Study of the efficiency of a hybrid pumping system (photovoltaic/ electric) for better rural setting management

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Abstract. The Maghreb countries, particularly Algeria have a high solar potential. The German Space Agency (DLR), showed exceptional sunshine levels, of 1200 kWh/ m2/ year in Northern Great Sahara. According to satellite evaluation, the German Space Agency (ASA) concluded that Algeria represents the most important solar potential of Mediterranean basin, i.e.: 169.000 TWh/year for thermal solar, 13.9 TWh/year for solar photovoltaic. Currently, this renewable energy represents a response to the environmental problems and also a sustainable solution to the current energy crisis. In Algeria, electricity consumption in agricultural sector represents a significant part of national consumption. Farms in the Saharan regions use the diesel group to satisfy the electrical energy needs in case of electricity lack (due to failures or farms isolation). In this context, a study was carried out at the laboratory of renewable energy of the University of Biskra, in which the main aim is to determine the hybrid pumping system efficiency, a system powered with the electrical energy and another with photovoltaic energy. The data obtained showed that the two systems have similar efficiency. This confirms that photovoltaic resource use for irrigation is the best economic compromise for sustainable agricultural development in isolated arid regions.

Keywords. Rural environment - Efficiency - Pumping - Hybrid system – Photovoltaic systems.

Etude de l'efficacité d'un système de pompage hybride (photovoltaïque / électrique) pour une meilleur gestion du milieu rurale

Résumé. *Les pays du Maghreb et en particulier l'Algérie ont un potentiel solaire élevé. L'Agence Spatiale Allemande (DLR), a enregistré des niveaux d'ensoleillement exceptionnels de l'ordre de 1200 kWh/m²/an dans le Nord du Grand Sahara. Suite à une évaluation par satellites, l'Agence Spatiale Allemande (ASA) a conclu, que l'Algérie représente le potentiel solaire le plus important de tout le bassin méditerranéen, soit :169.000 TWh/an pour le solaire thermique,13,9 TWh/an pour le solaire photovoltaïque. Cette dernière présente à l'heure actuelle une réponse aux problèmes environnementaux et une solution durable à la crise actuelle de l'énergie. En Algérie, la consommation de l'énergie électrique dans le secteur agricole représente une part non négligeable par rapport à la consommation nationale. Les fermes agricoles dans les régions sahariennes utilisent le groupe diesel pour satisfaire les besoins en énergie électrique en cas d'absence de réseau (dû à des pannes ou à l'isolement). Dans ce contexte, une étude a été réalisée au niveau du laboratoire d'énergie renouvelable de l'université de Biskra dont le but est de déterminer l'efficacité d'un système de pompage hybride, il s'agit d'un système sous-alimentation électrique et d'un autre sous-alimentation photovoltaïque. Les résultats obtenus ont montré que l'efficacité des deux systèmes est similaire. Cela prouve que l'utilisation d'une source photovoltaïque pour l'irrigation est le meilleur compromis économique pour un développement agricole durable dans les régions arides isolées.*

Mots-clés. *Milieu rurale - Efficacité - Pompage - Système hybride - Système photovoltaïque.*

I - Introduction

Faced with fossil resources dwindling, climate change, greenhouse gas emissions and sustainable development principles, all countries whether developed or developing, are seeking of alternatives to these malfunctions (Joubert-Garnaud, 2010). Total area of Algeria is 2,381,740 km², with significant natural potential (fertile land, water richness, and non-renewable fossil groundwater) weakly exploited; it constitutes one of the highest solar deposits in the world (Djafouret and Aida, 2009; Maafi, 2000).The insolation duration on almost the entire national territory exceeds 2000 hours annually and can reach 3900 hours (High Plateaus and Sahara). The energy received daily on a horizontal surface of 1m2 is 5 KWh over most of the national territory, i.e. nearly 1700KWh/ m2/ year in the North and 2263 kWh / m2 / year in the South of Algeria (Bouzidi, 2010).

The significant solar energy availability (Himri, 2009) and the geographical location of Algeria may make water pumping application through photovoltaic solar pumps as a solution for agricultural surfaces irrigation and water drinking supply in isolated sites (Bouzidi, 1999).

The role of a hybrid system is to generate uninterrupted power in isolated regions; it is not only to bring energy power, but also a social and economic development tool of rural areas (Kebour *et al.*, 2017). The kilowatt-hours number produced may seem insignificant compared to the national energy production capacity, but these few tens or hundreds of kWh can revive a village or a community hopes (Saheb-Koussa and Belhamel, 2007).

Solar energies are promising for water pumping and crops irrigation in the agricultural regions of southern Algeria, such as OuedSouf, Biskra, Adrar municipalities where agriculture is experiencing renewed interest. In these environments where a lack of electric power is pointed (Bouzidi, 1999), a lot of water drilling is required, and significant sunshine and winds are available all year round (Kendouci *et al.*, 2013, Bentouba and Bourouis, 2016). Indeed, Biskra municipality has all these criteria to launch a of renewable energy programs.

The purpose of this study is to determine the efficiency of a hybrid pumping system, a system under electric power and another under photovoltaic power. The study was carried out at the Laboratory of Renewable Energy, Department of Electronics- University of Biskra located in the south-east of Algeria (34 ° 50'46.27''N-5 ° 44'49.69''E).

II - Materials and methods

The equipment employed for tests is the HM 310 test bench (Figure 1), it was used to study the pumping system behavior. Several measurement tests can be performed such as: Flow Measurements, Pressure Measurements, Temperature Measurements, Rotation Speed Measurements, Yield Calculations (Camara, 2011).

Figure 1. Test bench HM 310 (Mebrek, 2016)

1. Photovoltaic module

The module nominal voltage is usually adapted to 22-volt load and the modules will therefore generally have 36 cells. The modules can be connected in series (Figure 2a) and in parallel

(Figure 2b) to increase the voltage and intensity of use. However, take certain precautions are important due to the existence of less efficient cells or to some cells occlusion (due to dust) can permanently damage the cells (Madani, 2006). PV modules used in this study are illustrated in Table1.

a. in series b. in parallel

Figure 2. Schema of four modules (Mebrek, 2016).

Table 1. Characteristics of the PV module

I_{max}	5.07 A
V_{max}	17.52 V
V_{oc}	22.2 V
I_{cc}	5.61 A
E	1000 W/m²
T	25°C

2. DC-AC converter

The design of whole photovoltaic system is done in order to extract maximum power from photovoltaic generator, whatever the illumination and temperature disturbance, supplying the devices with AC voltage from solar panels requires an inverter use providing DC / AC conversion.

In the photovoltaic pumping system, the connection between the photovoltaic generator and the pump driven by an AC motor is made by an inverter (Figure 3). This inverter makes possible to achieve an optimal transfer of power between the generator and the motor-pump unit under the variable conditions of the power produced and the power demand. This transferiscontrolled by the frequency variation.

3. Methods

This test is based on two main axes; the first is the supply of the pumping system (HM310 test bench) via the electrical network (A) and the second is power supply by a photovoltaic generator (B) (Figure 3).

III - Results and discussion

The performance tests on the centrifugal pump and on testing loop of HM310 bench allowed producing the characteristic curves [(H - Q), (P_ab -Q), (Ƞ - Q)].

1. Study of characteristics (Current-Voltage and Power-Voltage)

The combination of several photovoltaic cells in series and in parallel series lead to photovoltaic generator, of which the system operating point corresponds to the curve point with a value of Im = 26, where the produced power is maximum (Figure 4).While the maximum power which obtained by the following formula: (dp) / (dv) = 0, the results revealed a value of 4500W (Figure 5).

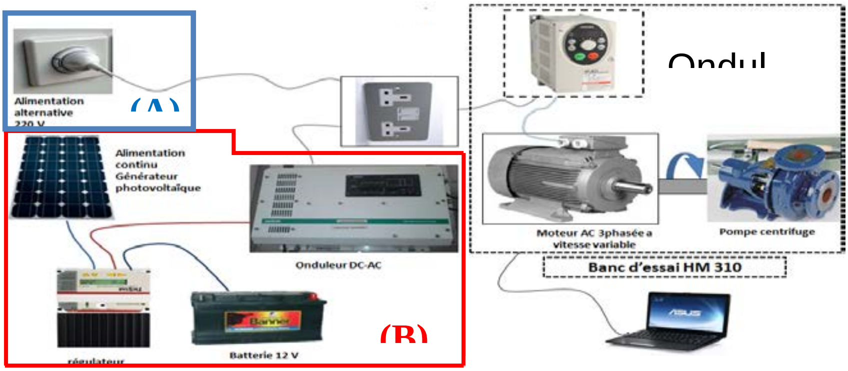

Figure 3. A pumping system for the two cases of power supply.

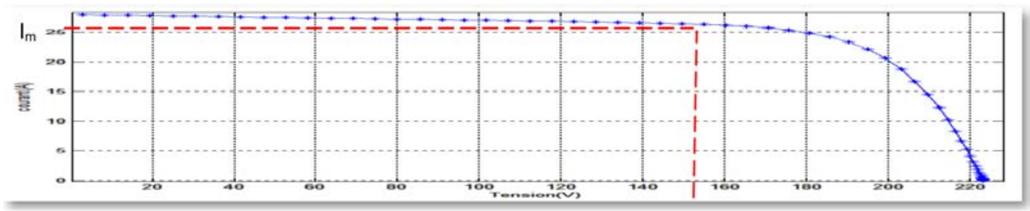

Figure 4. Relationship between current and voltage of a photovoltaic module.

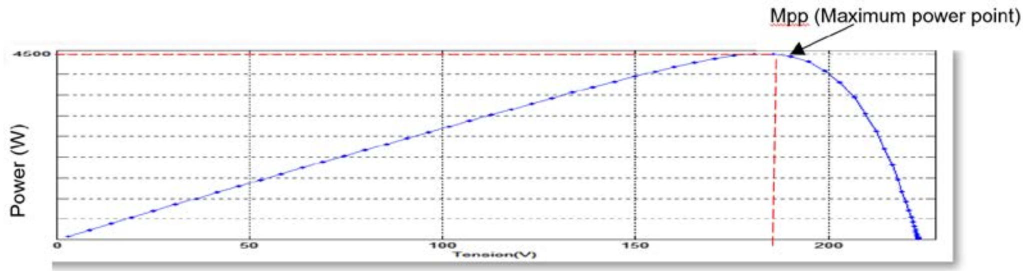

Figure 5. Relationship between power and voltage of a photovoltaic module.

2. Influence of illumination

When a constant temperature was maintained at different illuminations (Figure 6), it has been noticed that the increase of the short-circuit current is much greater than the open circuit voltage, which explains why the illumination is proportional with the power.

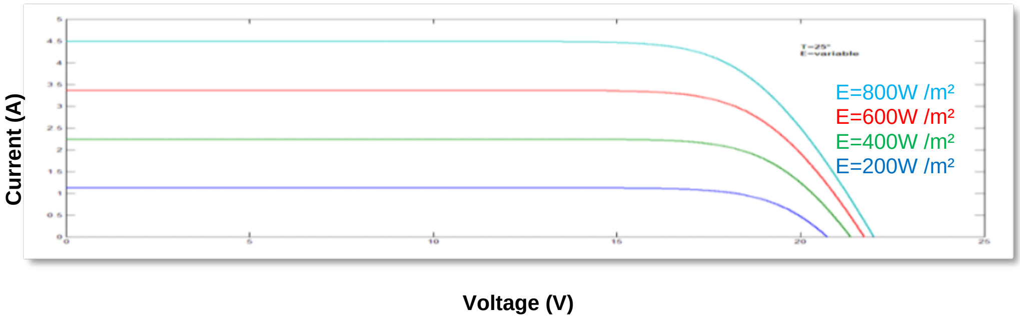

Figure 6. Influence of different illuminations on the voltage.

3. Influence of temperature

We performed a simulation in which constant illumination was maintained for different temperatures (Figure 7). It has been noticed that the characteristic curves present different shapes according to the different temperatures. The no-load voltage decreased with temperature, in contrast to the short-circuit current. The change in no-load voltage is substantially compensated by the short-circuit current variation, and the nominal power supplied by a module varies very slightly with the junction temperature.

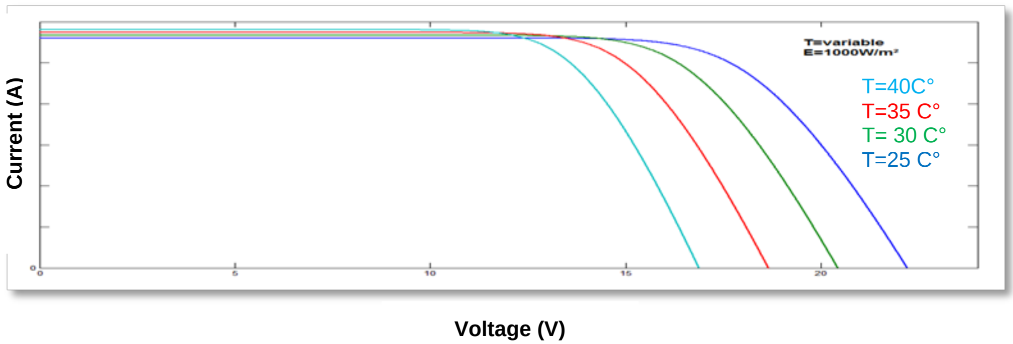

Figure 7. Simultaneous influence of the different temperatures on the current.

Concerning to results obtained for the temperatures influence on power, it was observed that the temperature has a negligible influence on the short-circuit current value; however, the open-circuit voltage drops sharply when the temperature increases, as a consequence the extractable power decreases (Figure 8).

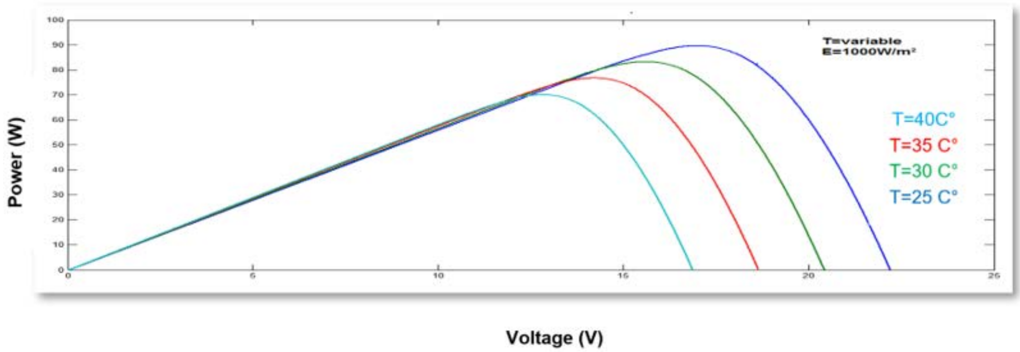

Figure 8. Simultaneous Influence of Different Temperatures on Power.

The irradiation standard internationally accepted for measuring the response of photovoltaic panels is a radiant intensity of 1000 W/ m² and a temperature of 25°C. Mahammedi (2014) has shown that the panel power decreases by about 0.5% per degree of cell temperature increase above 25°C. However Zeitouny *et al.* (2018) reported that photovoltaic cells performance is significantly affected by temperature.Usually, environmental parameters have a direct effect on energy conservation performance and efficiency (Necaibia *et al.*, 2018).

4. Comparison between the results obtained with grid power supply and those of photovoltaic PV

The curves of type (H-Q) (Figure 9 and 10) represent the evolution of total pressure height developed by the pump according to flow. It was observed that for zero flow (shut-off valve) the splash point was obtained, while increasing the flow the head decreases to a value H min for Q_max (valve fully open) for different speed values. The two power type supplies have given almost the same results.

Voltage (V)

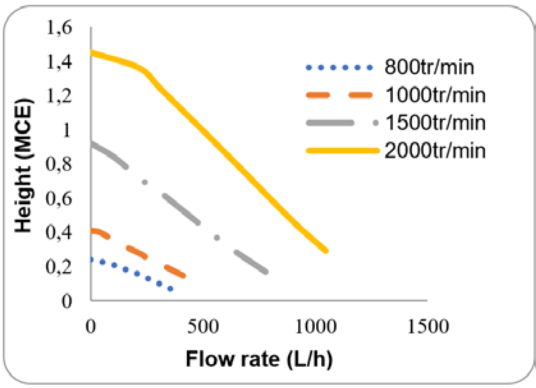

Figure 9. Height-flow characteristic of a bench powered by Power grid.

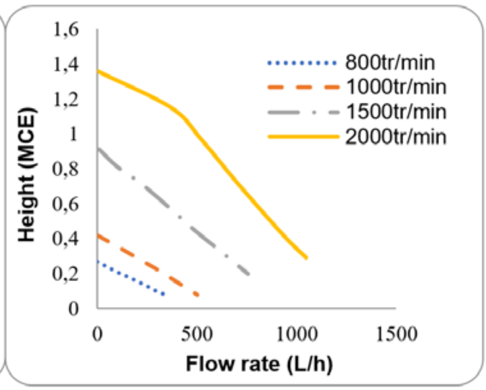

Figure 10. Height-flow characteristic of a bench powered by PV.

In addition, the type curves (Ƞ-Q) (Figure 11 and 12) represent the pump's performance evolution according to flow, have shown that for zero flow the output is zero, on the other hand, when the flow increases until Q_max = 1000 L/ h, this corresponds to a yield value of 30%.

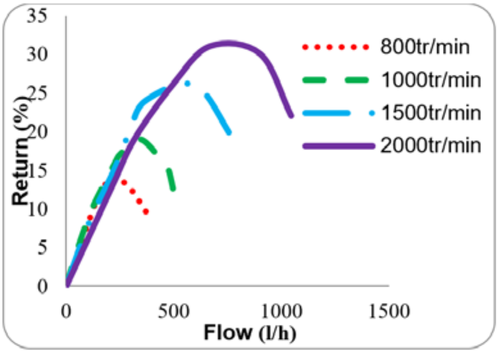

Figure 11. Performance-flow characteristic of a test bench powered by Power grid.

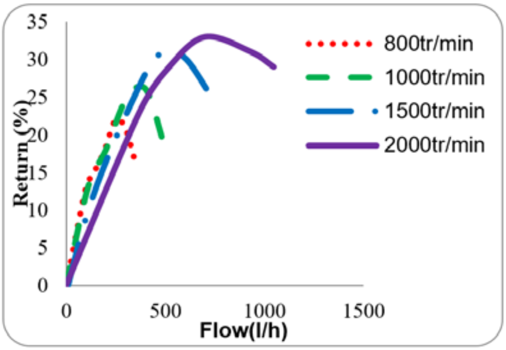

Figure12. Performance-flow characteristic of a test bench powered by PV.

The results obtained from the two methods showed that power supply by Power grid and by photovoltaic generator are almost similar; this highlights the power supply efficiency by photovoltaic generator.

The recorded data by Abbes *et al.* (2012) showed that the hybrid photovoltaic-wind energy system with storage: sizing and life cycle analysis allowed to optimization of multi-source system sizing with batteries as well as the economic and environmental evaluation; such system was dedicated to 4-person residential habitat based in La Rochelle. Moreover, Boutelhig *et al.* (2017) indicated that water pumping by the photovoltaic system seems to be most adapted for domestic water providing in Algeria desert regions. Indeed, the use of photovoltaic pumping system for palm grove irrigation in Ouargla showed great efficiency (Djafour and Aida, 2009).

IV - Conclusions

The results obtained from the two pumping methods comparison (the first pumping system HM 310 test bench powered by an electrical network, and the second powered by a photovoltaic generator) showed that the effectiveness of both systems is similar. This demonstrates that photovoltaic source use for irrigation is the best economic compromise for sustainable agricultural development in isolated arid regions.

The system with power grid requires relatively low investment cost, but relatively high operating cost, care and maintenance. However, for photovoltaic system the investment cost is important, but very low maintenance and operating costs. As a result, photovoltaic solar energy can be a sustainable solution for desert regions.

Acknowledgments

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