



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



Amit Kumar Rohit*, Amit Tomar*, Anurag Kumar, Saroj Rangnekar

Energy Centre, Maulana Azad National Institute of Technology, Bhopal, M.P.-462003, India

ARTICLE INFO

Article history:

Received 4 April 2017

Revised 19 April 2017

Accepted 24 April 2017

Available online 5 May 2017

Keywords:

Photovoltaic
Instruments
Labview software
Characteristics
Sensors

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.

© 2017 Tomsk Polytechnic University. Published by Elsevier B.V.

This is an open access article under the CC BY-NC-ND license.
(<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

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]:

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

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

* Corresponding authors.

E-mail addresses: amitrohit8@gmail.com (A.K. Rohit), amittomar1589@gmail.com (A. Tomar).

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.)
V_{oc}	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.

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

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/m², with the surface area of the solar cell (m²). P_{out} is the electrical output of the solar cell.

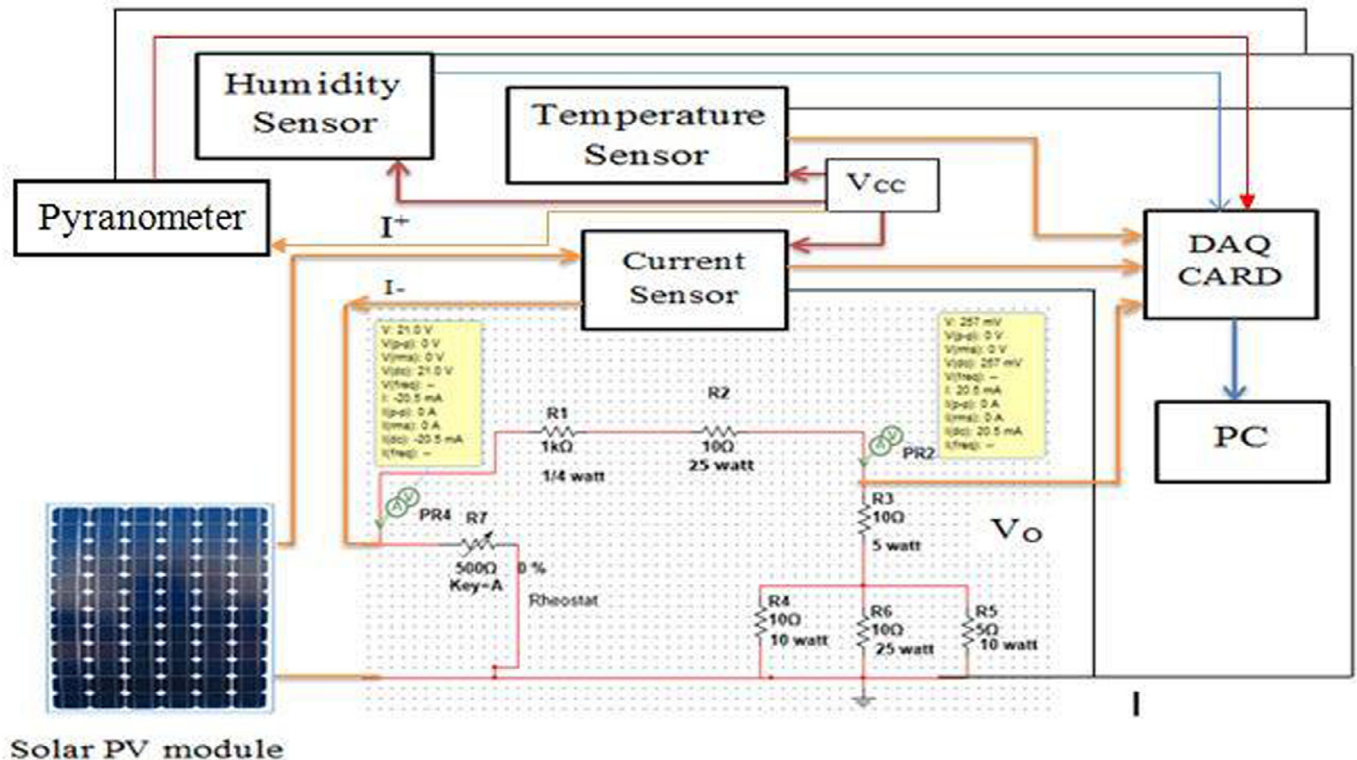


Fig. 1. Block diagram.

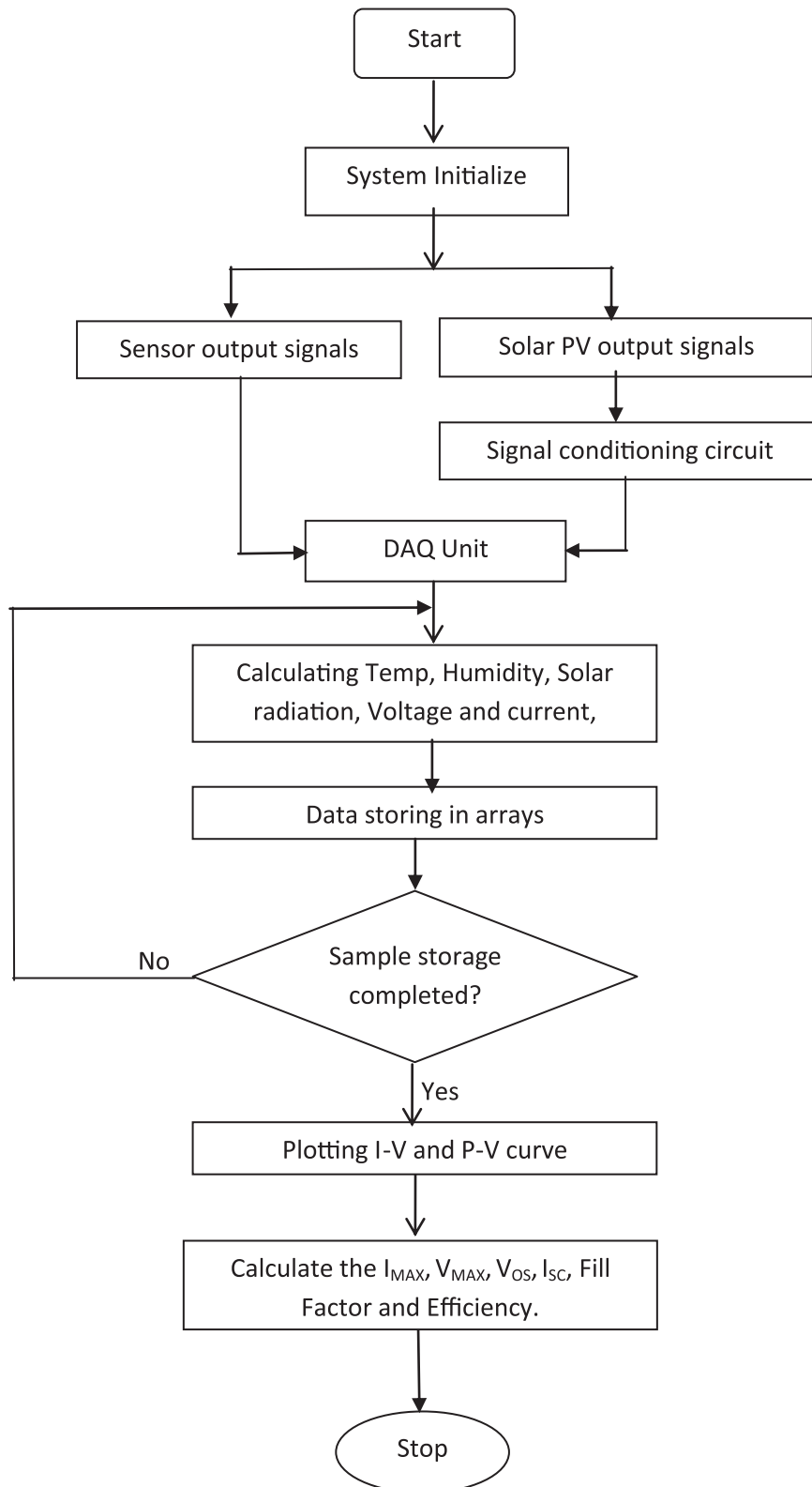


Fig. 2. Flow chart of the LabVIEW program.



Fig. 3. Sensors and instruments used in the developed system.

3. Proposed system

3.1. Block diagram

Fig. 1 shows the block representation of the developed system. A standalone solar PV module is kept outside in the open environmental condition. Data is acquired, stored and converted using NI DAQ module and LabVIEW software. NI DAQ can handle signals up to 11 V and few milliamperes. To maintain the voltage and current signals from solar PV module within the safe range as input to DAQ, circuit is developed which works as a signal conditioning unit. These signals are then processed by the DAQ unit. LabVIEW software is used in this system to interface NI DAQ with the computer to do the computations based on the data acquired. LabVIEW software consists of a library of a function tools. Function tool is a part of a real-time simulation. DAQ card provides analog input into the digital form, goes to DAQ assistant block of the LabVIEW software to store and display data on computer.

NI-Multisim software is used to simulate the developed circuits to reduce the voltage and current according to the requirement of the input terminals of the DAQ card. Multisim is simulation and circuit design software which is suitable for circuit analysis.

3.2. Operational sequence of the LabVIEW program

Fig. 2 shows the flow chart of the main program based on LabVIEW software to monitor the solar photovoltaic module. Flow chart shows the step by step process. The system acquired the data from the sensors, such as pyranometer, temperature sensor and humidity sensor. Data is collected into the cluster (functional tool) to display in form of table and graph on the LabVIEW front panel and the I–V characteristics of the solar photovoltaic module is obtained. Further, multiplying the voltage and the current, calculates the output power, P–V curve and obtained the other parameter such as; V_M , I_M , V_{OC} , and I_{SC} .

3.3. Description of complete setup

A monocrystalline photovoltaic module is taken for an experiment and testing the performance with different (5 Watt) rating PV module. Fig. 3 shows pyranometer which is used to measure solar radiation to calculate the efficiency of the solar module. It can measure both direct and diffused radiations. NI-USB-6351 is a data acquisition device, which is used to interface, communicate and transfer the data to the computer. Virtual panels are built using LabVIEW software which is based on a graphical programming language.

Solar PV module is kept outside in open environmental conditions. Above panel is a 5-Watt power rating ($I_{SC} = 0.68$ A,



1: Data display. 2: Current sensor. 3: Electric Load. 4: DAQ Card. 5: Rheostat.
Figure 4. Experimental Setup

Fig. 4. Experimental setup.

$V_{OC} = 10$ V) with temperature and humidity sensors in open environment. Pyranometer provides the accurate measurements of the solar radiation. Data is received from weather station and pyranometer. AMT1001 is a resistive-type humidity sensor measures humidity and LM-35 temperature sensor to measure temperature of photovoltaic module. Fig. 4 shows hardware setup of the proposed system and Fig. 5, graphical program in LabVIEW for the developed setup.

4. Result

Real time data acquisition and monitoring of 5 W PV module is carried out in the Energy Centre. Different parameters successfully acquired and displayed on the front panel of the LabVIEW software as shown in Fig. 6. It shows the storing of different parameters in tabular form and graph containing the characteristics of solar PV module. The efficiency of the PV module is computed by the LabVIEW which is 12.23% and fill factor of the module is 78% (0.78). Fig. 7 shows closer view of I–V and P–V characteristics of PV module.

5. Conclusion

A PC based virtual platform using LabVIEW software for real-time monitoring of solar PV system is developed. In this paper, instead of theoretical work, it presents a practical approach to acquire real time data and compute various parameters of the system. Results of various parameters obtained are suitably displayed on the developed front panel in LabVIEW providing ease of access to the acquired data. This system with little modifications can be easily used for data acquisition and monitoring of large solar PV modules and systems. The developed system can be used for industrial applications as well as educational purposes in academic institutes.

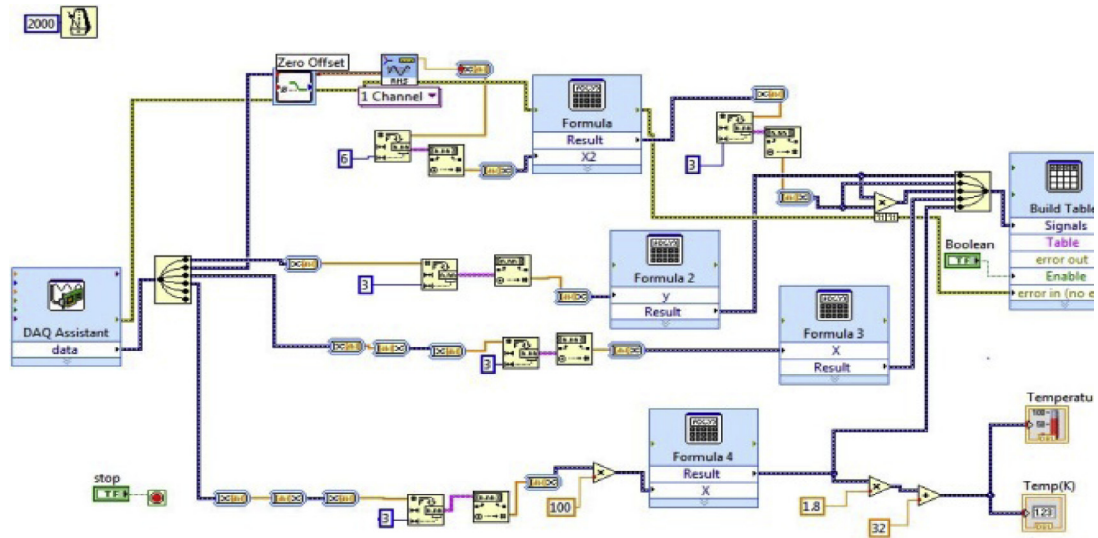


Fig. 5. LabVIEW program for data acquisition.

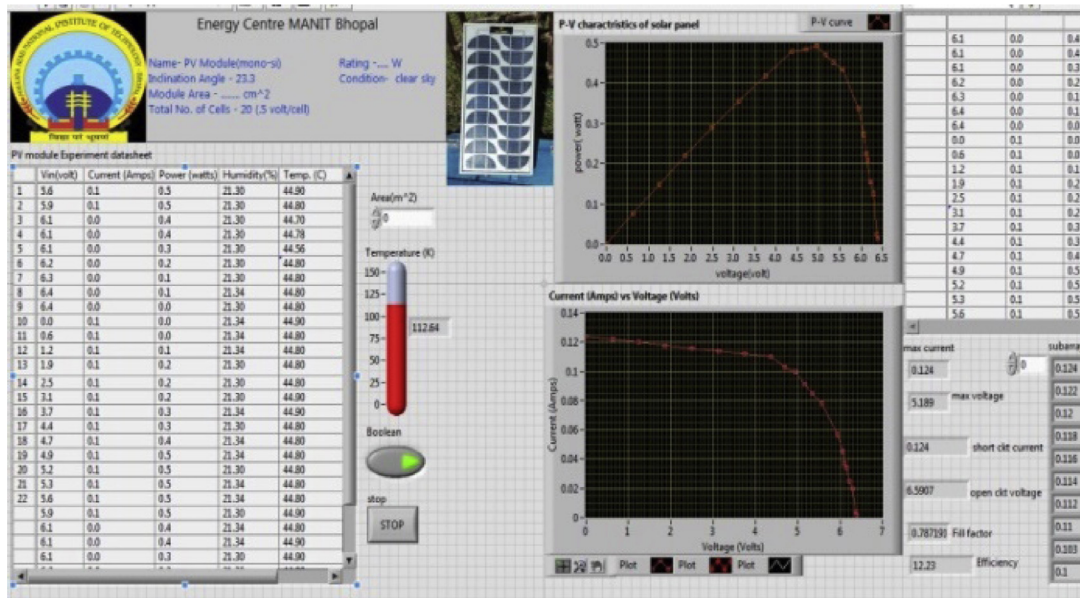


Fig. 6. Data display on LabVIEW front panel.

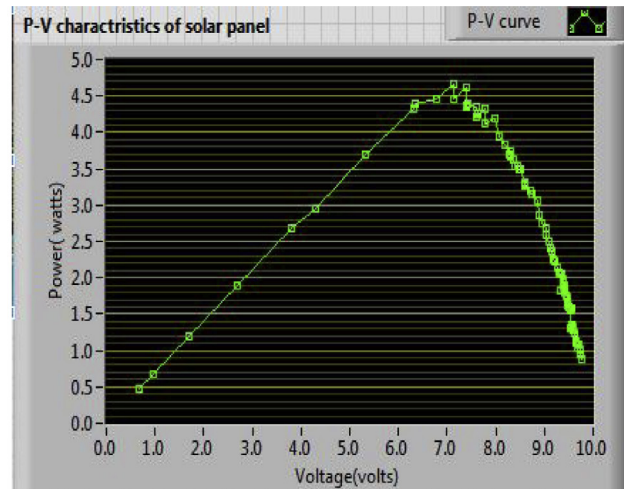
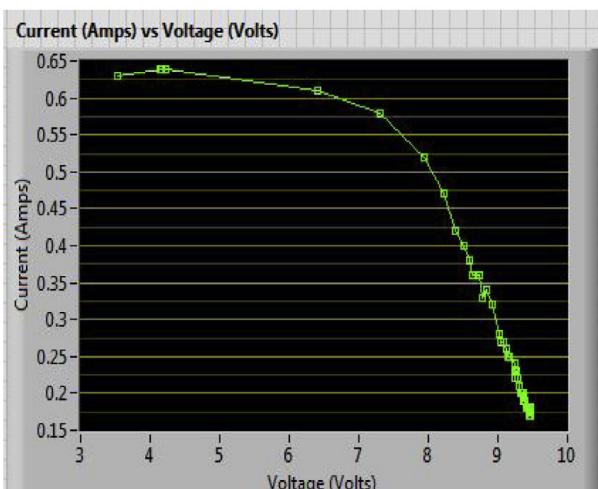


Fig. 7. I-V & P-V characteristics of 5 Watt solar PV module.

References

- [1] V. Ahmed C., M. Kassa, PV-standalone monitoring system performance using Labview, *Int. J. Smart Grid Clean Energy* 3 (1) (2013) 44–50.
- [2] O. Ben Belghith, L. Sbita, Remote GSM module monitoring and photovoltaic system control, in: *Green Energy, 2014 International Conference on, Sfax, 2014*, pp. 188–192.
- [3] P. Bauer, R. Ionel, Labview remote panels and Web services in solar energy experiment – a comparative evaluation, in: *Applied Computational Intelligence and Informatics (SACI), 2013 IEEE 8th International Symposium on, Timisoara, 2013*, pp. 263–268.
- [4] Alex See Kok Bin, Shen Weixiang, Ong Kok Seng, S. Ramanathan, Low I-Wern, Development of a LabVIEW-based test facility for standalone PV systems, in: *Electronic Design, Test and Applications, 2006. DELTA 2006. Third IEEE International Workshop on, 2006*, p. 6.
- [5] G. Bayrak, M. Cebeci, Monitoring a grid connected PV power generation system with labview, in: *Renewable Energy Research and Applications (ICRERA), 2013 International Conference on, Madrid, 2013*, pp. 562–567.
- [6] V.B. Raja, V. Shanmugam, R. Narayani, Innovative approach and performance analysis using LabVIEW in solar assisted vapour absorption cooling system, in: *Energy Efficient Technologies for Sustainability (ICEETS), 2013 International Conference on, Nagercoil, 2013*, pp. 808–813.
- [7] C. Chompoo-Inwai, J. Mungkornassawakul, A smart recording power analyzer prototype using labview and low-cost data acquisition (daq) in being a smart renewable monitoring system, in: *Green Technologies Conference, 2013 IEEE, Denver, CO, 2013*, pp. 49–56.
- [8] Y. Yadav, R. Roshan, S. Umashankar, D. Vijayakumar, D.P. Kothari, Real time simulation of solar photovoltaic module using labview data acquisition card, in: *Energy Efficient Technologies for Sustainability (ICEETS), 2013 International Conference on, Nagercoil, 2013*, pp. 512–523.
- [9] G. Yang, M. Chen, LabVIEW based simulation system for the output characteristics of pv cells and the influence of internal resistance on it, in: *Information Engineering, 2009. ICIE '09. WASE International Conference on, Taiyuan, Chanxi, 2009*, pp. 391–394.
- [10] B. Shankar, M.K. Sarithlal, S. Sharat, J. Freeman, K. Achuthan, Remote triggered virtual laboratory for Hooke's law using LabVIEW, in: *Industrial Electronics Society, IECON 2013 - 39th Annual Conference of the IEEE, Vienna, 2013*, pp. 3729–3734.
- [11] Jen-Hao Teng, Shun-Yu Chan, Jin-Chang Lee, R. Lee, A LabVIEW based virtual instrument for power analyzers, in: *Power System Technology, 2000. Proceedings. PowerCon 2000. International Conference on, vol. 1, Perth, WA, Australia, 2000*, pp. 179–184.
- [12] F. Attivissimo, A. Di Nisio, M. Savino, M. Spadavecchia, Uncertainty analysis in photovoltaic cell parameter estimation, *IEEE Trans. Instrum. Meas.* 61 (5) (2012) 1334–1342.
- [13] S. Rapuano, F. Zoino, A learning management system including laboratory experiments on measurement instrumentation, *IEEE Trans. Instrum. Meas.* 55 (5) (2006) 1757–1766.
- [14] H. Patel, V. Agarwal, MATLAB-based modeling to study the effects of partial shading on pv array characteristics, *IEEE Trans. Energy Convers.* 23 (1) (2008) 302–310.
- [15] Phang Yoke Yin, M.V. Chilukuri, Remote power quality monitoring and analysis system using LabVIEW software, in: *Instrumentation and Measurement Technology Conference, 2009. I2MTC '09. IEEE, Singapore, 2009*, pp. 279–283.