

Laboratory-Scale Testing of a Solar Panel-Based Portable Power Bank Design

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Article Information

Article History

Received : September 10, 2024

Revised : September 23, 2024

Accepted : September 29, 2024

Keywords:

Device charging; Power source; power bank; Solar panel; Energy storage.

Kata Kunci:

Pengisian daya perangkat; Sumber daya; bank daya; Panel surya; Penyimpanan energi.

ABSTRACT

The increasing need for mobile device charging, especially in outdoor and remote areas, presents challenges due to limited access to power sources. This issue is particularly relevant for individuals who travel frequently, such as motorcycle taxi drivers. To address this issue, a foldable solar panel-based portable power bank has been developed, which is designed to efficiently convert solar energy into electrical power to charge smartphones. Laboratory-scale tests show that the device can charge a smartphone from 20% to 100% within four hours under peak sunlight conditions, and from 20% to 75% under lower sunlight. To further improve its usability, future development should increase the energy storage capacity, improve efficiency under different sunlight conditions, add weather resistance, and expand compatibility with other devices, making it more suitable for outdoor and travel applications.

ABSTRAK

Meningkatnya kebutuhan pengisian daya perangkat seluler, terutama di daerah luar ruangan dan terpencil, menghadirkan tantangan karena terbatasnya akses ke sumber listrik. Masalah ini sangat relevan bagi individu yang sering bepergian, seperti pengemudi ojek. Untuk mengatasi masalah ini, power bank portabel berbasis panel surya yang dapat dilipat telah dikembangkan, yang dirancang untuk secara efisien mengubah energi matahari menjadi daya listrik untuk mengisi daya smartphone. Pengujian skala laboratorium menunjukkan bahwa perangkat ini dapat mengisi daya smartphone dari 20% hingga 100% dalam waktu empat jam di bawah kondisi sinar matahari puncak, dan dari 20% hingga 75% di bawah sinar matahari yang lebih rendah. Untuk lebih meningkatkan kegunaannya, pengembangan di masa depan harus melakukan peningkatan kapasitas penyimpanan energi, meningkatkan efisiensi di bawah kondisi sinar matahari yang berbeda-beda, menambahkan ketahanan terhadap cuaca, dan memperluas kompatibilitas dengan perangkat lain, sehingga lebih cocok untuk aplikasi luar ruangan dan perjalanan.

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INTRODUCTION

In Indonesia, the majority of PLN's electricity generation still relies heavily on non-renewable energy sources such as coal combustion (Saputri, Linelson, et al., 2023). The prolonged

use of these non-renewable resources for electricity generation poses a significant risk of rapid depletion, especially with increasing energy demand (Farghali et al., 2023; Sun & Yao, 2023). Industrial growth further exacerbates this issue as more machines and processes become dependent on non-renewable energy. To mitigate this depletion, the exploration of alternative energy sources has become a critical endeavour. One promising solution is the transition to renewable energy, particularly solar energy (Lorent et al., 2024), for generating electricity.

Indonesia holds immense potential for solar energy utilization due to its geographical location on the equator, allowing the country to receive sunlight for 10-12 hours daily (Widodo et al., 2010). Due to its location on the equator, Indonesia has an average solar energy generation potential of 4.8-5.1 kWh/m²/day, which equates to approximately 112,000 GWp/day (Saputri, Linelson, et al., 2023; Saputri, Richard Stanlee, et al., 2023). Given this abundant solar potential, leveraging it for electricity generation could play a pivotal role in reducing the nation's reliance on non-renewable energy. In tandem with the rise of modern technology, the need for electricity has become ever more urgent. Virtually all electronic devices, including smartphones and various gadgets, require a steady power supply to function. However, recharging these devices often necessitates a connection to the PLN power grid through a charger or adapter. This becomes problematic in scenarios where electrical outlets are unavailable, such as during outdoor activities or power outages (The European Commission, 2021). This has led to a growing demand for power banks or portable chargers, allowing users to keep their devices powered on the go. Power banks are designed to charge portable electronic devices such as smartphones and tablets (Divya M. et al., 2018). However, the actual capacity they provide often falls short of what is stated on the product, leaving customers disappointed with their performance (Diao et al., 2020).

Current power banks available in the market, however, come with certain drawbacks. These devices typically weigh more than 100 grams due to their battery capacity, and their size and weight increase with higher capacities. Additionally, conventional power banks should be charged through electrical outlets once depleted, which can be time-consuming and impractical for outdoor use (Spaven et al., 2022). These limitations make traditional power banks less convenient for users, especially in situations where portability and fast charging are essential. The power bank based on the solar power is one of the solution. Research related to it is conducted by several researchers.

Debjyoti Basak et al. have developed a solar-powered power bank that effectively charges smartphones. The system integrates solar panels, lithium batteries, and power bank modules, assembled according to a proposed circuit diagram. The power bank's effectiveness was tested and confirmed in its ability to charge smartphones (Basak et al., 2024). Similarly, Agus Ismangil and Haddy Prasetya Susanto explored the growing demand for energy and the potential of solar energy as a viable, eco-friendly solution. Their research involved a setup using 5-volt solar panels, a 5000 mAh battery, and an ATmega 328 microcontroller with an LCD display for battery indicators. Testing with two mobile phones demonstrated the system's capability to charge batteries by 26% and 22% respectively within one hour. The solar panel, when exposed to sunlight from 9 am to 3 pm, efficiently charged the battery, suggesting that the power bank is both economical and amenable to further development with higher-capacity components (Ismangil & Susanto, 2019).

To address these limitations, this study proposes the design of a portable power bank powered by three solar panels, aimed at providing multipurpose reserve power generation. This solar-powered portable power bank is designed to harness solar energy to supply backup electricity and eliminate the need for external recharging. Its lightly, foldable design, and self-recharging capability make it a highly practical solution for outdoor use or in locations with limited access to power outlets. The objective of this study is to design and conduct laboratory-scale testing of a solar panel-based portable power bank. This power bank is intended to self-sustaining through the use of solar energy. The study will evaluate its effectiveness as a sustainable and portable energy solution under various conditions, including outdoor settings. The expected benefits include reducing dependency on non-renewable energy sources, enhancing user convenience, and promoting the use of renewable energy technologies in portable electronic devices. The laboratory-

scale testing will assess the performance of the design in terms of energy efficiency, charging speed, and practicality for daily use. This research contributes to the broader goal of advancing renewable energy integration in everyday applications, promoting environmental sustainability, and supporting energy independence.

RESEARCH METHODS

This research involves several stages, including the design, assembly, and testing of the solar panel-based portable power bank. The methodology based on the tools and materials provided is outlined as follows.

Preparation of Tools and Materials

In this stage, all the necessary tools and materials are gathered for the project. This includes mini solar panels, a step-down converter, cables, a smartphone, and other supporting equipment. Before beginning the assembly process, it is important to ensure that all components are in proper working condition to avoid any interruptions during the assembly or testing phases.

System Assembly

The assembly process involves connecting the components to create the solar panel-based portable power bank. The first step is assembling the solar panels. The three 6V 1W 200mA mini solar panels are connected in parallel to increase the power output. Cables are used to link the panels, and the connections are secured with solder to prevent power loss. Afterward, the output from the solar panels is connected to a USB step-down converter, which will stabilize the output to 5V 3A. A USB Type C cable is used to connect the converter output to the smartphone for charging. To prevent loose connections and potential short circuits, masking tape is applied to secure the cables.

Power Testing

The power testing phase is divided into two parts. First, the output of the solar panels is measured. The solar panel system is placed under direct sunlight, and a multi meter is used to measure the voltage and current produced. This ensures that the power output from the solar panels matches the expected specifications. The second part involves testing the smartphone charging functionality. The smartphone is connected to the converter using a USB Type C cable, and the charging process is observed. Key data such as the time taken to charge the phone and the stability of the power supplied are recorded.

System Efficiency Analysis

In this step, the efficiency of the charging process is analyzed. The data collected from the solar panel's power output and the charging time are evaluated. The results are compared with the initial system specifications to assess how effectively the solar panels charge the smartphone. This analysis will help determine the overall performance of the portable power bank and whether it meets the intended objectives.

Working Principle

In this experiment, the function of each component used can be described as follows:

1. Mini Solar Panel 6V 1W 200mA: Converts sunlight containing photon energy into electrical energy.
2. Converter Step Down USB In 6V - 24V Out 5V 3A: Reduces the input voltage from 6-24V to a stable 5V output.
3. Cables: Serve as connectors between components to transmit electrical signals.
4. USB Type C Cable: Connects the step-down converter to the smartphone's Type C charger, allowing power to flow during charging.
5. Masking Tape: Secures the three solar panels, cables, and converter together.
6. Smartphone: Acts as the device to verify that power is being received from the power bank, indicated by the charging icon.

7. Soldering Tin: Melts to bond the positive and negative terminals of the solar panels to the cables.
8. 15 cm Wire: Serves as a connector between the positive and negative terminals of the solar panels and the cables.
9. A4 Paper: Acts as a covering layer for the back of the solar panels, making the wiring invisible and flexible for easy folding.

The overall working principle of the system of the system is sunlight is converted into electrical energy through the solar cells. Solar cells are a set of devices with semi-conductor materials that can convert the sunlight energy it receives into electrical energy. That are also called photovoltaic and are made of semi-conductor materials which are generally silicon (Dada & Popoola, 2023). Then, the electrical energy is stored in the Step-Down converter. Afterward, connect the smartphone to the Foldable Solar Power Bank using a charging cable. The smartphone battery will charge, which can be seen by the charging indicator.

In photovoltaic systems, one of the aspects to understand is how solar energy is converted into electrical energy. This process involves the interaction between the intensity of solar radiation received by the solar panel and the surface area of the panel. Once this energy is absorbed, it is transformed into electrical power through the photovoltaic cells. The power generated is influenced by several factors, such as the intensity of solar radiation, the panel's surface area, the voltage, and the current produced by the photovoltaic cells (El Hammoumi et al., 2022; Susanto et al., 2022). To explore this further, we will discuss how to calculate the energy received and the instantaneous power generated by a photovoltaic system. Before calculating the instantaneous power produced, it is essential to determine the energy received. This energy is the product of the intensity of the solar radiation and the surface area, expressed by the equation (Joewono et al., 2023):

$$E = I_r \times A, \quad (1)$$

where I_r is the intensity of solar radiation in watts per square meter (W/m^2), and A is the surface area in square meters (m^2). Meanwhile, the instantaneous power generated by the photovoltaic cell can be calculated by multiplying the voltage and current produced, using the formula (Joewono et al., 2023):

$$P = V \times I, \quad (2)$$

where P is power in watts (W), V is the potential difference or voltage in volts (V), and I is the current in amperes (A).

The operational flow of the foldable solar power bank system is that the solar panels are arranged in series by connecting the negative terminal to the positive terminal to form a Foldable Solar Power Bank. At both ends of the Foldable Solar Power Bank, there are two unconnected cables. These cables must be attached to the USB Step-Down converter. Once the connections are made, place the Foldable Solar Power Bank in the sun. Finally, connect the USB Step-Down converter to the smartphone using the charging cable to start the charging process.

RESULTS AND DISCUSSION

The results of this experiment showed that the solar panel used was able to provide efficient enough performance to charge the cell phone battery. The design is very simple as shown in Figure 3. Where the system consists of 3 connected mini solar panels. During the observation between 09:00 and 13:00, the solar panels generated a current of 1855mA with a voltage of 3962 mV, which was enough to charge the cell phone battery from 20% to full (100%) within 4 hours. In the later period, between 14:00 and 18:00, the current generated by the solar panel decreased to 1246mA with a voltage of 1454 mV, which successfully charged the cell phone battery from 20% to 75% in the same time of 4 hours. This difference in performance is influenced by the decreased intensity of sunlight in the afternoon.

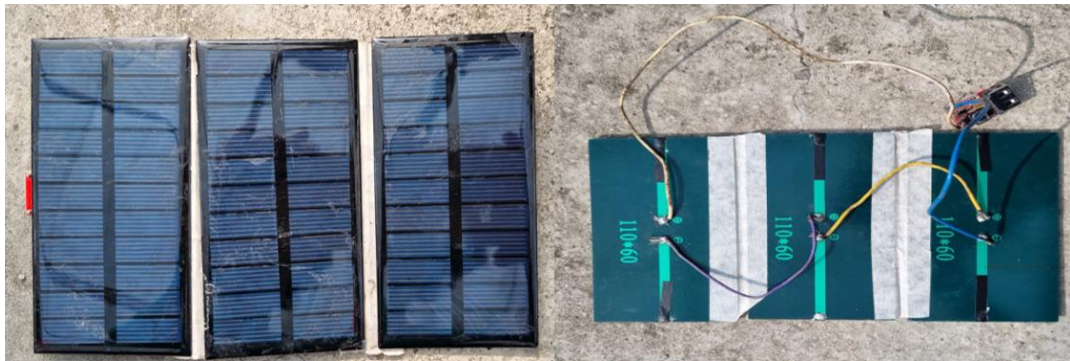


Figure 1. Views of the Foldable Solar Power Bank: Front and Back

This charging success shows that the solar panel is quite reliable under sufficient sunlight conditions. Despite the difference in performance between morning and evening, the panel was still able to provide sufficient power to recharge the cell phone battery significantly. These results are proof that renewable energy, especially solar energy, can be utilized for practical daily applications such as cell phone charging, which is essential in the modern technological era.

In addition, the practicality of the foldable solar power bank design makes it suitable for travel. Since it requires no external power source other than sunlight, it will be one of the solutions for users who are often on the move, such as online motorcycle taxi drivers. They can keep their phones charged without having to stop to look for a power source in a certain place, which can save them time. It can be operated easily and remains efficient as long as the weather is favorable, especially under the bright sun.

Another advantage of this lab-scale foldable solar power bank design is its relatively low production cost, considering that this experiment uses simple and affordable components. Because it is only lab-scale, this system does not require too much technology or capital. This tool can be an opening that can later be developed and mass-produced at an economical price, making it more accessible to the general public. This opens up opportunities for environmentally friendly technological innovations that are accessible to all.

Thus, this foldable solar power bank offers a sustainable solution in utilizing renewable energy. With its practicality, charging efficiency, and low production cost, it has the potential to become a product of interest to a wide range of people, especially those who travel frequently and need a practical and environmentally friendly charging solution. This experiment proves that with simple innovations, we can develop useful and sustainable technologies in the modern era.

CONCLUSION

The foldable solar power bank experiment demonstrates that this device is highly efficient in converting solar energy into electrical energy to charge smartphones. With its compact design and ability to provide power solely from sunlight, the power bank successfully charged a smartphone from 20% to 100% within four hours during peak sunlight hours and from 20% to 75% under lower sunlight conditions. This efficiency and portability make it a practical solution for users who are often on the move, such as motorbike taxi drivers, without relying on external power sources.

To improve its usability, further development could focus on increasing the power bank's energy storage capacity and efficiency under varying sunlight conditions. Additionally, incorporating a weatherproof casing and expanding its compatibility with more devices could enhance its functionality for outdoor and travel use.

ACKNOWLEDGEMENTS

The authors would like to express their heartfelt gratitude to Universitas Multimedia Nusantara for their invaluable support and resources throughout the course of this research. The university's provision of equipment, facilities, and guidance was instrumental in the successful completion of this project. Without their continued encouragement and assistance, this research would not have been possible.

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