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Virtual lab based real-time data acquisition, measurement and monitoring platform for solar photovoltaic module

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ABSTRACT

The work presents real-time data acquisition and monitoring of solar photovoltaic modules using LabVIEW. A graphical program has been developed to obtain efficiency and fill factor of solar PV module. A front panel is designed, displaying all the acquired data such as; voltage, current, solar radiation, ambient temperature, humidity, Current vs. Voltage and Power vs. Voltage graphs which make it very useful to understand the performance behavior of the solar photovoltaic module in real time. Data acquisition and monitoring for solar panels of different ratings are carried out. This tool is an effective platform for experimental study in the laboratory of different solar photovoltaic modules with access to real-time data.

1. Introduction

Solar energy can be a major source of power and can be utilized by a photovoltaic system. This has significantly contributed to the sustainable energy supply. Solar energy has become an attractive emerging technology due to several advantages, such as; easy maintenance, reduced cost of solar panels and simple installation. There are several ways to monitor solar PV systems which are currently being used to acquire & monitor the data and now also used in disaster management system. The work [1] provides the experimental test facility system and monitoring the performance for measuring the meteorological parameters to display on LabVIEW front panel. Techniques for environment monitoring and controlling under less controlled conditions is carried out [2,6]. The authors in ref. [3,7] present a distance laboratory for monitoring of a remote solar photovoltaic system in real time with few parameters. In this paper [4,9–12] I–V and P–V characteristics are measured in solar simulator using LabVIEW. It explains the development of an on-site test platform to collect the data and evaluate the performance of the grid connected photovoltaic system [5,15]. The output power of photovoltaic cells and the energy depend on solar radiation [8]. E-learning management system is proposed to provide a platform to students including theory as well as practical experiments on real-time instruments [13]. Researchers [14] used MATLAB based modeling and simulation scheme suitable for the study of I–V & P–V characteristics of photovoltaic array under the non-uniform insulation due to partial shading.

This work is mainly focused on, measuring the parameters such as; voltage, current, temperature, solar radiation and humidity with characteristics of solar photovoltaic modules in real time. The objective of this research paper is to develop a platform as an educational tool to study the real-time performance of photovoltaic modules. The proposed LabVIEW based virtual instrument system can be expanded according to the need of the engineers, and research scholars. This work is carried out in different sections starting with introduction of photovoltaic cells; Section 2 describes the measurement system; Section 3 discusses the results; and Section 4 conclusions.

2. Photovoltaic cell I-V characterization theory

PV cells can be modeled as a current source in parallel with a diode. When there is no light present to generate any current, the cell behaves like a diode. As the intensity of incident light increases, current is generated by the photovoltaic cell [14]. In an ideal cell, the total current ‘I’ is equal to the current I_{ph} generated by the photoelectric effect subtracted by the diode current I_D, according to the equation [15]:

$$I = I_{ph} - I_d = I_l - I_0\left(exp^{\left(\frac{qv}{kT}\right)} - 1\right) \quad (1)$$

$$I = I_{ph} - I_0\left(exp^{\frac{q(V+I.R_s)}{n.k.T}} - 1\right) - \frac{V + I.R_s}{R_{sh}} \quad (2)$$

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Nomenclature

I_l	Leakage current across the shunt resistance
I_o	Reverse saturation current
I_{ph}	Photoelectric current
V	Diode Voltage (Volt)
K	Boltzmann constant ($1.38^* \ 10^{-23}$ m^2 kg s^{-2} k^{-1})
q	Electron charge ($1.6 * 10^{-19}$C)
DAQ	Data Acquisition Unit
V_m	Maximum Voltage (Volt)
I_m	Maximum Current (Amp.)
Voc	Open Circuit Voltage (Volt)
I_{sc}	Short Circuit Current (Amp.)
R_{sh}	Shunt Resistance (Ohm)
R_s	Series Resistance (Ohm)
n	Ideality Factor
T	Temperature (K)
FF	Fill Factor
P_{max}	Maximum Power
I_{mp}	Current at maximum power
V_{mp}	Voltage at maximum power
SPV	Solar photovoltaic
P_t	Total current of the solar cell.
V	Voltage in volts(V)
I	Current in amperes(A)
VI's	Virtual Instruments

2.1. Short circuit current (I_{SC})

The short circuit current I_{SC} corresponds to the short circuit condition when end terminal is short circuited so the impedance is low and the voltage equals 0.

$$I(\text{at}\,V = 0) = I_{SC} \tag{3}$$

I_{SC} occurs at the beginning of the forward-bias sweep and is the maximum current value in the power quadrant. For an ideal cell, this maximum current value is the total current produced in the solar cell by photon excitation. $I_{SC} = I_{MAX} = I_{ph}$ for forward-bias.

2.2. Open circuit voltage (V_{OC})

The open circuit voltage occurs when there is no current passing through the cell.

$$V(\text{at}\,I = 0) = V_{OC} \tag{4}$$

2.3. Fill factor (FF)

The Fill Factor (FF) is essentially a measure of quality of the solar cell. It is calculated by comparing the maximum power to the theoretical power that would be output at both the open circuit voltage and short circuit current together.

$$FF = \frac{P_{max}}{P_t} = \frac{I_{mp}.V_{mp}}{I_{sc}.V_{oc}} \tag{5}$$

Typical fill factor ranges from 0.5 to 0.82. It is generally expressed in percentage.

2.4. Efficiency (η)

$$Efficiency = \frac{P_{out}}{P_{in}} \tag{6}$$

P_{in} is taken as the product of the irradiance of the incident light, measured in Watt/m^2, with the surface area of the solar cell (m^2). P_{out} is the electrical output of the solar cell.

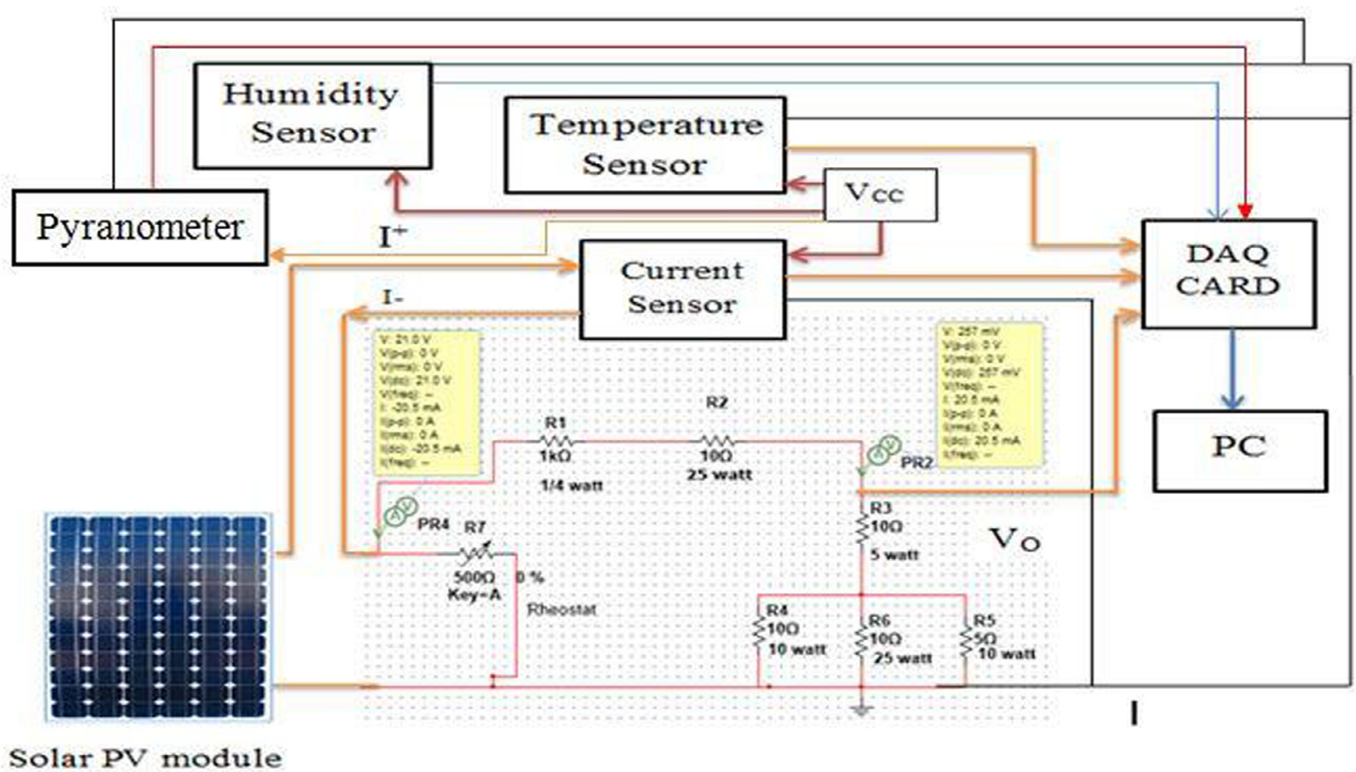

Fig. 1. Block diagram.

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