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Adaptation and Evaluation of SF1 Future Pump for Irrigation Purposes

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ABSTRACT

This study focuses on adapting and evaluating the SF1 Future Pump for small-scale agriculture. The experiment was conducted at Jimma Agricultural Engineering Research Center and Bulbul River. The treatments considered for the experiments were three and five different with a combination of suction and deliver head (4m, 6m, and 8m) and (4m, 6m, 8m, 10m, and 12m) respectively. The parameters used during the investigation were head, flow rate, Voltage Discharge, and Solar radiation. Assesses performance under varying heads, examining factors such as flow rate, efficiency, and the impact of solar radiation. Based on the experiment, the pump has been delivering a maximum flow rate of 28.21L/min and a minimum of 15.85L/min at the combination head 4SH4HD, and 8SH12HD respectively. The minimum voltage and current to operate the system were 25 volts and 1.35 amps respectively. The pump efficiency was increased as the dynamic heads were decreased. Results reveal an inverse relationship between head and flow rate, while voltage and current positively influence flow rate.

Keywords: Dynamic head; Delivery head; Flow rate; Suction head; Solar pump; SF1 future pump; Irrigation efficiency; Small-scale farming.

1. Introduction

The government of Ethiopia has targeted the agricultural sector for market-led growth and rural transformation to build resilience to climate change and foster economic growth. Agriculture dominates Ethiopia's economy, representing 40% of GDP and 75 of workforce employment. Only approximately 250,000 hectares of agricultural land out of a potential of 5 million are irrigated in Ethiopia at present. Many small farms grow teff and other rain-fed subsistence crops using manual labor and animals. As part of Ethiopia's ambition to become a middle-income country by 2030, the improvement of efficiency in the agriculture sector is critical. About 1.4 million farmers are engaged in small-scale irrigated agriculture in Ethiopia, between 210,000 to 400,000 of whom use motor pumps (FAO, 2012). The government's strategy is to transition existing motor pump users to solar, while also introducing new solar pump irrigation to those not currently irrigating. Given the number of existing and potential pump users, the scope for expanding the solar pump market for irrigation appears significant. The Clean Development Mechanism (CDM) program aims to extend the use of solar irrigation pumps to enhance farming productivity, while enabling savings from fuel costs for diesel irrigation pumps and offsetting carbon emissions (UNFCCC, 2016). At the same time, the program seeks to strengthen private sector involvement in renewable energy access, by assisting this sector to become instrumental in the widespread sales of household- and community-level renewable energy technologies. The Ministry of Agriculture has the task of developing financing models for households to purchase solar pumps for irrigation and raising awareness about the opportunity to acquire solar pump technologies, possibly with private-sector enterprise support. At the same time, the DBE is supposed to raise awareness among microfinance institutions (MFIs) about possibilities for acquiring financing to enable onward lending to households for solar technologies.

Ethiopia is one of the solar belt countries and its economy depends on agriculture. The agricultural sector offers significant market opportunities for irrigation in both the smallholder and commercial sectors. It allows diversification of crops while increasing crop yields. However, typical irrigation systems consume a great amount of conventional energy through the use of electric motors and generators powered by fuel. Many of the existing irrigation pumps were built using grants from international organizations, development banks, and federal and state authorities.

The systems suffer from increasingly frequent breakdowns in equipment and high costs of accessing diesel fuel. For this reason, an adaptation of a solar water pump for irrigation is important. Solar energy is the most abundant source of energy in the world. Solar power is not only an answer to today’s energy crisis but also an environmentally friendly form of energy. Solar powered Irrigation System provides a sustainable solution to enhance water use efficiency in agricultural fields using renewable energy systems removes workmanship that is needed for flooding irrigation. Photovoltaic water pumping system is one of the best alternative methods for irrigation.

The SF1 Future pump is an innovative solar-powered pump specifically designed for small-scale agricultural irrigation applications using low-pressure sprays and drip. It is of positive displacement reciprocating piston type with the capability to suck water up to 8m from shallow wells, rivers, and dams and 1250 l/hour deliver water up to 8m, the total lift of the pump is up to 15m supplied with 120W solar panel Fitted with a 60V DC motor with in-built controller include USB port used for charging the phone. It can provide enough water to irrigate one acre (4047 m^2). High-efficiency pump that is tolerant to water containing suspended solids and also capable of running dry without damage. The Sf1 Future pump is of exceptionally robust design for long life and is the most efficient and cost-efficient solution to small-scale farm irrigation requirements. This system can be a suitable alternative for farmers in the present state of energy crisis in Ethiopia.

The purpose of evaluating the variation of head impact on flow rate and the variation of voltage and current impact on flow rate is to understand the relationship between these parameters and the performance of the solar pumping array. By plotting graphs, the study aims to determine how changes in head, voltage, and current affect the flow rate of the pump. Therefore, this study was initiated with the objectives of adapting the SF1 future pump and evaluating the performance of SF1futurepump on farmer’s fields.

1.1. Study Objectives

The following are the objectives of this study:

(1) To adapt the SF1 Future Pump for Ethiopian small-scale agricultural needs. (2) To evaluate the pump's performance under different suction and delivery heads. (3) To determine the relationship between solar radiation, voltage, current, and pump efficiency. (4) To identify the optimal operating conditions for the SF1 Future Pump at local condition.

2. Materials and Methods

2.1. Materials

The materials used during the test were a tachometer, Tape meter**,** 60L container**,** and Multimeter for Current and voltage reader.

2.2. Components of SF1 future pump

The components of the pump were a solar panel, DC motor, Flywheel, Sturdy frame, Air vessels, Suction hose, and Delivery hose.

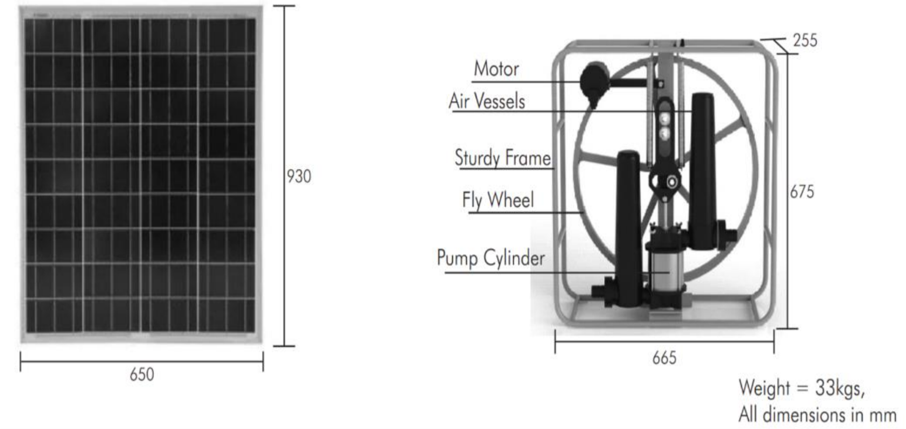

Figure 1. Sf1 future pump components

2.3. Description of the study area

The study was conducted by the Jimma Agricultural Engineering Research Center and Bulbul River in the Jimma Zone of Oromia Regional State of Ethiopia.

2.4. Methods

The flow rate of the pump delivered at the given head was expressed in the form of lh^{-1} or less^{-1}. The discharge of the SF1Future pump used in the test was measured by volumetric method by collecting the water in 60-liter container and the subsequent time taken to fill the container was recorded using a stopwatch. The same was repeated for five trails and the average of five trails was considered.

2.4.1. Treatment and data collection

The treatments considered for the experiments were three and five different with a combination of suction and deliver head (4m, 6m, and 8m) and (4m, 6m, 8m, 10m, and 12m) respectively. The collected data were head, voltage, current, discharge, and solar radiation.

2.4.2. Working principle of Sf1 future pump

The Future pump SF1 solar water pump works via a series of interconnected parts. They work together to convert the sun's energy into mechanical energy which draws water through the pump. The 120-Watt solar PV panels power the DC motor on the pump, the motor then turns a pulley; the pulley can be placed in two gears (this optimizes the pump for higher and lower lifts). The larger pulley is for low lifts this optimizes for higher flow rate. The smaller pulley setting is for high lifts, this makes it for the pump to push water up. The pulley rests on the flywheel and makes it turn. The combination of the main shaft, bearings, and a yoke changes the rotational fly motion into an up and down force. This force moves the piston up and down in the pump cylinder. Inside the pump there are two valves, to ensure the pump sucks water in on the up stroke pushes water out on the down stroke.

The Future Pump SF1 Solar Pump is a robust solar-powered irrigation pump specially designed for small-scale agricultural uses using low-pressure spray, hoses, and drip applications. It comprises three principal components, the PV solar panels, a specially designed DC motor that is coupled to a flywheel, and a positive displacement reciprocating piston-type pump.

Figure 2. SF1 future pump

A special feature of the Future pump is its simplicity of design and operation being simple to set up and maintain by the user. It is also flexible in operation and efficient and an ideal solution for all small-scale farmer irrigation applications (Korpale et al., 2016).

The performance of the solar water pumping system was calculated by the following parameters:

Solar radiation availability at the location, Total dynamic head (TDH): Sum of suction head (height from suction point till pump), discharge head (height from pump to storage inlet), and frictional losses, Flow rate of water, Total quantity of water delivered, losses (m) Incident solar radiation to the PV array gives the input power (Watts) to the system given by,

$$Pi = Is * AC \qquad \ldots(1)$$

The D.C. output power from the photovoltaic array is given by,

$$Po = V * I \qquad \ldots(2)$$

The hydraulic power output of the pump,

$$Ph = \rho * g * Q * H \qquad \ldots(3)$$

Array efficiency ($E\ a$) is the measure of how efficient the PV array is in converting sunlight to electricity,

$$Ea = \frac{Po}{Pi} \qquad \ldots(4)$$

Subsystem efficiency ($E\ s$) is the efficiency of the entire system components (inverter, motor, and pump),

$$Es = \frac{Ph}{Po} \qquad \ldots(5)$$

Overall efficiency ($E\ o$) indicates how efficiently the overall system converts solar radiation into water delivery at a given head,

$$Eo = \frac{Ph}{Pi} \qquad \ldots(6)$$

It can be written in the form of efficiencies as,

$$Eo = Ea * Es \qquad \ldots(7)$$

3. Result and Discussion

3.1. Variation of head impact on flow rate

The variation of head impact on solar flow rate is presented in Figure 3. As shown in the figure, when the head of the system increases 4m to 12m the flow rate of the pump was decreased. This shows that there is an inverse relationship between flow rate and head.

The maximum flow rate was 28.21L and the minimum flow rate of 15.85L/min was obtained from the combination of 4SH*4HD and 8SH*12HD respectively. These findings suggest that as the head increases, the pump is less efficient in delivering water at a high flow rate. The result is also agree with (Lepicard et al., 2017).

The pump was discharged horizontally 100m, lifted maximum suction, and delivered head 8m and 12m.

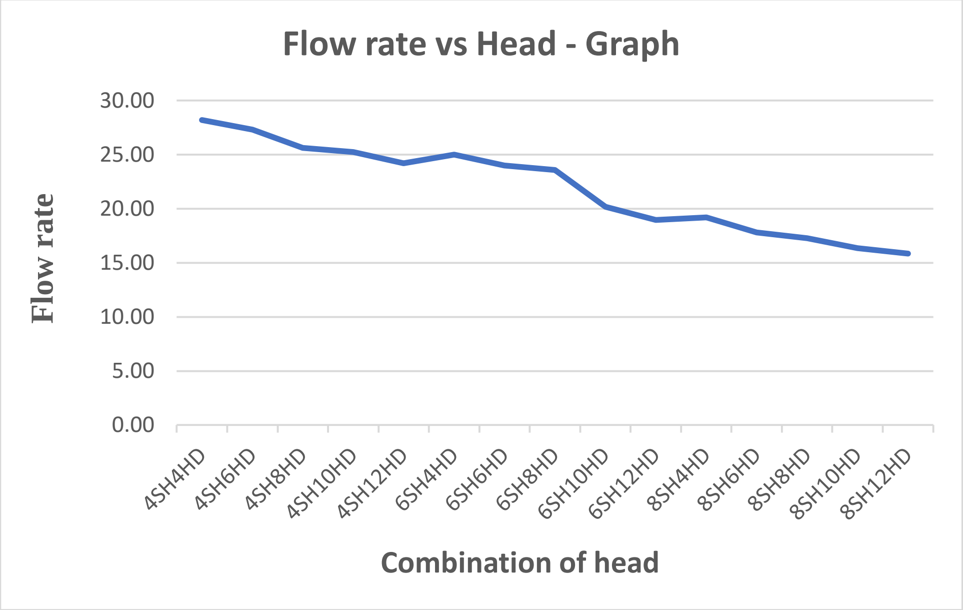

Figure 3. Head versus flow rate graph

3.2. Variation of efficiency with head

The plot of the overall efficiency with a static head in Figure 4 indicated that this particular pump works most efficiently as the dynamic head of the pump was decreased. The efficiency, μ, is computed as the percentage of the ratio between the output power of water and the input electrical power,

$$\mu = \frac{\rho Q g H}{VI} \qquad \ldots(8)$$

Where g is the acceleration due to gravity, h is the elevation head, I is the input current, Q is the flow rate, and V is the input voltage.

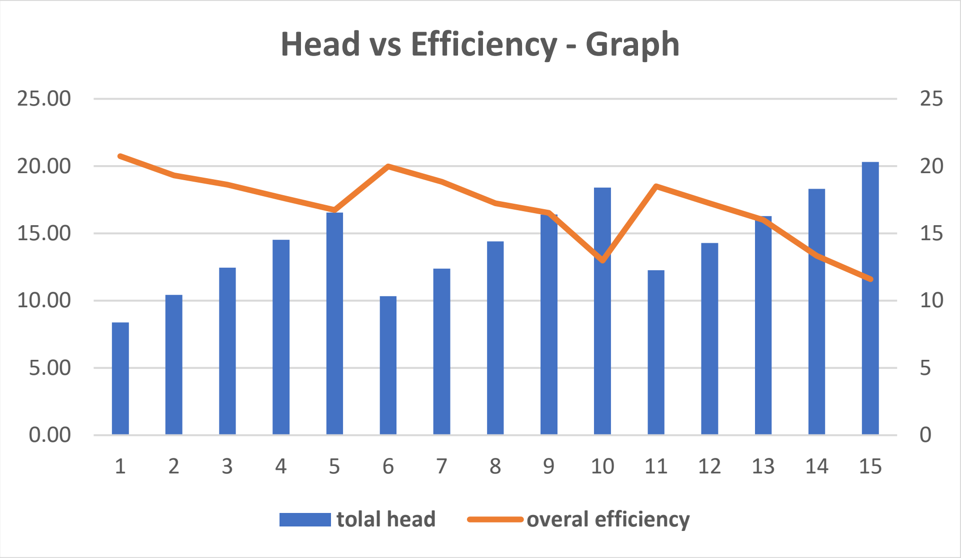

Figure 4. Total dynamic vs overall efficiency

3.3. Variation of voltage and current impact on flow rate

The results have shown that as the head of the system increased, the flow rate of the pump decreased, and an inverse relationship. Additionally, as the voltage and current of the system increased, the flow rate of the pump also increased at a constant head. These findings provide valuable insights into the performance and efficiency of the SF1 future pump under different conditions.

The variation of voltage produced was in the range from 25 to 45 volts and correspondence variation in the current generated was raised from 1.35 to 1.98 amp, as shown in Figure 5 when the voltage and current of the system increased from 25volt to 45volt the flow rate of the pump also increases at constant head. The minimum voltage and current to operate the system are 25 volts and 1.35 amp. The result is similar to (Dannies, 1959).

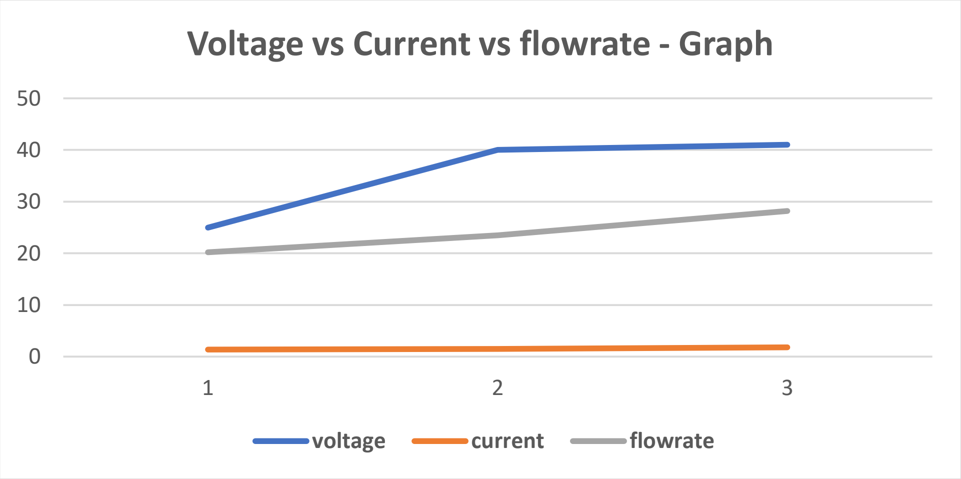

Figure 5. Voltage, current, and flow rate graph

3.4. Variation of solar radiation impact on flow rate

The Temperature value was changed from 18. 3 to 27.6 0C for a corresponding change in solar intensity in the range of 474 to 827 Wm^{-2}. As we have seen from the graph, the solar intensity increases from the morning of 2:30

to 7: and decreases starting from 8:00 in local time. Significant flow rates also existed at the time of maximum solar intensity.

The graph shows that as solar intensity increased from 474w/m^2 to 827 w/m^2 also voltage and current of the system increased from 25 volts to 45 volts, and the flow rate of the pump also increased at a constant head Figure 6. This indicates a positive relationship between voltage, current, and flow rate. The results suggested that higher voltage and current levels result in a higher flow rate of the pump.

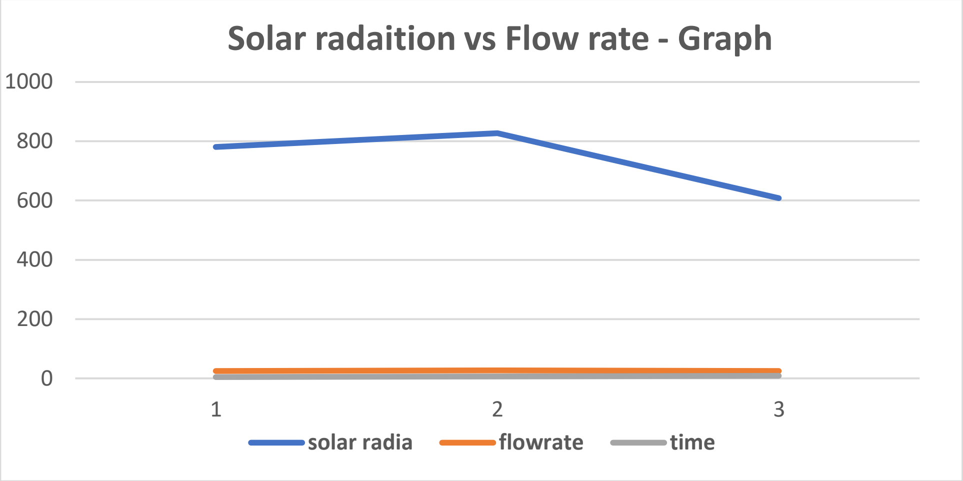

Figure 6. Time versus solar intensity graph

Figure 7. Photo taken during data collection at JAERC, and Bulbul River

Figure 8. (a) Spare part & (b) Photo taken during the watering of the crop

4. Conclusion and Recommendations

4.1. Conclusion

Based on the result, the pump has been delivering a maximum flow rate of 28.21L/min and a minimum of 15.85L/min was obtained from combination head 4SH4HD, and 8SH12HD respectively. The minimum voltage and current to operate the system were 25 volts and 1.35 amp respectively. This indicates that the SF1 Future pump is capable of efficiently delivering water for irrigation purposes and it is a function of head and solar radiation.

4.2. Recommendations

Based on the result and conclusions the following recommendations were made for the Future Pump SF1 solar power water pump system:

➢ The pump was directly connected, for further utilization adding energy storage is more important.

➢ Farmers should be advised, well-trained, and monitored by experts to acquire knowledge and create awareness about the importance of the Future Pump SF1.

➢ Overall, the recommendation is to promote the use of the Future Pump SF1 solar power water pump system in rural areas for agricultural purposes, while ensuring that farmers are well-informed and trained on its benefits and proper usage.

Declarations

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Competing Interests Statement

The authors have declared that no competing financial, professional, or personal interests exist.

Consent for publication

All the authors contributed to the manuscript and consented to the publication of this research work.

Availability of Data and Material

Supplementary information is available from the authors upon reasonable request.

Authors' contributions

All the authors took part in literature review, analysis, and manuscript writing equally.

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