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IoT Based Solar Powered Fertilizer Sprayer

Gayathri Devi G.[1], Dhanavi M.[2]

[1]Assistant Professor, [2]Student, Department of Electrical and Electronics Engineering, AMC Engineering College, Visvesvaraya Technological University, Bengaluru, India.

E-mail: [1]gayathridevi.gopinathan@amceducation.in, [2]dhanavi.shritijha@gmail.com

Abstract

The increasing demand for sustainable and energy-efficient agricultural practices has increased the need to develop smart farming systems. This research study presents the design and implementation of a solar-powered IoT-based fertilizer sprayer, a sustainable and economical approach to the traditional application of fertilizers. The proposed system uses renewable solar power sources, wireless communication based on the Internet of Things, and automated fertilizer spraying system for increasing the precision of fertilizer spreading process. A photovoltaic panel harvests solar power to charge the battery of the proposed sprayer in order to make it energy-efficient and sustainable for use in agricultural fields. The proposed sprayer is designed on the basis of an ESP32 microcontroller, which is capable of performing both computations and wireless communications. Using solar power and reducing the manual labour contribute to the improved agricultural efficiency and resource utilization.

Keywords: Internet of Things (IoT), Solar Energy, Fertilizer Sprayer, Smart Agriculture, ESP32, Automation, Renewable Energy.

1. Introduction

Agriculture plays a major role in sustaining the global population and supporting economic development. Recent agriculture techniques have encountered several challenges, including increasing food demand, scarcity of natural resources, increased labor costs, and issues related to the environment because of the increased use of fertilizers in farming. Fertilizer application techniques have been highly laborious, ineffective, and unequal in terms of application, leading to the wastage of resources and low productivity.

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The recent development of IoT technology and renewable energy systems increase the possibility for the emergence of smart agriculture systems. IoT technology enables real-time monitoring and remote control of farming operations. Renewable energy sources such as solar energy serve as a sustainable alternative for conventional energy sources. The integration of these technologies may significantly increase the resource utilization and reduce operational costs in agricultural applications.

The design of the sprayer includes a photovoltaic solar panel to recharge the battery which provides electricity for constant functioning without any reliance on additional sources of electricity. The processing part of the sprayer is based on the ESP32 microcontroller that performs all functions related to control of processes within the sprayer, while enabling wireless operation. It uses Bluetooth technology and the Dabble application to connect a smartphone to the sprayer.

The integration of solar energy, IoT technology, and spraying system in the designed spraying device is beneficial for sustainable farming and increased agricultural production.

2. Related Works

The recent innovations in the field of smart agriculture are more focused on the utilization of renewable energy in automated spraying devices. Accordingly, the solar powered seed sprayer machine was designed by Al-Talib et al. [1] to minimize the reliance on the use of fuel. Likewise, Khule et al. [2] designed a solar powered seed sprayer machine.

The integration of the Internet of Things (IoT) technology has added to the effectiveness of agricultural spraying machines. Choudhary et al. [3] have introduced an IoT-based multiple spraying machine along with wireless monitoring. Their contribution emphasizes the advantages of using wireless technology in the process of making the detection more accurate and minimizing the involvement of human labor. Ahalya et al. [4] developed a similar solar-powered pesticide sprayer for vineyards.

Some recent research works focus on developing multifunctional and intelligent spraying systems. For example, Doke et al. [5] invented a solar powered pesticide sprayer that is multifunctional and portable. Similarly, Mallan et al. [6] introduced an intelligent solar powered automatic fertilizer sprayer to increase agriculture production. Again, Mulani and

Karande [7] recommended precision farming by using an intelligent solar powered pesticide sprayer.

Remote-control capabilities have become an important feature in modern agriculture. Kayode et al. [8] developed a remotely controlled solar power-driven pesticide sprayer vehicle that works at a relatively safe distance by reducing direct contact with dangerous chemicals. Ngoma and Masenga [9] designed a remote-controlled solar power-driven pesticide and herbicides sprayer for modern agriculture.

Environmental sustainability is another area that has received significant attention in recent times. Rahman & Mohamad [10] proposed a solar power integrated sustainable system, which can be used to spray insecticide for crops. The combination of renewable energy and effective spraying techniques play a major role in incorporating sustainable farming practices.

Although, the recent studies have successfully demonstrated the advantages of solar-powered and IoT-enabled agricultural sprayers, several limitations remain unaddressed. Many of these designs concentrate mainly on the spraying of pesticides, have very little or no user interface, or do not have a control mechanism that is user friendly and cheap to use by small-scale farmers. There are other challenges like communication range, battery life management, and user convenience that still make it difficult. To address these challenges, the proposed system integrates solar-powered operation, Bluetooth-based wireless communication using the ESP32 microcontroller, and smartphone-based control through the Dabble application. This combination provides a low-cost, energy-efficient, and user-friendly fertilizer spraying solution that supports sustainable agriculture.

3. Proposed Methodology

3.1 System Overview

The proposed solar-powered IoT fertilizer sprayer provides a suitable energy-efficient, and cost-effective method of applying fertilizer to agricultural land. The system utilizes solar energy as the main source of power and wireless communication technologies that make it possible to control the operation of the sprayer via a smartphone. The designed fertilizer sprayer reduces the human effort while ensuring efficient fertilizer delivery.

3.2 Working Principle

The proposed model starts with solar panels absorbing sun rays and converting them into electricity. The electricity that is generated with the help of solar charge and stored in a 12-volt rechargeable battery. The stored electricity is used for powering ESP32 microcontroller, DC motors, water pump, and other electronic components.

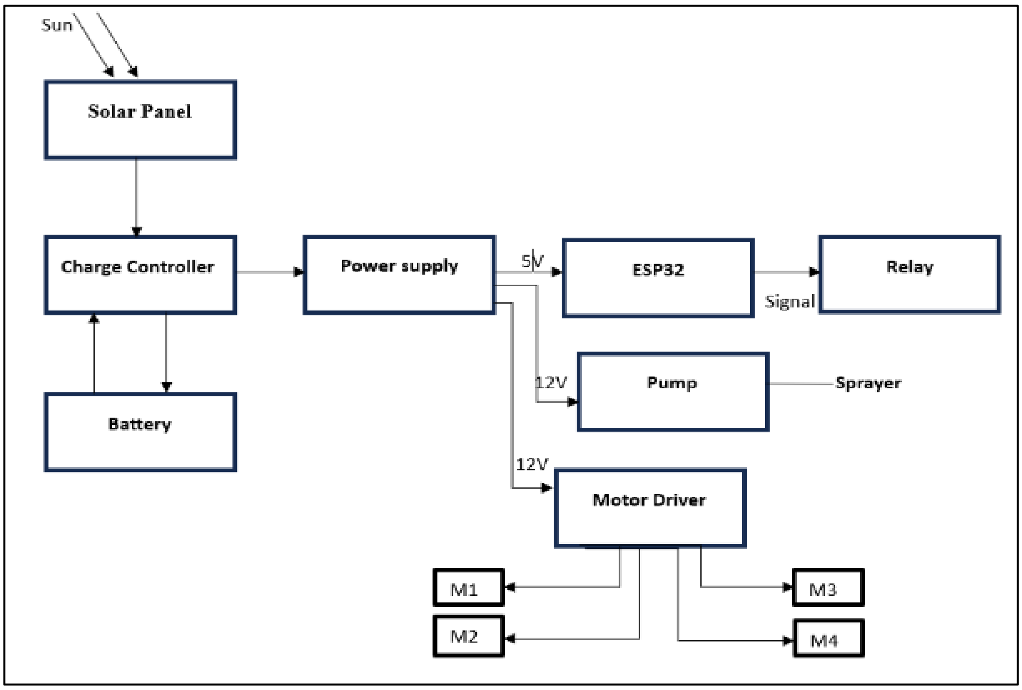

Figure 1. Block diagram of the IoT-based solar-powered fertilizer sprayer system

Figure 1 shows the hardware design of the proposed fertilizer sprayer system. The energy produced by the solar panel is regulated using the charge controller and stored in the battery to ensure continued operation. The stored energy is then supplied to various components depending on the required voltage using the power supply unit. The ESP32 microcontroller acts as a decision-making component to regulate the function of the sprayer by receiving the instructions wirelessly from the user. The motor driver component helps in connecting the controller to the drive motors, which help to move the vehicle within the field. The relay functions as a switch that controls the activation of the pump to release the fertilizer.

The ESP32 microcontroller functions as the master control component of the entire setup. It is programmed with the use of Arduino IDE and controls the movement of the sprayer. Bluetooth technology is used for connecting the ESP32 microcontroller with the Dabble mobile application such that farmers are able to control the device from smartphones.

The fertilizer solution stored in the tank is supplied using a 12-volt DC pump and sprayed uniformly on the crops. The proposed system will support the use of soluble fertilizers such as urea, potassium nitrate, mono ammonium phosphate, and liquid organic fertilizers like seaweed extracts and fish emulsions. These types of fertilizers are very easy to dissolve in water and facilitate better plant growth and production.

Table 1. Hardware components and specifications of the proposed fertilizer sprayer

S.No	Component	Specification	Function
1	Solar Panel	12 V Photovoltaic Panel	Converts solar energy into electrical energy
2	Solar Charge Controller	12 V, 10 A	Regulates battery charging and discharging
3	Rechargeable Battery	12 V, 1.3 Ah	Stores electrical energy
4	ESP32 Development Board	Wi-Fi & Bluetooth Enabled	Main controller for system operation
5	Motor Driver Module	L298N	Controls DC motor movement
6	Relay Module	5 V Single Channel	Switches the fertilizer pump ON/OFF
7	DC Motors	100 RPM, 12 V	Drives the sprayer vehicle
8	DC Pump	12 V, 8 W	Pumps fertilizer solution to the nozzle
9	Fertilizer Tank	5 L Capacity	Stores liquid fertilizer solution
10	Spray Nozzle	Adjustable Type	Sprays fertilizer uniformly
11	Chassis Frame	Mild Steel/Acrylic	Supports all system components
12	Wheels	Plastic/Rubber	Enables vehicle movement
13	Dabble Mobile Application	Android Application	Provides wireless control interface
14	Connecting Wires	Copper Conductors	Electrical interconnections

Hardware configuration for the designed fertilizer sprayer entails several interrelated parts, as described in Table 1. The solar panel acts as the primary source of renewable energy that powers the 12 V battery through the solar charger. The battery powers all the modules in the proposed system. The ESP32 microcontroller acts as a control unit for the entire system and control the system operation through the smartphone application using the Bluetooth communication interface. The L298N motor driver acts as an interface between the ESP32 and DC motors, making it possible for the system to be moved remotely through control of the motors. The relay module is utilized in switching the fertilizer pump ON and OFF in accordance with the commands issued by the controller. The 12V DC pump delivers the fertilizer uniformly across the agricultural field.

4. Results and Discussion

The developed IoT-enabled solar-powered fertilizer sprayer device is designed to allow efficient and accurate fertilization through automation. With the incorporation of both IoT and solar energy, the system becomes less reliant on traditional energy sources and also requires less labour. The renewable energy source allows for sustainable functioning of the device, conserves energy and also prevents environmental pollution. Real-time monitoring and control increase the fertilizer utilization efficiency and crop yield. In addition, the system promotes green farming by using organic fertilizers.

Figure 2 shows the developed IoT-enabled solar power-driven fertilizer sprayer from different perspectives, showing its overall design and hardware configuration. The device is mounted on a mobile wheeled platform and is made up of a solar panel, fertilizer storage container, spraying head assembly, and electronic control components. The side view shows the structure and mobility of the device, while the front and top views show the configuration of the solar energy harvesting component and the spraying device.

Figure 2. Fabricated IoT-based Solar-powered fertilizer sprayer prototype

The solar panel serves as the primary energy source and supplies energy to both the control module and actuator module, by eliminating the reliance on traditional energy sources. The built-in fertilizer tank along with the sprayer nozzle helps to achieve the accurate delivery of fertilizers, while the IoT-based control system ensures efficient monitoring and control. The renewable energy, wireless control, and automation of spraying increases the fertilizer usage efficiency and decreases human labour, and promotes sustainable agricultural practices.

4.1 Field Testing and Validation

The actual performance of the implemented IoT-driven solar-operated fertilizer sprayer was determined by performing a test operation on-site under real conditions using the developed system prototype. The device was made up of a 12V rechargeable battery, an 8W DC fertilizer pump having a flow rate of 10L per minute, a 10A solar charge controller, and a 12V photovoltaic solar panel. The device was controlled wirelessly by the Dabble mobile app through the Bluetooth connection of the ESP32 microcontroller.

Experiments were conducted in an open agricultural environment that received around 4 to 5 hours of direct sunlight per day. A solution of organic fertilizer that had been made by diluting seaweed extract in water was loaded in a 5-liter capacity fertilizer tank and utilized for testing purpose. The major purpose of this test was to evaluate the efficacy, battery life, solar charging abilities, and operational reliability of the device.

Table 2. Performance evaluation of the proposed fertilizer sprayer

Parameter	Measured Value
Spray Rate	9.5–10 L/min
Spray Coverage Area	25–30 m² per 5 L tank
Battery Backup Time	60–70 min of continuous operation
Solar Charging Duration	4–5 h for full charge
Fertilizer Utilization Rate	200 ml per 10 m² (diluted liquid fertilizer)

Table 2 summarizes the performance parameters obtained during field testing. The experimental result shows that the proposed sprayer is capable of delivering fertilizer uniformly across the target area with reduced wastage. The 12 V DC pump ensured the steady flow rate throughout the entire experiment, providing the necessary flow rate of the fertilizer. The coverage area reached 25-30 m² with the use of one 5-liter tank.

The battery performance of the battery has been determined satisfactory, providing approximately 60–70 minutes of continuous operation on a full charge, as indicated in Table III. In addition to this, the battery could easily be recharged through the solar power charging process in 4-5 hours of light exposure with a maintained voltage level of about 12.6 V.

Table 3. Battery performance evaluation of the proposed fertilizer sprayer

Parameter	Value
Battery Capacity	12 V, 1.3 Ah
Theoretical Backup Time	117 min
Practical Backup Time	60–70 min
Solar Charging Time	4–5 h

The Bluetooth-controlled interface allowed for reliable communication between the smartphone and the ESP32 controlled circuit for starting, stopping, and controlling the sprayer. There were no communication errors recorded throughout the testing process. Additionally, the spraying mechanism operated without nozzle, leakages, or malfunctioning of the pumping system.

Overall, the validation results obtained from field prove the efficiency of the proposed system, which is also energy-independent and convenient for users. The integration of solar power supply, wireless controller, and automated spraying technologies help to reduce labor costs and increase the efficiency of fertilizer utilization. The proposed system can be used in real-time on a larger scale, since the size of batteries, solar panels, and fertilizer tanks can be increased.

4.2 Fertilizer Compounds Used

The proposed fertilizer sprayer is designed to operate with various water-soluble and liquid organic fertilizers commonly used in agricultural applications. These fertilizers can be diluted with water and sprayed uniformly through the nozzle assembly without causing blockage or affecting pump performance. During field testing, a seaweed extract-based liquid fertilizer was selected due to its eco-friendly nature and ability to enhance plant growth and stress resistance. The fertilizer compounds compatible with the proposed system are listed in Table 4.

The proposed fertilizer sprayer is designed with different types of water-soluble and liquid organic fertilizers that are often used in farming operations. Such fertilizers may be mixed with water and sprayed through the nozzle unit without experiencing any blockage or impacting pump operation. The different types of fertilizer compounds suitable for the suggested device are presented in Table 4.

Table 4. Fertilizer compounds compatible with the proposed sprayer

S.No	Fertilizer Compound	Chemical Formula	Type	Purpose
1	Urea	$CO(NH_2)_2$	Nitrogen Fertilizer	Promotes vegetative growth and improves leaf development
2	Potassium Nitrate	KNO_3	NPK Fertilizer	Supplies nitrogen and potassium for healthy plant growth
3	Mono-Ammonium Phosphate (MAP)	$NH_4H_2PO_4$	Phosphatic Fertilizer	Enhances root development and flowering
4	Seaweed Extract	Organic Compound	Organic Fertilizer	Improves plant growth, nutrient absorption, and stress tolerance
5	Fish Emulsion	Organic Nutrient Solution	Organic Fertilizer	Provides nitrogen, micronutrients, and organic matter

Among these fertilizers, seaweed extract, which is diluted in water, was used in the testing process of this prototype. The test result showed in the system performed perfectly in terms of smooth pumping and even spraying without any clogging of the nozzles or leakage. The ability of the system to handle different fertilizer solutions increase its versatility and suitability for various agricultural crops and farming practices

4.3 Limitations

Although the proposed IoT based fertilizer sprayer using solar energy performed well during its test results, also there are still some limitations. The IoT based fertilizer sprayer uses solar energy as its main source of power. Therefore, its performance might get affected when the weather is not sunny. The use of Bluetooth as its main communication protocol limits the range of the user from the sprayer. Presently, the system is only suited for small to medium scale agricultural farming due to the size of the battery, solar panels and fertilizer tanks used in the device. In addition, the system does not have intelligent sensor technology for detecting soil nutrients, obstacles and also path navigation capabilities. Also, the spraying of the fertilizers is done manually through the mobile application, thus the spray accuracy depends on the user.

5. Conclusion

The proposed IoT-based solar-powered fertilizer sprayer with combined solar energy, ESP32 microcontroller, wireless Bluetooth control, and spraying mechanism has greatly reduced manual labour and improved fertilizer application efficiency. The tests performed in the field showed the reliability of the device and its ability to work with the speed of 9.5 – 10 L/min and cover 25 – 30 m^2 per tank, and continuous operation up to 70 minutes on a fully charged battery. The solar charging system successfully enabled sustainable operation without depending on external power sources. Furthermore, the proposed sprayer effectively handled various water-soluble and organic fertilizers, ensuring uniform distribution without causing any leakage. The designed system enhanced precision agriculture by optimizing resource utilization and reducing operational costs. Future enhancements may include Wi-Fi connectivity, GPS-based navigation, cloud monitoring, and sensor-based automation to further enhance the system intelligence, efficiency, and scalability for large-scale farming applications.

References

[1] Al-Talib, Ammar AM, Yap Chee Xian, Ain Atiqa, and Nor Fazilah Abdullah. "Solar Powered Seed Sprayer Machine." International Conference on Artificial Life and Robotics (ICAROB) 2023: 678-682.

[2] Khule, R. B., Kundan Gahukar, Bhawar Ninawe, and Saurabh Balbudhe. "Development and Manufacture of Solar Power Seed Sprayer Machine." International Journal for Research in Applied Science & Engineering Technology (IJRASET), 2024, vol 12, no. 4: 1-8

[3] Choudhary, Swapna, Kamlesh Kalbande, and Nitin Dhote. "IoT based multi-point pesticide spraying machine." In 2021 6th international conference on inventive computation technologies (ICICT), IEEE, 2021: 432-436.

[4] Ahalya, M., A. Muktha, M. Veena, G. Vidyashree, and V. J. Rehna. "Solar Powered semi-automatic pesticide sprayer for use in vineyards." SSRG International Journal of Electronics and Communication Engineering (SSRG-IJECE) 2017, vol 4, no. 4: 54-57.

[5] Doke, Madhuri S., Pratiksha B. Rupnar, Pranjali R. Nagane, Shivani D. Pujari, Manjeet Kumar, Suhas B. Khadake, and Sagar S. Kawade. "Solar Powered Pesticides Sprayer with Multipurpose Application." International Journal of Advanced Research in Science, Communication and Technology 2026, vol 6, no. 10: 186-199.

[6] Mallan, Srinivasan, K. Karthick, B. Cheran, and S. Karthickram. "Smart Solar Powered Agricultural Fertilizer Sprayer." In IOP Conference Series: Materials Science and Engineering, IOP Publishing, 2021, vol. 1084, no. 1: 012072.

[7] Mulani, Altaf O., and Kailash J. Karande. "Precision Farming with a Solar-Powered Automated Pesticide Sprayer." In International Conference on Cognitive and Intelligent Computing, Singapore: Springer Nature Singapore, 2024: 231-242.

[8] Kayode, Joseph Friday, Samuel Olufemi Amudipe, Chubike William Nwodo, Sunday Adeniran Afolalu, Adebisi Olayinka Akinola, Omolayo Michael Ikumapayi, Bankole Ibrahim Oladapo, and John Olaoluwa Akinyoola. "Development of remote-controlled solar-powered pesticide sprayer vehicle." Discover Applied Sciences 2024, vol 6, no. 3: 101.

[9] Ngoma, Daniel Herman, and Banet Lukas Masenga. "Design and Development of a Remote-Controlled Solar-Powered Pesticides/Herbicides Sprayer for Modern Agriculture." ABUAD Journal of Engineering Research and Development (AJERD) 2026, vol 9, no. 1: 340-351.

[10] Rahman, Muhammad Shafiq Abdul, and Khairul Anuar Mohamad. "Eco-Friendly Solar Powered Insecticide Spray System for Sustainable Agriculture." Evolution in Electrical and Electronic Engineering 2025, vol 6, no. 2: 438-445.