THE USE OF HEAT PUMP SYSTEMS IN DISTRICT HEATING

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Abstract **– One of the schemes of heat pump system usage for the decrease of return delivery water temperature after district heating systems is considered. Transcritical HPS cycles which use CO_2 (R744) as a working agent are examined as well.**

Keywords: *heat pump systems, transcritical cycle, district heat systems.*

1. INTRODUCTION

Introduction of integrated heat supply systems consisting from CHP plants and distributed power generation sources, for example, heat pumps systems, is one of the ways to increase district heating systems efficiency. The problems of heat pumps usage in district heating systems for achieving delivery water high temperature schedules are not covered wide enough in corresponding literature.

This article outlines the scheme of the central heat supply station (CHSS) with built-in heat pump system with CO_2 (R744) as the working agent.

Heat pump cycles for cold (winter) and transitional (autumn, spring) periods of the heating season are shown and the possibility to obtain heat pump systems COP in 4.2…6.2 range during HPS transcritical cycle work is demonstrated.

Results of the pay-back period estimation and net present value based on methods described in [3, 4, 5] for HPS usage in CHSS with the thermal power of 1.6 MWt are demonstrated as well.

2. HEAT PUMPS IN DISTRICT HEATING

The use of CO_2 as a working agent for the heat pumps is proved in [6, 7, 8] and a lot of other papers. As a result of the fact that heating system power for the winter and the transitional period differs in 2,5-3 times, only one HPS usage looks to be economically inappropriate to ensure district heating and hot water-supply. It seems to be more rational to ensure district heating and hot water-supply using 2-3 HPS with the decreased power, where each HPS operates at its temperature of evaporation and its span of the sliding temperature of the gas cooler.

This problem requires the additional research and will be discussed in the next papers. When the evaporator of HPS is installed at the outlet of the delivery water of CHSS of district heating system (DHS) and the gas cooler is installed at the mixing DHS pipe line it becomes possible to decrease the temperature schedule of heating. Water temperature decrease on the inlet of DHS allows of trunk pipelines capital intensity reducing (during their maintenance or reconstruction).

The decrease of the return water temperature coming to CHP plants leads to the reduction of the low-potential heat used for CHP plant auxiliaries and it becomes possible to produce additional electricity as well.

The aggregate of mentioned factors brings to the decrease of the fuel consumption which leads to the increase of technical and economic characteristics of DHS as a whole and improves the ecological situation in the region because of the decrease of CO_2 emissions and water losses from the cooling towers to the atmosphere.

2.1. Heat pump scheme for district heating

Let’s consider the scheme of the central heat supply station (CHSS) with built-in heat pump.

On the fig.1: 1- DHS control valve, 2- load (many-storied buildings), 3 – gas cooler, 4- compressor, 5 – HPS evaporator, 6 - CHSS circulation pump of, 7- throttling valve, 8 – internal heat exchanger of HPS.

Heat pump system is connected to the DHS return water pipe line which comes back to CHP plant.

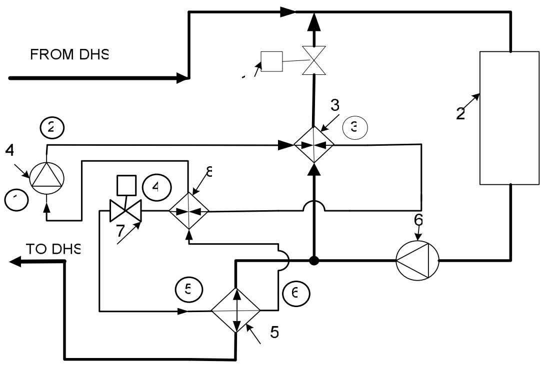

Figure 1: Schematic of CHSS with built-in HPS.

Other part of return water flow which is being mixed with direct water from power plant and is heated in the HPS gas condenser (due to heat export out of HPS).

The cooled flux of the return water on power plant can enter in network heaters or in the steam turbine condenser (in the main or in the built-in heat exchanging bank).

2.1.1. Temperature charts

Equations which determine the dependence between direct and return delivery water temperatures are described in different manuals, see for example [9, 10], and are not cited here.

For the delivery water coming from the CHP plant the temperature schedule 80/30 is applied, and for DHS schedule is – 80/35. The specified temperature of the ambient air is assumed to be equal to -16^{0}C, and the temperature of the ambient air when heating season is finishing is assumed to be 6^{0}C.

80/35 temperature chart usage is determined by the fact that currently massive introduction of horizontal double-pipe heat systems in multistoried buildings is planned. In this case the temperature of the water supplied is the same for all heating appliances.

2.1.2. Heat pump cycle

The transcritical cycle of heat pump in the h-p Diagram for Carbon Dioxide (R744) (H [kJ/kg] –P [MPa]), at the ambient temperature -9^{0}C is shown at the Figure 2.

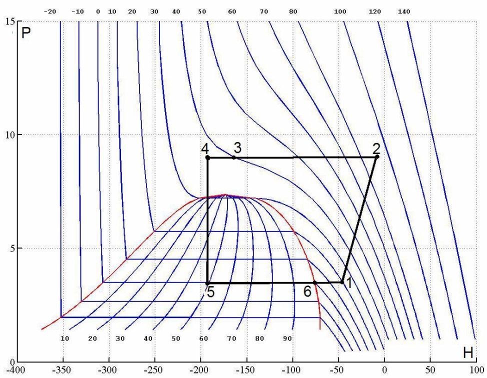

Figure 2: Thermodynamic cycle for the temperature of the air -9^{0}C.

Parameters values of the working agent in points 1…6 of HPS (see, Fig.1) are shown in Table 1.

№ of the point	T(^{0}C)	P(MPa)	H(kJ/kg)
1	20	3,5	-45,5
2	90	9	-9,47
3	40	9	-162,87
4	37,2	9	-192,38
5	0	3,47	-192,38
6	0	3,47	-75,82

Table: 1. Parameters and their values

The Coefficient of Performance of HPS is [COP=4,26] (Recall that COP is defined as the desired heat transferred divided by the work done on the compressor).

The transcritical cycle of heat pump in the h-p Diagram for Carbon Dioxide (R744) (H [kJ/kg] –P [MPa]), at the ambient temperature 6^{0}C is shown at the Figure 3.

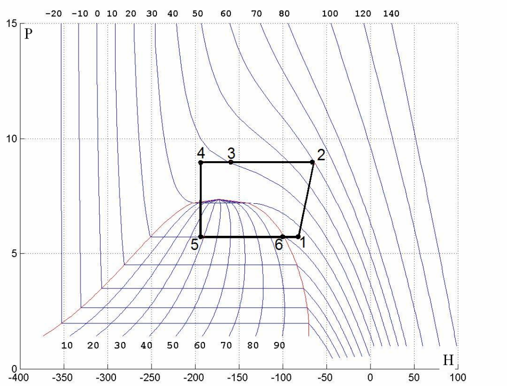

Figure 3: Thermodynamic cycle for the temperature of the air 6^{0}C.

Values of parameters of the working agent in points 1…6 of HPS (see, Fig.1) for this case are shown in Table 2. In this case [COP=6,24].

P-h diagrams are made according to the equations elaborated by R. Span and W. Wagner [11].

№ of the point	T(^{0}C)	P(MPa)	H(kJ/kg)
1	25	5,73	-81,87
2	60	9,0	-64,04
3	40	9,0	-162,87
4	37	9,0	-194,01
5	20	5,73	-194,57
6	20	5,73	-98,70

Table: 2. Parameters and their values

After the investigation of thermodynamic cycles becomes evident that it is necessary to use the adjustable compressor and heat-exchange equipment with varying heat-exchange surface which changes depending on the ambient temperature and the temperatures of the direct and return delivery water or the use of some HPS of the smaller output.

Modeling results show that with the decrease of the ambient temperature the relationship between the CHSS thermal power and HPS thermal power increases from 0, 13 at the ambient temperature 6^{0}C to 0, 39 at the ambient temperature -9^{0}C.

2.1.3. Economic efficiency of the use of HPS

One of the most important indexes of the investment project is pay-back period and Net Present Value. We assumed the bank rate to be equal 0.14, inflation index equals 0.1.

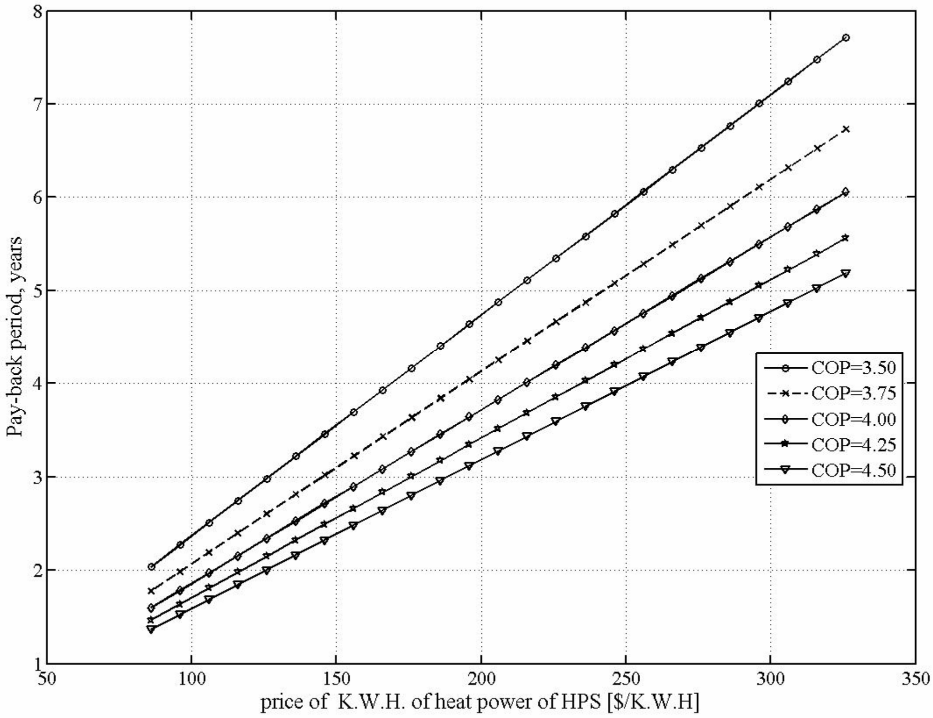

Fig.4 Relationships between the pay-back period of HPS (heat pump station) and the price of K.W.H. of HPS at the different COP of HPS.

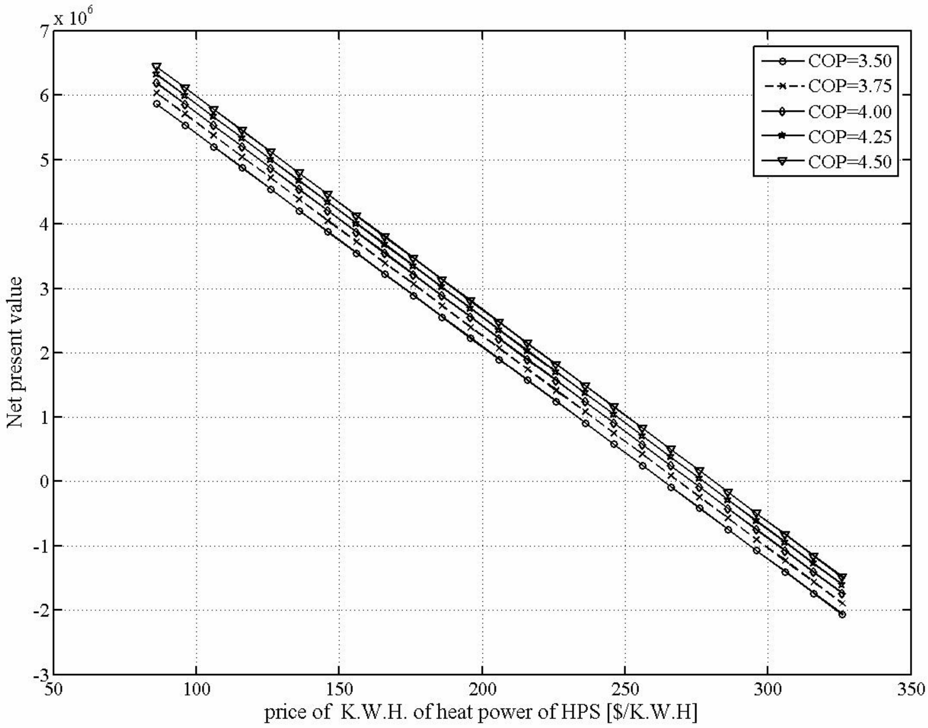

Fig.5 Relationships between the NPV of HPS (heat pump station) and the price of K.W.H. of HPS at the different COP of HPS.

Figure 4 shows the relationships between the pay-back period of HPS (heat pump station) and the price of K.W.H. of HPS at the different COP of HPS. Figure 5 shows relationships between the NPV of HPS (heat pump station) from COP and the price of K.W.H. of HPS.

4. CONCLUSIONS

The scheme of CHSS with built-in HPS which works in the integrated heat supply system with the reduced temperature chart of heat supply system is examined. Carbon Dioxide is used as a working agent in HPS. The transcritical cycles of HPS are examined in the dependence of the ambient air temperature. The directions of the efficient use of heat pump systems on CHSS are proposed. The indices of technical and economic efficiency of the use of HPS in CHSS are determined.

Acknowledgments (if any) should appear as a separate non-numbered section before the list of references.

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