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IoT enabled solar-powered grass cutter utilizing radiant solar energy

Gnanasekaran Sasikumar,[1*] K. Mujiburrahman,[2] R. Subhashini,[3] S. Sabarunisha Begum[4]

[1]Department of Mechanical Engineering, GMR Institute of Technology, Rajam, Andhra Pradesh, India. [2]Department of Automobile Engineering, Hindusthan College of Engineering and Technology, Coimbatore, India. [3]Department of Information Technology, Sona college of Technology, Salem, India. [4]Department of Biotechnology, P.S.R. Engineering College, Sivakasi, India.

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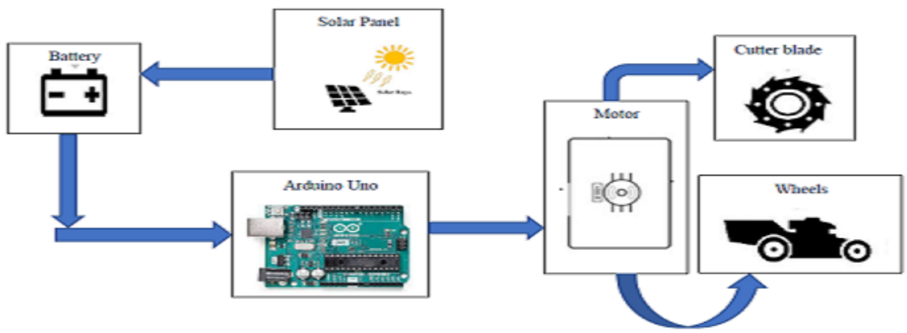
Article

ABSTRACT



The advanced technology driven machines are leading the engineering of coming up new tools. The IoT-enabled solar-powered grass cutter harnesses radiant energy from the sun as its primary power source and further, the machine integrates IoT (Internet of Things) technology to enable it to process the trimming of grass with improved efficiency and minimal human intervention. This type of technology driven grass cutter is especially valuable for maintaining vital areas like hotels, stadiums, parks, and public spaces. Herein, a new IoT based solar energy powered grass cutter design is reported. The key components that drive the functionality of this advanced grass cutter include the NodeMCU, a WIFI module, motor drivers, a solar panel with a charge controller, a battery, and an ultrasonic sensor for obstacle detection. The final designed grass cutter components work seamlessly to automate grass cutting operations in outdoor spaces towards ensured effective and obstacle-free processing of the task.

Keywords: Node MCU, IoT, grass cutter, Ultrasonic sensor, Solar energy, Fusion 360

INTRODUCTION

Traditional grass cutters can be broadly categorized into two main types: fuel-based and electric-based models. Fuel-based grass cutters are typically powered by gasoline or diesel engines. These internal combustion engines burn fossil fuels to generate the necessary power for cutting grass efficiently. While these machines have been widely used for their effectiveness, they come with a range of environmental challenges. One of the most significant environmental impacts of fuel-based grass cutters is the emission of harmful pollutants. These machines release exhaust fumes containing pollutants like carbon dioxide (CO_2), nitrogen oxides (NOx), and particulate matter into the atmosphere. These emissions contribute to air pollution, which can degrade air quality and have adverse effects on human health. Carbon dioxide, a greenhouse gas, is a major contributor to global warming and climate change. Furthermore, fuel-based grass cutters contribute to noise pollution due to the operation of their internal combustion engines. The constant noise generated can disrupt quiet neighborhoods, disturb wildlife, and create an unpleasant environment for both operators and nearby residents. Noise pollution can have negative impacts on human well-being, causing stress, sleep disturbances, and other health issues.

Electric-based grass cutters are an alternative to their fuel-based counterparts. These machines are powered by electricity from the grid or rechargeable batteries. Electric grass cutters offer several environmental benefits compared to fuel-based models. One of the primary advantages is their lower emissions during operation. Electric grass cutters produce zero tailpipe emissions at the point of use, contributing to reduced local air pollution and improved air quality. This is especially true if the electricity is sourced from renewable energy sources like solar or wind power, as it further decreases the carbon footprint associated with their operation. Electric grass cutters have clear environmental benefits over traditional fuel-based ones, but they're not perfect. The batteries

*Corresponding Author: Gnanasekaran Sasikumar, Professor, Department of Mechanical Engineering, GMR Institute of Technology, Rajam, Andhra Pradesh, India.
Tel: +91- 8941-251592 Email: sasikumar.g@gmrit.edu.in

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they use can cause problems during production and disposal due to materials and energy use. Also, if the electricity they use isn't from renewable sources, their green advantage can diminish.

The IoT-based grass cutter has emerged as a groundbreaking solution that goes beyond the constraints of conventional methods. This technology harnesses the energy of the sun as a renewable power source, effectively reducing reliance on fossil fuels and minimizing the carbon footprint. By utilizing solar power, these machines substantially lighten their environmental impact and promote sustainable practices in lawn maintenance.

Furthermore, the incorporation of IoT technology offers a range of advantages that dominate traditional methods. These grass cutters can be programmed for efficient and automated operations, optimizing cutting patterns and adjusting schedules based on real-time weather conditions. This intelligent automation not only improves the quality of grass cutting but also conserves resources by operating precisely when needed. The ability for remote monitoring and control via IoT connectivity is another distinguishing feature of these smart grass cutters. Operators can oversee and manage the machine's functions from a distance, reducing the need for constant human presence on-site. This not only enhances safety but also reduces labor requirements, making the maintenance process more efficient and cost-effective. Moreover, the use of solar power in these IoT-based grass cutters ensures a quiet and clean operation, as they generate minimal noise and emit no direct exhaust emissions. This characteristic makes them exceptionally suitable for urban and environmentally sensitive areas, where noise and pollution are significant concerns.

LITERATURE REVIEW

A control strategy based on nonlinear decoupling control method is proposed in this paper to improve the maneuverability and stability of in-wheel-motor-drive electric vehicle.[1] A programmed microcontroller chip is designed to control watering automatically based on soil moisture detected using a domestic soil moisture sensor.[2] Development of autonomous travel for small robots that need to travel and cover the entire smooth surface, such as those employed for cleaning tables or solar panels is investigated.[3]

An autonomous remote control solar power lawn mower robot is designed and fabricated that can be controlled through mobile phone. The current technology which are commonly used for cutting grasses are very tedious and pollute the environment[4]. Due to the rapid development of wireless charging technology, sensors can be recharged when they are within limited charging ranges of mobile devices.[5]

Rapid growth in technology has created opportunities to design and develop high-end applications and tools. Conventional mowers are fuel-powered and require personnel assistance for operation. A smart lawn mower powered by a solar photovoltaic (PV) panel is developed and controlled by an Internet of Things- (IoT-) based technique. The feasibility of applying a mobile manipulator powered by solar energy as a harvesting robot in agriculture is assessed. The designs are started by designing the robot's mechanics and the mobile manipulator control. The motion of the mobile base and arm robot manipulator are approached using FLC. FLC design is also intended to predict the robot's charging source based on the light sensor attached to the charging system.[6]

A study was designed to clean the school field in an easier, faster, safer and more cost-effective way. The device has the hardware such as Arduino Uno microcontroller, HC-05 Bluetooth module, WIFI module, two 12 volt wiper motors as wheels, 24 volt EBike blade motor, motor driver, two caster wheels, switch and two 12 volt 7 Ampere rechargeable lead acid battery that are connected in series[7]. Renewable energy sources are considered as the alternative energy sources because of rising environmental concerns and depleting conventional energy resources. Solar energy has a significant role for meeting the increased requirement of electricity with the reduced environmental impact.[8] In view of the complexity and particularity of the development of agricultural robot technology, it is essential to summarize its development characteristics and make reasonable judgments on its development trend. From the classification of agricultural robot systems, the development of main types of monitoring robots, non-selective and selective working robots for crop farming, livestock and poultry farming and aquaculture were introduced.[9] Greenhouse-level high-throughput analysis for automated plant imaging and interaction is important for the identification of productive and resource efficient genetic crop lines. The development of an automated gantry system that allows specification of and interaction with individual plants in a 64-square-meter (900-square-foot) greenhouse plot is discussed. The system minimizes custom hardware to allow construction using mostly Commercial-off-the-shelf (COTS) components so that greater resources could be allotted for imaging, 3D plant mapping, and fertilizer application systems.

Artificial Intelligence (AI) through robotic system offer solutions for autonomous system with high cutting efficiency for lawn mowing. The design, fabrication, and performance evaluation of a prototype robot for lawn mowing is discussed. The Auto-desk Inventor 2018 was used for the computer aided design and simulation of the automatic lawn mower. The electrical circuit connections between the microcontroller and the rest of the electrical systems were also designed with the aim of producing a system that can cut grass at high efficiency with little human intervention[10]. The Internet of things (IoT) is a technology that incorporates a vast amount of abundant and heterogeneous objects which generate information about the physical world continuously.[11] To reduce pollution as well as human efforts need to develop an automated machine that utilizes renewable energy sources such as solar energy. The main idea behind this paper is to develop a solar-powered grass cutter.[12] An electric lawn mower supplied from batteries was designed and constructed. Li-ion cells are used because of their high volumetric and weight energy density. Two separate motors are used – one for the traction and the other for the main blade drive.[13] Bringing automation in the farming system is the need of the modern era. The shortcomings of the manual agriculture system can be rectified by exploiting the automatic process which results in higher production of crops. An automated remotely controlled system is proposed that can fulfill the water usage for agricultural land. An improved fuel consumption and emissions control strategy based on a mathematical and heuristic approach is presented to optimize Parallel Hybrid Electric Vehicles.[16]

A promising multiple access technique, non-orthogonal multiple access is proposed to provide communication service between the base station associated with MEC and far IoT devices. In this paper, the multiple power beacons (PBs) benefits to uplink of NOMA-MEC system with the wireless powered IoT are discussed[17]. The development of autonomous travel for small robots that need to travel and cover the entire smooth surface is discussed. An obstacle-available surface and target this travel on it by proposing a spiral motion method is developed by developing autonomous avoidance of obstacles[18]. The IoT based Smart Shopping Cart is proposed which consists of RFID sensors, Arduino microcontroller, Bluetooth module, and Mobile application.[19]

To improve the maneuverability and stability of in-wheel-motor-drive electric vehicle, a control strategy based on nonlinear decoupling control method is proposed.[20] A smart Decision Support System (DSS) that acquires the input parameters based on real-time monitoring to optimize the yield that realizes sustainability is developed. The proposed model comprises three basic units including an intelligent sensor module, smart irrigation system and controlled fertilizer module.[21] The application of fuzzy hybrid methods has notably increased in recent past. But, the application of fuzzy hybrid methods for modeling systems or processes, such as fuzzy machine learning, fuzzy simulation, and fuzzy decision-making, has been relatively limited in the energy sector.[22-24]

METHODOLOGY

In the proposed model, the NodeMCU functions as the central control unit, overseeing the entire operation of the device. The power supply is applied to the system through batteries which are rechargeable with the help of solar panel. Wheels are connected to the DC motors and these DC motors are connected to motor driver which controls the speed and direction of the motors simultaneously. NodeMCU controls the communication between the model and user with the help of mobile application. An ultrasonic sensor is mounted on the top of the model which avoids the model to collide with any obstacle. The figure 1 shows the connections of the designed model.

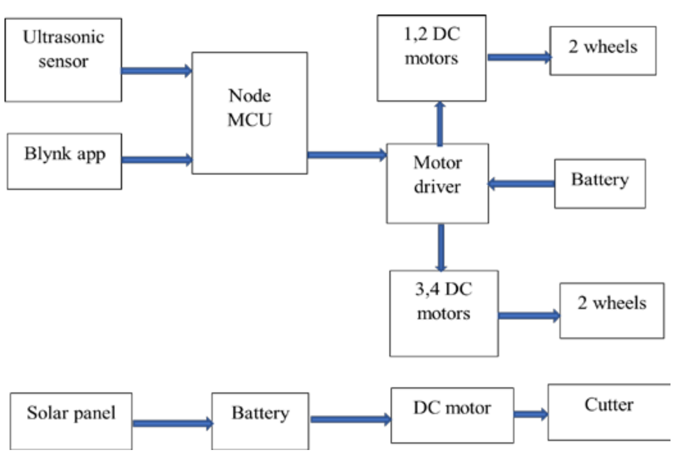

Figure 1. Components of the designed model

The designed model consists of the following components and specifications:

Node MCU (ESP8266): The ESP8266 is a low-cost Wi-Fi chip developed by Espr essif Systems. It can be used as a standalone device, or as a UART (Universal Asynchronous Receiver/Transmitter) to Wi-Fi adaptor to allow other microcontrollers to connect to a Wi-Fi network.

L298N Motor Driver: This L298N Motor Driver Module is a high-power motor driver module for driving DC and Stepper Motors. This module consists of an L298 motor driver IC and a 78M05 5V regulator. L298N Module can control up to 4 DC motors, or 2 DC motors with directional and speed control. The module can drive DC motors that have voltages between 5 and 35V, with a peak current up to 2A.

Solar panel: The 12V 20W solar panel is a compact and efficient device that converts sunlight into electricity. Designed for small-scale applications, it is ideal for charging 12V batteries in off-grid solar systems and powering electronic devices. With a moderate efficiency of 15% to 20%, it ensures effective energy conversion in limited sunlight conditions.

DC motors: These motors are Operating at 12V, these motors provide high torque output of 10 Kg-cm, making them suitable for tasks that require a strong rotational force. With a speed of 1000 RPM (rotations per minute), they offer a balanced combination of torque and speed for various projects. The side shaft design allows for easy integration and connection with other mechanical components. These geared motors are built to withstand demanding conditions and provide reliable performance over an extended period.

Ultrasonic sensor: An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal. Ultrasonic waves travel faster than the speed of audible sound.

DESIGN CALCULATIONS

Selection of motors:

Torque = coefficient of friction between ground and wheels * mass of the bot(kg) * radius of wheel [14,15]

- Coefficient of friction between ground and wheels = 0.6
- Mass of the bot = 10kg
- Radius of the wheel = 5cm

T = 0.6*10*5

=30kg-cm

We have four wheels, hence 30/4=7.5 kg-cm ≈ 8kg-cm

Torque on each wheel is = 8 kg-cm

We need 8-10 kg-cm torque carrying DC motors.

Torque = 10kg (approx.) Speed = 1000 rpm Weight = 300gms

Power = 2πNT/60

= (2*3.14*1000*10)/60 = 1046.6 watts

Power of motor = 1046.6 watts

Wheels

Load carrying: 15kg

Height: 10cm

Width: 4cm

Shaft diameter: 6mm Weight (4 wheels): 150 grams

Solar panel

Watt(W) = 20w

Voltage (V)= 12v

W = I*V

20 = 12*I ⇒I = 1.6A

Current I = 1.6A

Weight = 2.2kg

Selection of battery

For 12v and 0.5kW DC motor

P = VI

0.5 = 12*I

I = 0.0416 ⇒ 41.6 amp (for each motor)

For 4 motors 166.4amp current is required.

So, 45c 12v 3600-4000 Mah battery is required because,

45*3600 = 16200ma ⇒162 amp

We need 45C rating ,3600-4000 Mah battery.

WORKING PRINCIPLE OF PROTOTYPE

NodeMCU acts as brain of the proposed model. The 12v rechargeable battery used to power-up the electronic components, these batteries are charged by the 12v 20W solar panel. All the DC motors which are of 1000 rpm are connected to the motor driver module which controls the speed and movement/ direction of the DC motors. NodeMCU consists of WIFI chip which connects the user and prototype with the help of mobile application (Blynk). Initially a code is dumped in NodeMCU, the code is generated in such a way that it operates all the required functions of the prototype, and provides high level programming interface for WIFI connectivity. When the user touches the button of forward movement in the application, the signal is recognized for forward movement of grass cutter and moves forward, similarly the grass cutter operates for all directions. On and off mechanisms control the grass cutting operation. Finally, an ultrasonic sensor which is mounted on the prototype stops the movement of the prototype if there is any obstacle and prevents colliding.

DESIGN AND SIMULATION OF PROTOTYPE

The prototype is designed and simulated using FUSION 360 software as shown in Figure 2 and Figure 3.

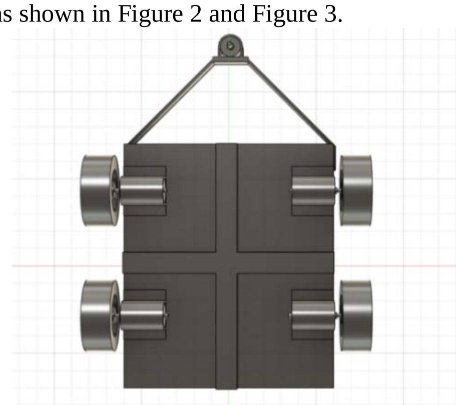

Figure 2. Design of proposed Prototype

Simulation

Uniform Displacement Load= 80 N

Maximum Displacement = 6.093E-04 mm (Y-axis)

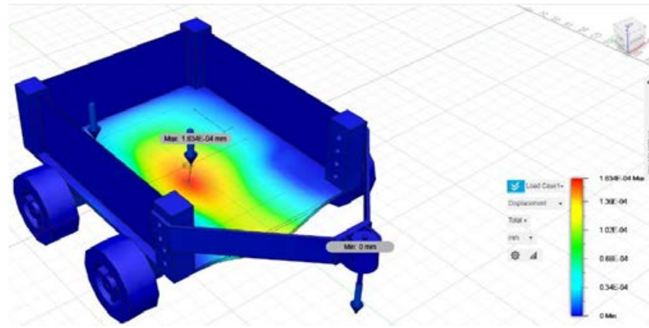

Figure 3. Simulation of prototype using Fusion 360

The comparison between the traditional Grass Cutters and IoT-based Solar Power Grass Cutters are mentioned in the Table 1.

Table 1. Traditional Vs IoT-based Solar Power Grass Cutters

Aspect	Traditional Grass Cutters	IoT-based Solar Power Grass Cutters
Efficiency and Coverage	Area covered per unit of time	Consistent coverage, automated operation
Cutting Precision	Manual control accuracy	High precision through automation
Cutting Time	Time taken for a specific area	Faster and more time-efficient
Safety	Operator safety	Obstacle detection and immediate halt
Energy Efficiency	Fuel consumption	Solar-powered, energy-efficient
Labor and Operator Fatigue	Physically demanding	Minimal operator effort required
Environmental Impact	Noise, emissions	Eco-friendly, minimal environmental impact
Maintenance	Mechanical upkeep	Sensor calibration, occasional checks

RESULT AND DISCUSSION

The IoT-enabled solar-powered grass cutter represents a breakthrough in lawn maintenance, delivering superior performance and exceptional environmental advantages compared to traditional methods. It offers consistent, efficient, and precise grass cutting, reducing operator fatigue significantly. Harnessing clean solar energy minimizes its carbon footprint and mitigates noise and air pollution. The solar based cutter will help the user to avoid from mowing their own lawns and will reduce environmental and noise pollution.

Furthermore, meticulous 3D modeling and simulation using FUSION 360 attest to its structural integrity, durability, precision, and stability. Despite a higher initial cost, long-term benefits include reduced operating expenses and a greener approach to landscaping and lawn care. This innovation benefits parks, hotels, public spaces, and environmentally conscious individuals, ushering in a cleaner, quieter, and eco-conscious era in green space maintenance.

The following results are obtained when the stress analysis is performed to the prototype: when a point load of 2kg is applied on four supports and UDL (uniformly distributed load) load of 8kg is applied on the base and a point load of 0.5kg is applied on the front part of the prototype. The simulation (Stress analysis) of the prototype is shown in the Figure 4.

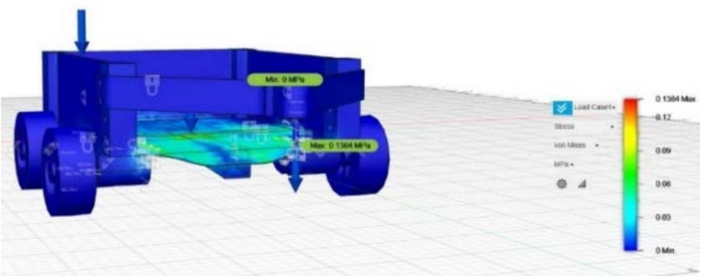

Figure 4. Stress analysis of prototype

From the stress analysis it can be concluded that, a safety factor of 15, consistently applied to both the overall structure and individual components (Safety Factor per Body), indicates a highly conservative and safe design.

Displacement analysis is a critical step in preparing a model because it helps assess structural integrity, safety, and compliance with standards, while also supporting design optimization and material selection. It plays a fundamental role in ensuring that the model functions as intended and meets performance and safety requirements. The simulation of the displacement analysis is shown in the Figure 5.

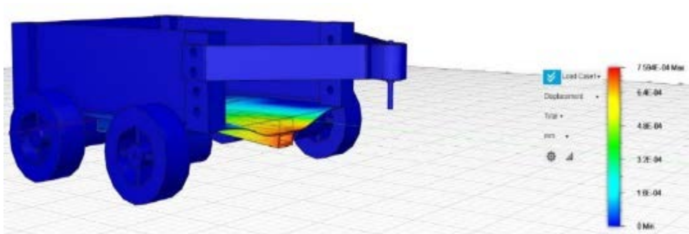

Figure 5. Displacement analysis of prototype

The results showed that, the maximum displacements observed in the model are certainly on the order of micrometers, signifying very small deformations in response to the applied loads. These values suggest that the prototype experiences minimal overall deformation, as well as slight movements in the individual X, Y, and Z directions.

Conclusion

In conclusion, the IoT-based solar-powered grass cutter effectively addresses the environmental challenges posed by traditional grass cutters. By harnessing renewable energy, employing smart technology for automation and remote control, and ensuring minimal emissions and noise, these innovative machines represent a dominant and sustainable choice for maintaining green spaces across a variety of settings. Through their efficient, eco-friendly, and forward-looking design, IoT-based grass cutters are poised to revolutionize the landscape of lawn maintenance and contribute to a greener and cleaner future. The results from stress, strain, and displacement analyses collectively indicate that the prototype exhibits minimal deformation, maintains structural integrity, and responds well to the applied loads, and also indicates that additional assessments may be needed to ensure the design meets all necessary criteria for structural integrity and performance.

The following benefits are realized from the designed solar grass cutter:

- reduced costs due to better blade efficiency and less weight of total components
- reduced fuel costs, no pollution, and no fuel residue due to utilization of solar energy
- The sensors used in the prototype are not affected by the environment
- The DC motor maintains consistent speed when used in load settings
- The solar panel constantly charges the battery
- The labor cost is reduced as it can be operated by a normal person.

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Conflict of Interest statement

The authors do not have any conflict of interest for this work.

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