Implementation Of A Mini-Data Acquisition Unit For Operating Parameters For Photovoltaic Solar Installations In Rural Areas

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Abstract—**Photovoltaic solar energy has experienced a significant boom in recent years. This has been true in particular for water pumping and electrification of isolated rural areas where the network conventional electricity is almost non-existent. Sometimes sizing errors due to the absence of actual data from the installation site or the lack of effective monitoring and personalized installation linked to the absence of reliable operating data from photovoltaic installation constitute obstacles in the sustainability and popularization of photovoltaic installations. The objective of this research work is to propose a device for acquiring and displaying physical and meteorological parameters important in the sizing, management and monitoring of photovoltaic installations. An electronic acquisition card is designed and produced with a graphical interface under the LabVIEW environment. The proposed acquisition unit is equipped with several modules' measurement and a central processing unit built around a 18F4550 microcontroller. This data logger is able to record data at the desired step under the format .txt…. xlsx and others thus facilitating their exploitation with spreadsheets such as Excel. The device produced can be use in the maintenance of photovoltaic installations, in the monitoring of operating parameters and their performance and in the quality control of the various constituent elements. Therefore, the device we have designed and constructed is suitable for photovoltaic systems in isolated rural areas.**

Keywords—data logger; photovoltaic solar installation; pic18F4550 microcontroller; sensors; LabVIEW;

I. INTRODUCTION

Photovoltaic solar energy is a green, renewable and inexhaustible energy at the human scale. However, the equipment that is mobilized for the conversion, the processing and conditioning of the electrical signal and the various receivers are subject to malfunctions that drastically reduce the performance of the PV generator, or cause the total shutdown of the production of photovoltaic electricity. One of the causes of these malfunctions is the bad sizing of the installations, and to this we can add the lack of timely maintenance based on the monitoring and exploitation of operating parameters of these installations.

Various authors have worked on data acquisition for dimensioning, as well as the exploitation of operating parameters for monitoring the performance of PV installations. Forero et al., (2006) propose a prototype of a data acquisition for acquiring data based on the virtual instrument method implemented in LabVIEW software for the characterization of photovoltaic modules. Their device makes it possible to visualize in real time the I-V and P-V characteristics of a photovoltaic module as well as the evolution of ambient temperature and irradiance as a function of time. Hocine et al., (2010) propose device for acquiring the voltage and the current generated by a pv module as well as the ambient temperature. NAIM et al., (2012) propose a device for monitoring the charging current and voltage of a 12V solar battery and the ambient temperature via a 16F716 microcontroller by viewing parameters on display 7 segments. Nfaoui and El-Hami, (2017) propose a device for acquisition and remote transmission of meteorological and electrical data such as speed and wind direction, ambient temperature, voltage and current of a PV field. Vinay et al., (2020) propose a data acquisition system for the monitoring of photovoltaic systems based on the Internet of Things (IoT) thus allowing to have remote and free access to data that provides information on the performance of the field irradiance, wind speed and temperature of the installation site.

With regard to the work of the various authors mentioned above, it is easy to observe that only some of the electrical meteorological parameters of the system are taken into account. This restriction does not ensure an efficient control and monitoring of PV systems. This research work is about the implementation of an acquisition device for a wider range of parameters. This includes in particular taking into account almost all electrical, meteorological and other parameters specific to the equipment used in the PV system.

II. MATERIALS AND METHODS

A. Block diagram of the mini data acquisition unit

Figure 1 below illustrates the synoptic of the mini data logger to be designed. There are a total of nine reading modules based essentially on the collection of current, voltage, temperature and frequency. Furthermore, it should be specified that the system offers the possibility of extending to other sensors.

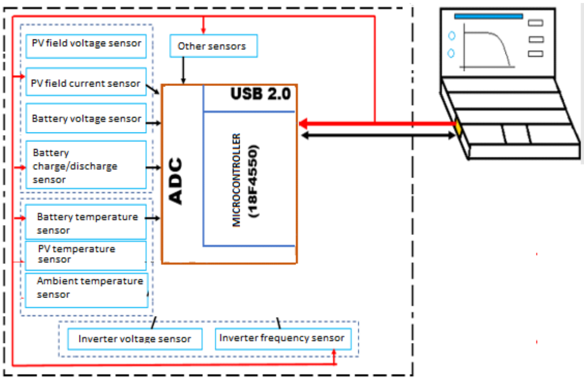

Fig. 1.*General block diagram of the data acquisition device*

B. PV array and battery voltage measurement

The voltage delivered by the photovoltaic field and/or the battery (battery bank) is generally greater than 5V. We therefore choose to measure the voltage at the output of the field and the battery using the assembly below:

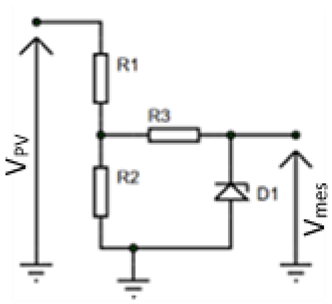

Fig. 2.*DC voltage measurement circuit*

The measured voltage (V_{mes}), image of the voltage of the photovoltaic field (V_{pv}) or of the battery (V_{bat}) is given by the following relationship:

$$V_{mes} = \left(\frac{R_2}{R_1+R_2}\right) V_{pv} \quad (1)$$

$$V_{mes} = \left(\frac{R_2}{R_1+R_2}\right) V_{bat} \quad (2)$$

Zener diode D_1 has a Zener voltage less than or equal to the maximum voltage that can withstand the microcontroller on each of its input pins (i.e. 5V).

C. Converter voltage measurement

Indeed, the inputs of a microcontroller can only receive positive signals; we measure AC voltage by combining a step-down transformer (220V/9V), a full-wave rectifier and a voltage divider using the diagram in Figure 3 below

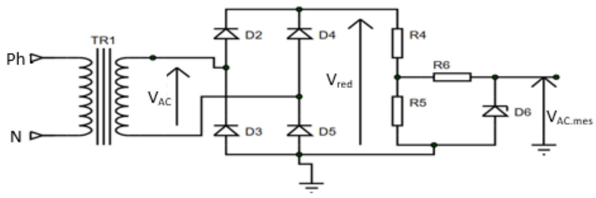

Fig. 3.*DC/AC Converter Voltage Measurement Circuit*

Assuming that diodes D_2, D_3, D_4 and D_5 are identical, we have:

$$V_{red} = V_{AC} - 2\,V_d \quad (3)$$

With: V_d the voltage drop across a diode.

For the rest of the assembly, we use the same equations as those used for the sensor of DC voltage which gives us in this case:

$$V_{AC.mes} = \left(\frac{R_5}{R_4+R_5}\right) V_{red} \quad (4)$$

Thus $V_{AC.mes} = \left(\frac{R_5}{R_4+R_5}\right)(V_{AC} - 2\,Vd)$

D. Current measurement

For current measurement, we choose the use of shunt resistors, based on the Ohm's law. Indeed, the voltage V at the terminals of an ohmic conductor of resistance R through which a current I is flowing is equal to the product of the resistance R and the current I.

In our case, knowing R and being able to measure V_{shunt}, we can measure in real time the current which crosses R and consequently the current consumed by our load because in series with R.

We therefore have:

$$I = \frac{V_{shunt}}{R} \quad (5)$$

Therefore, for the measurement of the different currents by the mini-control unit, we use the differential amplifier circuit as illustrated on figure 4 below. The voltage drop at the terminals of the shunt resistor is very low and of the order of a few mV in a certain range.

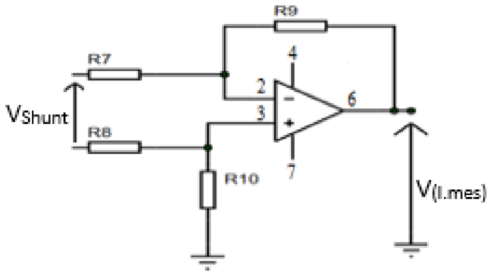

Fig. 4.*Differential Amplifier Circuit*

Applying Millman's theorem to this assembly and setting:

$$\begin{cases} R_7 = R_8 \\ R_9 = R_{10} \end{cases}$$

We have the following transfer function:

$$V(I_{mes}) = \frac{R_9}{R_7} V_{shunt} \quad (6)$$

With: V_{shunt} the difference between the voltage on the non-inverting input (V_+) and the voltage on the input inverting (V_-) i.e.: $V_{shunt} = (V_+ - V_-)$

So:

$$V(I_{mes}) = \frac{R_9}{R_7}(V_+ - V_-) \quad (7)$$

E. *Frequency measurement*

The frequency measurement is done using the assembly in figure 5 below (zero crossing detector). This circuit uses the saturation of the op amp. It generates $+V_{cc}$ if V_+ (voltage on the non-inverting input) is greater than V_- (voltage on the inverting input), or $-V_{cc}$ (in our case $-V_{cc} = 0V$). Thus, we obtain a signal in slots or square which is the double frequency of the signal at the terminals of the AC load.

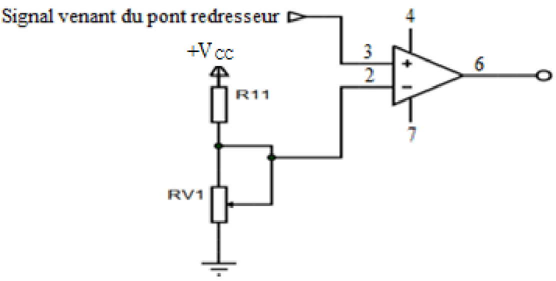

Fig. 5.*Zero Crossing Detector Circuit*

F. *Temperature measurement*

For temperature measurement we use LM35Z reference sensors which are linear sensors its essential characteristics are:

Measuring range/ -50° to 150°

Sensitivity/ 10 mV/°C

Accuracy/ ± 1°C

G. *Data acquisition circuit*

Data acquisition is provided by the HIGH RANGE category microcontroller of the American company Microchip reference 18F4550. It has a RISC architecture. Given that the device we implement must be compatible with a wide range of machines (computer), it has a USB interface. The exploitation of the datasheet of the microcontroller makes it possible to design the diagram in figure 6 below:

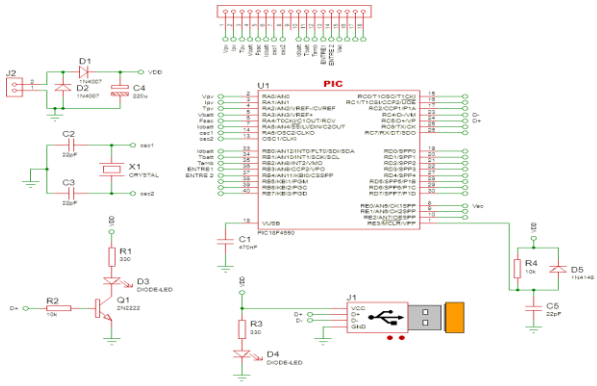

Fig. 6.*Data acquisition circuit*

III. EXPERIMENTAL DEVICE

Figure 7 below presents the didactic test and measurement bench **Electronic Work Bench TB-1200** that we have used to test, characterize and validate the proper functioning of the mini-power plant acquisition.

Fig. 7.*Electronic Work Bench TB-1200*

Figure 8 presents the experimental device made up of several elements, namely: a PV module (60Wp), a battery (12V/7 Ah), a variable resistor (100 Ω) and a load regulator (12V/10 A), the computer and the data acquisition device designed and produced.

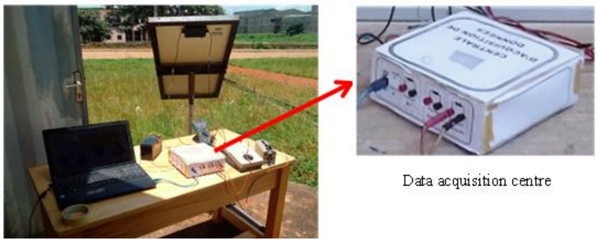

Fig. 8.*Experimental bench*

IV. RESULTS

A. *Calibration curves of the different sensors*

Before assembling the various sensors as presented on the general synoptic of figure1, all the sensors of the system have been checked, and calibrated for a maximum accuracy of the measurements taken. The diagrams below (Figures 9, 10, 11, 12, 13, 14 and 15) present the curves calibration of all sensors in the system. We note that these calibration curves are almost linear, which corresponds to their respective transfer functions (equations 1, 4 and 7). Thus, by performing linear regressions (black dotted line) on our different measurement points, we observe that the output voltage of these various sensors is proportional to the input quantities. This proportionality is marked by the leading coefficients of each of these curves. Thus, based on the correlation coefficients (R^2), we find that the various sensors are of high precision because R^2>0, 99.

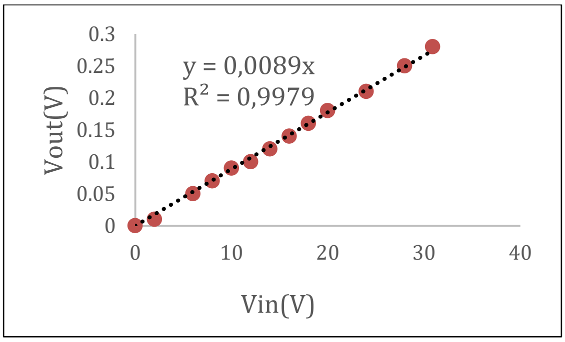

Fig. 9.*PV array voltage sensor calibration curve*

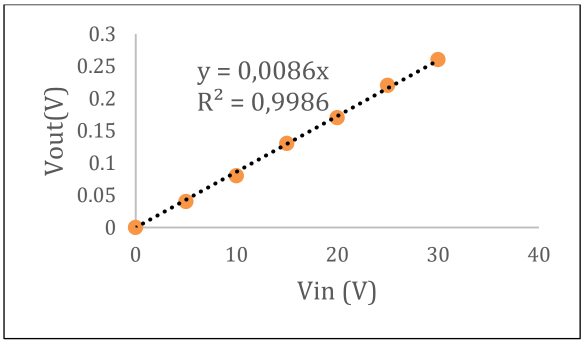

Fig. 10.*Battery voltage sensor calibration curve*

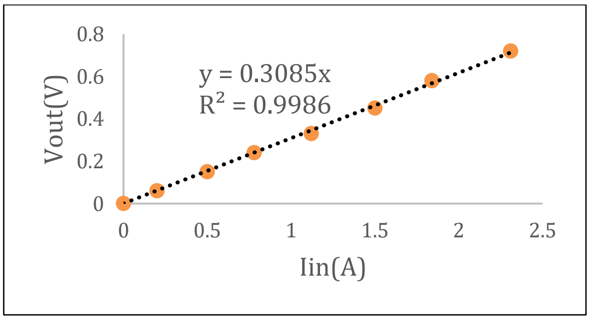

Fig. 11.*Calibration curve of the current sensor generated by PV panel*

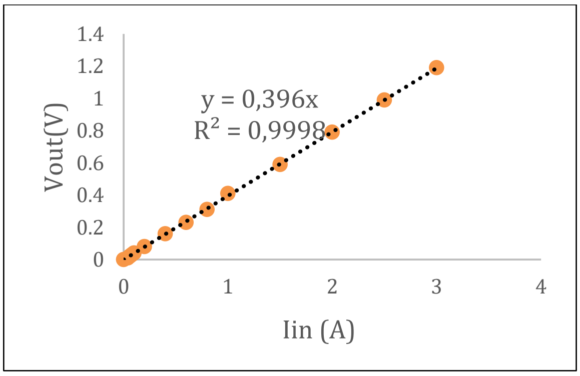

Fig. 12.*Calibration curve of the battery charging current sensor*

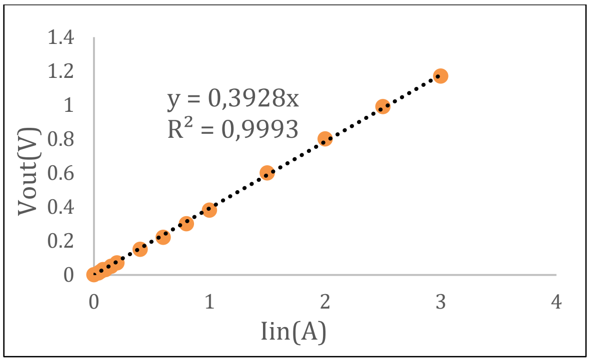

Fig. 13.*Calibration curve of the battery discharge current sensor*

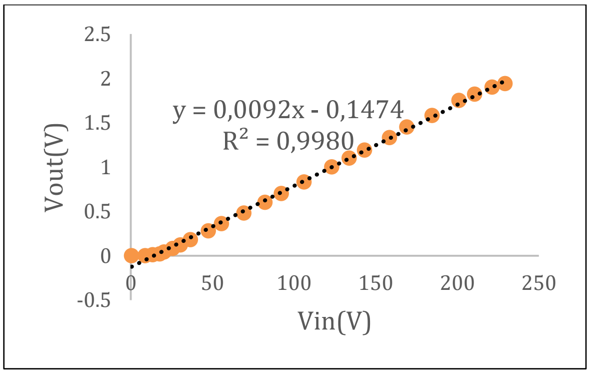

Fig. 14.*Inverter voltage sensor Calibration curve*

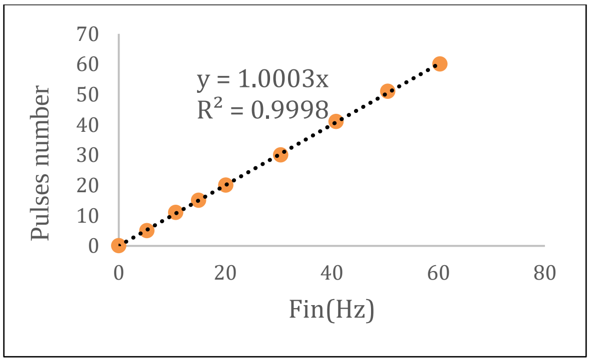

Fig. 15.*Calibration curve of the frequency sensor of the signal delivered by the inverter*

B. Test of the mini central data acquisition

1. Sensor accuracy test

The diagram in figure 16 below shows the operating flowchart of the data acquisition device. Codes written based on the architecture of this flowchart are loaded into the microcontroller. The default acquisition step is programmed at 10 ms due to the sampling frequency and the display refresh rate.

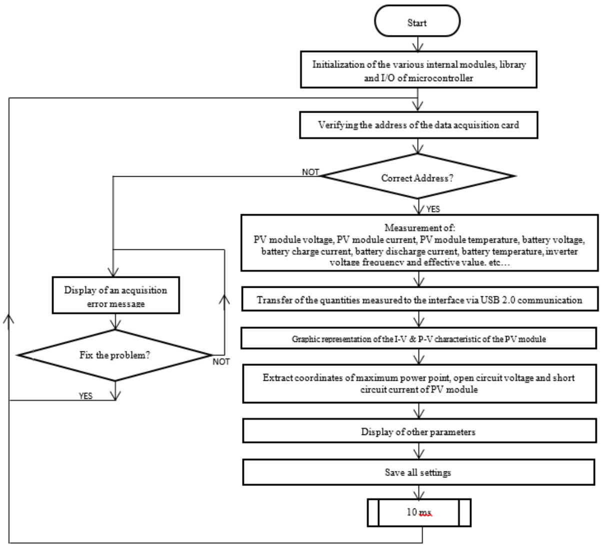

Fig. 16.*Operation flowchart of the mini-power plant*

After loading the codes into the microcontroller, tests are carried out in order to guarantee the functionality and reliability of the acquisition device. At first, it is a question of carrying out a series of tests on each sensor in order to be reassured of the good transcription of their different transfer functions during the development of the human-machine interface (HMI) under the Labview environment. The diagrams in figures 17, 18, 19, 20, 21 and 22 show the curves used to observe and to compare the behavior of the various sensors with respect to quantities taken for reference. The reference quantities are values fixed and displayed by the measurement devices of the Electronic Work Bench TB-1200.

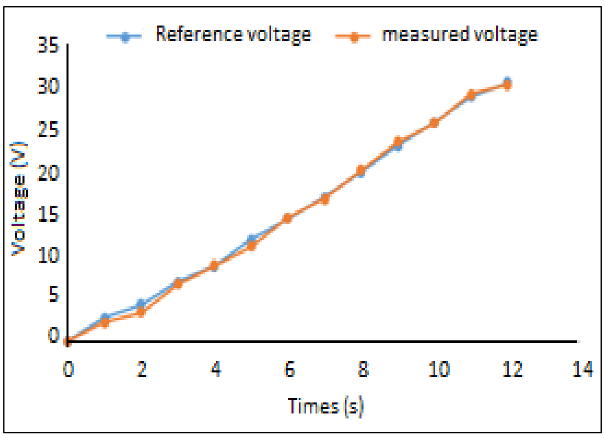

Fig. 17.*Response of the photovoltaic field voltage sensor*

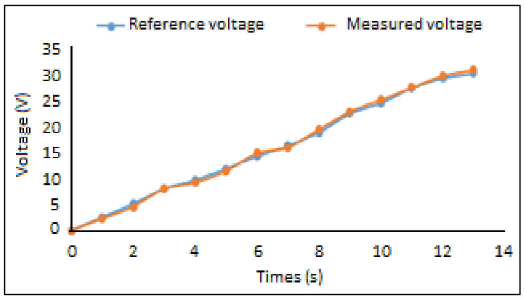

Fig. 18.*Battery voltage sensor response*

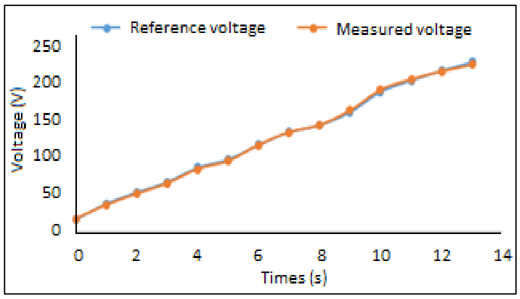

Fig. 19.*Inverter voltage sensor response*

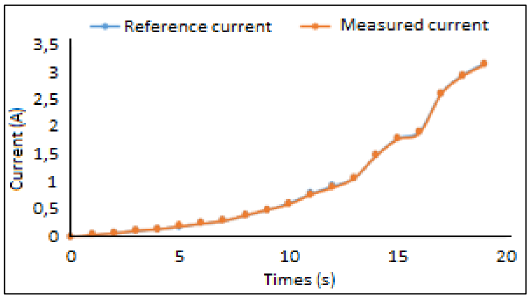

Fig. 20.*Response of the current sensor generated by the photovoltaic field*

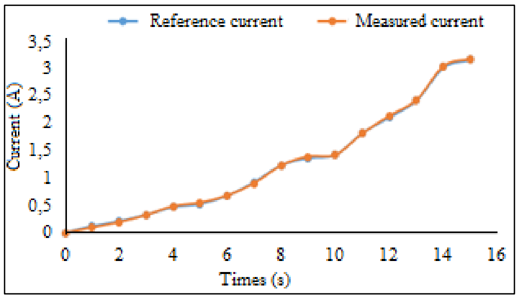

Fig. 21.*Battery charge current sensor response*

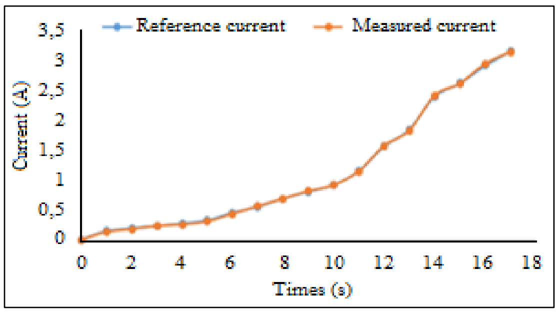

Fig. 22.*Battery discharge current sensor response*

We note that the curves of the reference quantities (curve in blue) and the curves of the measurements (curve in orange) made by the mini-data acquisition are almost super imposable, which highlights the fidelity and precision of the various sensors.

2. *Data acquisition interface*

The diagram in Figure 23 below shows the data acquisition interface of the device designed and built. It can be divided into four parts:

- A graphic and numerical display is reserved for the photovoltaic field parameters
- A digital display is specifically reserved for the operating parameters of the battery bank;
- A digital display is reserved for the voltage (effective value) and the frequency of the signal delivered by the DC/AC converter;

An input interface allows the user to set the desired acquisition step and assign the name to the measurement file.

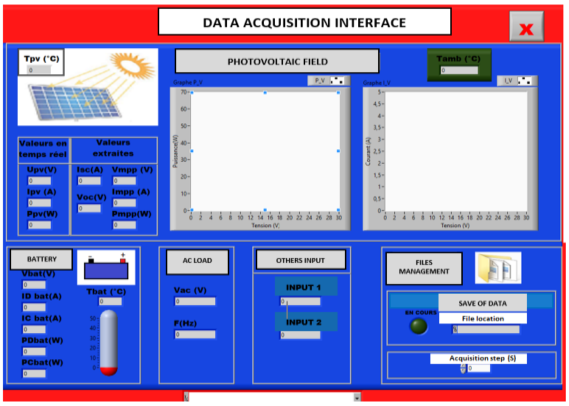

Fig. 23.*Data acquisition interface*

3. *Validation test of the data acquisition device*

For the validation of the data acquisition device, tests are carried out in connecting the latter to the photovoltaic field. To obtain the current voltage characteristic (I-V) and power-voltage (P-V), we used a variable resistor that we connected to the terminals of the PV module and gradually adjusted its value and the acquisition device records the data and plots the curves which are instantaneously displayed on the visualization interface as presented in figure 24

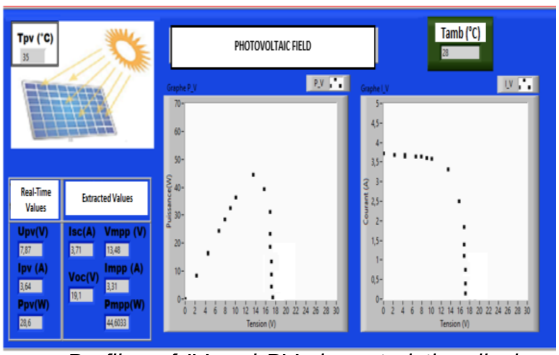

Fig. 24.*Profiles of IV and PV characteristics displayed by the interface*

V. CONCLUSION

The results presented in this research work are obtained from experimental tests and from simulations based on models developed in Matlab/Simulink. A methodical sequence of the stages of design and construction of a data acquisition centre suitable for isolated rural areas is presented. The implementation of a high-precision electronic device in communication with a graphical interface developed in LABVIEW makes it possible to collect, process, display and store the operational data. The data acquisition device is powered via the USB cable through which the data also passes. The architecture of the acquisition device proposed in this work has the advantage of flexibility, ease of use, and above all adaptability to photovoltaic installations in isolated areas.

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