Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)
2008, 4 (2), 137 - 142

Promotion of Photovoltaic Water Pumping System (PVPS) for Irrigation in Desert Regions (Ghardaia/Algeria)

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Abstract: Supply water to remote and desert regions for daily use in irrigation and livestock watering remains the great concern of the agriculture field workers. However, photovoltaic water pumping system (PVPS) offers a possibility, as a stand alone system, a reliable long life and clean energy to overcome this problem. The abundance of both solar irradiance and the underground water source, in the desert areas are suitable to promote this new technology in these regions. Characterization test has been carried out with our test facility at URAER/Ghardaia on Grundfos solar pump, having the following electrical characteristics (DC 30V - 300V, Imax = 7A, P= 900 W), powered by (2 x 6) isofoton PV module array, with nominal power (110w/24v) for each module . The obtained results has been used for a stand alone PVPS design to supply a farm with a maximum daily need of about 50m^3 of water, for crop irrigating and livestock. Through simulation studies, it has been found that the maximum power required to extract such amount of water, in summer is approximately 2.425 kW. The obtained results are satisfactory and the effectiveness of such installation will be compared at long-term with high cost of other energy sources as diesel, and gas.

Key words: (PVPS) Photovoltaic water Pumping System, Desert region, irrigation, livestock, stand alone system, solar irradiance, underground water source, characterization, test facility.

INTRODUCTION

The Geographic location of Algeria north the equator, favourites the solar energy uses in water pumping, mainly in remote arid areas. Indeed, there is a large solar radiation covering the whole Algerian south and there is an abundance of high quantity of underground water located at very low depths.

In particular, In the Ghardaia region, the daily average of solar irradiance received on a south facing PV cell tilted with an inclination angle equal to the latitude of the site reaches more than 7 kWh/m2/day. The average daylight hours range from five (5) up to more than ten (10) hours. The static water level of wells and boreholes varies from 20m to 40m, in the Metlili and Sebseb vallies, and from 5m to 20m in Hass Lefhal and El-Golea regions.

Since the high cost of AC motor pump consumption of electricity influence on the crops production, the majority of inhabitants of such areas obtain water from bored wells by means of water pumps, which are driven by diesel engines. The diesel motors are associated with maintenance problems, high running cost, and environment pollution. However; these advantages allow the photovoltaic water pumping systems to be more adequate and appropriate solution to supply water for drink, irrigation and livestock in these regions.

On March 2005, complete PV water pumping test bench has been erected in The Applied Research Unit for Renewable Energies (URAER)/Ghardaia .The facility has been acquired from CIEMAT/Spain upon the cooperation between Algeria and Spain in the field of renewable energies. The goal of this test facility has been to carry out the solar pump characterization and to assess the suitability of PVPS as new utility for supplying water for irrigation and domestic use, thus it is reliable to enhance the local crop production in the desert regions.

A characterization test has been carried out on Grundfos submersible PV pump with electrical characteristics(DC 30V - 300V, Imax = 7A, P=900 W), the obtained results were used in the study of (PVPS) design for a real farm located in Sebseb valley, about 60 km from the site.

LOCATION and METEOROLOGICAL CHARACTERISTICS of GHARDAIA

Location: about 600 Km south of Algiers
Latitude: 32° 36' N
Longitude: 3° 81'E
Elevation: 450 m, above sea level
Soil specification: Classified as arid area.
Rate of sunny days: varies between 77% and 80% per year.
Daylight hours: approximately ranges from 5 up to more than10 hours.
Min. and Max. Ambient Temperature vary from 26 °C to 42 °C, in summer
Daily Average Irradiation: Varies between5 and 8 sun-hours on PV horizontal surface.
Agriculture: Palm trees, Livestock and other local vegetables.

SYNOPTIC of THE PHOTOVOLTAIC PUMPING LAB. / GHARDAÏA SITE

The stationary PV water pumping facility installed at URAER/Ghardaïa, consists of a complete test bench assembled by the following parts:

Inside the lab

- Stainless steel tank (artificial well), type acerinox 1.4301 2B / 034DC7, completed by hydraulic system which involve two flow meters, two pressure sensors and control valve to adjust the water pressure.
- MPPT (300W) for low power
- DC/AC inverter for three phase pumps.
- Electrical panel display which displays the following parameters:
  - Current I(A)
  - Voltage V(V)
  - Temperature (°C)
  - Irradiance (W/m^2)
  - Pressure P1: simulated well head ranges from 0 to 160m.
  - Pressure P2: simulated well head ranges from 0 to 10m.
  - Pressure P3: static level of the tank (artificial well) ranges from 0 to 2.50m.
- Connexion box to select the different configuration (DC pump, DC/AC pump via the inverter and DC pump via MPPT).
- Data acquisition connected to PC

Outside the lab

- PV generator composed of 110 watt/24V 26 Isofoton modules, implemented about 40m away from the lab, south facing, tilted with an inclination angle equal to 32°.
- Earth installation.

CHARACTERIZATION OF PV-POWERED PUMP SET

The characterization test has been carried out by our test facility at the outdoor condition of the site. The PV pump consists of Grundfos DC pump with nominal power (DC 30V - 300V, Imax = 7A, P= 900 W), powered by 12 isofoton modules array with nominal power (110 W x 12 = 1320 W).

Stated below the results of a typical day on 7th March 2008 under clean sky and cold weather:

PV-ARRAY OUTPUT

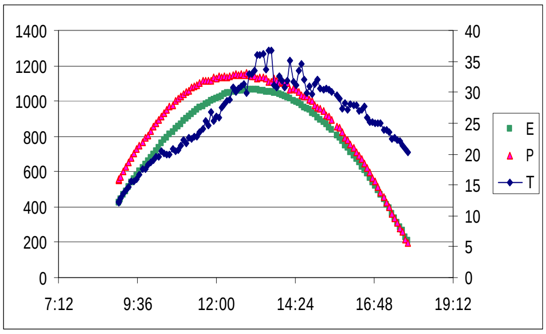

Figure 1. Variation of the daily peak power according to the daily irradiance and temperature.

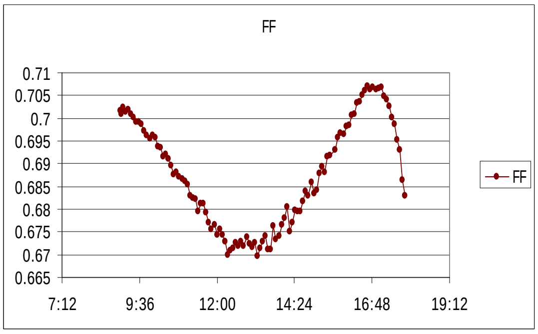

Figure 2. Variation of the daily fill factor.

GRUNDFOS PUMP

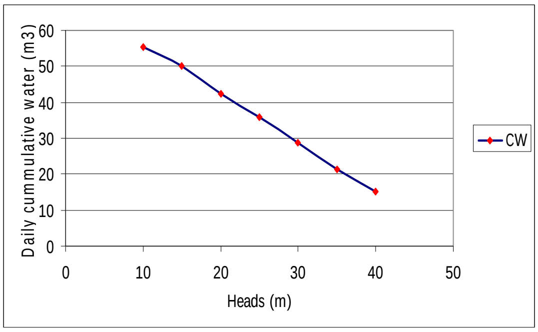

Figure 3. Variation of the daily pumped water According to different heads

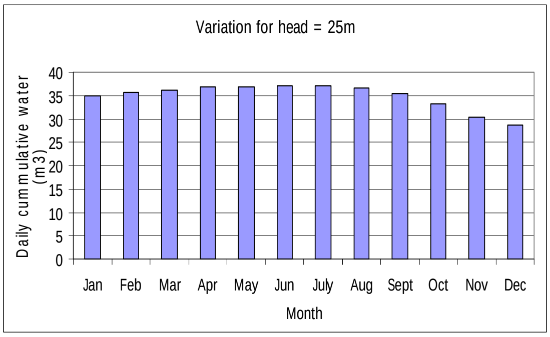

Figure 4. Variation of the monthly daily pumped water for head=25m

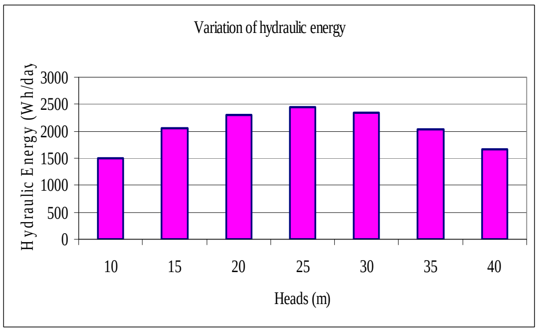

Figure.5. Variation of the hydraulic energy required by the pump according to different heads

DISCUSSION

In the field of solar noon, the irradiance incident on the PV array varies from 1000 to 1100 W/m^2 and the peak power varies between 1100W and 1200W, for PV cell temperature ranges from 25°C to 30°C.

The Fill Factor varies between 0.67 and 0.71.

The array efficiency is reliable.

The variation of hydraulic energy of the pump according to different heads shows that the optimum head is 25 m.

PV WATER PUMPING SYSTEM (PVPS) DESIGN

PV powered pumping system usually consists of at least a PV array, a couple of water motor pump, and storage tank. Other components may include batteries and charge controller, a solar tracker, and water level sensors or float switches.

The PV power is produced directly by sun shining on a tilted array of PV modules.

Several modules are then connected on array to provide enough power to run motor pump set in a pumping system. This array is usually mounted on a simple structure oriented toward the sun at an inclination angle close to the latitude of the site. This ensures that ample energy from the sun will shine on the array during all seasons of the year.

The DC motor-pump is the most selected because PV arrays supply DC power directly, however, AC motor-pumps require DC-AC inverters and can be used for high power applications.

To avoid the increase of maintenance requirements and the high cost of the PV pump set, and the decrease of its reliability, the inclusion of batteries for energy storage is replaced by storage tank to store water during the pumping hours on daylight. This allows an adequate use of the water according to the plant and livestock need.

STAND ALONE PVPS STUDY ON REAL FARM IN SEBSEB

Purpose of the project

Provide the farm with a monthly daily required quantity of water by mean of Photovoltaic Water Pumping System installation (PVPS) for irrigation and livestock watering.

Characteristics of the site

Location: Sebseb village, 60 km southwest of Ghardaia.

Classified as arid region (sandy soil)

Latitude: 32° 09’, Longitude: 3° 35’, elevation: 465 m above the sea level.

Daily average irradiance: varies between 5 and 8 kWh/m2/day on horizontal surface

Yearly sunny days: about 80% per year,

Ambient temperature varies between 26°C and 42°C, in summer

Sandy storms in spring and in autumn

Agricultural region: famous with palm trees, peanuts, and other vegetables.

Technical data of the well

An optimum PVPS design requires the following well specification data:
Maximum daily water needs: 50m^3 /day
Diameter of the well: 1.80m
Static water level (Static head): 22m
Drawdown water level (Dynamic head): 25m
Distance between the well and the tank: 200m
Diameter of the water conduction pipe: 50/60
Elevation of the storage tank above the ground: 10m
Total Manometric Height TMH: 40m
Capacity of the tank: 200m^3

Estimation of the water need

It is more complex to estimate the water requirements for an irrigation application, and thus is beyond the scope of this work. The kind of crop, meteorological factors (temperature and humidity, wind speed and cloud cover), method of irrigation (prevent any water losses) and the variation of insolation throughout the seasons of the year are the principal factors to be considered.

Three different needs on should be considered to determine the quantity of water to be pumped by such PV-powered water pumping system:

- Water for drinking and cooking
- Water for livestock
- Water for crop irrigation

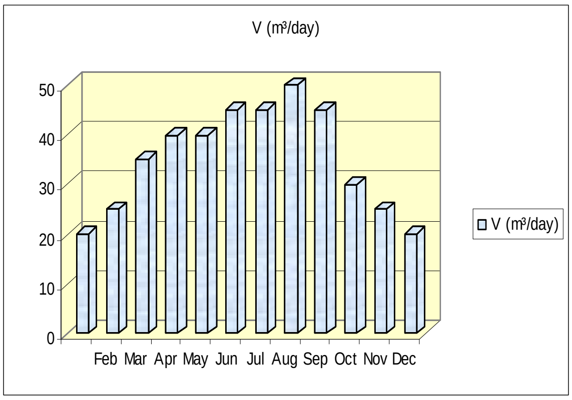

Figure 6. Variation of the monthly daily need in water by the farm

The farm demand in water is estimated at most 50m^3, in summer; it will be approximately the maximum system's requirement during 7 sun-hours daily. There is no energy storage (no batteries). The farm has a storage consists of a ground storage tank of 200 m^3 capacity. It is enough to satisfy the farm need in water and the surplus quantity is used to substitute any deficit in water demand during the cloudy days when there is no much insolation level to provide the starting current for the motor pump, or when the system is stand by for further maintenance.

The water in the well does not always stay at the same level throughout the year. To be sure the well will produce enough water year-round; measurements should be made during the driest month of the year, when the water level in the well and the recharge rate are usually the lowest.

Estimation of the required energy

The insolation is measured in sun-hours,
(1 sun-hour = 1 kwh/m^2 /day)

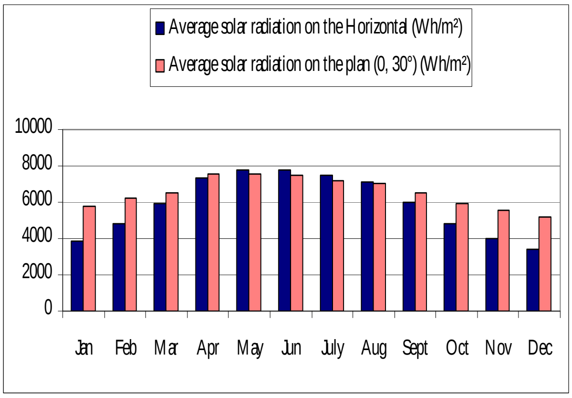

Figure 7. Variation of the yearly solar irradiance on horizontal and tilted surface.

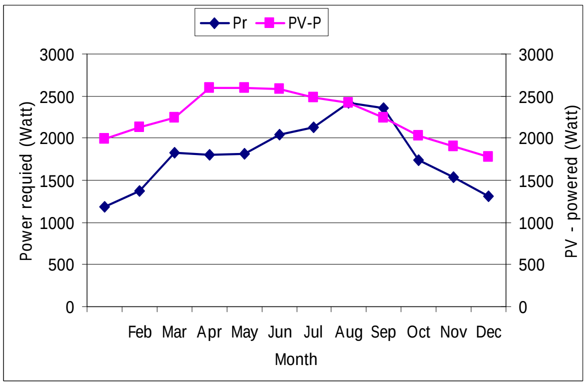

Figure 8. Variation of the monthly daily required PV power and the provided PV power.

The daily required hydraulic power:

$$Eh = Ch * V * TMH = 2.725 * V * TMH \text{ [1]}$$

Assuming the overall efficiency of the couple pump- electric motor is Eff = 40%

The daily required electric energy:

$$Ee = \frac{Ch * V * TMH}{Eff} \text{ [1]}$$

The following model estimates the peak power required by the pump

P = Ee / (Sh x (1–Losses)) [1]

The critical month from a design viewpoint is one with the minimum ratio of sunlight available to the maximum amount of water required. This method requires more solar power, thus the number of the PV module decrease. The demand on irrigating water varies in linear with the solar irradiation. The greatest needed amount of water is in August; however, the correspondent required energy will be approximately the maximum required power by the pump set.

Implementation

The submersible pump must be placed below the lowest expected drawdown level, and must be equipped by float switch to protect the pump from running dry.

-Configuration of the PV generator according to the available PV modules:

With isofoton PV module (110w), the estimated number of Isofoton PV module required by the field is determined by mean of the following model:

$Nm = (P_{max}/110) \times C_e$

$Nm = (2425/110) \times 1.25$

C_e is the error coefficient of the PV isofoton module, and is estimated at 1.25

The number of the Isofoton PV module is estimated at 28 modules.

For efficient operation, it is necessary that the Voltage/Current characteristics of the pump set match those of the array. The solar submersible centrifugal pump is well matched to the output of the PV array.

-Selection of the optimum tilt angle, optimum panel azimuth angle and avoid the shade place at installation.

-Estimation of the minimum monthly average solar radiation of global irradiance on tilted PV panel.

Assessment

After implementing the PVPS, an opportunity assessment can be conducted (follow up) by our PV lab. The assessment can include tasks such as evaluating the efficiency of the system, reviewing PV system extensions according to the increase of water demand and evaluating the PVPS cost effectiveness.

CONCLUSION

PVPS can also foster the agriculture development mainly in rural and remotes desert areas and reduce environment impact by using solar energy source to eliminate line extensions. Additionally, the water delivered to each site can be adjusted to particular needs simply by adding or subtracting PV modules.

For a best linearity between the solar irradiance and irrigation water demand, an adequate study must be carried out between the PV pumping team and the local agriculture room to enhance some kind of crops during seasons where there is surplus of PV energy.

The use of PV powered water system is limited, probably because PV power is a new technology, and allows potential users are simply unfamiliar with it as well as the high cost.

The Know how to use this new technology must be the care subject of the researchers in this field to make it more adaptable by the farmers.

Improve local agriculture

Provide long-term stability

Stand alone applications such as livestock and water pumping.

Table 1. Comparison of pumping options

Energy source	Advantages	Disadvantages
Solar PV-powered	Free source of energy Clean (no pollution, no emission) Easy to install Low maintenance Reliable long life Low recurrent costs System Flexibility(mobility and modularity) and can be matched closely to need	Relatively high capital cost Lower output in cloudy weather (An adequate study can solve these problems)
Diesel (or gas)-powered	Moderate capital cost Can be portable Extensive experience	Noise and pollution problems Inadequate maintenance Reducing life Fuel often expensive and supply intermittent

Nomenclature

C_e : Isofoton PV module Error coefficient
E_e : Electric Energy in (Wh/m^2/day)
Eff : Couple motor electric pump Efficiency=4%
Eh : Hydraulic energy
Ch : Hydraulic constant =2.725 ($Kg.s.h/m^2$).
FF : Fill Factor
Losses : overall losses due to dust and T° (20%)
Nm : Number of module
P_{max} : maximum power required
PV : Photovoltaic
PVPS : Photovoltaic Pumping System
Sh : Sun-hour (1 sun-hour = kWh/m^2/day)
V : Daily volume of water in (m^3 /day)
TMH : Total Manometric Height in (m)

Knowledgements

I'm in great dept to Mr. Hadj Mhammed Idriss for his friendly guidance.
I would like to appreciate the help of my colleague Mr. Yahia Bakelli – PV pumping team.
A very special thanks goes to my colleagues: Mr. Ismail Smaoui and Mr. Abdelhamid Mraoui for their support.
Thanks to my colleague Mr. Rachid Khanniche for his help in reviewing the text.
Thanks to my wife for her plenty encouragement.

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