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# Design and Field Testing of a Portable Wind Turbine Power Bank for Emergency Use in Remote Outdoor Activities

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*Abstract* - **Currently, many outdoor activities, such as hiking and camping, are increasingly popular. However, these expeditions often require access to emergency power for essentials such as cell phones, USB fans, and USB lighting. The power supply from a standard power bank is limited and insufficient to last for several days. To generate power from natural resources like wind, a power bank integrated with a wind turbine generator is necessary. This project aimed to design a portable wind turbine that integrates a power bank for use in remote locations. A flowchart was used to design the prototype, and snowball sampling was employed for the survey. The portable power-generating system consists of a small turbine, a generator, and a battery charger. Field testing was conducted on the prototype. The results showed that the DC generator produced a voltage ranging from 5.25 V to 16.35 V at wind speeds between 3.01 m/s and 6.35 m/s. A 40,000 mAh power bank combined with the wind turbine generator can recharge a smartphone 10 to 13.33 times. This indicates that the 40,000 mAh power bank can fully charge a smartphone within two hours and power a USB fan and USB light for at least eight to ten hours each. The study concludes that campers can harness wind as a natural resource to charge smartphones, USB lights, and USB fans by using a wind turbine generator integrated with a power bank. It is recommended to include additional ports and loads for enhanced functionality.**
*Keywords:* **Wind Turbine Generator, Power Bank, Portable Power System, Field Testing, Outdoor Activities**

## I. INTRODUCTION

Wind power is a crucial component of horizontal-axis wind turbines (HAWTs), offering an environmentally friendly and flexible energy source while enhancing national energy security, particularly in the face of dwindling global fossil fuel reserves. Wind is harnessed to produce electricity by converting the kinetic energy of moving air into electrical energy through wind turbines or wind energy conversion systems. A wind turbine comprises three primary components: the blade, the shaft, and an automobile alternator [1]. Wind energy consumption is the dominant contributor to the broader category of renewable energy sources. According to 2017 data, wind energy accounted for 52% of global renewable energy consumption, surpassing solar energy, which accounted for 21% [2]. A power bank, also referred to as a portable charger, is utilized when conventional power sources are insufficient. Power banks are compact, battery-operated devices capable of recharging various electronic devices. These gadgets store electrical energy, which can later be used to charge mobile phones, tablets, computers, cameras, and other portable electronics [8].

The predominant source of global wind power is currently derived from large HAWTs featuring three blades positioned upwind of the tower. These turbines are designed with the primary rotor shaft and electrical generator situated at the top of a tower, necessitating alignment with the wind direction. Small turbines use a basic wind vane for orientation, whereas larger turbines typically employ a wind sensor in conjunction with a yaw system. Additionally, most of these turbines feature a gearbox that converts the slow rotation of the blades into a faster rotation suitable for driving an electrical generator [3]. HAWTs are widely used in modern wind energy systems. They employ aerodynamic blades, or airfoils, attached to a rotor, which can be positioned either upwind or downwind. HAWTs typically have two or three blades and operate with high blade tip speeds [4]. In the case of upwind rotors, a yaw mechanism or tail vane aligns the turbine with the wind, while downwind rotors have coned blades that allow the turbine to self-orient.

A substantial body of literature has been published on harnessing wind energy, and various research efforts have been reviewed. Sudhakar and Saxena conducted a study on portable generators harnessing low-speed wind energy [5]. Saikumar *et al.,* designed a compact wind generator for charging electronic devices [6]. A new concept has been implemented for a portable, cost-effective, and easily assembled HAWT system designed to harness wind energy and generate electricity for individual use.

The maximum electrical power extraction, following Betz's law principle in an open flow area, remains a determining factor in the system's design. Our measured Betz Limit (C) for the designed wind turbine is approximately 0.48, indicating an absorption capacity of up to 48% of the wind's kinetic energy. Furthermore, the system demonstrates the ability to produce a consistent DC voltage and current, with minimum wind speeds ranging from 35 to 55 km/h (approximately 10 to 15 m/s). It is inferred that the HAWT can effectively charge rechargeable devices, such as smartphones or power banks, under these conditions.

Although optimal performance requires outdoor placement to access sufficient wind, the absence of a waterproof protection system limits its use during the wet season. Future improvements could lead to a more advanced portable wind turbine with enhanced electricity generation and a waterproof mechanism, utilizing materials like acrylic or PVC, as demonstrated by this initial prototype [7].

In the Philippines, support for wind energy systems is increasing due to the recent completion of a wind resource map of the country. Potential wind energy generation locations have been identified, with most situated on the western side of the archipelago. Notable promising areas include Cuyo Island (wind speed of 5.58 m/s), Basco, Batanes (5.39 m/s), Catanduanes (4.15 m/s), and Tagaytay City (5.0 m/s) [8]. The study of horizontal-axis-type wind turbines was first carried out by Yoshida, who demonstrated that small wind generators could effectively operate under low wind velocity conditions and diverse wind directions. The loop wing is designed with three to four fail-safe mechanisms to ensure safety during typhoons or power outages. This feature has been implemented in three locations in the country: Itdi-DOST in Taguig City, the City Environmental Management Office in Marikina City, and Guaran Food in San Pablo City, Laguna [9].

Pampanga is predominantly characterized by flat plains, with elevated areas concentrated in the eastern and north-eastern regions along the borders with Tarlac and Nueva Ecija. Notably, elevated terrains contribute to the province's topography in the municipality of Arayat. Within this area, Mount Arayat stands out as a potentially active stratovolcano, a significant geographical feature amidst the generally flat landscape. Although Pampanga is not widely recognized for extensive mountain ranges or high elevations, these eastern areas introduce a noticeable shift in topography, contrasting with the prevailing flat terrain across much of the province.

With the help of a wind power bank, individuals can harness renewable resources. This portable, lightweight device stores electrical energy generated from wind power. Additionally, a power bank is equipped with a unique circuit that regulates power flow [10]. Various studies evaluate the efficiency and effectiveness of small wind turbines. Wind energy is renewable and, in general, has fewer environmental impacts compared to many other energy sources. Wind turbines do not emit pollutants into the air or water, and they do not require water for cooling [11]. Previous research has concluded that a wind-powered mechanism can effectively serve as a mechanical input for a power bank.

With an efficiency of 52.30% in terms of power conversion, this wind-powered mechanism is a highly efficient energy source. Additionally, the wind power bank offers several advantages over other power banks, including its use of renewable energy, low initial cost, reduced electrical power consumption, and comparable efficiency to conventional power banks [10].

In today's mobile-centric society, there is a growing demand for self-sufficient power solutions for portable devices. This need is particularly evident in isolated regions, especially at higher altitudes where wind resources are viable and access to electricity is often limited. In such scenarios, having a reliable source of compact and sustainable power is essential for recharging critical devices such as mobile phones, walkie-talkies, emergency lights, and other equipment [2].

This study addresses the following problems: (1) The wind turbine generator exhibits lower overall efficiency due to fluctuating wind power during extended outdoor activities; (2) There is a need for a power bank generation system to meet the continuous demand for electrical energy; (3) Many individuals engage in outdoor activities, such as camping, research, mountaineering, tourism, and expeditions, which often last for several days and require portable equipment.

The study's primary goal is to develop a lightweight combined power bank and wind turbine for use in remote locations. The specific objectives are: (1) To identify the wind speed that provides the greatest overall efficiency; (2) To generate sufficient electrical energy continuously to charge two mobile phones and operate both a lamp and a small fan; (3) To design a lightweight wind turbine system for portability, enabling deployment in various locations, with a focus on remote areas.

## II. METHODOLOGY

The waterfall method is a sequential approach in which each project phase begins only after the completion of the preceding phase. This method is straightforward and effective, particularly when the project objectives are well-defined [7]. In the requirements phase, the focus is on determining the desired power output of the generator, including the ability to supply power to smartphones, portable lamps, and portable fans, as well as addressing portability specifications such as size, weight, and ease of setup for folding parts.

During the design phase, decisions are made regarding the blade size and shape, the housing (or nacelle) and tower, as well as the design of the DC generator, with an emphasis on portability. The building phase involves gathering materials for the blades and the wind turbine generator to construct the prototype, followed by analysis to evaluate the prototype. In the testing phase, the system is assessed by testing the prototype under various wind speeds to ensure it meets the requirements and adheres to safety protocols. Finally, the deployment and maintenance phase provides guidance on installation and usage in different settings while gathering user feedback as necessary.

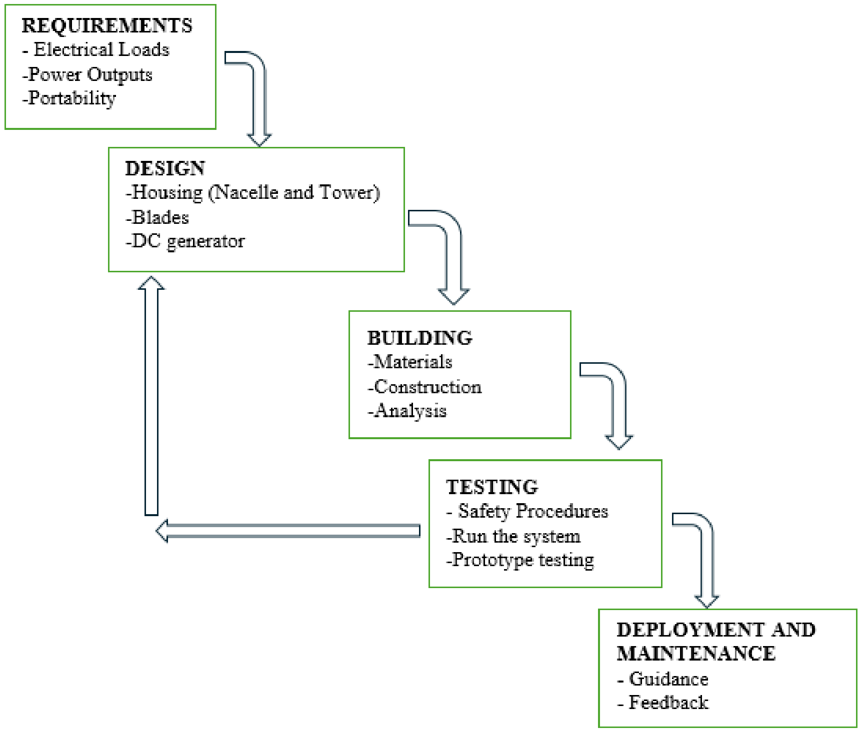


Fig. 1 Flowchart

The researchers used snowball sampling by surveying the campers and hikers that have an experienced in camping and hiking three or more times. Snowball sampling, also referred to as chain sampling or network sampling, is a non-probability sampling technique wherein new participants are recruited into the sample by existing participants. This method proves beneficial particularly in researching individuals with distinct characteristics that are challenging to locate, such as those with rare medical conditions. Creating with one or more initial study participants, snowball sampling progresses through referrals from these individuals, steadily expanding the sample size until reaching the desired representation or a point of saturation [16].

*A. Flowchart*

The accompanying flowchart for the wind turbine with a built-in power bank exemplifies its innovative and efficient design. This intricately crafted diagram outlines the sequential steps of operation, providing a comprehensive visual representation of the system's functionality. Each step in the flowchart clarifies the specific processes and interactions involved in the turbine and power bank integration, showcasing the thoughtful engineering behind the device. This visual aid not only enhances our understanding of the product's functionality but also demonstrates the meticulous planning and execution that went into creating a seamlessly integrated small wind turbine with a power bank.

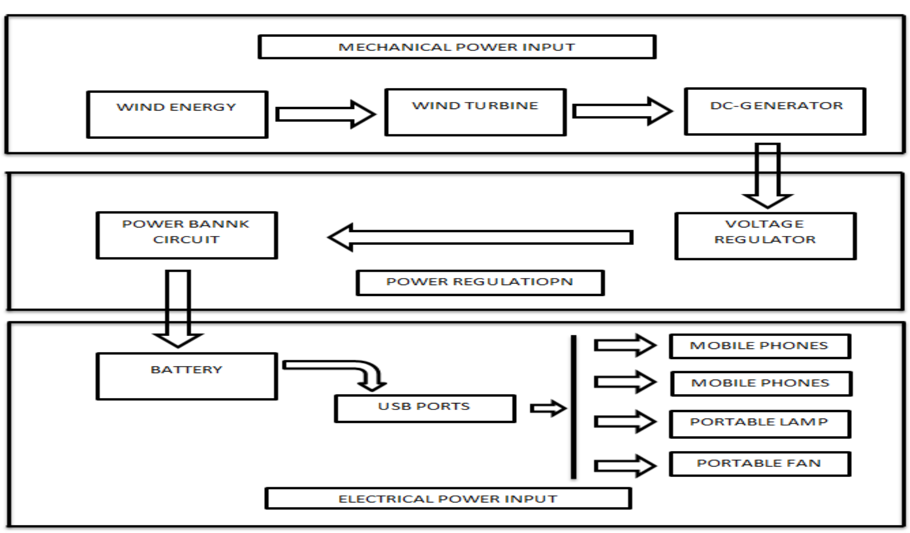


Fig. 2 Diagram of the Wind Turbine Generator Integrated with Power Bank

*B. Single Line Diagram*

This diagram illustrates a system that captures wind energy and converts it into electricity. The wind turbine's rotating blades generate mechanical energy, which is then converted into electrical energy by a DC generator. A volt/ampere indicator measures the generated electricity. The power is then routed to a voltage regulator, which adjusts it to the appropriate levels for charging a battery. The battery stores the energy, and a USB port allows this stored power to be used for charging devices. This system offers a method for converting wind energy into storable and portable electricity for electronic devices.

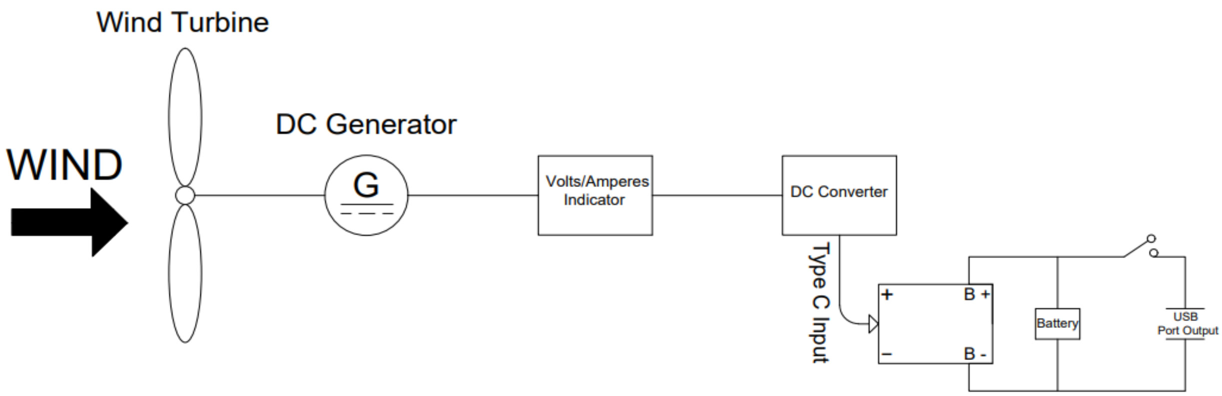


Fig. 3 Single Line Diagram (Electrical & Mechanical Parts)

*C. Equations*

The turbine blades of the wind turbine play a critical role in harnessing wind energy efficiently. To capture the maximum amount of kinetic energy from the wind.

To determine the size of blades using the formula [17], [18], [19]:

$$Blade\ Length = \frac{2 * Wind\ speed * R}{\pi * TSR}$$

Where:
Wind Speed = is the average wind speed in m/s
R = is the radius of the turbine rotor in meters
TSR = is the tip speed ratio

To determine the watts and RPM of the DC Generator using the formulas [20].

$$DC\ Generator = \frac{Rated\ Capacity * \ Average\ Voltage}{1000}$$

$$RPM = \frac{WS * \ 5280}{\pi * D * 60}$$

Where:
WS = is the wind speed in miles per hour
D = is the diameter in ft

To determine the Stand Height using the formula [21]:

$$Stand\ height = \frac{v^2}{2g}$$

Where:
V = is the velocity (m/s)
G = is the gravity (m/$s^2$)

A portable charger, or power bank, is a small, battery-operated device that stores energy to recharge electronics without the need for an outlet. It is ideal for travel and camping and is available in various sizes and capacities. The power bank capacity is determined using the formula [8]:

$$Power\ Bank\ Capacity = \frac{Total\ watts\ of\ the\ loads * 100\ mA * Number\ of\ Hours}{5\ volts\ (1A)}$$

Where:
Total watts of the loads = the combined power consumption of all connected devices.
Number of hours = the number of hours the power bank is used.

The voltage regulator functions as a monitoring device for the DC generator's voltage output, adjusting it to 5 volts as needed for the power bank, which has a 5-volt input. The anemometer is a device used to measure wind speed. This device is added to the product to provide the user with information on whether the wind speed at their location is sufficient to generate power or if the wind speed is too strong and may cause damage to the product.

The digital voltmeter ammeter is a device that displays the voltage and current generated by the DC generator. It is integrated into the product to measure and show the generated volts and amperes. This device informs the user if the generated volts/amperes are sufficient to charge the power bank and also acts as a safety feature by indicating if the generated volts/amperes exceed the product's capability.

The efficiency of the generator in converting wind power to electrical power is equivalent to the power coefficient and can be represented by [14].

$$\eta\text{overall} = \left(\frac{P_{\text{electrical}}}{P_{\text{wind}}}\right) 100\%$$

Where:
$P_{electrical}$= Electrical Power generator by DC generator (in watts)
$P_{wind}$= is the power extracted from the wind (in watts or any other power unit)

The calculation of kinetic energy extracted from the wind is determined using the provided formulas. It is important to note that these formulas offer an approximate estimation, and the actual generation of wind power can be affected by several factors, including wind direction, turbulence, and the specific design characteristics of the wind turbine.

The power available in the wind can be calculated using the formula [12]:

$$\text{Pwind}= \frac{1}{2}\,\text{A}\rho V^3$$

Where:
P is the power extracted from the wind (in watts or any other power unit),
A is the area intercepted by the wind turbine blades ($A = \pi r^2$) (in square meters),
ρ is the air density (in kilograms per cubic meter) (1.293 kg$m^{-3}$),
V is the wind speed (in meters per second),

## III. RESULTS AND DISCUSSION

### *A. Design*

As shown in Figure 4, wind speed is generally measured using an anemometer. The researchers added tail fins to help the turbine consistently face the wind. The prototype features three blades, each 38 cm in length. These blades harness wind energy, which is directed through the wind turbine to a 200-watt DC generator, converting it into direct current electricity. The specifications of the DC generator are 220V, with a maximum rotational speed of 5000 rpm and a maximum power output of 40W. The generated electricity flows through cables to a volts/ampere digital indicator, which provides real-time readings of the voltage and current generated, helping the researchers ensure the system's performance remains within safe limits. As the voltage increases, the researchers use a voltage regulator to adjust the output from the DC generator to 5 volts, which is ideal for the power bank. When the voltage reaches the optimal level of 5 volts, the power bank will begin charging. The power bank has a capacity of 40,000 mAh. To achieve this capacity, the researchers incorporate ten Li-Polymer batteries, each rated at 4000 mAh with a voltage range of 3.2V to 4.2V per cell. These batteries are configured in parallel to achieve a combined voltage of 12 volts. The electricity is then delivered through the USB ports, allowing charging cables to be plugged in and used to charge devices.

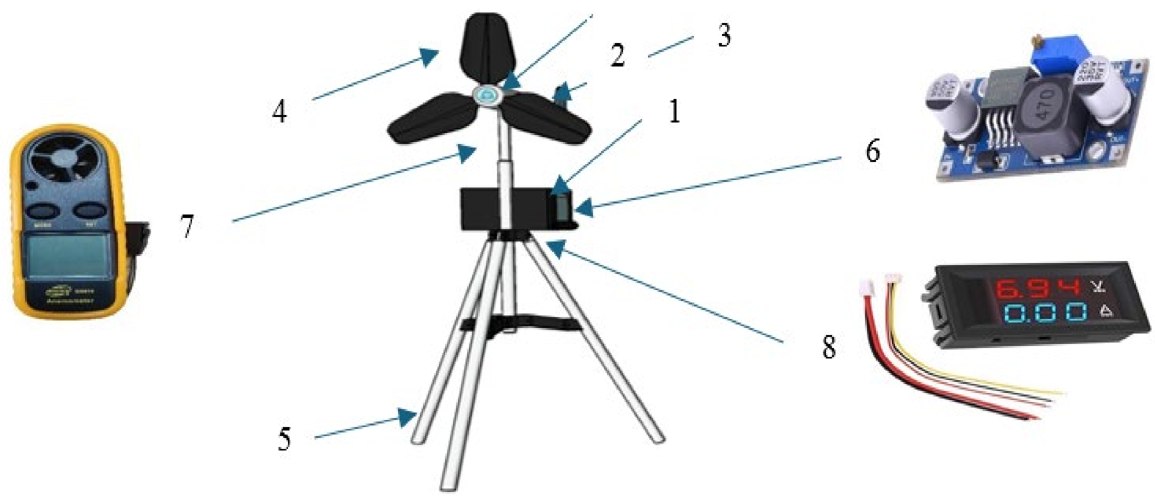


Fig. 4 Wind Turbine Generator Integrated with Power Bank

1. Power Bank
2. DC Generator
3. Tail Fin
4. Blades
5. Stand
6. Voltage Regulator
7. Anemometer
8. Digital Voltmeter Ammeter

The researcher used the formula for overall efficiency, calculated as Pelectrical/Pwind x 100, to determine the overall efficiency. As illustrated in Figure 5, wind speeds averaged between 3.01 m/s and 4.65 m/s, and the overall efficiency of the wind power bank ranged from 49.74% to 67.20%. In summary, there is a clear correlation: higher wind speeds correspond to greater overall efficiency. The wind speed with the highest overall efficiency is 4.65 m/s.

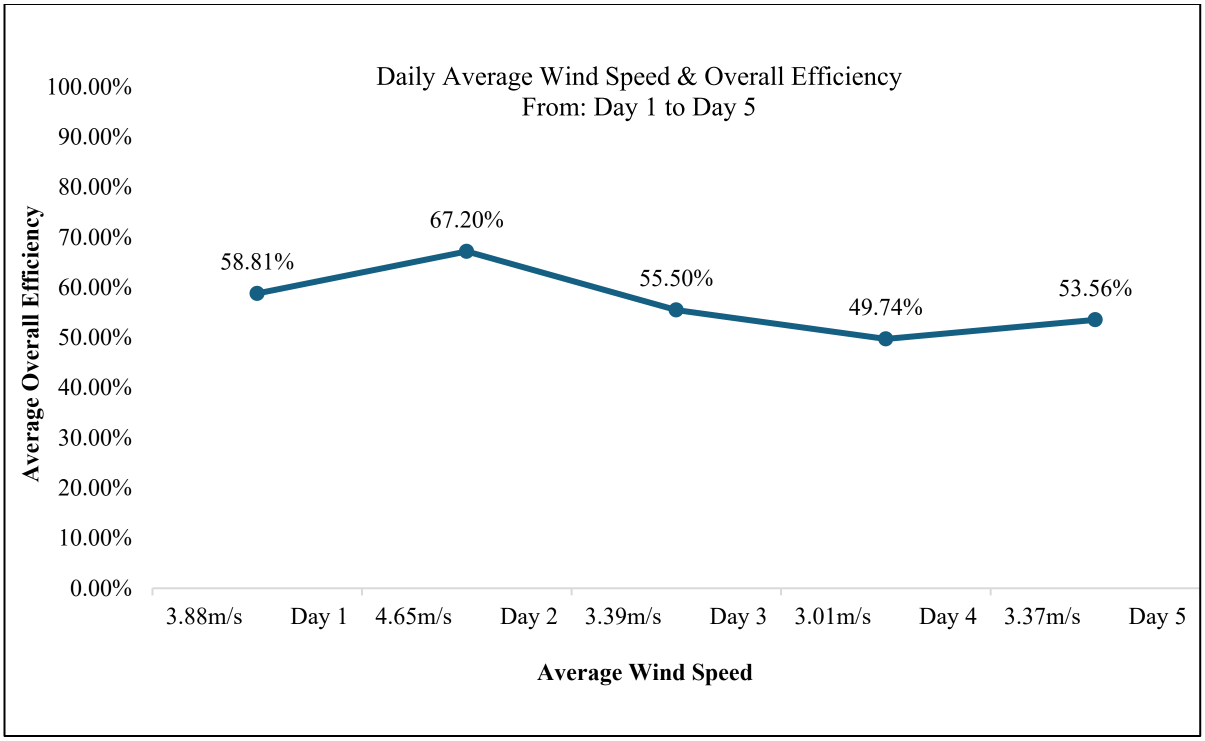


Fig. 5 Daily Overall Efficiency

TABLE I THE AVERAGES OF WIND SPEED (M/S), VOLTAGE AND CURRENT

| Days | Wind Speed | Voltage | Current |
|---|---|---|---|
| Day 1 | 3.88m/s | 5v | 2.43A |
| Day 2 | 4.65m/s | 5v | 4.3A |
| Day 3 | 3.39 m/s | 5v | 1.17A |
| Day 4 | 3.01 m/s | 5v | 0.74A |
| Day 5 | 3.37 m/s | 5v | 1.04A |

TABLE II THE AVERAGES OF WIND POWER (INPUT), ELECTRICAL GENERATOR (OUTPUT) AND OVERALL EFFICIENCY

| Days | Wind Power (Input) | Electrical Generator (Output) | Overall Efficiency |
|---|---|---|---|
| Day 1 | 18.04w | 12.14w | 58.81% |
| Day 2 | 29.21w | 21.5w | 67.20% |
| Day 3 | 10.40w | 6.07w | 55.50% |
| Day 4 | 7.20w | 3.71w | 49.74% |
| Day 5 | 9.52w | 5.21w | 53.56% |

As shown in Table I, the averaged voltage and current for 5 days from 10 a.m. to 5 p.m. meet the required voltage and current for the wind power bank. The table indicates that it can generate sufficient electricity to charge the loads with a minimum wind speed of 3.01 m/s, producing at least 5V and 0.74A. Table II shows the averages of wind power (input), electrical generator (output), and overall efficiency. As observed in Table II, the results for wind power (input), electrical generator (output), and overall efficiency are not consistent because they depend on wind speed. In summary, higher wind speeds lead to increased electricity generation, which is necessary to charge the mobile phone and operate both a lamp and a small fan.

*B. Survey Tally Form*

*Ratings:*
5 – Strongly Agree 4 – Agree 3 – Neutral 2 – Disagree 1 – Strongly Disagree

| | | | |
|---|---|---|---|
| 1 | The weight of the wind power bank is light. | 1 | 4 |
| 2 | The product is easy to transport from different locations. | 3 | 2 |
| 3 | I had no trouble walking while carrying the product. | 2 | 3 |
| 4 | I find the product`s weight to be well-balanced for its intended use. | 2 | 3 |

The table above shows the survey tally form of the gathered data for the study entitled ‘Design and Development of a Wind Turbine Generator Integrated with a Power Bank for Windy Remote Areas.’ This part includes indicators such as the weight of the power bank, ease of transport to different locations, ease of carrying the product while walking, and the balance of the weight for its intended use.

In response to the first question, 80% (4 out of 5) of the respondents had a neutral opinion on whether the weight of the wind power bank is light, while 20% (1 out of 5) agreed. For the second question, 60% (3 out of 5) of the respondents agreed that the product is easy to transport to different locations, whereas 40% (2 out of 5) had a neutral opinion. Regarding the third question, 60% (3 out of 5) of the respondents had a neutral opinion, and the remaining respondents agreed that they experienced no difficulty walking while carrying the product or prototype. Finally, in the fourth question, 60% (3 out of 5) of the respondents had a neutral opinion on whether they found the product's weight to be well-balanced for its intended use, while 40% (2 out of 5) agreed.

## IV. CONCLUSION AND RECOMMENDATIONS

In conclusion, this study aimed to address the need for portable power generation in remote areas, particularly for outdoor activities such as camping and hiking. By developing a wind turbine integrated with a power bank, the study sought to harness natural resources like wind to provide sustainable energy for essential devices. Through the design, construction, and testing of the prototype, it was found that the wind turbine generator could effectively recharge smartphones, USB lights, and USB fans using wind energy. The results demonstrated that the system could meet the electrical demands of users over multiple days of outdoor activities, providing a reliable and renewable power source. Additionally, feedback from survey respondents indicated a generally positive perception of the product's portability and usability. In summary, the development of a wind turbine integrated with a power bank offers a promising solution for meeting the power needs of outdoor enthusiasts in remote areas, with potential for further improvements, such as additional ports and enhanced lightweight design.

The researcher and participants recommend the following.

1. Design a portable wind turbine without compromising on performance or functionality.
2. Improve the prototype to reduce weight for improved portability and ease of use.
3. Add loads like a laptop.
4. Increase the output level for greater effectiveness.

Primarily, the researchers would like to thank Almighty God for providing strength, wisdom, and knowledge to the students; their beloved parents for their constant support throughout the research; the group members for their dependable collaboration; and especially their instructor, Engr. Armie Tolentino, for guiding and supporting the students throughout the entire process. Additionally, the researchers would like to express their sincere gratitude to their advisers, Engr. Genesis Tira and Engr. Ramon Vicente Escober, for their invaluable guidance, support, and encouragement throughout this research. Their expertise and insight have been instrumental in shaping this thesis.

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