HEAT PUMPS TECHNOLOGY IN A CENTRALIZED HEAT SUPPLY SYSTEM OF RUSSIAN FEDERATION LARGE CITIES

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Abstract

In cities of Russian Federation there are large possibilities of using low-grade heat (LGH) in urban power facilities with the help of the heat pumps technology application. The experience of the heat pumps installations (HPI) application demonstrates the problem existence. Two principal schemes of LGH utilisation on district boiler-houses (DBH) and on heat power station (HPS) are under consideration. For heat supply reliability and profitability there are interconnections between water main of thermal HPS and DBH networks for DBH switching-off in summer. The estimations demonstrate that in heat supply systems of large cities it is possible to use till 45-50 % of LGH with CC 6-8 and till 60-70 % of LGH with CC 4-5. It is about 40 % HPS LGH put to the heating season and about 60 % - to the not heating season. In the not heating season it is possible to use about 20-25 % of thermal emissions on HPS, or 12-15 % from all LGH annual volume. For 600 million $ HPI investments payback time will make 3-3.5 years. Other rather perspective direction in HPI application can become carbonic acid using as a good mass and heat carrier.

KEYWORDS

Heat issue, heat power station, low-grade heat, heat pump installation, energy tariffs, inlet network water, principal scheme, estimations, investments payback time.

INTRODUCTION

During 1991-1997 the heat issue on the Russian heat power stations (HPS) have decreased from 721,9 to 515,1 million of Giga cal, on district boiler-houses (DBH) heat issue was 1218,5 and total heat issue in Russian Federation was 2630,6 million of Giga cal. In Moscow, St.-Petersburg and Ekaterinburg the heat issue on HPS makes 70-85 %, and on DBH - 15-30 % from all volume [1].

In cities of Russian Federation there are large possibilities of using low-grade heat (LGH) in urban power facilities with the help of the heat pumps technology application.

Until recently, activities on development of heat pumps technology were separate. In Russian Federation were constructed heat pump installations (HPI), which mainly execute demonstration functions. There are installations in Nizhni Novgorod, Novosibirsk, Saratov, Moscow, St.-Petersburg and other cities. The increased interest to heat pumps technology development has been exhibited in last 5-6 years. It is conditioned by continuous rise in price of primary power resources. The prices on power supplies are also increase.

The experience of the HPI application demonstrates the problem existence. The main problem is the absence of normative - legal documents regulating interplay of urban power facilities structures, financial structures (commercial banks, investment funds etc.) and energy providers. There is no clearness at mutual business accountings for produced heat at availability HPI and financing of the

given technology. The difference of interdepartmental concerns restrains collaboration of the called documents and exploitation of already set HPI.
However the heat pumps technology will be called for in future. Now only on HPS of the "RAO ES of RUSSIA" not less than 140 - 150 million Giga cal is throw-out in environment by a circulating system of cooling water (CSCW). In Russian Federation regions the LGH loss volume is various, for example, at the open water-pumping scheme. It is necessary to consider centralised heat supply system (CHSS) features in each region. Until recently, effective technologies of LGH utilisation were missed.

Let's consider HPI application advantages in CHSS conditions. For heat supply reliability and profitability there are interconnections between water mains of thermal networks HPS and DBH for DBH switching-off in summer. The heat is transmitted by means of HPS hot water. It changes a part of combined development of thermal and electrical energy in a non-heating season. However, in last 3-4 years in connection with transition to market relations this CHSS operation principle was disturbed by the cause of the HPS and DBH thermal energy tariffs difference. The HPS thermal energy tariffs were underestimated in comparison to their value for DBH. In outcome the urban services Teploenergo have gained a thermal energy HPS on the undervalued tariff and realised on overpriced (established for Teploenergo firms). Thus there were no additional expenses. Now producing and HPS and DBH heat realisation fulfils separately all the year. Such situation takes place in Moscow.

TECHNICAL POTENTIAL ESTIMATION OF CHSS LGH USAGE AND SCHEMATICS

The fields of HPI application in CHSS with HPS LGH utilisation with high conversion coefficient (CC) 6-8 due to interconnections between HPS and DBH thermal mains are shown on the table 1. In a fig. 1 the scheme LGH HPS utilisation with usage on DBH is adduced. The network water temperature graphs in urban HPS networks and DBH are differing slightly. The flow of inlet network water (INW), recoverable on HPS, passes through HPI evaporators and cooling up to temperature 20-25°C. Chilled INW temperature is substantiated with CHSS regional features account. INW moves in the condenser of a steam turbine (in the main or built-in tube bundle). The condenser executes functions of additional INW heater. Now LGH on HPS completely "rejects" in the environment by a circulating system of cooling water (CSCW);

Table 1 The HPI application in CHSS

HPI application field in CHSS		Heating temperature, °C						
		30	40	50	60	70	80	90
Heating of supplied water in thermal networks	on HPS	+	+	+				
	on DBH	+	+	+				
Water heating in heater system	on central heat point (CHP)			+	+	+	+	
	of CHP hot water facilities		+	+	+			
DBH return network water heating using interconnections						+	+	+
Social objects heating: schools, buildings association, basins and others		+		+	+	+	+	
general purpose objects heating and hot water facilities (HWF):	industrial objects (shops, buildings)			+	+	+	+	+
	underground parking			+	+	+	+	+

The HPI application in CHSS is represent to most effective. The team working in the most advantageous temperature range for heat pump and conventional CHSS equipment is possible. The HPI scheme used in CHSS for LGH utilisation is showed below. The electric power development on HPS on thermal consumption increases, the fuel consumption on DBH (Fig. 1) reduces.

In a fig. 2 HPI take LGH from CSCW and transmit it to its crude water (from a flow A up to flow B after chemical water clearing (CWC)). The heated water goes in a vacuum deaerator and then in the main flow of network water. CC makes 7-9 on 1-st HPI stage and 5-6 on 2-nd HPI stage. The INW flow, recoverable on DBH, passes through HPI condensers heated on 15-20^{o}C (it may be more), that results in essential fuel consumption reduction on DBH.

For such scheme the interconnections between thermal HPS and DBH mains should be involved and the problems of mutual settlements between HPS and DBH are resolved, according to HPI belonging and individual share of the investors in HPI facilities. There is a possibility of facility HPI and large HPI manufacturing at plants of Russian Federation.

The heating by dead steam expediency of chilled INW supplying in the condenser is shown by the OAO "Ural TMZ" specialists for central heating T-250/300-240 turbines.

The estimations demonstrate that in heat supply systems of large cities it is possible to use till 45-50 % of LGH with CC 6-8 and till 60-70 % of LGH with CC 4-5. In first case consumption by the HPI compressor will be minimum. It is about 40 % HPS LGH put to the heating season and about 60 % - to the not heating season. The estimations of HPI operational effectiveness are carried out for LGH with CC 6-8.

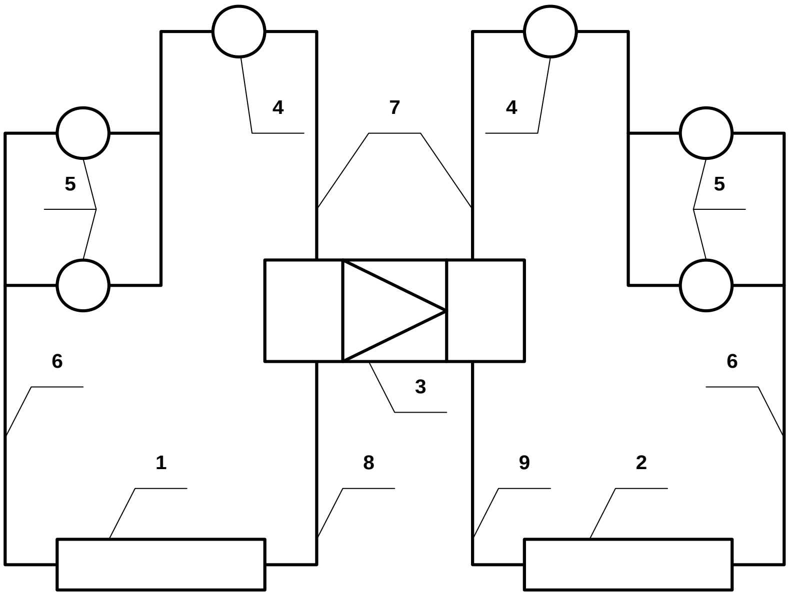

Fig. 1The principal scheme of heat power station (HPS) low-grade heat (LGH) utilisation on district boiler-houses (DBH)

1-HPS; 2-DBH; 3-heat pump installation (HPI); 4-pumpes of network water; 5-thermal customers; 6-primary network water (PNW) pipe lines; 7- inlet network water (INW) pipe lines; the 8- INW chilled pipe line, recoverable on HPS; 9- INW heated pipe line, recoverable on DBH;

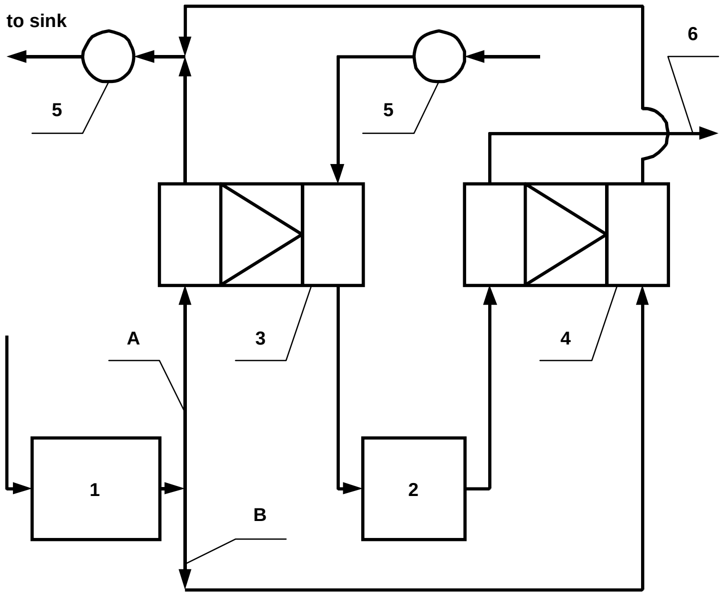

Fig. 2 The principal scheme of circulating system of cooling water (CSCW) low-grade heat (LGH) utilisation on heat power station (HPS).
1 - LGH source; 2 - chemical water clearing (CWC); 3 - HPI-1; 4 - HPI-2; 5 - circulation pumps and feed water pumps; 6 - network water after heating in HPI-1 and HPI-2.

In the not heating season it is possible to use about 20-25 % of thermal emissions on HPS, or 12-15 % from all LGH annual volume. This level can be essentially increased, if the economic heat warehousing solutions for the summer season, for example, in underground storage or self-contained lenticles on no-bottoms will be retrieved, as in Sweden and other countries. In the heating season this value can reach 80 % from a volume of thermal emissions on HPS, i.e. about 32 % from LGH volume of thermal emissions. The LGH usage volumes are depended on region.

The high CC values can be reached using HPI for a partial heat carrier heating with additional heating in CHSS. The LGH transformation cycle realises in one temperature range because of technical and thermodynamic expediency. The high performance of HPI application is stipulated for heat carrier parameters values affinity in HPS networks and DBH.

At HPI building the costs minimisation and exploitation simplicity is relevant. The HPI equipment manufacturing base availability is required at rather reasonable prices on the equipment.

The heat pumps technology application efficiency estimation and scales in CHSS in cities of Russian Federation is conducted. The technically sold potential LGH HPS in CHSS at the HPI application expense can be not less than 70-80 million Giga cal annually (with CC 5-8). It is equivalently 12-14 million tons of standard organic fuel annual economies. Consumed power of HPI compressor will make 2.3-2.5 thousands MWt with approximately 14 thousands Giga cal/hours total HPI power.

The consumption of the electric power on the HPI compressor drive will make about 14 thousand GWt×h/year, and heat development with the help HPI - approximately 70 million Giga cal/year. At the average tariffs for heat (140 Rouble/Giga cal) and electric power (300 Rouble/MWt×h) in "RAO ES of RUSSIA" the economies will make about 185 millions $ annually. For 600 million $ HPI investments payback time will make 3-3.5 years.

The HPI operational effectiveness can be notably greater. HPI application estimations with 40 Giga cal/h power on Moscow HPS demonstrates that payback time will make a little more than 2 years. On occasion there are rather favourable use HPI conditions in CHSS.

On aeration station LGH INW flow transportation to adjacent thermal DBH networks is possible. It will demand to build 2 separate HPI, one of which transfers the INW heat from network adjacent. The adjacent network flow is heated on HPI using aeration station LGH and then heat up in DBH. At such LGH utilisation scheme the CC will not exceed 3.5-4.

At HPS INW flow chilldown with the help of HPI mounting the only one HPI stage is necessary. LGH is transmitted throw interconnection from cooled HPS INW flow to DBH INW flow. Thus CC makes 6-8. It is one of major features of HPS LGH using with the help of HPI return network water heating that is recoverable on DBH.

Other direction of HPI application is depends of network water on HPS and DBH loss heat cost. In a fig. 2 the scheme of CSCW LGH utilisation on HPS for heating crude and chemically cleared water for network water losses fulfilment is shown. The crude water in 1-st stage is preheated up to 30^{o}C, and in 2-nd stage up to 50^{o}C. The circulating water going on water-cooling towers will be used as LGH source. The application HPI at 1-st stage of a heating of crude water provides CC 7-9, and at 2-nd stage 5-6.

Heating DBH network water going throw HPS networks interconnections can increase HPI productivity for HPS LGH utilisation. The heat consumption on HPS for network water loss fulfilment and the HPS LGH utilisation with the help of HPI, placed on HPS are increases. HPI CC will be 6-8, but it is necessary to determine the tariffs for network water sold to DBH. The tariffs should stimulate HPS on HPI building and DBH interest to network water from HPS networks losses fulfilment.

It is necessary to mark that the HPI types differ on a principle of operation, which results in the different solutions on HPI application in CHSS. All earlier set up responds more to compressive type HPI, whereas broad application can find an absorbing type HPI (AHPI). For example, at availability LGH and the vapour with different parameters on HPS allow to organise HPS LGH utilisation practically without power consumption also including supplied network water heating. Let's not esteem explicitly AHPI efficiency problems in CHSS, we shall mark only that fact, that AHPI can provide CC about 1,7-2, sometimes higher, but without power consumption. AHPI advantage is absence of rotated mechanical parts that simplifies HPI control procedure activity.

Other rather perspective direction in HPI application can become carbonic acid using as a good mass and heat carrier. This direction demands steadfast attention from stands of the application and creation actual fields substantiation of manufacturing capabilities on carbon dioxide cycle compressors manufacturing. More details of this problem are given in [2].

Nomenclature

HPS-heat power station; DBH-district boiler-house; LGH-low-grade heat; HPI-heat pump installation; CSCW-circulating system of cooling water; CHSS-centralised heat supply system; CC-conversion coefficient; INW-inlet network water; CHP-central heat point; CWC-chemical water clearing; HWF - hot water facility; PNW-primary network water; AHPI-absorbing type HPI

Referemce

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