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Intelligent Optimization of Solar Air Heating System in Large Scale Construction of and its Application

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Abstract

The monomer thermal performance of solar air collector is the bottleneck problem of the design application of practical engineering. By combining the experimental and theoretical researches, this paper uses the heating load and thermal efficiency of the optimization module at different flow rates, and puts forward the efficiency normalization treatment method; analyzes the heat transfer intensity, heating capacity, thermal efficiency and indoor heating effect of the module under different operation modes; with the microprocessor as the core, sets up the intelligent control system of solar air heating with multiple sensor information fusion; adjust the running state of fan and heating units according to the changes of indoor and outdoor environment in real time. The practical application shows that the intelligent control system can ensure a comfortable indoor environment and improve the thermal efficiency of the system.

Keywords*: Solar energy; Building energy efficiency; Environmental protection; Controller; Heating*

1. Introduction

At present, most of the control part of solar energy water heater in China needs a lot of intermediate relay and time relay to meet the requirements of production process. As a result, the circuit design becomes complex and tedious, faults occur frequently, which bring lots of inconvenience to the use and daily maintenance. Solar water heater technology is the most widely used technology with the highest commercialization degree in solar heat utilization. But the automatic control system of most water heaters is controlled by single-chip microcomputer. The development cost of single-chip microcomputer is higher than that of PLC. PLC is featured with fast speed, high reliability, small size, full functions and simple programming. By improving or perfecting the deficiency of existing solar water heater control system, design and develop new solar water heater control system (the automatic control system of the solar water heater based on PLC).

2. Ask Questions

Large amount of hot water is required in industrial and agricultural production as well as daily life. The water consumption is large but the water temperature is not high, which is generally in the range of 40℃~60℃. For example, the shower water temperature is between 35℃ to 40℃, and it will be too hot when exceeding 60℃. The temperature of hot water for oil fouling removing in industry is relatively higher, which is usually at about 90℃. Solar water heater is currently the most common solar energy utilization device with the best effect, which has been applied all over the country for that it has simple structure, easy usage and does not need personnel management. Flat plate solar

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collector, a major part of the flat plate solar water heater, consists of transparent glass, heat absorber, insulating layer, etc. When placed in the sunlight, the black metal can absorb solar radiation and thus improve the temperature. Meanwhile, it will radiate heat value around. When the energy absorption equals the energy dissipation, the temperature of sheet metal will remain the same, which is called the "equilibrium temperature". If there is flow channel in sheet metal, the fluid will continuously take away heat. In order to achieve the equilibrium temperature, the sheet metal will constantly absorb the radiation energy of the sun.

3. System Design

3.1. Objective of System Design

According to use habits and humanization design of the water heater, the designed control system has the following functions:

(1) Automatic control function. In the automatic operation mode, the system can automatically control the operation and stopping of the water supply pump and the switches of solenoid valves. Timing controller can timing normally in outage, thus it is used as the power control of PLC. Within the timing control time, the timer connects the power of the PLC, and the PLC will turn on the power supply of various control equipment according to the pre-written program, and adjust the execution of the program at any time according to the changes of the input signal. In the nonworking time of the system, the timer will automatically disconnect the power of the PLC. The work period is 6 ~ 18 hours, which can be solved with the timing controller and the timer command of the PLC.

(2) Dust removal function. Use the temperature switch to test if the environment temperature is appropriate for dust removal, and the temperature switch is 4 ℃. Dust removal requires 2 continuous min with a solenoid valve.

(3) Liquid level control function of water tank. The volume of the water tank is 200 L, and the liquid level should be control at 180 L.

(4) The water tank should has the heating water supply and heat preservation functions.

(5) Alarm function. When fault occurs, the fault indicator light will flicker and the alarm bell will ring. The operators can press the sound damping button to stop the bell rings, but the fault indicator light will still flicker until the clearing of fault;

(6) Water saving function. Water supply valve will open for 5 min and stop for 2 min.

(7) Switchover of manual/automatic control.

3.2. Sensor Selection

Various high performance sensors will conduct the measurement and data collection on the climate environment, send the measurement results to PLC through the interface, and then the PLC will make integrated control to the whole solar water heater according to the control requirements. Because the sampling values of the system on environment are the analog signal output by the sensor, and the distance between the sensor and PLC is far, the 4-20 mA current output sensors are selected to reduce the interference in the transmission and ensure the accuracy and reliability of sampling values. Temperature error can be compensated with circuit or software, and different compensation methods are very different in the overall temperature coefficient which is related to the temperature characteristic of the element. Generally, the sensitive element and the temperature coefficient of circuit are taken into consideration. The base-point drift of common temperature sensors is obvious than other meteorological sensors. The thermistor belongs to adsorption element, which will inevitably be contaminated during the measurement. The base-point drift caused by contamination can only be corrected and solved by re-

examination. If pollution is serious, and the basis-point drift distance is too large and cannot be renewable, the sensor can only be scrapped.

Technical index of temperature sensor

(1) Temperature range: -0℃ ~ 70℃ (extendible on request)
(2) Humidity range: 10%/RH--99% RH
(3) Power supply: AV220V ± 10%
(4) Temperature error: ±0.2℃, maximum: ± 0.5℃
(5) Data resolution: 0.1
(6) Data update cycle: About 1 second
(7) Date cable: 3-type twisted-pair
(8) Data transmission distance: less than 1200m

3.3. Design of System Circuit

The design of main circuit:

(1) The contactor KM1 and contactor KM2 respectively control the forward and inversion of the motor.

(2) The motor is supplied with thermal relay to realize the overload protection.

(3) Selecting automatic switch Q as the main power switch can realize the short-circuit protection of main loop, and insulate the three-phase alternating-current supply, which is more convenient to use and maintain.

(4) FU1, FU2, FU3, FU4, FU5, and FU6 respectively realize the short-circuit protection of each load loop.

FU8 realizes the short-circuit protection of the PLC control loop.

Draw the main circuit diagram of electrical control according to the above design principle, which is shown in Figure 1.

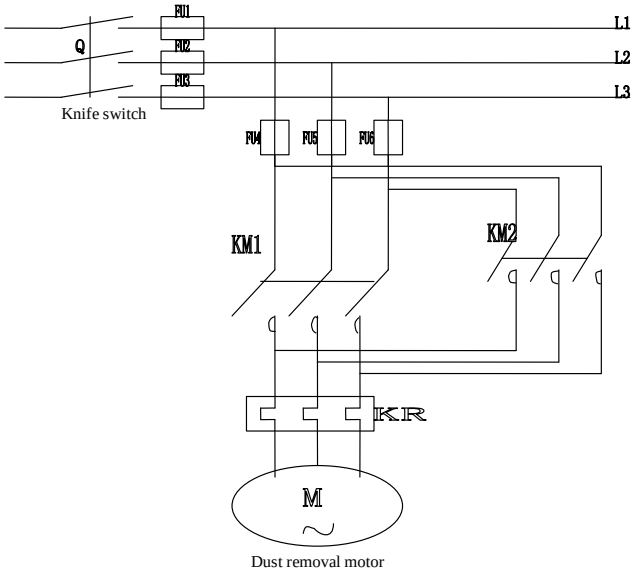

Figure 1. Main Circuit Diagram of Electrical Control

The design of PLC control circuit

According to the control requirements, overall design and the selected components of the system, design the control schematic diagram of the system and PLC external wiring diagram. The PLC I/O Control principle diagram of solar water heater system is shown in Figure 2.

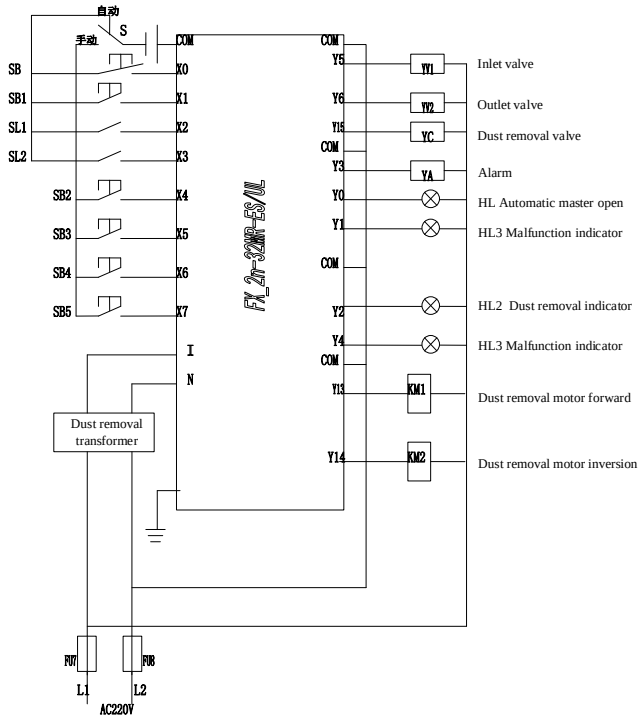

Figure 2. PLC I/O Control Principle Diagram of Solar Water Heater System

The water heater is mainly composed of collector, circulating pipe and water tank, etc. The diagram for the typical water heater device is shown below. In the follow figure, the Collector 1 is placed at the optimum slope; one end of down pipe 2 is connected to the bottom of the circulating water tank 3, and the other end is connected to the lower header of collector 1. Rising water pipe 5 is connected to the upper part of circulating water tank 3, and the other end is connected to the upper header of collector 1. The make-up water tank 4 supplies cold water for circulation water tank 3. After absorbing the solar radiation, the temperature within the collector will rise and the water temperature will also rise. Then, the specific gravity of water will reduce, and the water will flow into the upper part of the circulation water tank via the rising water pipe. Besides, because the specific gravity of the cold water at the bottom of the circulation water tank is larger, the cold water will flow into the lower part of the collector through the lower part of the water tank and rise after heated in the collector. By the constant convective circulation, water temperature will gradually rise until the heat absorption of the collector equals to the heat radiation, and then the water temperature will no longer rise. The water heater adopts the principle of cyclic heating, and thus is known as the circulating water heater.

The diagram of heater device

1. Collector
2. Down pipe
3. Circulating pipe
4. Make-up water tank
5. Rising pipe
6. Tap water pipe
7. Hot water outlet pipe

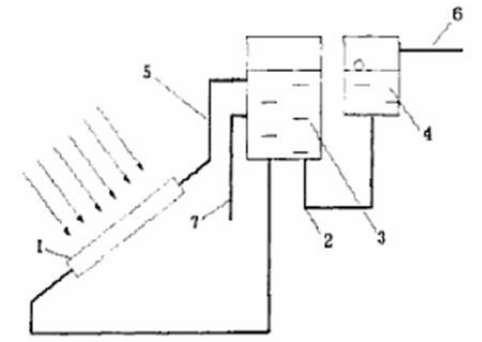

Figure 3. Diagram of Solar Water Heater

Basic working process of the water heater

(1) Endothermic process. After penetrating the glass cover plate, the solar radiation will be absorbed by solar panels and then is passed to the water in the heat-absorbing tube through the fins and tube wall. After the water in the heat-absorbing tube absorbs heat, the water will rise due to the reduction of specific gravity and form a upward force and a thermal-siphon system. With the rising of the hot water, the hot water is stored in the upper tank top. Meanwhile, the cold water will constantly added through the lower circulating pipe. By such circulation, the water in the whole tank will rise to a certain temperature.

(2) Water circulation pipeline. Domestic solar water heater usually work in the natural circulation way without external power, and a well-designed system can circulate with a temperature difference more than 5℃~6℃.The distribution rationality of the water circulation pipeline, pipe diameter and pipeline can directly affect the heat exchange efficiency of the collector. In most cases, the flow pattern in the system pipeline of natural circulation domestic water heater can be regarded as laminar flow. The resistance of the pipeline system in collector is mainly from on-way resistance and the local resistance is much smaller, The on-way resistance in branch pipes is much bigger than the main pipe. The resistance of the pipeline system in collector is mainly from on-way resistance and the local resistance is much smaller, the on-way resistance in branch pipes is much bigger than the main pipe. When water temperature rises, the on-way resistance will reduce and the influence of local resistance will increase due to the reduction of kinematic viscosity. Within a certain range, when the diameter of main pipe remain the same and increase the diameter of branch pipes, the on-way resistance will decrease rapidly, and the local resistance will decrease accordingly. Generally, the radius of branch pipes should be more than 10 mm. When the diameter of main pipe reaches a certain value, increasing the diameter of main pipe has little influence on the reduction of the system resistance.

4. Implementation

Optimize the function for library: (1) install automatic control system and use energy-saving light source in light area of the reading rooms. divide the reading room into several rectangular areas, and each area is equipped with pyroelectric infrared sensor and photosensitive resistance. With the single-chip microcontroller as the control core, use pyroelectric infrared sensor to detect if there are people in the area. If there are people in the area, control the number of open lamps in the area according to the strength of the light. The system is equipped with RS - 485 network interface, which can transmit the data to school energy saving platform to monitor the on-off condition of each lamp, as shown in Figure 4. The light source adopts T5 fluorescent tube. Compared with the traditional T8 series, T5 lamp source is featured with energy saving, environmental protection, high brightness, long life and other advantages. There are 5106 fluorescent

lamps in total in the library, and the total wattage (calculated as T8 series) is 168629 watts. With statistics of energy-saving monitoring platform, the measured wattage under full load is 112100 watts, saving almost 40% of the electric quantity.

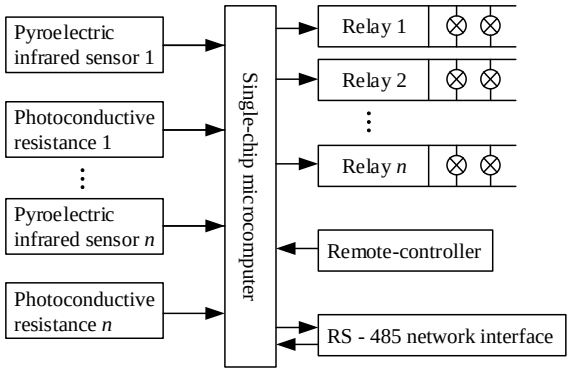

Figure 4. Frame Diagram of System Composition

The non-negative pressure water supply equipment cascades the water supply pipe network, and detect the pressure of inlet and outlet through the pressure sensor. Compare the detection value and the target value, automatically calculate the pressure needs to be added on the original water supply network and determine the number of pumps and the output frequency of the inverter. Adjust the rotate speed of the pump accordingly to meet the requirement of water consumption and thus realize constant voltage. The non-negative pressure frequency conversion water supply equipment can make full use of the original pressure of the major pipeline network without producing negative pressure on the major pipeline network, saving more than 30% of the traditional water supply equipment. Energy-saving operation management is to comprehensively use the principle and methods of natural science and social science to make scientific planning, organizing, scheduling and supervision for the whole project such as distribution, supply, transformation, and consumption of building energy in order to improve the comprehensive utilization of energy. In terms of school operation and management, a series of energy-saving measures are taken to the library, which is shown in the following measures and Figure 5.

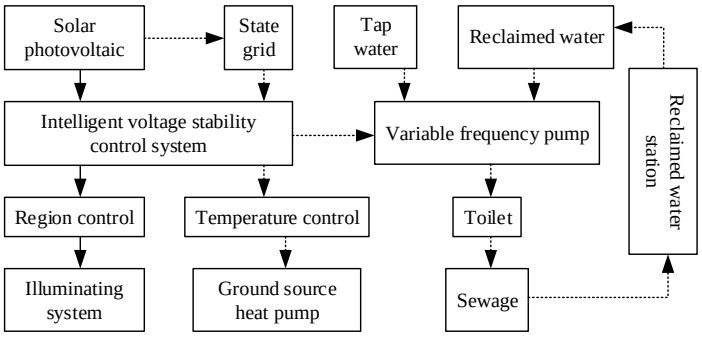

Figure 5. Operation Diagram of Energy Saving System

Figure 6. Laying of Solar Equipment

5. Conclusion

The heating system of self-developed solar air collector module (module) is the research object, which adopts the experimental research, theoretical analysis and simulation calculation to systemically study the influence of the module thermal property, heating effect, the climate adaptability of module heating capacity, and the flow rate of module thermal cycle on the module thermal efficiency and indoor temperature field distribution. Build the macro physical model of the module and the mathematical model of the environmental control system of the laboratory, and simulate the auxiliary thermal source control system in TRNSYS.

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