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# Implementation of a Solar Pumping Test Bench Controlled by Speed Variator

Elmostafa Aitiaz [1] , Khalid Assalaou[1] and Lahoussine Elmahni[1]
[1]*LMERFaculty of Science, Ibn Zohr University, Morocco mos.aitiaz@gmail.com*

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***Abstract***

In this paper a solar pumping test bench controlled by a speed variatorwas presented. The studied bench consists of a photovoltaic generator, a DC-DC controller, a storage battery, a DC-AC converter, a speed variator, an asynchronous motor and a powder brake replacing the centrifugal pump. The test bench was described block by block while presenting the characteristics given by the manufacturer. The performance and characteristics of the used photovoltaic panels have been practically determined and compared with those given by the manufacturer. Finally, measures were taken for different drive speeds of the asynchronous motor in order to see the advantages of variable speed solar pumping compared to fixed speed pumping.The studied bench can serve as a didactic platform for testing and measuring a photovoltaic pumping system driven at variable speed.

***Keywords:*** *Photovoltaicsystem, solar panel, solar water pump, pumping test bench, pumping by speed variator.*

## INTRODUCTION

The integration of renewable energy sources has recently been increased thanks to the rapid evolution of power electronics [1]. The exploitation of these sources of energy offers a security of supply to the consumer and represents an unlimited source of energy. Solar energy is considered one of the best renewable energy solutions especially when it comes to ensuring electricity coverage in remote locations (usually mountain areas or isolated rural areas).

The photovoltaic solar pumping system is one of the common applications of photovoltaic energy[2]. It is used to ensure the supply of drinking water for the populations or for the irrigation fields of cultures or the agricultural farms. A photovoltaic solar pumping system is mainly composed of three parts[3]:

- 
- The photovoltaic generator (PVG) with or without storage battery.
- The DC / DC converter and / or DC / AC.
- The hydraulic part (coupling of a DC or AC induction motor and a centrifugal pump) [2].

In this article, we will present a bench test and measurement of a photovoltaic pumping system with energy storage system and adrive system by an induction motor controlled by a speed variator. This article consists of three parts.

In the first part, we have given a synoptic diagram of the structure of the test bench. We have also described the main components of the bench, starting from the photovoltaic generator (PVG) to the induction motor.

In the second part, we explained the principle of operation of the different blocks of the system. We have also detailed the technical characteristics of the test bench using the data provided by the manufacturer.

The third part will be devoted to the presentation of two examples of test and measurement carried out on the bench. The first example concerns the characterization of the

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photovoltaic generator and the second deals with the measurement of the energy balance for frequencies of the speed variator ranging from 0 to 50Hz.

## DESCRIPTION OF THE SYSTEM

### Synoptic diagram

The synoptic diagram of the test bench studied is shown in Fig. 1. It includes among others [4]:

- A photovoltaic generator (PVG) that converts solar energy into continuous electrical energy.
- A DC / DC controller placed on the DC bus which acts as a battery charge controller and adapts the energy from the PV generator to the rest of the system.
- A DC / AC converter that converts continuous electrical energy into alternative energy.
- An AC / AC converter representing the speed variator, this block makes it possible to vary the amplitude and the frequency of the sinusoidal electrical quantity supplying the asynchronous motor.
- An asynchronous induction motor that drives the centrifugal pump.
- A powder brake that replaces the centrifugal pump.

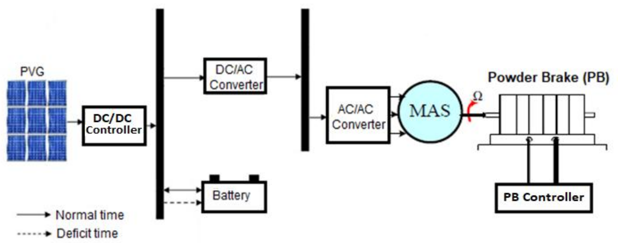


**Fig. 1.**Solar pumping system controlled by speed variator**.**

### Solar pumping test bench

The constituents of the test bench produced are given in images of Fig. 2, 3 and 4:

- The photovoltaic generator (PVG) is made by paralleling two photovoltaic panels of the brand ISOFOTON IS 75-12, with a peak power of 75 Wp each.
- The DC / DC controller representing the charge controller is chosen from the Vectron energy brand reference blue SCC010010010.
- For the storage battery we used a 12V NOWERGEL battery with a capacity of 80 Ah.
- The converter (DC / AC) is taken from the CRISTEC brand, SOLO range -12V-200VA.
- For the speed variatorwe used the reference ATV312H037M2of Schneider brand.
- The asynchronous motor and the powder brake are of the LEROY SOMER brand used for didactic manipulations.

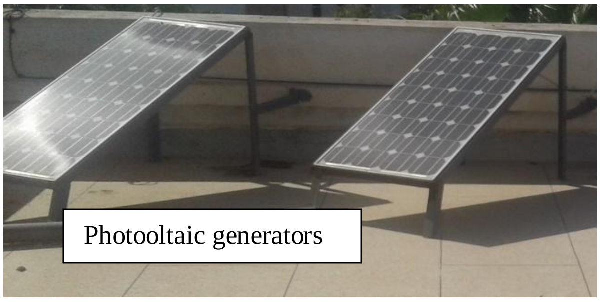


**Fig.2.**Photovoltaic generators

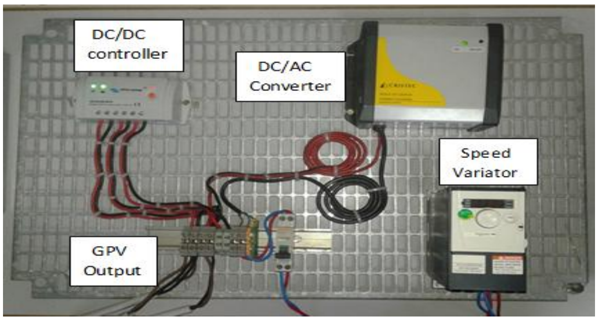


**Fig.3.**DC/DC controller, DC/AC converter andspeed variator

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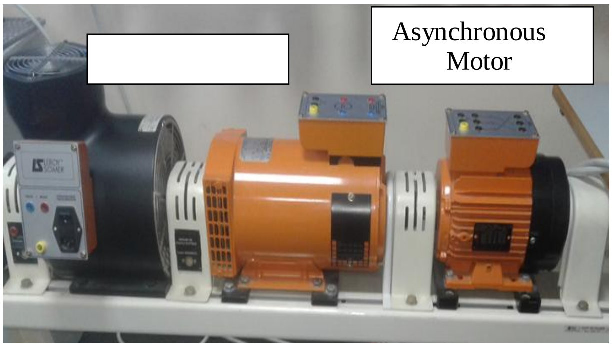

**Fig. 4**. Asynchronous motor and Powder brake

## Photovoltaic Generator (PVG)

### Photovoltaic cell.

A photovoltaic cell is a sensor made of a semiconductor material that converts the absorbed light energy into electrical current. The operating principle is based on the absorption properties of light radiation by semiconductor materials.[5]

Constitution of a photovoltaic generator (PVG)

Under standard sunlight conditions (1000W / m², 25 ° C, AM1.5), the maximum power delivered by a 150 cm² silicon cell is approximately 2.3 W at a voltage of 0.5V. This low power is insufficient for most domestic or industrial applications. The photovoltaic generator thus consists of a series / parallel network of numerous photovoltaic modules, grouped into photovoltaic panels made up of identical modules. When the cells are assembled in series, the voltages add up; while if they are connected in parallel, the currents add up. These cells must have the same characteristics.

The used photovoltaic generators are of the brand ISOFOTON IS 75-12. The module consists of 36 multi-crystalline silicon solar cells in series and provides 75Wc of maximum rated power. The table 1 shows the electrical characteristics from the manufacturer's data sheet.

| ElectricalCharacteristics | |
|---|---|
| STC Power Rating $P_{mp}$ (W) | 75 |
| Open Circuit Voltage $V_{oc}$ (V) | 21.6 |
| Short Circuit Current $I_{sc}$ (A) | 4.67 |
| Voltage at Maximim Power $V_{mp}$ (V) | 17.3 |
| Current at Maximim Power $I_{mp}$ (A) | 4.34 |
| Panel Efficiency | 11.2% |
| Fill Factor | 74.4% |
| Power Tolerance | -10.00% ~ 10.00% |
| Maximum System Voltage $V_{max}$ (V) | 760 |

**Tab.1.** Electrical characteristics of photovoltaic module IS-75/12.

### Battery

In photovoltaic systems, lead acid battery storage is the most widely used technology, because for its low cost and availability at all times. The most commonly used equivalent electric models are the R-C model called "CIEMAT" model.

In our system we used a *Gel battery*. A Gel battery is a lead-acid battery with valve regulation and free maintenance. Gel batteries are extremely robust and versatile. This type of battery emits few vapors and can be used in places without much ventilation.

### DC / DC controller

The DC / DC controller also known as the charge controller is the central element of a photovoltaic system. It controls the transfer of energy between the PV generator, the battery and the load while optimizing the life of the battery. A charge controller controls the battery current to

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limit its charge and discharge. In the test bench we used a load controller of the brand Vectron energy type PWM (pulse width modulation). The PWM controller consists of an electronic switch that opens and closes at a certain frequency, which allows the charging current to be regulated according to the state of charge precisely. When the battery voltage is below the limiting voltage of the regulator, the switch is closed. The battery then charges with the current delivered by the photovoltaic generator. When the battery voltage reaches a predetermined regulation threshold, the switch opens and closes at a fixed frequency to maintain a mean current injected into the battery [6]. The technological specifications are given in Table 2.

| BlueSolar PWM-Light | 12/24-5 | 12/24-10 | 12/24-20 | 12/24-30 |
|---|---|---|---|---|
| Battery Voltage | 12/24V with automatic system voltage detection* | | | |
| Rated charge current | 5 A | 10 A | 20 A | 30 A |
| Recommended solar array | 36 cell for 12 V / 72 cell for 24 V | | | |
| Automatic low voltage load disconnect | Yes | | | |
| Maximum solar voltage | 28 V for a 12 V system and 55 V for a 24 V system (1) | | | |
| Self-consumption | < 10 mA | | | |
| Overload protection | Shut down after 60 s in case of 130% load | | | |
| | Shut down after 5 s in case of 160% load | | | |
| | Short circuit: immediate shut down | | | |
| Grounding | Common positive | | | |
| Operating temp. range | -20 to +50°C (full load) | | | |
| Humidity (non condensing) | Max 95 % | | | |

**Tab. 2**. Technological specifications of the DC/DC controller.

Speed variator

A Speed variator is an electronic device used to vary the speed of an engine, a necessity for many industrial processes. In solar pumping applications, the Speed variatoroccupies an important place because the solar pump does not have a constant flow rate. It is characterized by a variable flow throughout the day: when the sun rises, the pump produces a low flow and as the sun increases, the flow of the pump also increases. The pump's flow rate is regulated by the variation of the frequency of the drive and therefore the speed of rotation of the motor. A servo system must be provided to adjust the flow of the pump according to the available energy on the PVG and the battery[7]. In our system we chose the Schneider ATV312H037M2 drive. This drive is intended for the realization of autonomous water pumping systems, in rural areas of developing countries devoid of electrical energy, but also provides a solution for isolated pump installations in agriculture, in some mountain areas and on offshore platforms.

## TESTS AND MEASUREMENTS

The tests and the measurements were carried out on the solar pumping bench in order to validate the performances of the various blocks constituting the bench. Firstly, the characteristics of the photovoltaic panels are determined experimentally and then compared with the manufacturer's data. Secondly, a power budget at different frequencies has been developed with emphasis on the transfer energy from the photovoltaic generator to the centrifugal pump. The two manipulations presented in this section are only non-exhaustive examples of the tests and measurements that could be carried out on the solar pumping bench.

Characterization of Photovoltaic Panels:

Description of the measurement setup:

The experimental setup is presented in Fig. 5. The measurements of the current-voltage characteristics are firstly determined for each of the two panels, and then measured for the photovoltaic generator constituted by the paralleling of the two panels.

The experimental setup of Fig. 5 is carried out by placing a voltmeter in parallel with the photovoltaic panels and an amperemeter in series. A 330 Ω rheostat placed in series is used to adjust the measured values. For different values of the rheostat, the current and the voltage at the output of each panel are measured. The results of the

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measurements are given in the form of graphs represented in Fig. 6and7.

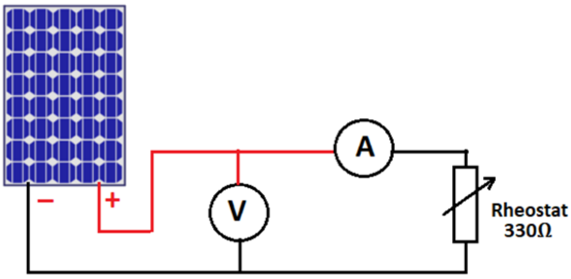


**Fig.5.**Experimental setup for measuring the characteristics of photovoltaic panels

Analysis and discussion:

Thecurrent-voltage characteristics of the two photovoltaic panels are similar to the standard characteristics and the measured values are within the limits given by the manufacturer (Tab1). Note also that the two panels have virtually the same voltage unladen panel against 1 gives a higher short circuit current (3.3A against 2.66A). At the power level, the panel 1 can provide a higher maximum power (42.6W against 37.75W). It can be seen that the two panels are of the same reference (ISOFOTON IS 75-12) but their performances are different. This may be due to several factors: performance degradation due to non-compliance with the instructions for use, location of the two panels (shading problem), changing climatic conditions during measurements ... etc. Concerning the characteristics of the photovoltaic generator constituted by the parallel positioning of the two panels. It can be seen that the short-circuit current is practically equal to the sum of that of the panels 1 and 2 and the maximum power of the photovoltaic generator is slightly less than the sum of the powers of the two photovoltaic panels ($P_{PVGmax}$ = 73.63W and $P_{PV1max}$ + $P_{PV2max}$ = 42.6 + 37.75 = 80,35W).

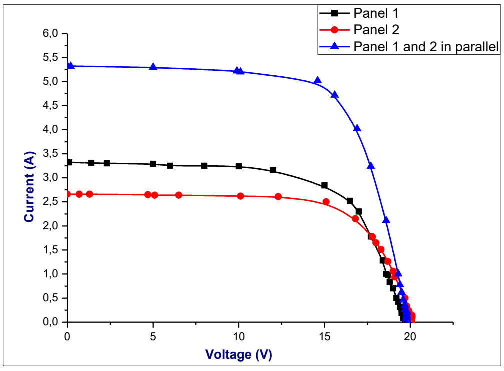


**Fig.6**Current-voltage characteristic of thephotovoltaic panels

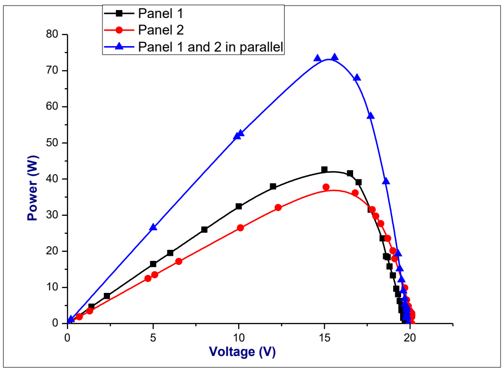


**Fig.7.** Power-voltage characteristic of thephotovoltaic panels

Energy balance of photovoltaic pumping test bench:

Description of the measurement setup:

The experimental setup is given in fig.8. In the present manipulation, we measured, for frequencies of the variator speed from 0 to 50Hz, the current and the voltage at the output of the photovoltaic generator and the exit of the battery. The values of the powers at the output of each block were determined in order to evaluate the power budget. The results of the measurements are given in Fig.9 to 11.

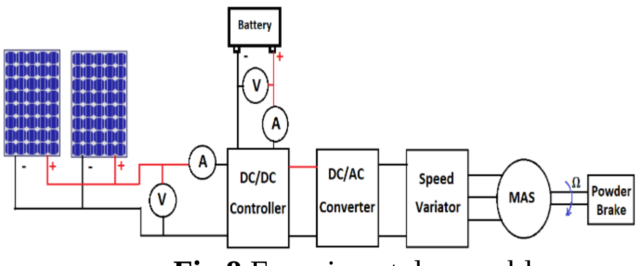


**Fig.8.**Experimental assembly

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Analysis and discussion:

By analyzing the characteristics given in the Fig.9 to 12, it can be seen that the current at the output of the photovoltaic generator increases with the increase of the frequency to a limit value where it becomes practically constant. The current at the output of the battery begins to increase substantially from 20Hz. The voltages at the output of the photovoltaic generator and the battery have decreasing speeds with the frequency. The power provided by the PVG increases until it reaches a maximum (at the frequency 20 Hz) then undergoes a slight decrease. The power at the output of the battery starts to grow linearly from 20Hz. The total power provided by the set (PVG and the battery) increases linearly with the increase of the frequency. It can be noticed that the power absorbed by the asynchronous motor, driving the centrifugal pump, increases linearly with the frequency.

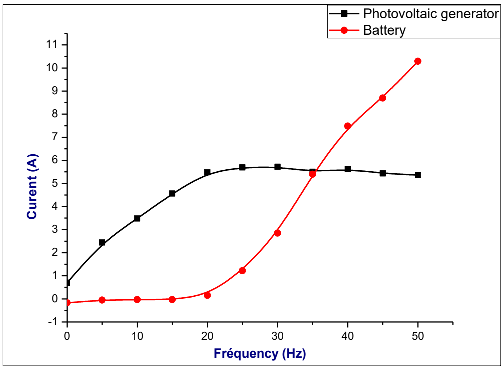


**Fig.9.**Current-Frequency characteristicof thephotovoltaic generator and the battery

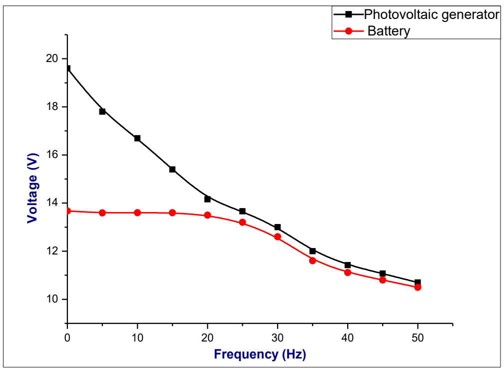


**Fig.10.**Voltage-Frequency characteristicof thephotovoltaic generator and the battery.

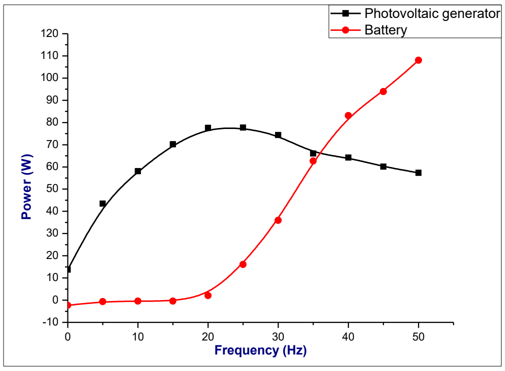


**Fig.11.**Power-Frequencycharacteristic of the photovoltaic generator and the battery.

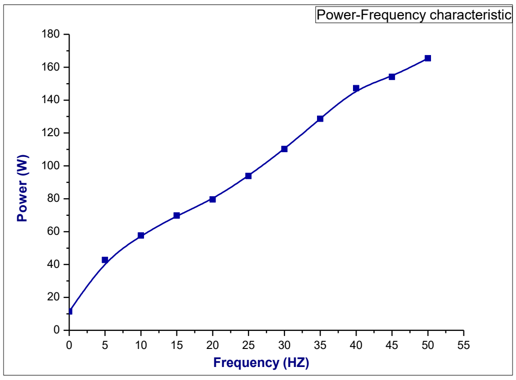


**Fig.12.**Characteristic of the sum power ($P_{PVG}$ + $P_{Bat}$) as a function of the frequency.

## CONCLUSION

In this paper we have presented a structure of a solar pumpingtest bench controlled by a speed variator. Firstly, we have given a brief overview of the state of art of photovoltaic energy and photovoltaic pumping systems. Secondly, and with the help of manuals and manufacturer documents, we have presented the characteristics andperformances of the various blocks constituting the test bench (Photovoltaic Generator, The battery, the DC / DC controller, the DC / AC converter and the asynchronous motor with its powder brake). In the experiment, we have treated two manipulations:the first concerned the characterization of the two photovoltaic panels then that of the photovoltaic

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generator constituted by the paralleling of the two panels. From the results of the manipulation we have concluded that the two panels have slightly different performances despite the fact that they are the same model. The paralleling of the two panels allowed us to double the available photovoltaic power. In the second manipulation we have measured the current and voltage quantities at the output of the photovoltaic generator and the battery for frequency ranging from 0 to 50 Hz. According to the results of the measurements we have found that the currents increase with the frequency against the voltage decrease. In terms of the power budget, it has been concluded that the power supplied by the PVG assembly and the battery increases linearly with the frequency of rotation of the motor and therefore with the flow rate of the centrifugal pump. It is then necessary to realize a servo system that will control the flow rate of the pump according to the power available at the photovoltaic generator and the battery, hence a new research perspective.

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