Experimental Investigation on acquisition data of Current-voltage and power characteristics for photovoltaic panel parameters: Applied In Algeria-Tamanrasset

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Abstract

The practical design of acquisition data based on Arduino board for photovoltaic module parameters. The design is optimized to measure the parameters (photonic current IPh, factor of quality γ, resistance series Rs, and reverses saturation current I0), of solar cell modules presenting 21.7V as open circuit voltage and a low short circuit current below 3.45A. The Data acquisition allows for trace the (I-V) (P-V) characterization of monocrystalline and polycryctalline modules within real operate conditions and enables to detected the potential failure of anomalies in behavior electric. This design based on low cost components, current and voltage sensors and Arduino Mega board, A prototype has been implemented and field tested for characterization of two type of modules. The interface is optimized using Python software.

Keywords: Diffuse solar radiation; Clearness index; Sunshine duration; Algerian Big South.

1. Introduction

The huge expansion of the photovoltaic PV system plants all over the continents signifies their importance as one of the most popular renewable energy sources. The PV plant is based on assumption that PV array will operate in a maximum power point region[1]. Evaluation of performance parameters of PV modulesis assumed to be important, and the most important parameter of PV module is the I-V characteristic curve, which provides important information about PV module sper formance.

The measurement of the IV-PV characteristic of photovoltaic arrays is the greatest interest among PV installers, operators, users and researchers. It allows for accurate determination of the behavior electric of the PV device within real conditions and enables validation of performance and comparison with either previous data or expected data[2]. Many programmable loads can be found on the market that can be used as IV- tracers for PV devices in laboratories[3][4]

A lot of efforts have been made by researchers to develop these types of dispositive. However, the commercial available ones are often expensive. In this context, it is possible to build an I-V tracer and acquisition system by using quite simple and much cheaper circuits, In order to extract the PV module characteristics parameters by the collection the I-V data.

This paper presents the design and development of a low cost and portable current-voltage (I-V) PV modules measurement devise that is able to extract the PV module characteristics parameters within real operate conditions of irradiance and temperature, by the collection the I-V data. The recorded data can be retrieved and used later in the performance comparisons.

Three types of available modules: Amorphous, Monocrystalline and Polycrystalline silicon PV Modules were the samples investigated test with the developed I-V tracer.Measurement of the global solar irradiance at the same angle of the PV module is realized with pyranometer and the data collection has been carried out using acquisition data based on Arduino board. This board permitting to switch between different load resistance values. The device is also composed of current, voltage and temperature sensors which are compatible with Arduino board.

With the Python Graphical user interfaces (GUI) softwareaspecial program were developed in order to control the data-collecting, monitoring and visualizing process of PV module I-V Tracer

Finally, a PV conversion has been estimated according to the model of four parameters: Photonic current IPh (A), Quality factor (γ), Resistance series RS (Ω) and reverses saturation current (I0). The photovoltaic conversion power increases according the illumination. On the other part the temperature increasing causes a decrease in conversion power. The simulated values obtained by Matlab software showed a similarity with the measured values.

2. Materials and Methods

2.1 Component of developed system

Description of the hardware and also software components that used in the implementation of the I-V tracer for PV module are explained in this section.TheI-V tracer will be controlledusing computer code programmed with Python programing language.

2.1.1 Hardware Components

The Arduino boardwith ATmega Microcontroller board is the heart of the control circuit of this measurement system.ARDUINO is an open-source electronics platformused for building sample electronics projects. In this study Arduino MEGA board base on theATmega2560 Microcontroller is used.The board provides a group of digital and analogue Input/output pins which can interface to multiple expansion boards and other circuits.(See Figure 1).

The current measurement is achieved by using the ACS712 Hall Effect current sensors, and the voltage is measured with Arduino Voltage Sensor Moduleallows you to measure the supply voltage from 0.025V to 25V.

The temperature at the back surface of the PV module is carried out using a numerical sensor (thermocouple type-K and an amplifier digital MAX6675). This sensor has a resolution of 0.25°C, and communicates directly with Arduino Mega 2560 board. The global solar irradiation is measured using a Kipp&Zonen CMP11 pyranometer.This instrument is the most widely used secondary standard pyranometer in the solar energy application. A detailed pyranometer characteristics can be found in Ref [5].

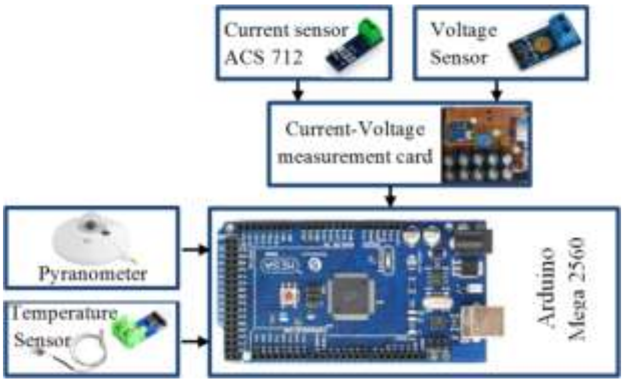

Fig.1: Schematic representation of the developed acquisitions system.

Arduino MEGA is used for implementing the control of the I-V Tracer, it supplied the 9 to 12 V. In our configuration one digital output is used for the rely (D9), tree analog inputs for current and voltage sensors. Another analog input is used for the temperature sensor.

a) Principe of Current-Voltage (I-V) measurement

The IV-PV tracer use as a basis the capacitive load and electrical sensors connected with Arduino board. The load capacitor is the most usual method by commercial equipment for the IV-PV curve measuring devices [6]. An implemented electronic circuit is used in order to make the process of charge and discharge of the load capacitor and to measure the output voltage-current, output current and operating temperature using suitable sensors. The extracted data are stored in the computer memory.

The basic electronic circuit of the Current-Voltage measurement is shown in Figure 3.Under normal operation the relay is open and the capacitor is discharged,once the rely is closed by signal coming from digital pin D9 the PV array is connected to the capacitor load thus charging from 0 to V_{OC}. Current and voltage are taking during the charging process, which correspond to the I-Vcharacteristics of the PV module. After that, the relay will be close, and the load capacitor discharged into a resistor for the trace of the next measurement[7][8].

The capacitor charging time t_c depends on its capacitance$C$, and the instantaneous values of short-circuit current I_{SC} and V_{OC}, through the following equation:

$$t_c = \frac{V_{OC}}{I_{SC}} . C \quad (1)$$

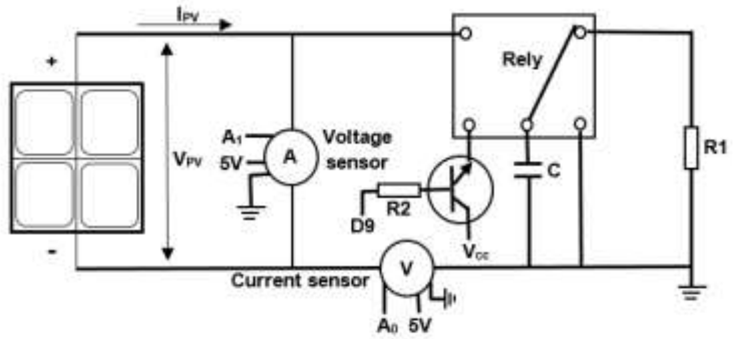

Fig. 2 Electronic circuit for Current-Voltage (I-V) measurement of the photovoltaic module.

The Current-Voltage measurement card is mounted in basedon the previous electroniccircuit, and this kind of card is adapted and integrated in Arduino board as show in Figure 3.

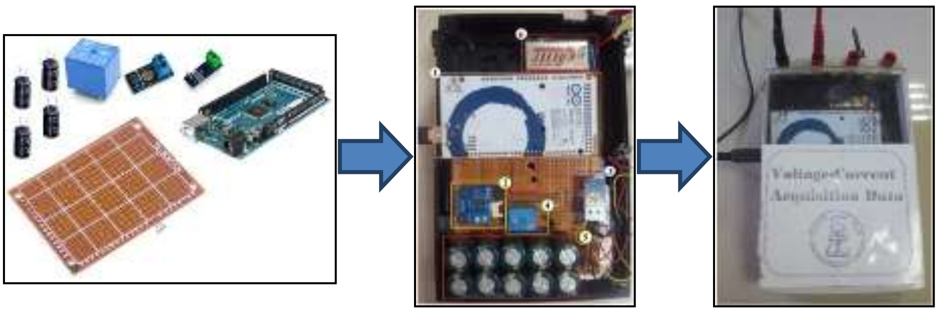

Fig. 3: Schematic representation of the developed PV module I-V Tracer.

b) Software Components.

The main program of this project is PYTHON which is a global and professional program and a global language with very high features [1]. Graphical user interfaces (GUI) provide control over points and control in software uses, dropping the need to understood a language or writing commands for work [1]. PYTHON was used to execute this project.Through Python GUIthe internal code and the special program were developed in order to control the data-collecting, monitoring and visualizing process of PV module I-V Tracer (See Figure 4).In this project, we used the USB Serial Communication to send or receive the information from the Arduino board to the computer via the developed code.

1.2 Methodology of I-V tracer and monitoring-system

A low-cost I-V tracer and monitoring-system of individual photovoltaic (PV) modulesunder realistic operating conditions was developed in this study. This system includes Arduinotechnology for sensors and the data acquisition process, a variety of adapted sensors available to measure electric and other parameters such as temperature and the solar irradiation, a laptop and an application developed in python with Graphical User Interface (GUI) interface.Schematic illustration of the developed systemis presented in Figure 5.

We have designed an Arduino-based experiment to check the linear relationship between charge and voltage drop in a capacitor installed in the mounted electronic card. The electric charge stored in a capacitor is determined by the numerical integration over time of the electric current during the charging or discharging processes through a resistor. Finally the output current and voltage from PV module are measured and transmitted from the Arduino Mega boardto the computer through an USB serial connection.

Several programs have been used in this project to create a separate program that is used to measure the electric parameters of PV modules, to trace the current-voltage and power-voltage curves and to save the results in images.

During the acquisition procedure, the measured data of the current, voltage and the power will plotted directly in Python GUI program, and the necessary information are saved in CSV file format, which can be used later in the performance comparisons.

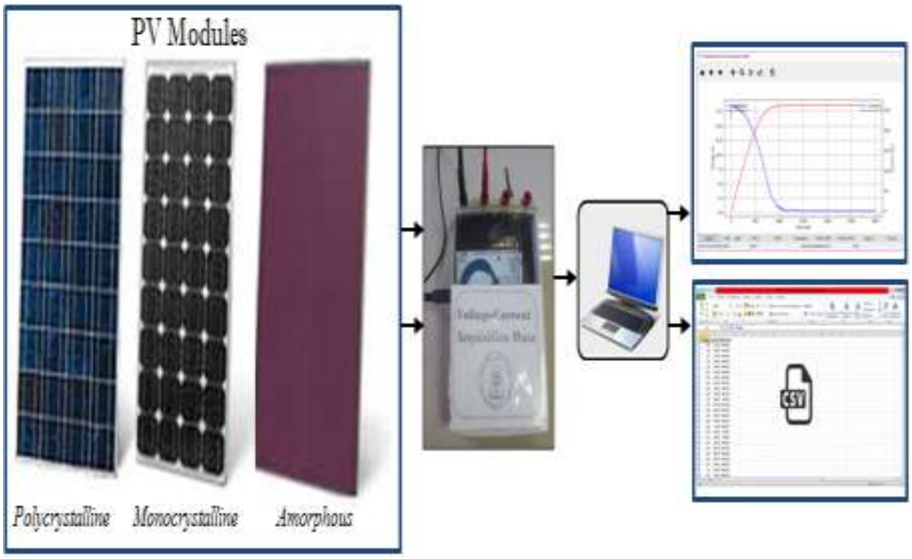

Fig. 4: PV system with I-V Tracer

The design and the development of this specific I-V Traced prototype have been carried out in the University Center of Tamanrasset located in the extreme south of Algeria. Some photos were taken during the first experimental tests are shown in Fig. 6. These tests were made on three types of available modules: Amorphous, Monocrystalline and Polycrystalline silicon PV Module (Fig. 6).The characteristics of different PV modules are given in table 1.

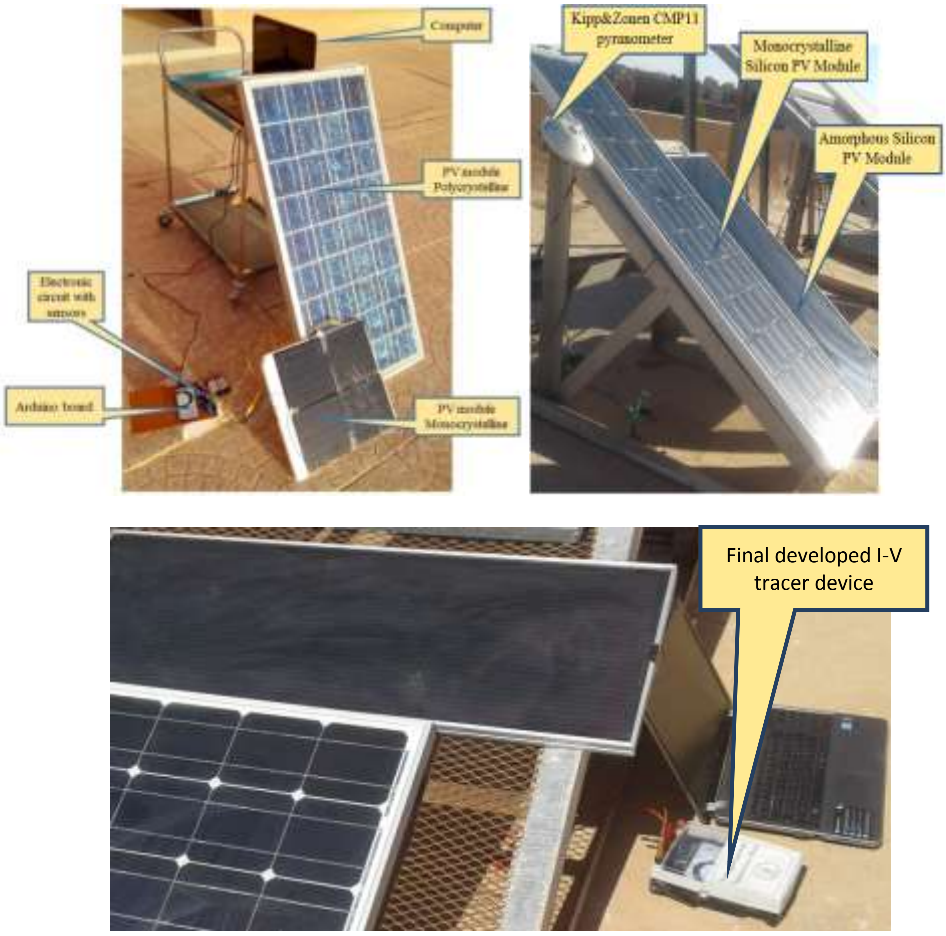

Fig.5: Photographs of the first experimental tests.

Tables 1: MSX60 module characteristics

Module	**Reference**
Number of cells (Ns)	36
Saturation current I_{sc} (A)	3.8
Over Circuit voltage U_{oc} (V)	21.1/Ns
Maximum power current I_p (A)	3.5
Maximum power voltage U_p (V)	17.1/Ns

Tables 2: SQ150 module characteristics

Module	**Référence**
Number of cells (Ns)	60
Saturation current I_{sc} (A)	4.8
Over Circuit voltage U_{oc} (V)	43.4/N_s
Maximum power current I_p (A)	4.4
Maximum power voltage U_p (V)	34/Ns

2. Solar cell modeling

An illuminated solar cell can be modeled Fig. 5 [9], [10] by an electrical circuit composed of a single diode, a generator of photonic current I_{Ph}, a series resistance R_s and shunt resistance R_{SH}.

The output voltage (V) is linking with the terminal current (I) by the equation delivered by a solar cell [9], [10]:

$$I = I_{Ph} - I_0 \left(\exp\left(\frac{v + R_S I}{n V_{th}}\right) - 1 \right) - \frac{V + R_S I}{R_{SH}} \tag{2}$$

Where $I_0$is the diode reverse saturation current, n is the ideality factor andV_{th} is the thermal voltagegiven as follow:

$$V_{th} = k_B T / e \tag{3}$$

Where e is the electron charge, k_B the Boltzmann constant, T the operating temperature.

2.1 Solar module modeling

PV module contains (m_p) parallel branches composed of (m_s) cells connected in series, can be modeling using a single diode model. The output current (I_M)of the PV module is written as a function ofoutput voltage (V_M) as[11]:

$$I_M = I_{phM} - I_{0M} \left(\exp\left(\frac{V_M + R_{SM} I_M}{n_M V_{th}}\right) - 1 \right) - \frac{V_M + R_{SM} I_M}{R_{SHM}} \tag{4}$$

The physical parameters of the PV module are

$$R_{SM} = (m_s/m_p) R_S \,; n_M = n \cdot m_s \,;\, R_{SHM} = (m_s/m_p) R_{SH}; I_{0M} = m_p I_0; I_{phM} = m_p I_{ph}. \tag{5}$$

3. Experimental results of the I-V Tracer PV modules with deferent R_s and P_s:

The developed data acquisition process is started by measuring solar irradiance received on the PV module surface using a pyranometer inclined at the same angle of the PV module. By using the developed device,the collected data of the irradiation and the temperature at the back surface of the PV module will be record every ten minutes in CSV file. The data of one selected dayare plotted in figure3, this figure showthe variation in the two measured parameter in the time range of 10:0 and 16:20.

We took our experimental results in this defect under the same conditions (T = 30 ° C, E = 1000W / m²).

To achieve this fault, a resistance has been inserted in series at the output Rs. For each value of the series resistance taken from the PV for example {Rs = 10kΩ, Rs = 6kΩ. Or Rs = 2KΩ}, the measured electrical quantities (I and V) at the output of the photovoltaic panel for each case are mentioned in the following table:

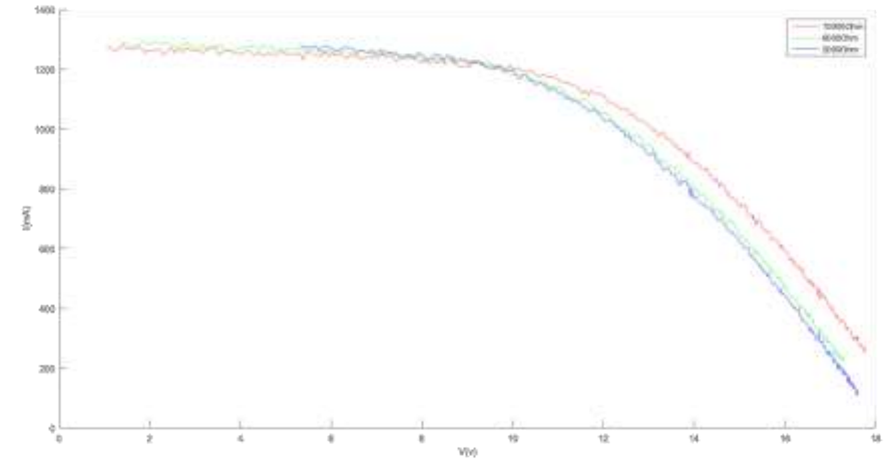

Fig.6: The characteristic I = f (V) for the default case of Rs

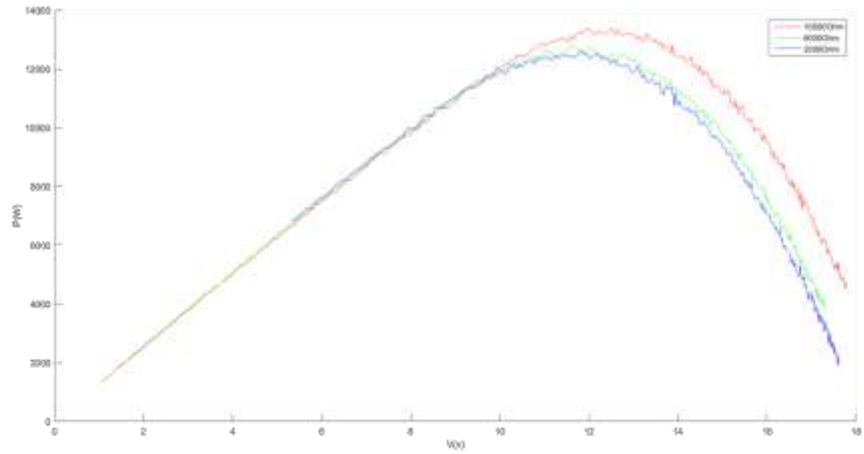

Fig.7: The characteristic P = f (V) for the default case of Rs

We took our experimental results in the healthy case and with this defect under the same conditions (T = 30 ° C, E = 1000W / m²).

To achieve this fault, a resistance has been inserted in parallel with the load at the output Rp.For each value of the parallel resistance taken from the PV for example {Rp = 10Ω, Rp = 8KΩ or Rp = 1KΩ}, the electrical quantities measured (I and V) at the output of the photovoltaic panel for each case are mentioned in the following table:

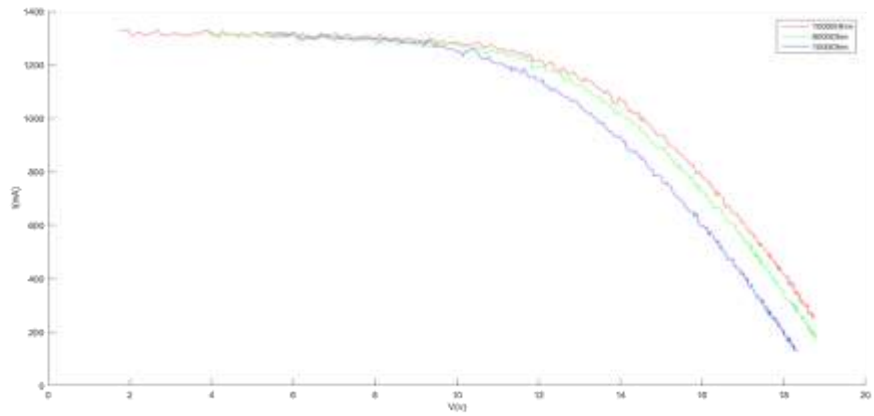

Fig.8: The characteristic I = f (V) for the default case of Rp

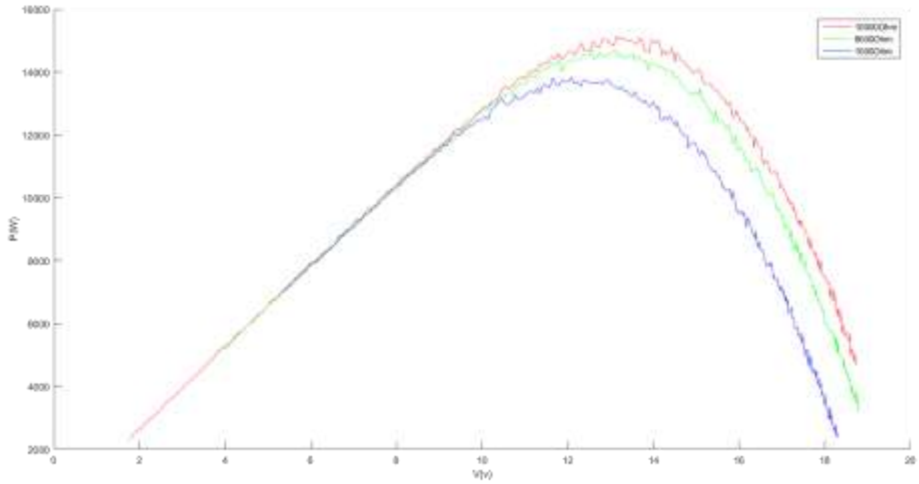

Fig.9: The characteristic P = f (V) for the default case of Rp

4. Conclusions

This work aims to design and implement of a low cost and portable I-V Tracer for photovoltaic (PV) modules characterization using Arduino board, python code and electrical measurement sensors (Voltage and Current Sensors), that is able to extract the PV module characteristics parameters within real operate conditions of irradiance and temperature, by the collection the I-V data. The recorded data can be retrieved and used later in the performance comparisons. A computer code programmed with Python programming language was developed and used to communicate with the Arduino board to control the data-collecting, monitoring and visualizing process. The collected measurements of current, voltage, solar irradiation and temperature are then saved in CSV format file.

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