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Design and construction of sun tracking systems for solar parabolic concentrator displacement

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ABSTRACT

Solar concentrator technology is becoming more prevalent today and studies performed on this subject have gained a great deal of interest in the world. In order to design a new solar parabolic concentrator that will be installed to operate in more efficient and more feasible way, it is necessary in the first step to analyze such parameters like solar irradiations values, and solar angles. Therefore, in this work, theoretical studies have been performed for solar angles using time and geographic parameters in Tunisia. An experimental measurement of solar irradiations has been done using a high precision metrological station to determine the diffuse, the direct and the global irradiations on the horizontal plane.

In the second step each solar concentrator technology has its specifications in terms of mobility, orientation and the accuracy of the tracking system. In this work three pilot sun tracking systems for a solar parabolic concentrator were designed and constructed in the Research and Technology Center of Energy in Tunisia. Those trackers are able to follow the sun position on both axes (azimuth and elevation angles). We have described and determined the sun tracking errors of each one. A comparative study of the three sun tracking systems with a commercial tracker has been conducted. Basing on efficiency and economical criteria one of the sun tracking systems was selected. The total price of the chosen tracker is estimated to be around 1300 Euros and its tracking error is inferior to 0.2°. The advanced accuracy of the new tracker was achieved with the use of reduction gear unit.

Contents

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1. Introduction

Sun-tracking system plays an important role in the development of high solar concentration applications that directly convert the solar energy into thermal or electrical energy. Several methods of sun following have been surveyed and evaluated to keep the solar panels, solar concentrators, telescopes or other solar systems orthogonal to the sun beam [1,2].

In first step solar trackers can be classified under three categories one-axis, two-axis and multi-axis sun-tracking system [3,4] which differs related to the solar concentrated technology.

Single axis trackers have one free degree of movement that allows the rotation of the mechanism around one axis. These trackers pursue the sun position on a daily basis from east to west or north to south [5–8]. Two axes tracker has two free degrees of movement that allows the rotation around two axes. These trackers follow the sun both from east to west on a daily basis and from north to south on an annual basis. Solar concentrator technologies essentially photovoltaic panels, concentrated photovoltaic panels and solar parabolic concentrators require two axes sun-tracking systems.

Yilmaz et al. [9] conducted an experimental comparative test of 4.6 KW PV panels with both fixed and double axes tracking system. They showed the important enhancement of power production and system efficiency. Noel et al. [10] used a tracker to control mirrors reflecting sun rays toward a CSP system using Fresnel lenses. Mavromatakis et al. [11] used a new patented design consisting of a heliotrope sliding mechanism for a photovoltaique (PV) panels. Sebastijan et al. [12] developed a new prediction algorithm for solar angles; meanwhile Ying-Pin [6] used an optimization method in order to identify the tilt angles for PV panels in the region of Taiwan. Several studies showed that the use of sun tracking systems for PV panels increased the average energy efficiency compared to the fixed PV panels. These systems can be applied in all types of solar arrangements to increase their electricity generation capacity.

Perpiñán [13] developed a method to estimate and to optimize the cost of energy function for a PV panel using tracking systems. Meanwhile, Clifford et al. [14] built up a one axis sun tracking system based on thermo-mechanical method consisting of a bimetallic trips dilatation. Tina et al. [15] tested a photodiodes sensor for two axes tracker. Nelson et al. [16,17] conducted tests on PV panels and reported that during heavy overcast tilting the panels towards the zenith will increase the energy harvest to approximately 50% compared to a system that simply tracks the sun's path through the sky every day regardless of the sky conditions. Koussa et al. [18] conducted a comparative study of the performance for the fixed, one axis and two axes tracking system taking into consideration the diverse parameters which intervene in day length, weather conditions, sky state. They evaluated the considerable contribution of the tracking systems in the PV system overall performance. Ying Xue et al. [19] employed a declination-clock mounting system by combining both time-based control and sensor-based control which revealed the tracking system effect on application for both PV and CSP applications.

Abdallah and Badran [20] deployed a sun tracking system for enhancing the solar still productivity. They compared a fixed and a sun tracking solar still and they showed that the use of sun tracking increased the productivity around 22%. Sungur [21] tested PV panels with a two axes sun tracking system. He obtained 42.6% more energy at 37°60, latitude (Konya, Turkey). Cruz-Peragón et al. [22] compared a fixed and a tracked electrical energy production system; they revealed an energy gain (higher than 20%) for most of the national territory.

On the other hand dual sun tracking system can be classified into two categories: passive (mechanical) [23] and active (electrical) trackers. Many research studies related to active sun tracking system have been conducted. Nuwayhid et al. [24] adopted both the open-loop and closed-loop tracking schemes into a parabolic concentrator attached to a polar tracking system. In the open-loop scheme, a computer acts as a controller to calculate two rotational angles, as well as to drive the concentrator along the declination and polar axis. In the closed-loop scheme, nine light-dependent resistors (LDR) are arranged in an array of a circular-shape "iris" to facilitate sun-tracking with a high degree of accuracy. It consists of an electronic circuit for controlling a sun tracking system especially for cloudy days. This dual axes sun tracker is based on the exploitation of the imbalance created between two resistors LDR separated by an opaque wall [25].

Furthermore, experimental studies have been conducted for a two-axes solar concentrator using automatic sun tracking system integrated in diverse applications such as solar cookers and their performance was investigated showing the important efficiency enhancement [26–28].

The aim of this paper is to choice the adequate sun tracking system of solar parabolic concentrator (SPC) that follows the sun along both axes (azimuth and elevation angles) with most precision, to reach an advanced efficiency for the SPC. A comparative study of three pilot sun tracking systems was held in the Research and Technology Centre of Energy in Tunisia (CRTEn).

The work plan of the paper is organized as follows. In Section 2, the annual solar irradiations (global, diffuse and direct) and the solar angles variations in Tunisia were given. In Section 3, the three solar tracking systems are presented. In Section 4, a comparative study between the three trackers and a previous work has been conducted where we have cited many selection criteria of each one of them. The main remarks of this work are highlighted in the conclusion.

2. Solar irradiation and solar angles in Tunisia

The concentrating solar collectors use optical elements to focus large amounts of solar irradiation into a small receiving area and