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Three Years Monitoring Energy Efficiency of a Geothermal District Heating System

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ABSTRACT

The main objective in doing the study is to present the monitoring of energy efficiencies results of a Geothermal District Heating System (GDHS) related studies during 2006–2008. This study deals with a monitoring and assessment of energetic analysis of a Geothermal District Heating System in Turkey. In the analysis, actual system yearly average data of three heating seasons are used to assess the district heating system energetic efficiency performance. It is expected that this study will fill a considerably large gap since it is the first attempt towards monitoring GDHS in terms of energy efficiency.

1. INTRODUCTION

The production capacity of geothermal systems is quite variable and different systems respond differently to production, depending on their geological setting and nature. Therefore, comprehensive management is essential for the sustainable use of all geothermal resources. In other words, efficient management is required in order to avoid over exploitation, which mostly occurs due to lack of knowledge and poor understanding as well as in situations when many users utilize the same resource, without common management (Axelsson and Stefansso, 2003).

Energy and exergy efficiencies are considered by many to be useful for the assessment of energy conversion and other systems and for efficiency improvement. However, the use of ambiguous efficiencies that are not clearly defined does not serve this purpose well. A clear, correct, and effective use of energy and exergy efficiencies is crucial in efficiency improvement efforts, which are often a key objective in energy management and policy making (Kanoglu et al., 2007).

In the analysis, actual system yearly average data of three heating seasons are used to assess the district heating system energetic efficiency performance. It is expected that this study will fill a considerably large gap since it is the first attempt towards monitoring GDHS in terms of energy efficiency.

2. SYSTEM DESCRIPTION

2.1. Geothermal Distrcit Heating Systems (GDHSs)

Figure 1 show a schematic of the GDHSs which consist mainly of three cycles: (a) energy production cycle (EPC) or geothermal well loop, (b) energy distribution cycle (EDC) or district heating distribution network and (c) energy consumption cycle (ECC).

Geothermal fields are far from district Central Heating Station (CHS) and have abounded with considerably rich geothermal resources. The primary thermal water is reinjected into the well(s) and discharged via natural direct discharge after extracting its enthalpy, while the secondary fluid (i.e., clean hot water) is utilized to heat the buildings through the substation heat exchangers in GDHSs.

2.2. Salihli GDHS

The Salihli geothermal field is about 7 km from the town Salihli (about 55 km far from the city Manisa, located in the western part of Turkey). It has a maximal yield of $0.175 m^3/s$ at an average reservoir temperature of $86^{\circ}C$. The Salihli GDHS was initially designed for a capacity to cover 20,000 residences equivalence. Of these, 5470 residences equivalence are heated by geothermal energy as of December 2006. The outdoor and indoor design temperatures for the system are $4^{\circ}C$ and $22^{\circ}C$, respectively. Modeled system of main cycles where hospitals, greenhouse, and official buildings heated by geothermal energy were also included. At the beginning of 2007, there were 14 wells ranging in depth from 40 to 513 m in the Salihli GDHS. Of these, 6 wells were in operation at the date studied. Seven wells (designated as K2, K5, K11, K12, K15, K18, and K19) are production, greenhouse and balneology wells. Seven wells (designated as K1, K3, K4, K7, K9, K16 and K17) in the system are reinjection wells. The primary thermal water is reinjected into the well(s) and discharged via natural direct discharge after extracting its enthalpy, while the secondary fluid (i.e., clean hot water) is utilized to heat the buildings through the substation heat exchangers. The well head temperatures of the production wells vary from 62 to $99^{\circ}C$, while the volumetric flow rates of the wells range from 36 to 576 m^3/h. Geothermal fluid is sent to the primary plate type heat exchanger (between the geothermal fluid and the district heating water) and is cooled to about 38-$42^{\circ}C$, as its heat is transferred to the district heating water.

The geothermal fluid is discharged via natural direct discharge and reinjected (reinjection studies are expected to be completed in the near future). The temperatures obtained during the operation of the Salihli GDHS are, on average, 86-88/38-$42^{\circ}C$ for the district heating distribution network and 56-57/40-$42^{\circ}C$ for the building circuit. By using the control valves for flow rate and temperature at the building main station, the needed amount of water is sent to each housing unit and the heat balance of the system is achieved. Geothermal fluid collected from the production wells at an average well heat temperature of about $86^{\circ}C$, is pumped to the inlet of the heat exchanger mixing tank, a main collector (from four production wells) with a total mass flow rate of about 175 kg/s (Ozgener and Ozgener, 2008; Ozgener and Ozgener, 2009).

3. A KEY BRIEF OF ENERGY ANALYSIS

An accurate analysis can be realized by evaluating the energy losses for every single component of the system.

The energy efficiency of the GDHS can be defined as the ratio of total energy output to total energy input as follows:

$$\eta_{system} = \frac{\sum_{i=I}^{n=k} \dot{E}_{useful,HE,i}}{\dot{E}_{brine}} \qquad (1)$$

where in most cases “output” means “useful”.

3.1. Measurements and uncertainties

The pressures and temperatures of fluids (including water and thermal water) are measured by the technical staff with Bourdon-tube pressure gauges and fluid-expansion thermometers, respectively. As known it is well that, the errors and uncertainties in data recording and experiments may arise from instrument selection, instrument condition, instrument calibration, environment, observation and reading and test planning. An uncertainty analysis was needed to prove the accuracy and reliability of the experimental data taken. Such uncertainty analysis is performed through the method described by Holman (2001). In the present Salihli GDHS, the pressure and temperature data of fluids (e.g., water and geothermal) were measured and recorded hourly by using Bourdon-tube pressure gauges and fluid-expansion thermometers, respectively. The volumetric flow rates of geothermal fluid are measured by using flow meters. Especially volumetric flow rates of re-injected thermal water is measured by ultrasonic flow meter in Salihli GDHS. Table 1 shows total uncertainties of Salhli GDHS in Turkey. Fig. 2. Illustrate an experimental measurement on thermal water production and energy distribution pipe lines by using ultrasonic flow meter.

4. RESULTS AND DISCUSSION

Pressure drops due to the liquid flow friction, and thermal water of intermingling molecules of different species through molecular diffusion are neglected in this study. The thermodynamic properties of the fluids used in the present study are based on the actual data taken from the Salihli GDHS measured and recorded average value of 2004/2005, 2006/2007 and 2007/2008 heating seasons, respectively. The thermodynamic properties of water are obtained from the general thermodynamic tables and software. The number of the wells in operation in the geothermal fields may vary depending on the heating days and operating strategy.

Average monthly energy efficiency monitoring results of the Salihli GDHS can be reached from Ozgener and Ozgener (2009). A number of variables have been monitored with a relatively high frequency from September 2007 until April 2008 (an hour interval). In this research authors focus on the EDC, EPC, ECC, thermal water production and water temperatures and their mass flow rates, re-injected thermal water temperatures and its mass flow rates, daily ambient temperatures etc. The monitored energy efficiency values are obtained for a range from 53.69% to 67.37% for different reference state values, basically from 0ºC to 20ºC for a better coverage and presentation of how the varying reference state temperature affects the performance of the system in terms of energy demands.

CONCLUSIONS

In GDHSs, optimum operating points of each pumps should be defined according to ambient and reservoir temperatures, and thermal water usage in heating seasons. A more detailed statistical GDHSs analysis of the high resolution dataset can provide more insight in the behavior of the GDHSs during daily cycles. It is expected that the present study will help engineers and investigators in the design, operation and simulation of GSHP systems in terms of energetic performance evaluations.

NOMENCLATURE

$\dot{E}$	energy rate (kW)

Greek letters

η	energy (first law) efficiency (%)

Subscripts

HE	heat exchanger
i	successive number

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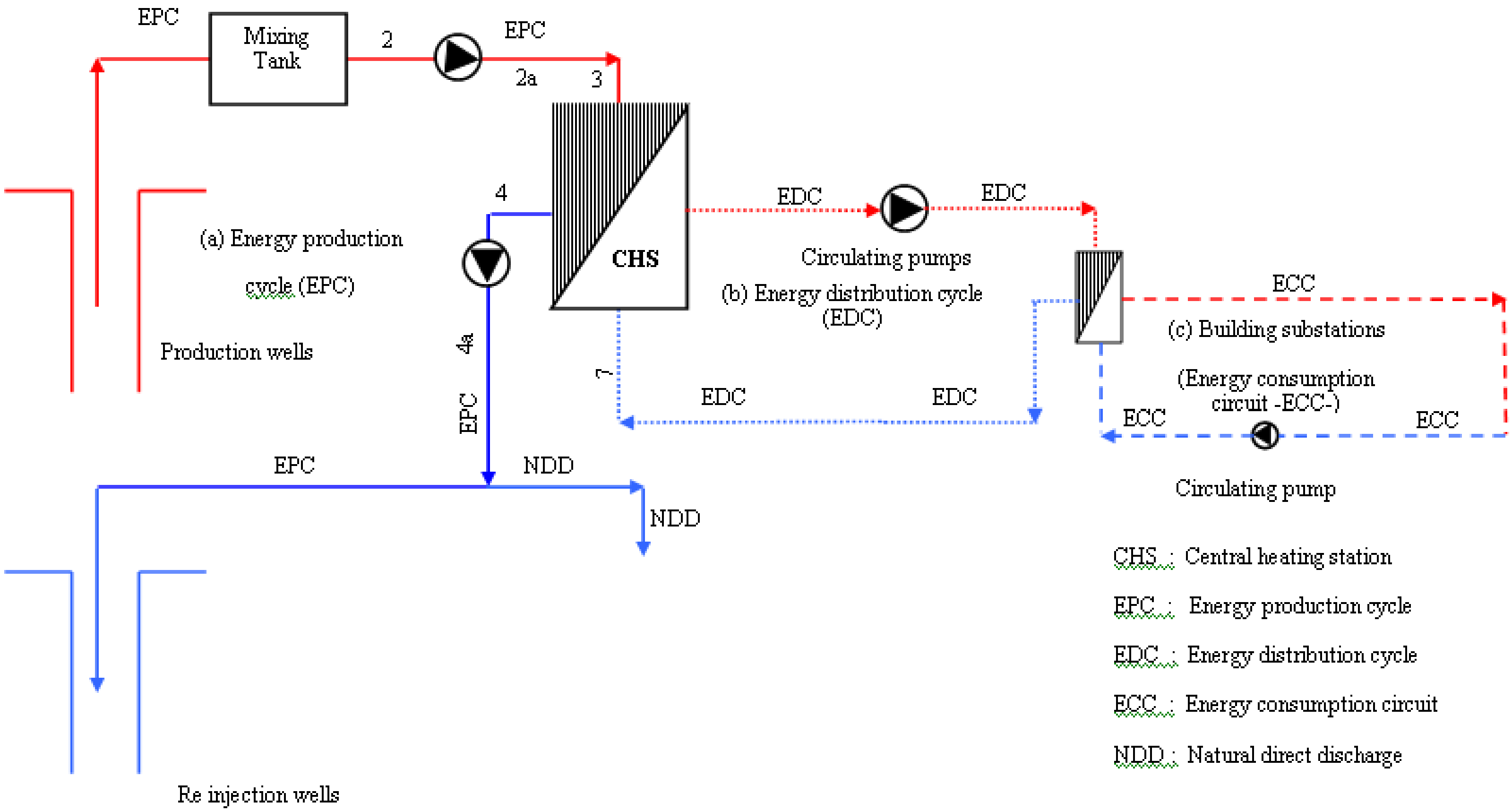

Figure 1: Basic simplified geothermal district heating energy system schema of Salihli adopted from (Ozgener and Ozgener, 2008; Ozgener and Ozgener, 2009)

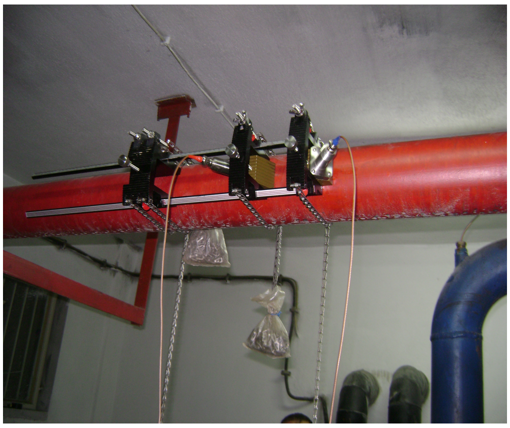

Figure 2: A view of an experimental measurement and monitoring studies on thermal water production and energy distribution pipe lines by using ultrasonic flow meter (Ozgener and Ozgener, 2009)

Table 1. Total Average Uncertainties of the Measured and Calculated Parameters of Salihli GDHS Adopted from Ozgener and Ozgener (2009).

Item no	Measured quantities		
	Description	Unit	Total uncertainty (%)
1	Temperature by using installed thermometers	ºC	±1.97
2	Temperature by using infrared thermometer	ºC	±1.00
3	Pressure	bar	±1.71
4	Volumetric flow rate by using installed flow meters in SGDHS	m^3/s	±0.32
5	Volumetric flow rate by using ultrasonic flow meter	m^3/s	±0.22
Item no	Derived quantities		
	Description	Unit	Total uncertainty (%)
1	Mass flow rate	kg/s	±0.38
2	Energy rate	kW	±0.43
5	Energy efficiency	%	±4.5
Uncertainty in reading values of table			±0.20