COMMISSIONING OF HVAC SYSTEMS WITH HEAT PUMPS AND RECOMMENDATIONS ON IMPROVING THEIR ENERGY EFFICIENCY

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Abstract. This report outlines the results of practical use of continuous monitoring complex with remote access to HVAC systems based on heat pumps. Application of the developed complex for the analyzed systems allowed to eliminate errors in their operation and allowed to introduce specific measures to improve their efficiency.

Key words: heating, heat pump, commissioning, air conditioning

1 INTRODUCTION

The market of HVAC systems with heat pumps is growing constantly in Ukraine. Unfortunately, calculation methods for the study of rational applications of heat pumps do not always provide good agreement with actual characteristics of the designed and operated systems. For several operating HVAC systems there were developed commissioning systems that allow checking real characteristics of not only heat pumps, but also of HVAC systems in general.

2 INTRODUCTION TO THE PROBLEM

Unfortunately, during the operation of HVAC additional factors that have a negative impact on the work of system elements, including heat pumps appear. First of all they include:

- change of the operational modes of hydraulic and air system elements;
- change of the characteristics of elements during their operation;
- change in the characteristics of the freon in the heat pump circuit;
- Personnel error, etc.

To identify negative impact of the stated factors the need in formation of additional information system appears. It should provide solution to the following tasks:

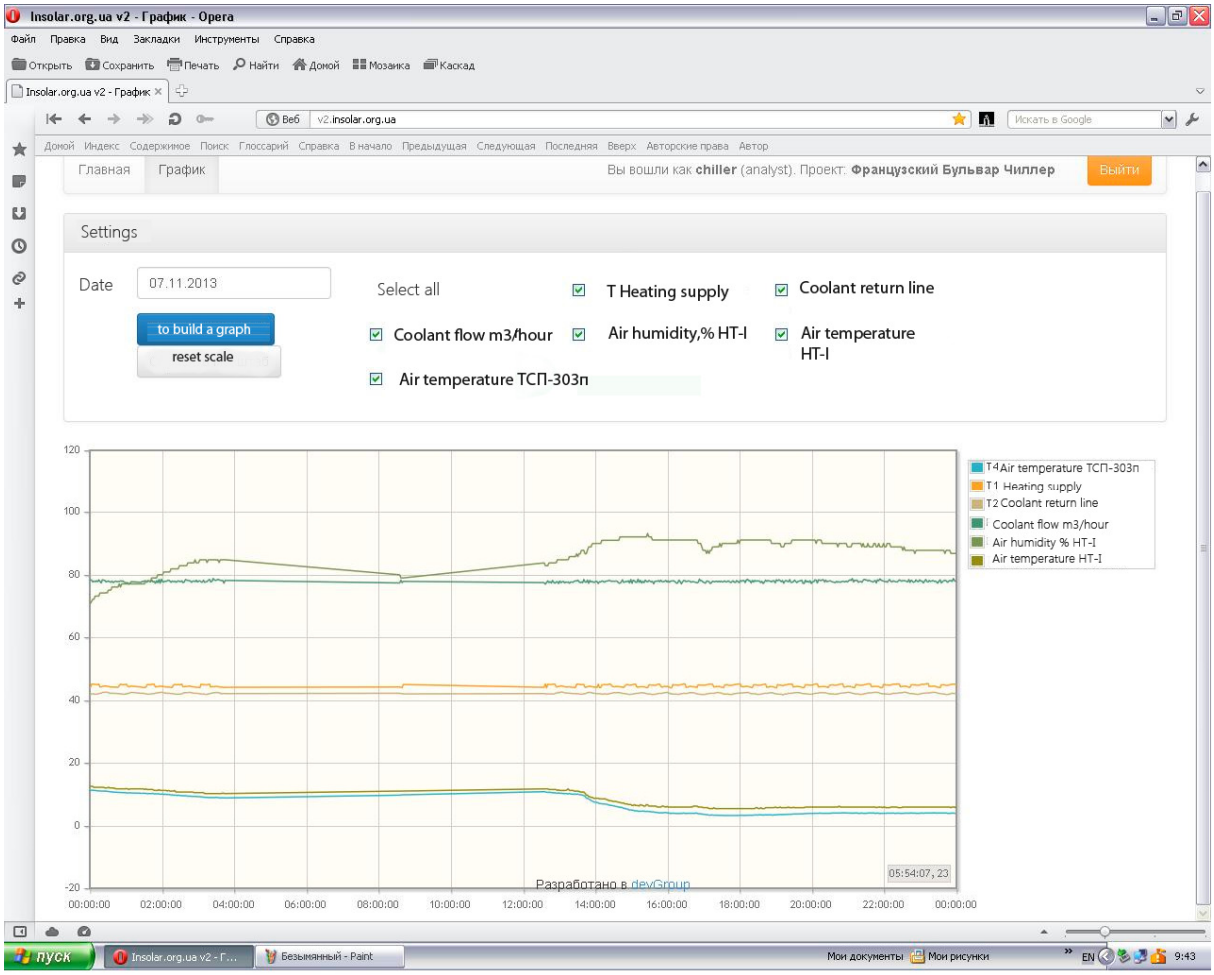
- to measure operating conditions of Freon and working fluids in the internal HVAC system circuits;
- to measure technical parameters of power consumption ;
- to ensure the collection, processing , storage, transmission and analysis of the data;
- to prepare and make a decision on the introduction of corrective actions;
- to implement corrective actions
- to evaluate the results of the correction.

For the development of such system, it is necessary to make a decision on the method of:

- measurements (disposable or continuous);
- collection, processing, storage and transmission (autonomous data collecting system (remote systems);
- processing and presentation of data.

Thus, the diagnostic system is formed as an interactive automated system of monitoring and decision making.

For this purpose special software designed for the collection, storage and procession of the data was developed. During constructing graphs a user can optionally choose the settings for a predefined period of time for the selected sensor. Figure 1 shows the window interface of the program.



3 CONTENT

Testing of the methodology for commissioning and formation of monitoring system was conducted on the following HVAC systems with heat pump of the “air-water”: types:

- on bivalent heating system consisting of the district heating system and two heat pumps with heating capacity of 480 kW each , being at the same time the main source of cold for an air conditioning system for an office center in Kharkov (System 1);
- on heat pump system with heating capacity of 95 kW operating up to outdoor air temperature of -19 ° C (System 2);
- on heat pump system with heating capacity of 240 kW for an office building (system 3);
- on the heat pump system with heating capacity of 480 kW, for a shopping center and it is also a source of cold for the air conditioning (system 4).

For the formation of the monitoring system considering the application of the mentioned systems the methodology of continuous monitoring of mode parameters in real time was set up. For this purpose the following elements were included in the system:

- Transducers (temperature sensors, a relative humidity sensor, a flow meter, an electricity meter, etc.);
- data transmission equipment from remote access points;
- a personal computer with special original software designed to represent received information in graphical format.

Figure 2 shows elements of the measurement equipment.

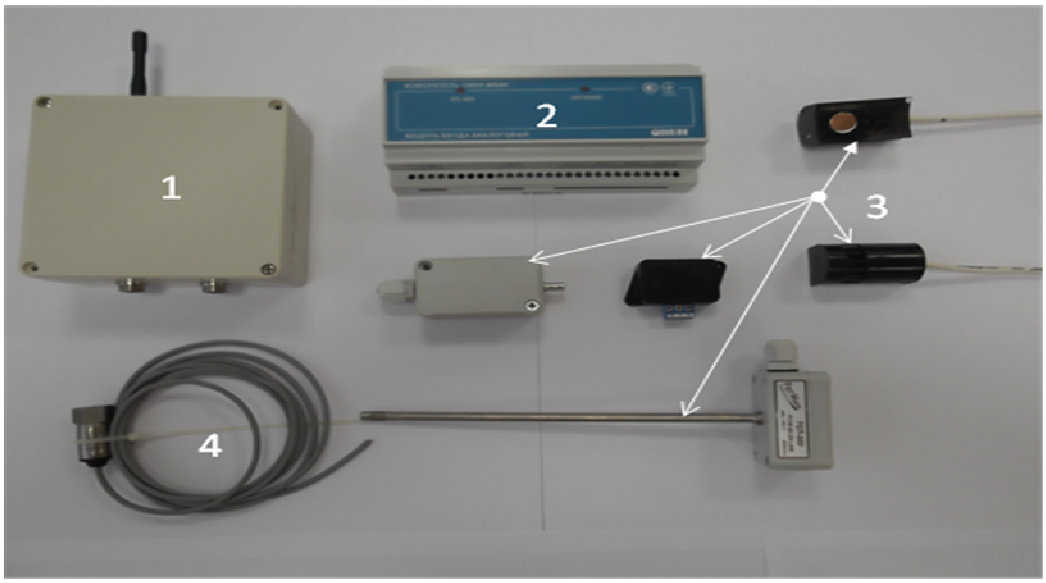


Figure 2: Elements of the measurement equipment
1- data transmitter, 2 – data concentrator, 3 – temperature sensors; 4 – pressure sensor.

3.1 System 1

In the premises of business and retail center located in an urban area with compact planning the heating system (that has total heating capacity of 924 kW) is based on air heat pump. The layout of the sensors for system 1 is shown in Figure 3.

The heat pump provides heating for the site up to the outdoor temperature of minus 5 - 8 °C, ensuring the production of about 70% of the required heat during the heating season. At lower temperature, it is possible to switch to the heating of the district heating network. Energy savings on heating at tariffs of 2011 was no less than $ 25,000. The difference in capital costs for the system with the function of heating (heat pump mode) and system operating only in cooling mode was about $ 32,000.

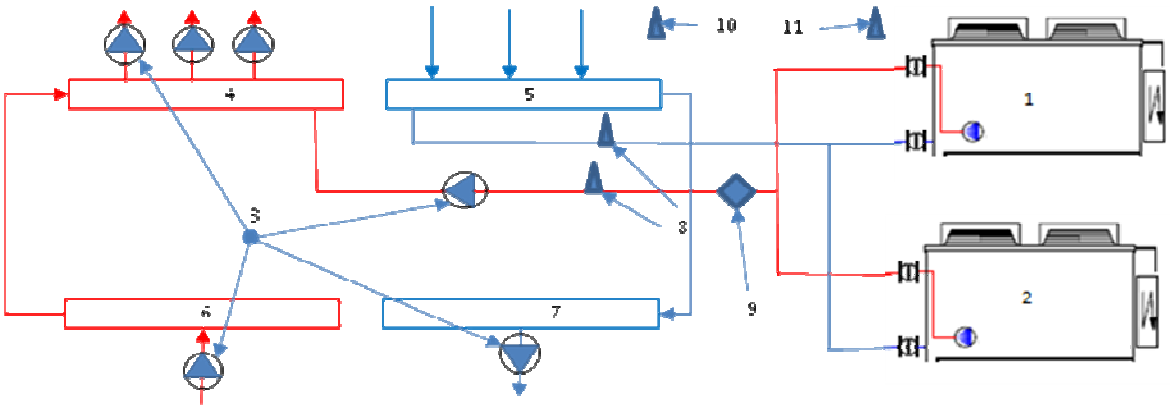


Figure 3: Layout of sensors for System 1

1, 2 - chiller - heat pump, 3 - pumps , 4 - coolant discharge manifold 5 –return manifold, 6.7 supply and return manifold of the district heating system , 8 - temperature sensors , 9 - flow meter 10 - outside air temperature sensor 11 - relative humidity sensor of outdoor air

As a result of parameter modes measurements of the system the following is determined:

- optimal mode of the heating system switching to the use of heat pump or central heating system taking into account daily and weekly work schedules of offices, current outdoor temperature and current energy prices;
- the effect of relative humidity of outside air on the daily average COP of the heat pump, due to changes in cycle time "operation - defrost ";
- possibility of using the heat of discharged ventilation air for the partial heating of the outdoor air, supplied for the condenser;
- possibility of lowering the temperature of water without compromising comfort in rented premises while improving the COP of the heat pump.

3.2 System 2

In the retail and office building with the volume of 17580 m3 , located in the central part of Kharkov where limits of getting heat from the city heating station are almost exhausted ,the heating, ventilation , hot water supply and air conditioning are performed on the basis of air chillers - heat pumps (Project " Ekotermo engeniering ", Kharkov) . The layout of the sensors for the system 2 is shown in Figure 4.

The thermodynamic heat recuperation of the exhaust air with the help of built-in “air to air" heat pumps is applied for the ventilation system. Performance of the system using only heat pumps is possible to minus 19 ° C. There is a backup electric boiler of 100 kW. Operating costs for heating in comparison with the traditional system of district heating is 47% lower.

According to the results of heating system diagnostics, the following shortcomings in the organization of its work are revealed:

- capacity of fan coil units was selected on the basis of the work conditions in cooling mode. However, in actual operating conditions in the heating mode, according to the temperature measurement in building, it became possible to reduce the temperature of the heating supply water at the input by 2 - 3 ° C, which in its turn led to the increase in COP of the heat pump. At the air temperature minus 10 ° C the increase was 6 - 7% and at the air temperature plus 2 ° C the increase was 7 - 8.5 % ;
- Radiators and fan coil units were supplied with heat from the heat pump. The branch of the radiator required elevated temperature, while for fan coil units such heating supply water temperature was excessive. It was offered to divide these systems and

to carry the heat supply only from the heat pump to fan coil units (93 % of the total required heat output of the building), and to supply heat from electric boilers to radiators (7 % of the total required heat output of the building) with elevated temperature. This has led to the increase in the overall efficiency of the heat supply system due to lower water temperature of the heat pump, and to the improvement of comfort in buildings with radiator heating.

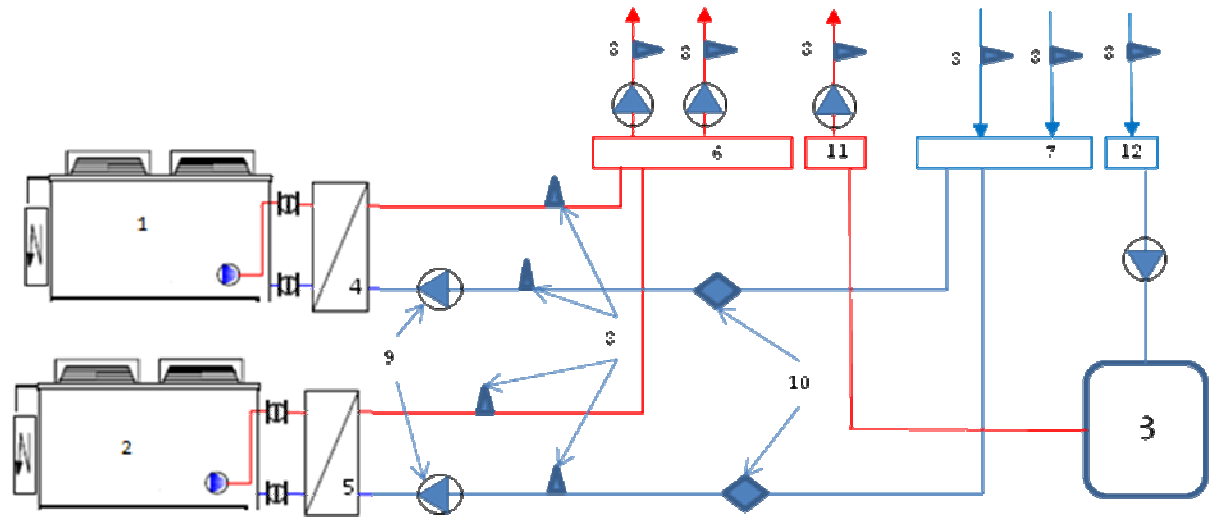


Figure 4: The layout of the sensors for the system 2

1, 2 - heat pump chiller , 3 - electric boiler , 4, 5 - heat exchangers, 6, 7, supply and return manifolds of fan coils , 8 - temperature sensors , 9 - circulation pumps , 10 - flow meters , 11, 12 - supply and return manifolds of radiators

3.3 System 3

The diagram of the heat supply system of shopping center on the basis of air source heat pump and gas boiler is shown on figure 5. Analysis of the results of this one-time monitoring of the heating system performance revealed a number of fundamental shortcomings in its organization. First of all a low level of maintenance is noticed. Mistakes in mutual work of heat pump and gas boiler are identified. Separate time intervals were identified during the heat pump operation in heating mode with the outdoor temperature between 15 -18 ° C. Analysis of temperature on the refrigerant circuit pipes and refrigerant pressure in the circuit showed that the heat pump worked with low quantity of refrigerant .

According to the results of the diagnostics next measures were developed on:

- regulation of the hydraulic control of the heating system;
- restart of automatic system of temperature regulation of the gas-fired boiler;
- refill of the refrigerant circuit of the heat pump.

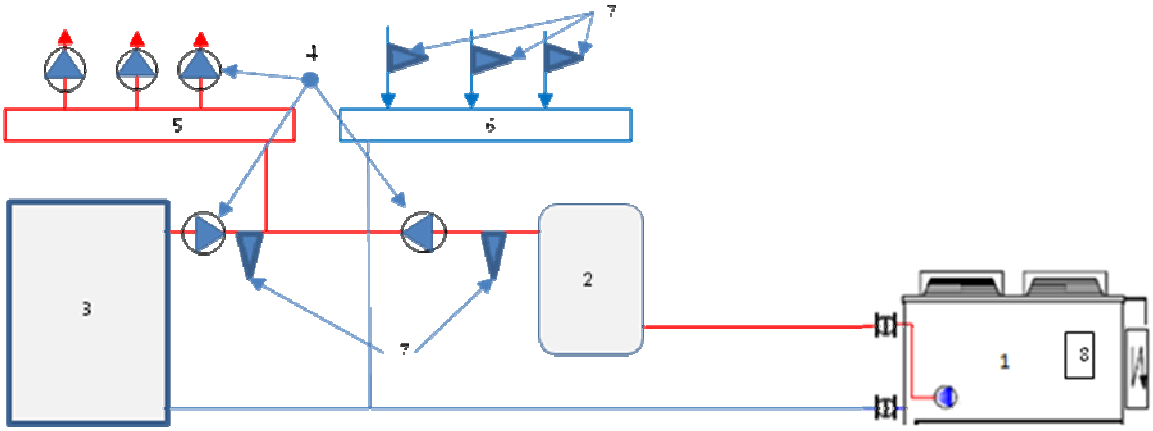


Figure 5: Layout of sensors for the system 3

1 - chiller - heat pump, 2 - expansion tank, 4 - circulation pumps, 5, 6 supply and return manifolds of fan coils, 7 - temperature sensors, 8 - pressure sensors

3.4 System 4

Figure 6 shows the element of the heating system scheme on the basis of the air heat pump for shopping center with an area of 27000 m2. The layout of the sensors for the system 4 is shown on Figure 6.

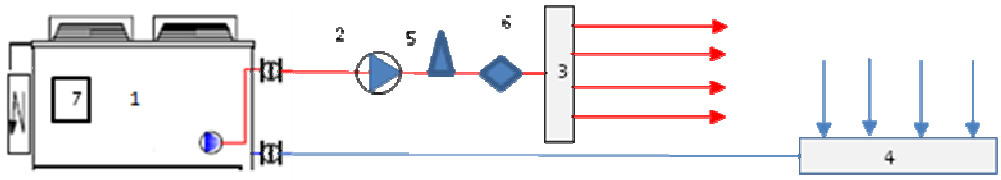


Figure 6: The layout of sensors for the system 4

1 - chiller - heat pump, 2 - Circulation pump, 3, 4 supply and return manifolds, 5 - temperature sensors

This heating system has been put into operation in October 2013. To adjust the mode of operation the system of continuous monitoring with remote access was mounted. Figure 7 shows graphics of parameter changes during the day for system 4 (07 November, 2013)

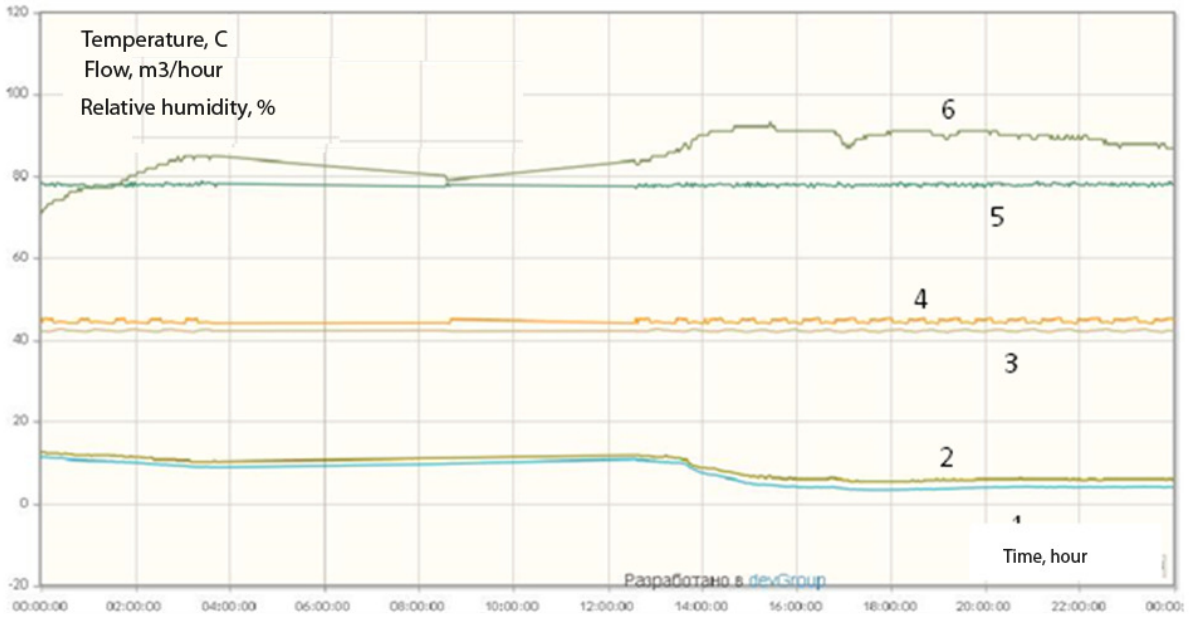


Figure 7: Graphics of parameters change during the day for the system 4

1, 2 - outside air temperature, 3 - temperature at the outlet of the system, 4 - flow temperature, 5 – relative air humidity, 6 -coolant flow m3/hr

Continuous commissioning of the operational mode of system 4 had been conducted from October until January 2013. During this period it was possible to establish the following:

- use of heat pump allowed to increase efficiency of the heat supply system in comparison with gas boiler more than twice that is based not only on high efficiency of heat pump at outdoor temperatures to minus 3 ° C (average COP temperature for the temperature from minus – 3 up to plus 5 ° C was 2.76) but also on low efficiency of gas boiler that is caused, on the one hand, by the fact that it operates at low loads, and on the other hand, by low quality of natural gas in the gas supply system.

According to the results of the performed commissioning follows that:

1. Commissioning of existing HVAC systems allowed to reach a new level of understanding the processes that take place in the analyzed systems in real time.
2. An experience in commissioning of existing equipment with the selection and installation of sensors, organization of data transmission channel is gained.
3. Unique experience in analysis of the results of commissioning and development of proposals on technical improvement systems and improvement of maintenance is gained.
4. The new market of engineering services - commissioning and improving of HVAC systems starts to develop In Ukraine that in its turn will contribute to further development of market with such systems in Ukraine.