

PV-standalone monitoring system performance using LabVIEW

Chokri Belhadj Ahmed*, Mahmoud Kassas, Syed Essamuddin Ahmed

EE-Department, King Fahd University of Petroleum and Minerals, Dhahran, 31261, Saudi Arabia

Abstract

This paper presents and discusses the performance evaluation, monitoring and analysis of a stand-alone Photovoltaic (PV) system. This experimental investigation achieves its objectives using Laboratory Virtual Instrument Engineering Workbench (LabVIEW) interface capabilities. The installed PV generator system operates in extreme and severe weather conditions. The local area is characterized by a high level of irradiation, high humidity variations, very high ambient temperature and frequent dust storms. Two PV panels of 150 W rating each are used. Each panel feeds a variable resistive load separately and simultaneously. The constructed LabVIEW engine displays environmental parameters and the associated electrical variables (voltage, current and power) on dedicated graph windows continuously in a real time manner. The current versus voltage (I - V) and power versus voltage (P - V) characteristics are taken for any chosen panel, displayed and stored accurately. LabVIEW allows appending any characteristics for the sake of comparison, investigation and research purposes. LabVIEW has shown high performance in communicating with several devices simultaneously and high capability of displaying several variables behavior at a time. The designed virtual instrument (VI) filters are programmed to execute different tasks on a priority basis. The developed system reveals and stores the pronounced impact of dust, the variation of temperature and the irradiation changes on the PV panel power output behavior. The monitoring results are very satisfactory. The online data display in multi-scale window frame is very informative. The online efficiency evaluation is very useful for system operation and analysis. The developed system was found to be very supportive for research and educational purposes.

Keywords: PV generator; standalone performance; on-line monitoring; weather effects, efficiency

1. Introduction

Photovoltaic energy is a clean and renewable. The Photovoltaic (PV) generation plays an important role in energy storage and in solving environmental issues. Such power generation helps reducing gases emission and controls the pollution of the atmosphere. Electricity produced by PV systems has been used increasingly around the world for more than a decade. Many countries at the governmental level, private sectors, and individuals have been installing PV systems, especially; a country such as Saudi Arabia is an excellent candidate for harvesting power from the sun. In the wake of PV system installation, a performance PV real-time monitoring system is of increasing importance to evaluate all important parameters such as irradiance, output voltage, current, power, panel temperature, humidity, wind, and ambient temperature.

The literature reveals some microcontroller-based data acquisition (DAQ) systems for monitoring and evaluating the performance of the PV-systems [1]. Recently, Laboratory Virtual Instrument Engineering Workbench (LabVIEW) based monitoring systems have been developed for PV power generation systems [2-5]. LabVIEW is a graphical programming package used to process, display and store collected data in PC hard disk [6]. The prototype of standalone PV monitoring system using data acquisition, a battery array, a solar array simulator, and personal computer has been developed [7]. The performance of PV power plant using the Virtual Instrumentation concept has been introduced [8]. The equipment is

* Manuscript received June 11, 2013; revised July 17, 2013.

Corresponding author Tel.: +966 38603535; E-mail address: bachokri@kfupm.edu.sa.

capable of real time signal measuring giving information about the performance of the PV power plant, as well as of the energy quality generated by it. Performance results and analysis of large scale photovoltaic system of 80 kW have been presented [9]. Authors evaluate and analyze performance of the PV system showing the effect of environment conditions on the operation characteristics. Electrical performance estimation of PV module using designed measurement system has been studied [10]. The data measurements are obtained from visual studio Basic.Net (2005) and measurement studio, National Instrument, equipped with interface and operated by a general IBM-PC.

In this paper, a performance monitoring and experimental test system for measuring metrological parameters and electrical parameters for PV-standalone system is proposed. Automatic data acquisition, DAQ, technology made by National Instrument (NI) is used as hardware for monitoring the PV system performance. The software of the data acquisition system based on LabVIEW package is used to display, store, and process the collected data in the PC-hard disk. The objective of this research is to develop a platform for standalone PV monitoring system to collect the data and evaluate the performance.

2. Experimental Set-Up

The developed system is used to monitor and analyze a stand-alone photovoltaic system located at King Fahd University of Petroleum and Minerals (KFUPM) campus, Dhahran, Saudi Arabia. This system is formed by two solar panels, environmental parameters and irradiation sensors, isolation amplifier, resistive load banks, amplifier circuit and data acquisition instrument (DAQ). The entire system is monitored and controlled by LabVIEW environment.

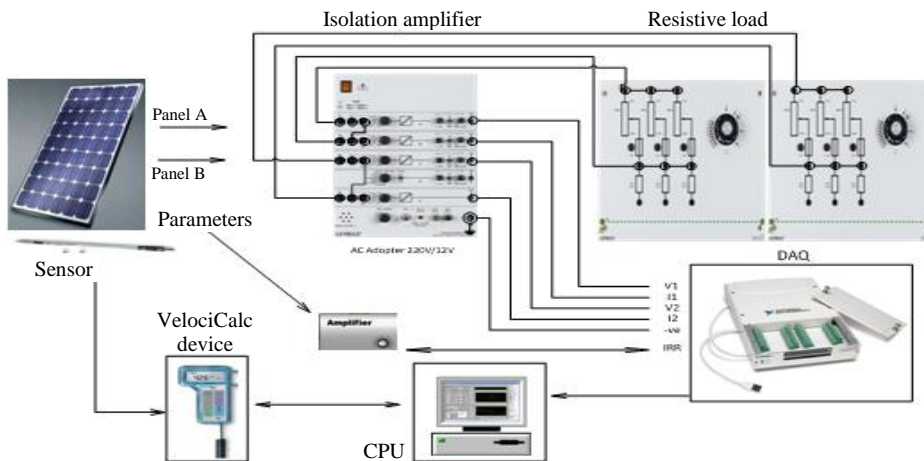


Fig. 1. The constructed PV system experimental set up.

Fig. 1 shows the block diagram of the stand-alone PV system experimental set-up. Each panel has a maximum power of 150 W, open circuit voltage of 43.2 V, short circuit current of 4.49 A, maximum power voltage of 36V and maximum power current of 4.16 A. All of these characteristics are under clean standard test condition of 1000 W/m^2 at 25°C . The panel has a length of 1580 mm, width of 808 mm and the actual irradiation exposed area of 1.5 m^2 . The panels are installed and exposed to whole day sun irradiation and inclined at a fixed angle of 23° from horizontal surface. Two VelociCalc Plus devices having model number 8386A are used to measure weather parameters. The first one is dedicated to measure the ambient temperature, relative humidity and wind speed in the vicinity of both panels. The second device is fully dedicated to measure the panel temperature. These data are processed in VelociCalc Plus devices and transferred to CPU through serial RS232 connections after converting RJ45 to RS232. The continuous irradiation measurement is conducted using the RESOL device having model number solar cell CS10 type E sensor. The short circuit current of the irradiation cell measurement is amplified and processed through amplifier circuit. Each panel voltage and current are measured through

LEYBOLD four channel highly linear, noise-immune isolating amplifiers model number [735 261]. The conditioned currents and voltages are channelled to LabVIEW environment through National instrument device DAQ NI USB-6251.

3. LabVIEW Development

LabVIEW software manages communication between CPU and the I/O modules. Measurement & automation explorer (MAX) software tool is used for the configuration of data acquisition hardware device and the software. This tool creates tasks, channels, scales, interfaces and virtual instruments. The serial instrument or device includes software utilities and hardware drivers for communication, and also includes the documentation on the stop bits, parity bits, baud rates, and packet size that the instrument used.

In LabVIEW programming, computer processors can execute the code when the graphical icons are joined and wired together, and then directly compiled to machine code. A block diagram functions in the data flow path that actually dictates when and in what order the program will execute. All inputs data must be available at a node for execution, and then it carries out data to its output and supplies to the next node in the path. We also used Express VIs that simplifies common programming tasks and algorithm creation. DAQ Assistant Express VI is used on the block diagram and configures it to execute the function. The DAQ Assistance Express VI prompts you to select the channels you want to send and receive data to I/O module (DAQ), and configure parameters like terminal configuration, scales, sample rate, triggering, and synchronization. After completing the configuration, the LabVIEW development environment writes the necessary code (represented by the Express VI) for you which is actually the task of reading real outer signals into inner files for analysis.

In the front panel we configure and customize the control parameters to communicate with serial port and in the block diagram window we connect the blocks for serial connection. To perform the serial communication task, VISA resource is opened and configures COM port. VI will then first write command V for data, read data and then close the VISA session that opened to port for every specified reading cycle. A specific command is written and sends to the device then the response is read back. VI will then wait if the reading is performed until the specified number of bytes is received at the port. Fig. 2 (a) shows the developed graphical programming block diagram and Fig. 2 (b) shows the corresponding front panel control area.

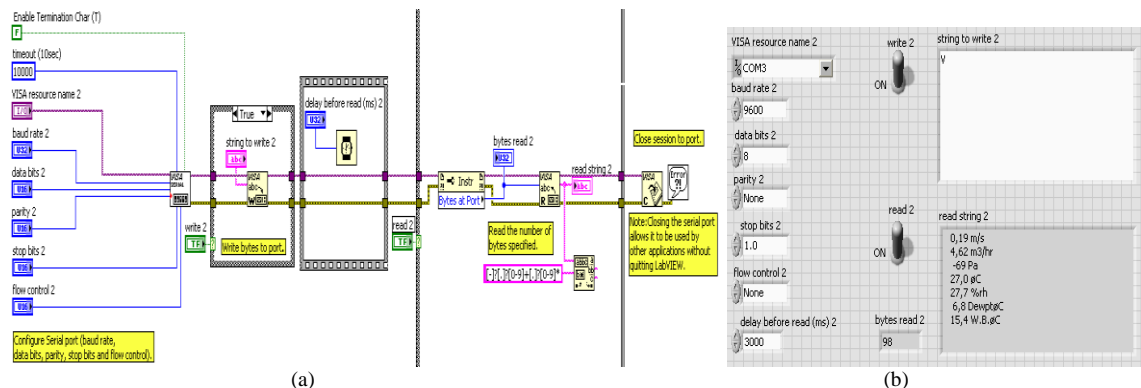


Fig. 2. Serial Communication in LabVIEW: (a) block diagram and (b) front panel.

Data received from the device are in string format which needs to be processed for display and storage. The module is developed as shown in Fig. 3. It is designed to segregate, concatenate and then arrange the entire data in an array form. The resultant values are then joined to make an array and a table for continuous reading and monitoring. The data is then saved to a excel file. Graphs and charts are used to display plots of data in a graphical form. The outcome of this developed module leads to the segregated environmental parameters namely; wind speed, humidity, ambient temperature and panel temperature.

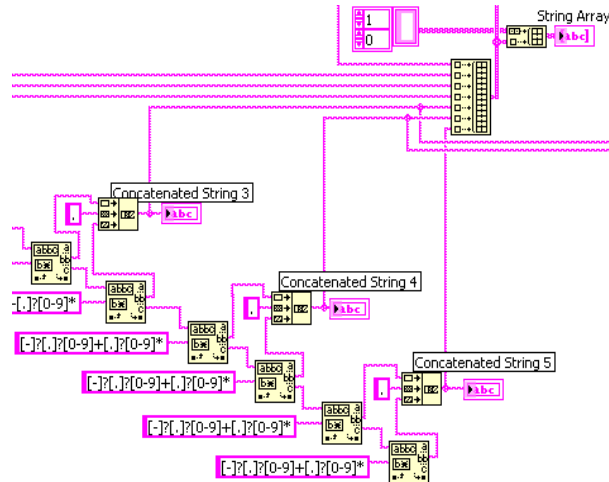


Fig. 3. Data conditioning for analysis, displaying and storage.

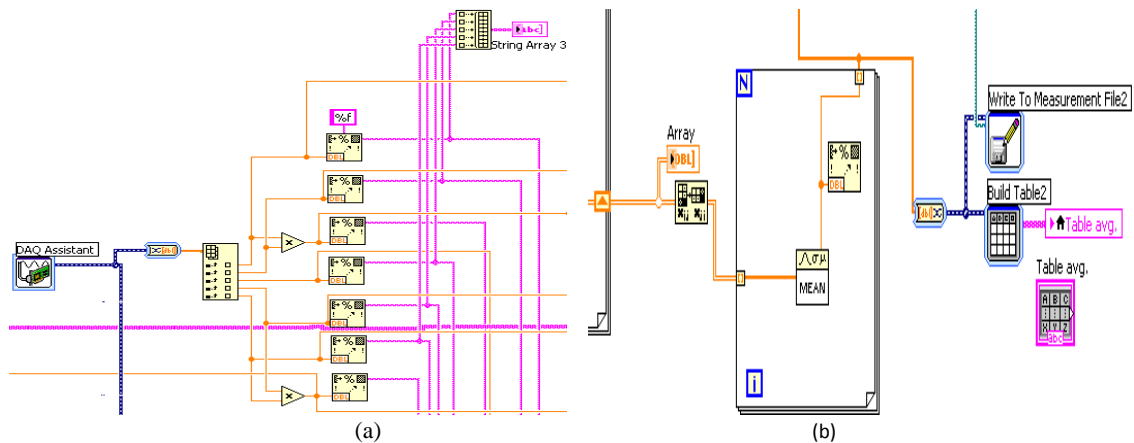


Fig. 4. Developed program for: (a) DAQ assistant data processing (b) averaging of all parameters

Fig. 4 (a) shows LabVIEW data processing path coming from the data acquisition system through the Express DAQ Assistant. The VI allows to setup different channels for parameters with scaling factor and corresponding calibration of each channel. The instantaneous values of all variables like voltages, currents and irradiation could then be processed, analyzed, used for online control, online display and storage. Fig. 4 (b) shows the developed module for taking a mean value of a certain specified time interval for any desired variable.

The voltage and current points are taken and captured along the *I-V* curve starting from open circuit load to short circuit load. The subsequent *P-V* curve points are captured simultaneously while the load resistance is being varied. The corresponding block diagram is shown in Fig. 5. This module is based on the corresponding front panel manual control button for data collection. *I* and *V* data are measured and *P* is calculated. The data points are collected in an array and then converted to dynamic format in order to build the corresponding *X* and *Y* axis. The *I-V* and *P-V* curves are displayed on the front panel directly. The subsequent stage is the module to super-impose the next *I-V* and *P-V* curve. Finally the corresponding *I-V* and *P-V* data are stored in a measurement file

The front panel of the developed virtual instrument depicts graphics and numerical data of all parameters and variables. The data are stored in the measurement file and in Excel format. All stored information is based on instantaneous and mean values. When the block diagram has a branch or node, then the code is executed in parallel automatically and managed by LabVIEW filters. Thus parallel nature makes multitasking and multithreading simple to implement.

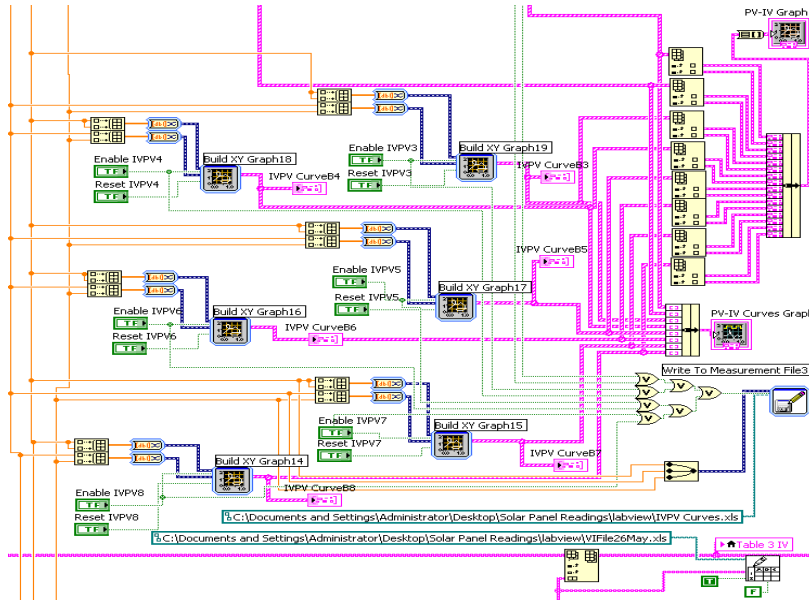


Fig. 5. Developed module for I-V and P-V curves

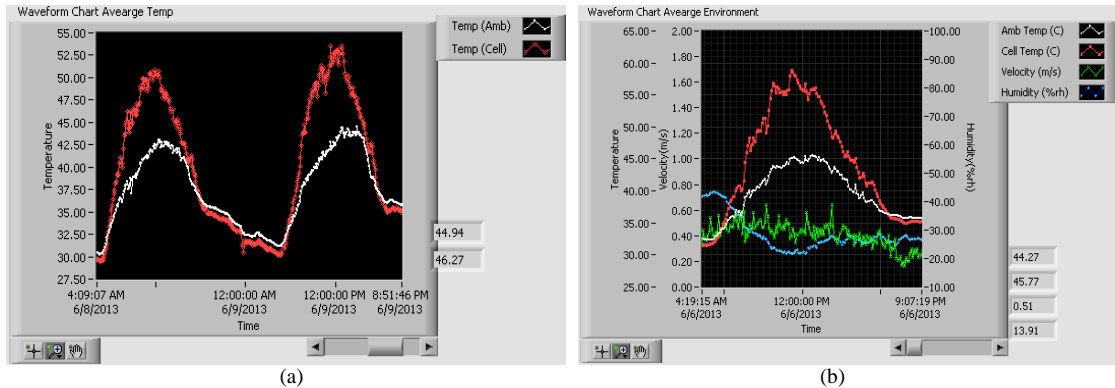


Fig. 6. Online behaviour for: (a) 2-days ambient & cell temp. (b) 1-day wind speed, relative humidity & temp.

4. Results & Discussion

Fig. 6 (a) and (b) show the weather parameters with the desired averaging interval of 5 minutes for each point. The super imposed graphs display both ambient and panel temperatures which have shown a sharp and nonlinear increase of the panel temperature over the ambient temperature for two days measurement. Fig. 6 (a) shows a maximum panel temperature of 50.90 °C for the first day while 53.56 °C for the second day in comparison to ambient temperatures which are 42.49 °C and 42.72 °C, respectively. It is believed the compounded rise of panel temperature is due to several reasons such as ambient temperature rise and irradiation increase which drives more circulating panel currents that cause the internal heat. The display of humidity, wind speed, ambient temperature and panel temperature in the same graph will help to analyze the impact of each factor on the energy output of the panel as shown in Fig. 6 (b).

Panel A is dusty and panel B is clean, but both panels A & B are exposed to the same environmental conditions such as humidity, wind speed, irradiation and load resistance. Fig. 7 (b) clearly shows higher level of power output and larger flat curve (plateau). The plateau starts at 9am until 12:20 PM for a level of 95.2 W to 95.6 W while corresponding curve zone of the dusty panel A starts at 9:30am until 12am for a level of 84.2 W to 83.9 W. The harvest energy from the clean panel is clearly much higher than the

energy harvested from the dusty panel. The maximum power difference is 12.25% at low dust exposition level.

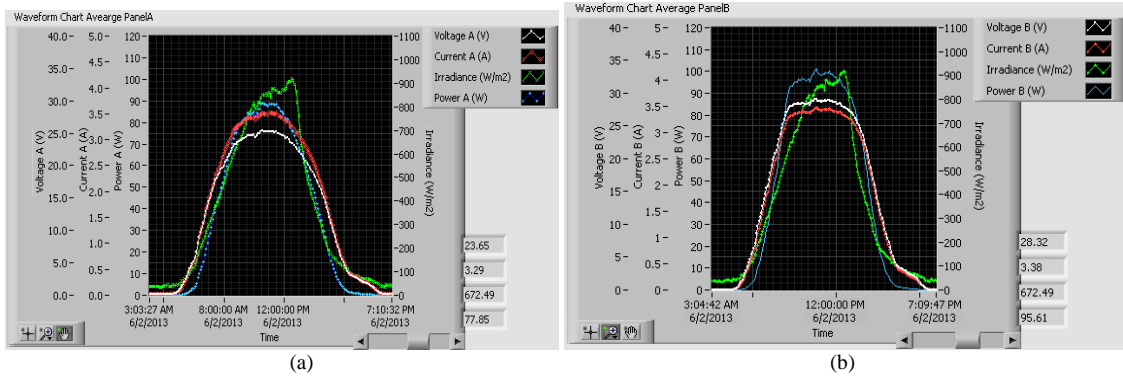


Fig. 7. Displayed graph for: (a) Online dusty panel A (b) Online clean panel B

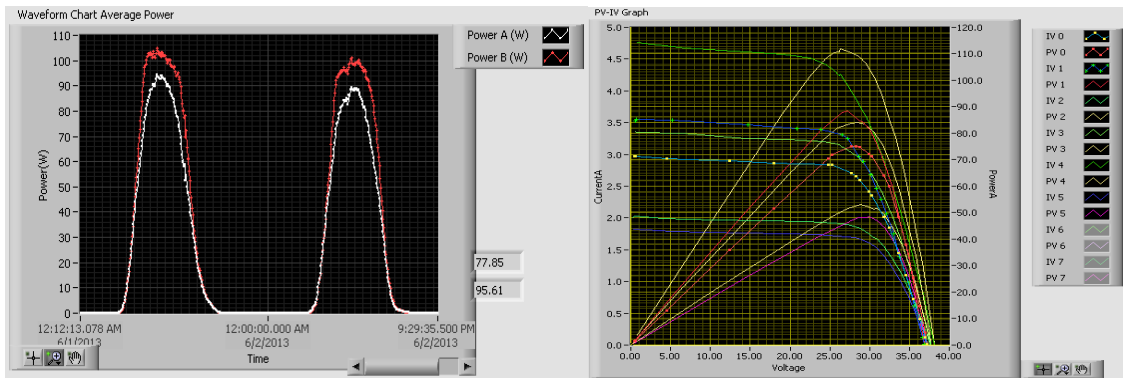


Fig. 8. Dusty & clean panel online power for two days

Fig. 9. Dusty & clean panel I-V & P-V Curves

Fig. 8 shows the online monitoring of both panels output power for two consecutive days. The displayed results show the consistency of the clean panel (red colour) behaviour in harvesting more energy than the dusty panel (white colour). The importance of keeping the panel clean to harvest more power is emphasized by this module. Several factors such as the dust level, the ambient and the panel temperatures, the day time irradiation level and the surrounding hot or cold air affect the maximum output power of the panel for the fixed resistive load. The evaluation of maximum power point is very important and to be determined by I-V and P-V curves. The relevant module is designed to obtain I-V and its corresponding P-V curve at any desire time while the online monitoring modules are ON and the online data is being in streaming position and recorded. Fig. 9 shows three I-V curves (green colour) for the clean panel and their corresponding P-V curves (yellow colour) and three I-V curves (blue colour) for the dusty panel and their corresponding P-V curves (red colour) are super imposed in one graph for analysis, performance evaluation and determination of maximum power points. The results are summarized in Table 1.

Table. 1. Results of I-V & P-V curves

Panel	Time	Ambient temp.(°C)	Panel temp.(°C)	Irradiation level(W/m ²)	Max. Power(W)	Voc (V)	Isc (A)
Clean	10:45AM	42.5	49.8	890	111.96	38.14	4.75
Clean	01:15PM	43.3	46.5	560	84.16	37.73	3.35
Clean	2:30 PM	42.5	45.7	270	53.01	37.57	2.01
Dusty	11:20AM	46.6	54.7	940	88.35	36.85	3.56
Dusty	01:30 PM	46.4	51.2	490	75.17	37.19	2.98
Dusty	02:30 PM	44.3	48.4	270	48.3	37.15	1.83

5. Conclusion

An experimental set up was built for a standalone PV performance monitoring system Using LabVIEW environment. The whole integrated system was tested for real time measurements as well as for I - V and P - V characteristics under different environmental conditions.

- 1) LabVIEW shell was tested for clear day time under normal ambient temperature and clean panel conditions. The output power was monitored at real time rate. The stand alone system performance was mainly affected by the irradiation variation during the day. The developed system displayed graphically and recorded all the weather parameters as well the relevant voltage, current and power at high frequency measurement and at the designated average time interval.
- 2) The interface capability of displaying several parameters and variables simultaneously in a multi-scale window frame was very useful for analysis purposes. Each panel variable could be monitored separately on real time basis for unlimited number of days. The data is continuously stored and recorded by a file per day.
- 3) The simultaneous performance of PV clean panel and similar dusty panel were investigated using LabVIEW system through the I - V curves along with its corresponding P - V curves for each panel. The appended curve results have demonstrated clearly better performance in favor of the clean panel. LabVIEW graphs have revealed a different slope for the dusty panel I - V curve to declare the change in the electrical parameters such as parallel and series resistance of the dusty panel.
- 4) The automatic appending capability for online environment is a very good feature of the developed LabVIEW system. Power output evaluation as well as the monitoring of panel temperature under different irradianations would be essential for the healthy and efficient system exploitation. System levels evaluation and a comparative feature have been successfully tested and displayed the performance of clean and dusty panels under the impact of different levels of irradianations.

Acknowledgements

The authors acknowledge the support of King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia for this research work.

References

- [1] Chang C, Zhu J, Tsai H. Model-based performance diagnosis for PV systems. In: *Proc. of SICE Annual Conference*, 2010:2139-2145.
- [2] Wichert B, Dymond M, Lawrance W, Friese T. Development of a test facility for photovoltaic-diesel hybrid energy systems. *Renewable Energy*, 2001; 22(1-3):313-319.
- [3] Koutroulis E, Kalaitzakis K. Development of an integrated data acquisition system for renewable energy sources systems monitoring. *Renewable Energy*, 2003; 28(1):139-152.
- [4] Forero N, Hernández J, Gordillo G. Development of a monitoring system for a PV solar plant. *Energy Conversion and Management*, September 2006; 47(15-16):2329-2336.
- [5] Aristizabal AJ, Gordillo G. Performance monitoring results of the first grid-connected BIPV system in Colombia. *Renewable Energy*, 2008; 33(11): 2475-2484.
- [6] X Zou, Bian L, Yonghui Z, Haitao L. Performance monitoring and test system for grid-connected photovoltaic systems. In: *Proc. of IEEE Power and Energy Engineering Conference (APPEEC)*, Asia-Pacific, 2012:1-4.
- [7] Bin A, Weixiang S, Seng O, Ramanathan S, I-Wern L. Development of a LabVIEW-based test facility for standalone PV systems. Presented at: Third IEEE International Workshop on Electronic Design, Test and Applications, 2006.
- [8] Aristizabal AJ, Arredondo CA, Hernandez J, Gordillo G. Development of equipment for monitoring pv power plants, using virtual instrumentation. In: *Proc. of IEEE 4th World Conference on Photovoltaic Energy Conversion*, 2006:2367-2370.
- [9] J.H. So, Y.S. Jung, B.G. Yu, H.M. Hwang, G.J. Yu, & J.Y. Choi. Performance Results and Analysis of Large Scale PV System. In: *Proc. of IEEE 4th World Conference on Photovoltaic Energy Conversion*, 2006:2375 – 2378.
- [10] Kwak SH, Moon CJ, Jeong MS, Park BJ, Kim SM. Electrical performance estimation of pv module using designed measurement system. In: *Proc. of 8th International Conference on Power Electronics*, 2011:2612-2617.