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LabVIEW Based PV Panel Online Characteristics And Parameters Estimation

Chokri Belhadj Ahmed[a,*], Mahmoud Kassas[a], Syed Essamuddin Ahmed[a,]

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

Abstract

This paper focuses and presents the online performance, characteristics evaluation and parameters estimations for stand-alone Photovoltaic (PV) panel. The PV panel is subjected to very harsh working surrounding conditions characterized by very high air temperature, very high humidity fluctuations. The local area experience heavy and seasonal dust storms. The area is rarely cloudy and the irradiation level is on the high side in most period of the year. This experimental work is centralized around Laboratory Virtual Instrument Engineering Workbench (LabVIEW) environment. Three LabVIEW graphical programming blocks are developed to acquire data, to present numerical display and to store environment and electrical parameters. The Fourth block is dedicated to execute graphical online display of environment data. The Fifth module follows and display the electrical variables under clean and dusty condition. The sixth block is designed to acquire the I-V and P-V characteristics simultaneously. The seventh module estimates series and shunt resistance of PV panel under changing condition. The developed environment was fast and accurate in collecting and storing the data. It was very satisfactory to monitor the weather parameters and its impact on the electrical PV performance. The developed system was successful to reach I-V and P-V characteristics accurately. The series and shunt resistance were estimated and found to very close to the simulation results.

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Keywords: *PV generator; Standalone performance; On-line monitoring; Weather effects, efficiency*

1. Introduction

Performance of a standalone PV system is greatly affected by the environmental parameters. These parameters are irradiation, ambient temperature, surface panel temperature, humidity, and wind speed. High temperature and humidity

* Corresponding author. Tel.: +966-13-860-4238 ; fax: +966-13-860-3535 .
E-mail address: bachokri@kfupm.edu.sa

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will drift down the performance of the PV-panels away from the rated values. Also, dust deposition on the PV-panels will add another degradation of the performance of the PV system. To evaluate the performance of the PV-system, well-designed monitoring systems must be developed and connected to the PV system. There are many published research papers using either microcontrollers or DAQ LabVIEW interface.

The effect of dust deposition on PV-system in harsh environment has been presented[1]. They found out that if the dust deposition density increased from 0 to 0.36 mg/cm^2, the efficiency decrease as well as the short circuit current I_{sh} is degraded by 17.7%, but on the other hand, the open circuit voltage V_{oc} has shown little effect. Other work on dust affect has been proposed[2]. They conducted experimental study to evaluate the electrical characterization of some PV modules in presence of powder on the PV panel surfaces. Performance monitoring and test system for grid connected PV systems has been developed[3,4]. They measured meteorological data and electrical parameters using LabVIEW to quantify the potential for performance improvement of standalone PV system. Monitoring PV power plant using LabVIEW has been presented[5]. They introduced the behavior of parameters characterizing the energy quality such as total harmonic distortion, harmonic components, frequency, and voltage of the PV system as well as meteorological data. The performance of the grid connected 1-kW PV system has been monitored and analyzed for 8 years[6]. They monitored irradiation into horizontal plane and irradiation in the plane of nodules, ambient temperature, surface panel temperature, and the wind speed using data acquisition system. They were able to show monthly energy production, capture losses, and system losses. King[7] in his paper was presenting alternative methods for specifying and monitoring PV system performance that are easier to understand, less ambiguous, more accurate, less costly, and more efficient. He evaluated the performance of PV system based on ac-energy efficiency that the system efficiency can be calculated during system design and it can be measured after system installed. Parameters estimation of PV cell has been analyzed[8]. They evaluated the uncertainty on series and shunt resistances by seven-parameter model of PV cell using data provided by the manufacturer, measured environmental parameters, and semi-empirical equations.

2. Experimental Setup

The developed system is used to monitor and analyze a stand-alone photovoltaic system located at KFUPM campus, Dhahran, Saudi Arabia. This experimental setup is made of one stand-alone PV panel, data measurement and collection interface equipment. All devices are connected through the central processing unit.

Figure 1 shows the block diagram of the stand-alone PV system experimental set-up. The used panel has a following characteristics (Maximum Power (P_{max})= 150 W, Maximum Current (I_{max}) = 4.16 A, Maximum Voltage (V_{max}) = 36 V, Short Circuit Current (I_{sh}) = 4.49 A and Open Circuit Voltage (V_{oc}) = 43.2 V). These values are given by the manufacturer and taken under standard testing conditions of non-dusty clean environment. The exposed panel area to the solar irradiation is 1.5 m^2. The panel temperature, ambient temperature, humidity and wind speed were taken by VelociCalc device and directly transmitted to LabVIEW interface. The irradiation is measured continuously using precision spectral pyranometer (Eppley Radiometer). The electrical variable such as load voltage and load current are measured and processed through isolating amplifier module (LEYBOLD). The variable resister load bank is equipped with variac to tune its value from zero to infinite resistance. LabVIEW interface is simultaneously communicating with the environmental and electrical measurements in a specified data collection rate.

3. Online Data and Storage

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. A specific command is written and sends to the device then the response is read back. Virtual instrument (VI) will then wait if the reading is performed until the specified number of bytes is received at the port. Figure 2(a) shows the developed graphical programming block diagram and figure 2(b) shows the corresponding front panel monitoring area.

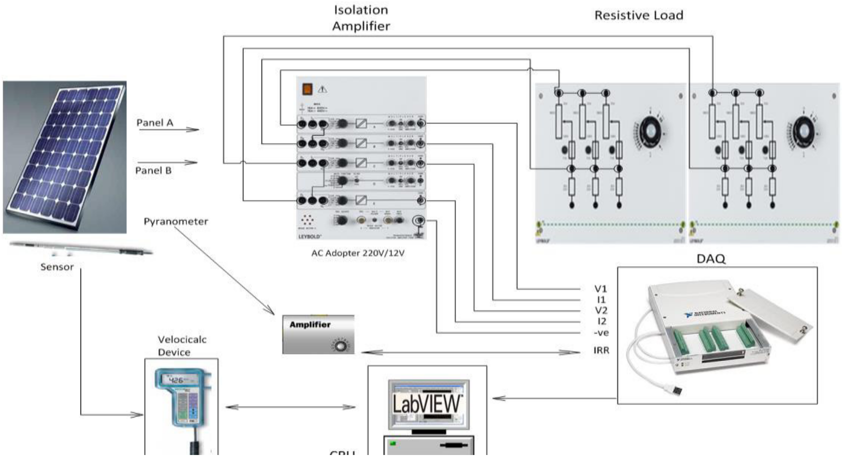
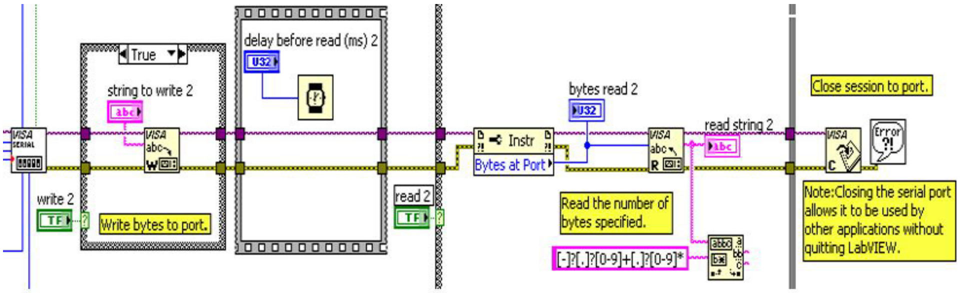


Figure 1 Experimental setup of stand alone PV system



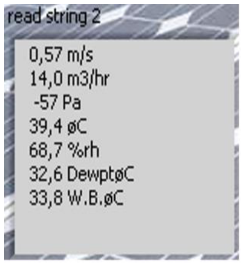


Figure 2 (a) Graphical programming block diagram for acquiring environmental data

Figure 2 (b) Front panel display of environmental

Data received from the device are in string format that needs to be processed for display and storage. The received data is displayed as follows: wind speed, volumetric flow rate, differential pressure, temperature, relative humidity, dew point and wet bulb temperature. A module is developed to segregate, concatenate and then arrange the entire data in an array form as shown in figure 3. The resultant values are then joined to make an array and a table for continuous reading and monitoring. The array shown in figure 3 is excluding wet bulb temperature. The pressure shows a negative sign because an appropriate connection is not applied. The data is then saved to an excel file. Graphs and charts are used to display plots of data in a graphical form. Figure 4 shows LabVIEW third block data processing coming from the data acquisition system through the Express DAQ Assistant. The instantaneous measured values of all variables like voltages, currents and irradiation could then be processed, analysed, used for online display and storage. The outcome of product of voltage and current is power.

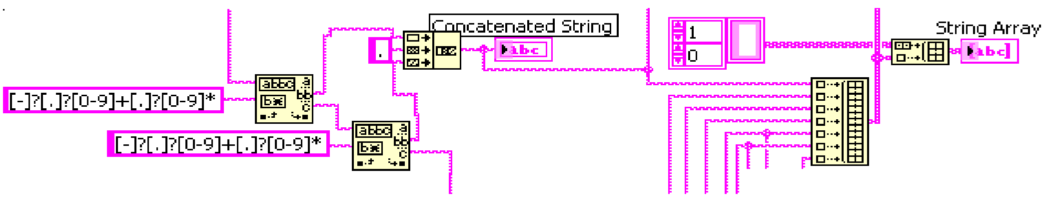


Figure 3. (a) Module for data processing and display block diagram

Figure 3. (b) Data display front panel diagram

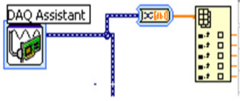
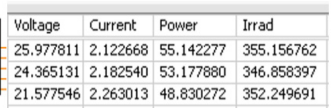


Figure 4. (a) Electrical data scaling and processing block diagram



Voltage	Current	Power	Irrad
25.977811	2.122668	55.142277	355.156762
24.365131	2.182540	53.177880	346.858397
21.577546	2.263013	48.830272	352.249691

Figure 4. (b) Data scaling and processing front panel diagram

4. Online Performance

Figure 5 show the fourth block, the weather parameters with the desired averaging interval of 5 minutes for each point continuously for two days. The super imposed graphs display humidity, wind speed and both ambient and panel temperatures that have shown a sharp and nonlinear increase of the panel temperature over the ambient temperature measurement during day time that is normal temperature behavior. This multi-scale plot with time follows the variations in weather parameters in continuous way. The blue plot shows the phenomenon of sharp increase of humidity in night and low at day hours that is typically characteristics of Dhahran area. The green plot follows the wind speed variation in low level pattern.

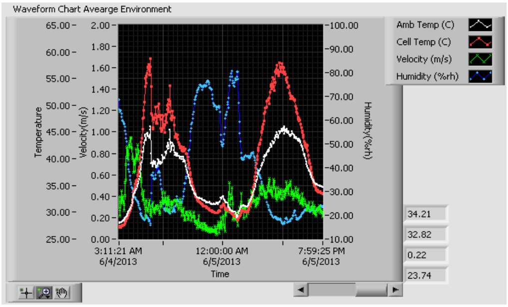


Figure 5. Weather data parameters online display

Figure 6(a) shows the performance of clean panel whereas the performance of dusty panel is shown in figure 6(b). The both similar panels were exposed to the same environmental conditions such as humidity, wind speed, irradiation and load resistance for two days. Figure 6(a) clearly shows higher level of power output for longer period of time than the dusty panel figure 6 (b). The zones of highest amount of power for clean panel were 106W and 103W while the highest amount of power for dusty panel were 90W and 85W. The harvest energy from the clean panel is clearly much higher than the energy harvested from the dusty panel. The maximum power difference is 15.15% for the first day and 17.47% for the second day. This result was taken for low dust deposition level.

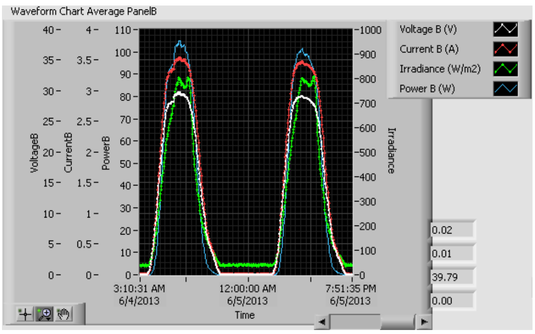


Figure 6. (a) Online performance of a clean panel

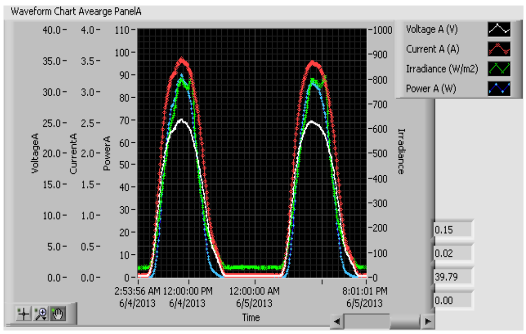


Figure 6. (b) Online performance of a dusty panel

5. I-V and P-V Characteristics

The voltage and current points are taken and captured along the I–V curve starting from open circuit to short circuit. The subsequent P-V curve points are captured simultaneously while the load resistance is being varied. The corresponding block diagram is shown in figure 7. This module is triggered by a dedicated front panel control knob. 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. Files must be in MS Word only and should be formatted for direct printing, using the CRC MS Word provided. Figures and tables should be embedded and not supplied separately.

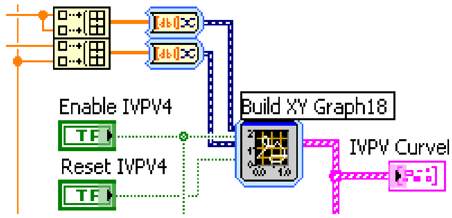


Figure 7. I-V and P-V characteristics block diagram

The evaluation of maximum power point is very important and has to be determined from I-V and P-V curves. The relevant module is designed to obtain I-V and its corresponding P-V curve at any desired time while the online monitoring modules are ON and the online data is being in streaming mode and recorded. The I-V and P-V curves could be obtained from a stand by panel or cell running under the same environmental condition thus the maximum power is obtainable on a regular base.

Figure 8 shows three I-V curves (from top to bottom consecutively, orange, pink and white color) and their corresponding P-V curves (purple, blue and red color) for the clean panel and three I-V curves (from top to bottom consecutively, white, pink and orange color) and their corresponding P-V curves (red, green and blue color) for the dusty panel. All these curves are super imposed on the same plot for analysis, performance evaluation and determination of maximum power points.

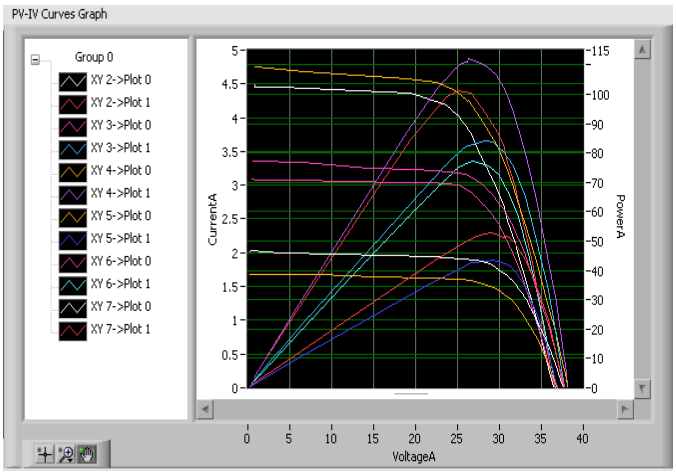


Figure 8. I-V and P-V characteristics display for clean and dusty PV panel

6. Parallel and Series Resistances

The method applied to reach the I-V curves at any environments condition consists of fast variation of the load resistance from a very high value (open circuit) to a zero resistance (short circuit) passes by the maximum power point. The objective is to reach the values of Rp and Rs experimentally under environmentally changing conditions.

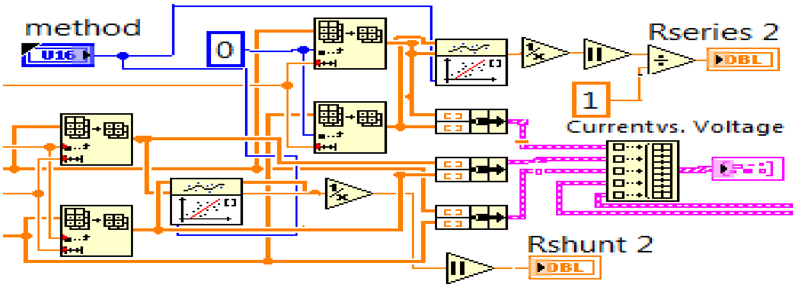


Figure 9. (a) Parallel and series resistances module block diagram

For this purpose, a tangent method is carried out. The slope of the tangent to the upper left side of I-V curves determines the values of Rp. The slope of the tangent to the lower right side of I-V curves determines the values of Rs. The tangent starts at practical short-circuit current (I_{sc}) for Rp value and starts from open-circuit voltage (V_{oc}) for Rs. Both determined values are digitally displayed by the same module in the front panel. The accuracy of obtained values of Rp and Rs are validated by simulation results. Figure 9(a) shows the developed block diagram for estimating the values of Rp and Rs and figure 9(b) & 9(c) shows the corresponding front panel for clean and dusty graphical results. The obtained results for clean panel is Rp equals 147.8 Ω and for Rs equals 1.12 Ω while the obtained results for dusty panel is Rp equals 111.32 Ω and Rs equals 1.15 Ω. The obtained values of Rp shows the decrease of 36.55 Ω. This is the impact of dust accumulation on the value of Rp. For such environmental conditions, the panel output power is reduced while the panel is dusty. Refereeing[9] to figure 10 used in our simulation, the decrease of the value of the shunt resistance Rp will reduce the amount of output current and consequently the output power. The results show no practical change of the value of Rs due to accumulation of dust. Further study is being conducted for excessive amount of dust accumulation on PV panel during dust storm that is frequent in our area of Dhahran.

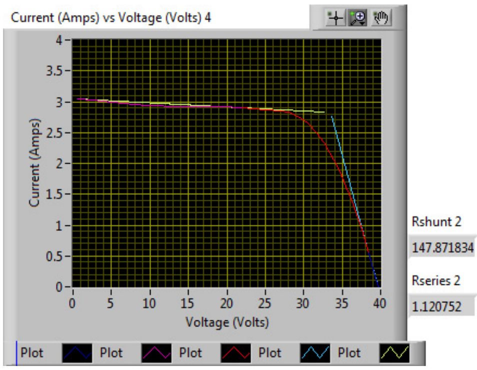


Figure 9 (b) Parallel and series resistances determination for clean panel

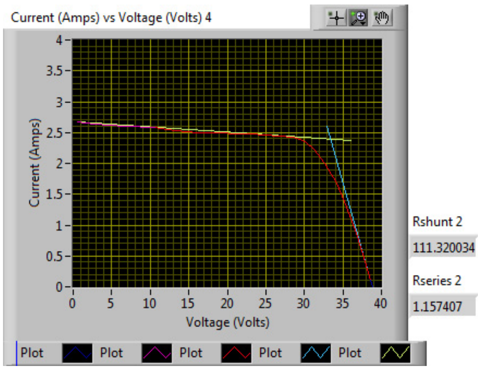


Figure 9 (c)Parallel and series resistances determination for dusty panel

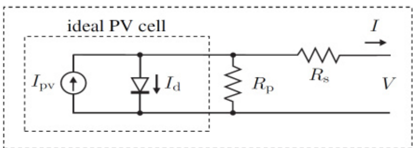


Figure 10 Schematic diagram of PV panel

$$I = I_{pv} - I_o\left[\exp\left(\frac{V + R_s * I}{Vt * a}\right) - 1\right] - \frac{V + R_s * I}{R_p} \quad (1)$$

7. Conclusions

The seven graphical programming blocks of LabVIEW environment system were developed. The system was successfully tested for a standalone loaded PV panel under different environment conditions. The system was meant for data collection at defined rate, data storage, online monitoring characteristics display and parameter estimations.

- First task was communicating with external environmental sensors, with current and voltage measurement devices through interface. The data was arranged and ordered in a systematic way in several columns with the corresponding time and date. Then the data is simultaneously stored in Excel sheet.
- The second task is for online graphical display for the variations of air temperature, panel temperature, wind speed and relative humidity. The instantaneous numerical display of these parameters are carried out at the same time. The current, voltage and power were treated by an equivalent module.
- The third task is I-V and P-V characteristic display at any time under any clean and dusty condition of PV panel. The open circuit voltage, short circuit current, maximum power, current and voltage for maximum power are easily obtained.
- The final task is to obtain the shunt and series resistance of the PV panel through the corresponding slopes on the displayed I-V curves. The values were also digitally displayed.

The developed system under different environmental condition has given satisfactory results.

Acknowledgements

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