Energy and Buildings 111 (2016) 207–217

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Assessment of surface geothermal energy for air conditioning in northern Tunisia: Direct test and deployment of ground source heat pump system

Nabiha Naili*, Majdi Hazami, Issam Attar, Abdelhamid Farhat

Laboratoire des Procédés Thermiques (LPT), Centre de Recherches et des Technologies de l'Energie (CRTEn), PB 95, Hammam Lif 2050, Tunisia

ARTICLE INFO

Article history:
Received 4 December 2014
Received in revised form 4 November 2015
Accepted 10 November 2015
Available online 14 November 2015

Keywords:
Geothermal energy
Horizontal ground source heat pump
Experimental study
Energetic analysis
Energy efficiency

ABSTRACT

The aims of this paper are (1) to evaluate the geothermal resources in Tunisia and (2) to test the deployment of the surface geothermal energy for cooling application. The experiment consists of installing a ground source heat pump (GSHP) system, was carried out in the 'Centre de Recherches et des Technologies de l'Energie' (CRTEn) at Borj Cédria, northern Tunisia. The GSHP is composed with horizontal ground heat exchanger (GHE) connected to a reversible geothermal heat pump (GHP), which is connected to a chilled ceiling panel (CCP) system installed in a climate test room. The status of geothermal energy and its utilization are pointed out, the test of the direct use of surface geothermal is examined as well as the evaluation of the GSHP system for air conditioning. The important findings of this study are: (1) Tunisia benefits from important geothermal resources, but its use remains very limited, (2) the only use of the (GHE) has reduced the average temperature inside the climate test room of about 2 °C during 1 day. (3) The test of the GSHP system proves that it is a profitable solution in Tunisia, the coefficient of the performance of the GHP and the whole system are found to be 4.46 and 3.02, respectively.

1. Introduction

In Tunisia, the building sector uses nearly 30% of the total national consumption of energy [1]. Besides, with the high rhythm of the population growth and the urbanization in the Mediterranean region [2], this proportion is in continuous increasing [3]. Indeed, until 2030 the building and the transport sectors are expected to be the first national energy consumer [4]. Indeed, the building sector represents a very high energy cost that our country cannot afford. Therefore, it is time to propose solutions aimed at reducing the energy demand consumed in Tunisian buildings. Consequently, it is necessary to replace the current conditioning units, large energy consumers and big emitters of green-house gases (GHG), with new technologies better energy efficiency, based on renewable energies (RE).

In Tunisia, the interest to RE is still very trivial. Despite, the improvement of the integration of RE in the national production energy from 0.4% in 2000 to 1.7% in 2010 [5], it remains very feeble. Indeed, according to the attractiveness indices of renewable energy, in their outcome N°35 appeared at November 2012, Tunisia is placed at the thirty-fourth place among 40 countries [6]. Such situation should encourage the Tunisian government to develop technologies which benefits from renewable energy.

Geothermal energy is the form of renewable energy that seems to be well adapted for heating and cooling buildings. It is an abundant, clean (effectively no green-house gas emissions) and reliable (renewable or sustainable) natural resource [7].

One of the well-known applications for the use of geothermal energy in buildings is the ground source heat pump (GSHP) systems.

The use of GSHP systems for space conditioning is a very old technology. Indeed, the first geothermal heat pump was invented in 1912 by Heinrich Zoelly, and then, after 1946 it has been marketed for the first time by Donald Kroeker [8].

The performance of the GSHP is usually expressed in terms of its coefficient of performance (COP), which is the ratio of energy output to supplied energy (electricity for the compressor, circulating pump etc.) of GSHP [9]. In the study of the GSHP systems, it is very important to estimate the heat transfer in the GHEs [10], therefore, it is of practical importance to evaluate the methods for the heat transfer in GHE and to propose some systematic rules

---

Abbreviations: CCP, chilled ceiling panel; GHE, ground heat exchanger; GHP, geothermal heat pump; GSHP, ground source heat pump; HGSHP, hybrid ground source heat pump.

* Corresponding author.
E-mail address: nabiha.naili@crten.rnrt.tn (N. Naili).

http://dx.doi.org/10.1016/j.enbuild.2015.11.024
0378-7788/

Nomenclature

COP	coefficient of performance
C_P	specific heat of water at constant pressure, J kg^{-1} °C^{-1}
d	depths, m
Q_{hr}	heat absorbed from the test room, W
Q_{hg}	heat transferred to the ground, kW
T	temperature, °C
$\dot{m}$	mass flow rate, kg s^{-1}
w_{da}	uncertainty of data acquisition system (%)
w_{me}	uncertainty of measurement (%)
w_{ro}	uncertainty in rotameter reading (%)
w_{sl}	uncertainty associated with system leakages (%)
w_{te}	uncertainty of the thermocouple (%)
w_{Ti}	total uncertainty in measurement of temperature (%)
$w_{\dot{m}}$	total uncertainty in measurement of mass flow rate (%)
$\dot{w}_c$	power input to the compressor, W
$\dot{w}_{\sum p}$	power input to the circulating pumps, W

Subscripts

f	fluid
g	ground
in	inlet
o	outlet
out	outdoor
s	soil
w	water

for real applications [11]. Naili et al. [12,13] studied the effect of various parameters such as mass flow rate of circulating water, length, buried depth and inlet temperature on the heat exchange rate obtained by horizontal GHE. The authors' results show that the maximum heat exchange rate, for a GHE with 50 m of length buried at 1 m of depth is obtained with a mass flow rate of about 0.12 kg s^{-1}.

Bansal et al. [14] studied experimentally and numerically, using a computational fluid dynamics modeling with FLUENT software, the effect of the GHE length and the thermal conductivity of the soil in its surrounding on the thermal performance of the GSHP system. The effect of the soil thermal conductivity and duration of continuous operation on the thermal performance of earth air tunnel heat exchanger were also evaluated by Misra et al. [15]. Transient analysis of these parameters was carried out using CFD simulation platform FLUENT 6.3. Esen et al. [16] tested the performance of an air-conditioning system formed by ground coupled heat pump with two different depths for ground heat exchanger: 1 m and 2 m. Their experience showed that the performance of the GSHP system increases with the depth (2.5 for 1 m and 2.8 for 2 m). Cui et al. [17] developed a numerical model, based on finite element, to simulate hybrid ground-coupled heat pump with domestic hot water heating (DHW). The authors concluded that the horizontal GSHP can offer almost 95% of total DHW demand. CFD simulations were carried out by Congedo et al. [18] to analyze three main geometries of horizontal ground heat exchangers: linear, helical and slinky. In their study, the authors concluded that the most important parameter for the heat transfer performance of the system is the thermal conductivity of the ground around the heat exchanger.

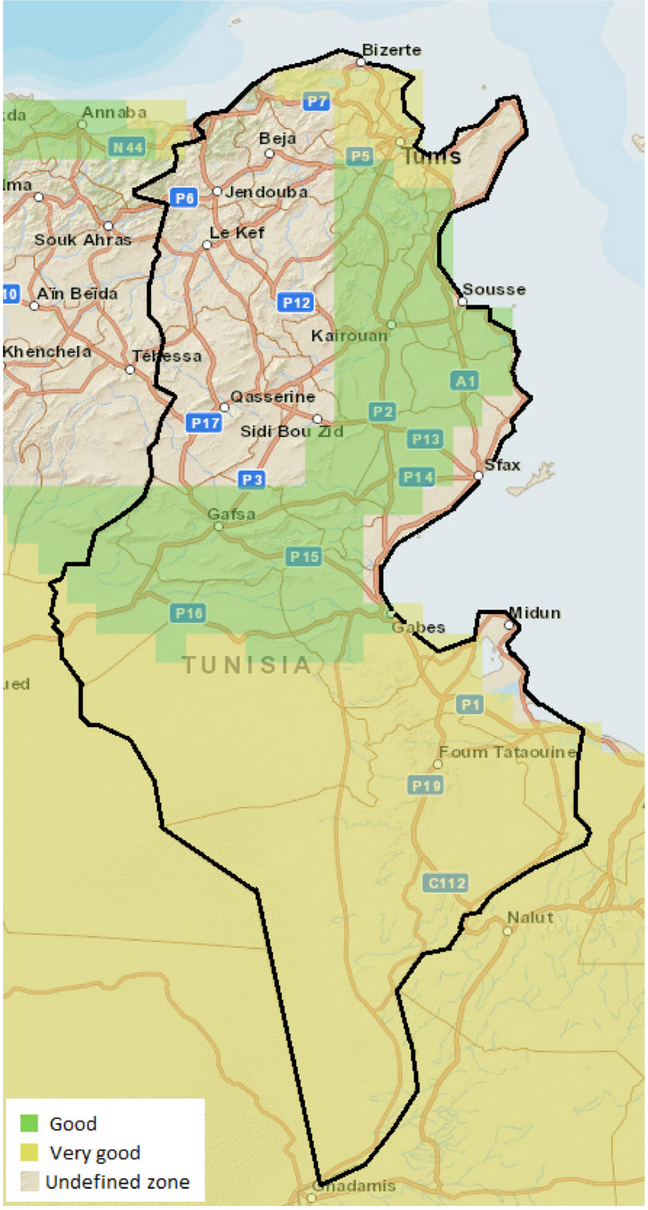

Fig. 1. Performance indicator map [22].

Recently, Luo et al. [19] studied the experimental thermal performance of GSHP for long-term space cooling and heating. The results show that the COP of the GSHP decreases by 8.7% for cooling mode, while it decreases by 4.0% for heating space.

Tunisia is interested to develop the geothermal industry, which opens up new opportunities for economic problems that the country will face in the near future especially, after the Tunisian revolution of January 14, 2011.

This work aims at: (1) evaluating the geothermal energy in Tunisia and (2) testing the deployment of the surface geothermal potential for cooling application in Tunisia. The experiment was carried out at the "Laboratoire des Procédés Thermiques" (LPT) in the "Centre de Recherches et des Technologies de l'Energie" (CRTEn) at Borj Cédria, northern Tunisia. The experimental set-up consists of installing and testing a ground source heat pump (GSHP) system for cooling mode.

The status of geothermal energy and its utilization are pointed out, the test of the direct use of surface geothermal is examined as well as the evaluation of the GSHP system for air conditioning.