Journal of Namibian Studies, 34 S2(2023): 400-408 ISSN: 2197-5523 (online)

Economic Viability of Solar Photovoltaic Water Pump for Sustainable Agriculture Growth in Ban Don Toom, Mahasarakham province

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Abstract

Mahasarakham is an agricultural province where the total land area is utilized for the cultivation of crops. But this sector is drastically affected by the energy crisis currently worrying the whole world. The research presents solar technology utilization for sustainable growth of the agriculture sector of Mahasarakham is presented. Water pumping is a major energy-consuming operation of the agriculture field that may be shifted to solar energy-based electricity. This work elaborates on the economic feasibility of PV solar-powered water pump systems. Solar PV water pump system viability is estimated based on economic determinants like NPV and payback periods. Simulation outcomes predict that installing a single 3 kW, DC-solar PV water pump will result in 8 MWH electric power savings and greenhouse gas emission reduction produced due to fuel combustion for generating base-case electric power. Commercial implementation of solar PV water pumping technology can be a milestone in figuring out energy and economy-related agricultural issues and reducing environmental concerns. The results showed that the operating time of the highly efficient solar pumping system is at 2 p.m., and the measured water volume is 14,400 liters per hour. The knowledge and understanding assessment results before and after transferring knowledge to the community in the use and maintenance of solar pumps showed that the mean scores from the participants' test were. It was found that the mean scores from the training participant assessment form participants were able to use the knowledge from the training at the level of 9.99, most satisfied, the solar pump was found cost-effective and beneficial for horticulture crops as compared to the diesel pump.

Keywords: Photovoltaic, Water Pumping, Gas Emission

Introduction

Solar photovoltaic energy can be converted into usable electricity to operate the water pump in a photovoltaic water pumping system. Solar water pumping technology might be considered a viable alternative to pumping systems that are powered by electricity, diesel, or gasoline due to the fact that it is more cost-effective and less harmful to the environment. [1]. Photovoltaic water pumping systems convert solar radiation into electricity via PV panels with the mission to power the electric pumps. The electrical energy produced by the PV modules is used to supply DC motors or to be converted into alternating current by the inverter. Depending on the installation, it is possible to store energy in batteries. Another option is thermodynamic conversion which converts solar energy into mechanical energy to run the solar pump. Agriculture is one of the most water- and energy-intensive sectors of the economy, consuming about 70% of global freshwater withdrawals. Access to clean and affordable water for irrigation is an essential step towards guaranteeing water and food security, improving incomes, and living standards, decarbonizing an energy-intensive sector, and attaining the United Nations Sustainable Development Goals [2]. solar water pumping systems for irrigation, highlighting the water–food–energy nexus aspects and recent advances, and current and future challenges. To improve the qualities of photovoltaic water pumping, the suitable is proposed Lasta and Konrad (2018) [3] were the first to propose a classification, distinguishing between arable farming, PV greenhouses, and buildings. However, the authors did not yet address highly elevated and ground-mounted agrivoltaics. Brecht et al. [4] suggested another classification defining crop production and livestock as the two main applications of agrivoltaic systems. While the authors also included highly elevated and ground-mounted systems, a newer suggestion by Gorjian et al. [5] The formation of assigns typical tilt and tracking technologies of PV modules and agricultural applications to both classes. illustrates a revised version of the classification as used in Gorjian et al.

Recently, the performance of photovoltaic solar water pumping system is investigated with helical rotor pump [6]. The effect of solar radiation and total head on water output of photovoltaic solar water pumping system has been analyzed with the optimized PV array configuration. The effect of variation of radiation on the performance of the pump has also been studied.

Mahasarakham is an agricultural province where the total land area is utilized for the cultivation of crops. But this sector is drastically affected by the energy crisis currently worrying the whole world. We have used the recorded solar radiation data at the Northeast site, in Thailand. The use of photovoltaic energy as an electrical source to supply pumping systems is a well-adapted solution for a great part of these areas. In the Saudi territory, there is a great solar energy potential; the daily mean irradiation received on a surface tilted with an angle equal to the latitude of the site.

In the upcoming decades, PV is projected to become one of the main technologies meeting the global energy demand. Agriculture is a major contributor to the production of greenhouse gases and is also increasingly impacted by severe weather. As a result of climate change and rising water scarcity, this industry must take action to reduce its carbon footprint and become more resilient to the effects of climate change.

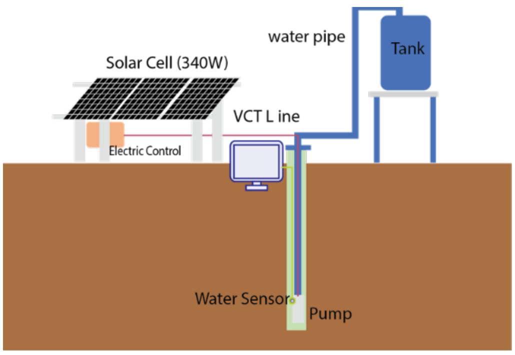
Materials and Methods

Photovoltaic water pumping systems are particularly suitable for water supply in remote areas. The experimental data are obtained with our pumping test facility, the performances are calculated using the measured

meteorological data of in Ban don toom, Mahasarakham province, Thailand. The Photovoltaic water pumping systems

is composed by: photovoltaic generator of 3 KW, a submersible helical pump of the Grundfos is a 1.5" helical rotor pump for high heads and low flow rates, flow meter of type Electromagnetic and Agilent data logger system connected to computer for data acquisition and treatment as shown in **Figure 1.**

Figure 1. The Photovoltaic water pumping systems.



The Photovoltaic water pumping systems is installed

in a reel well of 120 m of depth. Powered by the selected PV array, the pump is tested for a fixed head of 80 m during sunny days. The output power P (W), hourly flow rate Q (m^3/h), the current I (A), voltage V (V), the solar radiation intensity E (W/m^2) all data of the instantaneous were stored in the data logger Agilent.

Experimental Measurements

The parameters used in our present work accuracies and uncertainties measurement. The flow meter of type electromagnetic used has been tested and calibrated the flow meter is ±5 ml/min. T-type thermocouples ±5 C, Pressure transducer ±1.5 mbar, Voltage measurement ±0.06 V, Current measurement ±0.15 A. The results of the uncertainty of measured irradiance indicate that the measurement of global solar irradiance can approach 5% [7]. The Silicon irradiance sensor used has been calibrated and tested with the measurement given by the pyranometer. The results of the uncertainty of measured irradiance indicate that the measurement of global solar irradiance can approach 5% [8].

The Photovoltaic water pumping systems models

The modeling of the motor-pump characteristics is based on the experimentation of the helical pumping subsystem. These characteristics can be represented only by electrical power (P_{mp}) and flow rate (Q) for each total head (h). The electrical power (P_{mp}) is given by the following **Eq. 1.**

$$P_{mp} = E_{pv}.H_G.A_{pv}.\eta_s.\eta_p \tag{1}$$

Where

E_{PV} is the efficiency (%) of Photovoltaic panels
H_G is the solar radiation (Wh/m^2)
A_{PV} is the area of solar panels
η_p is the number of parallel panels
η_s is the number of serial panels

The values of these parameters are given as follow [9]:

E_{PV} = 14%, A_{PV} = 0.502 m^2, η_s = 8.00 and η_p = 3.00

For a given power P_{mp}, we obtain the calculated flow rate Q from the relation by the following **Eq. 2**

$$Q = -b \pm \sqrt{\frac{b^2 - 4a\left(P_{mp} - C\right)}{2a}} \tag{2}$$

Error analyses

Correlation coefficients (R^2) and root mean square error (RMSE) were criteria for the accuracy of the fit. The higher R^2 and the lower RMSE represent good fits to the model. These parameters were calculated as follows: **Eq. 3- Eq. 4**

$$R^2 = 1 - \frac{\sum_{i=1}^{N}\left(X_{pre,i} - X_{exp,i}\right)^2}{\sum_{i=1}^{N}\left(X_{pre,ave} - X_{pre,i}\right)^2} \tag{3}$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(X_{pre,i} - X_{exp,i}\right)^2} \tag{4}$$

where $X_{exp,i}$ is the i^{th} experimental values, $X_{pre,i}$ is the i^{th} predicted values, $X_{exp,ave}$ is the i^{th} experimental average values, N is the number of observations and z is the number of constants.

Net present value (NPV) is a capital budgeting technique used to estimate the current value of the future cash flows that a proposed project or investment may generate. Capital budget planners might find NPV useful because it provides results in dollar values and can be a fair indicator of an investment's profitability. NPV allows you to use present values to determine the potential future earnings of a project. NPV is given by the following **Eq. 5**

$$NPV = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1+i)^t} \tag{5}$$

Where

NPV is Net present value
i is discount rate; 0.08 %
n is The age of the project is 20 years.

Results and Discussion

The examination of these experimental data enables us to suggest a straightforward mathematical model, which is shown below. The following mathematical models are then proposed, assuming there is a total headcount of h: The following is an illustration of one example of the measurement values are shown in **Figure 2.**

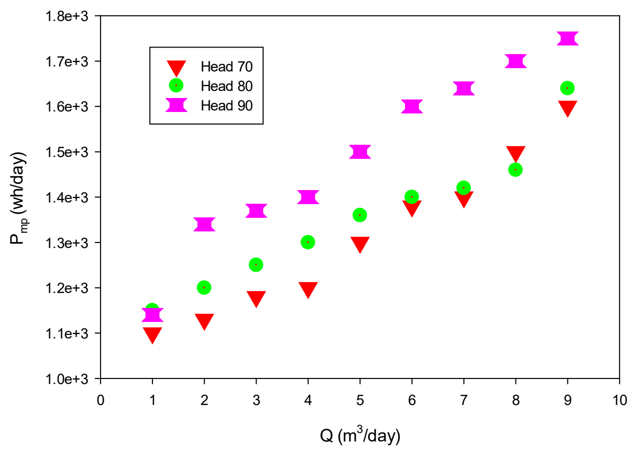


Figure 2. Experimental data of pump power P_{mp} versus the flow rate Q for different heads.

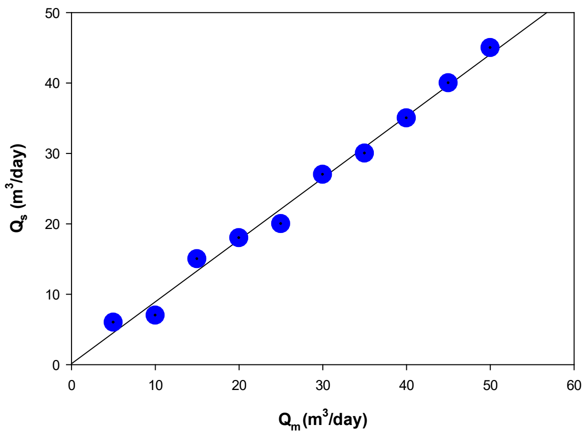
demonstrates that there is a correlation between an increase in pump power and a rise in flow rate Q for a variety of head heights following the model as mentioned in the connection **Eq. 2** This research aim is to simulate versus experimental water flow rate is given by the following **Table 1**.

Table 1 Correlation between simulation versus experimental water flow rate.

Head (m)	$Q_s = f(Q_m)$	Correlation coefficient	RMSE
70	$Q_s = 0.891Q_m + 0.17$	0.874	0.0006
80	$Q_s = 0.933Q_m + 0.26$	0.911	0.0031
90	$Q_s = 1.025Q_m + 0.09$	0.983	0.0015

The flow rate Q_S by using only the solar radiation data. The model obtained by fitting as shown in **Figure 3.**

Figure 3. Simulated flow rate (Q_{S}) versus Measured flow rate (Q_{m}) at head 90 m.



The researchers went to the research area at Don Tum village. Kaeng Loeng Chan Subdistrict, Mueang District, Maha Sarakham Province From surveying the needs of farmers in the community, agricultural plots, types of economic crops, and culture crops, from the preliminary data, the researcher calculated the water consumption rate (Q) and the water velocity in the pipeline. From the community, it was found that agriculture has a usable area of 4,800 square meters. Plants require water at 0.003 cubic meters/ day per square meter. Therefore, 1 day requires water 4,800 x 0.003 = 14.40 cubic meters/day or 14,400 liters/ day, working 5 hours a day.

The calculation of NPV has a result value equal to 28,000 baht in the case of a solar pumping system. Equipment has an average useful life of about 20 years and has a depreciation rate of 8% per year, so i = 0.08. The project is suitable or worth the investment or not, the value of the calculated NPV must be greater than zero. which a water system project with solar energy The result of the calculation is positive. Once the pumping system has been in use for 20 years, the payback will be at 9 years.

The results of the knowledge and comprehension assessment both before and after the information was transferred to the community about the operation and maintenance of solar pumps showed that the mean scores on the test taken by the participants were. A qualitative study of participants' perceptions is shown in **Table 2.** It was found that the mean scores from the training participant assessment form participants were able to use the knowledge from the training at the level of 9.99 most satisfied.

list	satisfaction	mean	s.d
Project participants have knowledge and understanding about solar pumping systems that can be used to improve their quality of life	highest level	9.71	0.30
Project participants can apply the knowledge gained from the training	highest level	9.83	0.25
Project activities focus on real practical skills	highest level	9.99	0.01
Innovations brought to academic service attracted the attention of project participants	highest level	9.94	0.60

Conclusions

The results showed that the operating time of the highly efficient solar pumping system is at *2* p.m., and the measured water volume is 14,400 liters per hour. The knowledge and understanding assessment results before and after transferring knowledge to the community in the use and maintenance of solar pumps showed that the mean scores from the participants' test were. It was found that the mean scores from the training participant assessment form participants were able to use the knowledge from the training at the level of 9.99, most satisfied, the solar pump was found cost-effective and beneficial for horticulture crops as compared to the diesel pump***.***

The authors would like to gratefully acknowledge the Thailand Science Research and Innovation (TSRI), Rajabhat Maha Sarakham Universitying (RMU, Thailand) for the financial support.

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