Monitoring the performance of a GSHP system in the Mediterranean climate of Cyprus

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ABSTRACT

This study analyzes the operation of a geothermal system in the Mediterranean climate zone. The system's ground source heat pump (GSHP) is made up of five separate vertical ground heat exchangers (GHEs), one double helicoidal coil in a well, and an open loop (well) system. A building management system (BMS) constantly monitors the entire GSHP system. The performance of the system was preliminarily examined in cooling mode (summer time), based on the recorded data, after studying the power flows in and out of the system's keypoints. The obtained results demonstrate higher heat exchange values inside the open well, indicating that this type of GHE should be used whenever applicable. Furthermore, the coefficient of performance (COP) for the month tested (June 2019) was shown to be around 5; thus, GSHP systems operating under Mediterranean climate conditions can be considered high efficiency solutions.

1 INTRODUCTION

Currently, the residential sector in the European Union (EU) accounts for more than a quarter of overall primary cooling energy demand [1], while buildings account for almost 40% of total EU energy consumption [2]. To that purpose, Cyprus, like other EU nations, has accepted various EU directives, such as 2009/28/EC, 31/2010/EC, and 27/2012/EC, promoting geothermal energy development, energy consumption reduction, and increased energy efficiency in the building sector [3].

If used properly, geothermal energy systems have the potential to provide substantial energy, environmental, and economic benefits [4]. Because of its great efficiency and environmental friendliness, the ground-source heat pump (GSHP) system is one of the most well-known types of geothermal systems and renewable energy technologies for heating and cooling buildings. Ground heat exchangers (GHEs) are used in GSHPs because they are designed to meet energy demand in both summer and winter [5]. GSHPs may be employed instead of conventional and less efficient air-source heat pumps (ASHP) depending on viability. In comparison with ASHP systems, for each kWh electric, GSHPs can produce 50% extra thermal energy [6].

It should be noted that the ground thermal properties play an essential role in maximizing efficiency. Once the system geometry has been determined, the operating temperature profiles

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must be defined. The hydraulic and thermal problems can be uncoupled if the velocity of the heat carrier fluid remains constant. This enables the calculation of the energy balance and the resolution of temperature distribution problems.

The coefficient of performance (COP) represents the cooling or heating performance of a GSHP system. The COP of a HP is the ratio of heat removed/added to the building to the energy consumed by the heat pump, which includes the energy consumed by the HP and the circulating pumps [7]. It should be noted that the temperature of the fluids exchanging heat at the evaporator and condenser stages affects HP performance. As a result, variable environmental circumstances, such as the Mediterranean climate zone, and different demand situations during a season can cause considerable differences in the machine's overall performance.

The current study's goal is to show the hybrid configuration and practical operating results of the GSHP system used for space air cooling at the University Municipal Library of Limassol.

Existing research in the literature concerning GSHP systems rely on theoretical and computer models, with only a few focusing on the practical operation performance of the GSHP systems. Among such studies in the literature regarding GSHP systems and their efficiency (COP) and viability, one can mention some relevant to the Mediterranean region, such as Urchueguía et al. [7], Emmi et al. [8], Esen et al. [9] and García-Cespedes et al. [10]. Regarding Cyprus, Michopoulos et al. [11] presented a feasibility analysis for the installation of GSHP systems.

2 METHODOLOGY

A GSHP system was installed in late 2018 as part of the refurbishment of the historical building of the University Municipal Library of Limassol, as a new alternative means to cover the building's heating and cooling needs. Limassol has a Mediterranean climate, with long, warm, dry summers from June to October and pleasant winters with intermittent rain from December to April [12]. A Building Management System (BMS) was implemented to monitor temperatures and flow volumes in several keypoints of the system in order to apply best practices. The BMS maintains high system reliability by sending out timely notifications in the event of a malfunction via emails and text messages, and it preserves records of temperature readings, volume, flow, and energy. The GSHP system installed at the library building includes five boreholes with different GHEs U-tube configuration, one GHE of helicoidal configuration in a well and one complex of open wells. Also, the GSHP system employs two chillers, each of which operate in alternating days.

In conjunction with the GHEs and chillers, the GSHP system was divided into fourteen regions numbered F01 to F14. The overall goal was to evaluate the performance of each of these groups independently by a study of data obtained by the BMS system, such as energy, flow volume, and incoming and outgoing temperatures in the system, all of which are automatically recorded in the BMS. Using the data, one can determine the heat flow rate (power) transported to or from the system in each area F. Furthermore, one can calculate the COP defined as:

$$\mathrm{COP} = \frac{\text{Power absorbed or rejected to the building}}{\text{Total electrical power into the system}} \qquad (1)$$

3 RESULTS

The data used to prepare the graphs in the sequel were gathered using the BMS platform tools. As previously stated, the GSHP system employs two chillers. The results shown hear are for chiller 2. The GSHP system is considered as a closed system in which energy enters and exits in equilibrium, i.e. GHEs load (loss) + losses to the environment = Building load + Electric Power consumed (*energy balance*).

Figure 1 depicts the specific power in each component of the GSHP system as a function of time, where time is the calendar day (from day 153 to day 181 of the year 2019, i.e., June 2019, which is in summer season). During the summer, the flow rate of the unit's evaporator (F09), which absorbs the building load, ranges between 14 and 20 m^3/h, with a temperature difference of roughly 4°C. The heat rejection condenser (F07) has a flow rate of 12 to 17 m^3/h and a temperature differential of roughly 4°C. Furthermore, the electricity absorbed from the building by the system (yellow color) indicates that the peak cooling load was at 135 kW and the peak demand from the chiller (blue color) at 25 kW.

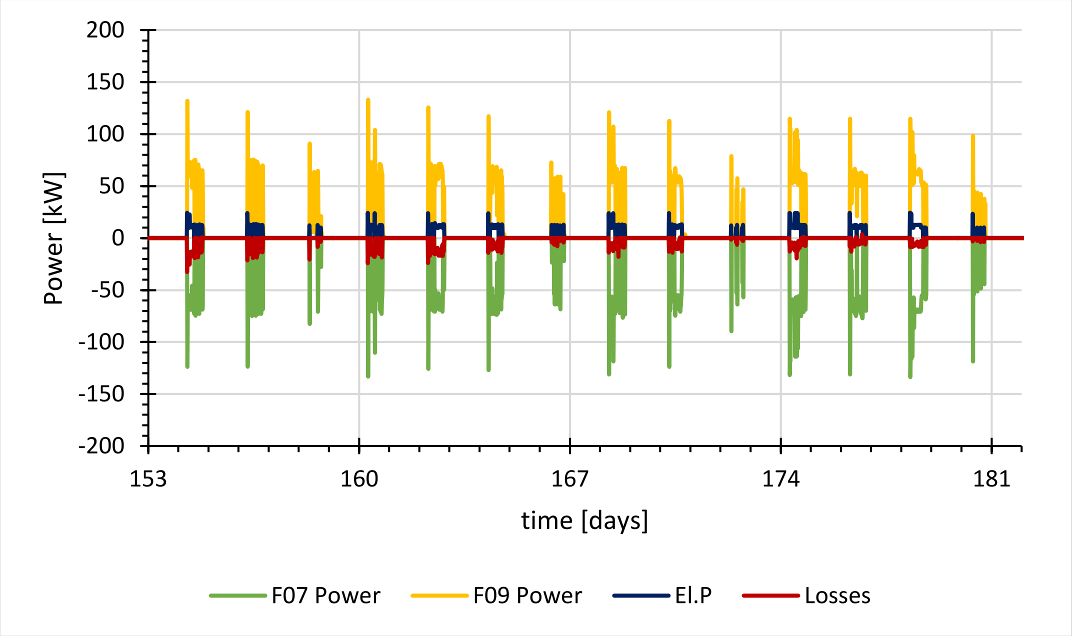

Figure 1: Power entering and exiting the GSHP system (F07: GHEs Load (loss), Losses: losses to the environment, F09: Building load, El.P: Electric Power consumed)

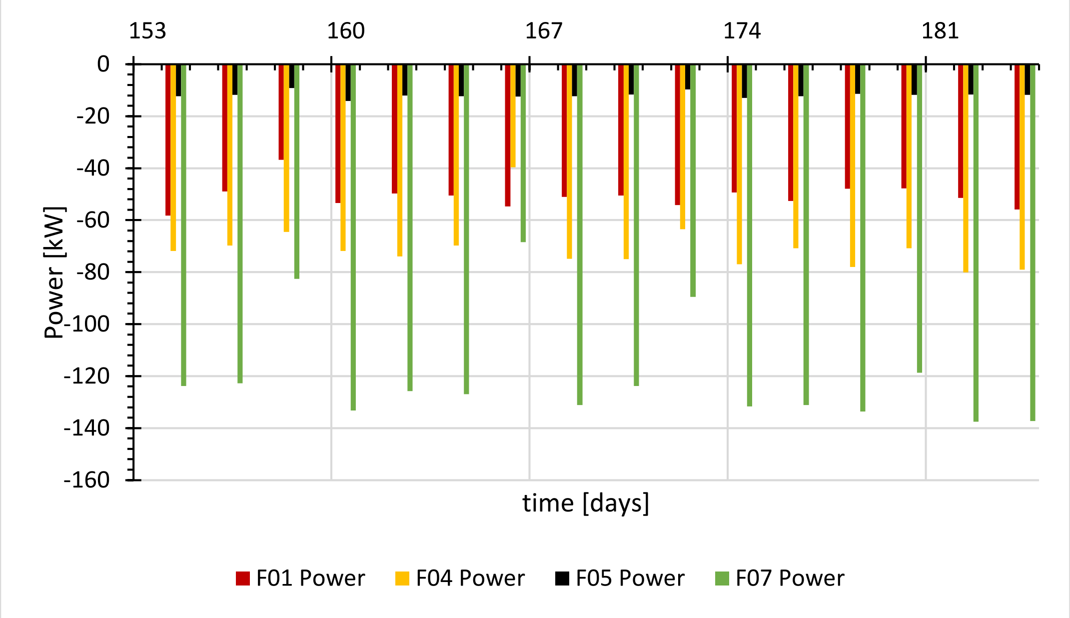

Figure 2: Power rejected to the ground by the GHEs in June 2019 (mean daily values during operational time) (F01: boreholes, F04: open well, F05: helicoidal configuration in a well, F07: total power rejection, equal to the sum of F01 + F04 + F05)

In general, chillers are among the most energy-intensive components of a building, a fact that has a significant impact on operational costs. Assuming that the electric power consumed by the chiller is equal to the total electric power consumed by the system, the COP of the system can be determined using Figure 1 and the energy balance above, with a mean value of 5 for the month of June 2019.

Figure 2 depicts the power rejected to the ground by the GHEs in June 2019, with F01 representing the sum of the boreholes, F04 representing the well, F05 representing the helicoidal coils in the well, and F07 representing the aggregate of these three sources. The open well has the maximum power, between 60 and 80 kW, as shown in the graph, followed by the sum of the boreholes, which has a power between 40 and 60 kW. Because of their small size, the helicoidal coils in the well reject a lower quantity, between 10 and 15 kW. GHEs reject from 70 and 138 kW of total power to the ground.

4. DISCUSSION AND CONCLUSION

The overall goal of this research was to describe the operating outcomes of a GSHP system utilized for space air-conditioning that had been installed in the Mediterranean climatic zone. The collected data, from the BMS, for all parts of the system (boreholes and wells) were analyzed for the cooling operating mode. The investigation revealed that heat exchange values were higher inside the open well. The open well had values ranging from 60 to 80 kW, which is greater than the heat exchange accomplished by the sum of the boreholes (40 to 60 kW) or the helicoidal coils in the well (10 to 15 kW).

The operation of the chillers was also investigated as they have a significant impact on operational costs being the system's top electricity consumers. Chiller 2 COP had a value of roughly 5.0 in the study situation for the month of June 2019. The good energy performance results confirm that GSHP systems positioned in the Mediterranean climate zone are high efficiency alternatives for primary energy savings.

Of course, it is necessary to investigate the heating mode as well as re-test the system with current data, as the Library is now fully operational following the Covid19 epidemic years.

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