HEAT PUMPS APPLICATION IN BULGARIA

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Abstract

Heat pumps have received a wide application in Bulgaria for space heating of buildings and greenhouses and have been utilizing for more than 20 years.
The total installed heat pumps capacity for geothermal use amounts up to 13.3 MWt, the annual energy use is 162 TJ/year and average capacity factor - 0.39.
Heat pumps applications have been analyzed in terms of the technological advantages and disadvantages appearing in many years of exploitation.
The new stage of geothermal heat pumps development started in Bulgaria with the application of low temperature ground water. A recently constructed installation (1999) for space heating and air-conditioning of a commercial building in Sofia is discussed in more details. The heat pump is used in ground water open loop mode. The water temperature is about 14^{o}C, flow rate is of 3.1 l/s, heat pump heating capacity is 140 kW and cooling capacity - 130 kW. The economic results of its exploitation show high efficiency and prospects for a future application.

Keywords - heat pumps, geothermal heat pumps, Bulgaria

1. Introduction

Geothermal energy use for space heating has a long tradition in Bulgaria. The first experiments have been realized within the period 1950-1980 on hydrothermal reservoirs in Southern Bulgaria (towns of Kjustendil, Sapareva banja, Velingrad, etc). Direct schemes for space heating, greenhouses and swimming pools have been constructed there. The choice of those sites was based mainly on the comparatively high water temperature – above 70^{o}C.
The water temperature on the territory of the country is varying within the interval 20^{o}C-100^{o}C [2]. About 72% of the discovered flow rate is of temperature up to 50^{o}C and is not suitable for conventional radiator systems. The application of low temperature thermal waters (40^{o}C-60^{o}C) assumed introducing plate heat exchangers and heat pumps in the technological schemes.
The first modern Bulgarian systems for a complex use of geothermal waters have been constructed after 1980. Some of them are assisted by plate heat exchangers and heat pumps and others - only by heat pumps.

Totally eight geothermal heating systems applying heat pumps have been built up in Bulgaria. They have proved their high economical efficiency during the long period of exploitation under the existing climate conditions and resource.

The biggest installed capacity for a geothermal system in Bulgaria amounts to 15 MWt, out of which 5.85 MWt are for the heat pumps and 9.2 MWt - for the fossil fuel boiler. This system is located in a Black sea resort ("Slanchev den") and provides space heating, air-conditioning and domestic hot water for several buildings [1].
All installations assisted by heat pumps are currently in operation. The major problems appeared during their exploitation are related to corrosion caused by the geothermal water.
Lately most of the new administrative and one-family buildings have been built for low temperature heating systems ($50^oC/45^oC$, $45^oC/40^oC$) applying fan coils for the internal installation. This fact implies that comparatively low temperature waters in Bulgaria could achieve a wider application under these circumstances.

Geothermal waters of temperature above 50^oC might be used only by heat exchangers under the existing climate conditions in the country, resource potential and heat load of the buildings. Heat pumps are better choice for geothermal water temperature less than 50^oC. In the cases of high heat loads both equipments have been applied - heat exchangers and heat pumps.

The intensive construction of buildings (administrative, commercial and hotels) in the bigger towns of the country nowadays has led to a wide introduction of air-to-water type heat pumps. The existing legal regulations for their application are more favorable compared to those for the water-to-water type. Companies carrying out this activity avoid applying for well drilling permissions and also starting a procedure for receiving a concession for geothermal water use. On the other hand the disadvantage of these new systems is the reduction of effective coefficient of transformation at outside temperatures below 0^oC. The air temperature decreases during the wintertime down to about (-12^oC) - (-14^oC) although this is for a short period. That imposes an installation of additional equipment for pick load and breakdown load to be in cooperation with the heat pump at outside air temperature below (-5^oC). Despite these disadvantages air-to-water heat pumps are mostly used nowadays instead of water-to-water type in order to speed up the construction of the new systems.
Most of the built up air-conditioning systems in Bulgaria assisted by air-to-water heat pumps are of capacity ranging from 0.1 to 0.3 MWt.

2. Heat pumps application

2.1. General information

Basic information on the existing indirect geothermal systems assisted by heat pumps water to-water type is presented in Table 1. They were built in the period 1981-1991.
The constructed geothermal stations assisted by heat pumps are mainly located in tourist centers developed on the northern Black sea coast (numbers 4, 5, 6, 7 and 8, Table 1). They are in operation all the year round and provide heating, air-conditioning and ventilation. Geothermal station (number 3, Table 1) is located in a spa complex in SW Bulgaria. Two installations (number 1 and 2, Table 1) are used for space heating of two indoor swimming pools situated in spa centers.

The installed heat pumps capacity for the all eight stations is ranging from 0.1 to 2.9 MWt per unit. The bigger installations (Figure 2 and 3) are equipped with heat pumps delivered from the leading world producers, like SULTZER, MC QUAY and TRANE. The rest of the equipment is also imported, like circulation pumps, plate heat exchangers, etc. Only for one installation (Varna city1) is used Bulgarian made heat pump of capacity 0.5 MWt.

Table 1. Indirect geothermal installations in Bulgaria assisted by heat pumps (water-to-water type)

N	Locality	Water temp. ^{o}C	Heat pump capacity, kW	Number of units	COP	Full load, hr/year	Thermal energy used, TJ/yr
1	Hisar town	46	260	1	4.5	1051	0.765
2	Bankja town	36	260	1	4.7	3013	2.22
3	Sandanski town	40	1200	4	4.6	3819	12.91
4	"St.Konstantin and Elena" resort, (Black sea coast)	42	5850	2	4.3	4774	77.16
5	Varna city-1	37	1500	4	5.8	4207	18.8
6	Varna city-2	55	2860	2	6.3	3849	33.34
7	"Golden sands " resort, Black sea coast (Magnolia hotel)	30	1000	1	5.4	4496	13.19
8	"Golden sands" resort, Black sea coast (Riviera)	31	350	1	4.9	3590	3.60

Some Bulgarian companies, like Institute of Refrigeration and Air-conditioning (Sofia), Pinguin J.N.,Ltd (Sofia) and others started assembling heat pumps, using imported elements - compressors type Bitzer, heat exchangers - Onda or Riva Cold, automatics - Danfoss, Siemens Landis & Staefa Division, plate heat exchangers - Alfa Laval, etc.

Type of the scheme and heat pump selection for every single system depends on many factors, like:

- Flow rate and water temperature of the geothermal source
- Type of the internal heating and air-conditioning installations (low temperature fan coil or high temperature radiator system)
- Climatic conditions of the region
- Chemical water content
- Heat load of the building.
- Term of concession contract, etc.

Figure 1. Heat pumps installation in"St.Konstantin and Elena"resort, (Northern Black Sea coast)

Figure 2. Heat pumps installation in "Golden sands" resort, (Northern Black Sea coast)

2.2. Advantages and disadvantages of heat pumps installations

The long period of heat pumps exploitation discovered clearly their advantages and disadvantages under the complex conditions in the country. The systems built for the hotels located on the Black sea coast have a higher load factor compared to those situated inside the country.
Advantages:

- High coefficient of performance (COP) - (4 - 6).
- High load factor - up to 0.58 for a system on the Black Sea coast.
- Low prime cost of the produced energy – (5.4 EUR/GJ - 6.8 EUR/GJ)
- Good comfort inside the building maintained by the air-conditioning systems.
- No contamination of CO_2, SO_2 and NO_x, which is of great significance for the resort and spa areas.

Disadvantages:

- Corrosion on the intermediary heat exchangers. They have to be replaced after 6-7 years of exploitation.
- Scaling on the surfaces of the intermediary heat exchangers.

The disadvantages are related mainly to the lack of water processing with inhibitors. Most commonly the geothermal fluid is used for balneotherapy after being used for heating and its chemical content should remain unchanged.
The heating season in Bulgaria lasts about 160 - 180 days and during the summer time the geothermal energy is partially used only for domestic hot water preparation. For this reason the

load factor of the systems is low of average about 40% - 46%. Most of the existing geothermal wells are rather old and deteriorated and additional pick load systems are commonly built to meet 60% of the heat load in case of break down.
No new systems using water-to-water heat pumps have been built after 1991 for the following reasons:

- High initial investments
- Long lasting procedure for obtaining permissions for drilling and wells legalization.
- Long lasting procedure for delivering a concession for geothermal energy use and in some cases a high concession fee.
- Lack of geothermal water treatment with inhibitors before using for balneotherapy.
- Lack of domestic and foreign investments for building up new spa complexes or renovating the existing ones.

Most of the spas in Bulgaria are situated in mountainous regions and are operating as tourist and recreation centers as well. For this reason they are excellent opportunity for a cascade geothermal waters use. Geothermal water application is environmentally friendly compared to the air pollution caused by fossil fuels commonly widely used for heating in the spa centers.
Heat pumps application will be growing under the new construction technologies because they proved to be energy efficient and meet successfully the requirements of the local market.

3. Utilization of low water temperature for heating and air-conditioning

Recently started the application of geothermal heat pumps that is a new step of technological application for ground water energy use in the country.
The first installation of that kind was built in Sofia City in 1999, Figure 3 and 4.

Figure 3. Space heating, air-conditioning and ventilation (Curtis-Balkan Ltd, Sofa City)

Figure 4. Heat pump (Curtis-Balkan Ltd, Sofia City)

It provides heating and air - conditioning for an administrative and industrial building of a private American company Curtis-Balkan, Ltd. The whole project is designed and constructed by Bulgarian specialists.

3.1. Basic information [3]

- Water source

The heat pump utilizes underground water from about 80 m deep well by a submersible pump (GRUNDFOS) fixed at 30 m depth. The water temperature is 14^{o}C and the flow rate used is 3.1 l/s.

- Brief description of the installation, Figure 5.

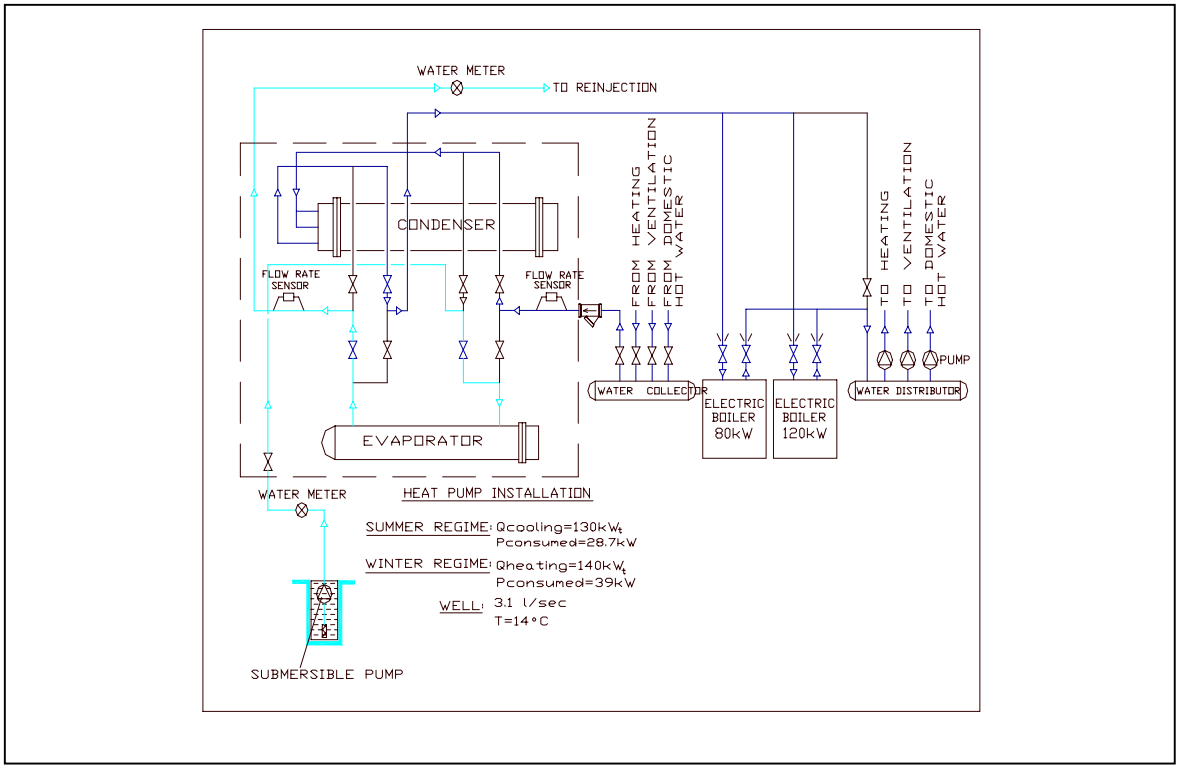

Figure 5. General scheme of the geothermal installation (Curtis-Balkan Ltd, Sofia City)

The scheme is designed for the following outside parameters: winter reference temperature - (-16^{o}C), summer reference temperature - (+ 33^{o}C) and 32% humidity. The number of the heating hours amounts to 4896.

The required microclimatic parameters inside the building are achieved by a system of fan coils for heating during the wintertime and cooling during the summer time. The aluminum radiators are installed in the humid rooms. Ventilation system is fit with the production premises.

The energy supply to the whole system is provided by a heat pump of 140 kW (heat capacity) and 130 kW (cooling capacity). The heat pump installation is water-to-water type. The applied

electrical compressor is type BITZER (made in Germany). Two electrical boilers of 80 kW and 120 kW capacities are installed for the peak and breakdown loads.
The domestic hot water preparation is carrying out in a tank with additional electrical heaters. Circulation pumps (WILO) provide circulation of hot/cooled water to the heating, air-conditioning and ventilation systems.
A central controller provides automatic regulation of the heat pump operation and the peak load boilers. Room thermostats control the regime of exploitation of fan coils in each premise. The regulation of the ventilation is by a separate system controlling the temperature of the supplied air.

All requirements related to the thermal insulation of the building have been fulfilled and it reached a high thermal stability. That led to low heat and cooling loads and high efficiency of system operation. According to the obtained summarized data the mean prime cost of 1 GJ of produced heat (respectively cold) is 6.1 EUR/GJ. It is lower than the cost of 1GJ produced by the fossil fuels heat plants moreover that they are still subsidized by the Government.

Conclusions

The future development of the heating systems in the country would be associated with the wider application of low temperature fan coils systems applying heat pumps water-to-water, air-to-water and GSHP. They have proved to be the most economically effective solution for the buildings constructed in the country during the last several years. In addition they are environmentally benign compared to the conventional fossil fuels heating systems.

References

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