Heat Pumps Earth-Water

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Abstract—**The article deals with heating of large properties using heat pumps of earth-water type. An example of use of geothermal energy can be seen in the heating systems installed in the Assembly Hall of VSB - Technical University Ostrava. The source of heat comprises 10 heat pumps connected within cascade pattern with the total installed capacity of 700 kW. The primary source of energy for heat pumps is formed by the set of 100 boreholes to the depth of 140 m.**

Keywords— Heat pumps, geothermal energy

I. INTRODUCTION

Geothermal energy belongs to sources of renewable alternate energy. This is a flow of geothermal heat from the depth of the Earth since its very creation. The centre of the Earth stores sufficient amount of geothermal energy, its sources can be reached yet within the top layer of the Earth crust. Geothermal heat also includes the heat element supplied to the Earth upon creation of our solar system. The Sun is a source of all energy received by the Earth from space. However, this heat only warms the atmosphere, water surfaces and a thin surface layer of continental rocks. Solar radiation supplies thermal energy into the Earth and prevents rapid escape of heat from internal parts of the Earth.

II. GEOTHERMAL ENERGY

The thermal field of the Earth is characterised by several basic terms: geothermal gradient, temperature gradient, heat flow and heat conductivity of rocks. The geothermal gradient refers to the number of meters of descent below the surface to achieve a temperature increase by 1 °C. However, the neutral zone close to surface must be accounted for, as the temperature in this area is affected by external impacts. The average value of geothermal gradient is 33 m, what means that the temperature increase will be equal to 3 °C for every hundred metres travelled to the depth. The temperature gradient is a vertical gradient in the Earth crust. It is expressed in degrees of Celsius per one meter of depth. Its value fluctuates between 0.01 and 0.1 °C per meter of depth. Temperature data from depths greater than any levels reached so far are calculated on geophysical models. Heat flow (W) expresses the amount of heat Q passing through a unit of area per one unit of time t.

$$P = \frac{\mathrm{d}Q}{\mathrm{d}t} \tag{1}$$

The value of heat flow allows partial derivation of the temperature increase rate with the depth reached. As far as utilisation of geothermal energy is concerned, potential options can be found mainly in cases with high heat flow values. The heat flow density ($\mathrm{mW \cdot m^{-2}}$) is expressed as passing of specified heat output through the area of 1 $\mathrm{m^2}$.

$$q = \frac{\mathrm{d}P}{\mathrm{d}S} = \frac{\mathrm{d}^2 Q}{\mathrm{d}S \cdot \mathrm{d}t} \tag{2}$$

The heat flow density on the Earth surface ranges within 30 and 120 $\mathrm{mW \cdot m^{-2}}$. The mean value calculated from several tens of thousands of measurements is equal to 70 $\mathrm{mW \cdot m^{-2}}$. Heat conductivity ($\mathrm{W \cdot m^{-1} \cdot K^{-1}}$) of rocks determines the ability to conduct heat and it depends on rock types in the Earth crust.

Sources of geothermal energy can be divided by temperature to low-, medium- and high temperature ones. The temperature of low-temperature sources remains below 150 °C. These are used for heating in residential developments, industrial processes and heat pumps. The temperature range for medium temperature sources is within 150 and 200 °C. These are used for direct heating and power production. The level reached by high temperature sources is above 200 °C. These can be used for power production.

III. HEATING OF LARGE PROPERTY USING HEAT PUMPS

An example of heating in a large property might be the building with Assembly Hall of VSB - Technical University in Ostrava. 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 by the exchange station of the centralized heat supply. The total built-up area amounts to 3,917 $\mathrm{m^2}$. 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. These boreholes are located within the parking area at the Assembly Hall building and library of VSB-TUO. The boreholes fittings include four-pipe equipment with two loops of 32 mm polyethylene pipeline of nominal diameter 32 mm with a special connection mount. The boreholes have been fitted with approximately 70,000 m of polyethylene 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 18,000 litres. The system of 110 boreholes converges into five collector shafts, which means 22 boreholes per 1 shaft. Every shaft is then linked with a separate pipe, mounted with a separate circulating pump. The heat loss incurred within the Assembly Hall, at the outdoor temperature of -15 °C, amounts to approx. 1,200 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 I.
PERFORMANCE PARAMETERS OF IVT HEAT PUMPS

Temperature (°C)	Heating output (kW)	Power input (kW)	Heating factor (-)
0/35	67,8	16,7	4,06
0/50	69,8	22,3	3,13

Fig. 1. The Assembly Hall of VSB-TUO

IV. ASSESSMENT OF MEASURED DATA

The heat pumps are controlled by the ProCop software. The software provides automatic monitoring of all values within 10-minute intervals and saves results into the database.

Data used for assessment have been collected over the heating season in the period of 2011/2012. The heating seasons subject to assessment within the period of 2011/2012 started on 1st October and ended on 30th April respectively.

Table II shows the source of heating season with energy supplied by heat pumps and energy supplied into air-conditioning system and the energy supplied into central heating, the energy consumer by heat pumps and outside temperature. Further data include resultant heating factor calculated for the heating season.

TABLE II.
ENERGY SUPPLIER AND CONSUMER DURING THE HEATING SEASON OF 2011/2012

Heating season	2011/2012
Energy supplied by heat pumps (GJ)	1445,97
Energy supplied into the air conditioning system (GJ)	305,84
Energy supplied into the central heating (GJ)	1140,12
Energy consumed by heat pumps (kWh)	143178
Average outdoor temperature (°C)	4,2
Heating factor of heat pumps (-)	2,8

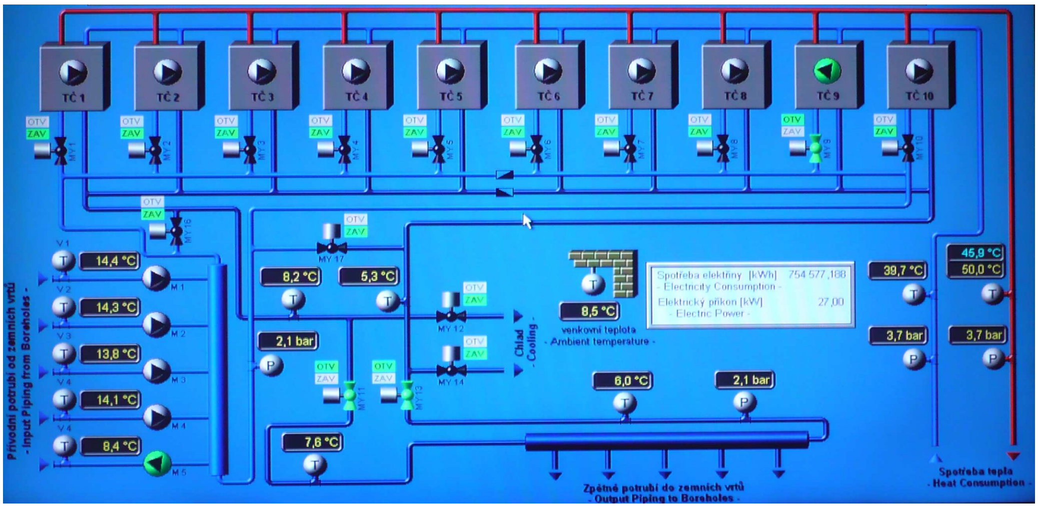


Fig. 2. Heat Pumps Connection Diagram

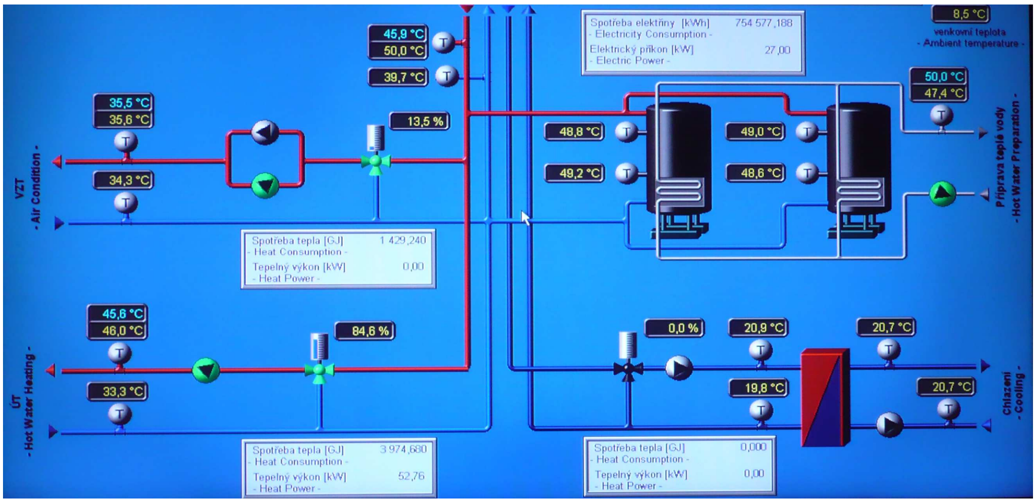


Fig. 3. Connection Diagram for Energy Supplied from Heat Pumps

A. Assessment of Energy Produced and Consumed by Heat Pumps

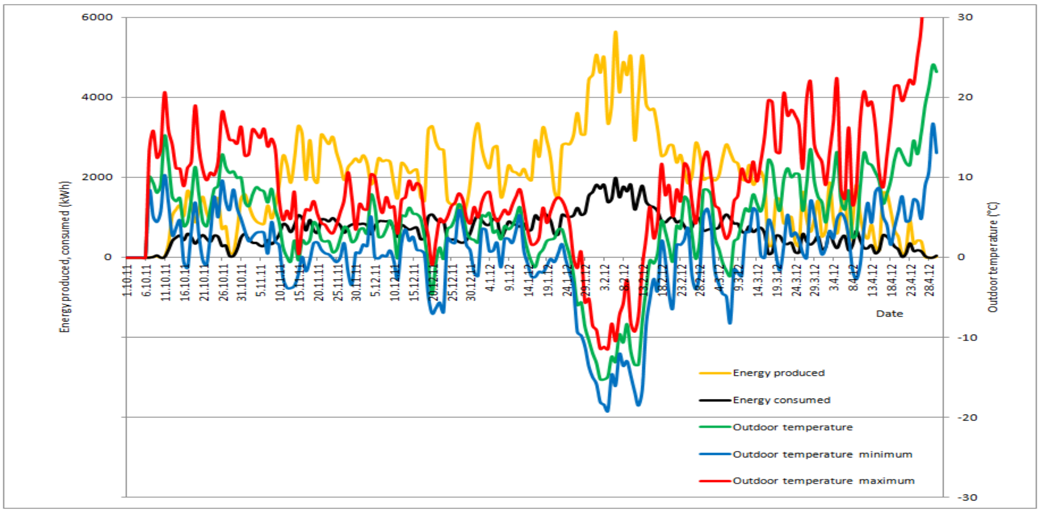
The Graph 1 shows course of energy produced and consumed by heat pumps during the heating season. The energy produced by the heat pumps is supplied into the central heating and air-conditioning systems. The graph shows the dependency of the energy produced by the heat pumps on the outdoor temperature, as the decreasing outdoor temperature rises the heat loss of the building. The volume of the consumed energy is determined by the sum of energy for heat pumps compressor drive, circulating pumps in the primary circuit and the control power supply.

B. Assessment of Heating Factor of Heat Pumps

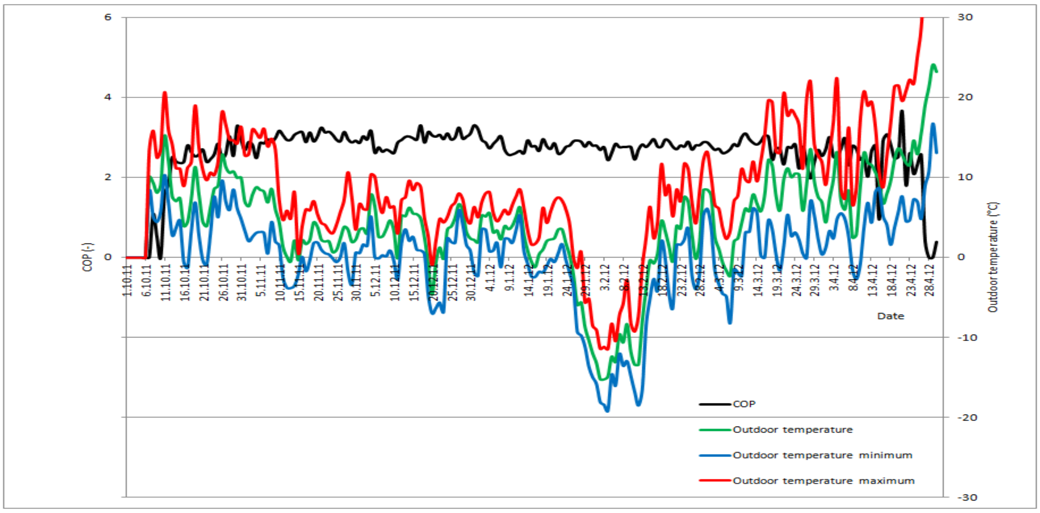
The Graph 2 shows the course of heating factor of heat pumps during the heating season. This graph can be used to define the dependency of heating factor on the outdoor temperature. The outdoor temperature is expressed in daily, minimum and maximum values. When the outdoor temperature achieves positive values, the heating factor experiences an imbalance, which is caused by activation of the heat pumps and circulating pumps. With the outdoor temperature at negative levels, the heating factor experiences a slight drop, yet heat pumps still have enough energy from boreholes.

C. Assessment of Temperature Courses in Individual Borehole Circuits

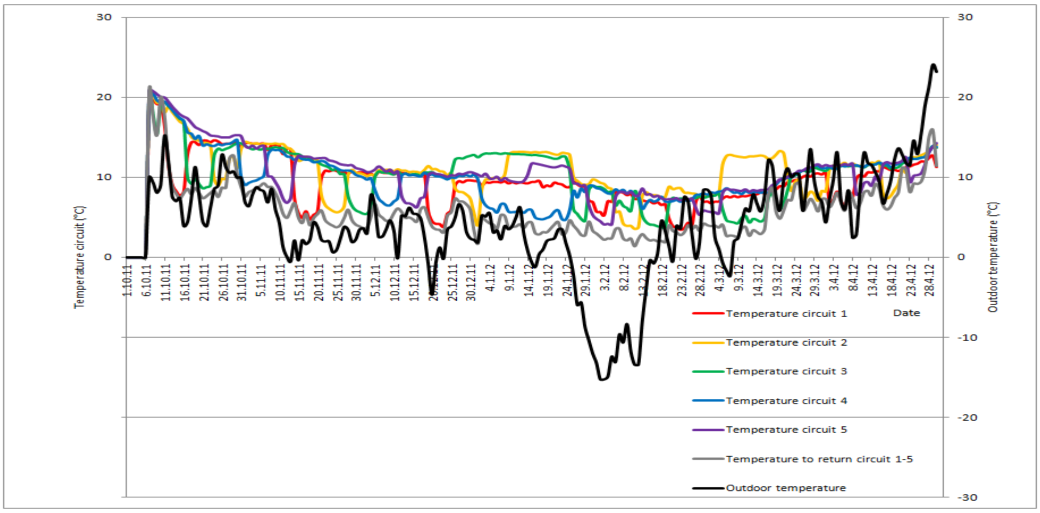
Graph 3 shows courses of temperature in particular borehole circuits and outdoor temperature during the heating season. The heat pumps use the system of 110 boreholes drilled to the depth of 140 m. The boreholes form a drilling field extended within the parking area at the Assembly Hall building and library. The boreholes are distributed in 10x10 m pattern under the parking area. These boreholes are linked into 5 circuits. One circuit is then made of 22 boreholes. If we extract heat from a specific circuit, the temperature in the boreholes will be reduced over a certain period of time. The extracted circuit will be disconnected; its boreholes will be restored, while the system makes use of another circuit in the mean time. The duration of specific circuit utilisation is equal to 7 days.



Graph 1. Courses of Produced and Consumed Energy by the Heat Pumps



Graph 2. Course of Heating Factor of the Heat Pumps



Graph 3. Courses of Temperature in Individual Borehole Circuits

Fig. 4. Heat Pumps, 10 units

Fig. 5. Circulation Pump in the Primary Circuit, 5 units

V. CONCLUSION

Heating in large properties can be ensured by means of heat pumps. Heat pumps supply up to three times the volume of heat compared to the amount of power they consume from the mains. Heating with heat pumps system is set for fully automatic operation with control options depending on utilisation of the building. The data measured on heat pumps relate to the heating season of 2011/2012. The data was used as base to assess the course of heating season in the building. The total energy supplied by heat pumps amounted to 1,445.97 GJ, out of which 305.84 GJ were supplied into the air-conditioning and 1,140.12 GJ into the central heating system respectively. The total amount of electric power consumer by heat pumps reached 143,178 kWh. The heating factor of the heat pumps during the heating season resulted in 2,8. The low heating factor is due to asynchronous utilisation of the building. The coldest day in heating season subject to assessment was 3th February 2012, when the temperature reached -15.2 °C and the heat pump system was still sufficient for heating in the building.

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