Revista Română de Inginerie Civilă, Volumul 15 (2024), Numărul 1

The integration of air-water heat pumps in existing office buildings. Case study

Integrarea pompelor de căldură aer-apă în clădirile de birouri existente. Studiu de caz

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DOI: 10.37789/rjce.2024.15.1.5

ABSTRACT
In an existing office building, integrating air-to-water heat pumps into a district heating system can bring multiple benefits in terms of energy efficiency and thermal comfort. The article deals with the implementation solution for the efficiency of district heating systems, exemplified by a case study related to an existing office building. The study was carried out following the multiple breakdowns that occurred in the thermal energy distribution system from the district heating company, as well as the interruption of thermal energy for long periods of time.

Key words: *air-water heat pumps, district hesting systems*

1. INTRODUCTION

A heat pump and a district heating system are two distinct elements, but which can be integrated to provide efficient heating and cooling of an existing office building.

The district heating system refers to the infrastructure and components used to provide heat inside the building. This includes ducts, fan coils, ventilation and other relevant components.

In Romania, district heating systems register a high percentage of inefficiency, determined by the diversity of problems in the production-transport-distribution chain, the implementation of rehabilitation and modernization measures that would lead to their energy and economic efficiency. The solution that can ensure the energy efficiency of district heating systems in Romania is presented in the case study presented below [1].

2. PRODUCTION TECHNOLOGIES OF THE THERMAL AGENT

➢ ***The air-water heat pump***

The surrounding air contains heat even when temperatures drop below zero degrees Celsius. Therefore, we can take advantage of this with the help of an air-water heat pump, which in the cold season extracts the heat from the air and water, with the help of the compressor, and then distributes it inside the home through the consumers. In the warm season the above cycle is reversed, with the pump extracting coolness from the air and introducing it into the building.

In terms of efficiency, in the case of this type of device, it is shown by the COP indicator – the higher it is, the more efficient the heat pump is [2]. Of course, not only the COP index is important in the choice, but also other factors. Put simply, heat pumps have the same operating principle as air conditioners, only their efficiency is much higher. How an air-to-water heat pump works can be seen in the simplified diagram below (Figure 1).

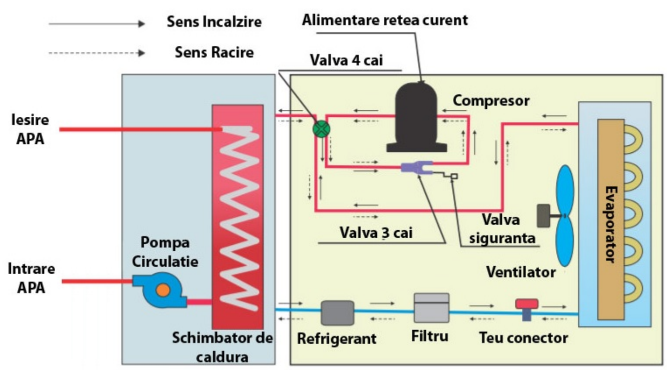

Figure 1. Operating diagram of the air-water heat pump

From this diagram it can be seen that the device can heat the building, but it can also cool it, changing the direction of rotation of the thermal path. Heat pumps that can heat and cool the home are called reversible heat pumps.

➢ **The district heating system**

District heating systems are technical systems designed to provide heating and hot water in buildings and urban areas. These systems are used especially during the cold season to maintain a comfortable temperature in homes, offices, public institutions and other spaces.

There are several types of district heating systems, but the most widespread is the centralized heating system. It consists of a thermal plant located in a central area of the city or neighborhood, which generates heat by burning fuels such as natural gas, coal or oil. The heat produced in the plant is then distributed via a network of pipes to neighboring buildings, where it is used for heating and domestic hot water.

District heating systems have the advantage of providing a centralized source of heat, eliminating the need to have individual heating plants in each building. This can lead to greater energy efficiency and cost savings as more efficient centralized heat production can be achieved. However, there are also disadvantages associated with district heating systems, such as heat losses in the network, dependence on complex infrastructure and the risk of breakdowns in case of failures.

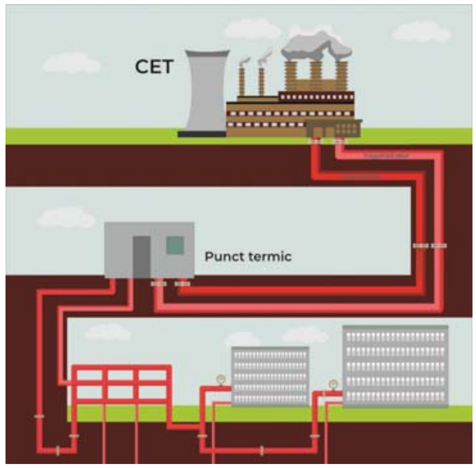

Figure 2. Scheme of the district heating system [3]

In recent years, more advanced heating technologies have appeared, such as geothermal systems, heat pumps or solar thermal panels. They use renewable or non-conventional energy sources to generate heat, reducing environmental impact and contributing to sustainability.

Each country and region may have its own rules and regulations regarding the implementation and management of heating systems, and the provision of these services may be carried out by specialized companies or local authorities.

3. CASE STUDY. INTEGRATION OF AIR-WATER HEAT PUMPS IN THE DISTRICT HEATING SYSTEM

In order for an existing office building to be able to integrate a heat pump system and a district heating system, certain modifications and adaptations of the existing installation may be required. Here are some important steps in implementing this project:

• Assessment of the existing installation to determine how a heat pump system can be integrated. It is important to consider existing parameters such as the type of heating used (eg radiators, fan coils), temperature control and the configuration of the heating network.

• Heat and cooling demand analysis [4], [5]: It is important to assess the heat and cooling demand of the office building, based on the heated surfaces and the local climate. This will help to properly size the heat pump system and determine the capacity needed to meet the heating and cooling requirements.

• Selection of the appropriate heat pump: Based on the analysis of the heat and cooling needs, the right heat pumps can be selected for the office building. It is important to consider the energy efficiency, costs and specific technical requirements of the building.

• Adaptation of the existing heating system: Depending on the type of existing heating system, modifications to the installation may be required. It is also important to ensure compatibility between heat pumps and the existing heating system to achieve optimal performance.

• The implementation of an advanced control system is essential to efficiently manage heat pumps and the thermal system as a whole. It should allow temperature monitoring and regulation as needed and optimize system operation to save energy.

Prepared following the study of the requirements from the design theme submitted by the beneficiary, the solution complies with the norms and standards in force, so as to ensure the comfort of the users and the necessary performance levels.

The heating system had a high number of breakdowns in the last 2 years, with long periods of interruption of the heating agent, but also with low temperature supply. Following the contract signed with the heating system, the building had to be supplied with a constant heating agent at a temperature of 90ºC. In the cold season of 2021 and 2022, there were several days when the building was fed with agent at a temperature of 60-70ºC. At this temperature, it was not possible to ensure the entire heating and preparation of hot water for consumption. Following these thermal agent breakdowns/ interruptions, the beneficiary decided, in addition to the existing system, to supplement with a solution provided with air-water heat pumps.

Figure 3 shows the temperature variations of the thermal agent recorded by the BMS system of the building, for a period of 14 days. It can be seen how the temperature of the thermal agent dropped below 70ºC over a long period of time, of approximately 4 days. There were also interruptions of the heating agent, where the temperature dropped to around 25ºC over a period of 10-12 hours.

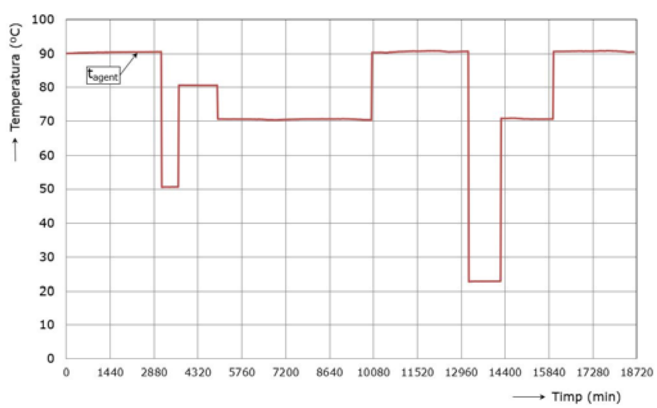

Figure 3. Flow temperature of the thermal agent that supplies the thermal module

To better understand the studied situation, we will present some data about the building:

• Building destination: office building
• Floors: S+P+6E+Ft
• Façade type: Glass front, with a very high thermal transfer coefficient
• Useful area: 9000 sq m
• Heat requirement: 650 kW
• Cooling requirement: 930 kW

- **Description of the existing situatio**

- **The building's heating system**

The building is heated using a thermal point that produces 80/60ºC hot water thermal agent and consists of a fully equipped and automated thermal module, circulation pumps, expansion plant. The heating agent is transported to the distribution points through pipes made of steel. A distributor-collector set, pressure equalization cylinder, adjustment elements, circulation pumps are located at the distribution point.

The thermal point is located in a specially designated space in the basement of the building that contains the thermal modules.

The distribution of the thermal agent is carried out through a two-tubular system, made of drawn black steel pipe, thermally insulated against temperature loss with a mineral wool mattress cased on aluminum foil, with a thickness of 50 mm, considering the fact that through this system 80/60ºC hot water circulates for the cold season.

Space heating is carried out differently using various systems, depending on the destination of the respective space. Thus, the following heating elements are used:

- the office spaces, which also require cooling, are heated by means of uncased fan coil units mounted in the false ceiling, provided with two batteries: one for heating and one for cooling;
- the rooms in the basement are heated by means of steel radiators;

- **The building's cooling system**

The air conditioning of the building is carried out by means of fan coil type cooling equipment, air treatment plants and chillers. Two chillers are installed, one operating in the "free cooling, no glycol" system, for operation also during the cold season with high electricity savings, and one operating only during the warm season, with a highly efficient "turbocor" compressor. . The chillers produce cold water 7/12ºC, with air-water heat pump operation, in the case of the "free cooling" chiller, respectively water-water, in the case of the "turbocor" chiller, by direct expansion of the freon. For the water-cooled chiller, an open cooling tower is mounted, which will supply the water from the condensing circuit of that chiller.

The fan coil units used are non-encased, mounted in the false ceiling. All fan convectors are provided with two batteries each: one for heating and one for cooling. Thus, regardless of the season, the spaces benefit from both cooling and heating, depending on the needs.

The air cooling unit is mounted outside the building, on the common platform for the air conditioning and ventilation equipment, located on the terrace of the building; the water-cooled chiller is mounted on the technical level inside the technical room.

The distribution of the thermal agent from the chiller to the fan convectors is done through a two-tubular system made of drawn steel pipe. To prevent the formation of condensation and the loss of cooling energy, the distribution system is insulated with tubes or a porous rubber mat, with a thickness of 19 mm.

- **Describe the proposed situation**

The alternative and backup solution for the emergency heating, or backup cooling as the case may be, of the studied office building is treated.

The need for this solution appeared with the multiple breakdowns that occurred in the thermal energy distribution system from the heating company, as well as the interruption of thermal energy for long periods of time.

Thus, an alternative system was implemented for emergency heating of the building in case of total interruption of thermal energy from the heating company and a complementary backup system, when the energy supplied by the heating company is not at the required/necessary parameters for correct operation of the installations. The system can also ensure the cooling reserve in case of a breakdown on the existing cooling equipment of the building.

In detail, 3 operating scenarios are distinguished:

- ✓ When the district heating company completely interrupts the supply of thermal energy - in this case, the 2 heat pumps will be turned on and will supply the heating agent glycol solution 63/58C, so that, on the heat exchanger's secondary, we can supply to the building, to the heating system VCV thermal agent 60/50C, and thus we can ensure an emergency heating of the building, during the day (when the building is functional, occupied) with the 320-360-380kW that can be delivered by the 2 heat pumps, depending of the outside temperature. This power was also selected in order to use the pipes already existing in the building and not have to replace/recreate routes in the functional building. In this scenario, the ventilation units will not work permanently, but only when the outside temperature is higher (the period from the middle of the day - 11-15 hours), so that we do not cool the building, considering that we do not deliver all the necessary energy the building to reach comfort parameters;

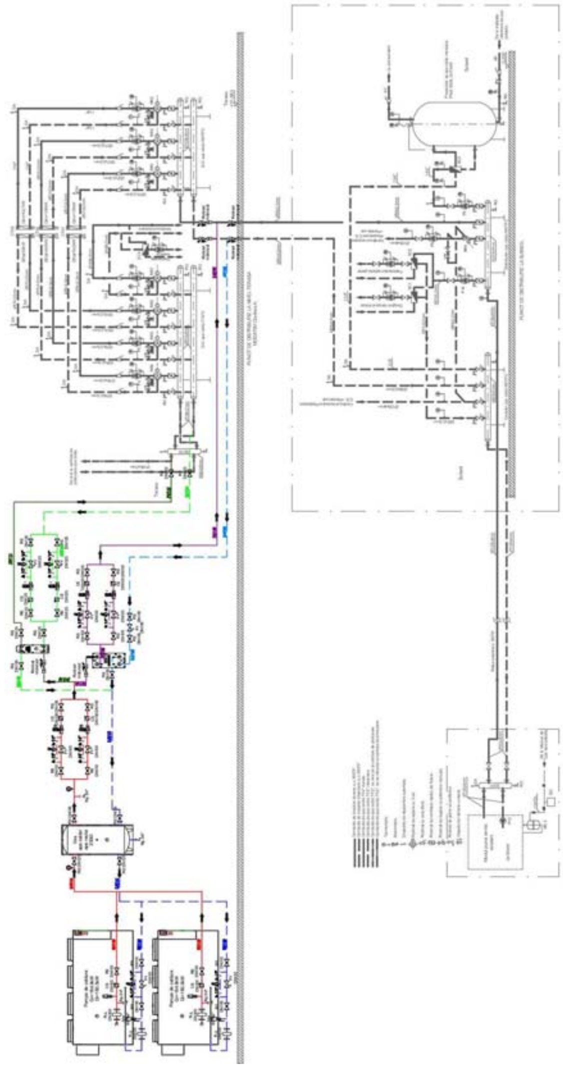

Figure 4. Functional diagram of the proposed solution

✓ The district heating company does not interrupt the supply of thermal energy, but delivers it at lower parameters, and thus it is not possible to maintain the comfort temperature in the building - in this scenario, the system will work with the 2 heat pumps on, providing the heating agent glycol solution 63 /58C, so that, on the secondary side of the heat exchanger, we can supply to the building, only for CTAs, thermal agent 60/50C, and thus we can ensure the heating of the ventilated air, with the 320kW delivered by the 2 heat pumps. The rest of the energy will be taken from the heating system. In this scenario, comfort parameters can be ensured for the entire building, both for the VCV system and for the CTA;

✓ Summer operation, in case of failure of the existing main cooling equipment of the building - in this case, the solution allows starting the heat pumps in cooling mode, delivering glycol agent at 7/12ºC, which does not allow us to deliver after the heat exchanger heat, chilled water agent with a temperature of 9/14ºC and thus being able to supply to the VCV or to the CTAs a power of 370kW.

The equipment that will have to be installed to realize the scenarios described above are:

- *Heat pumps, model Zeta Rev HP XT 18.4*
- *Simple circulation pumps for the circuit Storage vessel - Heat exchangers, Hot heat exchanger - Building installation, Cold heat exchanger - Building installation.*
- *Plate heat exchanger for heating and cooling.*

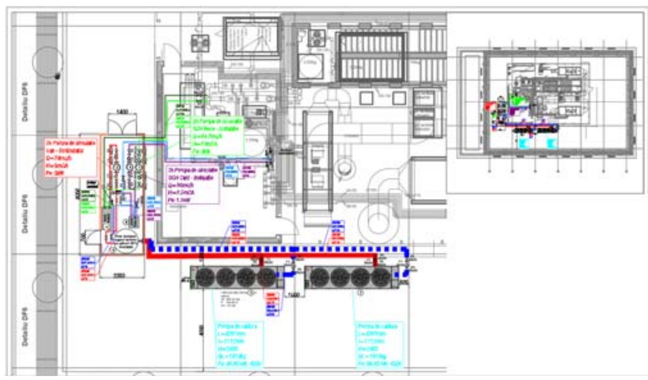

Figure 5. Location plan of the equipment in the proposed solution

4. CONCLUSIONS

The need for this solution appeared with the multiple breakdowns that occurred in the thermal energy distribution system from the heating company. Implementation of an alternative system for emergency heating of the existing office building, in case of total interruption of thermal energy from the heating company and a complementary backup system, when the energy supplied by the heating company is not at the required/necessary parameters for operation the correctness of the installations.

The alternative system distinguishes 3 operating scenarios:

• the district heating company completely interrupts the supply of thermal energy - in this case, the 2 heat pumps will be switched on and will supply heating agent to the building, the HCV system, and thus we can ensure an emergency heating of the building, during the day, when the building is functional, occupied. the heating company completely interrupts the supply of thermal energy - in this case the 2 heat pumps will be switched on and will supply heating agent to the building, to the HCV system and thus we can ensure an emergency heating of the building, during the day, when the building is functional, occupied.

• the district heating company does not interrupt the supply of thermal energy, but delivers it at lower parameters, and thus the comfort temperature in the building cannot be maintained - in this scenario, the system will work with the 2 heat pumps on, supplying thermal agent to the building, only for CTAs and so we can ensure the heating of the ventilated air.

• Summer operation, in case of failure of the main existing cooling equipment of the building – in this case, the solution allows the heat pumps to be started in cooling mode.

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