ISSN 1808-8546 (ONLINE) 1808-3765 (CD-ROM)

DESEMPENHO DE DOIS SISTEMAS DE BOMBEAMENTO POR ENERGIA FOTOVOLTAICA NO MEIO RURAL

ALARISSE COSTA AVELAR[1]; VANESSA DE FÁTIMA GRAH PONCIANO[2]; EZEQUIEL SARETTA[3]; ISAAC DE MATOS PONCIANO[4]; EVERTON FARIAS COUTRIM[5] E MURILLO RIBEIRO DE GONÇALVES NUNES[6]

[1] Discente do curso de Agronomia, Instituto Federal Goiano, IF Goiano Campus Iporá, Av. Oeste, 350, Parque União, Iporá, Goiás, Brasil. alarisse.costa@estudante.ifgoiano.edu.br
[2] Professora Doutora, IF Goiano Campus Iporá, Av. Oeste, 350, Parque União, Iporá, Goiás, Brasil. vanessa.grah@ifgoiano.edu.br
[3] Professor Adjunto, Universidade Federal de Santa Maria. Rua Ernesto Barros, 1345, Santo Antônio, 96506-322, Cachoeira do Sul, Rio Grande do Sul, Brasil. ezequiel.saretta@ufsm.br
[4] Professor Doutor, Faculdade de Iporá, R. Serra Cana Brava, 512, Boa Vista, Iporá, Goiás, Brasil. ponciano.i.m@gmail.com
[5] Discente do curso de Agronomia, Instituto Federal Goiano, IF Goiano Campus Iporá, Av. Oeste, 350, Parque União, Iporá, Goiás, Brasil. everton.coutrim@estudante.ifgoiano.edu.br
[6] Discente do curso de Agronomia, Instituto Federal Goiano, IF Goiano Campus Iporá, Av. Oeste, 350, Parque União, Iporá, Goiás, Brasil. murillo.ribeiro@estudante.ifgoiano.edu.br

1 RESUMO

Apesar da oferta interna de energia do Brasil ser composta em sua maioria por fontes não renováveis, o uso das fontes de energias renováveis no Brasil é três vezes maior que a média mundial. O uso de energia fotovoltaica para o bombeamento de água é uma das utilizações mais promissoras dessa fonte energética. Sendo que a energia solar é variável para os diferentes locais, seja pelo padrão climático, latitude e componentes atmosféricos, a avaliação do desempenho de bombeamento em diferentes localidades é de extrema importância para a obtenção de informações mais precisas. Diante do exposto, o presente trabalho visa avaliar o desempenho de duas motobombas fotovoltaicas, uma submersa e outra de superfície, para o bombeamento de água para uso rural, no município de Iporá-GO. Utilizou-se uma motobomba submersa Anauger R-100 e uma de superfície Shurflo 2088 instaladas a painéis fotovoltaicos. Através das análises dos dados coletados por sensores observou-se que para as mesmas condições a motobomba Anauger R-100 apresentou um melhor desempenho em bombeamento, obtendo maior vazão, maior tempo de funcionando e eficiência global do sistema.

Palavras-chave: eficiência, irradiância, viabilidade.

AVELAR, A.C.; GRAH PONCIANO, V.F.; SARETTA, E.; PONCIANO, I.M.; COUTRIM, E.F.; NUNES, M.R.G.
PERFORMANCE OF TWO PHOTOVOLTAIC PUMPING SYSTEMS IN THE RURAL AREA

Recebido em 12/11/2021 e aprovado para publicação em 30/11/2021
DOI: http://dx.doi.org/10.15809/irriga.2021v1n4p653-660

2 ABSTRACT

Although Brazil's energy matrix is composed mostly of nonrenewable sources, the use of renewable energy sources in Brazil is three times greater than in the world. The use of photovoltaic energy for pumping water is one of the most promising uses of this energy source. Since solar energy is variable for different locations, whether due to weather pattern, latitude and atmospheric components, evaluation of pumping performance in different locations are extremely important to obtain relevant information. Given the above, this study aims to evaluate the performance of two photovoltaic motor pumps, one submerged and one surface, for pumping water for rural use, in the municipality of Iporá-GO. An Anauger R-100 submerged motor pump and a Shurflo 2088 surface motor pump installed in photovoltaic panels were used. An Anauger R-100 submerged motor pump and a Shurflo 2088 surface motor pump installed on photovoltaic panels were used. Through the analysis of the data collected by sensors, it was observed that for the same conditions the Anauger R-100 motor pump presented a better pumping performance, obtaining greater flow, longer running time and overall system efficiency.

Keywords: efficiency, irradiance, viability.

3 INTRODUCTION

The advent and development of energy from various sources has enabled progress in several Brazilian regions. Although Brazil's domestic energy supply is largely composed of nonrenewable sources such as oil and natural gas, the use of renewable energy sources in Brazil is three times greater than the global average, according to the Ministry of Mines and Energy (GOVERNMENT OF BRAZIL, 2020), due to the extensive use of hydroelectric power.

Photovoltaic energy, or solar energy, is energy that generates electric current from photons present in solar radiation. According to the 2020 National Energy Balance, photovoltaic energy contributed 2.8% of the total distribution of "other renewable sources," a 92% increase compared with that in 2018 (ENERGY RESEARCH COMPANY, 2020). This increase can be explained by the reduction in the costs of installing and obtaining the materials needed for solar panels, in addition to tax incentives for generating electricity from renewable sources (SILVA et al. 2017).

The distribution and maintenance of quality electricity in rural areas remains a concern for rural producers. As they move further away from larger distribution centers, problems involving electricity capacity become more common. Despite government efforts through public policies, such as the Luz para Todos and Electrificação Rural (Light for All and Rural Electrification) programs, which aim to ensure the access of electricity to all, many rural communities and families still lack electricity.

As an alternative to this problem, photovoltaic (PV) solar energy can contribute to the development of rural production by leading to greater independence from electricity services and reducing operating costs, enabling producers to obtain a satisfactory income and reducing rural exodus (TABOSA et al. 2019). In addition to social and economic aspects, PV energy provides rural workers with a wide range of possibilities for the technological development of their activities (SILVA et al. 2017).

The use of photovoltaic energy for water pumping is one of the most promising uses of this energy source. There are several pumps available on the market adapted for solar panels, and the choice should be based on the installation project (FLORES, 2019). This type of pumping system offers producers easy installation, low maintenance and operating costs, and allows for use in locations without access to electricity (GHONEIM, 2005).

In this context, evaluating the pumping system provides more accurate information on the performance of the pumps for the different study sites. Since solar energy varies across locations due to climate change, latitude, and atmospheric components, evaluating pumping systems using this energy source is crucial for gathering information on financial savings from energy costs and pumping system efficiency.

In view of the above, the present work aimed to evaluate the performance of two photovoltaic motor pumps, one submerged and the other surface, for pumping water for rural use in the municipality of Iporá-GO.

4 MATERIALS AND METHODS

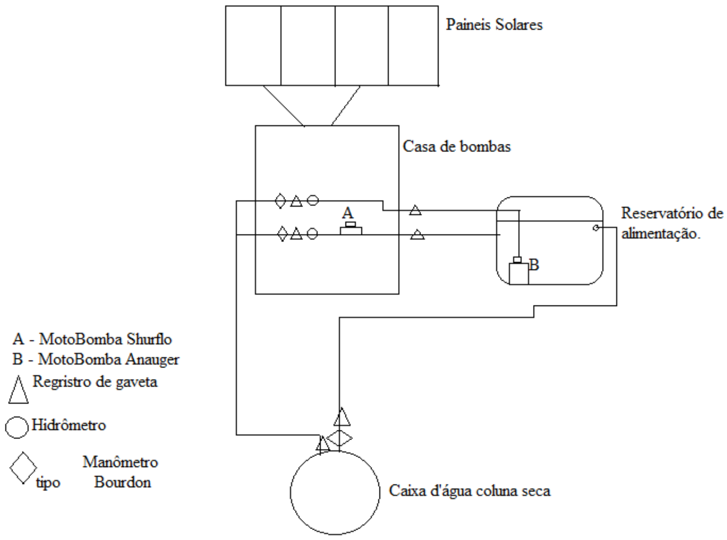
This experiment took place in the experimental field of the IF Goiano School Farm – Iporá Campus (16°25'29” S, 51°09'04” W and an altitude of 584 m). Data collection was carried out during June 2021. The city of Iporá has two well-defined seasons: the wet season, which occurs from October to March and corresponds to spring and summer, and the months of April to September, which are related to the dry period and are characterized by the autumn and winter seasons. The average temperatures vary between a minimum of 18°C and a maximum of 26°C. According to Alves and Mariano (2015), the climate of Iporá can be defined as the Aw savanna type, with an average annual precipitation of 1628 mm, according to data provided by the National Water Agency (ANA).

The data used for the analyses were collected during June, the winter solstice, when the sun is at its smallest angle relative to the Earth's axis. June 21 presents its further decline relative to the Earth's plane, resulting in the shortest day. Thus, the data were collected under critical conditions, as the sun's rays reach the panel at an oblique angle, and their most efficient reception is perpendicular.

The photovoltaic generation system consists of four panels facing north, with two generators connected in series with the Anauger R-100 pump (submersible pump), one generator connected with the Shurflo pump (surface pump), and one generator connected with the Datalogger. Each PV system was independent.

Each pumping system had a Bourdon pressure gauge and a slide valve to control flow. The photovoltaic system powered the motor pump, which collected water from a feed/stabilization water reservoir and pumped it to a dry-well, cup-type water tank approximately 7 meters high. The water remained in this closed-loop flow (Figure 1).

Figure 1. Description of the photovoltaic pumping system.



Source: own authorship.

Data recording was performed via a FieldLogger datalogger with analog and digital inputs and a 24 V auxiliary power supply. For each pumping system, the following data were measured: electrical voltage (V), current (A), horizontal solar irradiance (ITH) (W m-²), inclined solar irradiance of the PV generators (which are oriented to the north at an angle of 16°, according to the local latitude), ITA (W m-2), pumping volume (L) and pumping time (h).

The daily pumping time (h) was determined via water meter data, and the flow rate of each pump (L min-1) was calculated on the basis of the volume pumped every 15 minutes and the time interval between water meter readings. The electrical power and overall system efficiency were calculated according to Equations 1 and 2, respectively.

$$P = I \times V \tag{01}$$

where P is the electrical power (Watts), I is the current (Ampère) and V is the electrical voltage (Volts).

$$\eta_G = \frac{Ph}{ITA \times Ef} \tag{02}$$

where η_G is the overall efficiency (%), Ph is the power consumed by the motor pump (W), the ITA radiation on the inclined plane (W/m²) and Ef is the panel efficiency, which is 15% (0.1515).

5 RESULTS AND DISCUSSION

The importance of solar angles is verified through Table 1, where it is possible to observe the difference in total irradiance between the horizontal plane (ITH) and the irradiance in the inclined plane (ITA). In their studies, Kaufmann (2014) noted differences between the average horizontal irradiance (kWh) and the average inclined irradiance (kWh). For August 16th, the horizontal irradiance was 52.17 kWh, and the inclined irradiance was 63.98 kWh.

Table 1. Data on solar irradiance in the horizontal plane (ITH), solar radiation on the inclined plane equal to the latitude of the site, 16° (ITA), the power generated by the panels accounting for an efficiency of 15.15% and the power consumed by the motor pumps Anauger and Shurflo.

Solar Panel Data	Critical month - June
Accumulated ITH (W/m²)	559780.0
Accumulated ITA (W/m²)	714754.0
Accumulated generated power (W/m²)	108285.2
Monthly generated power (kWh)	27.1
Monthly power consumption Anauger (kWh)	20.8
Shurflo monthly power consumption (kWh)	2.2

Table 1 shows that the accumulated power produced by a solar panel in the month of June resulted in 27.1 kWh. Kaufmann (2014) also demonstrated that in 9 days in the month of August, the solar panel generated a daily average of 11 kWh.

Table 2 shows the pumping time where Anauger presented greater results than Shurflo did, which is explained by the presence of the Driver in its system. Aleman, Paes and Ferreira (2019) reported a similar average daily operating time when the same model of motor pump, Anauger R-100, was used between 9 and 15 hours per day. The pumped volume of Anauger was 82.87% greater than the volume pumped by the motor pump Shurflo during the month of June.

Table 2. Hydraulic data of the pumping system for the Shurflo 2088 surface pump and the Anauger R-100 submersible pump.

	Shurflo	Anauger	Difference
Accumulated volume (m³)	139.30	254.75	115.44
Average flow rate for the period (L/min)	7.03	12.4	5.40
Average power (W)	8.73	66.9	58.12
η_G (%)	8.49%	42.67%	34.18%
Average daily pumping (h)	08:14:54	10:20:52	02:05:58

The motor pump Shurflo presented an average daily flow of 3360 L/day. Kolling et al. (2004), under conditions of better system performance, reported a flow rate of 5565 L/d with the same motor pump. The Anauger R-100 motor pump presented an average daily flow of 7440 L/day, which was 76.39% higher than that of the Shurflo 2088 motor pump. Despite these differences, Aligah (2011) reported that although several models and sizes of photovoltaic motor pumps exist, the majority of those used in agriculture have average flow rates between 7 and 15 liters per minute (10080 to 21600 L/day).

The overall system efficiency, which refers to the steep PV energy conversion efficiency (ITA) to hydropower, is influenced primarily by the performance of the motor pump in the photovoltaic system. Data for generating the efficiency graphs were collected daily, using 10 days of data. Figures 2 and 3 show that the higher the motor pump's power consumption is, the higher the overall system efficiency—that is, the greater the motor pump's efficiency in utilizing energy supplied by the photovoltaic generator to pump water.

Figure 2. Anauger R-100 overall performance by electrical power.

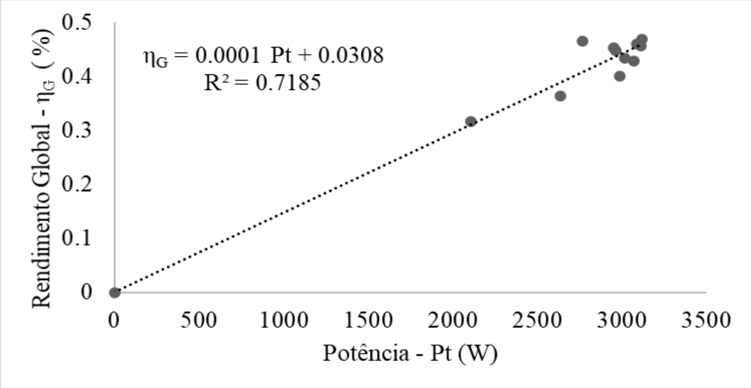
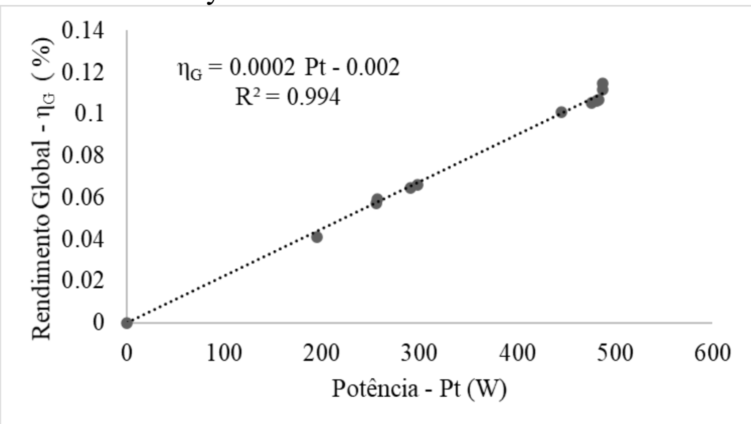


Figure 3. Shurflo Overall Yield by Electrical Power.



Kolling et al. (2004) evaluated the efficiency of the motor pump in relation to the irradiance level and concluded that the overall efficiency of the system increases with increasing radiation but subsequently decreases, which can be explained by the fact that the hydraulic power of the motor pump is limited and that the light energy is not. Vera et al. (2019), using monocrystalline solar panels, reported that the power of the panels and the hydraulic power were constant. They also reported that the overall efficiency of the system used was within the expected standards.

From the above, it is possible to note differences between the hydraulic and energy performance of the motor pumps, although both operated in situations that did not require the maximum capacity provided by the manufacturer, thus not demonstrating maximum efficiency. Therefore, for future studies, tests should be conducted with motor pumps to study their behavior and obtain their performance at different flow rates and head heights. The head used in the pumping system could subsequently be increased to observe whether the performance of both motor pumps will reach more satisfactory values.

6 CONCLUSION

For the same conditions, the Anauger R-100 motor pump presented better performance in pumping water from photovoltaic energy sources, resulting in higher flow, longer operating time, greater pumped volume and better overall system efficiency.

7 ACKNOWLEDGMENTS

The Goiás Research Support Foundation (FAPEG) for granting financial support for the research project (Announcement 03/2015). To the Goiano Federal Institute for the physical and technical conditions for the implementation of the research project.

8 REFERENCES

ALEMAN, CC; PAES, RG; FERREIRA, TS Photovoltaic pumping for drip irrigation . *In:* WORD IRRIGATION FORUM, 3., 2019, Bali. **Proceedings […].** Bali: Word Irrigation Forum, 2019, v.1, p. 1-9.

ALIGAH. MA Design of photovoltaic water pumping system and compare it with diesel powered pump. **Jordan Journal of Mechanical and Industrial Engineering** , Jordan, v.5, p.273-280, 2011.

ALVES, WS; MARIANO, Z., F. Spatial distribution of maximum and minimum absolute temperature and relative humidity: a case study in Iporá/GO. **Training Journal** , Presidente Prudente, v.2, p.192-211, 2015.

ENERGY RESEARCH COMPANY. **National Energy Balance 2020.** RIO DE JANEIRO, 2020. Available at: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-479/topico-521/Relato%CC%81rio%20Si%CC%81ntese%20BEN%202020-ab%202019_Final.pdf . Accessed on: June 22, 2021.

FLORES, AAB **Sizing of hydraulic pumping for water lifting powered by photovoltaic solar energy.** 2019. Monograph (Energy Engineering) - University of Brasília, Brasília. 2019.

GHONEIM, A. Design optimization of photovoltaic powered water pumping systems. **Energy Conversion Management** , London, vol. 47, p. 1449-1463, 2006.

GOVERNMENT OF BRAZIL. **Use of renewable sources in Brazil is three times greater than the world.** 2020. Available at: https://www.gov.br/pt-br/noticias/energia-minerais-e-combustiveis/2020/07/uso-de-fontes-renovaveis-no-brasil-e-tres-vezes-maior-que-o-mundial . Accessed on : June 22, 2021.

KAUFMANN, GV **Assessment of the potential for photovoltaic solar generation and real-time analysis of the operation of a photovoltaic panel installed in the city of Lajeado/RS** . 2014. Monograph (Environmental Engineering) – UNIVATES, Lajeado.2014.

KOLLING, EM; SOUZA, SNM de; RICIERI, RP; SAMPAIO, SC; DALLACORT, R. Operational analysis of a photovoltaic water pumping system. **Agricultural Engineering** , Jaboticabal, v.24, p.527-535, 2004.

SILVA, FV P; FEITOSA, H. O; PEREIRA, C. F; SILVA, JA S; FEIOSA, EO Potential of solar energy for irrigation in the municipality of Barbalha-CE. **Energy in Agriculture** , Botucatu, v.32, p.57-64, 2017.

TABOSA, FJ DA S., COSTA, EM, DO AMARAL FILHO, J., TROMPIERI NETO, N., ARAÚJO, JA, DOS SANTOS, CPB Analysis of the demand for electricity in rural areas of Brazil. **Planning and Public Policies** , Brasília, v. 1, n.52, p. 149-188, 2019.

VERA, AAP; BELTRAN, HJC; TOREES, JCZ; GUZMÁN, JJM; BRAGA, SL Experimental study of a photovoltaic direct current water pumping system for irrigation in rural- isolated region of Arequipa, Peru. **Renewable Energy** , Brighton, vol. 141, no. 1, p. 1-11, 2019.