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Optimizing and Controlling the Productivity of a Flat Plate Collector by Using an Electronic System

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Abstract

The Flat Plate Collector (FPC) is a thermal solar collector used in housing or residential applications that allows the conversion of solar radiation to thermal energy (e.g. hot water). In this paper we propose a new approach that improves the hot water production through the combination between a simple and improved architecture model. The optimization of the thermal energy efficiency is guaranteed by using an electronic architecture that controls the mono-axial tracker. Some experimental tests aiming the comparison between the stationary and improved FPC are presented.

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Keywords: Energy efficiency, Thermal collector, Flat-plate collector, Incidence angle modifier, Renewable energy, Electronic systems.

1. Introduction

The solar tracker is used to increase the solar radiation exposure in an optimum manner, and it optimizes the performance of a remarkable way relative to a fixed installation. So we opted for the use of a solar tracking system with tree optimal angles in order to minimize electrical consumption of tracker. Several studies are made to improve the energy efficiency of each FPC or PV systems, especially photovoltaic system who know a great worldwide reputation. Peng et al. [1] presented a study to optimize the energy productivity of the flat-plate collector, studying the impact of the incidence angle modifier on the energy performance. However, news designs and the architectures

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by Rustu et al. and Kamal et al. [2, 3] presented intelligent trackers in order to improve energy production for PV. A comparison of three different collectors for process heating application presented by Brunold et al. [4] shows a result of measuring the effectiveness of the collector and of the incidence angle modifier. Later an evaluation of a tracking flat plate solar collector in Brazil presented by Maia et al. [5] shows the useful energy gain and efficiency of a flat plate solar collector were evaluated for a period of one year. Finally, a plurality of sun tracking systems was compared to fixed devices, was presented by Anoune et al. [7], discussing an approach to improve the productivity of a FPC by using a mono-axial tracker while a prediction study have been done to compare a fixed model in south orientation with a model with a mono-axial tracker. Otherwise, a series of experimental tests have been held for the two systems aiming their comparison of their productivity over time along the day.

In this article, we use a mathematical model to define efficiency and calculate the energy absorbed by the solar collector FPC, where we also call equations of efficiency to show the impact on performance causing by IAM (incidence angle change) on thermal productivity of the collector. We propose after a design of an electronic control system dedicated to the piloting the tracker and an operating algorithm of the mono-axial tracker with three positions.

We will provide a test bench for our thermal system including a dynamic and a static FPC, taking into consideration the same technical configuration of the both solar collector to achieve the solar performance testes, and the hot water productivity. We carrying out its tests in our new improved thermal systems that include the FPC thermal collector equipped with an intelligent electronic system specially designed for controlling a mono-axial tracker with three positions, then a circulation pump the heat transfer fluid, after that a storage tank, finally setting a thermal heating resistor.

In the end, we discuss the results of experimental tests of the thermal systems taking into consideration the graphs of solar radiation light energy, the hot water productivity and the influence of the consumption behavior of hot water on the electrical consumption. All these tests are performed separately for stationary and improved FPC.

Nomenclature			
		T_m	Average temperature in the collector (°C).
Q_a	Heat gain of fluids (W).	T_a	Ambient temperature (°C).
m	Mass flow rate, kg/s.	a_1	First order heat loss coefficient
C_p	Heat capacity of water (J/ (kg K).	a_2	Second order heat loss coefficient
T_0	Outlet fluid temperature (°C).	F'	Collector efficiency factor
T_i	Inlet fluid temperature (°C).	K_θ	Incidence angle modifier
A	Surface area of solar collector (m²).	$K_{\theta L}$	Longitudinal incident angle modifier
η_0	Optical efficiency.	$K_{\theta T}$	Transversal incident angle modifier
G	Global solar radiation (W/m2).	$(\tau\alpha)_e$	Effective transmittance – absorbance product.
η	Collector operating efficiency.	$(\tau\alpha)_{en}$	Normal incidence

2. Impact on performance of a solar thermal collector as a result of the IAM (Incident Angle Modifier)

The heat gain of fluids is given by the expression:

$$Q_a = mC_p(T_0 - T_i) \tag{1}$$

$$Q_a = A.\eta_0.G \tag{2}$$

The optical efficiency of the collector FPC is:

$$\eta_0 = \tau_s\,.\,\alpha_s \tag{3}$$

The efficiency of a solar heating collector can be characterized by three independents coefficients of temperature, and can be calculated at any operating point using an equation in the following form:

$$\eta = \eta_0 - a_1.\frac{(T_m - T_a)}{G} - a_2.\frac{(T_m - T_a)^2}{G} \tag{4}$$

Global solar radiation cannot be perpendicular to the planar surface of the collector only for a few minute, there is often an angle of incidence which is denoted θ, the direction of incidence is not only described by this single angle,