

Mathematical Control Algorithms A Multifunctional Heat Point At The Base Of A Cascade Heat Pump

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Abstract

In the article the algorithm of work of multifunctional thermal point on the basis of heatpump installations in various operating modes is described. Main operating modes: heating, conditioning, hot water supply, and ventilation.

On the basis of the developed algorithms, flowcharts of work of a control system of multifunctional thermal point are formed subsequently. Control algorithms of multifunctional thermal point are divided into three main functional groups: the block of control of temperature in rooms, the block of control hot water supply and the ventilation control block.

Keywords: control algorithm, heating, conditioning, ventilation, cascade heat pump, power efficiency.

1 Introduction

Now the sector of automation of processes of production and distribution of thermal and electric energy is seriously developed both in industrial, and in the household sector [1-3]. Heating and hot water supply systems on renewable energy sources are encountered more often (geothermal and solar energy) [4-7]. It is already difficult to attribute them to nonconventional systems. The automation systems of similar installations are capable to work on algorithms of priority a renewable source, connecting a source on organic fuel only in case of the shortage of a renewable source. Control algorithms of multifunctional thermal point have been developed based on the key needs and characteristics the standard consumer. Further, the developed control algorithms can be realized on any programmable controller for the heat pump [8-10].

2 Methods of functioning the multipurpose thermal point

A multifunctional thermal point on the basis of cascade heatpump installation is intended for providing the consumer with thermal and refrigerating energy at the implementation of heating, hot water supply, conditioning, and ventilation.

The appearance of the multifunctional thermal point at the test bench is presented in figure 1.



Figure 1. Appearance of a multifunctional thermal point at the test bench

Control algorithms of multifunctional thermal point are divided into three main functional groups: the block of control of temperature in rooms, the block of control hot water supply and the ventilation control block.

The block of control the temperature in rooms carries out the two operating modes by means of the cascade heat pump: heating and conditioning [11-14]. The mode of heating joins at achievement in temperature below the established value. Temperature is defined by means of the thermal sensor from which signal is sent to the controller. Conditioning joins manually and carries out cooling of

air in rooms and refrigerators in the established range of temperatures. The block of control the hot water supply maintains constant water temperature in the boiler. Control of temperature is exercised depending on the established value, but not less than 52 °C to avoid colonies of pathogenic bacteria.

The ventilation control block enables of return a part of the warmth which is carried away with ventilating air.

Operating mode "Conditioning"

The conditioning mode can be either passive or active depending on the necessary level of cooling. The most priority is the passive mode as during his work thermal point consumes fewer times electric power, than in the active mode. The passive mode can give the air cooled up to the temperature not below 16 °C to the room. The choice of a mode is carried out by the logical block, depending on the chosen cooling temperature. To enable passive conditioning, the controller of the multifunction heating station sends a signal to the:

- turning on the circulation pumps of the ground heat exchangers system;
- turning on the fans of fan coil units.
- To enable active conditioning, the controller of the multifunction heating station sends a signal to the:
- turning on the 1st cascade of heatpump;
- turning on the circulation pumps of fan coil units and its fans.

In case of work without intermediate accumulation of cold the 1st cascade turns on. In case of use of the cold accumulator for conditioning, or for recovery of ventilation the 5th cascade turns on.

Operating mode "Heating"

In the heating mode the signal goes for turning on of the following equipment:

- the circulation pump between the condenser of the cascade and buffer tank;
- the circulation pump of the heating system.
- Work of all circulation pumps is continued before achievement in the room of the established temperature. In case of shutdown of heating switching off of the following equipment is made:
- the circulation pump between the condenser of the cascade and buffer tank;
- the circulation pump of the heating system.

Then the system passes to the choice of a source of warmth.

The warmth received from the cascade of the thermal pump is more priority than subjects, than temperature of the used source is higher^[15].

The heat accumulator of average solar activity accumulates warmth with the temperature of 30-40 °C. This temperature is suitable for heating. If the heat accumulator of average solar activity has temperature above the established value (the accumulator - in the charged state), then the signal on turning on of the following equipment is given:

- the circulation pump between the heat accumulator and buffer tank;
- the circulation pumps of the heating system.

When developing thermal point it is offered to use the low solar activity, most characteristic of the heating season, for the heat accumulator at the

temperature of 20 °C. Then there will be transformation in the corresponding cascade of the heat pump to 30-40 °C. If the temperature of the heat accumulator of low solar activity is above the established value (the accumulator is charged), then signals for turning on of the following equipment:

- the circulation pump between the evaporator of the cascade and the heat accumulator;
- the circulation pump between the cascade condenser and buffer tank;
- the circulation pumps of the heating system;
- compressor and internal automatic equipment of the fourth cascade.

Work is continued until temperature in the accumulator does not decrease to the established value (the accumulator is discharged), or indoor temperature will not rise to certain value.

The Air of circumambient is a renewable source of low-potential energy. At temperature more than 0 °C air is more priority, than ground circuit which, as a rule, works in zone of negative temperatures.

Operating mode "Hot water supply"

Hot water supply is provided from an indirect heating boiler. The boiler can be heated by solar collectors at operating mode with high solar activity. For lack of this activity, the heat carrier of buffer tank of system of heating with temperature of 30-40 °C is used. This warmth is transformed by the third cascade of heatpumping installation up to the required temperature (to 55-60 °C). High solar activity is priority source in comparison with the cascade of heatpumping installation by the criterion - economy of primary energy.

If a temperature in the boiler is lower than the specified (55-60 °C), then the system of automatic equipment checks the temperature in a collector regarding detection of the mode of high solar activity.

Work of installation is continued until the temperature in a solar collector doesn't decrease to the established value, or temperature in the boiler won't reach the established value.

If the temperature in solar collectors below the established value (55 °C), and temperature in the boiler hasn't reached the established value of 55-60 °C, then the system switches over to an operating mode from a buffer tank with warmth transformation.

If the temperature in a buffer tank is less than the established value (25 °C), at a temperature in the boiler not reached a preset value (55-60 °C), then there is a heating of a buffer tank. Heating of a buffer tank is carried out on the algorithm similar to a heating mode algorithm, with the choice of a source of warmth on priority.

Operating mode "Ventilation"

Multifunctional thermal point on the basis of cascade heatpump installation has an opportunity to use a secondary energy resource in the form of warmth of the air which is carried away with ventilation. Recovery is carried out by the fifth or sixth cascade of heatpump installation. Unlike the existing ways of recovery, utilization will be carried out not at the time of course of waste air, and in advance – from the cold accumulator. From the cold accumulator warmth will be selected, freezing a coolant (water, or other substance with a lower temperature of freezing) which

then will thaw, having taken away warmth of the carried-away air. Such way allows to transfer effectively at a constant temperature and power warmth from ventilating installation by the main cascade of the heat pump, without creating the additional cascade for ventilation of rooms.

Work is continued until the temperature in the compact cold accumulator reaches the established value.

Automation monitors the temperature of the coolant in a compact accumulator of cold and, if necessary, gives a signal for its recharging.

Automatic control system for the thermal point in operation

In 2017 the experimental sample of multipurpose thermal point has been made. The control algorithms

of the thermal point described above have been put in the controller of an experimental sample. Further on an experimental sample preliminary tests of a sample and its automatic equipment within the plan of works on the second stage have been carried out. Tests of the second stage were preparation for the main tests of the third stage. For each contour of the cascade of heatpump installation, the established temperatures are individually exposed values Δt and interaction algorithms with other cascades.

Figure 3 shows the schedule of dependence of temperatures of the 1st cascade of the cascade heat pump from time during starting tests is submitted. Are additionally separated by vertical lines the starting, operating and stopping mode of the cascade.

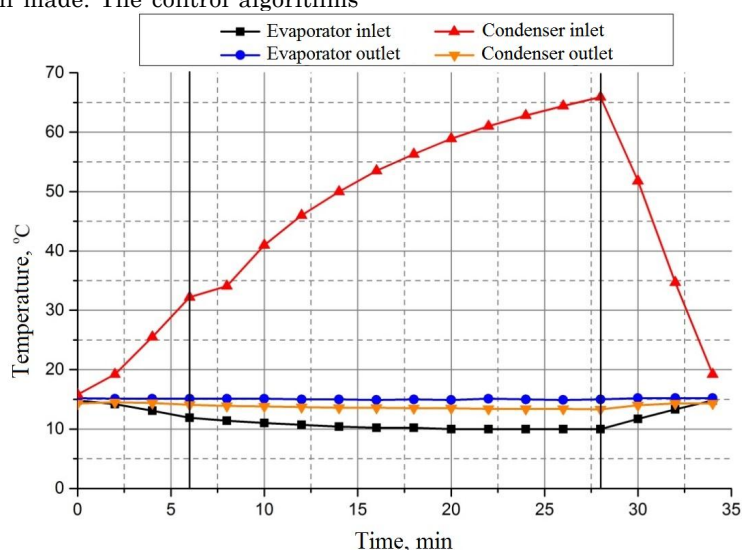


Figure 3 – The temperature dependence of the first cascade heat pump as a function of time: 0-6 min. - starting mode; 6-28 min. - Work mode; 28-34 min. - stop mode

Figure 4 shows the dependence of pressure in evaporators and condensers from time during the starting tests.

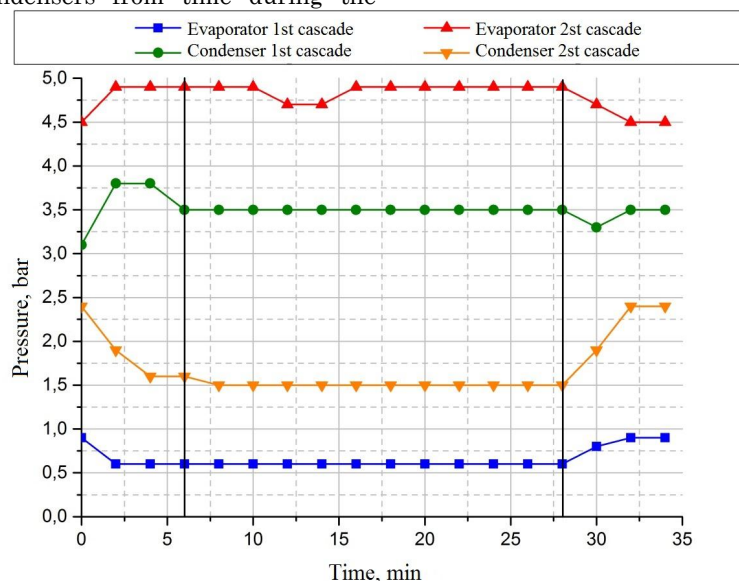


Figure 4 – Dependence of pressure in evaporators and condensers from time: 0-6 min. - starting mode; 6-28 min. - Work mode; 28-34 min. - stop mode

After analyzing the data in Figures 3-4, the starting, working and stopping modes of the installation. These modes are separated from each other by vertical lines. The starting mode of the

experimental setup lasted 6 minutes, after which the unit entered the operating mode, in which it was up to 28 minutes of testing. At the 28th minute of the start-up test, the installation was stopped. After switching

off the compressor of the test circuit for 6 minutes, the values of the pressure and temperature of the circuit assume the initial values. This is observed on the graphs shown in Figures 3-4.

3 Conclusion

Algorithms of work of multipurpose thermal point on the basis of heatpump installations in various operating modes have been described in this article: conditioning, heating, hot water supply, ventilation.

On the basis of the developed algorithms were made flowcharts of work of system. They formed the basis of an automated control system of the experimental exemplar of multipurpose thermal point on the basis of the cascade heatpumping plant. In the course of trial tests cascades and automatic equipment were adjusted. Also the starting, operating and stopping duties were allocated and readiness of carrying out field comprehensive tests on an actual object is provided.

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