Energy 75 (2014) 379–389

Contents lists available at ScienceDirect

Energy

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

Experimental study on a hybrid energy system with small- and medium-scale applications for mild climates

S. Nizetic [a, *], D. Coko [b], I. Marasovic [c]

[a] Department of Thermodynamics and Heat Engines, University of Split, Faculty of Electrical and Mechanical Engineering and Naval Architecture, Postal Address: R. Boskovica 32, 21000 Split, Croatia

[b] Department of Electronics, University of Split, Faculty of Electrical and Mechanical Engineering and Naval Architecture, Postal Address: R. Boskovica 32, 21000 Split, Croatia

[c] Department of Electronics, Group (Chair) for Nanoelectronics and Photovoltaics, University of Split, Faculty of Electrical and Mechanical Engineering and Naval Architecture, Postal Address: R. Boskovica 32, 21000 Split, Croatia

ARTICLE INFO

Article history:
Received 27 March 2014
Received in revised form
25 July 2014
Accepted 28 July 2014
Available online 23 August 2014

Keywords:
Split air-conditioning system
Heat pump
Heat recovery
Coefficient of performance
Photovoltaic system

ABSTRACT

This paper presents the design and performance of a hybrid energy system. The hybrid energy system consists of a standard air-conditioning unit (i.e., a split system), with an integrated boiler for heating water. The entire system is driven by a small off-grid photovoltaic plant and was tested at a geographical location with a typical Mediterranean climate in the summer. Three different working regimes were analyzed: a daytime working regime, a nighttime working regime, and an intense working regime. The boiler water consumption was also simulated to investigate its effect on the overall performance of the hybrid energy system. Experimental measurements in different work regimes indicated that the hybrid energy system achieved a COP_c between 5.0 and 6.0. The mean engaged electric power of the compressor ranged between 500 and 700 W. The mean temperature of the water heated in the boiler ranged from 43.1 °C to 51.0 °C, with a maximum recorded value of 60.6 °C. The research results demonstrate that the hybrid energy system could be implemented in small- or medium-scale residential touristic facilities for countries with mild climates, where heat pump systems can be used to achieve relatively high seasonal COP (coefficient of performance) values.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Heat pump technology [1–4] has been widely used for heating/cooling purposes in different types of buildings because heat pumps are highly efficient devices that can be used year round in countries with mild climates. For example, in countries with typical Mediterranean climates, heat pump systems can be efficiently used both in the summer and winter. The most commonly used devices in residential and touristic facilities on the Mediterranean coast are split air-conditioning units, i.e., split systems. The primary advantages offered by these systems are their reasonable energy costs, easy maintenance, and simplicity, which provide the final users with flexibility. Geographical locations with mild climates frequently exhibit favorable solar characteristics that facilitate the use of PV (photovoltaic) technology [5–8] and allow water to be heated in general systems [9]. Therefore, in recent years, a variety of hybrid energy systems have been developed, and their technical performance characteristics and economic viability have been explored. Experimental studies [10,11] were conducted on a hybrid PV heat/pump system that achieved a mean COP (coefficient of performance) of approximately 4.0. In previous studies, different cooling techniques were also tested for PV panels, but only a modest improvement in the electrical PV efficiency was obtained. A multi-unit heat pump system that simultaneously regulated the temperature and humidity of the supply air was developed and tested in Ref. [12]. A ground coupled heat pump system coupled with solar collectors was developed and the effect of the source temperature on the COP was tested in Ref. [13]. A method was developed in Ref. [14] for the dynamic testing and evaluation of a combined solar-thermal heat pump hot water system. This method was used to directly measure the thermal power contribution of the auxiliary source and to subsequently determine the COP. In Ref. [15], a numerical study was performed on a hybrid heat pump system for existing buildings. The authors found that the SPF (seasonal performance factor) heat pump factor could be increased using a hybrid heat pump system consisting of a retrofitted

* Corresponding author. Tel.: +385 21 3055954.
E-mail address: snizetic@fesb.hr (S. Nizetic).

http://dx.doi.org/10.1016/j.energy.2014.07.087
0360-5442/© 2014 Elsevier Ltd. All rights reserved.

air–water heat pump and gas boiler. An analytical expression for the electrical efficiency of a PV–thermal hybrid air collector was developed in Ref. [16], and the annual electrical efficiency for a glass-type PV module was increased by combining a PV module with a duct. In Ref. [17], an experimental analysis was performed on a PV–thermal solar heat pump air conditioning system in a water heating mode, demonstrating that the mean PV efficiency of the hybrid system could be improved by over 20% compared with a conventional PV module. In Ref. [18], a PV solar-assisted heat-pump/heat-pipe system was designed and tested in different operational modes. In Ref. [19], the cooling seasonal performance factor was analyzed for a hybrid ground-source heat pump in parallel and serial configurations. In Ref. [20], a novel solar PV/loop-heat-pipe heat pump system was developed for heating water, and a maximum COP of 8.7 was attained. This concept was further developed in Ref. [21], and simulations and analyses were compared with the experimental data. The design and performance of a solar hybrid air-conditioning system for high-temperature cooling in a subtropical climate were analyzed in Ref. [22]; the primary energy consumption was found to be 47% lower than that of a conventional air-conditioning system used for small- or medium-scale applications. The study of a hybrid solar energy and ground storage heat pump system was elaborated in Ref. [23], where the average achieved coefficient of performance equals 4.7 in winter period and 3.9 in summer period. An annual performance of a building-integrated photovoltaic/water-heating system for warm climate applications was analyzed in Ref. [24] and a higher energy output is generated compared to conventional solar systems. The use of a solar assisted geothermal heat pump coupled with a small wind turbine system was studied in Ref. [25] and economic viability was also proven. In Ref. [26] the development of a hybrid solar-assisted cooling/heating system was elaborated, where the established reduction of power consumption ranged from 34.5% to 81.2%. A dynamic modeling of a hybrid photovoltaic–thermal heat pump system was presented in Ref. [27] and the maximal recorded coefficient of performance was 7.9. A case study for different renewable energy options in building applications is provided in Ref. [28]. In Ref. [29] the development of a hybrid, i.e. absorption/CO_2 compression hybrid heat pump system was analyzed to explore increase possibilities in the coefficient of performance when carbon dioxide is used as a refrigerant. A performance analysis of a rooftop wind solar hybrid heat pump was provided in Ref. [30] and it is concluded that a developed hybrid energy system can reduce annual carbon dioxide emissions by up to 30% comparing to conventional energy systems. The authors in Ref. [31] have generally been analyzing several factors that affect the performance and characteristics of hybrid, photovoltaic–thermal collector energy systems. A detailed review on the energy and exergy analysis of solar-assisted heat pumps was presented in Ref. [32], and a review of the advances in solar PV/thermal hybrid collector technology was provided in Ref. [33].

The objective of this study was to investigate the design and performance of an experimental hybrid heat pump system driven by a PV system in a geographical location with a typical Mediterranean climate. Air-conditioning heat pump split systems and boilers for heating water can be found in most households or small- and medium-scale touristic facilities in Mediterranean countries. Thus, the goal was to develop the hybrid energy system and test its performance, i.e., to find an efficient energy solution by adapting technologies that are currently available on the market.

2. Experimental configuration

2.1. Air-conditioning heat pump split system

A simplified schematic of the experimental hybrid energy system is shown in Fig. 1 (in the cooling mode). The heat pump system was a standard air-conditioning split unit, which was connected to

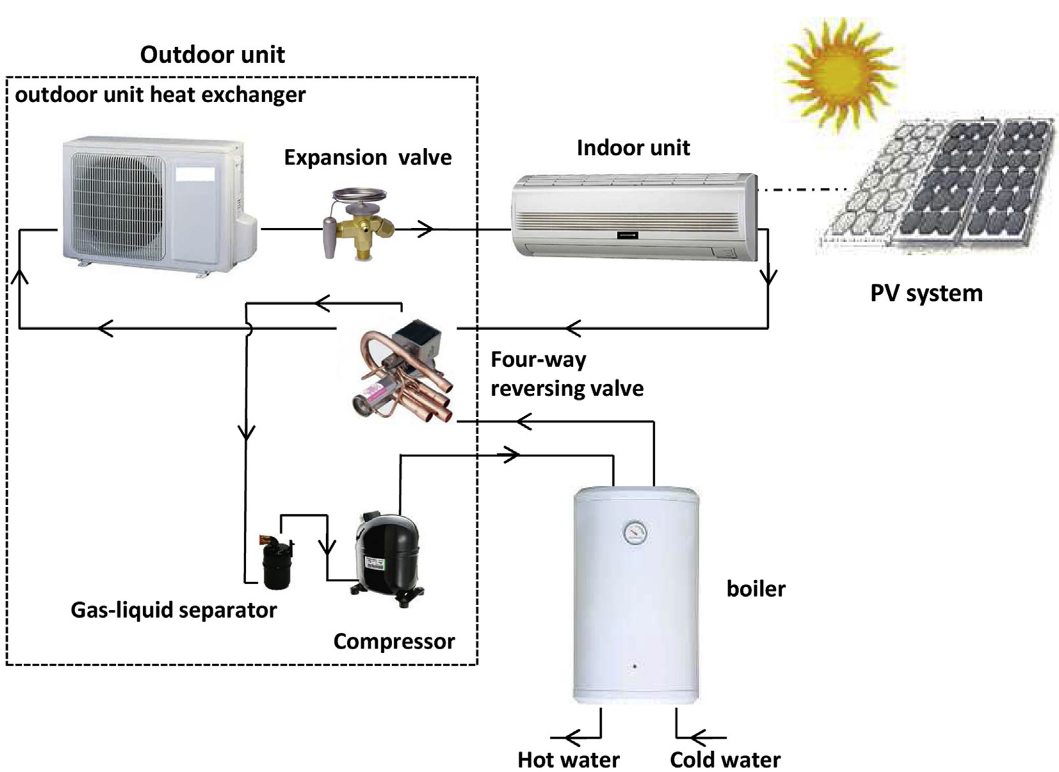

Fig. 1. Simplified schematic providing an overview of the developed hybrid energy system.

Download English Version:

https://daneshyari.com/en/article/8076822

Download Persian Version:

https://daneshyari.com/article/8076822

Daneshyari.com