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Design and Implementation of a Solar-Powered Power Bank with Integrated Wireless Charging

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***Abstract*—The increasing dependence on portable electronic devices has created a strong demand for reliable, sustainable and efficient mobile power solutions. Conventional power banks rely entirely on grid-based electricity, which limits their usability in remote areas and contributes indirectly to environmental degradation. This engineering-based project focuses on the de-sign, development, and working of a solar power bank integrated with wireless charging technology. Unlike survey-based or perception-oriented studies, this paper emphasizes the practical working model, hardware components, system architecture, and operational mechanism of the proposed device.The proposed system utilizes photovoltaic solar panels to harvest solar energy, which is regulated through a charge controller and stored in rechargeable lithium-ion batteries. The stored energy is then supplied to output ports and a wireless charging module for charging compatible electronic devices. Wireless charging is achieved using electromagnetic induction based on Qi-standard principles, enabling cable-free energy transfer. The project aims to provide a compact, portable, and eco-friendly charging solution suitable for outdoor usage, emergency situations, and off-grid environments. The integration of renewable energy with wireless technology enhances usability and reduces dependence on conventional power sources**

***Index Terms*—energy storage, photovoltaic system, renewable energy, solar power bank, wireless charging**

I. INTRODUCTION

The rapid growth of portable electronic devices such as smartphones, wearable gadgets, and wireless accessories has significantly increased the demand for portable energy storage systems [1]. Traditional power banks, although widely used, depend entirely on electrical grid charging, making them unsuitable for use in remote locations and during power outages [2]. Moreover, the rising concerns related to energy sustainability and environmental protection have encouraged engineers and researchers to explore renewable energy-based charging solutions [3]. Solar energy is one of the most abundant and clean sources of renewable energy available [4]. The integration of solar technology into portable power systems provides an effective solution to reduce dependence on conventional electricity [6]. A solar power bank harnesses solar radiation using photovoltaic panels and converts it into electrical energy that can be stored and used for charging devices [2]. When combined with wireless charging technology, the usability and convenience of such a system are further enhanced [5]. Wireless charging technology eliminates the need for physical connectors and cables by transferring energy through electromagnetic fields [8] . This not only improves user convenience but also reduces mechanical wear and tear on charging ports [8] . The integration of solar charging and wireless power transfer presents an innovative engineering solution that aligns with the goals of sustainability, portability, and user-friendly design [10]. This project-based study focuses on the design and working of a solar power bank with seamless wireless charging, emphasizing practical implementation rather than survey-based analysis [11]. The objective is to design a functional prototype that can charge electronic devices using solar energy and demonstrate wireless power transfer under real operating conditions [12]. The main contribution of this work lies in the practical design, integration, and experimental validation of a solar-powered power bank with wireless charging.

II. LITERATURE REVIEW

Renewable energy–based portable power solutions have gained significant attention due to the growing demand for sustainable and mobile energy systems. Ahmad and Rahman [1] designed a solar-powered portable charging system emphasizing efficiency and portability, demonstrating the feasibility of compact renewable charging devices. Similarly, Ashraf et al. [2] developed a solar-based mobile power bank system integrating photovoltaic modules with energy storage units, highlighting improved charging reliability for mobile electronics. Research has also emphasized optimizing solar energy harvesting and storage mechanisms. Bhatia and Singh [3] explored renewable energy–based portable power systems using solar technology, focusing on improving durability, energy efficiency, and user convenience. Patel and Shah [9] further examined solar energy harvesting and storage for portable electronic devices, stressing effective battery coupling and enhanced charge retention to ensure continuous power availability. Battery safety and performance management are critical components of portable renewable systems. Kumar and Verma [7] proposed a solar charging design incorporating lithium-ion battery protection circuits to prevent overcharging, overheating, and capacity degradation. Complementing this, Ustun and Mekhilef [13] reviewed energy storage technologies for renewable energy applications, highlighting advancements in battery management systems, storage reliability, and performance optimization under variable load conditions. Wire-less charging technologies have also contributed to portable energy solutions and technologies. Choi et al. [5] discussed improvements in wireless power transfer systems for portable devices, emphasizing enhanced transmission efficiency and reduced energy loss. Lu et al. [8] provided a comprehensive review of wireless charging fundamentals, global standards, and network applications, offering a strong theoretical foundation for modern wireless energy systems. Song et al. [12] contributed by proposing constant current and constant voltage charging strategies that improve stability, efficiency, and charg-ing precision in wireless power systems. Power electronics and energy conversion technologies underpin the effectiveness of renewable charging solutions. Rashid [10] detailed essential power electronic circuits, devices, and control techniques that enable efficient energy conversion and regulation. Boldea and Nasar [4] examined electric drives and renewable energy systems, emphasizing their role in energy control and system integration. Additionally, Khan and Arsalan [6] reviewed solar power technologies for sustainable development, focusing on scalability, environmental benefits, and long-term viability. Recent performance-focused studies further validate practical implementations. Singh and Tiwari [11] conducted performance analyses of solar-powered portable charging devices, confirming system efficiency under real-world conditions. Verma and Sharma [14] designed and tested a solar-based wireless charging power bank, demonstrating successful integration of solar harvesting with wireless charging technology. Overall, existing literature demonstrates steady progress in solar energy harvesting, advanced storage integration, wireless power transfer, and power electronics, collectively enabling efficient, reliable, and sustainable portable charging systems.

III. SYSTEM ARCHITECTURE AND WORKING PRINCIPLE

The proposed solar-powered power bank system consists of four major subsystems: the solar energy harvesting unit, power regulation unit, energy storage unit, and output charging unit.The overall architecture of the system is shown in Fig. 1. The solar energy harvesting unit utilizes photovoltaic solar panels to convert sunlight into electrical energy. The generated DC voltage varies depending on solar intensity and environmental conditions. The power regulation unit consists of a charge controller and voltage regulation circuitry. This unit ensures safe and efficient charging of the battery by preventing overcharging, deep discharge, and reverse current flow. The energy storage unit comprises rechargeable lithium-ion batteries that store the regulated energy for later use. These batteries provide a stable power supply even when solar input is unavailable. The output charging unit includes both wired and wireless charging mechanisms. USB output ports are used for conventional wired charging, while a wireless charging module based on electromagnetic induction enables cable-free charging.

Fig. 2 shows the circuit schematic of the proposed system.

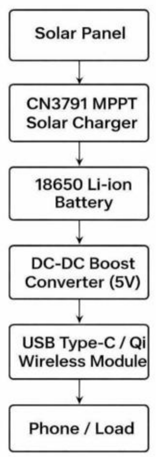

Fig. 1. Block diagram of the proposed system.

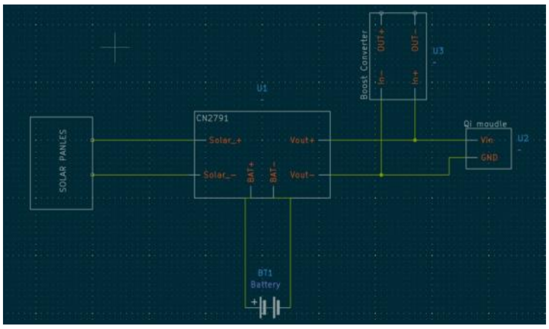

Fig. 2. Circuit schematic of the system.

IV. HARDWARE COMPONENTS

The following components are used in the proposed system:

- Solar panel (10 W, 12 V)
- 18650 lithium-ion battery (3.7 V, 3800 mAh)
- CN3791 MPPT solar charging module
- DC-DC boost converter (5 V output)
- Wireless charging transmitter module (Qi-compatible)
- USB output module
- Connecting wires

V. METHODOLOGY AND MODEL DEVELOPMENT

The development of the working model follows a systematic and structured engineering methodology, ensuring reliability, safety, and functional efficiency of the solar power bank with wireless charging. The methodology is divided into multiple stages, including requirement analysis, component selection, circuit design, hardware integration, and performance testing. In the initial stage, detailed power requirements are analyzed based on the intended application of the solar power bank. The charging voltage and current requirements of common electronic devices such as smartphones and wireless accessories are studied to determine appropriate system ratings. Based on this analysis, component specifications are carefully selected to achieve an optimal balance between efficiency, portability, and cost-effectiveness.

The solar panel is selected based on its voltage output, current rating, and conversion efficiency. The output of the solar panel is directly connected to a solar charge controller module. The charge controller plays a critical role in regulating the fluctuating voltage generated by the solar panel and ensures safe charging of the lithium-ion battery. It protects the battery from overcharging, deep discharge, and reverse current flow, thereby enhancing battery life and system safety.

A. Power Calculation

The output power of the system is calculated using:

$$P = V \times I \qquad (1)$$

For USB output:

- Voltage $V = 5V$
- Current $I = 1A$

$$P = 5 \times 1 = 5W \qquad (2)$$

B. Battery Energy Calculation

The energy stored in the battery is given by:

$$E = V \times Ah \qquad (3)$$

- Battery = 3.7V, 3800mAh = 3.8Ah

$$E = 3.7 \times 3.8 = 14.06Wh \qquad (4)$$

C. Charging Time Estimation

Charging time is estimated using:

$$t = \frac{E}{P} \qquad (5)$$

Assuming solar input $\approx 2W$ effective:

$$t = \frac{14}{2} \approx 7 \text{ hours} \qquad (6)$$

D. Prototype Development

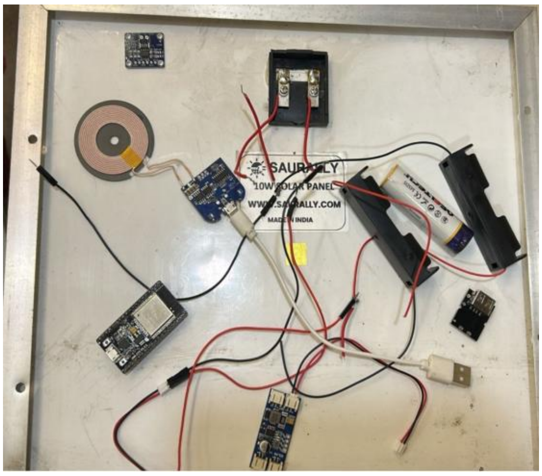

Fig. 3. Initial hardware setup of the prototype

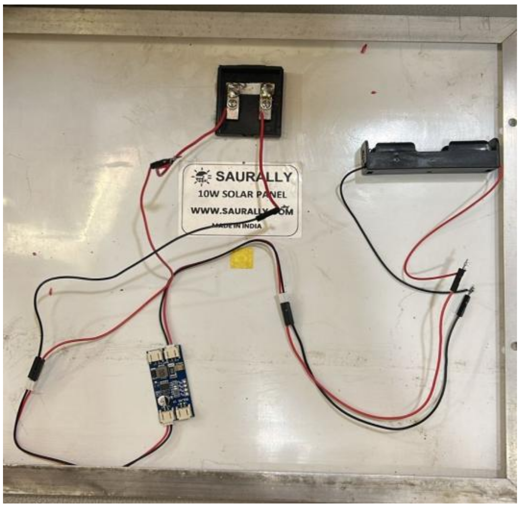

Fig. 4. Circuit assembly during development

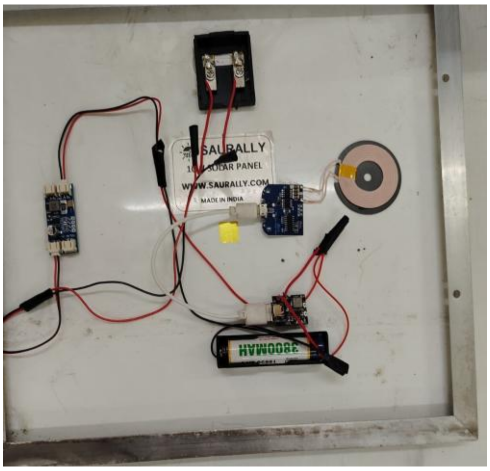

Fig. 5. Completed solar power bank prototype

VI. EXPERIMENTAL RESULTS AND OBSERVATIONS

The developed prototype was tested under direct sunlight conditions to evaluate its performance. The solar panel was able to generate sufficient energy to charge the lithium-ion battery through the charge controller. The system provides a regulated output voltage of 5V with an output current ranging from 0.8A to 1A for wired charging. The battery charging time using solar input was observed to be approximately 6–8 hours under good sunlight conditions. The wireless charging module operates at a power level of approximately 5W. However, due to energy losses in electromagnetic induction, the efficiency of wireless charging is observed to be around 60–70%, which is consistent with typical Qi-based systems. It was also observed that charging performance depends on alignment between the transmitter and receiver coils, as well as environmental conditions such as sunlight intensity.

The obtained results are consistent with standard low-power solar charging and wireless power transfer systems reported in literature.

TABLE I: EXPERIMENTAL RESULTS

Parameter	Value
Output Voltage	5V
Output Current	0.8–1A
Battery Capacity	3.7V, 3800mAh
Battery Energy	14.06 Wh
Solar Charging Time	6–8 hours
Wireless Output Power	~5W
Wireless Efficiency	60–70%

Fig. 6. Output of the proposed system

VII. CONCLUSION

This project demonstrates the design and working of a solar power bank integrated with wireless charging. The model validates the feasibility of combining photovoltaic energy harvesting with wireless power transfer in a compact system. The system effectively charges portable electronic devices, reducing dependence on grid-based electricity. It supports both wired USB and wireless charging under suitable con-ditions. The integration of a solar charge controller, energy storage, DC-DC regulation, and wireless module ensures safe and stable operation. Proper component selection and power management are essential for efficiency and safety. However, limitations include slow charging under low-light conditions and lower wireless charging efficiency due to energy losses. Despite these limitations, the system shows strong potential for improvement with advancements in solar cells, wireless charging, and power management, and has applications in outdoor, emergency, and remote environments.

VIII. FUTURE SCOPE

The future scope of the solar power bank with wireless charging is promising with advancements in renewable energy and portable electronics. Improvements include high-efficiency solar panels, enabling faster charging under low-light conditions, and flexible designs for better portability. Fast wireless charging standards can increase charging speed and support more devices. Smart power management systems using microcontrollers can optimize power flow, improve efficiency, and extend battery life. IoT-based monitoring can enhance user experience through real-time tracking. Durable, waterproof designs can improve usability in harsh environments. Mass production and cost optimization can make the system more accessible, supporting sustainable energy adoption.

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