Renewable and Sustainable Energy Reviews xxx (xxxx) xxx

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

High temperature central tower plants for concentrated solar power: 2021 overview

R.P. Merchán, M.J. Santos, A. Medina *, A. Calvo Hernández

Department of Applied Physics and Institute of Fundamental Physics and Mathematics (IUFFYM), University of Salamanca, 37008 Salamanca, Spain

ARTICLE INFO

Keywords:
Concentrated solar power
Solar power towers
Technologies Overview
High Temperature Receivers
Thermal Energy Storage and Hybridization
Power Cycles
Thermo-economic Data

ABSTRACT

Among the diverse technologies for producing clean energy through concentrated solar power, central tower plants are believed to be the most promising in the next years. In these plants a heliostat field collects and redirects solar irradiance towards a central receiver where a fluid is heated up. Afterwards, the same fluid or eventually another one heated in a heat exchanger develops a thermodynamic cycle that produces a mechanical power output, transformed in electrical energy through an electrical subsystem. Quite high temperatures can be reached in the solar receiver, above 1000 K, ensuring a high cycle efficiency. This review is focused to summarize the state-of-the-art of this technology and the open challenges for the next generation of this kind of plants. An actualized review of the plants working nowadays as well as the plants under development and research projects is presented. Updated thermo-economic data are collected in a comprehensive way. Each of the subsystems of a typical plant are surveyed, putting the emphasis on the more relevant research lines and the issues to be solved in the next years. Heliostat field margin of improvement, high temperature receivers and the most suitable thermodynamic cycles to take advantage of high temperature heat are detailed. Thermal storage and hybridization concepts are also surveyed. It is stressed the importance to design the plant as a whole, optimizing subsystems and their coupling to improve overall plant performance. Finally, a prospect for future R&D in this field is performed.

1. Introduction

Current anthropogenic intensification of climate change, energy demand growing and fossil fuel exhaustion have made imperative the necessity of a new energy generation paradigm looking for an increase of generated power, but from cleaner sources reducing pollutant emissions. Among the different renewable energy sources, Concentrated Solar Power (CSP) technology constitutes a very interesting option that employs solar radiation as main energy source. This technology stands out thanks to its ability to produce reliable, safe, efficient and clean power reducing, or even fully removing, pollutant greenhouse effect emissions associated with conventional fuel combustion [1]. In Concentrated Solar Power systems, direct solar radiation is concentrated in order to obtain (medium or high temperature) thermal energy that is transformed into electrical energy by means of a thermodynamic cycle and an electric generator. Main advantage of concentrated solar power technology against other conventional renewables as photovoltaic or wind energy is its potential for hybridization and also to store solar energy as heat. These possibilities allow to produce electric energy when desired and to rectify the inherently variable solar contribution, thus helping to stabilize and to control power output [2].

By 2013, there was about 3.4 GW of installed CSP operating capacity worldwide. Global CSP capacity grew 11% in 2019 to 6.2 GW. This is below the average annual increase of the past decade (about 24%), but CSP spread to new markets as France, Israel, Kuwait, China and South Africa. For the first time as much tower capacity as parabolic trough capacity was completed during 2019 [3]. According to the 2014 technology roadmap for Solar Thermal Electricity [1], the solar thermal electricity will represent about 11% of total electricity generation by 2050. In this scenario, called hi-Ren (High Renewables scenario), which is the most optimistic one, the global energy production will be almost entirely based on free-carbon emitting technologies, mostly renewables in 2050. As a consequence, the annual emissions from the power sector would fall from 13 $GtCO_2$ in 2011 to a mere 1 $GtCO_2$ in 2050. Thermosolar technology will be responsible for emissions reduction of 2.1 $GtCO_2$ and 9% cumulative emissions reduction over the entire scenario period, which is about half the contribution from photovoltaic electricity (20%).

One of the first prototypes for obtaining usable energy from concentrating solar radiation was developed by Augustin Mouchot, who presented it at the Universal Exhibition in Paris in 1878. That prototype

* Corresponding author.
E-mail addresses: rpmerchan@usal.es (R.P. Merchán), smjesus@usal.es (M.J. Santos), amd385@usal.es (A. Medina), anca@usal.es (A. Calvo Hernández).

https://doi.org/10.1016/j.rser.2021.111828
Received 23 March 2021; Received in revised form 10 September 2021; Accepted 26 October 2021
This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).