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Solar Powered Irrigation System Design with Venturimeter for Utilizing Natural Resources

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Abstract

This research focuses on enhancing crop productivity in agriculture by ensuring high quality and quantity of crops. Crops needs to be given adequate nutrients in an efficient and timely fashion as a way to accomplish this.. Thus, liquid-based fertilizers are selected for this purpose. However, farmers often face challenges in supplying fertilizers with the required quantity and precision. To address this issue, we propose a solution that leverages solar energy to power a submersible pump, enabling the supply of stored rainwater and liquid fertilizer to each plant. To ensure a uniform rate of flow for both the liquid fertilizer and water, we design a venturimeter throat diameter optimized for strawberry plantations. This approach aims to minimize effort and optimize the utilization of natural resources such as rainwater and solar energy for sustainable and effective agriculture practices.

Keywords: Submersible pump, solar energy, venturimeter throat diameter, uniform rate of flow, strawberry plantation, and sustainable agriculture.

INTRODUCTION

A Venturimeter is a device used in fluid mechanics and engineering to measure the flow rate of a fluid, such as liquids or gases, via a pipeline. It was invented in the 18th century by the Italian physicist Giovanni Battista Venturi and has since become an indispensable instrument in industries like as water supply, oil and gas, chemical processing, and others [1]. The Venturimeter (Figure 1) works on the basis of Bernoulli's equation, which connects fluid pressure to velocity and elevation. Structure and Working Principle:

A Venturimeter is made up of a tube with a tapered constriction in the center. The fundamental structure consists of three major components:

The inlet section is the wide region of the tube where the fluid first enters. The fluid has a relatively low velocity and high pressure at this stage.

The throat section of the tube narrows, forcing the fluid to accelerate as it passes through. Due to Bernoulli's principle, which indicates that as the fluid's velocity increases, so does its pressure, this constriction causes a reduction in pressure [2].

The tube widens again in the output region after passing through the throat. The fluid travels towards the outlet as it slows down and regains part of its former pressure. The pressure difference between the inlet and throat sections is used to determine the flow rate of the fluid.

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Applications of Venturimeter

Flow Rate Measurement: Venturi meters are mostly used to determine the flow rate of various fluids. It is especially beneficial when reliable flow measurements are required for process control, billing, or monitoring system efficiency. Water distribution networks, oil and gas pipelines, and industrial operations are examples of common applications.

Water delivery Systems: Venturi meters are commonly used to measure the flow of water in municipal water delivery systems. They assist utilities in managing water distribution, allocating costs, and detecting pipeline problems. Chemical Processing: In chemical industries, accurate measurement and control of fluid flow are crucial for maintaining product quality and safety. Venturi meters play a vital role in monitoring and optimizing the flow of chemicals and raw materials in various processes [3].

Aerospace and Aviation: Venturi meters are employed in aircraft and rocket propulsion systems to measure the flow of fuel and air. This ensures proper combustion and engine performance.

Environmental Monitoring: Venturi meters are used in environmental monitoring systems to measure the flow of gases, such as air pollutants, in exhaust stacks and ventilation systems.

Hydroelectric Power Generation: In hydroelectric power plants, Venturi meters are used to measure the flow rate of water through penstocks, helping operators manage the generation of electricity efficiently.

Venturi meters are used in the oil and gas industry to measure the flow of crude oil, natural gas, and different fluids via pipelines and processing facilities [4].

HVAC Systems: Venturi meters are used in heating, ventilation, and air conditioning (HVAC) systems to control the flow of air and guarantee ideal temperature and ventilation in buildings.

In conclusion, Venturi meters are adaptable devices that are used to measure and control fluid flow in a variety of applications. Their precision, dependability, and versatility make them valuable tools in fluid dynamics and engineering.

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2 \quad (1)$$

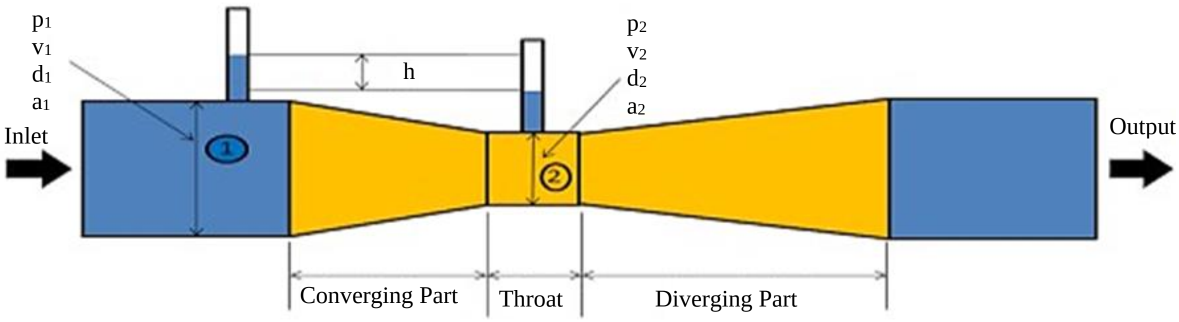

Figure 1. Venturimeter.

FLOW METER IN AGRICULTURE SECTOR

The demand for flow meters has multiplied in both cultivation and dam applications due to the increasing need for irrigation, water consumption, and the use of hydraulic energy stations for power supply. Flow meters play a crucial role in providing cultivators with accurate water flow measurements. This case study focuses on natural farming, an agricultural method that avoids the use of pesticides, fertilizers, genetically modified organisms, antibiotics, and growth hormones. However, even in natural farming, a sufficient and uniform flow of water is essential for successful crop production. In the context of strawberry plants, there are various planting methods, including flat beds, hill rows, matted rows, and raised beds. Planting on raised beds with dimensions of 4 × 4 meters is recommended. To ensure optimal spacing, the distance between plants should be 45 cm, while the distance between rows should be 60 cm, resulting in a total of 5445 plants [5].

Figure 2. Strawberry Plantation.

CALCULATION OF VENTURIMETER THROAT

The Strawberry Plantation (Figure 2), Covering An area of 2 acres will consist of 10,890 strawberry plants. To provide these plants with rich nutrients, a fertilizer-water mixture is used in the ratio of 1:4, where one part of fertilizer is mixed with four parts of water. The required nutrient quantities per acre per year are as follows: 93 kg of nitrogen, 70 kg of phosphorus, and 93 kg of potash.For the phosphorus requirement, it is advisable to incorporate the phosphatic fertilizer into the soil before planting. As for nitrogen, it should be applied in two doses -the first dose three weeks after planting and the second dose at the time of flowering. Potash, on the other hand, should be applied only at the time of flowering. Applying sufficient nitrogen in appropriate amounts results in a higher yield of early berries, with three weekly applications. Proper nutrient management is crucial for ensuring a productive and successful strawberry harvest [6–8].

No of Acres of land	= 2
For 2 Acres Mango plants	= 10890 Plants
Fertilizer required	= 10890 × 0.516 gm
	= 5620 gm
	= 5.62 Kgs
Fertilizer in liters	= 6 liters
Time for fertilizer Empty	= 128 seconds
Q_F	$= \frac{6}{360}$ =0.01666 lt/sec = 0.000017 m^3/sec

Submersible pump of 2 H.P with discharge of 0.0003795 m^3/sec, is chosen.Q_P = 0.0003795 m^3/sec

Total Discharge required is obtained by adding the discharge of chosen pump and discharge of thefertilizer.

$$Q_{Total} = Q_F + Q_P \qquad (2)$$

= 0.000017+0.0003795 = 0.000316

= 0.0004 m^3/secConsider,

Diameter of the throat = d_2

Diameter of the pipe = 0.03 m

Area of the throat $= \frac{\pi d}{4}$

Area of the pipe $= \frac{\pi d_1^2}{4} = 0.000706$ m^2

g = 9.81 m/sec^2

$$Q_{the} = \frac{A_1 \times A_2\sqrt{2g\delta h}}{\sqrt{A_2^2} - \sqrt{A_1^2}} \quad (3)$$

Coefficient of discharge = Q_{act}/Q_{the} (4)

C_d is the coefficient of discharge for venturimeter and its value is always less then 1, the value variesfrom (0.93-0.98)

H = Height of fertilizer in drum +Atmospheric pressure head

= 0.35 m + 10.3 m

=10.65

$$Q_{the} = \frac{A_1 \times A_2\sqrt{2g\delta h}}{-\sqrt{A_2^2}\sqrt{A_1^2}}$$

$$Q_{the} = \frac{0.0007 \times A_2 \times \sqrt{2 \times 9.81 \times 10.65}}{\sqrt{A_2^2 - A_1^2}}$$

Taking Q_{the} = 0.0004 m^3/sec on simplification A_2 = 0.00002742

D_2 = 0.0059 m

The throat diameter can be taken as 0.0006 m

DESIGN OF SOLAR PANELS OF 250 WATTS FOR 3-HP MOTOR SINGLE PHASE

Theoretically, a 3 Hp load works out to 3 × 746 = 2238 watts, say 2.3 KW.

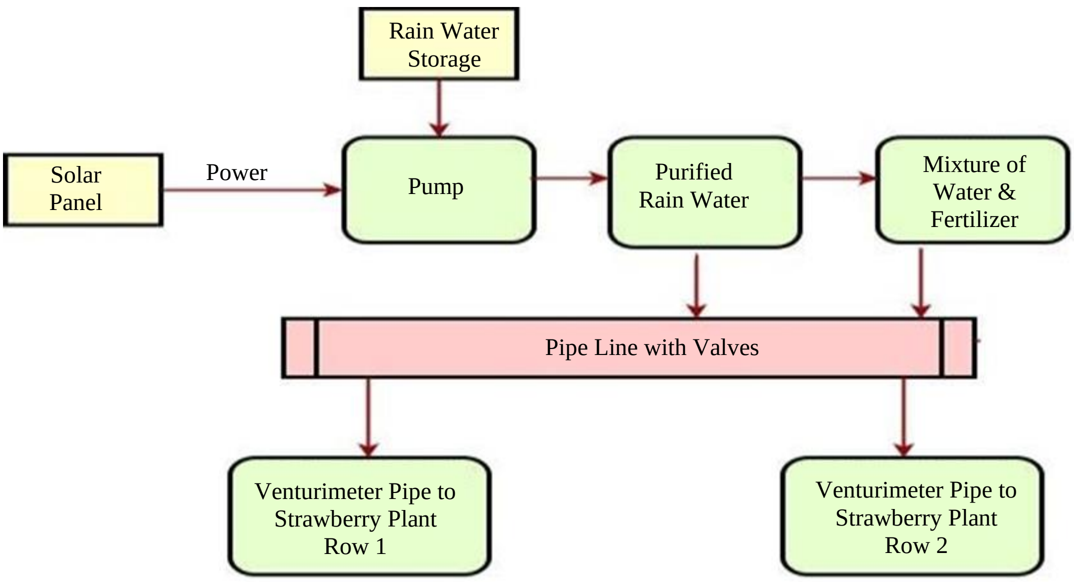

Figure 3. Strawberry Plantation with solar panel.

Most motors draw a higher starting current for short duration so we inflate the requirement to 2.5 KW. Second reason to inflate this is due to inductive power factor of say 0.8, so we need to produce more total power to feed 3.0 KW active power = 2.5/0.8 = 3.125 KW (Figure 3)

To generate 3.125 KW AC, if our inverter efficiency is 90% then DC power needed is 3.125/0.9 = 3.47 KW [9].

Most solar panels deliver slightly less power than that they are rated at, due to sun luminance, or angle or temperature in area. Typically a 200 watt solar panel may deliver up to 200 watts. So number of panels needed = 3.47 KW/200 watt = about 17.35 or 18 nos. In actual situation, the quality of panels, wiring, inverter and lastly the motor will greatly affect this calculation and you may end up either needing 19 or 23 panels as well (Figure 4).


Figure 4. Solar panel for 3 H.P pump.

Calculate the Size of Your Solar System

To figure out how to size your solar system, take your daily kWh energy requirement and divide it by your peak sun hours to get the kW output. Then divide the kW output by your panel's efficiency to getthe estimated number of solar panels you'll need for your system.

$$\text{(Daily kWh} \div \text{average sunhours)} \times 1.15 \text{ efficiency factor} = \text{DC solar systemsize} \tag{5}$$

Tables 1–3 shows the calulations

Sizing Battery Bank

The exact math for sizing your battery system is based on your daily power usage and the battery type.Based on usage of 10 kWh per day, here are some examples:

Lead Acid Sizing

$$10 \text{ kWh} \times 2 \text{ (for 50\% depth of discharge)} \times 1.2 \text{ (inefficiency factor)} = 24 \text{ kWh} \tag{6}$$

Battery capacity is specified either in kilowatt hours, or amp hours.Lithium Sizing

$$10 \text{ kWh} \times 1.2 \text{ (for 80\% depth of discharge)} \times 1.05 \text{ (inefficiency factor)} = 12.6 \text{ kWh} \tag{7}$$

For Lead Acid, 24 kWh is equal to:
(a) 2,000 amp hours at 12 volts
(b) 1,000 amp hours at 24 volts
(c) 500 amp hours at 48 volts

For Lithium, 12.6 kWh is equal to:
(d) 1,050 amp hours at 12 volts
(e) 525 amp hours at 24 volts
(f) 262.5 amp hours at 48 volts

Convertor

It converts the variable direct current (DC) output of a *photovoltaic (PV) solar panel* into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network [10]

Motor

The AC from the Solar panel pumps the motor.

Figure 5 and 6 shows the graphs on increase in the number of plants and increase in diameter.

Table 1. Calculated parameters of venturimeter

S.N.	Parameter	Value
1.	Throat Diameter	0.0006 m
2.	Discharge	0.0004 m^3/sec

Table 2. Diameter for different no of plants

S.N.	No of plants	Head	Throat diameter
1	10890	10.65 m	0.0006 m
2	5445	5.43 m	0.0003 m
3	2722	2.71 m	0.00015 m
4	1361	1.35 m	0.000075 m

Table 3. Solar panel calculations for 3 H.P motor

S.N.	Parameter	Value
1	DC power needed	3.47 KW.
2	No of panelsrequired	18-23
3	Lead acid sizing	24 kWh
4	Lithium Sizing	12.6 kWh

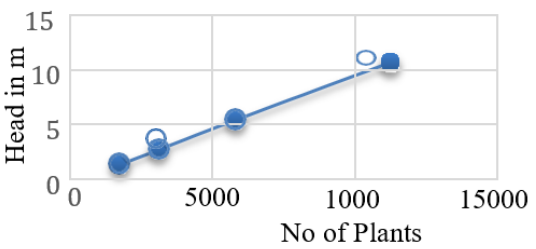

Figure 5. No of plants with Head in meters the graph indicates increase in no of plants require high head.

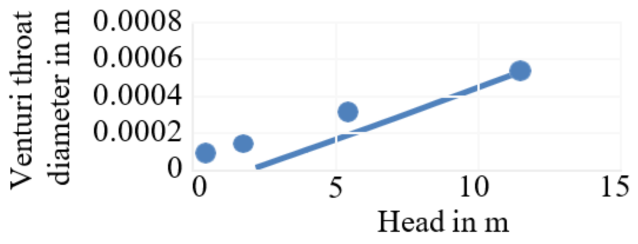

Figure 6. Head in meters with the venturimeter throat diameter the graph indicates increase in head requires larger throat diameter.

CONCLUSION

The design of the solar panel, submersible pump, and venturimeter throat is based on practical values gathered from a 2-acre strawberry field. The quantity of fertilizer needed may vary between different crops, seasons, and the specific nutrients required. Consequently, the throat diameter of the venturimeter is not standardized for all crops; it is adjusted based on the discharge quantity of the submerged pump. By determining the appropriate throat diameter, a uniform discharge quantity is achieved, minimizing fertilizer wastage and saving on fertilizer investments. Implementing this system requires minimal effort from farmers, as it ensures that all plantations receive a sufficient and required amount of fertilizers and water stored from rainwater. A loss coefficient reading has been calculated to determine the loss in pipe flow.. The results indicate that reducing the throat diameter when there are no plants and varying the head can help determine the minimum throat diameter required for smaller acres of land. This optimization approach enhances agricultural efficiency and resource utilization

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