

MODEL CALIBRATION FOR COMPARISON OF DIFFERENT CONFIGURATIONS OF GROUND SOURCE HEAT PUMP SYSTEMS

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Abstract: This paper describes part of a research project which aims to optimize heat pump systems with a borehole heat exchanger in terms of energy consumption. The research is dealing with different configurations and control strategy. In regard to a great number of different system configurations, only four basic of them were selected. The paper presents model calibration of a heat pump system on a real ground source heat pump at CTU in Prague used for heating of a part of laboratory. System consists of one 100 m deep borehole, 9 kW heat pump, storage tank and involved control. Model is compiled in simulation environment TRNSYS. Results of simulation are obtained for a simplified building. Weather data are used from databases of Meteonorm for two different outdoor regional temperatures in the Czech Republic. The calibrated model and three other basic configurations based on it are used to simulate several operating strategies. Factor HSPF is used for comparison of energy consumption. According to the simulation results, a heat pump with the same performance characteristics can save up to 29 % of energy due to optimized configuration and control.

Key Words: *heat pumps, calibration, TRNSYS, simulation*

1 INTRODUCTION

Greater expansion of heat pumping technology for heating of smaller buildings (family houses) in the Czech Republic is limited by economical aspects. Relatively high investment costs as well as not too accurately determined heat consumption and operating costs lead to disbelief in payback of a heat pump. This work deals with modeling of a heat pump system and concentrates on a comparison of several options of coupling between heating system and heat pump. Intention is to determine the best alternative with the highest HSPF factor. In the first step a model of a real heat pump was created in simulation environment TRNSYS (TRNSYS 1996), this existing facility was also used for calibration of particular system components. These components were afterwards used for creating of other models that were compared to each other in terms of energy consumption.

2 SYSTEM DESCRIPTION

Model calibration was carried out with data measured on a real system at Czech Technical University in Prague (see Figure 1). System configuration consists of a 100m deep borehole with double U-tube configuration, 9 kW water-to-water heat pump, 540 l storage tank, circulation pumps and control circuit. The heat pump is controlled according to water temperature in the bottom of the storage tank. If the temperature of water entering to the heat pump from the storage tank is lower than required temperature, heat pump is switched on. Because in this case the temperature sensor is located at inlet pipe to condenser of heat pump, after a preset time period the circuit pump must be switched on in order to deliver

required amount of water from the storage tank to the measuring point. In the system described above, 6 temperature sensors have been installed in the pipes. Resistance thermometers Pt 100 have been installed at condenser and evaporator of the heat pump and at feed and return piping of the heating system (see Figure 2). For determination of heating capacity, flow meters were installed in each circuit. The storage tank was equipped with 8 resistance thermometers in different layers in order to enable measurement of charging and discharging of heat (Dincer 2002). Electric meter is used for measuring of power draw. Monitoring of all values needed for calibration is completed with air temperature of the technical room and outside air temperature sensors. Measurement is continuous, every minute all measuring values are logged with data acquisition equipment ALMEMO 5590 and downloaded to the computer.



Figure 1: Real system for calibration (CTU in Prague)

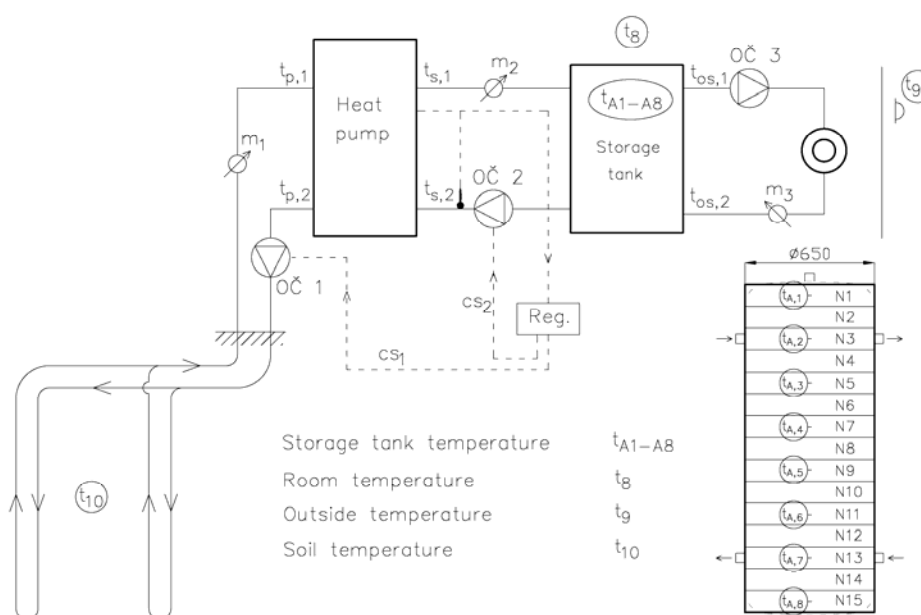


Figure 2: Measuring device on real system

2.1 Input Data

For calibration and simulation, intended for comparison of several variants in terms of energy consumption, the following input data are used.

2.1.1 Input data calibration

Input data used for model calibration: measured performance curves of the heat pump (see Figure 4), air temperature in the technical room (affects heat losses of the storage tank), outside air temperature, heat consumption for heating of the laboratory (computed using measured heating water flow rate and feed and return temperature - see Figure 5).

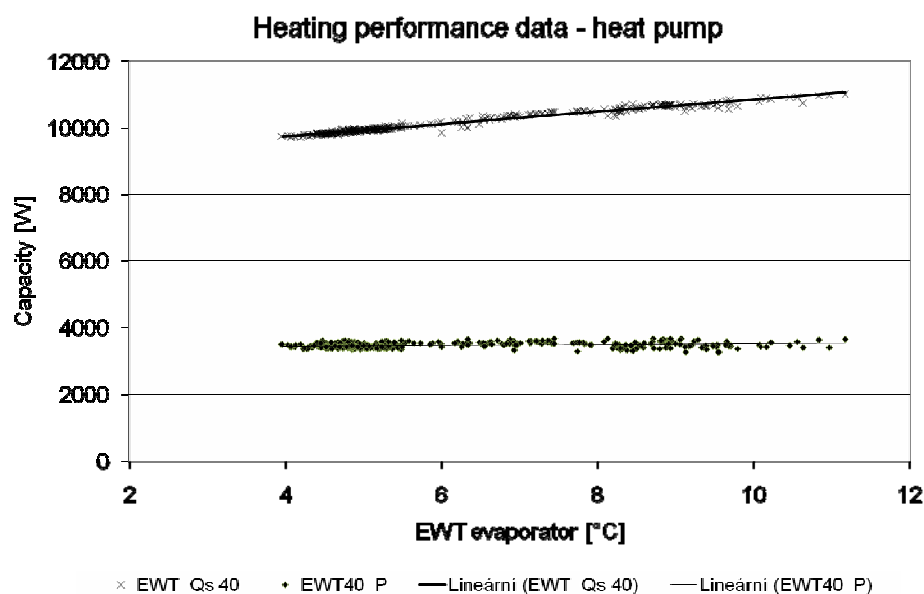


Figure 4: Heating performance data - calibration

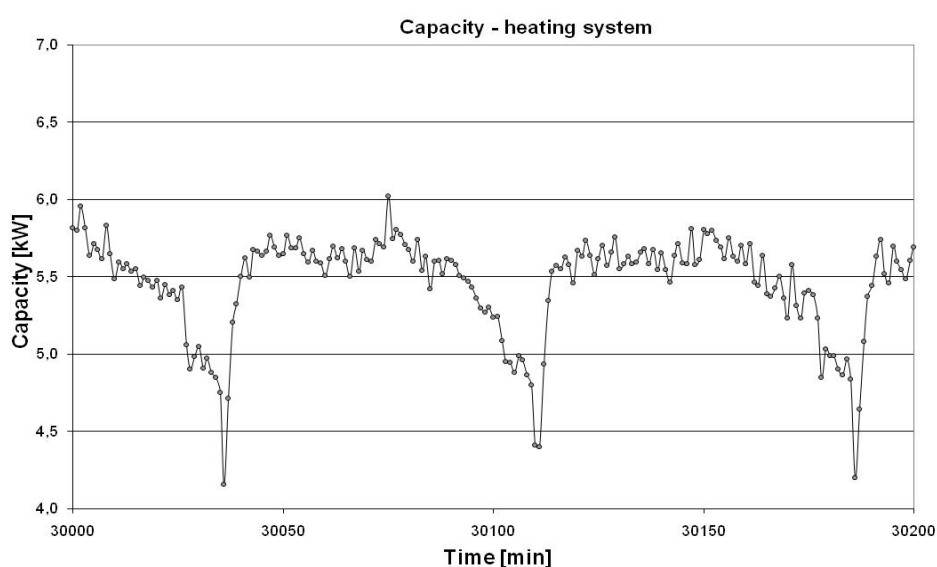


Figure 5: Capacity – heating system (measurement)

2.1.2 Input data simulation

Input data used for simulation of other configurations: building, weather data, heating performance data, next parameters are taken from the calibrated model. The simplified building is composed as a single-zone model with common wall composition and U-value according to the Czech standards. Glazing ratio is 30 % on the south wall, 8 % on the north wall, 10 % on the west wall and 20 % on the east wall. Heat loss of the building at outside air temperature of -12°C is 9 kW. Weather data are taken from Meteonorm database for 2 areas of the Czech Republic - Prague and Churanov (see Figure 6). The measured performance curves were complemented according to the manufacturer data for lower entering water temperature (EWT) into condenser (see Figure 7).

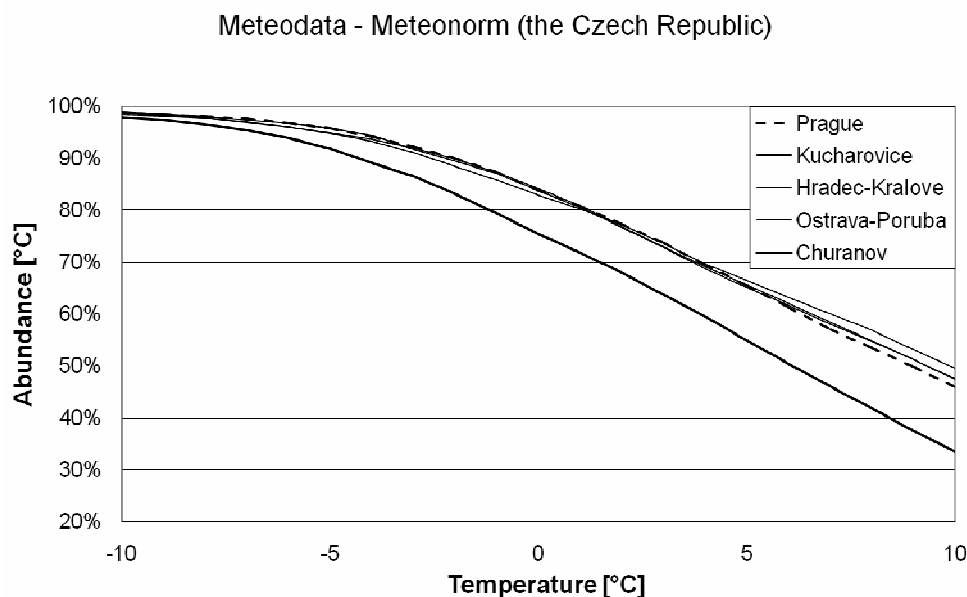


Figure 6: Meteodata

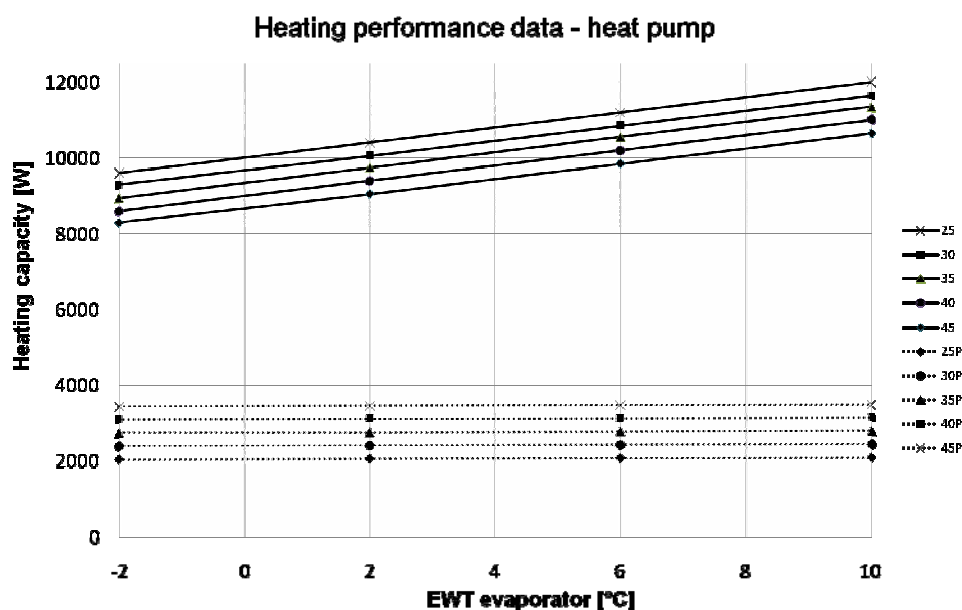


Figure 7: Heating performance data - simulation

3 RESULTS

3.1 Calibration

Calibration was being carried out from 31st November 2007 until 8th February 2008. Measuring and simulation was performed with a time step of 1 minute. Data evaluation was made for a short time period of several hours, comparison of capacity at evaporator and condenser of the heat pump is plotted in Figure 8. Long term comparison showing gradual cooling of the borehole is in Figure 9. Overall energy consumption of the heat pump for the calibration period was for the real system 2849 kWh and for the model 2684 kWh.

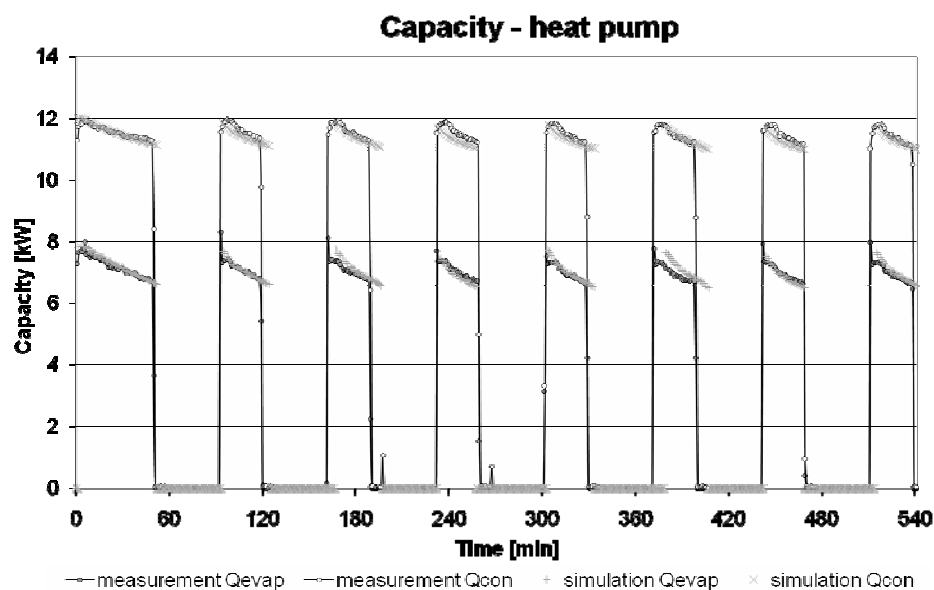


Figure 8: Capacity – measurement and simulation

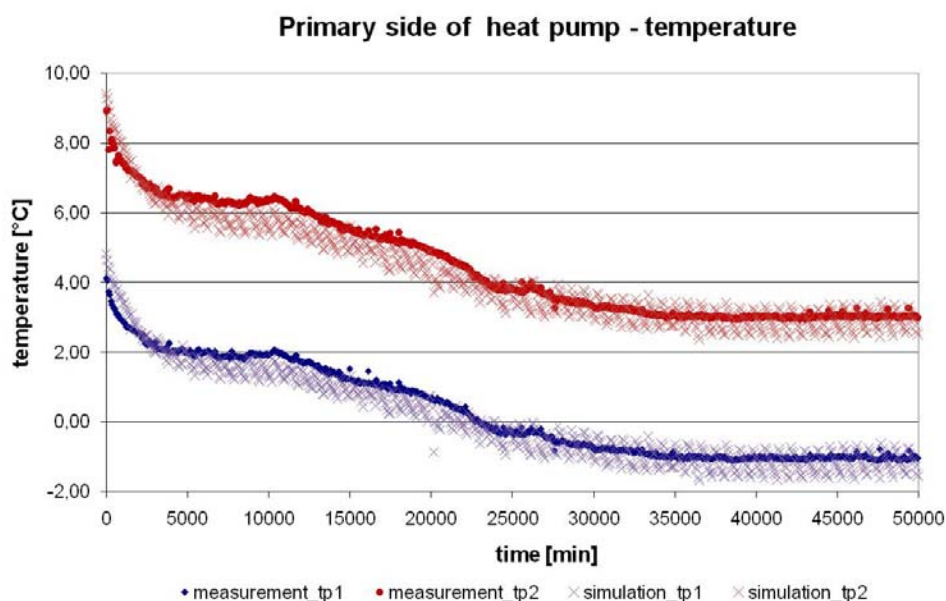


Figure 9: Primary side - measurement and simulation

3.2 Comparison of Configurations

In the early stage of research two basic configurations with two options of regulation were compared. Configuration no. 1 describes a system with the storage tank separating heat pump from the heating system with temperature control in the storage tank (see Figure 10). Configuration no. 2 describes the same system with temperature control in the storage tank, but in this case according to the outside air temperature. Configuration no. 3 shows a system with the storage tank placed on the return piping with temperature control in the storage tank. Configuration no. 4 is the same as no. 3, with the only exception in the temperature control of the storage tank - again according to the outside air temperature.

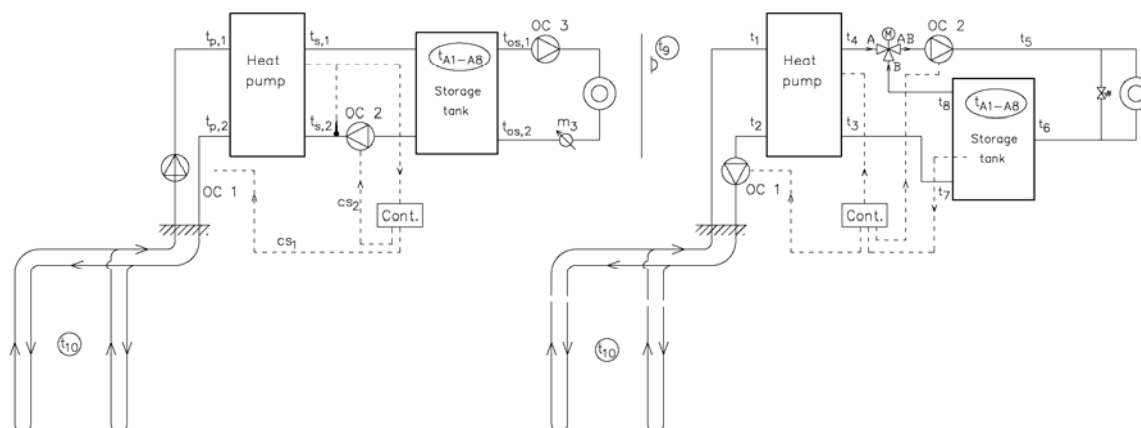


Figure 10: Configuration (configuration 1, 2 – left, configuration 3, 4 – right)

The following Table 1 shows the simulation results of four basic heat pump system configurations for two different locations.

Table 1: Comparison of simulation results

Margins	P [kWh]	average COP [-]	HSPF [-]
Config. 1 (Prague)	7386	2.95	9.27
Config. 1 (Churanov)	8291	2.94	9.22
Config. 2 (Prague)	6228	3.46	10.59
Config. 2 (Churanov)	7381	3.29	10.15
Config. 3 (Prague)	6963	2.87	9.15
Config. 3 (Churanov)	7823	2.85	9.12
Config. 4 (Prague)	5253	3.85	11.72
Config. 4 (Churanov)	6243	3.65	11.13

4 DISCUSSION AND CONCLUSION

Model created in simulation environment TRNSYS is able to describe behavior of a real facility from the energetic point of view with a good result, as can be seen in Figure 8 and Figure 9. Overall energy consumption of the heat pump for the calibration period was for the real system 2849 kWh and for the model 2684 kWh (5.8 % less). As can be seen in Table 1, the highest energy consumption occurs for the configuration 1 and the lowest for configuration 4.

The difference between the best and the worst option is 29 %. Average annual value of COP for a system using weather data for Prague is varying from 2.95 for configuration 1 to 3.85 for configuration 4. Heating seasonal performance factor (HSPF) for Prague is for the configuration 1 equal to 9.27 whereas for the best configuration reaches 11.72. Values of energy consumption for location Churanov are higher because of the weather data, but the trend is the same. According to the simulation results, a heat pump with the same performance characteristics can save up to 29 % of energy due to optimized configuration and control.

5 REFERENCES

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