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SMART SOLAR WIRELESS POWER BANK WITH ADAPTIVE SCREEN MANAGEMENT SYSTEM FOR ENHANCED ENERGY EFFICIENCY

1 **J. Pujitha** 2 **N.Venkata Ramana** 3 **B. Kasi Viswnadh** 4 **CH.Yesu Raju** 5 **S.K.Kalathmika**

1 Student, Department of Electrical and Electronics Engineering, Sir C.R Reddy College of Engineering

2 Assistant Professor, Department of Electrical and Electronics Engineering Sir C.R Reddy College of Engineering

3 Student, Department of Electrical and Electronics Engineering, Sir C.R Reddy College of Engineering

4 Student, Department of Electrical and Electronics Engineering, Sir C.R Reddy College of Engineering

5 Student, Department of Electrical and Electronics Engineering, Sir C.R Reddy College of Engineering

ABSTRACT: This project presents the design and implementation of a Smart Solar Wireless Power Bank with Adaptive Screen Management for Enhanced Energy Efficiency. The primary objective is to develop a sustainable and portable charging solution that harnesses solar energy and delivers it wirelessly to mobile devices. The system utilizes a high-efficiency Solar Panel to capture solar energy, which is then stored in a Lithium-ion battery through a TP4056 charging module. To address the common issue of energy wastage in power bank indicators, this project introduces an Adaptive Screen Management system using an Arduino microcontroller and an LDR sensor. This system automatically adjusts the brightness and operation of the LED Display based on ambient light conditions and battery status, significantly reducing unnecessary power consumption. The wireless power transfer is achieved using the principle of Inductive Coupling, allowing users to charge their devices without the need for physical cables. This integrated approach not only promotes renewable energy usage but also maximizes the overall efficiency of the power bank through intelligent energy management and low-power display technology

Key words—Solar Power Bank, Wireless Charging, Adaptive screen Management ,Energy Efficiency, Android Application, Renewable Energy ,Power Management System

I.INTRODUCTION

In the contemporary digital era, the dependency on portable electronic gadgets such as smartphones and wearable devices has reached an unprecedented level, making them essential tools for daily communication and productivity. However, the primary bottleneck remains in their limited battery life, which often fails during travel or in remote areas where conventional power outlets are unavailable. This project introduces the "Smart Solar Wireless Power Bank with Adaptive Screen Management System" as a sophisticated and eco-friendly solution to these challenges. By integrating high-efficiency monocrystalline solar panels with advanced wireless power transfer technology, the system provides an autonomous charging platform that harvests energy directly from sunlight. Unlike traditional power banks that rely on grid electricity and physical cables, this device offers a sustainable and cable-free charging experience, ensuring that users remain connected even in off-grid environments.

The core innovation of this project lies in its intelligent energy management, specifically through the implementation of an Adaptive Screen Management System. While most portable chargers feature a static display that consumes a constant amount of battery, our system utilizes an ambient light sensor (LDR) to monitor the surrounding environment. A microcontroller processes this real-time data to dynamically adjust the display's brightness— increasing visibility in direct sunlight and dimming the backlight in darker settings to prevent unnecessary energy drainage. This proactive approach to power conservation ensures that the maximum possible energy is reserved for the primary task of charging devices. By merging renewable energy harvesting with smart embedded logic, this project represents a significant advancement in portable power technology, offering a device that is not only environmentally responsible but also highly efficient and user centric.

II.STATEMENT OF THE PROBLEM

The increasing use of portable electronic devices such as smartphones and wireless gadgets has created a strong demand for reliable, portable charging solutions. Traditional power banks rely entirely on grid electricity, making them less useful in outdoor environments, remote areas, or emergency situations where power access is limited. Although solar-powered power banks provide an alternative, they often suffer from low efficiency, slow charging speed, and poor energy management, reducing their overall effectiveness.

In addition, existing power banks lack intelligent features to optimize energy usage, particularly in managing display screens that consume unnecessary power when not in active use. This leads to energy wastage and reduced battery performance. Therefore, there is a need for a smart solution that integrates efficient solar energy harvesting, wireless charging capability, and adaptive screen management to enhance energy efficiency, improve usability, and ensure sustainable power utilization.

III. METHODOLOGY

The proposed Smart Solar Wireless Power Bank system is designed by integrating a solar energy harvesting unit, battery storage system, wireless charging module, and adaptive screen management. Initially, a solar panel is used to capture sunlight and convert it into electrical energy, which is then regulated using a charging module to safely store energy in a rechargeable battery. The stored energy is managed through a power management circuit to ensure stable voltage output for device charging.

A wireless charging module is incorporated to enable cable-free charging of compatible devices using electromagnetic induction. Additionally, an adaptive screen management system is implemented using a microcontroller, which monitors user interaction and battery levels to control the display operation. The screen automatically adjusts brightness or turns off when not in use, thereby reducing

unnecessary power consumption. The overall system is tested under different environmental and usage conditions to evaluate its efficiency, charging performance, and energy-saving capability.

IV. BLOCK DIAGRAM DESCRIPTION

The proposed system consists of several functional blocks that work together to provide efficient energy generation, storage, and utilization. The solar panel captures sunlight and converts it into electrical energy, which is then regulated by the charging controller to ensure safe and stable charging of the battery. The battery acts as an energy storage unit, supplying power to the entire system when required.

The power management circuit distributes the stored energy efficiently to different modules while maintaining a constant output. The wireless charging module uses this power to charge electronic devices without the need for physical connections. A microcontroller is used to control system operations, including adaptive screen management, where the display automatically adjusts brightness or turns off based on usage and battery conditions. This helps in reducing unnecessary power consumption and improves overall energy efficiency.

V.WORKING PRINCIPLE

The working principle of the Smart Solar Wireless Power Bank with Adaptive Screen Management System is based on solar energy conversion, storage, and efficient utilization. When sunlight falls on the solar panel, it converts solar energy into electrical energy using photovoltaic cells. The generated electrical energy is passed through a charging controller circuit, which regulates the voltage and prevents overcharging the battery. The regulated energy is stored in the lithium-ion battery, which acts as the main energy storage unit. The Arduino UNO microcontroller continuously monitors the battery voltage and system status to ensure proper operation. The OLED display shows important information such as battery level and charging status. The stored electrical energy from the battery is supplied to the wireless charging module, which enables mobile devices to be charged without using cables. Additionally, the system uses an adaptive screen management technique to reduce unnecessary power consumption by controlling display brightness and usage. This improves overall system efficiency and extends battery life. Thus, the system efficiently converts solar energy into electrical energy and provides a reliable wireless charging solution. The core operation of this project revolves around two main stages: Energy Management and Wireless Transmission. Wireless Power Transfer (Inductive Coupling): The wireless charging module works on the principle of Faraday's Law of Induction. When the battery supplies power to the transmitter coil, it creates an alternating magnetic field. When a compatible smartphone (with a receiver coil) is placed nearby, this magnetic field induces an electric current in the receiver coil, which then charges the phone's battery without any physical wire connection. Adaptive Screen Management: To ensure maximum energy efficiency, the Arduino continuously reads data from the LDR (Light Dependent Resistor). In bright environments, the OLED display brightness is maintained for visibility. In darker conditions, the system automatically dims or manages the screen timeout to prevent unnecessary battery drain. Voltage Regulation & Safety: The Boost Converter ensures that even if the lithium-ion battery voltage fluctuates, a stable 5V output is maintained for the charging module. Simultaneously, the TP4056 module protects the battery from overcharging and deep discharging, ensuring a long life cycle for the power bank.

VI.RESULTS

The Smart Solar Wireless Power Bank with Adaptive Screen Management was successfully designed and implemented. The system was able to efficiently convert solar energy into electrical energy and store it in the battery for later use. The wireless charging module functioned properly, allowing devices to be charged without the need for cables. The power management system ensured stable output and safe operation under different conditions.

The adaptive screen management system effectively reduced power consumption by automatically adjusting brightness and turning off the display when not in use. Overall, the project demonstrated improved energy efficiency, reliable performance, and practical usability in outdoor and emergency situations, proving it to be a sustainable and user-friendly solution for portable charging needs.

Fig 1 : Power bank prototype internal structure

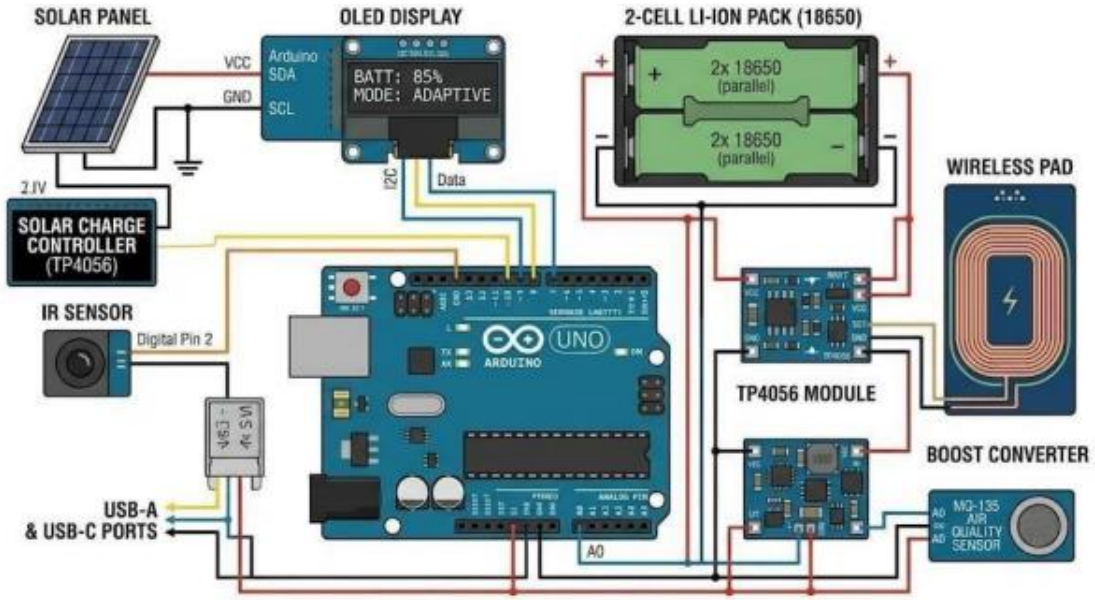

Fig 2: System connection diagram

Advantages

- Uses solar energy, making it eco-friendly and reducing dependence on grid electricity.
- Provides wireless charging, offering convenience without cables.
- Ensures portability, ideal for travel, outdoor use, and emergency situations.
- Improves efficiency through adaptive screen management, reducing unnecessary power consumption**.**

Disadvantages

- Dependent on sunlight, so performance reduces in cloudy weather or at night.
- Slow charging speed compared to conventional electric charging.
- Higher initial cost due to solar panel and advanced components.
- Lower energy conversion efficiency of solar panels limits power output.
- Wireless charging losses, making it less efficient than wired charging.

Applications

- Used for charging mobile devices like smartphones, earbuds , and smartwatches.
- Useful during travel and outdoor activities such as camping and trekking.
- Helpful in emergency situations like power outages and natural disasters.
- Suitable for remote and rural areas where electricity supply is limited.
- Can be used in military and field operations where portable power is essential.

VII.FUTURE SCOPE

- High-efficiency solar panels can be used to improve power generation even under low sunlight conditions.
- Fast wireless charging technology can be implemented to reduce charging time.
- An advanced battery management system can be integrated to enhance battery life and safety.
- Internet of Things (IoT) technology can be added for real-time monitoring of battery status and system performance.
- Artificial Intelligence (AI) can be used to optimize energy usage based on user behavior and environmental conditions.
- The system can be made more compact and lightweight to improve portability.

VIII.CONCLUSION

The Smart Solar Wireless Power Bank with Adaptive Screen Management System has been successfully designed, developed, and evaluated. The proposed system effectively integrates renewable energy with modern wireless charging technology, providing an efficient and ecofriendly solution for portable power requirements. The use of solar energy significantly reduces dependence on conventional power sources, making the system suitable for sustainable applications. The wireless charging feature enhances user convenience by eliminating the need for physical cables, while the adaptive system optimizes power consumption through automatic brightness control based on ambient conditions. The experimental results and performance analysis demonstrate that the system operates reliably and maintains stable performance under varying environmental conditions. Although minor limitations such as dependency on sunlight and relatively slower wireless charging exist, the overall system performance remains satisfactory. In conclusion, the proposed system presents a practical, energy-efficient, and user-friendly solution for modern charging needs. It holds

great potential for future enhancements and real-time applications, especially in outdoor and remote environments where conventional power sources are limited.

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