Design of a low cost irradiance meter using a photovoltaic panel

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Design of a Low Cost Irradiance Meter using a Photovoltaic Panel

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Abstract—**The purpose of this work is present a low cost irradiance (W/m^2) meter using a solar cell. By the constant monitoring of the open circuit voltage and the short circuit current of the solar cell it is possible to calculate the effective irradiance. This work pretends to avoid the use of classical solar irradiance sensors (e.g. pyronometer), which are expensive. The instrument consists of a solar cell, a simple sensing circuit and a microcontroller.**

***Index Terms*—Solar Cell, Irradiance, Pyronometer.**

I. INTRODUCTION

As it is known, the output power in a solar cell is directly related to the climate conditions. Several mathematical models have been developed to estimate the behavior of the photovoltaic (PV) panels. The exponential model [1] describes the electrical behavior of the PV panel, taking into consideration the irradiance and the temperature levels. This model is based on characteristics of the panel that are usually found in the manufacturer datasheet.

As explained in [2], the exponential model can be used to calculate the effective irradiance in the PV panel. This parameter can be calculated by measuring the open circuit voltage and the short circuit current of the PV. A low cost microcontroller (MCU) can be used to do the sensing and the calculations of the desired parameter. Solar irradiance sensors, also known as pyranometers [3], are expensive [4]. In the last years the pyranometer become widely used to estimate the electric generation given by the PV panels [7]. This paper presents a low cost portable irradiance meter, that present good accuracy at low price.

In fig.1 the block diagram of the system is presented. A MOSFET switch is used to produce the boundary conditions of the PV panel (short circuit current and open circuit voltage), then the signals are conditioned in order to be sensed by the MCU. The MCU has simple software that produces the "short and open" signals to the MOSFET and calculates the irradiance level.

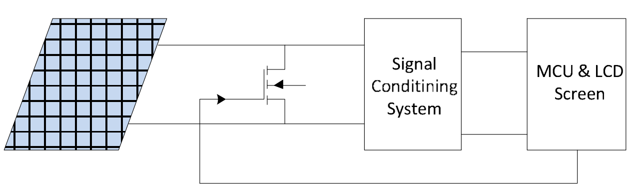

Fig. 1 Block Diagram of the System

II. DESIGN SPECIFICATION

This project consists of the design of an instrument that approximates the irradiation level and temperature in a PVM. This is done using an algorithm developed by Dr. Ortiz that uses his PVM model using the manufacturer data sheet [2]. To understand the algorithms is needed to be familiar with the PVM model equations that are:

$$I(V) = \frac{Ix}{1-\exp(\frac{-1}{b})} \cdot [1 - \exp(\frac{V}{b \cdot Vx} - \frac{1}{b})] \tag{1}$$

$$Vx = \frac{Ei}{Ei_N} \cdot TCV \cdot (T - T_N) + Vmax - (Vmax - Vmin) \cdot \exp\left(\frac{Ei}{Ei_N} \cdot \ln\left(\frac{Vmax - Voc}{Vmax - Vmin}\right)\right) \tag{2}$$

$$Ix = \frac{Ei}{Ei_N} \cdot Isc + TCi \cdot (T - T_N) \tag{3}$$

These equations relate the electrical characteristics of the PVM to the instantaneous irradiance and temperature levels. This relationship can be realized using the fixed point iteration, as explained in [2]. The iteration formulas are:

$$T(n+1) = T_N + \frac{Ei(n) \cdot (Vx - Vmax)}{TCV \cdot Ei_N} + \frac{Ei(n)}{TCV \cdot Ei_N} \cdot (V_{MAX} - V_{MIN}) \cdot ln\left(\frac{V_{MAX} - V_{OC}}{V_{MAX} - V_{MIN}}\right) \tag{4}$$

$$Ei(n+1) = \frac{Ix \cdot Ei_N}{Isc + TCi \cdot (T(n) - T_N)} \tag{5}$$

As can be seen, *Vx* (open-circuit voltage at one instant) and Ix (short-circuit current at the same instant) are need to complete the iterations. These values are obtained by opening the circuit and measuring the voltage, and by shorting the PVM and measure the current. All measurements are made by the microcontroller, in this case a PIC16F877A. The other values are taken from the data sheet of the PVM. Once, Ix and Vx are measured, the MCU start doing some iteration to calculate the temperature and the irradiation in that instant. In the fig. 2 is show the flowchart of the program.

The circuit implementation is shown in Fig. 3. The circuit consists in a switch and two signal conditioners. The voltage conditioner is used to decrement the voltage of the PV to a voltage level appropriate to be managed by the MCU, in this way can sensed the voltage of the PV. To sense the current a 0.001Ω resistor is used, because the voltage drop in the resistor is a small voltage, an op-amp is used to amplify this voltage to an appropriate level to be used by the MCU.

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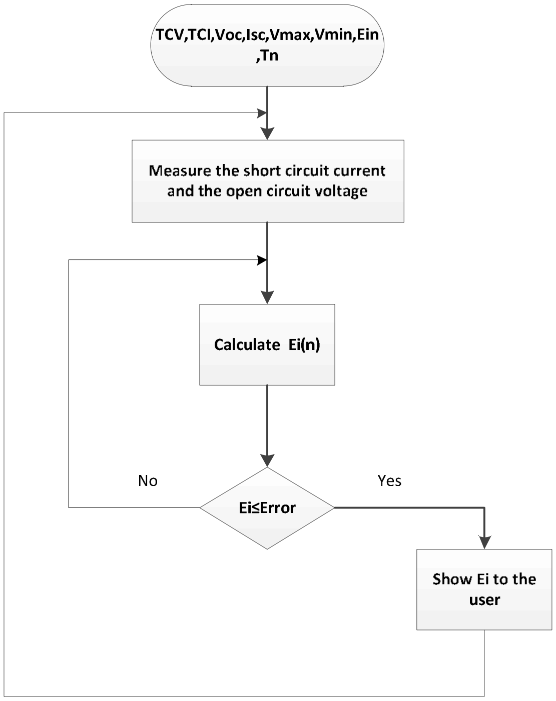

Fig. 2 System Flowchart.

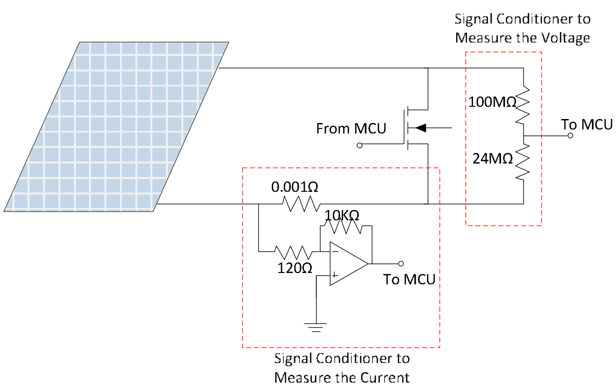

Fig.3 Measurement circuit

Ei (Pyranometer) [W/m^2]	Ei (Calculated by the Circuit)[W/m^2]	% Error
1240	1234.7	0.42 %
1246	1247.2	0.096 %
1250	1243.4	0.528%
1237	1224.6	1.00%
1236	1222.2	1.11%

Table 1. Experimental Results using the BP-SX305 at the 3:00 P.M. in Mayaguez, Puerto Rico

Fig.4 Experimental Setup

III. EXPERIMENTAL RESULTS

As show in the Table 1 the calculated irradiance is close to the values obtained by the pyranometer. The data was obtained at the 3:00 P.M at the UPR in Mayaguez Puerto Rico. The pyranometer used to recover the data was a LI-COR LI-200.Can be seen that percent of error is a small value, shown that the proposed system is enough close to the values obtained with the pyranometer. This data approved the initial concept of a viable low cost irradiance meter. The prototype support the idea of design a portable meter that can be used by a person or implemented with an embedded system using the output signal from the microprocessor. The prototype was implemented using an Olimex Development Board. This system presents a cost efficient way to measure the irradiance, at the same time can be possible obtain the calculated values, by a communication protocol to develop accurate maximum power point trackers (MPPT).

IV. CONCLUSION

The circuit have been presented, which is capable to measure the effective irradiance over a PVM. The proposed circuit eliminates the use of pyranometers, reducing dramatically the cost of the system without sacrificing the PV system performance. This circuit is easy to construct as it has few components. This circuit can be implemented in a small portable device to measure the irradiance practically anywhere with an ergonomic design. Also it can be integrated in others circuits like maximum power point tracker and data logging.

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