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DESIGN AND DEVELOPMENT SOLAR POWERED PESTICIDE SPRAYING ROBOT

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Abstract - *This paper presents the design and development of a solar-powered pesticide spraying robot intended for efficient and safe agricultural operations. The system comprises a solar panel, rechargeable battery, control unit, DC motor pump, pesticide tank, height-adjustable sprinkler sprayer, and a rocker–bogie-based motorized wheel mechanism. Solar energy is harnessed to charge the battery, which supplies power to the DC motors, pump, and remote-control receiver circuit. The rocker–bogie mechanism enables smooth and stable movement over uneven farmland, while remote control operation allows precise navigation without direct human exposure to harmful chemicals. The DC motor pump delivers pesticide from the storage tank to an adjustable sprinkler sprayer, ensuring uniform and controlled spraying suitable for different crop heights. The proposed robot operates independently of conventional power sources, reduces manual labor, minimizes pesticide wastage, and enhances farmer safety. Overall, this system offers an eco-friendly, cost-effective, and practical solution for modern agricultural pesticide application.*

Key Words: Solar-powered robot, Pesticide spraying system, Agricultural automation, Rocker–bogie mechanism, Remote-controlled vehicle, DC motor pump, Sustainable farming, Precision agriculture

1. INTRODUCTION

Agriculture plays a vital role in the economic development of many countries, yet it continues to rely heavily on manual labor for essential operations such as pesticide spraying. Conventional spraying methods require farmers to carry heavy equipment and work in close contact with harmful chemicals, which can lead to serious health issues and uneven application of pesticides. In addition, the increasing cost of labor and limited access to reliable electrical power in rural areas create further challenges for efficient crop management.

Automation and renewable energy technologies offer promising solutions to these problems. The use of robotic systems in agriculture can significantly reduce human effort while improving accuracy and consistency in field operations. At the same time, solar energy provides a clean, renewable, and widely available power source that is particularly suitable for agricultural environments. Integrating solar power with automated spraying systems can reduce dependence on fossil fuels and external electricity, making farming practices more sustainable and cost-effective.

In this context, the solar-powered pesticide spraying robot presented in this work is designed to automate the spraying process while ensuring farmer safety and environmental sustainability. The system incorporates a solar panel, rechargeable battery, control unit, DC motor-driven pump, and a height-adjustable sprinkler sprayer to enable uniform pesticide application for different crops. A rocker–bogie mechanism with motorized wheels allows stable movement over uneven farmland, while remote control operation ensures safe and convenient navigation. This project aims to provide an efficient, eco-friendly, and practical solution for modern agricultural pesticide application.

2. LITERATURE SURVEY

The increasing demand for precision agriculture and labor-saving technologies has stimulated extensive research into automated spraying systems. Early studies focused on mechanized boom sprayers and tractor-mounted systems that improved application uniformity over large fields but remained dependent on fuel and human operation. As small-scale and fragmented farms became more common, research shifted toward compact, mobile platforms capable of operating in tight spaces and reducing direct human exposure to chemicals.

A significant branch of research addresses robotic pesticide applicators. Several prototypes and experimental platforms have been developed that integrate wheels or tracks with liquid delivery systems to provide targeted spraying. These systems commonly employ pumps, nozzles, and simple control electronics to regulate flow and coverage. Research showed improvements in spraying accuracy and reductions in chemical use when robots followed predefined paths or used sensor-driven actuation to spray only where needed.

Renewable energy integration, particularly solar power, has been explored as a means to make field robotics self-sufficient in off-grid environments. Studies demonstrate that photovoltaic panels combined with battery storage can reliably power low-to-moderate load components such as DC motors, control electronics, and small pumps during daylight operations. Hybrid designs that combine solar charging with battery buffers enable operations during periods of low insolation and extend operational time without fossil fuels, making them attractive for rural and remote farms.

Mobility and terrain negotiation have been critical topics in literature. Conventional wheeled robots perform adequately on flat fields but struggle on uneven or rough terrain. To address this, investigators have evaluated alternative suspension and locomotion mechanisms—such as tracked systems, articulated wheel assemblies, and rocker–bogie linkages—that improve stability, obstacle negotiation, and wheel-ground contact. The rocker–bogie architecture, while more commonly reported in planetary rover research, has been adapted in some agricultural prototypes to maintain chassis stability and distribute loads across multiple wheels on uneven soil.

Spraying mechanisms and fluid dynamics also receive considerable attention. Research compares different nozzle types, droplet sizes, and pressures to optimize coverage while minimizing drift and runoff. Electrostatic spraying, ultrasonic atomization, and variable-rate nozzles have been tested to increase deposition efficiency and reduce pesticide consumption. Integration of flow sensors and closed-loop pump control is shown to maintain consistent application rates despite varying pump or terrain conditions.

Control strategies and autonomy range from simple remote-controlled units to semi-autonomous and fully autonomous systems. Remote-control solutions prioritize operator safety and simplicity, allowing manual guidance while keeping the operator at a distance from chemicals. Semi-autonomous approaches use GPS waypoint navigation and obstacle avoidance to follow preplanned paths. More advanced research integrates camera vision, LiDAR, and machine learning for crop-row detection, weed identification, and selective spot treatment—demonstrating substantial potential for precision applications but with increased system complexity and cost.

Several studies emphasize system-level challenges: payload-versus-energy trade-offs, the need for robust sealing and chemical-resistant materials, maintenance of pumps and nozzles, and the impact of field conditions (mud, vegetation, slopes) on mobility and reliability. Battery weight and solar panel sizing are recurring design constraints; designers must balance operational range, spraying capacity, and solar recharging capability to meet practical field requirements.

From a socio-economic perspective, literature highlights farmer acceptance, cost–benefit analyses, and training requirements. Adoption is influenced by capital cost, ease of maintenance, perceived reliability, and demonstrable savings in labor and chemical use. Pilot studies and field trials often recommend modular, repairable designs and provision of local technical support to increase uptake in rural communities.

Gaps and future directions identified across surveys include the need for standardized field trials to compare systems objectively, improved energy management strategies (including energy-aware path planning), enhanced sensor fusion for reliable autonomous operation under variable lighting and dust conditions, and cost reduction through component standardization. Researchers also point to environmental monitoring integration (soil moisture, weather) to enable context-aware spraying decisions and to regulatory and safety frameworks that guide autonomous chemical application.

In summary, the body of literature suggests that solar-powered, remote-controlled or autonomous pesticide-spraying robots are a promising direction for sustainable agriculture. Existing work demonstrates technical feasibility across core subsystems—power, mobility, spraying, and control—while also pointing to practical design trade-offs and real-world challenges that future research and development must address.

3. MATERIALS

The solar-powered pesticide spraying robot is constructed using readily available mechanical, electrical, and electronic components to ensure reliability, low cost, and ease of maintenance. The materials selected are suitable for outdoor agricultural conditions and provide efficient performance of the system.

Mechanical Components: The chassis is fabricated from mild steel or aluminum to provide sufficient strength while keeping the structure lightweight. Motorized wheels are used along with a rocker–bogie mechanism to ensure stable movement on uneven farmland. A height-adjustable vertical frame is provided to support the sprinkler sprayer, allowing easy adjustment based on crop height. A pesticide tank made of chemical-resistant plastic is mounted securely on the chassis to store the pesticide solution.

Electrical and Power Components : A photovoltaic solar panel is used as the primary energy source to convert solar energy into electrical power. A charge controller regulates the charging process and protects the battery from overcharging and deep discharge. A rechargeable battery supplies power to the DC motors, control unit, and DC motor pump. Wiring, connectors, and protective casing are used toensure safe and reliable power distribution.

Electronic and Control Components: The control unit consists of a microcontroller or relay-based control circuit to manage motor driving, pump operation, and power distribution. A remote-control transmitter and receiver module enables wireless operation of the robot for movement and spraying. Relays or motor driver modules are used to control the direction and speed of the DC motors. Switches and indicators are included for manual control and system status monitoring.

Spraying System Components: The spraying mechanism includes a DC motor-driven pump, flexible hoses, and a sprinkler-type spray nozzle. The pump draws pesticide from the tank and delivers it under pressure to the nozzle, which atomizes the liquid into fine droplets for uniform spraying. Flow control valves may be used to regulate the spraying rate and reduce pesticide wastage.

Overall, the materials used in this project are economical, durable, and suitable for field applications, making the system practical for agricultural use.

4. METHODOLOGY

The methodology of the solar-powered pesticide spraying robot involves a systematic approach that integrates mechanical design, power generation, control systems, and spraying mechanisms to achieve efficient and safe agricultural operation.

Initially, the mechanical structure of the robot is designed to support all components while ensuring stability on uneven farmland. A rigid chassis made of mild steel or aluminum is fabricated, and a rocker–bogie mechanism with motorized wheels is incorporated to enhance traction and smooth movement across rough terrain. A vertical height-adjustable frame is mounted on the chassis to hold the sprinkler sprayer, allowing the spraying height to be modified according to crop requirements.

Next, the power system is developed using a photovoltaic solar panel as the primary energy source. The solar panel converts sunlight into electrical energy, which is regulated by a charge controller and stored in a rechargeable battery. This battery supplies power to the DC motors, control unit, remote receiver circuit, and DC motor pump. Proper power distribution and protection are ensured through suitable wiring and electrical safeguards.

The control system is then implemented to manage movement and spraying operations. A control unit consisting of a microcontroller or relay-based circuit interfaces with a remote-control receiver. Based on commands received from the transmitter, relays or motor drivers are activated to control the direction and motion of the DC motors, enabling forward, backward, left, and right movements. This remote operation allows the farmer to control the robot from a safe distance.

The spraying mechanism is integrated by connecting a DC motor-driven pump to a pesticide storage tank through flexible hoses. When the pump is activated, pesticide solution is drawn from the tank and delivered under pressure to the sprinkler sprayer. The nozzle atomizes the liquid into fine droplets to ensure uniform spraying and minimal wastage. The height-adjustable unit allows effective spraying for crops of varying heights and growth stages.

Finally, the testing and validation phase is carried out to evaluate the performance of the robot. The system is tested for smooth mobility, reliable solar charging, effective battery backup, remote-control responsiveness, and uniform spraying coverage. Adjustments are made to improve stability, spraying efficiency, and power management. Through this methodology, the proposed system achieves an eco-friendly, cost-effective, and efficient solution for automated pesticide spraying in agriculture

5. BLOCK DIAGRAM

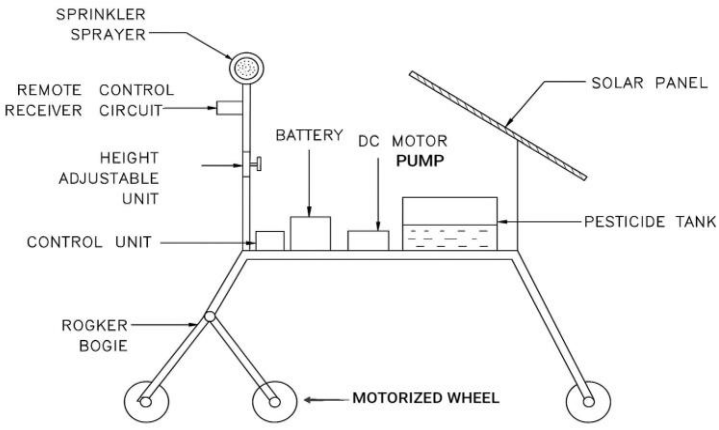

Fig-1 Block diagram

6. DESIGN AND MODEL IDEA

Fig-2 Design And Model Idea

7. WORKING PRINCIPLE

The working principle of the solar-powered pesticide spraying robot is based on the efficient utilization of solar energy, remote-controlled mobility, and a pressurized spraying mechanism to automate pesticide application in agricultural fields. The solar panel mounted on the robot converts sunlight into electrical energy, which is regulated by a charge controller and stored in a rechargeable battery. This stored energy serves as the primary power source for the control unit, DC motors, remote receiver circuit, and the DC motor-driven pump, enabling continuous operation without dependence on external electricity.

The movement of the robot is achieved through motorized wheels integrated with a rocker–bogie mechanism. This mechanism ensures stable and smooth motion over uneven and rough farmland by maintaining continuous wheel contact with the ground. The robot's navigation is controlled remotely using a transmitter–receiver system. Commands from the transmitter are received by the control unit, which activates the appropriate relays or motor drivers to control forward, backward, left, and right movements.

The spraying operation is carried out using a pesticide tank connected to a DC motor pump via flexible hoses. When the spraying command is given, the control unit powers the pump, which draws the pesticide solution from the tank and delivers it under pressure to the sprinkler sprayer. The sprayer nozzle atomizes the liquid into fine droplets, ensuring uniform distribution of pesticides across the crop surface and minimizing chemical wastage.

An important feature of the system is the height-adjustable sprayer unit, which allows the nozzle position to be modified according to crop height and growth stage. This adaptability improves spraying effectiveness for different crops. Overall, the coordinated operation of the solar power system, control unit, mobility mechanism, and spraying system enables efficient, safe, and eco-friendly pesticide application in agricultural fields.

8. CONCLUSION

The solar-powered pesticide spraying robot developed in this work provides an effective and sustainable solution for automating pesticide application in agriculture. By utilizing solar energy as the primary power source, the system reduces dependence on conventional electricity and fossil fuels, making it suitable for rural and off-grid farming areas. The integration of a rocker–bogie mechanism with motorized wheels ensures stable movement over uneven farmland, while remote-control operation enhances ease of use and protects farmers from direct exposure to harmful chemicals.

The height-adjustable sprinkler sprayer and DC motor-driven pump enable uniform and controlled spraying for different crop types and growth stages, reducing pesticide wastage and improving application efficiency. Overall, the proposed system demonstrates a practical, eco-friendly, and cost-effective approach to modern agricultural practices. With further enhancements such as autonomous navigation and sensor-based spraying, the robot can be extended to support precision agriculture and improved crop management in the future.

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