Solar Thermal Power Plants: A Brief Analysis of the Potential for Solar Generation in the State of Goiás

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ABSTRACT

Concentrated solar power (CSP) emerges as a promising solution to address the intermittency of renewable sources, such as photovoltaic solar energy, due to its ability to store thermal energy without the need for immediate conversion to electricity. This study aims to identify CSP systems that incorporate thermal storage to enhance the utilization of solar energy in Goiás. The methodology includes a literature review on CSP plants with thermal storage systems. Four types of solar concentrators were identified: parabolic trough, solar tower, linear Fresnel reflector, and parabolic dish. Thermal storage methods can utilize either sensible or latent heat. Goiás' geographical location is advantageous for CSP production, further enhanced by Brazil's industrial capacity, which already includes key components of the CSP supply chain.

Keywords: Concentrated solar power; Latent heat; Phase change material (PCM); Sensible heat; Thermal Storage.

INTRODUCTION

Although renewable and sustainable energy sources can mitigate problems associated with fossil fuels, such as air and water pollution, global warming, and impacts on human health, they also face significant challenges. These energy sources are intermittent and influenced by climatic variations, leading to a discrepancy between their availability and demand.

In this context, Heliothermic solar (or solar thermal) energy emerges as an alternative, despite being less financially competitive. These systems utilize solar radiation to heat a fluid to sufficiently high temperatures, enabling the generation of shaft power through a thermodynamic cycle. The main advantage of these systems is the ability to store thermal energy without the need for immediate conversion into electricity [1]. To achieve this, heat transfer occurs through concentrated solar power (CSP), where solar radiation is directed using mirrors or lenses to heat a storage material [2].

Several studies on thermal storage systems have been conducted worldwide in recent years. These works have numerically and experimentally evaluated the performance of such systems [3], the phase change material (PCM) candidates for latent heat thermal energy storage [2], system designs and optimization [4], as well as high-temperature storage [5], among other topics. While a few studies have been conducted in Brazil [6], but this topic remains unexplored in the state of Goiás. Thus, the objective of this study is to present different concentrated solar power (CSP) systems that use thermal storage and can be used to increase the utilization of solar energy in the region of Goiás.

MATERIALS AND METHODS

This work is classified as a bibliographic study, utilizing articles and technical reports as sources of information. A qualitative analysis of the data was conducted. We performed a search in the Scopus database on the topic of solar thermal energy, including existing types of thermal storage and their respective functionalities. We include studies carried out worldwide in the last five years. This approach allowed us to reach the conclusions presented in this paper.

RESULTS AND DISCUSSION

CSP generation encompasses four different technologies, namely: (i) parabolic trough, where the collectors are shaped like parabolic troughs, concentrating sunlight onto a receiver tube located at the focal line of the mirror [7]; (ii) solar tower, in which mirrors are arranged in a field around a central tower. These mirrors focus sunlight onto a receiver located at the top of the tower, heating a fluid (typically molten salts) to high temperatures [8]; (iii) linear Fresnel reflector, which operates similarly to parabolic troughs, but uses flat or slightly curved mirrors arranged in rows to direct sunlight onto an elevated receiver [9]; and (iv) parabolic dish, which uses a large mirrored parabolic surface to concentrate sunlight onto a focal point [10]. This last system typically employs a receiver with a Stirling engine, converting heat directly into electricity without the use of thermal storage systems.

The parabolic trough is the most mature technology and has the widest presence, though its maximum operating temperatures are below 400°C. The tubes are coated with materials that enhance the absorption of radiation and are encased in evacuated glass tubes to minimize heat loss. The solar tower is its closest competitor, primarily due to the high temperatures it can achieve, reaching up to 1000°C, which is advantageous for power generation in terms of higher thermal efficiencies, lower operational costs, and growth potential.

The storage method is classified according to the physical processes involved: (i) Sensible Heat Storage (SHS), where the working fluid is stored without a phase change; (ii) Latent Heat Storage (LHS), in which the PCM is evaporated (or melted) and stored, returning to its initial phase when thermal energy is transferred to an energy conversion process [2]. The choice of solar concentration method depends on the storage temperature and, consequently, the scale of storage. For a deeper understanding, we recommend the work of Jayathunga *et al*. [2].

There is a region in Brazil known as the "Solar Belt," which offers substantial potential for solar electricity generation due to its high irradiation levels. The state of Goiás is within this belt, favoring the use of solar thermal energy throughout the state. Additionally, the Brazilian industry already has some of the equipment needed for solar thermal power, such as steam turbines, steam generators, heat exchangers, and transformers. However, there is still a need to develop systems for energy capture and thermal cycle maintenance, as mirrors and solar concentrators must be imported, with these technologies and supplies being exclusively foreign.

CONCLUSION

This work investigates various thermal energy storage systems applicable to concentrated solar power (CSP) generation, with the goal of increasing solar energy utilization in the Goiás region. CSP generation includes four main technologies: parabolic troughs, solar towers, linear Fresnel reflectors, and parabolic dishes. The thermal storage method – sensible heat storage (SHS) or latent heat storage (LHS) – depends on the solar concentration method and the required storage scale. The "Solar Belt" in Brazil, which includes the state of Goiás, presents significant potential for solar thermal energy generation due to its high levels of solar irradiation. This is supported by the fact that the Brazilian industry is already equipped with several essential components for solar thermal energy systems.

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