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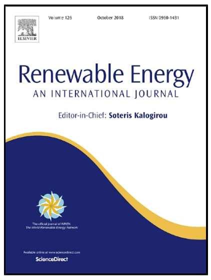

Annual performance of subcritical Rankine cycle coupled to an innovative particle receiver solar power plant

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Annual performance of subcritical Rankine cycle coupled to an innovative particle receiver solar power plant

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Abstract

Concentrated solar power plants using molten salts as heat transfer and storage fluid have emerged as the preferred commercial solution for solar thermal electricity in central receiver technology. Despite their ability to store large amounts of thermal energy and efficient receiver designs, further efficiency improvements are constrained by tight temperature restrictions when using molten salts (290 °C to 565 °C). In this work, a novel heat transfer fluid based on a dense particle suspension (DPS) is used due to its excellent thermophysical properties that extend the operating temperature of solar receiver and allow its coupling with higher-efficiency power cycles. In this paper, the design of a DPS solar receiver working at 650 °C has been optimized for two commercial sizes (50 MW_{th} and 290 MW_{th}) coupled to an optimized subcritical Rankine cycle. The results showed that a five-extraction reheated Rankine cycle operating at 610 °C and 180 bar maximizes power plant efficiency when coupled with a DPS central receiver, giving 41% power block efficiency and 23% sun-to-electricity efficiency. For optimization purposes at design point conditions, in-house code programmed into MATLAB platform was used while TRNSYS software was employed for annual plant performance analysis.

Keywords: Solar thermal, Steam Rankine cycle, thermodynamics optimization, particle receiver

Introduction

The installation and use of renewable energy sources for electricity production is gaining in importance due to stringent environmental standards seeking to reduce pollutant emissions and fossil fuel dependence. In this context, concentrating solar thermal technologies are considered to be one of the most promising means for electricity production in coming decades [1]. Concentrating solar power (CSP) has shown many advantages compared to other intermittent renewable electricity sources such as wind and photovoltaics. Amongst the main advantages are that solar thermal electricity is reliable, flexible and, when integrated with thermal energy storage (TES) systems, is not limited to operating only when the sun is shining [2]. In addition, when coupled with dry-cooling, the water requirement of CSP technologies is limited [3]. However, cost reductions achieved by competing technologies are forcing CSP developers to move a step further seeking for cost reductions due a highly competitive market and the lack of tariffs that correctly value the dispatchability of CSP [4]. This could be achieved through economies of scale [5,6], by implementing new technological developments leading to higher solar-to-electricity