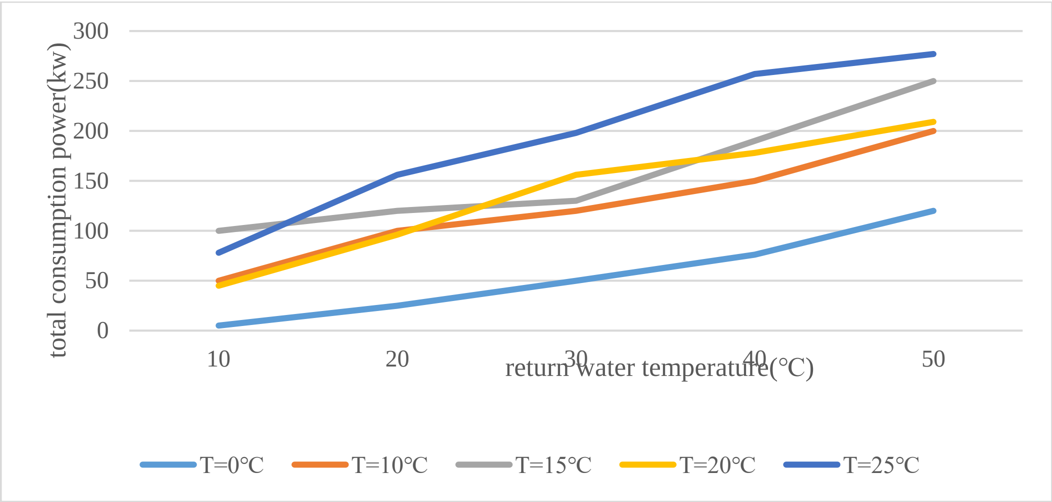

Figure 3: Change of total power consumption of unit after backwater temperature change at different ambient temperature

Similarly, the experimental results in Figure 3 show that the power consumed by the air energy heat pump hot water unit will also change, that is, when the backwater temperature increases, the power consumed will gradually increase, and when the ambient temperature is 0 ℃, the maximum power can be 244.3 kW.

5. Conclusion

The air energy heat pump hot water unit obtains the free energy from the air, subverts the traditional energy, heats the heat in a more energy-saving and environmental-friendly way, and has a broad application prospect and popularization value. At present, the air heat pump hot water unit is mainly used where the hot water demand is large, the number of units is usually 4 to 6, and the units and control cabinets are usually installed outdoors. Because the observation and control of unit parameters run on the control cabinet, it is very inconvenient for outdoor multi-unit. In view of this problem, a remote intelligent monitoring system for fresh air heat pump hot water unit is proposed. It is convenient for users to observe the operation parameters and load working state of the unit in remote computer. At present, the monitoring system of air heat pump hot water unit is combined with the industrial control configuration software to realize the function of computer remote monitoring, but this method is only suitable for the general monitoring operation of the unit. Based on the laboratory visual virtual instrument platform, the monitoring system of energy heat pump hot water unit is proposed in this paper. It can not only establish a man-machine friendly graphical monitoring interface, but also establish a fuzzy control model through the laboratory view. The water temperature setting and defrosting start and stop of remote intelligent control device are realized.

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