Renewable and Sustainable Energy Reviews 67 (2017) 954–987

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

A review on solar chimney systems

A.B. Kasaeian [a,*], Sh. Molana [a], K. Rahmani [a], D. Wen [b,c]

[a] Department of Renewable Energies, Faculty of New Science and Technologies, University of Tehran, Tehran, Iran
[b] School of Aeronautical Science and Engineering, Beihang University, Beijing, 100191, P.R. China
[c] School of Chemical and Process Engineering, University of Leeds, Leeds, LS2 9JT, U.K

A R T I C L E I N F O

Article history:
Received 8 December 2015
Received in revised form
29 August 2016
Accepted 14 September 2016

Keywords:
Solar chimney
Collector
Turbine
Power conversion unit
Solar updraft tower

A B S T R A C T

The increased utilization of solar energy has generated intensive interest in developing solar chimney (SC) technology in recent years. Many studies have been conducted in this area both experimentally and theoretically, whereas experimental studies are mainly focused on small-scale systems. This work provides a comprehensive and updated review that includes most of the experimental, analytical and simulational studies, the solar chimney applications, hybrid systems and geographical case studies based on extended references with different focuses in different sections. The technological gaps are identified and a summary of suggestions is given, including more experimental works on large-scale systems, and CFD analysis for optimization between geometrical parameters and output power. Further studies on some emerging applications of solar chimney technology including hybrid systems are also recommended.

Contents

1. Introduction

A solar chimney system consists of a solar collector, a chimney and a turbine (Fig. 1), which is also named as Solar Aero-Electric Power Plant (SAEP). It uses solar insolation to increase the temperature of the air, and the buoyancy force causes the flow of the air stream inside the solar chimney system. Air is warmed up due to the greenhouse effect under a transparent collector.

Cabanyes [1] proposed the solar chimney power technology for the first time. In this system, a chimney was utilized for air heating of a house. Inside the house, a type of wind blade was located for the purpose of electricity generation. Several patents were registered in Australia, the USA, and Canada since 1975 [2]. The first solar chimney power plant (SCPP) prototype was designed and constructed by Schlaich [3,4] and his colleagues in Manzanares, Spain, between 1981 and 1982, After establishing this plant, many researchers in different countries proposed their solar chimney designs and buildings. A large project with 200 MW was assigned by the government of Australia in Mildura. The proposed solar chimney was supposed to be 1000 m in height and 7000 m in the collector diameter. The output power of this plant was supposed to

* Corresponding author.
E-mail address: akasa@ut.ac.ir (A.B. Kasaeian).

http://dx.doi.org/10.1016/j.rser.2016.09.081
1364-0321/

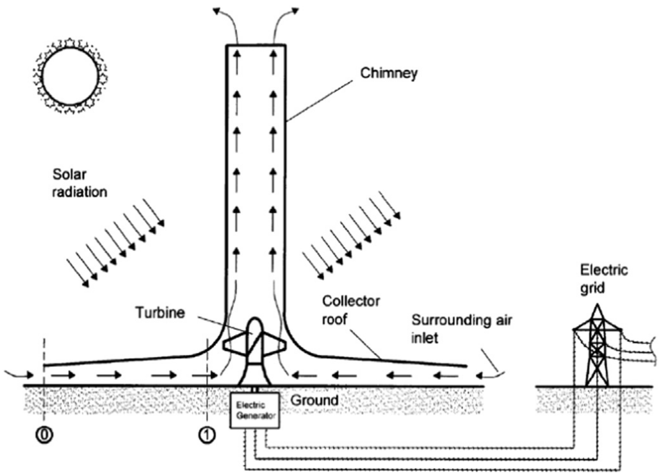

Fig. 1. An schematic overview of the solar tower principle [5], [with permission from Elsevier].

be capable of supplying power for 200,000 households [5,6]. A program for constructing a 100 MW SCPP in a desert in Rajasthan, India, was also scheduled, but was aborted later on due to the political tension between India and Pakistan [7]. A proposal of building of a 40 MW SCPP, called the Ciudad Real Torre Solar with a 750 m high chimney and 3.5 km^2 collectors in Ciudad Real, Spain, was presented [8]. The Namibian government agreed in 2008 to build a 400 MW SCPP, called the "Green Tower" with a solar chimney 1500 m high, 280 m chimney diameter, and 37 km^2 collector, which was also proposed to act as a greenhouse for agriculture applications [9]. Building of a 1000 m high solar chimney was suggested in Shanghai, China for tourism plans and power generation, and its validation was performed by the HUST team [10].

The review by Zhou et al. [10] provided a general vision of research and development of solar chimney power technology up to 2010. After the introduction of the basic physical process of solar chimney, they reviewed the experimental and theoretical studies, and discussed the economic aspects of solar chimney and some different types of solar chimneys such as floating solar chimney, solar chimney with sloped collector and mountain-laid chimneys. Chikere et al. [11] reviewed the previous studies focusing on the enhancement techniques of SCPP until 2011. An alternative enhancement technique, which utilizes waste thermal energy in the flue gas as the energy input in a solar chimney collector, was also proposed. Zhai et al. [12] provided a review of solar chimney applications in buildings in 2011, and summarized the applications of solar chimneys based on roof and walls of buildings and also the integrated configurations based on solar chimneys. Dhahri and Omeri [13] investigated the principles, the characteristics, the components and the operation of solar chimneys in their review paper. They also gave a brief overview of the research about SCPP which was categorized into three sections including the solar chimney projects, the numerical studies, and the unconventional solar chimneys until 2013. In 2014, Olusola Olorunfemi and Bamisile [14] presented a brief review of solar chimney, and limited the solar chimney applications to the desert prone villages with a focus on the northern regions of Nigeria.

It is clear that previous review papers are incomplete: some are regional, some are not up to date, and the contents are not comprehensive. Considering the rapid development of this field, it is essential to conduct a timely and critical review that captures the latest development. A comprehensive and updated review is presented in this work to gather all the works and analyze the gaps for showing a roadmap for future researchers. This work includes the experimental studies, analytical and simulation works, the solar chimney applications, hybrid systems and geographical case studies, as well as critical comments and suggestions for future work.

2. Review on experimental work

The first prototype solar chimney power plant with 50 kW peak power output was built by a German structural engineering company, Schlaich Bergermann [15] in Manzanares, around 150 km south of Madrid, Spain in 1981(Fig. 2). The plant had a solar chimney with 194.6 m height, 5.08 m diameter, 0.00125 m thickness of the metallic wall, and a collector of 122 m in radius with a PVC roof-cover, as well as a single-rotor turbine system equipped with four blades at the chimney base. The key characteristics of the Manzanares solar chimney are reported in Table 1. This prototype was in operation from 1982 to 1989 and the electricity generated was integrated into the local power grid. In

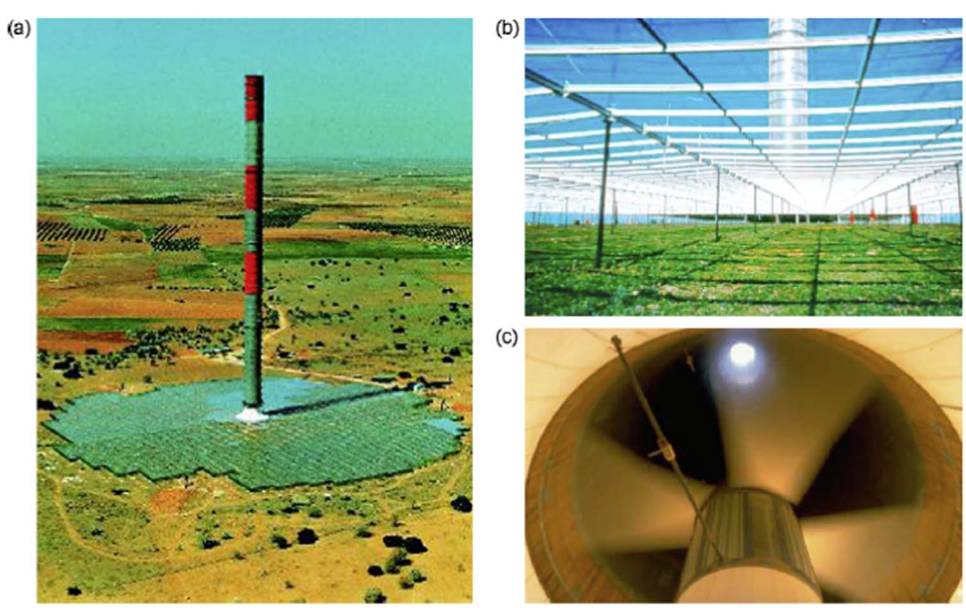

Fig. 2. Manzanares plant prototype: (a) the plant; (b) turbine; and (c) glass roof of the collector [10], [with permission from Elsevier].