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Comparative performance analysis between static solar panels and single-axis tracking system on a hot climate region near to the equator

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ABSTRACT

Photovoltaic solar energy has been explored as an energy solution to the decline of energy production, as well as environmental concerns. However, generate electricity through the sun still considered uncompetitive freight to other sources, cause it presents low efficiency and high production cost. In attempt to make it more attractive from a financial point view, solar trackers has been used to increase the photovoltaic systems efficiency. Considering its facts, this paper aims to perform a comparative study between a static photovoltaic solar panel and a one-axis mobility panel, installed in the city of Mossoró/RN. The city in study is located in the Brazilian semiarid, under high solar radiation levels, in a dry climate and hot region, reaching high temperatures during the day. After assembly the proposed systems, were performed operating analysis and performance comparative study between the static and mobile systems, which allowed to conclude that the panel using the sun tracking showed a low average gain in power generated relative to the fixed panel to the region where the systems installed.

Contents

1. Introduction

The world energy consumption has shown high growth over the past decades, driven by technological progress and human

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development. This growth, together with the possibility of reducing the fossil fuels supply, and also the growing concern to the environment preservation, have been encouraging factors to research and development of alternative energy sources, less polluting, renewable and produce little environmental impact [1].

Faced with this global scenery, the use of solar energy, especially with regard to the generation of electricity through photovoltaic panels, is increasing the installed power each year, reaching approximately 139 GW in 2013 [2].

The electricity generation through the sun can bring benefits, such as the diversification of energy sources, reduction of environmental impacts and reducing fossil fuels dependence [3,4]. Despite the advantages presented, photovoltaic electricity generation find obstacles to its popularization. Two factors limit its use today, namely, the high production costs and low efficiency compared to others alternative energy sources [5].

Looking for increase photovoltaic systems efficiency, researches have been developed using solar trackers. These devices keep the panels almost always directed toward the sun in order to always keep the surface perpendicular to the solar rays. Thus, there is a greater uptake of solar energy and consequent increase in energy production [6].

The first tracker was completely mechanical and introduced by Finster in 1962. One year later, Saavedra presented a mechanism with an automatic electronic control, which was used to orient an Eppley pyrheliometer [7].

Bione et al. compared the pumping systems driven by fixed, tracking and tracking with concentration PVs. The PV–V-trough system, consisted of four cavities and two PV modules to track the sun along its north–south axis, tilted at an angle of 20° towards the north. A theoretical simulation, as well as experimental comparison between three cases, was performed. By analyzing the daily characteristic curve for three given modes, the results showed that for a given irradiance, the pumped water flow rate was significantly different from one another. They proved that the benefits ratios obtained for water volume were higher than that for collected solar energy. The fixed PV, the PV with the tracker and the concentrating-tracking systems pumped 4.9, 7.4 and 12.6 m^3/day, respectively [8].

Tomson analyzed the performance of the two-positional control of single stand-alone flat plate concentrator. The collector was rotated around its single tilted axis twice per day with predefined deflections. The effect of different tilt angles, initial tilt angle, initial azimuth, and azimuth angle of the deflected plane were evaluated on the daily and seasonal gain. The comparison of simulation and experimental results indicated that using a simple tracking drive with low energy input for a brief daily movement, increased the seasonal energy yield by 10–20% comparing to that of a fixed south facing collector tilted at an optimal angle [9].

Ai et al. proposed and compared the azimuth and hour angle three-step trackers. The day length on the south facing slope was divided into three equal parts in order to adjust the tilt angle. The sum of the direct radiation received in each time interval and the sky diffusion and ground reflection radiation during a day were considered to derive the mathematical formula for the three-step tracking system to estimate the daily radiation on planes. They concluded that for the whole year, the radiation on the slope with optimized tilt angle was 30.2% and that for the two-axis azimuth three-step tracking was 72% higher than that on the horizontal surface. No significant difference was found between one-axis azimuth three-step tracking and hour angle three-step tracking power [10].

Michaelides et al. investigated and compared the performance and cost effectiveness of a solar water heater with collector surface in four situations: fixed at 40° from the horizontal, the single-axis tracking with a vertical axis, fixed slope and variable azimuth and the seasonal tracking mode where the collector slope is changed twice per year. To analyze the system, they used computer simulations using the TRNSYS simulation program for a thermosiphon system. The simulation results showed that the best thermal performance was obtained with the single-axis tracking. In Nicosia, the annual solar fraction (fraction of load that is provided by solar radiation) with this mode was 87.6% compared to 81.6% with the seasonal mode and to 79.7% with the fixed surface mode, while the corresponding figures for Athens were 81.4%, 76.2%, and 74.4%, respectively. From the economic point of view, the fixed surface mode was found to be the most cost effective [11].

Lorenzo et al. designed a single vertical axis (azimuth axis) PV tracker and evaluated backtracking features. Each of 400 trackers installed in Spain used a 0.25 hp standard AC motor. The tilt angle of the PV surfaces remained constant. They mentioned that the energy collected by an ideal azimuth tracker was about 40% higher than that corresponding to an optimally tilted static surface and 10% higher than that of horizontal axis tracking. They calculated the E–W and N–S shadowing between two adjacent trackers occurred in the morning or afternoon. They recommended that when shadowing occurs, it can be avoided by moving the surface's azimuth angle away from its ideal value, just enough to get the shadow borderline to pass through the corner of the adjacent surface (backtracking). Their comparison showed that the azimuth tracking land was 40% greater than static surface while the corresponding energy cost can be significantly reduced [12].

Ibrahim constructed an electronically one-axis concentrating collector with an electric motor for forced circulation. The collector was hinged at two points for its tilt adjustment with a tightening screw to continuously track the sun from east to west through a range of 180°. The collector efficiency was measured for different values of mass flow rates. It was concluded that the collector efficiency increases (reaching the maximum value of 62%) as the mass flow rate increases [13].

Stern et al. designed, fabricated, tested and demonstrated a modular and fully integrated 15 kW, one-axis solar tracking PV power. The tracker used potentiometer and integral pendulum to provide a positive feedback signal to the tracker motor and actuator. It was concluded that single-axis solar tracking provides 20% more energy in a typical year than that of a fixed-axis PV system. Also, the net reduction in the total cost of single-axis solar tracking grid connected PV power system was found to be 23.3% [14].

2. Sun-tracking methods

Over the years, researchers have developed smart solar trackers to increase the amount of energy generation. Before the introduction of solar tracking methods, static solar panels were positioned with a reasonable tilted angle based on the latitude of the location. The introductions of automated systems improve existing power generation over 50% [15].

There are mainly two types of solar trackers on the basis of their movement degrees of freedoms. These are single axis solar tracker and dual axis solar tracker. Again these two systems are further classified on the basis of their tracking technologies. Active, passive, and chronological trackers are three of them [16,17]. Previous researchers used single axis tracking system which follows only the sun's daily motion [18].

There are several implementations of single axis trackers. These include horizontal single axis trackers, vertical single axis trackers, tilted single axis trackers and polar aligned single axis trackers [19–21].

Al-Mohamad designed a single-axis sun-tracking system based on a programmable logic controlling (PLC) unit to investigate the