

Solar Water Pump with Four Different Time Slots for Farming Activities

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Abstract

This project aims to design a water pump system that runs on solar power and has four different time slots to maximise water utilisation and encourage environmentally friendly farming methods. Farmers face several obstacles since typical water pump systems are unwieldy, noisy, and difficult to operate. The goals of this research are to utilise Arduino to design a solar water pump system that distributes water at four distinct times, to provide an intuitive interface for adjusting the time slot, and to determine the overall power consumption of the system. The methodology involves designing and implementing a control system using Arduino, motor, water pump, and PV solar panel, focusing on four distinct time slots: morning, afternoon, evening, and late evening. Quantitative results from the study indicate that the system consistently delivers reliable performance, providing a steady water flow of 8.5 to 10 liters per minute with a daily power consumption of approximately 72.9W. The system efficiently operates within designated time slots, ensuring optimal water distribution and energy usage. In conclusion, the solar water pump system featuring four distinct time slots exhibits noteworthy advantages concerning energy efficiency, cost-effectiveness, and ecological effects. The initiative promotes sustainable water management, enhances the quality of life in rural communities, and shows the possibility for scalable and flexible renewable energy solutions in agricultural activities. The efficiency and affordability of such systems might be improved with more study and development, opening the door for wider use and promoting a sustainable future.

1. Introduction

Solar power refers to the conversion of energy from sunlight into electricity using photovoltaic cells or solar panels [1]. This process harnesses the energy produced by the sun's rays and transforms it into a usable form of electrical power. Solar power is a renewable and sustainable energy source, as it relies on the abundant and inexhaustible energy provided by the sun. Solar-powered water pumps operate by turning the sun's rays (photons) into electricity to power the pump [2]. It uses solar panels to capture photons (units of light) from the sun, resulting in direct current (DC) that powers the motor to pump water away from its source [2]. This is a clean way to pump water and increase production and efficiency for farms and other agricultural uses [3]. There is some importance of having solar as a source of energy for water pumps. One of them is that they provide an independent and reliable energy source, reducing dependence on conventional fuels and electricity grids [4].

Besides, Solar-powered water pumps produce clean energy without generating greenhouse gas emissions, contributing to a reduction in carbon footprint [5]. A solar water pump with four different time slots is a specialized irrigation system designed for farms. It integrates solar energy to power a water pump, and it includes a controller with programmable settings for four distinct periods. This system enables precise control over irrigation, optimizes water usage, and maximizes the use of renewable energy from solar panels.

2. Literature Review

2.1 Design of solar water pump

Research on solar water pumps covers various aspects, including design and operational efficiency. Akshay Prajapati (2018) explored the use of a Real Time Clock (RTC) interfaced with an Arduino to operate water pumps at specific time intervals, enhancing energy savings [6]. The system commands the pump motor to turn on and off according to programmed times, ensuring efficient water management. Ibrahim Alkhubaizi (2017) focused on the structure of solar water pumps, highlighting the central powerhouse consisting of a calibrated solar array. This setup ensures the system can meet diverse water demands, from irrigation to household usage, by efficiently processing electrical water pumps [7]. The effectiveness of these pumps is often gauged by the size of the required solar array. While, Jugendra Singh (2017) emphasized the use of PV solar panels in agriculture, reporting that their solar water pump system could deliver an average of 620 L/day at a delivery head of 8-10 feet. Despite some limitations, the system proved cost-efficient for agricultural operations [8].

Rajesh (2017) introduced a micro-controller-based circuit design for solar-powered irrigation. The system includes modules for energy conversion, motor operation, and sensor-based automation, forming a comprehensive solar-powered irrigation setup [9]. Lastly, Shoyo (2023) developed a system for measuring turbidity and pH in solar water pumps. When safe levels are detected, the system allows water to flow from the tank to the supply [10]. If dangerous turbidity levels are detected, the Arduino sends a signal to shut off the valve and redirect the water for purification.

2.2 Type of pumps in solar water pump system

Several studies have explored various types of pumps used in solar water pump systems, each focusing on different applications and performance metrics. Raden (2019) investigated a DC-based submersible water pump system for household use in rural areas, emphasizing the importance of water flow rate, total head value, and pump power consumption in determining efficiency [11]. The study found that the pump performance curve (PPC) can still indicate the operational total head range based on maximum efficiency, even if the actual water flow rate differs from the datasheet. Sujoy Ranjan Nath (2016) compared centrifugal and diaphragm pumps in solar photovoltaic (SPV) systems. The study revealed that centrifugal pumps increase in efficiency with more sun radiation, whereas diaphragm pumps decrease [12]. Consequently, centrifugal pumps are better for low-head small-scale applications, while diaphragm pumps perform better for high-head applications. Levon Govorkov (2021) focused on centrifugal pumps for agricultural and domestic water transportation, highlighting a simplified, cost-effective solar water pumping system without the need for battery storage [13].

While Andre Burta (2021) designed a circulation pump controlled by Pulse Width Modulation (PWM) to efficiently regulate water flow between solar system water tanks [14]. The system demonstrated adaptability to different communication protocols, enhancing its functionality. Ramzy E. Katan (1996) discussed the helical rotor pump's performance in solar water systems, noting the challenges of directly powering these pumps from a photovoltaic array due to their flat torque-speed characteristics [15]. Finally, Wu Hui (2022) studied jet pumps, using the Discrete Phase Model (DPM) to simulate the impact of sand particles on pump performance. The study found that medium-sized sand particles (0.8mm) caused the most significant abrasion, with wear patterns intensifying as particle size increased up to 1.4mm, beyond which wear diminished [16]. These findings provide a comprehensive understanding of different pump types and their suitability for various solar water pumping applications.

3. Methodology

Fig. 1 shows the flowchart of the water pump system. The process starts with initializing the Arduino timer, crucial for managing time-based operations. The system continuously reads the current time from the Arduino's internal clock to determine if the water pump should be on or off. The current time is compared with predefined time slots for pump operation. If the time fits within these slots, the pump is activated; otherwise, it is turned off. The flowchart depicts this continuous loop of reading the time and checking against the time slots.

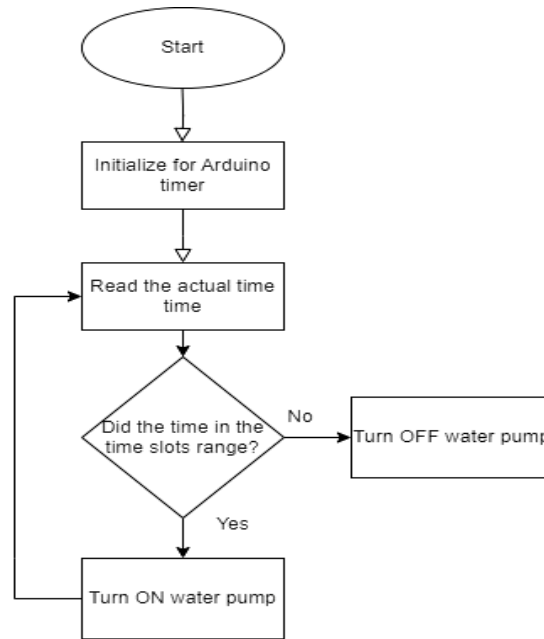


Fig. 1 Flowchart of the water pump system

3.1 Complete Prototype

Fig. 2 shows the complete prototype of a solar water pump system with four-time slots. The solar panel connects to a battery charging circuit via a solar charge controller, which outputs to a 12V battery. An Arduino Uno is powered by a battery and controls the water pumps through a relay module. The relay's VCC and GND are connected to the Arduino's 5V and GND pins, with the control pin (IN) on digital pin 8. The relay's Normally Open (NO) terminal connects to one terminal of the water pump, while the other terminal connects to the battery's positive terminal. The Common (COM) terminal connects to the battery's negative terminal. This setup allows the water pump to operate in four different time slots.

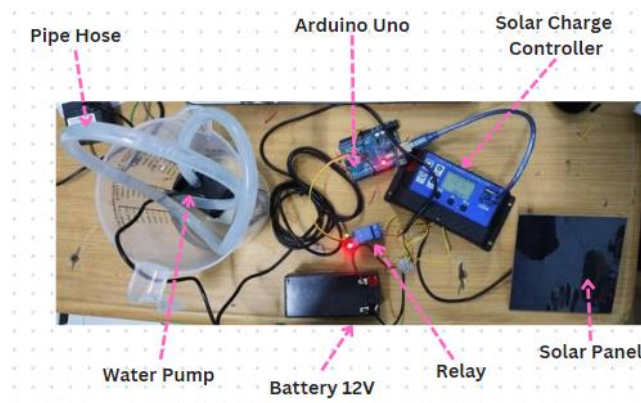


Fig. 2 Complete Prototype

3.2 Time Slot Programming

Using an Arduino timer, different time slots for the pump to operate can be programmed. The exact time slots for the water to be distributed:

Slot 1: 9:00 am - 10:00 am

Slot 2: 12:00 pm - 1:00 pm

Slot 3: 2:00 pm - 3:00 pm

Slot 4: 4:00 pm - 5:00 pm

4. Results and Discussion

This chapter details practical findings from extensive testing and observation of the pump's behavior during specific time frames. It begins with data on pump voltages, currents, power consumptions and pump rate of flow within the set periods. Additionally, this chapter emphasizes the system's potential for sustainable water management and adaptability in various settings, providing insights, implications, and directions for further research and practical use.

4.1 Voltages

Table 1 presents the water pump voltages during each time slot of the experiment. The solar panel outputs 18V, while the fully charged battery maintains 12.5V for the pump. At 12:00 pm, peak sunlight hours, the panel continues to supply 18V, but the battery drops slightly to 12.3V due to usage. By 2:00 pm, the panel outputs 12V, indicating a moderate charge level, and the battery matches this. In the final time slot, the panel supplies 11.8V under moderate sunlight, and the battery maintains 11.8V. The solar panel voltage varies with sunlight intensity, affecting the water pump voltages. Fig.3 illustrates the voltage decrease over time, correlating with reduced sunlight intensity.

Table 1 Results of water pump voltages during each time slot

Time slots (AM/PM)	9:00	12:00	14:00	16:00
Voltages (V)	12.5	12.3	12	11.8

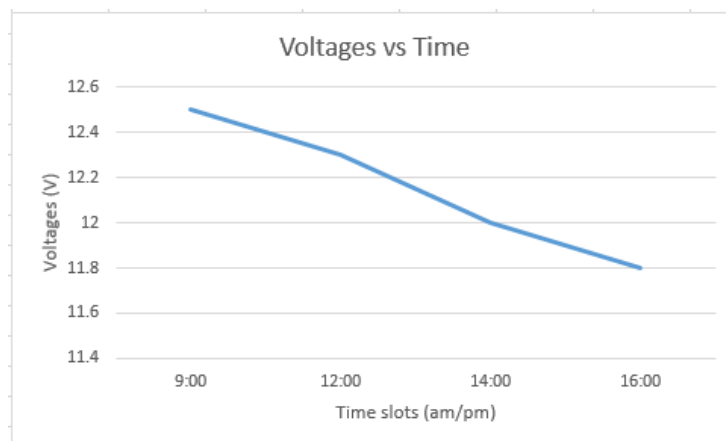


Fig. 3 Water pump voltages vs Time

4.2 Currents

Table 2 shows the water pump currents for each time slot obtained during experiments. In the first time slot, the solar panel produces 4A, generating 72W, with the water pump drawing 1.5A from the battery. In the second slot, the solar panel still supplies 4A and 72W, with the pump drawing 1.5A. In the third slot, the solar panel current decreases to 2A, resulting in 24W, but the pump still draws 1.5A. In the last slot, the solar panel current drops to 1.5A due to low sunlight, with the pump maintaining a constant 1.5A. This shows that the water pump current remains constant.

Table 2 Results of water pump currents during each time slot

Time slots (AM/PM)	9:00	12:00	14:00	16:00
Currents (A)	1.5	1.5	1.5	1.5

4.3 Power Consumptions

Table 3 shows the results for the water pump power consumption. In the first slot, the water pump uses about 18.75W, efficiently utilizing stored battery energy. In the next slot, it consumes around 18.45W due to a slight drop in battery voltage. For the third slot, consumption is about 18W. In the last slot, the pump uses approximately 17.7W as voltage decreases. Fig. 4 shows that power consumption decreases over time. The total daily power consumption of the water pump is about 72.9W.

Table 3 Results of power consumption from each time slot

Time slots (AM/PM)	9:00	12:00	14:00	16:00
Power (W)	18.75	18.45	18	17.7

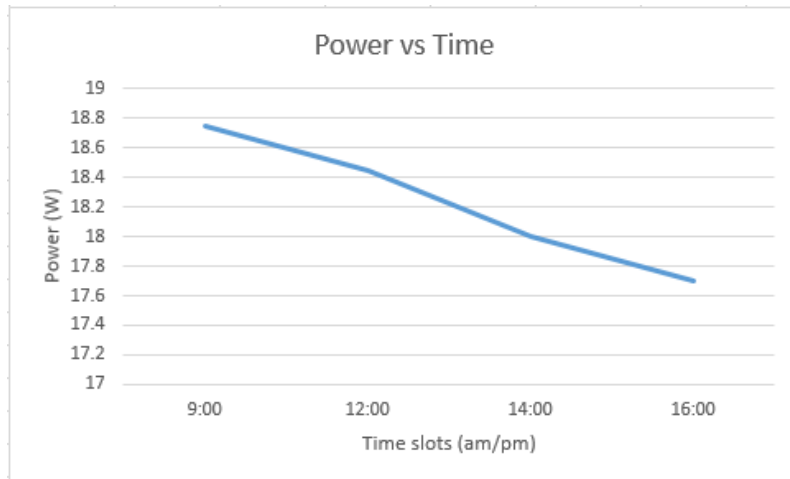


Fig. 4 Graph Power Consumptions vs Time

4.4 Rate of flow

Table 4 indicates the result of water pump rate of flow results. Initially, the water pump operates at an optimal flow of 10 liters per minute due to good sunlight intensity. In the next slot, the flow slightly decreases to 9.8 liters per minute due to a minor battery voltage drop. The flow continues to drop to 9 liters per minute in the third slot, reflecting reduced power availability. In the last slot, the flow rate further decreases to 8.5 liters per minute, indicating reduced voltage and power from the battery. Fig.5 illustrates this decreasing trend in the pump's flow rate.

Table 4 Rate of flow results

Time slots (AM/PM)	9:00	12:00	14:00	16:00
Rate of flow (liters/min)	10	9.8	9	8.5

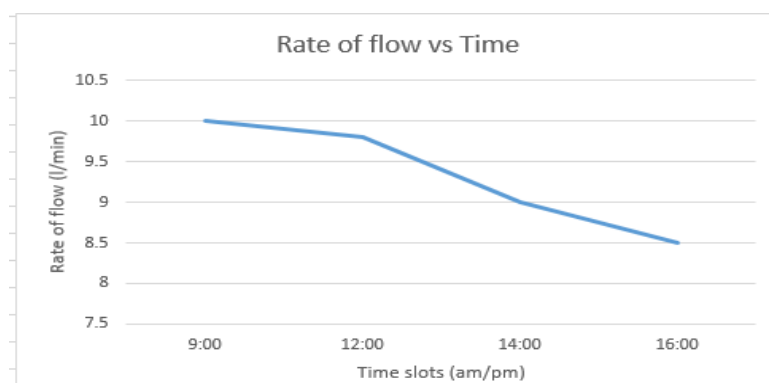


Fig. 5 Graph Rate of Flow vs Time

5. Conclusion

The Solar Water Pump with Four Different Time Slots study investigates the potential and efficiency of using solar energy for water pumps, especially in areas lacking conventional electricity. This sustainable solution addresses water management needs in remote and agricultural regions. The system consistently delivered reliable performance, maintaining a steady water flow essential for crop growth and productivity. The pump's daily power consumption is low, at only 72.9W, and the flow rate ranges from 8.5 to 10 liters per minute. Implementing four-time slots optimized water usage and energy consumption by aligning pump operation with peak sunlight hours, maximizing energy capture and minimizing wastage. This scheduling improved water management for irrigation and domestic use. The project's scalability and adaptability allow it to be tailored to various agricultural operations, from small farms to larger setups, with easy expansion or modification. In conclusion, the Solar Water Pump with Four Different Time Slots project demonstrated the effectiveness of solar-powered water pumps. The results showed high energy efficiency, economic savings, and positive environmental impact. The time-based operation ensures optimal water and energy use, making it a robust solution for sustainable water management. This project highlights the potential of renewable energy technologies to transform agricultural practices and improve life in rural and remote areas. Further research and development could enhance the efficiency and affordability of solar water pumps, leading to widespread adoption and a more sustainable future.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Muhammad Ikhsan Isham, Khairun Nidzam Ramli; **data collection:** Muhammad Ikhsan Isham; **analysis and interpretation of results:** Muhammad Ikhsan Isham, Khairun Nidzam Ramli; **draft manuscript preparation:** Muhammad Ikhsan Isham. All authors reviewed the results and approved the final version of the manuscript.*

References

- [1] S. Khan, "Things that you must know about the hand pump water," Ek Plate Biryani, <https://ekplatebiryani.com/hand-pump-water/> (accessed Apr. 2, 2024).
- [2] A. John, "5 common problem of water pump and solutions: Pump Supplies," Pump Supplies, <https://pumpsupplies.co.uk/5-common-problem-of-water-pump-and-solutions/> (accessed Apr. 2, 2024).
- [3] Radware bot manager Captcha, <https://iopscience.iop.org/article/10.1088/1757-899X/233/1/012002/pdf> (accessed Apr. 2, 2024).
- [4] "How does solar work?," Energy.gov, <https://www.energy.gov/eere/solar/how-does-solar-work#:~:text=Solar%20technologies%20convert%20sunlight%20into,in%20batteries%20or%20thermal%20storage> (accessed Dec. 25, 2023).
- [5] H. W. Media, "Solar Pumping explained: How do solar-powered water pumps work?: HWI," Healing Waters International, <https://healingwaters.org/how-do-solar-powered-water-pumps-work/> (accessed Dec. 25, 2023).
- [6] "Implementation of solar water pump controlled with four different times for power saving applications," International Journal of Advance Engineering and Research Development, vol. 4, no. 05, 2017. doi:10.21090/ijaerd.70985
- [7] I. Alkhubaizi, "Solar Water Pump," International Journal of Engineering Research and Applications, vol. 07, no. 05, pp. 01–05, 2017. doi:10.9790/9622-0705030105
- [8] J. Singh, R. K. Rawal, S. Ali, and R. Ali, STUDY ON SOLAR BASED WATER PUMP SYSTEM, Jul. 2017.
- [9] R. K. Megalingam and V. V. Gedela, "Solar-powered automated water pumping system for eco-friendly irrigation," 2017 International Conference on Inventive Computing and Informatics (ICICI), Coimbatore, India, 2017, pp. 623-626, doi: 10.1109/ICICI.2017.8365208.
- [10] S. H. Shovo and S. Karmarker, "Solar Based Smart Water Pump Control with Turbidity and pH Measuring System," 2023 3rd International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST), Dhaka, Bangladesh, 2023, pp. 223-227, doi: 10.1109/ICREST57604.2023.10070048.

- [11] R. A. Ardiansyah, M. Luthfi and C. Hudaya, "Performance Analysis of Solar-Powered Submersible DC Water Pump," 2019 IEEE International Conference on Innovative Research and Development (ICIRD), Jakarta, Indonesia, 2019, pp. 1-5, doi: 10.1109/ICIRD47319.2019.9074731.
- [12] S. R. Nath and R. Mandal, "Some studies on performance analysis of two different laboratory scale solar photovoltaic water pumping in irrigation systems," 2016 21st Century Energy Needs - Materials, Systems and Applications (ICTFCEN), Kharagpur, India, 2016, pp. 1-4, doi: 10.1109/ICTFCEN.2016.8052739.
- [13] L. Gevorkov and I. Kirpichnikova, "Model of Solar Photovoltaic Water Pumping System for Domestic Application," 2021 28th International Workshop on Electric Drives: Improving Reliability of Electric Drives (IWED), Moscow, Russia, 2021, pp. 1-5, doi: 10.1109/IWED52055.2021.9376393.
- [14] A. Burta, R. Szabo and A. Gontean, "Simple PWM Generation using Serial Interface for a Circulation Pump used in Solar Water Heaters," 2021 6th International Conference on Smart and Sustainable Technologies (SpliTech), Bol and Split, Croatia, 2021, pp. 1-4, doi: 10.23919/SpliTech52315.2021.9566386.
- [15] R. E. Katan, V. G. Agelidis and C. V. Nayar, "Performance analysis of a solar water pumping system," Proceedings of International Conference on Power Electronics, Drives and Energy Systems for Industrial Growth, New Delhi, India, 1996, pp. 81-87 vol.1, doi: 10.1109/PEDES.1996.537286.
- [16] Wang, W., Gao, C., Duran, J., Manuel, M. C., & Tayactac, R., "Research on Erosion and Wear of Jet Pump by Different Sand Particle Size Based on DPM Method," 2022 IEEE 13th International Conference on Mechanical and Intelligent Manufacturing Technologies (ICMIMT), Cape Town, South Africa, 2022, pp. 115-119, doi: 10.1109/ICMIMT55556.2022.9845263.