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Reliable and Inexpensive Solar Irradiance Measurement System Design

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Abstract

In this work, we present an innovative low cost sensor and algorithm for the monitoring and measurement of solar irradiance. This parameter is usually estimated using pyranometers, often based on thermopile. They are quite expensive, also because need additional hardware for data acquisition and manipulation as well as non-negligible installation costs. The system architecture and novel algorithm here proposed employ small PhotoVoltaic (PV) cells and a digital sensor interface. Moreover, the logic section permits to tilt the sensor allowing to track the sun with improved accuracy.

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Keywords: Differential capacitance sensors; bridge-based circuits; analog circuits; Wheatstone bridge; electronic interface.

1. Introduction

Solar irradiance is an important parameter to be measured for both atmospheric science and renewable energy system design. Since the technology is rapidly developing, a large number of pyranometers have been proposed in the last years (e.g. [1-5]), but both their cost and the maintenance requirements tend to be expensive. Users need a monitoring instrument that is robust, accurate, less expensive and capable of unattended long time operations. In this scenario, the system here addressed is able to provide a cheap solution for the measurements of solar irradiance, by means of PV cells and a microcontroller-based data acquisition and manipulation system implementing a dedicated algorithm for the measured data extrapolation. In the first prototype, an open-source electronic prototyping platform

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has been used for signal management, with the aim to demonstrate the potentiality of the proposed solution.

2. The proposed system

The PV cells, whose dimensions are 45x45mm, are series coupled and directly connected with a shunt resistor useful for sampling the voltage generated by the sunlight (Fig.1). The time dependent analog signal is directly dependent on the intensity of sunlight and is the input of the following digital sensor interface. The system is able to evaluate the solar irradiance (IRR_S) with a dedicated algorithm implementing the constitutive relation:

$$IRR_S = \left(e^{Vout \cdot A} - B\right) \cdot \frac{T}{T_R}$$

The A parameter in the equation can be defined as a conversion coefficient, while the B parameter is an offset factor; both of them take into account the physical characteristics of the PV elements and are determined experimentally. Moreover, T in the formula is the PV cells temperature, while T_R is the reference temperature used for system calibration. The functionality and reliability of the system is provided by the additional circuitry. The temperature sensors are placed below the PV cells, while four photoresistors define two orthogonal directions (Fig. 2) used by the algorithmic implemented in the microcontroller (Fig. 3) for alignment purposes. The tracking functionality of the PV cells is allowed by two servo-motors installed on the structure (Fig. 4) and driven by the same microcontroller (Fig. 3).

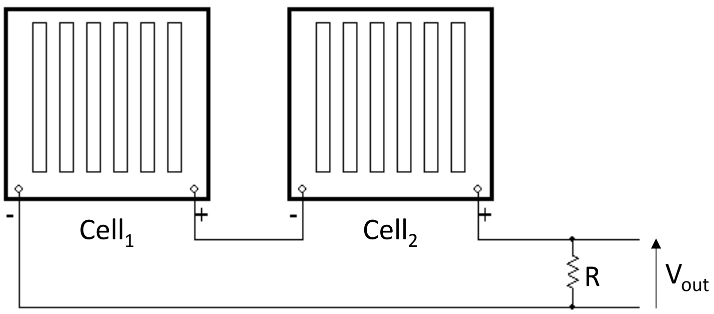

Fig. 1. The solar PV cells connection scheme.

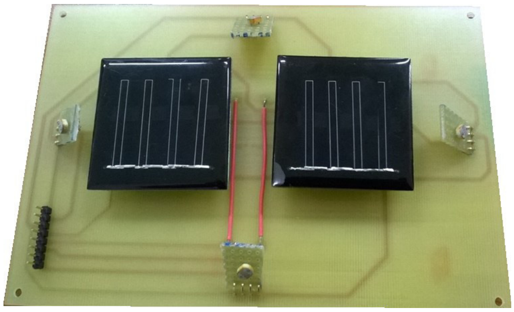

Fig. 2. Top view of the prototype board.

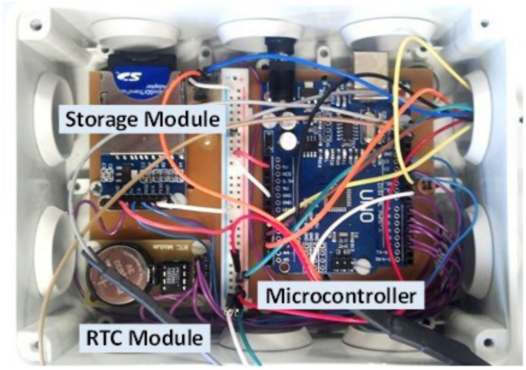

Fig. 3. Digital sensor interface.

3. Results

On field test and measurements have been performed showing a good accuracy and high sensitivity so validating the proposed algorithm and system hardware. In order to check the overall performance of the system, results have been compared with those provided by the *DPA053*, a typical thermopile pyranometer (Fig. 5), resulting in a good agreement. A compact version of the prototype is currently under construction with improved electronics, by taking advantage of the current mode approach and low voltage low power techniques [6-11], and even better performance.

4. Conclusions

We have here presented we present an innovative low cost sensor and algorithm for the monitoring and measurement of solar irradiance employing PV cells and a digital sensor interface that shows satisfactory performances.

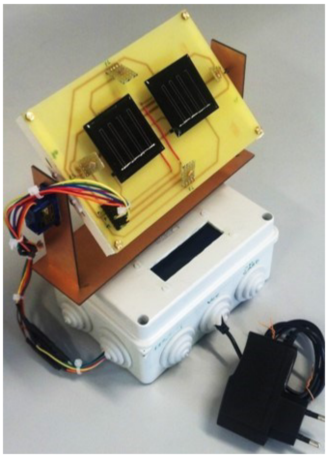

Fig. 4. The complete prototype system.

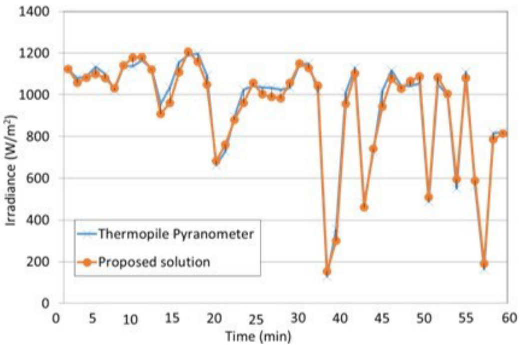

Fig. 5. Measured results compared with a thermopile pyranometer

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