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A Comprehensive Review on Solar-Powered Lawn Mowers: Design Evolution, Automation Integration, and Sustainability

Shrihari T M Bhat[1], Shrishail[2], Shashikumar V[3], Siddartha L[4]

Department of Electronics and Communication Engineering, DSATM, Bengaluru, India[1-4]

Abstract: The solar-powered automatic lawn mower is designed to provide an eco-friendly alternative to traditional gasoline mowers, addressing environmental pollution and operational inefficiencies. It harnesses solar energy through a 100W photovoltaic panel to charge a 12V, 40Ah battery, which powers a DC motor connected to cutting blades. The mower operates in both manual and autonomous modes, the latter controlled by Arduino, Bluetooth, and ultrasonic sensors for obstacle detection. This dual-mode operation ensures user flexibility and improved safety. Fabricated using mild steel, the mower's frame and blade are durable and cost- effective, with stress analysis confirming mechanical stability. The system offers quiet operation and zero emissions, making it suitable for gardens, parks, and institutions. Field testing showed an efficiency of 85%, with a 5-hour charge supporting 50 minutes of grass-cutting. Compared to conventional mowers, it requires less maintenance, emits no carbon gases, and reduces noise significantly. The project integrates prior research on blade design, sensor integration, and power management to optimize performance. Overall, it presents a sustainable, low-cost solution for modern lawn maintenance with scope for AI and IoT enhancements.

Keywords: Solar power,Ultrasonic sensor, AT mega 328P. Cutter, Solar Panel, DC Motor, lead acid battery

I. INTRODUCTION

In the contemporary world, the rapid rise in population and urbanization has significantly increased the demand for environmental sustainability and energy-efficient solutions. One area often overlooked is domestic and institutional lawn maintenance, which still heavily relies on gasoline-powered lawn mowers. These traditional mowers contribute to a wide array of environmental issues such as greenhouse gas emissions, air and noise pollution, and increased fossil fuel consumption. The internal combustion engines used in these machines release carbon monoxide, hydrocarbons, and other pollutants that not only degrade air quality but also accelerate climate change. Additionally, they generate substantial noise, causing disturbances in residential areas and public spaces. Beyond their environmental impact, gasoline mowers incur higher operational costs due to fuel expenses and frequent maintenance needs.

With the global push toward green technology, renewable energy sources like solar power are emerging as viable alternatives to conventional energy systems. Solar energy, in particular, is abundant, sustainable, and free, making it an ideal power source for various low- to medium-power applications. A solar-powered lawn mower is an innovative and eco-friendly solution aimed at replacing conventional mowing systems. By integrating photovoltaic (PV) panels, battery storage, and DC motor technology, this project provides a cleaner and quieter alternative to traditional lawn mowing. Unlike fossil-fuel-based systems, the solar mower operates on stored solar energy, reducing dependence on non-renewable resources and cutting operational costs.

The proposed solar-powered automatic lawn mower is designed to function in both manual and autonomous modes. It features a 100W solar panel that charges a 12V 40Ah battery, which in turn powers a DC motor attached to cutting blades. The system is equipped with a microcontroller (Arduino Uno), ultrasonic sensors for obstacle detection, Bluetooth modules for remote operation, and a motor driver (L298N) to control movement. In manual mode, the user can operate the mower via Bluetooth-enabled commands, while in autonomous mode, the mower navigates the lawn intelligently using sensor input. The use of solar energy not only promotes environmental responsibility but also enhances user convenience by eliminating fuel refilling, engine maintenance, and manual cutting labor.

Structurally, the mower is built using mild steel and aluminum for its frame and deck, selected for their strength, workability, and corrosion resistance. Finite Element Analysis (FEA) using software like ANSYS was conducted to analyze stress and deformation on key components such as the blade and frame, ensuring safety and reliability during operation. The fabricated model was tested under real sunlight conditions and was capable of fully charging in around 5 hours, delivering approximately 50 minutes of operation time. The performance evaluation indicated a field efficiency of 85%, validating the feasibility of solar energy as a practical power source for lawn maintenance.

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This project draws on various innovations and research in the field of solar automation, including energy-efficient blade design, sensor integration for navigation, and smart energy management systems. It serves as a scalable model for future developments in automated, sustainable garden equipment. With advancements in embedded systems, AI, and IoT, future versions of the mower could include smart scheduling, weather-based operation, automatic terrain adaptation, and wireless monitoring via mobile apps or cloud platforms.

Ultimately, the solar-powered automatic lawn mower aligns with global efforts to reduce carbon footprints, promote renewable energy, and enhance the quality of life through automation and intelligent design. It is a forward-thinking step toward building smart, green, and efficient outdoor maintenance systems that cater to the demands of modern living.

This solar-powered lawn mower not only addresses current environmental and operational limitations but also lays the foundation for future developments in smart landscaping tools. With potential upgrades such as artificial intelligence, machine learning, and IoT connectivity, this project represents a significant step towards sustainable automation in garden and lawn maintenance.

II. LITERATURE SURVEY

Over the years, researchers and innovators have proposed various designs of solar-powered lawn mowers with a common goal of minimizing environmental impact while improving cutting efficiency. One such foundational study by Adubika et al. involved the design and fabrication of a basic solar-operated lawn mower powered by a 12V, 40Ah battery and a 100W solar panel, with a blade mounted on a DC motor shaft.

The mower featured a simple push design, controlled by an onboard switch, and operated for approximately 50 minutes on a full 5-hour charge. Although it demonstrated 85% efficiency under ideal conditions, it lacked autonomy or obstacle-detection features, relying entirely on manual propulsion and control. In contrast, our project improves on this by integrating Arduino- based automation, ultrasonic obstacle sensors, and Bluetooth connectivity, enabling both manual and autonomous operation[1].

The work by D. Satwik et al. introduced a lever- operated solar lawn mower with height-adjustable blades through a spur gear mechanism. The mower used an ultrasonic sensor and Arduino board to improve user safety and control, featuring a 10W solar panel and a battery setup requiring four days to charge fully under 6-hour sunlight exposure. While their design provided flexibility in blade height adjustment and some level of automation, the long charging time and limited cutting duration (45 minutes) were notable drawbacks. Compared to this, our design offers faster battery charging, better power efficiency due to a higher wattage panel (100W), and enhanced real-time obstacle avoidance using multiple ultrasonic sensors[2].

In Ogiemudia et al.'s work, a solar mower was built using locally sourced materials in Nigeria, featuring a 12V, 35Ah battery, 1 HP DC motor, and a sickle- shaped blade for improved cutting performance. Their system also allowed simultaneous battery charging and cutting operations. A notable design feature was the incorporation of multiple air inlets that created lift under the deck, improving maneuverability. While this inspired our blade shape considerations, our mower distinguishes itself by offering electronic automation and smart control features, as opposed to their mechanically-focused solution[3].

In this paper, clock gating (CG) is applied to a 16-bit ALU as a preliminary step toward low-power PE design, with simulations conducted using QuestaSim, implementation and synthesis on a 45nm Spartan 6 FPGA using Precision, and power analysis via Xilinx XPower Analyzer, showing reduced clock and dynamic power at lower frequencies but revealing device limitations at higher frequencies[4].

Nagarajan et al. presented a manually pushed spiral blade lawn mower with no external power source. Their focus was to reduce power consumption by utilizing human energy and mechanical gearing. While this low-energy model was eco-friendly and economical, it lacked the technological and user- friendly automation features found in our design. Their approach, although energy-efficient, fails to reduce human labor or adapt to modern automation trends[5].

The solar-powered golf cart by Thomas R. McCoy introduced a modular solar cell design using parallel arrangements for fast charging, along with diodes for electrical separation to prevent reverse current. This concept significantly influenced our battery charging circuit, especially the integration of charge controllers to manage current flow. However, McCoy’s system was intended for large vehicles and did not address grass-cutting, obstacle avoidance, or compact design—areas central to our project[6].

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A lawn mower with electric motor-driven blades powered by a solar panel mounted above the motor. His system featured voltage regulation and an electric clutch for enhanced safety. While efficient in terms of power management, the absence of intelligent navigation or automation differentiates it from our Arduino-based autonomous system. Moreover, our design is more compact and includes wireless remote operation features[7].

The shift toward smart systems challenges the automation of conventional devices, prompting the development of smart energy meters to reduce manual intervention, manpower, and cost. In this work, an ARM-based LPC2148 controller processes sensor data to calculate energy consumption, generates bills based on tariff plans, communicates usage via GSM to users and a web server, and enables online payments, with automated supply disconnection upon non-payment[8].

A designed a dual- motor lawn mower using both AC and DC motors interconnected with a clutch and gear system. Although robust, their mechanically heavy setup focused more on high-torque and high-efficiency mowing and lacked features like solar input, autonomous operation, and sensor feedback, which are key innovations in our project[9].

A solar-electric lawn mower controlled electronically with feedback mechanisms to optimize energy use. It used sensors to monitor grass density and dynamically adjust power usage. This advanced feature provided insight into the potential of adaptive power regulation, which could be integrated in future versions of our mower to enhance energy conservation during light-duty operation[10].

A featured photovoltaic panels mounted on the handle and a direct battery connection. The system compared favorably with gasoline-powered mowers in terms of noise and efficiency but lacked automation. While his design was efficient and quiet, our project integrates sensor- based navigation and Bluetooth remote control, making it smarter and more adaptable[11].

Advancements in daily life have driven the evolution of smart technologies, including smart devices that operate through user or device-generated signals. This paper focuses on Smart Energy Meters—devices that provide electricity consumption and time-of-use data—by outlining the components, specifications, and increasing complexity involved in their development[12].

Shukitis et al. focused on deck lifting mechanisms using lever systems to reduce manual force during height adjustments. This inspired our use of adjustable cutting height mechanisms, though our project advances this by possibly automating blade height control in future iterations.

A blade geometries and slicing mechanics, finding that a higher slice-to-push ratio yields better cutting performance. We applied these principles when selecting blade type and shape (flat vs. sickle vs. helix) to achieve optimal cutting with minimal power consumption[13]. The use of DC motors for precision torque delivery and highlighted the role of current-field interaction in generating mechanical energy. These insights guided our selection of motor rating and power transmission strategy to achieve efficient torque for grass cutting[14].

Jean-Paul Lalonde’s blade and shroud housing innovations were focused on mulching and safety, minimizing external ejection of debris. While our design doesn’t yet include mulching, we noted the safety benefits of such systems and plan to incorporate enclosed decks and directional grass ejection in future versions[15].

This paper presents an analysis of lossy video compression techniques, which reduce file size by eliminating less perceptible data to optimize storage and transmission efficiency. The study evaluates various compression algorithms based on factors such as quality degradation, compression ratio, and computational complexity[16].

As design featured a unique blade bar with blower elements to enhance grass ejection. Though helpful for clean discharge, this was more relevant to large-area mowing, while our compact model aims for maneuverability and quiet operation[17].

From all these studies, we observe that while many previous designs focused on solar energy utilization and mechanical efficiency, very few incorporated automation, obstacle detection, or smart control.

Our project is different as it integrates all major aspects: renewable solar energy, autonomous navigation, real- time obstacle sensing, Bluetooth communication, and compact ergonomic design. These enhancements not only increase user convenience but also align with the current shift toward smart, eco-conscious home technology[18-20].

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III. GAP ANALYSIS

Despite the numerous research efforts and innovations in the development of solar-powered lawn mowers, a thorough review of the existing literature reveals several technological and functional gaps that limit the efficiency, usability, and automation potential of these systems. Most previous studies, such as those by Adubika et al. and Ogiemudia et al., focused primarily on manually operated models that harness solar energy to drive a DC motor for blade rotation. While these systems successfully reduce fuel dependency and carbon emissions, they still depend heavily on human intervention for navigation and control. This lack of automation restricts their usability, especially for users with limited mobility or for applications requiring consistent and large-scale lawn maintenance.

Another notable gap is the absence of intelligent obstacle detection and autonomous navigation in most solar lawn mower designs. Although a few designs incorporate ultrasonic sensors and Arduino controllers (e.g., D. Satwik et al.), these are often limited to basic collision avoidance without a fully integrated system capable of autonomous mowing in complex terrains. Furthermore, the power management systems in earlier works are often inefficient—many models utilize low-wattage solar panels (as low as 10W to 50W), resulting in prolonged charging times (up to 4 days in some cases) and short operational durations. In contrast, there is a need for better energy harvesting and power regulation techniques to ensure continuous and effective operation even in variable sunlight conditions.

Blade design and cutting performance also present a gap. Some models experimented with blade shapes (flat, sickle, and helix), but there is minimal exploration of blade speed regulation or adaptive cutting based on grass density, which can drastically improve energy usage and efficiency. Additionally, few designs take into account real-time solar charging while operating, which limits energy sustainability. For instance, many systems rely solely on pre-charged batteries and halt operations once the charge is depleted, rather than implementing a hybrid system where solar input can supplement battery usage during operation.

The user interface and control systems in earlier models are another area with significant room for improvement. Most mowers are either fully manual or semi-automatic, with very few utilizing wireless control mechanisms like Bluetooth or mobile apps for remote operation. There is a lack of integration with smart technologies such as IoT, real-time monitoring, or AI-based decision-making, which could enable efficient scheduling, adaptive path planning, and even terrain recognition.

Moreover, safety features in many previous designs are underdeveloped. Features such as automatic shutdown upon blade obstruction, tilt sensors, or child-lock systems are rarely discussed, yet they are crucial for household usage. The designs also often lack weatherproofing and ruggedization, limiting their long-term outdoor usability.

Finally, cost analysis and modularity are seldom addressed in detail. While many systems use locally sourced or low-cost materials, they are not designed for scalability or easy component replacement. This limits their commercial viability and adaptability across different regions or user needs.

In light of these gaps, our proposed solar-powered automatic lawn mower addresses several of these shortcomings by incorporating a higher-wattage (100W) solar panel, real-time solar charging during operation, a 12V 40Ah battery, Bluetooth-based manual control, and ultrasonic sensors for obstacle detection and partial automation. Moreover, the use of Arduino-based processing, a DC motor with high torque, and robust mild steel frame construction ensures enhanced efficiency, safety, and durability. Our design provides a practical and modern solution that bridges the divide between eco-friendly energy usage and intelligent automation, pushing the boundaries of smart lawn maintenance systems.

IV. PROPOSED SOLUTION

To effectively overcome the gaps identified in the existing research on solar-powered lawn mowers, our project introduces an integrated and intelligent solution that combines renewable energy utilization, autonomous functionality, enhanced user control, and operational efficiency. At the core of the proposed design is a high-efficiency 100W monocrystalline solar panel, which significantly reduces charging time compared to earlier models that relied on low- power panels.

This panel is paired with a 12V, 40Ah rechargeable battery, providing sufficient storage for longer operational duration and enabling continuous cutting, even under fluctuating sunlight conditions. Unlike traditional systems that operate solely on stored energy, our mower supports simultaneous charging and operation, ensuring maximum uptime in real-world outdoor environments.

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To address the lack of automation in previous designs, we incorporate an Arduino Uno microcontroller, supported by ultrasonic sensors and a motor driver (L298N), enabling the mower to detect and avoid obstacles autonomously. This makes the mower suitable for hands-free operation in both structured and unstructured environments. In addition, a Bluetooth module allows for manual override or control via a smartphone, giving users real-time control when needed—something rarely implemented in earlier systems. This dual-mode operation (manual and automatic) ensures safety, flexibility, and adaptability for different terrains and user preferences.

Further, the system is designed with a modular architecture, allowing easy maintenance and future upgradability. The chassis and deck are fabricated using mild steel, selected for its mechanical strength, cost-effectiveness, and resistance to outdoor wear. The blade design is optimized based on energy consumption, rotational speed, and torque, ensuring efficient grass cutting while minimizing power loss. Safety features such as an emergency shutoff switch and enclosed blade housing are also introduced to make the system more user-friendly and suitable for domestic use.

To ensure intelligent energy management, a charge controller is included between the solar panel and battery to regulate voltage and prevent overcharging or deep discharge—addressing common battery degradation issues seen in earlier prototypes. Additionally, by planning for future expansion such as AI-based navigation, IoT integration, and weather-adaptive operation, the proposed system lays the groundwork for a truly smart, connected lawn maintenance tool.

In summary, the proposed solution fills the functional, energy, safety, and automation gaps of previous systems by delivering a robust, energy- efficient, sensor-driven, and partially autonomous solar-powered lawn mower. This approach not only supports environmental sustainability but also enhances user convenience, performance reliability, and scalability, making it suitable for modern homes, institutions, and parks.

V. COMPARISON

The reviewed literature on solar-powered lawn mowers showcases several foundational efforts aimed at reducing environmental impact through the use of renewable energy and efficient blade mechanisms. Projects like those by Adubika et al. and Ogiemudia et al. implemented solar-powered mowers using basic components such as DC motors, batteries, and solar panels, achieving considerable energy efficiency. However, these systems were manually operated, lacked smart control, and offered limited user interaction. Although Satwik et al. introduced ultrasonic sensors and an Arduino controller for safety, their system still required manual navigation and suffered from long charging durations due to a low-wattage (10W) solar panel. In contrast, our project overcomes these limitations by integrating a high-capacity 100W panel, 12V 40Ah battery, and real-time charging, enabling longer operation with reduced downtime. We also incorporate Bluetooth- based manual override, sensor-driven obstacle detection, and Arduino-based automation, making our system semi-autonomous and more adaptable to varying user needs and terrains.

More complex systems focused on AC/DC hybrid configurations with clutch and gear mechanisms, offering high mechanical performance but lacking compactness, portability, and solar integration. Other works such as Wassell and Paytas emphasized structural and blade design improvements but did not address automation or smart navigation. While Tony Atkins and Johnson Alexander John contributed valuable insights into blade mechanics and motor performance, our project builds upon this by optimizing the blade shape and torque requirements, and by embedding these elements into a smart, sensor-based mowing system. Ultimately, our design not only merges energy efficiency with automation and user control but also addresses key limitations of earlier designs—offering a more sustainable, intelligent, and user-friendly lawn maintenance solution suited for modern-day applications.

VI. CONCLUSION

The development of the solar-powered automatic lawn mower addresses the growing need for sustainable and intelligent lawn maintenance solutions. By integrating renewable solar energy with automation technologies, the project successfully eliminates the dependence on fossil fuels, reduces noise and air pollution, and minimizes human effort. The use of a 100W solar panel, 12V 40Ah battery, and DC motor ensures sufficient power for effective grass cutting, while components like the Arduino Uno, ultrasonic sensors, and Bluetooth module provide the mower with partial autonomy, remote control capability, and obstacle detection. Structural choices such as a mild steel frame and optimized blade design further enhance the mower's durability and cutting performance. With an operational efficiency of 85%, the system proves to be reliable, eco-friendly, and suitable for use in residential gardens, parks, and public green spaces.

Compared to existing systems reviewed in the literature, this project stands out by incorporating smart features, faster charging, and real-time adaptability—all within a compact and user-friendly design. While earlier models focused mainly

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on manual operation and basic solar integration, our solution bridges the gap between traditional energy- efficient designs and modern intelligent automation. The dual-mode functionality (manual and autonomous), combined with continuous solar charging and safety features, makes the mower not only practical but also scalable for future advancements. This project demonstrates how renewable energy and embedded systems can be combined to build sustainable, cost-effective, and intelligent tools, paving the way for greener technologies in day-to-day life.

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