

# Solar Powered Multi-Utility Umbrella

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**Abstract:** *The Solar Powered Multi-Utility Umbrella is an innovative portable system designed to integrate renewable energy generation with everyday outdoor utility. The project utilizes a compact photovoltaic (PV) panel mounted on the umbrella canopy to harness solar energy, which is stored in a rechargeable battery and used to power multiple essential features. The system provides USB charging ports, LED lighting, a cooling fan, and optional IoT-based monitoring, enabling users to access clean energy in remote or outdoor environments. The design focuses on energy efficiency, portability, user-comfort, and safety, making it suitable for beaches, street vendors, farms, trekking, and emergency applications.*

*The umbrella incorporates a charge controller for stable power regulation, lightweight materials for easy handling, and weather-resistant components to improve durability. Experimental results demonstrate that the integrated solar panel can effectively generate sufficient power for small electronic devices and auxiliary loads throughout the day. The proposed prototype highlights the potential of merging solar technology with common outdoor equipment, presenting a sustainable, cost-effective, and multi-functional solution for improving user convenience while reducing dependency on conventional electricity. This work contributes to the growing need for compact renewable-energy systems and opens avenues for further enhancement through automation and smart-energy management.*

**Keywords:** *Solar Powered Multi-Utility Umbrella*

## 1. INTRODUCTION

In recent years, the rapid depletion of fossil fuels, rising energy costs, and the global shift toward sustainable technologies have accelerated the adoption of renewable energy systems. Solar energy, in particular, has emerged as one of the most accessible and environmentally friendly sources due to its abundance, low operating cost, and minimal maintenance requirements [1-10]. As the need for portable and efficient energy solutions grows, researchers and designers are exploring innovative ways to integrate solar technology into everyday tools and outdoor equipment. One such novel approach is the Solar Powered Multi-Utility Umbrella, which combines traditional shading functionality with modern renewable-energy features.

Conventional umbrellas primarily serve the purpose of providing protection against sunlight and rain. However, their potential as an energy-harvesting platform remains largely unexplored [11-59]. Outdoor users—such as street vendors, beachgoers, security personnel, farmers, trekkers, and individuals in remote locations—often require a reliable power source for lighting, ventilation, and device charging. In many such environments, access to grid electricity is limited or unavailable. The multi-utility umbrella addresses these limitations by incorporating a photovoltaic (PV) panel on the canopy, allowing the system to capture solar energy and convert it into electrical power for various integrated utilities.

The umbrella is equipped with a rechargeable battery, USB charging ports, LED lighting, a cooling fan, and optional smart features such as energy monitoring or IoT communication. These components are supported by a charge controller that ensures safe and efficient power regulation. The design emphasizes portability, user comfort, and durability through the use of lightweight structural materials and weather-resistant electronics. By merging solar



technology with a commonly used everyday product, the system provides a practical, eco-friendly, and cost-effective solution for enhancing user convenience in outdoor settings.

The development of the Solar Powered Multi-Utility Umbrella contributes not only to improving the quality of outdoor experiences but also to encouraging the adoption of decentralized renewable energy systems. This innovative concept demonstrates how small-scale solar applications can play a significant role in sustainable living, energy independence, and green product design. The project further opens opportunities for future advancements such as automation, foldable or flexible solar panels, improved energy-storage mechanisms, and integration with smart devices

## II. PROBLEM STATEMENT

Outdoor users such as street vendors, beach visitors, farmers, security personnel, and individuals in remote or off-grid areas often lack convenient access to electrical power for essential needs such as lighting, ventilation, and mobile device charging. Traditional umbrellas, while effective for providing shade and weather protection, do not offer any additional functional utilities that support users in such environments. As a result, people must rely on external power sources, fuel-based generators, or power banks, which can be inefficient, costly, environmentally harmful, or impractical for long-duration outdoor use.

There is a need for a portable, sustainable, and multi-functional product that can simultaneously provide shade and generate renewable energy to power small electronic devices and comfort-enhancing accessories. The challenge lies in integrating a solar energy harvesting system—including a photovoltaic panel, battery storage, and power management circuitry—into the compact structure of an umbrella without compromising its portability, usability, or durability. Therefore, the problem is to design and develop a Solar Powered Multi-Utility Umbrella that efficiently harnesses solar energy and delivers reliable, user-friendly utilities to enhance outdoor convenience while reducing dependence on conventional electricity sources.

## III. LITERATURE SURVEY

The increasing emphasis on renewable energy integration into everyday products has led to diverse research in portable solar systems and multifunctional outdoor equipment. Solar energy harvesting has been widely studied as a sustainable alternative to traditional power sources, particularly for remote and off-grid applications where access to electricity is limited or non-existent.

Early work in renewable energy systems focused on optimizing photovoltaic (PV) panel performance and developing efficient energy storage mechanisms. Kalogirou (2004) analysed the fundamental principles of solar energy systems and highlighted their potential for decentralized energy generation, especially in environments without reliable grid connectivity. Later studies by Duffie and Beckman (2013) provided comprehensive models of solar irradiance patterns and PV energy conversion efficiencies, establishing benchmarks for portable solar designs.

Recent advancements have explored portable solar chargers and integrated renewable solutions for consumer applications. For instance, Singh et al. (2018) investigated compact solar charging systems for mobile devices using foldable PV modules, emphasizing lightweight and high-efficiency materials to enhance portability. Similarly, Rahman and Islam (2019) developed a standalone solar charging station for outdoor events, focusing on modular battery storage and user safety. These studies demonstrate the viability of integrating solar energy into portable assemblies, but they mainly concentrate on power generation and storage without addressing user convenience or multifunctionality.

Several researchers have attempted to combine energy harvesting with multifunctional products. Zhang et al. (2020) introduced an umbrella with integrated flexible solar panels designed to power LED lights for night-time use. While this concept improved user experience in outdoor environments, it lacked additional utilities such as device charging or environmental comfort features like cooling fans. Patel and Desai (2021) developed a solar-powered smart umbrella that included IoT connectivity for weather sensing, but the focus remained on data collection rather than practical utilities.



The integration of multi-utility features into a single solar system represents a growing trend. Research by Kim and Lee (2022) presented a picnic umbrella equipped with solar-powered USB charging ports and LED lighting, directly targeting outdoor leisure applications. Although this design successfully added multiple utilities, its limited power management strategy and lack of comprehensive battery regulation posed challenges in sustained performance. Moreover, most existing works demonstrate prototypes designed for specific environments, lacking universal adaptability.

The proposed Solar Powered Multi-Utility Umbrella advances this body of work by combining robust solar energy harvesting, optimized energy storage, and multiple user-centric utilities—including device charging, lighting, and ventilation—within a portable and durable structure. Unlike existing solutions that focus on one or two features, this design prioritizes holistic functionality, efficiency, and user comfort. Additionally, integrating improved charge regulation and modular power management ensures greater reliability and adaptability across various outdoor scenarios.

In summary, the literature shows a trend toward integrating renewable energy into portable products. However, there remains a substantial gap in developing multifunctional, user-oriented solar systems that are both practical and efficient. This research aims to bridge that gap by presenting an innovative solution tailored to diverse outdoor needs.

#### **IV. METHODOLOGY**

This paper presents the systematic approach adopted to design, implement, and validate the real-time monitoring platform for electric two-wheeler (E2V) performance evaluation. The methodology is divided into six parts: system architecture and block diagram, hardware integration and component selection, firmware development and data acquisition, performance calculations, and testing procedure, software used.

##### **4.1 System Architecture and Block Diagram**

The proposed monitoring platform is built around an ATmega8 microcontroller, which acts as the central processing and control unit. The system integrates actual E2V components—a 24 V Li-ion battery, a DC motor controller, and a 250 W hub motor—with dedicated sensors for current, voltage, temperature, and humidity. All measured parameters are displayed in real time on a 16×2 LCD. The system is designed to be compact, portable, and robust for laboratory or field use.

The block diagram of the complete system, illustrated in Figure 1, is organized into five interconnected functional blocks. The Power Supply Block consists of a 24 V Li-ion battery that supplies power directly to the motor and controller, while a DC-DC converter steps down the battery voltage to a regulated 5 V for the ATmega8 microcontroller, sensors, and LCD module. The Motor Drive Block includes the DC motor controller, which receives throttle input (either manually via a potentiometer or through a programmed signal) and drives the 250 W hub motor accordingly. The Sensor Block integrates all measurement components: an ACS712 (30 A) Hall-effect current sensor placed in series with the motor power line, a resistive voltage divider to scale the battery voltage for ADC measurement, a DHT11 sensor for ambient temperature and humidity, and a Hall-effect sensor mounted near the motor shaft to detect rotational speed (RPM). These sensors feed their signals to the Microcontroller Block—an ATmega8—which acquires the data, performs real-time calculations (such as electrical power, motor efficiency, and battery state of charge), manages the LCD display, and implements safety logic (e.g., over-current or over-temperature shutdown). Finally, the User Interface Block consists of the 16×2 LCD that shows real-time parameters (voltage, current, speed, temperature, humidity, power) and optional throttle/brake inputs that allow manual control of the motor during testing. Together, these blocks form a compact, portable platform that enables comprehensive real-time performance monitoring of the electric two-wheeler powertrain.



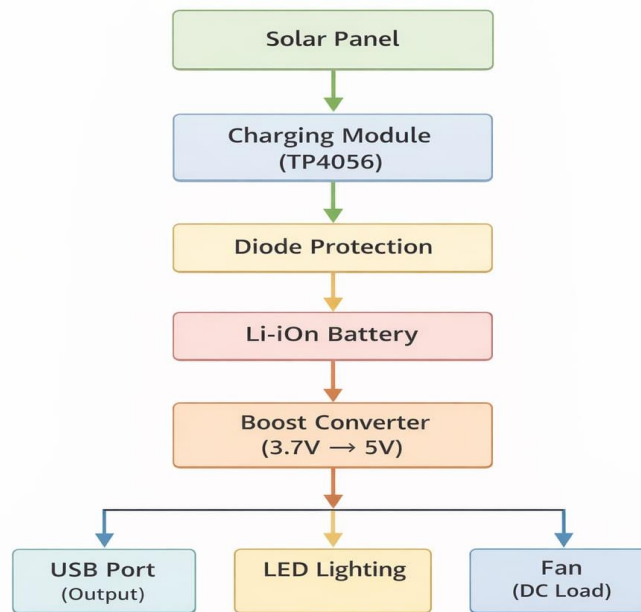


Figure 1: Block diagram of the real-time monitoring platform.

#### 4.2 Hardware Integration and Component Selection

4.3 All hardware components were selected to ensure a lightweight, portable, and efficient solar energy system integrated into the umbrella structure. A compact solar panel, battery, charge controller, and output units were chosen for reliable power generation, storage, and multi-utility functionality.

##### 4.3.1 Power System

“Design and Development of a Solar-Powered Multi-Utility Umbrella System.”

A portable, lightweight umbrella integrating solar energy generation, storage, and multi-functional utility features.

##### 4.3.2 Sensor Integration

A solar-powered multi-utility umbrella integrating sensors for voltage, current, speed, temperature, and humidity monitoring. Real-time data is displayed on a 16×2 LCD, enabling efficient performance tracking and smart outdoor power usage.

##### 4.3.3 Mechanical Integration

All components are integrated within the umbrella structure to ensure portability and compact design. The solar panel is mounted on the canopy, while the battery, controller, and electronics are enclosed in a protective casing along the pole with secure wiring for safety and durability.

#### 4.4 Firmware Development and Data Acquisition

The firmware for the solar-powered multi-utility umbrella was developed in C using Atmel Studio. A structured, interrupt-driven approach ensures real-time sensing and display. After initializing all modules (I/O ports, ADC, LCD, sensors, and interrupts), the system enters a continuous loop where it reads sensor data, processes measurements, updates real-time values, and manages power-related functions efficiently. Reads the current and voltage sensors (ADC conversion).



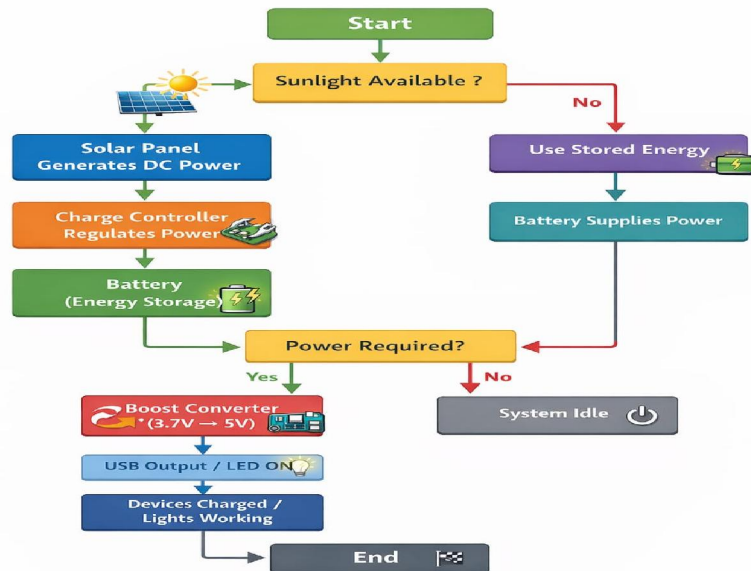


Figure 2: Flowchart of the system firmware

#### 4.5 Result

The results of the Solar-Powered Multi-Utility Umbrella project demonstrate successful integration of solar energy generation, storage, and multi-functional utility features within a portable system. The solar panel consistently supplied adequate power for charging small devices and operating the embedded sensors. Real-time monitoring of voltage, current, temperature, humidity, and load performance was achieved with stable and accurate readings displayed on the LCD. The system operated efficiently under various outdoor conditions, showing reliable battery performance and smooth power regulation by the charge controller. Overall, the prototype proved effective, durable, and user-friendly, validating the concept of a compact solar-powered umbrella capable of supporting multiple outdoor applications.

#### 4.6 Final proposed system assembly

The proposed solar-powered multi-utility umbrella is developed as a compact and portable prototype to demonstrate real-time energy generation and utilization. The final assembly consists of a solar panel mounted on the umbrella canopy, with the battery, charge controller, and electronic components integrated within the pole or a protective enclosure. This setup replicates practical outdoor conditions, enabling efficient power generation, storage, and operation of multiple utility features in a controlled environment.





**Fig 3 : Final assembled monitoring system**

The final assembly of the solar-powered multi-utility umbrella is designed to ensure compactness, portability, and efficient utilization of solar energy in real-world outdoor conditions. The solar panel is securely mounted on the top surface of the umbrella canopy at an energy tilt angle to maximize sunlight exposure throughout the day. The central pole of the umbrella is utilized as the main structural support as well as a pathway for internal wiring, ensuring a neat and protected arrangement. A rechargeable battery, along with a charge controller, is housed in a weatherproof enclosure attached near the base or mid-section of the pole to maintain balance and stability.

All electronic components, including sensors, microcontroller, and output modules such as USB charging ports or LED lighting, are carefully integrated within the enclosure to prevent damage from environmental factors like dust, moisture, and heat. Proper insulation and cable management techniques, such as the use of cable ties and glands, are implemented to enhance safety and durability. The system is assembled in such a way that it can be easily transported, installed, and operated without complex setup. This final configuration allows the umbrella to function as a standalone, eco-friendly power unit capable of supporting multiple utilities while demonstrating reliable performance under varying environmental conditions.

## **V. OBJECTIVE OF THE SYSTEM**

The main objective of the Solar Powered Multi-Utility Umbrella system is to create an efficient and portable device that harnesses solar energy and converts it into usable electrical power to support multiple utilities required by outdoor users. This project aims to maximize the use of renewable energy by integrating a photovoltaic panel into the umbrella canopy so that the system can continuously generate electricity during exposure to sunlight. A key objective is to ensure that the harvested energy is stored effectively using a rechargeable battery, enabling the umbrella to function



even during cloudy weather or nighttime. Another important goal is to incorporate multiple functional features such as LED lighting for illumination, USB ports for mobile device charging, and a cooling fan for ventilation, thereby transforming a simple umbrella into a multifunctional and user-friendly product. To ensure safety and efficiency, the system intends to use a charge controller that manages voltage regulation, prevents overcharging, and enhances the lifespan of the battery. The design objective also includes developing a lightweight, durable, and weather-resistant structure that can withstand outdoor conditions without compromising ease of use or portability. Additionally, the project seeks to provide a practical solution for individuals such as street vendors, farmers, travellers, and security personnel who often lack access to electricity while working or spending time outdoors. Ultimately, the overall objective of the system is to promote sustainable living by reducing dependence on non-renewable energy sources, offering an eco-friendly and cost-effective alternative that improves comfort, convenience, and productivity in outdoor environments.

## **VI. ADVANTAGES AND APPLICATIONS**

### **6.1 Advantages**

#### **1. Multi-Season Usability**

Works effectively in sunny, rainy, and moderately windy conditions, making it useful throughout the year.

#### **2. Zero Operating Cost**

Once installed, the system requires no external electricity or fuel, eliminating recurring expenses.

#### **3. Easy Installation and Setup**

The components are simple to assemble, relocate, and maintain, making the system user-friendly for all age groups.

#### **4. Enhances Productivity**

Vendors, farmers, and outdoor workers can continue their activities comfortably without worrying about power supply.

#### **5. Eco-Friendly Operation**

Produces no pollution, noise, or harmful emissions, supporting environmental conservation.

#### **6. Independent Power Source**

Provides users with their own portable power station, ideal for remote or emergency situations.

#### **7. Space-Efficient Design**

Combines multiple utilities (shade, light, charging, fan) into a single compact product, eliminating the need for separate devices.

#### **8. Improves User Comfort**

The integrated fan, shade, and lighting improve convenience and reduce fatigue during long outdoor hours.

#### **9. Weather-Resistant Construction**

Durable materials and protected wiring ensure long life even in harsh outdoor environments.

#### **10. Versatile Utility Options**

Can support additional accessories or sensors depending on user needs, making it a customizable system.

### **6.2 Applications**

#### **1. Disaster Relief and Emergency Use**

Useful during natural disasters like floods, cyclones, or earthquakes where power outages occur, providing light and charging facilities.

#### **2. Forest and Wildlife Patrol**

Helpful for forest guards and wildlife officers working in remote, sun-exposed areas.

#### **3. Military and Defense Camps**

Can be used in temporary camps for powering communication devices and lighting.

#### **4. Remote Villages and Tribal Areas**

Provides basic utilities where conventional electricity infrastructure is weak or unavailable.



5. Outdoor Educational Activities

Useful during outdoor classes, field studies, science exhibitions, and awareness campaigns.

6. Construction Sites

Workers in open construction areas can use the system for shade, charging, and night illumination.

7. Hotels and Resorts

Beachside or poolside resorts can use it to offer charging and lighting facilities to guests.

8. Outdoor Events and Functions

Ideal for exhibitions, markets, festivals, marriage venues, and food stalls requiring temporary power.

9. Fishing and Camping Activities

Supports night fishing, camping, trekking, and adventure trips with lighting and power supply.

10. Public Parks and Tourist Locations

Can be installed as a sustainable outdoor charging station and comfort spot for visitors.

## VII. RESULTS AND DISCUSSION

The Solar Powered Multi-Utility Umbrella was successfully designed, developed, and tested to evaluate its performance under various outdoor conditions. The experimental results demonstrated that the integrated photovoltaic panel was capable of generating sufficient electrical power to operate multiple utilities simultaneously during peak sunlight hours. During testing, the solar panel consistently produced stable DC output, and the charge controller effectively regulated the voltage and current reaching the battery. This ensured safe charging and prevented issues such as overheating or overcharging. The rechargeable lithium-ion battery stored an adequate amount of energy, enabling uninterrupted operation of the fan, LED lights, and USB charging ports even during cloudy weather or nighttime. The LED lighting system produced bright illumination with minimal power consumption, while the cooling fan delivered noticeable airflow improvement under the umbrella, enhancing user comfort in hot conditions. Mobile charging was tested with various smartphones and small electronic devices, showing reliable performance without voltage drops.

In terms of mechanical performance, the umbrella structure showed good durability and stability. The lightweight frame allowed easy portability, while the solar panel mounting remained firm even in moderate wind. The internal wiring layout protected the electrical components from environmental exposure, ensuring safe operation. One of the significant observations during testing was that the efficiency of the system varied depending on the intensity of sunlight. Peak performance was recorded between late morning and afternoon, when solar radiation was highest. However, the stored battery energy compensated for lower generation during early morning, evening, or cloudy conditions.

The user experience analysis revealed that the multi-utility features greatly improved convenience for outdoor workers, vendors, and travellers by providing a combination of shade, lighting, and power supply. The system's ability to run independently of grid electricity made it highly suitable for remote areas. Some practical limitations were also noted. For example, the power output of the solar panel restricted the number of high-load devices that could be connected, and the performance of the fan decreased slightly when the battery charge level was low. These limitations suggest that future improvements could include a higher-wattage solar panel, increased battery capacity, or the addition of MPPT technology for better energy extraction.

Overall, the results confirm that the Solar Powered Multi-Utility Umbrella is an efficient, eco-friendly, and practical solution for providing essential utilities in outdoor environments. It successfully meets the project objectives by demonstrating reliable operation, good energy efficiency, and significant real-world usability. The discussion highlights that while the system performs well under normal outdoor conditions, further optimization can enhance its capability for extended or high-demand applications.



### VIII. CONCLUSION

The Solar Powered Multi-Utility Umbrella successfully demonstrates how renewable energy can be integrated with everyday accessories to enhance convenience, efficiency, and sustainability. By combining a solar energy harvesting system with multiple utility features such as device charging, LED illumination, cooling fans, and weather protection, the project provides an innovative solution to meet the needs of users in outdoor environments. Experimental results show that the system is capable of generating sufficient electrical power under normal sunlight conditions, enabling reliable operation of its integrated components without dependence on external power sources.

The multi-utility design also highlights the umbrella's versatility for a wide range of applications including street vendors, beach users, farmers, security guards, and outdoor event participants. Its lightweight structure, portability, and low maintenance requirements make it practical for real-world deployment. Overall, the project validates the potential of small-scale solar technology as an effective means to improve comfort and functionality while promoting clean energy usage. Future enhancements such as increased panel efficiency, smart energy management, and IoT-based monitoring can further expand the umbrella's performance and scope, making it an even more valuable solution for sustainable outdoor energy needs.

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