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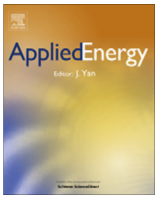

Shallow geothermal energy applied to a solar-assisted air-conditioning system in southern Spain: Two-year experience

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HIGHLIGHTS

- We present a new solar-assisted air-conditioning system's operation mode.
- This mode considers the shallow geothermal system action.
- It permits to save about 30% of energy consumption during one cooling period.
- It allows savings of 116 m^3 of deionised water throughout the summer period.
- Shallow geothermal system was proved as a good alternative to the cooling tower.

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ABSTRACT

This paper describes a shallow geothermal system that was designed as an alternative to the cooling tower in a solar-assisted air-conditioning system installed in southern Spain (Almería). The core idea of this solar-assisted air-conditioning system is to cover the cooling and heating load of the Solar Energy Research Centre (CIESOL), minimising its environmental impact. In this study, the cooling mode was further investigated. The shallow geothermal system has been operating since May 2010, providing groundwater at 22 °C via a 20-m-deep supply well as a cooling carrier medium. The shallow geothermal system application improves the solar-assisted air-conditioning system's efficiency, thereby reducing its electricity and water consumption. The results demonstrate that during one cooling period, the seasonal shallow geothermal system uses 31% less electrical energy than a cooling tower system. It also achieves savings of 116 m^3 in water consumption throughout the summer period.

1. Introduction

Direct use of geothermal energy is one of the oldest, most versatile and most common forms of utilisation of geothermal energy [1,2]. Making efficient use of renewable and non-renewable energy sources and curbing climate change are the greatest challenges facing most developed countries. As a result, an increasing number of geothermal installations have been observed in recent decades. While deep geothermal applications (greater than approximately 400 m in depth) are specific and of large size, shallow systems (less than approximately 400 m in depth) require no extraordinary geological settings or high geothermal gradients. They are based on simple, established technological principles and therefore are used in great numbers and are popular worldwide. For domestic cooling and heating in particular, the use of shallow geothermal energy is considered an environmental friendly alternative to traditional heating and cooling techniques [3–8]. Ground source heating and cooling systems are widespread in the US and Canada and in some European nations (particularly Switzerland, Germany and Scandinavia). Elsewhere in Europe (e.g., the UK, Ireland and the Mediterranean) they are regarded as an emerging technology [9,10].

One of the major technological variants of shallow geothermal systems is the application of an aquifer, or a groundwater reservoir. The material in an aquifer is highly permeable to water, and the boundary layer consists of more impermeable materials such as clay or rock. Water from precipitation continuously seeps down into an aquifer and flows slowly through it until it finally reaches a lake or sea. Aquifer systems have been used for many years, but in recent years in particular, with concerns about global warming growing, the concept is receiving renewed attention as a viable means of conserving energy and reducing fossil fuel use. Aquifer systems are commonly used in China and parts of Western Europe, particularly the Netherlands and Sweden, where its use is growing by 25% annually. Although office buildings remain the primary

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Nomenclature

T_{amb}	ambient air temperature (°C)
C_p	specific heat capacity of water (4.18 kJ kg^{-1} K^{-1})
S11	entering generator's temperature (T_{eg}) (°C)
S12	leaving generator's temperature (T_{lg}) (°C)
S18	entering evaporator's temperature (T_{ee}) (°C)
S19	leaving evaporator's temperature (T_{le}) (°C)
S20	return absorber's and condenser's temperature (T_{eac}) (°C)
S21	leaving absorber's and condenser's temperature (T_{lac}) (°C)
S52	entering heat exchanger's temperature (°C)
S53	leaving heat exchanger's temperature (°C)
S54	recharge well's temperature (°C)
S55	supply well's temperature (°C)
COP	coefficient of performance
SPF	seasonal performance factor
$\dot{Q}_{cool}$	cooling capacity (kW)
$\dot{m}_g$	generator's mass flow rate ($\dot{Q}_5$) (m^3 h^{-1})
$\dot{m}_e$	evaporator's mass flow rate ($\dot{Q}_4$) (m^3 h^{-1})
$\sum P_{in_1}$	total electricity consumption in cooling tower mode (kW h)
$\sum P_{in_2}$	total electricity consumption in shallow geothermal mode (kW h)
Q_{P_1}	electricity consumption of pump P1 (kW h)
Q_{P_2}	electricity consumption of pump P2 (kW h)
Q_{P_3}	electricity consumption of pump P3 (kW h)
Q_{P_4}	electricity consumption of pump P4 (kW h)
Q_{tower}	electricity consumption of cooling tower (kW h)
$Q_{osmosis}$	electricity consumption of deionized water system (kW h)
$Q_{chiller}$	electricity consumption of absorption chiller (kW h)
Q_{aux}	electricity consumption of auxiliary heater (kW h)
HVAC	heating, ventilationg and air conditioning

market for the technology, its use is gaining ground in industrial and agricultural applications. Many opportunities exist for aquifer systems to yield energy savings and reduce emissions [11]. The concept of shallow geothermal systems has been extensively discussed in literature [12–19]. However, relatively few studies have been conducted that have considered the application of aquifer thermal storage to solar-assisted air-conditioning systems, and no detailed statistic data on this type of application exist. In the study presented by Batlles et al. in [20], we compared the environmental performance and benefits of a solar-assisted air-conditioning system with a conventional heating, ventilating and air-conditioning (HVAC) system. We found that the consumption of deionised water for heat dissipation in the cooling tower, combined with the fact that freshwater in the Almería region is very scarce, imposes a drain on local freshwater resources. Therefore we concluded that our efforts should be addressed toward mitigating this impact by means of alternative heat dissipation methods. Thus, the main goal of this study is to propose the application of a new alternative heat dissipation system for the absorption chiller installed in the CIESOL building. We conducted this modification to improve the solar-assisted air-conditioning system's energy management and thereby make it more sustainable. It has been demonstrated that by correcting the significant energy, mechanical and operational deficiencies provoked by cooling tower operation, significant water and energy savings can be achieved. The first part of this study is focused on investigating the integration of the shallow geothermal system with the solar-assisted air-conditioning system. The second part of this study is focused on examining the comparison of the shallow geothermal system's operation with that of the cooling tower system. Finally, we present the environmental benefits achieved by our solar-assisted air-conditioning system because of the shallow geothermal system application.

2. Description of solar-assisted air-conditioning system

In this study, we use data registered in the solar-assisted air-conditioning system installed in the Solar Energy Research Centre (CIESOL), located on the campus of the University of Almería, a region in southern Spain with a Mediterranean climate. The system employs an array of flat-plate solar collectors with a total surface area of 160 m^2, and a hot-water-driven single-effect LiBr–H_2O absorption chiller. It also uses an alternative heat dissipation system consisting of a shallow geothermal system, two hot storage tanks, an auxiliary heater and two chilled water storage tanks. The air-conditioning covering the building's cooling and heating load is in operation during office hours, from 9 a.m. to 8 p.m Monday through Friday. Fig. 1 presents a view of the CIESOL building with the flat-plate solar collectors installed on the roof and the main system components. Analysis of this system and its various operation modes has been presented recently [20–22].

In this study, we tested the WFC SC 20 hot-water-driven single-effect LiBr–H_2O absorption chiller, manufactured by the YAZAKI

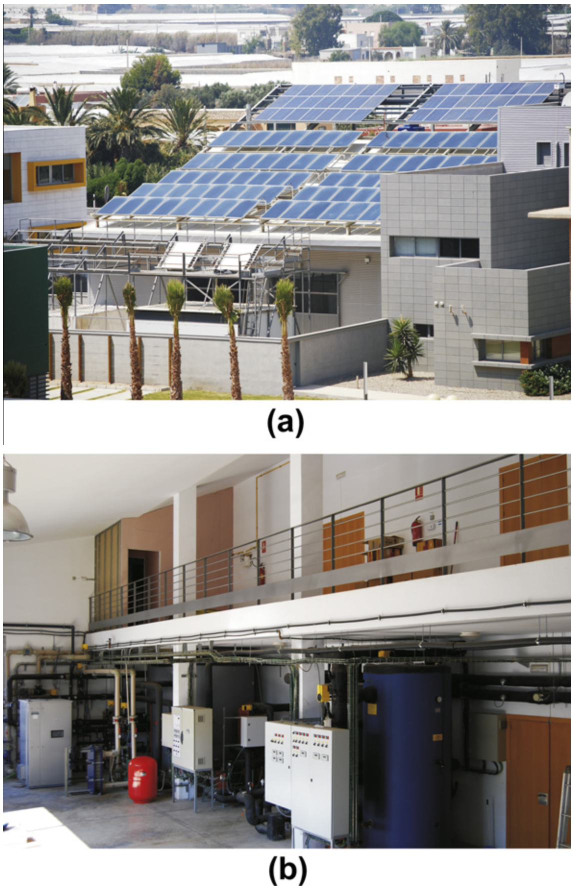

Fig. 1. (a) View of CIESOL building with array of flat-plate solar collector, (b) the nave with main system's components.