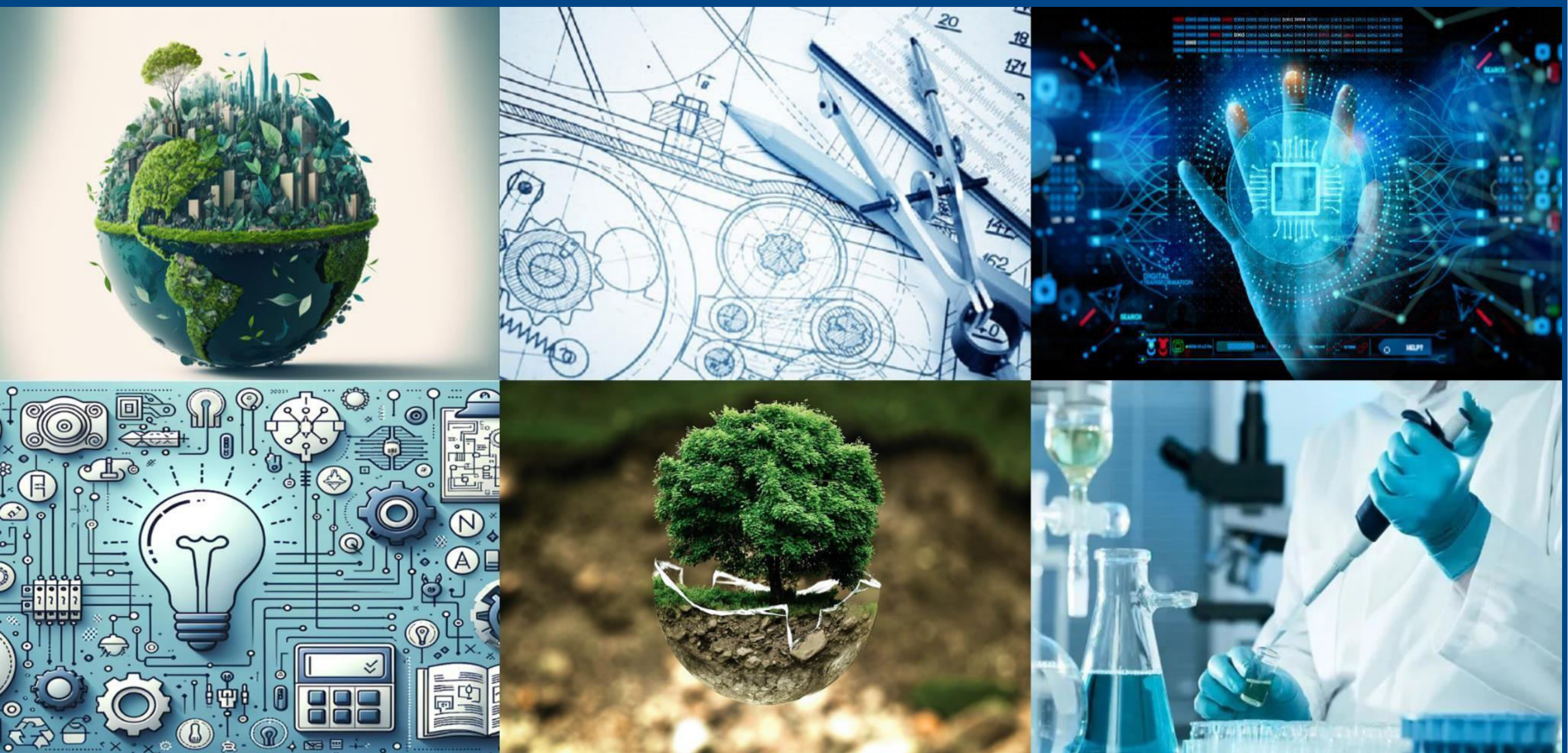
ISSN: 2582-7219

International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.206

Volume 8, Special Issue 2, November 2025

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An Optimized Battery Storage Based Solar Floor Cleaning Robot

B. Reuben[1], B. Prakash Ayyappan[2]

Assistant Professor, Department of ECE, Sri Bharathi Engineering College for Women, Kaikkurichi, Pudukkottai, India[1]

Associate Professor, Department of EEE, Sri Bharathi Engineering College for Women, Kaikkurichi, Pudukkottai, India[2]

ABSTRACT: The increasing demand for sustainable and energy-efficient solutions in cleaning systems has led to the development of solar-powered automation technologies. This project, titled "Battery Storage Optimised Based Solar Floor Cleaning," presents an eco-friendly, autonomous floor cleaning system powered by solar energy with a focus on efficient battery management. The system utilizes a solar panel to charge a rechargeable battery, which in turn powers the cleaning mechanism comprising motors for movement, brushes for sweeping, and a sprayer for wet cleaning. A microcontroller unit monitors the battery voltage levels and controls the cleaning operations based on available power, thereby optimizing the battery's lifespan and ensuring efficient energy usage.Battery storage optimization is achieved by regulating the charging and discharging cycles using embedded control logic. The system ensures that the cleaning unit only operates when sufficient energy is stored, and enters a low- power standby mode otherwise. This not only prevents battery over-drain but also maximizes solar utilization during daylight hours. The prototype demonstrates a viable solution for large- area floor cleaning applications such as in public buildings, educational institutions, and industrial facilities. With zero dependency on grid electricity and reduced human intervention, this project highlights the integration of renewable energy and automation in everyday cleaning systems.

KEYWORDS: Battery Management System, Pulse Width Modulation & Revolutions per Minute.

I. INTRODUCTION

The need for sustainable, efficient, and automated solutions in day-to-day operations has grown significantly in recent years. One of the critical areas where innovation is required is in the domain of cleanliness and hygiene, especially in large-scale indoor facilities such as shopping malls, hospitals, educational institutions, airports, railway stations, warehouses, and offices. These places require frequent and thorough floor cleaning to maintain hygiene standards. Conventionally, such cleaning tasks are carried out either manually or using electrically powered cleaning machines. While effective to a certain extent, manual cleaning is labor-intensive, time-consuming, and inconsistent in terms of quality. On the other hand, traditional electric floor cleaners are heavily dependent on grid electricity, leading to increased operational costs and carbon emissions.

In response to these challenges, this project proposes an innovative solution in the form of a Battery Storage Optimised Based Solar Floor Cleaning system. The main goal of the project is to develop an autonomous floor cleaner that operates using solar energy, thereby eliminating dependency on external power sources and contributing to a greener, more sustainable future. The system is designed to be self-powered through solar panels, which charge a battery during daylight hours. This stored energy is then used to power the cleaning mechanisms—such as motors, sprayers, and mopping systems—throughout the day.

A distinguishing feature of this system is its battery optimization functionality. Unlike typical solar-powered systems that use stored energy without control, this system continuously monitors the battery's voltage level using a microcontroller (e.g., Arduino or ESP32). It only initiates or continues the cleaning process if the battery level is within a predefined safe range, thus preventing over-discharge and ensuring longevity of the battery. When battery levels drop below the threshold, the system halts cleaning operations and enters a power-saving standby mode, resuming only when the battery is adequately recharged.

Addition to solar energy utilization and power optimization, the system also incorporates smart features such as obstacle detection using ultrasonic sensors, allowing it to navigate around furniture and walls safely. The integration of simple electronics and embedded systems enables autonomous operation with minimal human supervision, making it highly suitable for large public or private indoor environments.

The system design emphasizes cost-effectiveness, modularity, and environmental sustainability. Components such as solar panels, rechargeable batteries, motor drivers, and sensors are widely available and affordable, making the system accessible for mass adoption. Furthermore, the project promotes the use of clean energy in robotics and automation, demonstrating how renewable resources can be practically applied in real-world solutions.

This project not only addresses the increasing demand for automated cleaning systems but also contributes positively to environmental conservation and energy management. The successful implementation of this solar- powered cleaning robot has the potential to revolutionize the way floor cleaning is approached in modern infrastructure by reducing electricity consumption, labor dependency, and environmental impact. The combination of automation, solar technology, and smart battery management makes this system a sustainable and scalable solution for future smart cities and energy-conscious .

II. LITERATURE REVIEW

Sabiya Kirangi, Atul Shitole, Tejaswini Parate, Smita Pawar [1]. Developed a solar-powered floor cleaner designed for tiled indoor environments. The system harnesses solar energy to power the robot, demonstrating the feasibility of using renewable energy for indoor cleaning applications. The work serves as an important reference for understanding the practical application of solar power in cleaning systems.

Sayed Mohaiminul Hoque, Mashfiqul Hoque, Afif Bin Arfan; Israt Jahan, Islam Bin Mursalin [2]. Proposed a smart cleaning robot that uses IR sensors for obstacle detection and Arduino for control and automation. The integration of sensors with the Arduino microcontroller enabled efficient navigation and automation, highlighting the potential of microcontroller-based sensor integration for smart cleaning robots.

M. Glavin; W.G. HurleyFarjon [3]. Focused on battery optimization and maximum power point tracking (MPPT) charging methods to extend battery life in solar systems. By employing intelligent charge-discharge control, the study provides a core concept for optimizing battery usage, which is crucial for ensuring the long-term efficiency of solar-powered robots.

Mahendra Babu K J, Girish T M, Hari Krishna L S, Murali M E, Yellaling [4]. Designed a manually guided vacuum cleaner powered by solar energy. Although it required manual guidance, the study validated the application of solar energy in cleaning devices, providing insights into renewable energy integration for household cleaning solutions.

Chenrui Hu [5]. Introduced power-efficient control strategies for robots aimed at reducing energy consumption. The study’s findings align with the present work’s goal of designing energy-saving autonomous robots, emphasizing the importance of energy-efficient design in mobile robotics.

Jiajun Ma [6]. Paper explored the use of ultrasonic sensors for obstacle detection and autonomous navigation. The study demonstrated the effective use of ultrasonic sensing for smart object detection, providing a foundational technique for integrating collision avoidance in cleaning robots.

Qiang Wang, Yuanfan Li, Rongrong Li [7]. The authors discussed real-time energy harvesting techniques to enable mobile robots to use renewable energy sources like solar power. This work justifies the integration of solar-based mobility in cleaning robots, supporting the development of self-sustaining robotic platforms.

Pranav P, Midhun Shankar M, Tomin Jose, Vibin Chandi Varghese [8]. designed an automatic floor cleaner equipped with a water tank and pump for wet cleaning in industrial settings. The system’s ability to perform wet cleaning makes it relevant for developing dual-mode (wet/dry) cleaning robots, expanding their versatility.

K. Bhargavi, B. Kavya, P. Vamshi, P. Shiva, K. Sai Prakash [9]. Developed a solar-powered cleaner with switchable wet and dry modes. By enabling multifunctional cleaning modes using renewable energy, this paper supports the design of adaptable cleaning robots that can handle different surface requirements.

Irina I. Picioroaga, Constantin Bulac [10]. Proposed microcontroller-based algorithms to prevent battery over- drain, ensuring better battery health and longevity. The study's central idea of optimizing battery storage andextending the battery life cycle is critical to improving the performance and durability of solar-powered cleaning robots.

II. RELATED WORK

Cleanliness and hygiene are vital in both public and private indoor environments such as hospitals, schools, malls, factories, and offices. Manual floor cleaning is time- consuming, labor-intensive, and often inconsistent, while existing automated solutions are limited in efficiency and sustainability. Most commercially available robotic floor cleaners rely heavily on electricity from the grid and require regular manual charging, making them impractical for continuous operation, especially in remote or large facilities. Moreover, these systems do not utilize renewable energy sources and contribute to increasing carbon footprints.

A critical issue with existing solar-powered cleaning systems is the lack of energy management. These systems generally do not incorporate any mechanism to monitor battery levels or optimize energy usage. This results in inefficient battery utilization, premature battery degradation, system shutdowns during low power, and unnecessary interruptions in the cleaning process. As a result, the reliability and efficiency of such devices in real-world applications are significantly reduced.

The main problems identified are:
(i).High dependence on electrical charging sources (ii).Lack of renewable energy integration
(iii).Absence of smart battery optimization and energy monitoring
(iv).Limited autonomous navigation and poor obstacle detection
(v).Unsuitability for large or dynamic environments (vi).Lack of multi-mode cleaning (wet and dry)
These limitations highlight the necessity for a smart, energy-efficient, autonomous, and solar-powered floor cleaning system with real-time battery management— addressed effectively in the proposed project.

III. METHODOLOGY

The Battery Storage Optimized Based Solar Floor Cleaning system aims to address the shortcomings of conventional cleaning machines by integrating renewable energy, intelligent energy management, and autonomous navigation. This system is designed to operate efficiently using solar power, reducing dependency on grid electricity and minimizing the environmental footprint. It also incorporates smart battery management, obstacle avoidance, and autonomous operation, making it suitable for large-scale indoor environments.

IV. WORKING PRINCIPLE

4.1 Solar Panels: The solar panels are the primary source of energy for the system. They charge a high-capacity battery during daylight hours, ensuring the floor cleaner operates independently without the need for external power sources. The size and efficiency of the solar panels are selected to ensure that the cleaning robot can function for extended periods without requiring frequent recharges.

4.2Battery Storage:
A rechargeable battery is used to store the energy generated by the solar panels. The system is equipped with a battery management system (BMS) that ensures the battery operates within optimal charge and discharge limits. This prevents overcharging and deep discharge, thereby extending battery life. The BMS continuously monitors the battery's voltage and energy consumption, allowing the system to intelligently manage power and halt cleaning when energy levels drop below a safe threshold.

4.3 Cleaning Mechanism:

The cleaning system includes motors for vacuuming, scrubbing, and mopping. These are powered by the stored energy in the battery. The cleaner operates in both wet and dry modes, depending on the type of cleaning required. Wet cleaning uses water and detergent for tougher stains, while dry cleaning employs suction to pick up dust and debris.

4.4 Obstacle Detection and Navigation:

The system employs ultrasonic sensors, IR sensors, or LIDAR for obstacle detection and avoidance. These sensors help the robot navigate around furniture, walls, and other obstacles without human intervention. The system uses algorithms for real-time path planning, ensuring that it efficiently covers the entire cleaning area while avoiding any collisions.

4.5 Autonomous Operation:

The system is designed to operate autonomously, which means that the cleaning process requires minimal human supervision. Once activated, the robot navigates the room, cleans the floor, and returns to its charging station when the battery level is low. The autonomous operation includes the ability to handle multiple cleaning zones and even identify areas that need more attention.

4.6 Smart Battery Optimization:

The proposed system integrates a smart battery optimization algorithm that dynamically adjusts cleaning schedules based on battery levels. The robot is programmed to clean only when sufficient power is available. When the battery reaches a preset threshold, the cleaning process stops, and the robot goes into standby mode until it receives sufficient charge.

4.7 System Control and Monitoring:

The system can be monitored and controlled via a mobile app or web interface. The app allows users to start or stop the cleaning cycle, monitor battery levels, and schedule cleaning operations. Users can also receive notifications when the cleaning process is completed or if any issues arise, such as a low battery or obstacles blocking the path.

4.8 Energy Efficiency Features:

The system incorporates energy-efficient motors and sensors, reducing power consumption without sacrificing performance. The cleaning mechanism is optimized for minimal energy use while ensuring effective cleaning, thus increasing the operational time on a single battery charge.

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

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|| Volume 8, Special Issue 2, November 2025 ||

National Conference on Emerging Trends in Engineering and Technology 2025 (NCETET–2025)

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V. BLOCK DIAGRAM

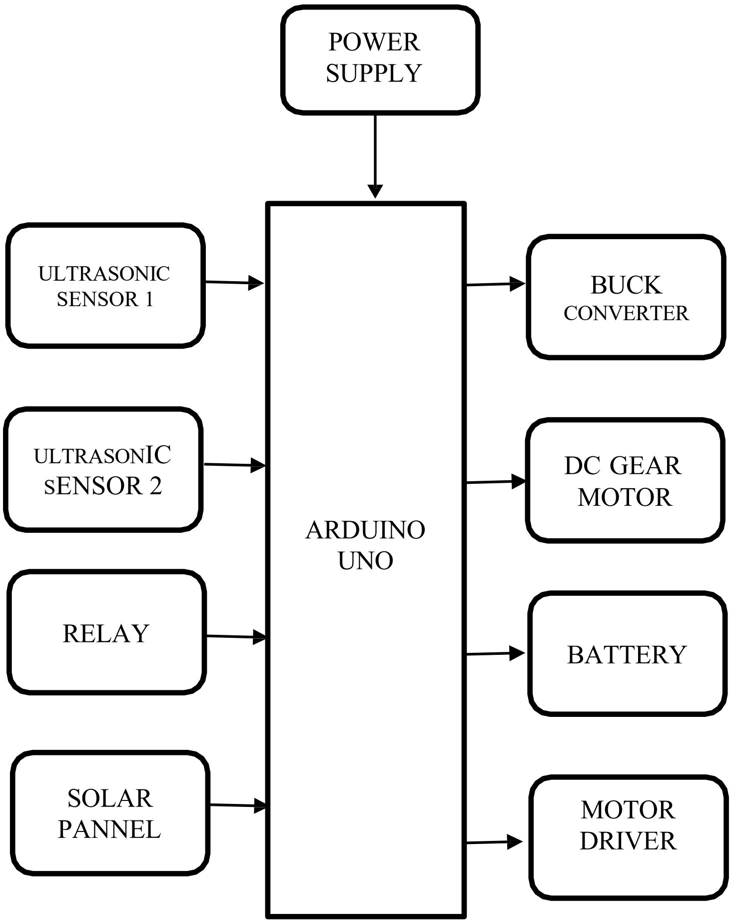

Fig.1. Block Diagram of Proposed System.

The system is controlled by an **ArduinoUno**, which serves as the central controller, managing all input and output components.

5.1 Power Supply: Provides the necessary electrical power to start and support the circuit. It distributes power to the Arduino and other components.

5.2 Ultrasonic Sensors (1 & 2): Two ultrasonic sensors are placed at the front of the robot. These sensors detect obstacles or walls by sending and receiving sound waves and help the Arduino navigate safely.

5.3 Relay: The relay acts as an electronic switch, controlling the cleaning mechanism, such as activating the cleaning brush or vacuum motor when the robot is running.

5.4 Solar Panel: The solar panel is responsible for harvesting solar energy. This energy is sent to the Arduino for managing charging functions.

5.5 Buck Converter: The buck converter steps down the voltage from the solar panel to a level suitable for charging the battery safely.

5.6 DC Gear Motor: The DC gear motors provide the driving force to move the robot over the floor. They are connected to the wheels and are responsible for forward and backward movement.

5.7 Battery: The battery stores the energy collected from the solar panel. It supplies power to the robot during night time or when sunlight is not sufficient.

5.8 Motor Driver: The motor driver controls the speed and direction of the DC gear motors, based on the instructions received from the Arduino.

VI. ARDUINO UNO

Fig.2. Arduino UNO

6.1 Central Controller:
The Arduino Uno acts as the brain of the cleaning robot. It reads data from sensors (such as IR sensors, ultrasonic sensors, or LDRs), processes it using the pre-programmed logic (code), and sends control signals to output devices such as motors, relays, buzzers, or displays.

6.2 Sensor Integration:
Ultrasonic Sensors: Used for obstacle detection and navigation. The Arduino processes the echo time and calculates the distance to avoid collisions.

IR Sensors: Detect floor edges or lines to ensure the robot doesn't fall off elevated surfaces or skip marked zones.

LDR (Light Dependent Resistor): Detects sunlight intensity. If used, it helps in monitoring when optimal solar charging is available.

6.3 Motor Control:
The Arduino sends PWM (Pulse Width Modulation) signals to motor drivers (e.g., L298N) to control the speed and direction of: DC motors (for movement)
Scrubber motors (for cleaning operation)
Based on sensor feedback, it decides when to stop, turn, or change direction.

6.4 Battery Monitoring and Optimization:
The system can include voltage divider circuits to monitor battery voltage levels via analog input pins.

Based on programmed thresholds, Arduino can stop the motor or put the system in standby mode when the battery is low and resume when charging is sufficient.

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6.5 Solar Charging Management: Arduino can control a relay module or MOSFET circuit to switch charging paths or disconnect the battery when it's fully charged, preventing overcharging.

6.6 User Interface (Optional) Arduino can be connected to:
LCD display (to show battery percentage, cleaning status) Buzzer or LED indicators (to give alerts or feedback)

6.7 Automation Logic:
The Arduino code follows a decision-making structure using: if-else conditions to respond to sensor inputs.
Looping structures to continuously monitor environment and perform cleaning actions.
Interrupts (if used) to react quickly to emergency inputs like obstacle detection.
.

VII. EVALUATION AND PERFORMANCE

1.2 Solar Power and Battery Management
Solar Panel Efficiency: The solar panel effectively charges the battery during daylight hours, ensuring that the robot remains powered even in areas where access to traditional grid power is limited.
Battery Performance: The battery provided reliable backup power during night-time or cloudy

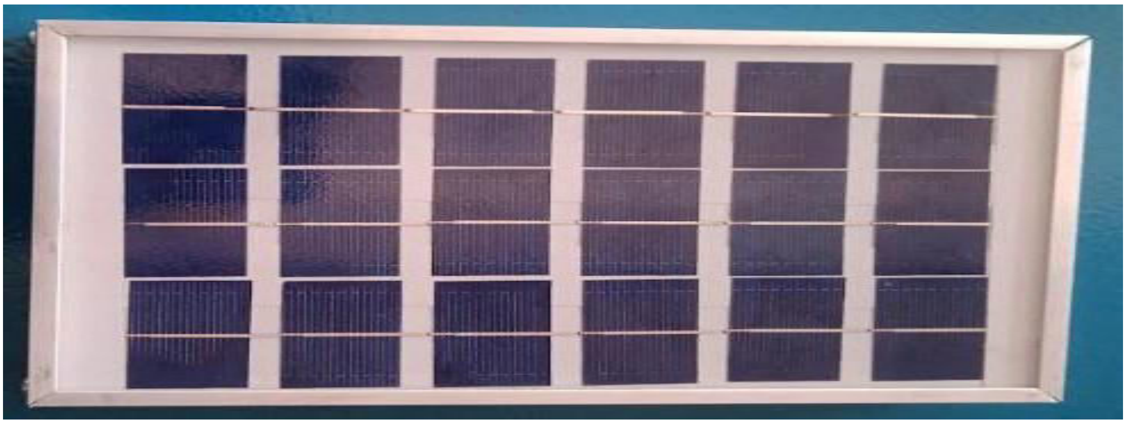

Fig.3. Solar Panel

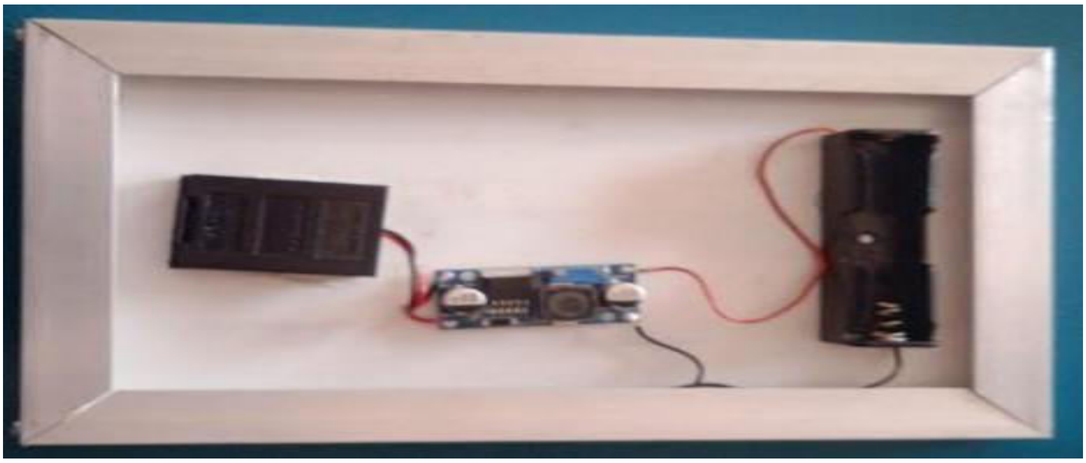

Fig.4. Solar Panel solar panel implement battery Storage

conditions. When the battery voltage dropped below the threshold (10.5V), the system automatically stopped the cleaning process, preventing further discharge. The system switched to solar charging mode to recharge the battery.

Energy Optimization: The system optimized power usage by running only essential components like the motors and sensors. When the battery level was adequate, the system operated continuously without relying on external power.

7.2 Obstacle Detection
Accuracy of Ultrasonic Sensor: The ultrasonic sensor detected obstacles in front of the robot with a high degree of accuracy. When an object was detected within the defined threshold distance (20 cm), the system immediately halted the robot, reversed it, and avoided the obstacle.

Safety and Navigation: The obstacle avoidance feature ensured that the robot moved freely around obstacles and cleaned the floor without getting stuck.

7.3 Motor and Cleaning Brush Operation
Motor Control: The motors ran efficiently to drive the robot forward, with the system reacting to changes in distance using the ultrasonic sensor. The robot was able to navigate around obstacles effectively while moving forward.
Relay Operation: The cleaning brush motor, controlled by the relay, activated when the robot was in motion, ensuring continuous floor cleaning. The relay mechanism allowed the system to activate and deactivate the cleaning motor efficiently.

7.4 System Monitoring and Feedback
Battery Monitoring: The system continuously monitored battery voltage using the Arduino, providing real-time feedback through the serial monitor. If the battery dropped below the predefined voltage level, the robot stopped and switched to solar charging mode.

Serial Communication for Debugging: The Arduino IDE’s serial monitor provided useful feedback during testing, displaying real-time data on battery voltage and obstacle distance, making it easier to debug and ensure the system functioned as expected.

7.5 Efficiency and Autonomy
Autonomous Operation: The robot was able to operate autonomously without manual intervention. It successfully navigated, detected obstacles, cleaned the floor, and recharged its battery using solar power.

Energy Efficiency: By using solar energy to power the system and only activating motors when necessary, the robot was able to achieve efficient use of resources and maintain extended operation time.

VIII. RESULT ANALYSIS

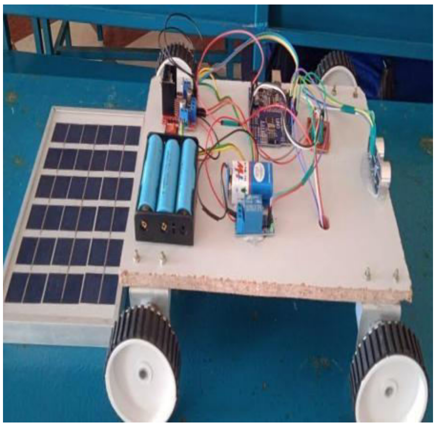

Fig.6.optimized solar power using floor cleaning robot

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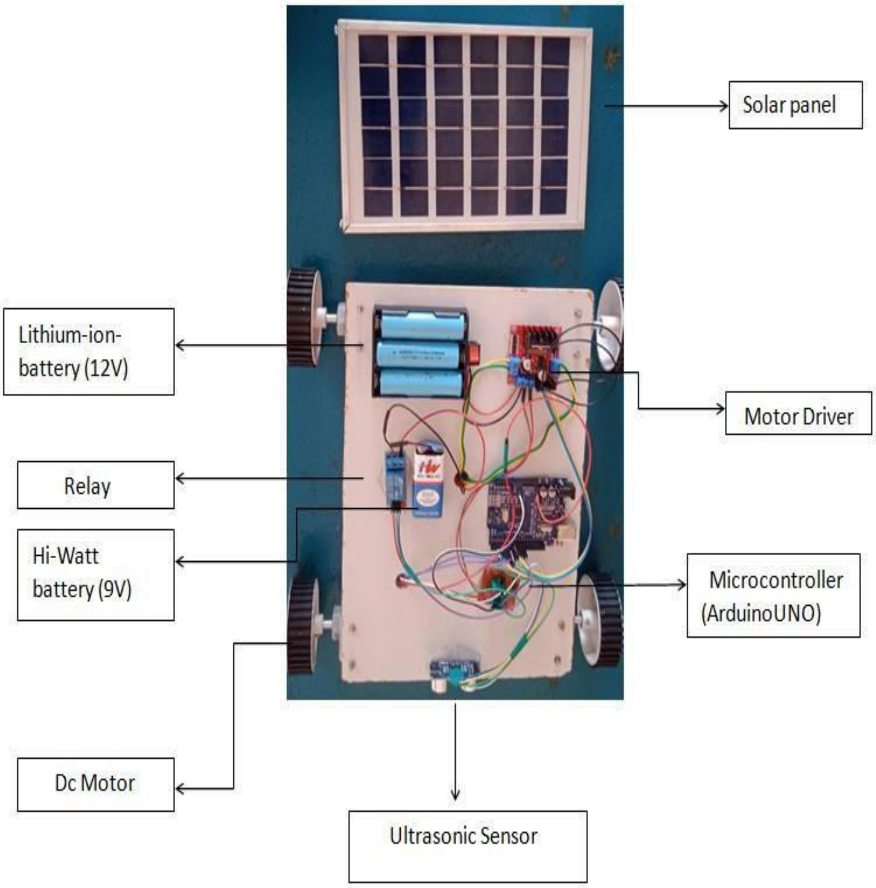

Fig.7.Top view of optimized solar power using floor cleaning robot

PIN SPECIFICATION:

- Microcontroller ATmega328
- Operating Voltage 5V Input Voltage (recommended) 7-12V
- Input Voltage (limits) 6-20V
- Digital I/O Pins 14 (of which 6 provide PWM output)
- Analog Input Pins 6
- DC Current per I/O Pin 40 mA
- DC Current for 3.3V Pin 50 mA

IX. ALGORITHM

Check for Obstacle Using Ultrasonic Sensor
Send trigger pulse
Measure echo pulse duration
Convert time to distance
If distance < safe limit (e.g., 20 cm):
  Stop motor
  Reverse or turn
Else:

Continue forward motion
Activate Floor Cleaning Brush
Turn ON relay to power cleaning motor
Move the Robot Forward
Activate motor driver pins to rotate motors forward

Continuous Monitoring Loop
Repeat battery check and obstacle detection
Log sensor data via serial monitor (optional)
If battery low during operation:
  Stop motors
  Switch to solar charging mode

Solar Charging Mode
Disconnect motor outputs
Allow battery to charge via solar panel
Monitor voltage until threshold is met
Resume operation
  Stop Condition
  Stop cleaning and movement when manual stop is triggered or battery is fully drained
End.

```
2   // Define motor driver pins constint motor1Pin1 = 2; constint motor1Pin2 = 3; constint motor2Pin1 = 4; constint
    motor2Pin2 = 5;
3   // Ultrasonic sensor pins constinttrigPin = 6;
4   constintechoPin = 7;
5   // Relay pin for brush motor constintrelayPin = 8;
6   // Battery voltage analog pin constintbatteryPin = A0;
7   // Voltage thresholds (adjust based on your battery type) const float batteryLow = 10.5;  // in volts
8   const float batteryFull = 12.6; // in volts
9   // Distance threshold for obstacle detection (in cm) constintobstacleDistance = 20;
10  void setup() {
11  // Motor pins pinMode(motor1Pin1, OUTPUT); pinMode(motor1Pin2, OUTPUT); pinMode(motor2Pin1, OUTPUT);
    pinMode(motor2Pin2, OUTPUT);
12  // Ultrasonic sensor pins pinMode(trigPin, OUTPUT); pinMode(echoPin, INPUT);
13  // Relay pin pinMode(relayPin, OUTPUT);// Serial for debugging Serial.begin(9600);
}
void loop() {
float voltage = readBatteryVoltage(); Serial.print("Battery Voltage: "); Serial.println(voltage);
if (voltage <batteryLow) { stopMotors();
digitalWrite(relayPin, LOW); // Turn off cleaning motor Serial.println("Battery Low! Switching to solar charging
mode...");
delay(1000); return;
}
long distance = getDistance(); Serial.print("Distance: "); Serial.println(distance);
if (distance <obstacleDistance) { stopMotors(); Serial.println("Obstacle Detected!"); delay(500);
reverseMotors(); delay(1000);
} else { moveForward();
digitalWrite(relayPin, HIGH); // Turn on brush motor
}
delay(200);
}
// ---------------------- FUNCTIONS ----------------------
floatreadBatteryVoltage() { intanalogValue = analogRead(batteryPin);
float voltage = (analogValue / 1023.0) * 5.0 * (12.6 / 5.0); // Adjust based on voltage divider
```

```
return voltage;
}
longgetDistance() { digitalWrite(trigPin, LOW); delayMicroseconds(2); digitalWrite(trigPin, HIGH);
delayMicroseconds(10); digitalWrite(trigPin, LOW);
long duration = pulseIn(echoPin, HIGH); long distance = duration * 0.034 / 2; return distance;
}
voidmoveForward() { digitalWrite(motor1Pin1, HIGH); digitalWrite(motor1Pin2, LOW); digitalWrite(motor2Pin1,
HIGH);
digitalWrite(motor2Pin2, LOW);
}
voidreverseMotors() { digitalWrite(motor1Pin1, LOW); digitalWrite(motor1Pin2, HIGH); digitalWrite(motor2Pin1,
LOW); digitalWrite(motor2Pin2, HIGH);
}
voidstopMotors() { digitalWrite(motor1Pin1, LOW);
digitalWrite(motor1Pin2, LOW); digitalWrite(motor2Pin1, LOW); digitalWrite(motor2Pin2, LOW);
}
```

X. CONCLUSION

In conclusion, the Battery Storage Optimized Based Solar Floor Cleaning system represents a significant advancement in the field of automated cleaning by combining renewable energy, intelligent control, and autonomous operation. By harnessing solar energy, the system eliminates dependency on external electrical power, promoting environmental sustainability and reducing carbon emissions. The integration of a battery management system ensures optimal energy usage, automatically switching to solar charging when needed, which enhances the robot's operational lifespan and reliability. The autonomous design, powered by an Arduino controller, allows seamless coordination of motor functions, obstacle detection, and cleaning mechanisms, reducing the need for human intervention and improving overall efficiency. The ultrasonic sensor's role in real-time obstacle detection enhances both safety and cleaning effectiveness, ensuring uninterrupted and precise performance. Furthermore, the system's ability to optimize energy use directly contributes to lowering operational costs, making it an economically viable solution for both residential and commercial applications. The project successfully addresses the need for sustainable and intelligent cleaning systems by integrating wet/dry cleaning modes, adaptive navigation, and efficient power management. With its low maintenance requirements and eco-friendly design, the system stands out as a practical, scalable solution for modern cleaning needs. Drawing upon insights from related works, the project incorporates best practices in energy optimization, obstacle avoidance, and autonomous control, reflecting a well- rounded and innovative approach. The findings demonstrate that renewable energy-driven robotics can play a crucial role in reducing environmental impact while delivering high performance. Overall, the system showcases the potential of combining smart technologies with sustainable energy to create efficient, cost-effective, and reliable cleaning solutions.

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