Heat pumps for heating Aula at VŠB - TU Ostrava

Zdeněk Hradílek, Petr Zach

Department of Electrical Power Engineering,
FEECS, VŠB – Technical University of Ostrava,
17. Listopadu 15/2172, 708 33 Ostrava-Poruba, Czech Republic
zdenek.hradilek@vsb.cz, petr.zach@vsb.cz

Abstract. The article deals with assessment of four heating seasons with operation of heat pumps in the Assembly Hall at Vysoká škola báňská – Technical University of Ostrava. The heating system in this newly built Assembly Hall makes use of 10 heat pumps manufactured by the IVT company from Sweden with the total capacity of 700 kW. The source of low-potential heat comprises of the system including 110 boreholes drilled to the depth of 140 m. The bivalent, i.e. auxiliary, source is then represented by the heat exchanger station for centralised heat supply. The heat loss incurred within the Assembly Hall, at the Outdoor temperature of -15°C, amounts to approx. 1200 kW.

1 Introduction

This article deals with assessment of the heating within the Assembly Hall of Vysoká škola báňská - Technical University of Ostrava. The Assembly Hall heating is provided by means of bedrock source heat pumps. The choice of primary heat source has substantial impact on the design and characteristics of heat pumps. The bedrock source heat pumps – the water carries heat from the depth of Earth´s surface using exchangers, the so called "collectors". The primary circuit of heat pumps is a closed one. The heat carrying liquid used within must be resistant to frost and friendly to the environment. The heat obtained is further transmitted into the heating water. Geothermal heat is accumulated within the Earth´s bedrock mass. Drawing of heat cause gradual and uneven decrease of water temperature within the layer around collector and this layer will be expanding on progressive basis. That depends especially on the specific output of the relevant collector, the method of collector installation, the bedrock mass material and the continuous period of heat extraction during the heating season.

2 Description of Heating in the Assembly Hall

The building with Assembly Hall and the Information Technologies Centre is heated using bedrock source heat pumps. The source of low-potential heat used comprises of ground boreholes. The heat pumps provide for 82-85% of the heat supply for the building in an average year. The bivalent, i.e. auxiliary, source of heat is represented

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by the exchange station of the centralised heat supply. The building includes the ceremonial assembly hall, auditoriums, the multi-purpose hall, the Information technologies Centre with computer classrooms, development laboratories and office premises. The Assembly Hall building is a four-storey object with basement, formed by a reinforced concrete monolithic structure with a light glass-metallic shell. The total built-up area amounts to 3917 m2. The building basement is designed as underground garage with the capacity of 40 parking bays. This area is also used for the technical amenities of the building: the transformer station, the heating and air conditioning control room, the electric distribution centre and storage space. The installed system of heat pumps is the largest one ever built in the Czech Republic and Europe. The heat source for this system comprises of 10 heat pumps manufactured by the IVT company from Sweden, with the total capacity of 700 kW based on the pattern of 110 boreholes drilled to the depth of 140 m (total borehole length of 15400 metres). The boreholes are located in the parking area adjacent to the Assembly Hall of VŠB – TUO and the library of VŠB – TUO. The boreholes fittings include four-pipe equipment with two loops of 32 mm PE pipeline classed DN with a special connection mount. The boreholes have been fitted with approximately 70000 m of PE piping. The boreholes have been injected with concrete mixture. The primary circuit is filled with an anti-freeze heat carrying liquid with the total volume of 18000 litres. The system of 110 boreholes converges into five collector shafts, which means 22 boreholes / 1 shaft. Every shaft is then linked with a separate pipe, mounted with a separate circulating pump. The heat loss of the hall – the heating performance required to achieve the necessary thermal comfort inside the hall, at the Outdoor temperature equal to -15°C, is approx. 1200 kW. The heating system includes the under-floor heating, heating bodies and air conditioning unit. The individual heating systems have been designed for low thermal gradient. The production of domestic hot water is provided by the plate exchanger within hot water accumulation magazines.

Table 1. Performance parameters of the heat pumps in accordance with EN255

Temperature [°C]	Heating output [kW]	Power input [kW]	Performance factor (-)
0/35°C	67.8	16.7	4.06
0/50°C	69.8	22.3	3.13

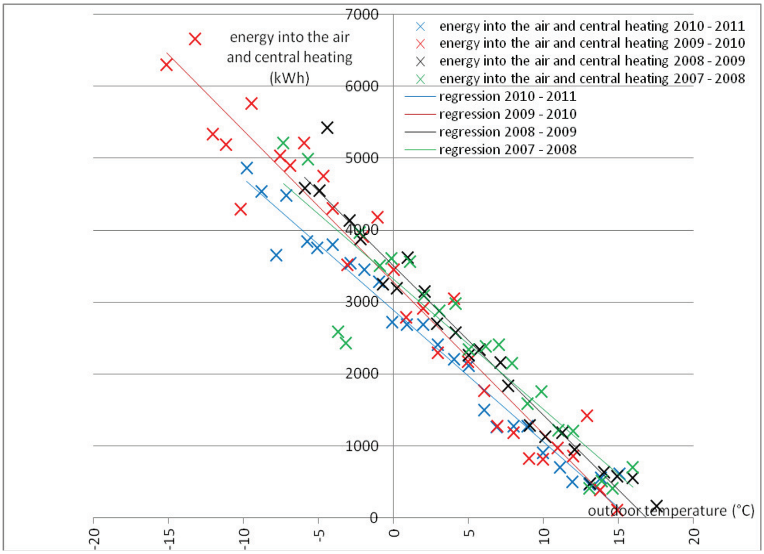
Fig. 1. Heat pumps, 10 units **Fig. 2.** Circulating pumps within the primary circuit

3 Assessment of the Database of Values Measured over Four Heating Seasons

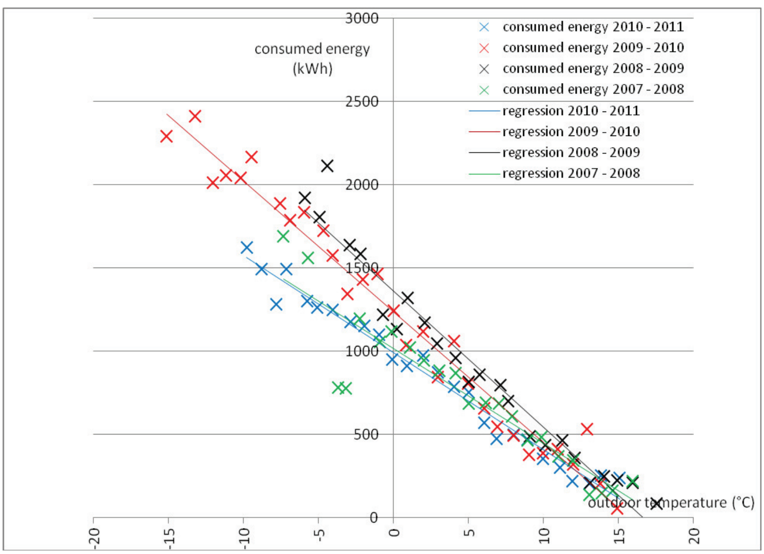
The heat pumps are controlled by the ProCop Monitor software. The software provides for automatic monitoring of all values within 10-minute intervals and saves results into the database. The ProCop Monitor monitoring and visualisation software is distributed in the Czech Republic by the Siemens company under the Visonik Alfa trade name. Data used for assessment have been collected over four heating seasons in the period between 2007 and 2011. The heating seasons subject to assessment within the period from 2007 till 2011 started on 1st October and ended on 30th April respectively. The tables below show assessment of the course of particular heating seasons: Outdoor temperature, the energy supplied by heat pumps, the energy supplied into the air conditioning system – hot-air heating, the energy supplied to the central heating system – under-floor heating + radiators, the energy consumed by heat pumps. Further data include resultant performance factor calculated per individual heating seasons. The performance factor represents the essential parameter showing the efficiency of a heat pumps, it is calculated as a ratio between the heat produced and the electric power consumed.

Table 2. Energy supplied and consumed in particular heating seasons

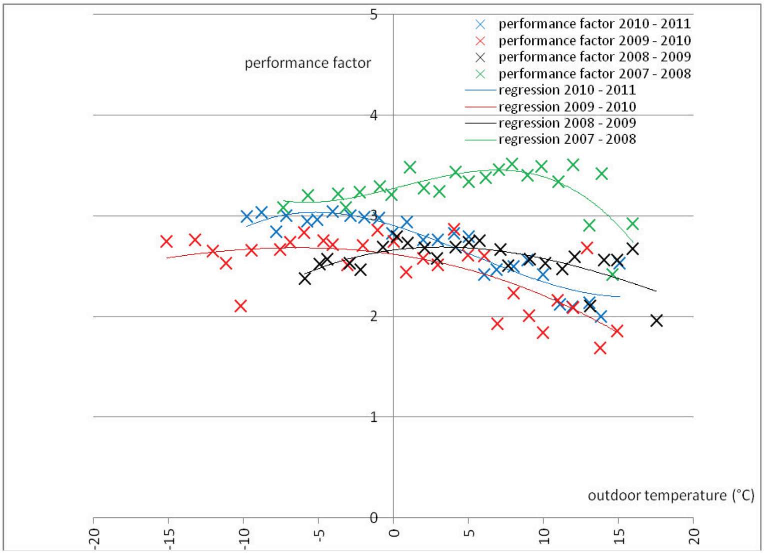
Heating season	2007-2008	2008-2009	2009-2010	2010-2011
Energy supplied by heat pumps (GJ)	1727.85	1529.52	1706.27	1524.20
Energy supplied into the air conditioning system (GJ)	307.88	300.31	343.64	291.65
Energy supplied into the central heating (GJ)	1419.97	1229.21	1362.63	1232.55
Energy consumed by heat pumps (kWh)	143114.23	160988.17	178908.69	150239.75
Performance factor of heat pumps per season (-)	3.35	2.64	2.65	2.82
Average outdoor temperature per season (°C)	5.44	5.96	4.54	4.63



Graph 1. Course of energy volumes produced by heat pumps



Graph 2. Courses of energy consumed by heat pumps



Graph 3. Course of performance factor of heat pumps

4 Evaluation of graph

The Graph 1 shows the course of energy produced by heat pumps. This energy is supplied to the central heating and air conditioning systems by heat pumps. The hall heating is more supported by the central heating system rather than the air conditioning heating capacity. That is due to the fact that the under-floor heating works with heating water from heat pumps at a lower temperature only. The lower the output temperature, the higher the performance factor of heat pumps. This graph help to determine the dependency of the energy produced on the outdoor temperature, as the decreasing outdoor temperature rises the heat loss of the building. At lower outdoor temperatures, the heat pumps need to produce more energy in order to maintain the thermal comfort inside the building.

The Graph 2 shows the course of energy consumed by heat pumps. The volume of energy consumed is determined by the sum of energy for heat pumps compressor drive, circulating pumps in the primary circuit and the control power supply. The graph can help to determine the total volume of energy consumed by heat pumps within particular months over the entire heating season.

The Graph 3 shows the course of performance factor of heat pumps. This graph can be used to define the dependency of performance factor on the outdoor temperature. When the outdoor temperature achieves positive values, the performance factor experiences a slight drop, which is caused by activation of the heat pumps and circulating pumps. With the outdoor temperature at negative levels, the performance factor stays constant, which means that heat pumps have enough of primary energy from boreholes. Heating of the hall uses more low-potential heat with the system of 110 boreholes. The boreholes converge into 5 circuits, which means 22 boreholes per 1 circuit. If we extract heat from a specific circuit, the temperature in boreholes will be reduced over a certain period of time. The extracted circuit will be disconnected, the boreholes within will be restored, while the system makes use of another circuit in the mean time. The duration of specific circuit utilisation if equal to 7 days. If technically practicable and cost-effective, the outside exchangers shall be slightly overrated. Utilisation of multiple boreholes is a bit more expensive, yet the heat pumps will gain more energy from the ground and there is no risk of depletion of the low-potential energy.

5 Conclusion

In the 2007/2008 heating season, the heat pumps supplied the energy of 1727.85 GJ and consumed the electric energy of 143114.23 kWh. These values then determine the performance factor over the heating season equal to 3.35. In the 2008/2009 heating season, the heat pumps supplied the energy of 1529.52 GJ and consumed the electric energy of 160988.17 kWh. These values then determine the performance factor over the heating season equal to 2.64. In the 2009/2010 heating season, the heat pumps supplied the energy of 1706.27 GJ and consumed the electric energy of 178908.69 kWh. These values then determine the performance factor over the heating season equal to 2.65. In the 2010/2011 heating season, the heat pumps supplied the energy of 1524.20 GJ and consumed the electric energy of 150239.75 kWh. These values then determine the performance factor over the heating season equal to 2.82. The coldest day was on 24th January 2010, when the average day temperature reached the level of -15.1 °C. The sole use of heat pumps for heating the assembly hall was sufficient in every heating season subject to assessment.

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