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Brayton technology for Concentrated Solar Power plants: Comparative analysis of central tower plants and parabolic dish farms

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

Department of Applied Physics and IUFFYM, Universidad de Salamanca, Salamanca, Spain

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ABSTRACT

Concentrated solar power plants intend to be key in the pool of renewable energy production technologies in the next future because of their versatility and high efficiency. In this work a comparative study between two promising technologies is developed. A central tower receiver surrounded by a heliostat field and a farm of parabolic dishes, both coupled to a hybrid Brayton cycle, are considered. Two power scales are surveyed (between 5 and 20 MW) at three different locations with quite different latitudes (between Sahara desert and medium European latitudes) and meteorological conditions. A modelling scheme developed by our group that allows to obtain the expected thermodynamic and thermo-economic plant records is applied. Key indicators like efficiency, net generated energy, levelized cost of electricity, and specific plant investment are calculated and analysed. Variability of natural gas prices and also land cost uncertainty are reflected on levelized cost of electricity range. Among the plants compared, minimum values are found within the interval [135–163] USD/MWh for central towers at the highest power considered and southern latitudes. In addition, the area needed for the installation of the plants and the influence of CO_2 taxes is also analysed. Displayed cashflows show larger investment costs for central tower than for dish farms. Finally, those systems are put into the context of other concentrated solar power, other renewable, like wind or photovoltaic, and other conventional power plants.

1. Introduction

Increasing energy demand together with fuel combustion concerns are the main drivers in the research of alternative and less polluting energy sources. A key advantage of Concentrated Solar Power (CSP) [1] plants over other renewable installations is the possibility of producing energy in a predictable and controllable way through hybridization [2] and/or storage [3]. Nowadays, most commercial CSP plants are a combination of Rankine cycles at medium temperatures together with Parabolic Trough collectors (PT) [4] or Central Tower receiver (CT) systems [5]. Nevertheless, larger efficiency layouts are being investigated through higher temperatures related to Brayton cycles [6]. On the way to fully functional plants with Thermal Energy Storage (TES), hybridization stands out as an intermediate step that allows reaching high temperatures in a straightforward way. However, this does not spoil that completely renewable plants, capable to produce energy fitting demand requirements, independently of seasonal or weather fluctuations, would be the final objective of this kind of studies [7]. With this aim, the development of high temperature and flexible storage systems will be required [8].

Recently, our group published an extensive analysis of the state-of-the-art and the expected research working lines for the next future on the field [9]. Briefly, some highlights are summarized here in order to bring to light the role of the investigation presented in this work. The working principle of CSP plants is quite simple, mirrors with different geometries reflect and concentrate direct solar radiation into a solar receiver. A working fluid flows through it reaching relatively high temperatures (approximately between 500 and 1000 °C). This fluid follows a thermodynamic cycle where heat input is transformed in mechanical work usually associated with the rotation of a turbine. Finally, an electrical subsystem transforms in turn this mechanical power in electrical power.

As these plants work with Direct Normal Irradiance (DNI), best locations are in principle those with higher DNI records. Usually regions between 15° and 40° at north or south latitudes are considered the best ones [2]. Nevertheless, sometimes another key ingredient to reach high efficiencies is forgotten, the mean ambient temperature at the plant site. In principle, locations with lower average temperatures are good to obtain high thermal efficiencies in the thermodynamic cycle that

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

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