

Performance Assessment of Rooftop Standalone PV System in Arid Region

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ABSTRACT

In this article, we present the investigation and outcomes for the deployment of a mini-photovoltaic power system of 800 Wp installed on the rooftop of a guard post at applied research in renewable energy (URAER) in the desert area of Ghardaia. The objective is to characterize and evaluate the behavior and dynamic performance of this kind of photovoltaic plant. The PV system is equipped with photovoltaic panels, a solar regulator (DC/DC), an inverter (DC/AC), and batteries for electrical storage. The solar regulator controls the charge and discharge of batteries. The monitoring system is based on an Agilent 34970a® data logger..

I. Introduction

A standalone photovoltaic (PV) system, also known as an off-grid solar system, is a setup that generates electricity from sunlight and operates independently of the utility grid. It typically consists of solar panels, a charge controller, a battery bank, an inverter, and other necessary components. The use of data loggers by professionals is growing rapidly; their friendly use and flexibility make them attractive. However, in order to calculate the performance of such a system, measurements and recording of different parameters, such as radiometric and meteorological data and electrical data, are essential. The Agilent 34970A® Data Logger seems to be a very powerful tool [1]. Photovoltaic energy is one of the most promising energy sources because it is sustainable and clean. Currently, much work is done on PV systems, which exploit this energy for different applications [2] and [3]. In autonomous PV applications, the control and optimization of the lifespan of the battery pass through an optimization of strategies management of charge and discharge by regulators [4]. The strategies that exist on the market are usually serial or shunt and only ensure a direct connection between the PV panels and batteries. They are characterized by control parameters of the charge and the end of discharge fixed by the manufacturer. A concrete application with electrical and radiometric measurements is described with a presentation of the results made by acquisition using the Excel support with a graphic representation example.

In this article, we present the performance assessment and outcomes for the deployment of a standalone mini-photovoltaic power system of 800 Wp installed on the rooftop of a guard post at applied research in renewable energy (URAER) in the desert area of Ghardaia.

The paper is divided as follows: Section 2 discusses the rooftop standalone PV system description. Section 3 provides a detailed the experiment setup. In section 4, the simulations results are discussed. Finally, the last section presents the conclusion.

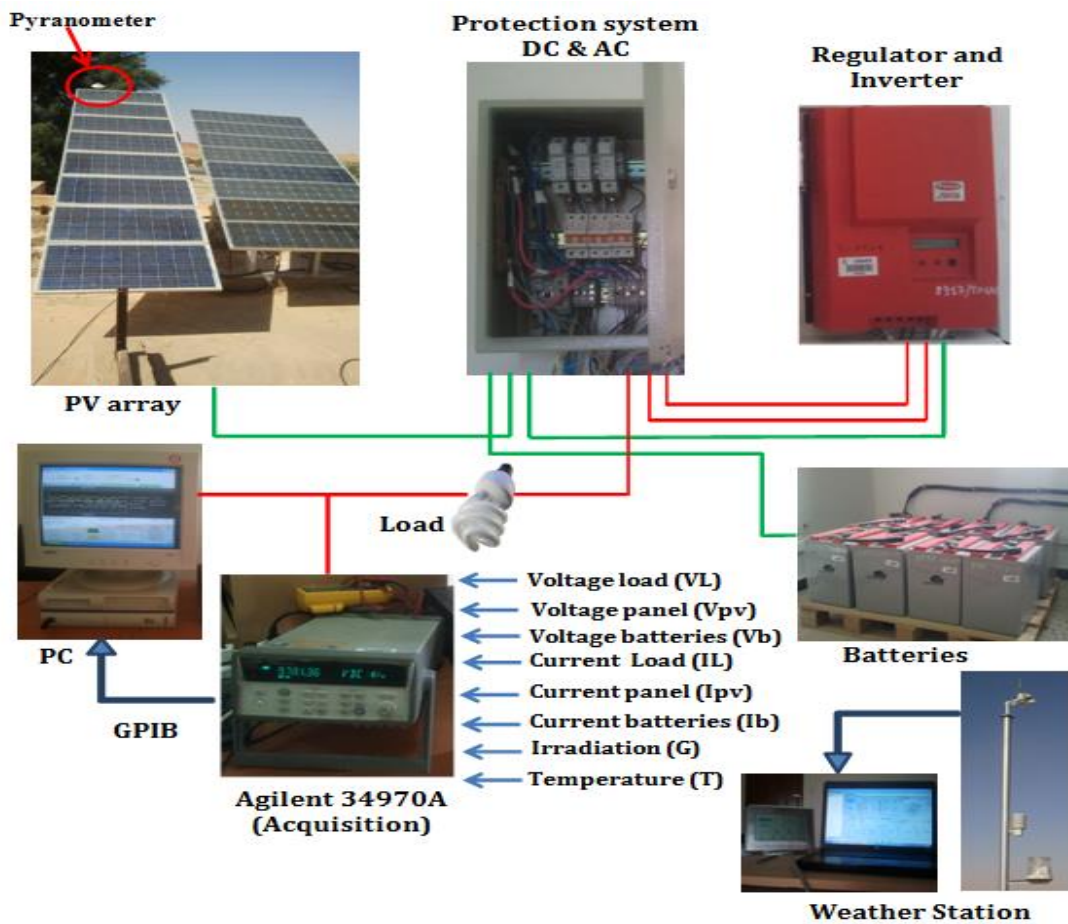
II. Rooftop standalone PV system description

The study focuses on a PV system located in the Ghardaïa region (Southern Algeria, $32^{\circ} 29' N$, $3^{\circ} 40' E$, 450m). The autonomous photovoltaic central consists of a generator with 16 photovoltaic modules. These modules are structured in two parallel, connected arrays. The first array consists of eight modules connected in parallel of the Tenesol TE 500 type with a peak power of 440 Wp and a nominal voltage of 24 V. The second array consists of eight modules structured into four parallel pairs of Tensol TE 500 type with a peak power of 400W and a nominal voltage of 24 V. The PV array is connected to a single-phase STECA inverter with 1 kWp [5].

The parameters measured are solar radiation measured at an inclined plane, ambient temperature, AC and DC current, and DC and AC voltages. These data are recorded thanks to the Agilent 34970A® data logger, which performs signal conditioning, amplification, and analog and contains a digital processor. All data is transferred and stored on the computer using the provided software named "Benchlink®." The different elements constituting our acquisition system are shown in Figure 1 and Table 1.



(a)



(b)

Figure 1. Rooftop stand-alone photovoltaic system.

Table 1. Meteorological electrical parameter measured

Measured parameters	Signal Type & Channel measurement	Sensors
Global Radiation on Inclined plane 32°, G (W/m^2)	DC Voltage (mV)/101	Pyranomètre CM 11 $S = 5\mu V/(Wm^{-2})$
Array Voltage V_{PV} (V)	DC Voltage (V)/102	regulator Steca
Load Voltage V_L (V)	AC Voltage (V)/103	Inverter Steca
Batteries Voltage V_{BAT} (V)	DC Voltage (V)/104	regulator Steca
Array Current I_{PV} (A)	DC Current (V)/105	Capteur a effet hall
Load Current I_L (A)	AC Current (V)/106	Capteur a effet hall
Batteries Current I_B (A)	DC Current (V)/107	Capteur a effet hall
Temperature T_{amb} (°C)	Mesure direct en °C	HeavyWeather ProWS 2800

II.1. Benchlink®data Logger Software

The software BenchLink® Data Logger, provided with the instrument, makes it possible to communicate with the data acquisition through a computer. This software gives, in a fast and flexible way, the possibility to configure channels and launch or end scanning; all these tasks are gathered on a spreadsheet. Thereafter, all measurements can be transferred and saved in a file for further treatment..

II.2. Monitoring Data Using Agilent Data Logger

It was necessary to make measurements of radiometric parameters and electrical quantities in order to evaluate the different yields of the installation. In our case, we have started measuring air temperatures as well as global radiation received on inclined surfaces. The different instruments were connected to the first seven channels of the standard module 34901A. The radiation was measured through channel 1 using a pyranometer, and the voltages V_{pv} , V_L , and V_b were measured through channels 2, 3, and 4, respectively. Finally, the currents I_{pv} , I_L , and I_b were measured through channels 5, 6, and 7, respectively. Below, in Figure 2, is given an example of set configuration, thanks to the BenchLink Data Logger software.

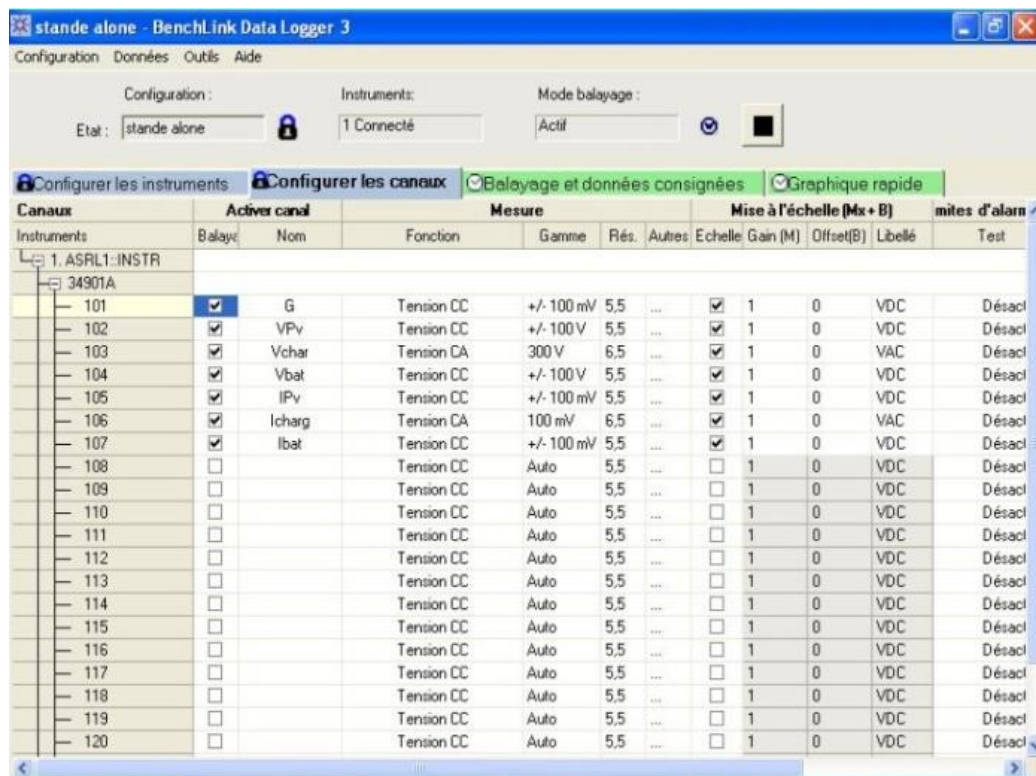


Figure 2. Example of configuration set

We can always view our measurements instantaneously using the option graphic setup. An example is given in Figure 3:



Figure 3. Example of measurement display

II.3. Exporting measured data

In order to be able to present the different measurements on spreadsheets or on graphical forms, it is necessary to transfer these data to a file in order to be treated lately, for example, exporting this data to an Excel file. Knowing that this software is familiar to many people, it has built-in statistical and charting capabilities that facilitate a variety of analyses. The software gives us the possibility to do so; we just need to click on export data, and then the data can be pasted when opening an Excel file [6–8].

N.B.: It is important to note that, when we used the RS-232 interface in order to export data, we always needed to stop the scanning, whereas with the GPIB interface we can transfer data without stopping the scan. This is still an important advantage for our recordings. An example of a measurement presented on a spreadsheet is given in Figure 4.

L29 fx =COMPLEXE.PRODUIT(D29;G29)

	B	C	D	E	F	G	H	I	J	K	L
1	Le temps	Vpv	Vch	Vbat	Ipv	Ich	Ibat	G eclai	Temperature	Ppv	Pch
2	00:00:04:724	23,951681	223,04953	24,618012	0,0025225	5,7499842	1,149491	42,5296	34.8	0,06041812	1282,5312733
3	00:02:04:724	23,950717	223,02729	24,616083	0,001181	4,1960614	1,1511545	42,4222	34.8	0,0282858	935,83620271
4	00:04:04:724	23,950931	222,99361	24,612977	0,0036495	3,5729816	1,14407	42,6798	34.9	0,08740892	796,75206544
5	00:06:04:724	23,94761	222,97072	24,610941	0,003274	4,2382884	1,145841	41,9284	34.9	0,07840448	945,01421611
6	00:08:04:724	23,944718	222,94694	24,608799	0,004079	5,0513044	1,1439625	42,6154	34.8	0,0976705	1126,1728589
7	00:10:04:724	23,945575	222,93175	24,605156	0,0045085	7,4955112	1,145358	42,959	34.8	0,10795862	1670,9874289
8	00:12:04:724	23,93829	222,91128	24,602585	-0,000644	4,2267952	1,148471	43,238	34.8	-0,0154163	942,20032832
9	00:14:04:724	23,936576	222,88046	24,600657	-0,0038645	7,2609296	1,159313	43,56	34.5	-0,0925029	1618,3193292
10	00:16:04:724	23,933362	222,86461	24,597443	-0,00161	5,3463796	1,1573805	43,7962	34.5	-0,0385327	1191,5188044
11	00:18:04:724	23,930577	222,82961	24,595836	-0,0012345	3,574757	1,1610305	44,7624	33.3	-0,0295423	796,56170815
12	00:20:04:724	23,932934	222,81376	24,593372	0,002147	5,004165	1,143426	44,8268	32.7	0,05138401	1114,9968193
13	00:22:04:724	23,924042	222,79175	24,590587	-0,003918	7,2212438	1,1655925	45,9646	32.7	-0,0937344	1608,8335433
14	00:24:04:724	23,924042	222,77612	24,587909	0,005582	7,3625588	1,147022	46,5656	32.2	0,133544	1640,2022827
15	00:26:04:724	23,920829	222,74905	24,584374	-0,0023615	7,0308424	1,1461095	46,2866	32.2	-0,056489	1566,1134652
16	00:28:04:724	23,921471	222,72967	24,583088	-0,0041865	7,4205566	1,163553	46,1364	31.9	-0,1001472	1652,7781227
17	00:30:04:724	23,917401	222,70898	24,580624	-0,001181	5,6330636	1,1469145	46,7804	31.9	-0,0282465	1254,5338486
18	00:32:04:724	23,913758	222,68345	24,577089	0,003918	4,0205736	1,155073	46,7374	31.6	0,0936941	895,31520022
19	00:34:04:724	23,871979	222,66253	24,574947	0,0037035	5,766109	1,1454655	46,1792	31.6	0,08840987	1283,8964181
20	00:36:04:724	23,907438	222,64316	24,572911	-0,00585	7,0320862	1,1651095	46,394	31.4	-0,1398585	1565,6458929
21	00:38:04:724	23,91333	222,62049	24,570019	0,004079	7,1418378	1,1441775	46,4798	31.4	0,09754247	1589,9194305
22	00:40:24:724	23,899725	222,57338	24,567019	0,001127	3,9206298	1,154858	45,9002	31.2	0,02693499	872,62782631
23	00:42:24:724	23,902724	222,55929	24,564877	0,003274	4,76768	1,152067	46,2652	30.9	0,07825752	1061,0914757

Figure 4. Exported data in Excel format

At this moment, we can start the constitution of our database; afterwards, we can perform different treatments as well as use them as input data in simulation programs..

III. Experimental setup

Fig. 5 represents the electric measuring stand-alone PV system achieved during this work. This system is composed of:

- PV array of the type TE500.
- Inverter DC/AC with a regulator (type: Steca)
- Two solar batteries in series (24V). Each one has 110 AH as a capacity.
- Acquisition interface using a BenchLink Data Logger.

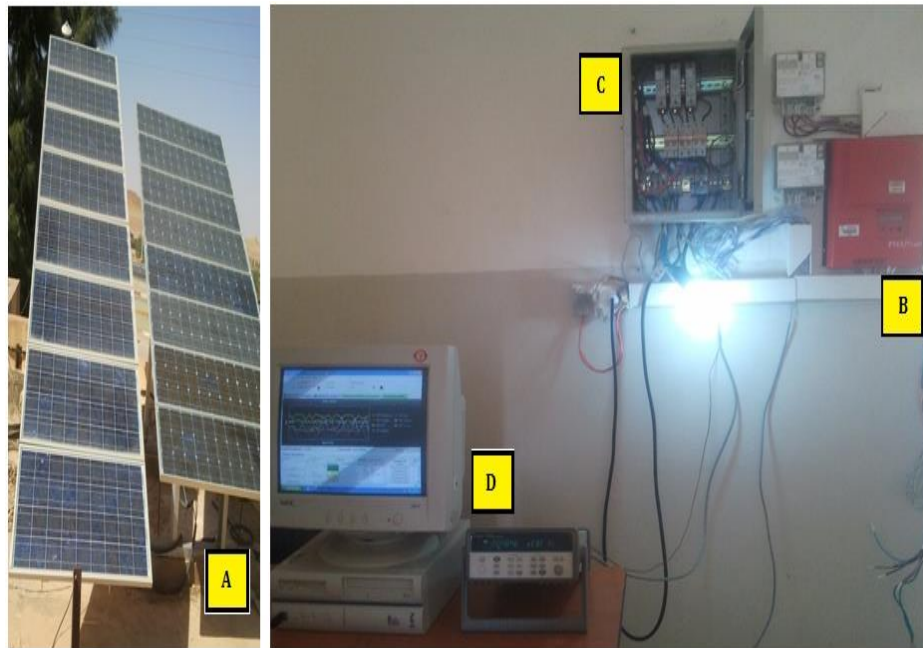


Figure 5. Experimental procedure; (A) Panels TE500, (B) Inverter, (C) Protection system, (D) Acquisition interface

IV. Results and discussion

In the graphs below, the measurement results and simulation are presented in real time, with a sampling $\Delta t = 5$ mn. In order to validate the set of blocks of the regulator designed in this work, we have tested the prototype during one day when irradiance undergoes rapid changes during charging solar batteries. In Figures, we represent the typical statements of results for radiometric quantities: irradiance and temperature (G , T), and electrical quantities (V_{pv} , I_{pv} , I_{bat} , V_{ch} , and I_{ch}). Battery operations are divided into two steps:

When the time varies from 19h to 05h, the voltage $V_{bat} = 25V$ and the current I_{bat} is substantially constant (1.15A), we are in the state of discharge.

When the time varies from 06h to 18h and the voltage $V_{bat} = 28.5V$, we are in the charging state (battery charge from the PV generator).

When the time varies from 06h to 18h, the illumination increases, so it causes an increase in the output power of the PV. We deduced that the illumination is proportional to the power and the generator current.

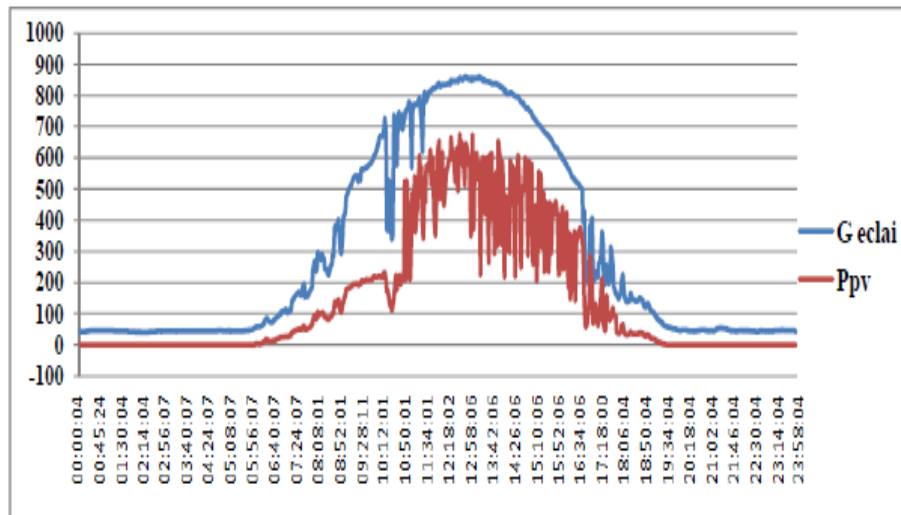


Figure 9. irradiation (blue color) and PV array power(brown color)

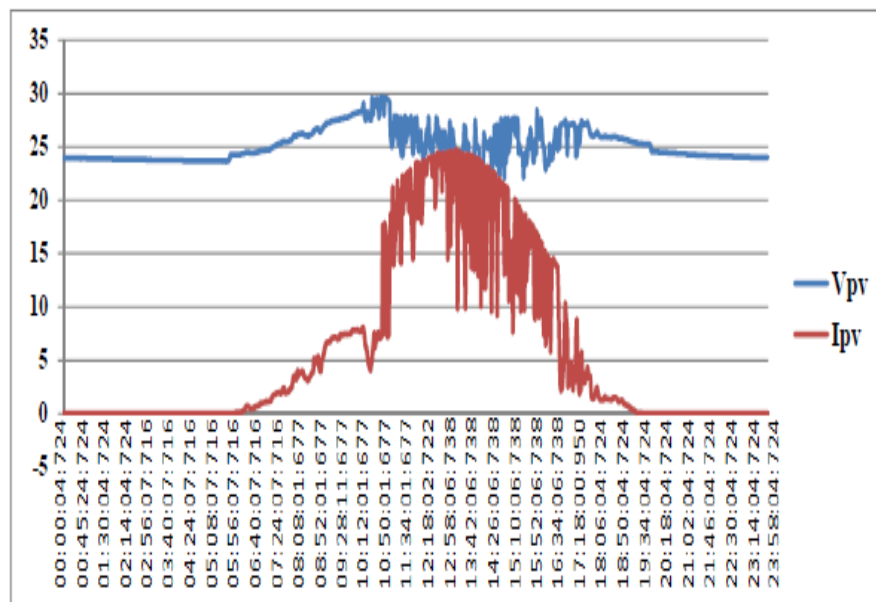


Figure 6. Current and voltage og the PV array

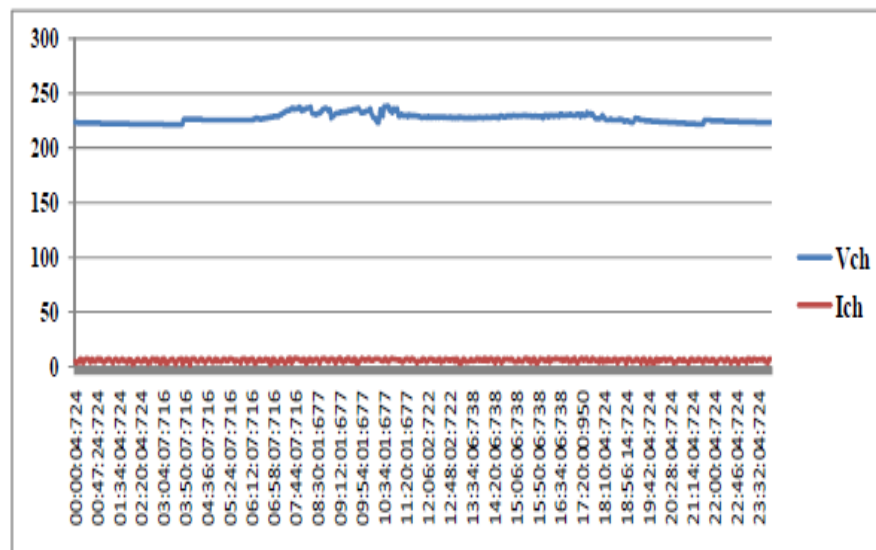


Figure 7. current and voltage og the load

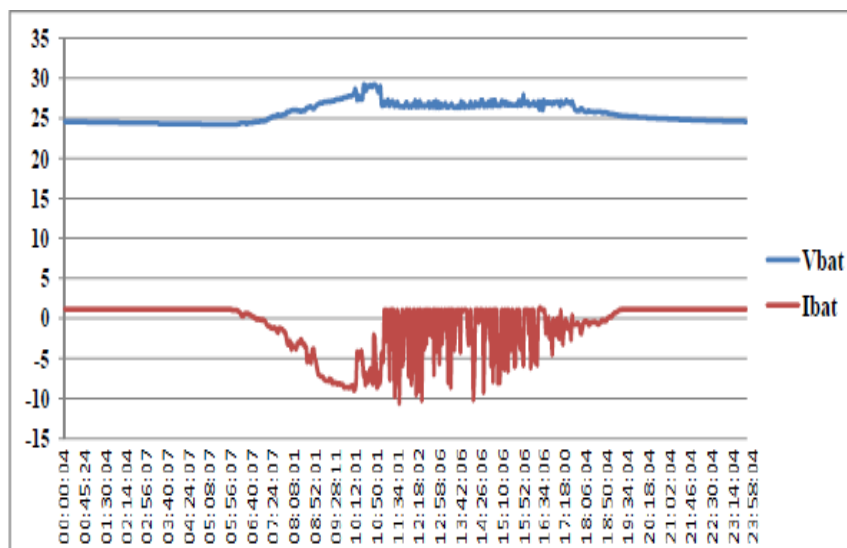


Figure 8. Current and voltage of the battries

V. Conclusion

In this article, we have presented the results related to the design, realization, and experimentation of an autonomous PV system equipped with a solar regulator in arid region. The solar regulator controls the state of charge of batteries. The results show that the MPPT regulator ensures and controls the state of charge of the batteries. The PV system was designed to work under optimal conditions during the day of the experiment. During charging phases, the PV panels work in optimum conditions, regardless of weather variations.

Acknowledgements

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