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Research on Energy Management Control Strategy of MHPA-PV/T Heat Pump System

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ABSTRACT

This article focuses on the MHPA-PV/T heat pump system and studies the energy matching relationship between the power generation and heat generation of the combined heat and power system and the user's electrical and thermal load requirements. Reasonable operation control strategies are proposed to meet the user's demand for electricity and suitable temperature water. Selecting the energy consumption period from 20:00 to 21:00 for testing, the feasibility of the selected control strategy was verified, while maximizing the energy utilization efficiency of the system.

KEYWORDS

MHPA-PV/T System; Energy Management; Control Strategy.

1. INTRODUCTION

At present, under standard conditions, the photoelectric conversion efficiency of monocrystalline silicon cells is 12%~17% [1], and the conversion efficiency of amorphous silicon (thin film) cells is about 6%~8% [2]. Most of the unused solar radiation energy is absorbed by the cells and converted into heat energy. If this heat is not dissipated in time, the temperature of the cells will rise, reaching up to 70 ℃ or even higher in summer. Research has shown that for every 1 ℃ increase in temperature of crystalline silicon batteries, the maximum output power will decrease by 0.4% to 0.5% [3]. Therefore, cooling and heat dissipation of solar cells is an important way to improve their power generation efficiency. At present, the main method for cooling and dissipating heat in solar cells is to add ribs, channels, and other structures on the back of the cell. The heat is taken away through natural or forced circulation of water or air, or the taken away heat is utilized to make photovoltaic thermal (PV/T) integrated modules to achieve the effect of combined heat and power supply [4]. Due to its ability to significantly improve the utilization rate of solar energy and shorten the investment payback period, photovoltaic thermal comprehensive utilization technology has greater potential for development and application [5].

This article takes the MHPA-PV/T heat pump system as an independent energy supply device. Under different operating conditions of the system, energy management and control strategies are studied based on the output characteristics of the system's power generation and heat generation, as well as the energy consumption characteristics of the user's electrical and thermal loads, in order to achieve effective energy matching between the system's power generation and heat generation and the user's electrical and thermal loads, thereby meeting the user's electrical and thermal load requirements.

2. SYSTEM COMPOSITION AND WORKING PRINCIPLE

The MHPA-PV/T heat pump system in this project mainly consists of MHPA-PV/T components, heat pump evaporation side circulating water system, heat pump system, high-precision constant temperature water bath, photovoltaic power generation system, and pipeline accessories. Among them, the MHPA-PV/T component is directly connected to the circulating water system on the evaporation side of the heat pump; The MHPA-PV/T module's heat collection system is indirectly connected to the heat pump system; The heat pump system provides constant temperature water bath heating to simulate the demand for constant temperature heating; The photovoltaic power generation system collects the generated electrical energy into the battery through a photovoltaic reverse control integrated machine. The structure of the flat plate micro heat pipe array solar PV/T heat pump system is shown in Fig. 1.

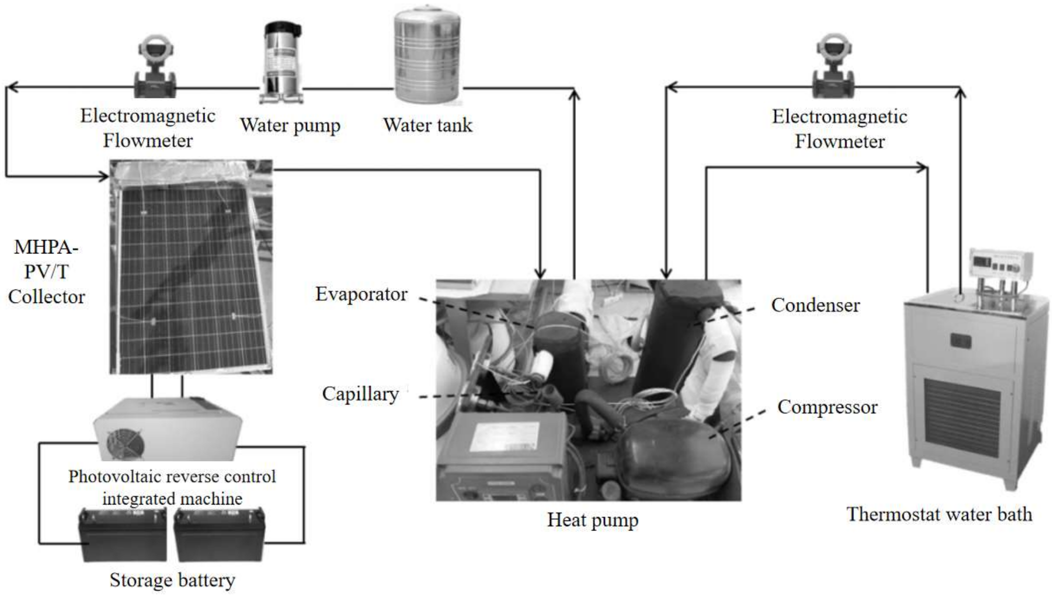

Fig.1 Schematic diagram of MHPA-PV/T heat pump system structure

Considering the characteristics of system power generation and heat generation, as well as the energy demand characteristics of users in different seasons, in order to regulate the relationship between system electrical power and user electrical load, batteries are used to regulate the storage or output of electrical energy; In order to regulate the relationship between system thermal power and user thermal load, a hot water storage tank is used, which stores the heat exchanged by the cooling system through a plate heat exchanger in the form of hot water; At the same time, considering the situation of excessive heat generation and limited heat storage in the heat storage tank, a radiator is used to instantly dissipate excess heat; The function of the heater in the hot water storage tank is to supplement the heat of the hot water storage tank by supplying power to the heater through the battery when the electrical power is greater than the electrical load and the thermal power is less than the thermal load.

3. CONTROL STRATEGY OF MHPA-PV/T HEAT PUMP SYSTEM

3.1. Thermal Load Following Control Strategy

Real time adjustment of output heat generation power based on heat load demand, without controlling output electrical power. When K_2 (the ratio of heat load demand to user electricity load demand) and

K_1 (the ratio of heat generation power to power generation power) are similar in size, choose the heat load following control strategy: when the system's electricity power is greater than the electricity load, the excess electricity in the system is transmitted to the battery for storage; When the system power is less than the electrical load, the insufficient electrical load demand can be supplemented by the battery. The process of heat load following control strategy is shown in Fig. 2.

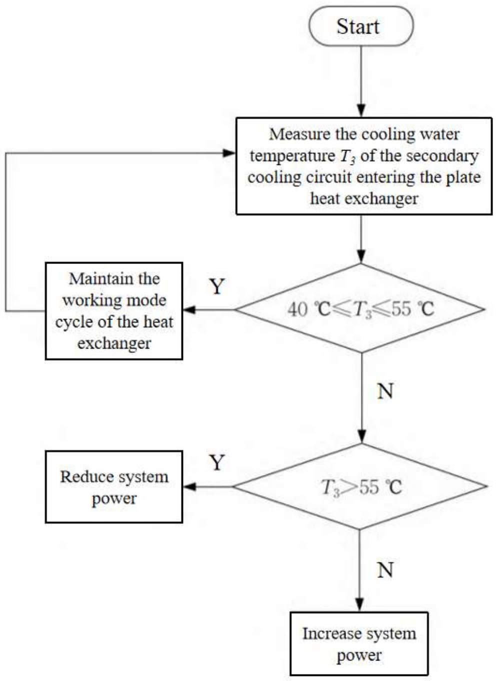

Fig.2 Thermal load following control strategy process

3.2. Electric Load Following Control Strategy

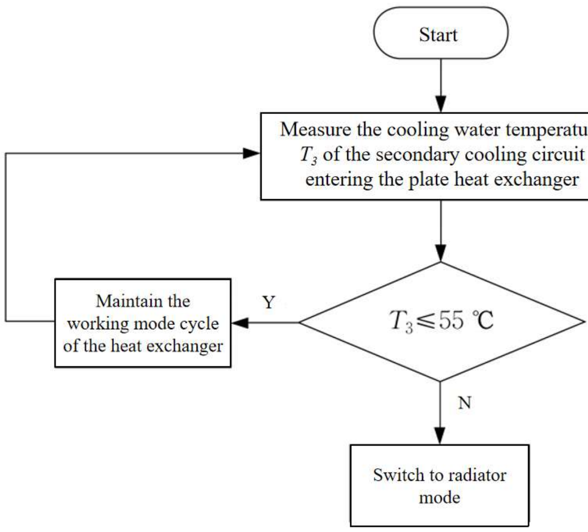

Fig.3 Process of electric load following control strategy

Real time tracking and adjustment of the system's output electrical power based on the power consumption of the electrical load, without controlling the system's output thermal power. When K_2 is much smaller than K_1, the electric load following control strategy is adopted. When the system's heat generation power is greater than the heat load demand, the thermal energy generated by the system is circulated through a plate heat exchanger in the waste heat recovery system and stored in the thermal storage water tank; As the temperature of the hot water storage tank continues to rise, when the temperature reaches the set upper limit value (pay attention to the T_3 upper limit temperature, $T_3 \leq 55$ ℃), the system needs to switch to the cooling mode. The flow of the electric load following control strategy is shown in Fig. 3.

3.3. Thermoelectric Coupling Control Strategy

According to the law of conservation of energy, the sum of the power generated by the system and the heat generated is equal to the sum of the user's electricity load and heat load. Under different operating conditions of the system, when K_2 is much greater than K_1, the system adopts a thermoelectric coupling control strategy. An electric heater has been added to the hot water storage tank, which can convert excess electrical energy into thermal energy as a supplement to meet the heat load demand. The flow of the thermoelectric coupling control strategy is shown in Fig 4.

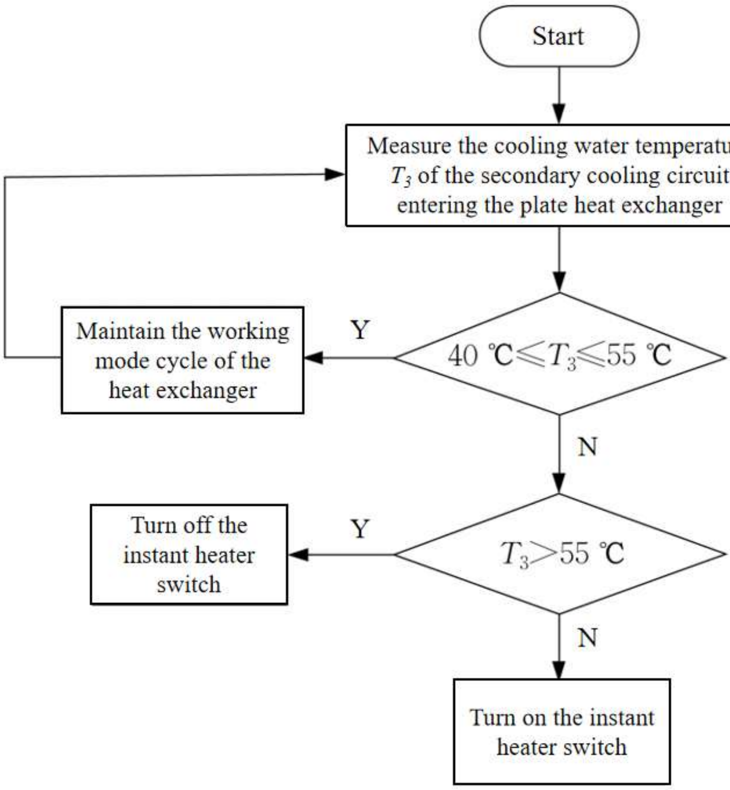

Fig.4 Thermoelectric coupling control strategy process

4. TEST VALIDATION

4.1. Testing and Verification of Heat Load

In spring and autumn, K_2 and K_1 are similar in size, and the thermal load following control strategy is selected for verification. Select 20:00-21:00 energy consumption period, with an electrical load demand of 5 kW·h and a thermal load demand of 4 kW·h, K_1=0.57, K_2=0.64. The relationship characteristics between system power generation and heat generation with time are shown in Fig. 5.

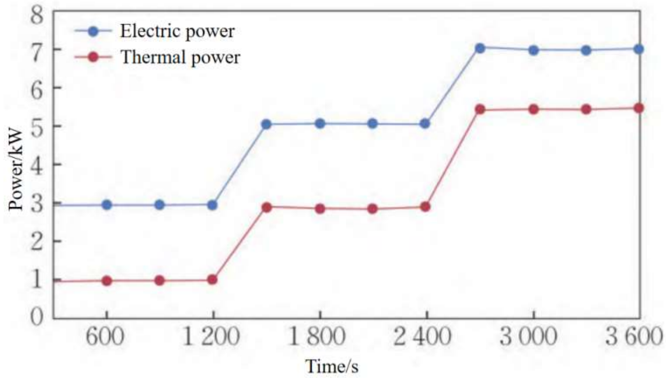

Fig.5 Operation diagram of spring and autumn heat load following control strategy

Choose a heat load following control strategy to adjust the heating power of the system by controlling the current during the operation of the fuel cell stack based on the temperature of the thermal storage tank. The current during the operation of the fuel cell stack is: 50 A during the 0-1200s period; During the period of 1200-2400s, the current is 90 A; During the period of 2400-3600s, the current is 130 A.

4.2. Testing and Verification of Electrical Load

In summer, when K_2 is much smaller than K_1, the electric load following control strategy is selected for testing and verification. Select the energy consumption period from 20:00 to 21:00, with an electrical load demand of 7.5 kW·h and a thermal load demand of 2.6 kW·h, K_1=0.81, K_2=0.35. The relationship characteristics between system power generation and heat generation with time are shown in Fig 6.

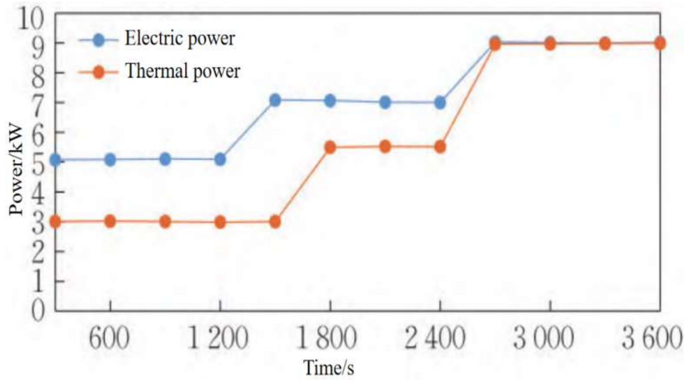

Fig.6 Operation results of summer electric load following control strategy

Choose a load following control strategy to adjust the system's power generation by controlling the current during stack operation based on the battery capacity. The current during the operation of the fuel cell stack is: 90 A during the 0-1200s period; During the period of 1200-2400s, the current is 130 A; During the period of 2400-3600s, the current is 170 A.

4.3. Testing and Verification of Thermoelectric Coupling

In winter, when K_2 is much larger than K_1, the thermoelectric coupling control strategy is selected for testing and verification. Select the energy consumption period from 20:00 to 21:00, with an electrical load demand of 5.0 kW·h and a thermal load demand of 6.6 kW·h. The total demand for electrical and thermal loads is approximately 10.8 kW·h, K_2=1.32, K_1=0.65. The relationship characteristics between system power generation and heat generation with time are shown in Fig 7.

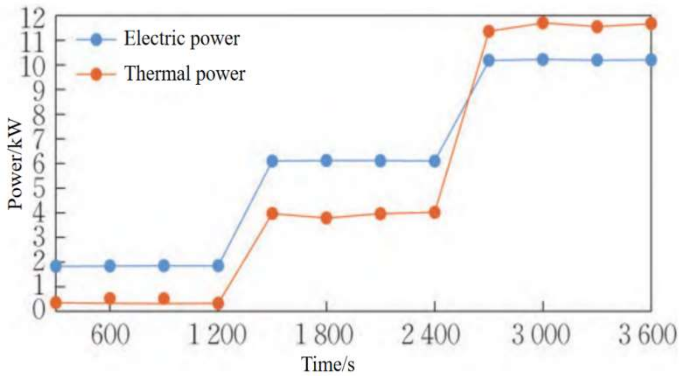

Fig.7 Operation results of winter thermal electric coupling control strategy

Choose a thermoelectric coupling control strategy to determine the total power demand of electrical and thermal loads based on the battery capacity and temperature of the thermal storage tank, in order to control the current during stack operation and adjust the system's operating conditions. The current during the operation of the fuel cell stack is 30 A during the 0-1200s period; During the period of 1200-2400s, the current is 110 A; During the 2400-3600s period, the current is 210 A.

5. CONCLUSION

During the residential energy consumption period, the thermal electric coupling control strategy is selected, and the combined heat and power system generates 6.04 kW·h of electricity and 4.8 kW·h of heat, which can meet the energy demand of users during this period (electricity load of 5.0 kW·h, heat load of 5.8 kW·h). The excess electricity generated is converted into thermal energy through the storage water tank heater, and the energy utilization rate of the system is 78.25%.

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