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DESIGN AND DEVELOPMENT OF A WIND - -TURBINE GENERATOR INTEGRATED WITH A POWER BANK FOR WINDY REMOTE AREAS

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Abstract

Many Outdoor activities are trending today, especially camping, and hiking. However, these adventures often require access to emergency power for essential devices such as smartphones, USB fans, or USB lights. A power bank has a limited source of power, and it is not enough to meet the needs of power for several days. A wind turbine generator integrated with a power bank is needed to generate power using a natural resource such as wind. This study aimed to develop a lightweight wind turbine integrated with a power bank for remote areas. The study used a flowchart in designing the prototype and snowball sampling for the survey. The portable power generation system consists of a small turbine, a small generator, and a battery charger. The prototype was tested in the field. Tests showed the DC generator generated a voltage of 5.25V – 16.35V with a wind speed of 3.01m/s – 6.35m/s. A wind turbine generator integrated with a 40000mah power bank can recharge a smartphone 10 -13.33 times. As a result, the 40000mah power bank can charge a smartphone for 2 hours to fully charge, and you can use a USB fan for at least 8-10 hours, and 10-12 hours of USB light. The study concludes that developing a wind turbine generator integrated with a power bank can help the campers to charge their smartphone, USB light, and USB fan with a natural resource such as wind. It is recommended to have an additional port and loads and to be more lightweight.
Keywords: Wind Turbine Generator, Power Bank

1. Introduction

Wind power is an important component of a horizontal-axis wind turbine, it offers an environmentally friendly and variable choice while also enhancing national energy security, especially in the face of declining global fossil fuel reserves. The wind is used to produce electricity using the kinetic energy created by air motion, which is transformed into electrical energy using 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 stands as the predominant constituent within the broader category of renewable energy sources. According to data from 2017, wind energy consumption comprised 52% of global renewable energy consumption, surpassing solar energy, which accounted for 21% [2]. When normal sources of power are insufficient, a power bank is also referred to as a portable charger. The power bank is a small, compact, and battery-operated device that can be used to recharge a variety of 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 horizontal-axis wind turbines (HAWT) featuring three blades positioned upwind of the tower. These turbines are designed with the primary rotor shaft and electrical generator situated at the pinnacle of a tower, requiring alignment with the wind direction. Small turbines rely on a basic wind vane for orientation, whereas larger turbines typically incorporate a wind sensor in conjunction with a yaw system. Additionally, most of these turbines feature a gearbox, converting the slow rotation of the blades into a faster rotation suitable for driving an electrical generator [3]. HAWTs, or Horizontal Axis Wind Turbines, are widely adopted in contemporary wind energy systems. They employ aerodynamic blades, also known as airfoils, attached to a rotor, which can be positioned either upwind or downwind. HAWTs usually feature two or three blades and operate with high blade tip speeds [4]. In the case of upwind rotors, a yaw mechanism or tail vane is necessary to align the turbine with the wind, while downwind rotors have coned blades that enable the turbine to self-orient.

A considerable amount 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 intended for charging electronic devices [6]. A new concept has been implemented for a portable, cost-effective, and easily assembled horizontal axis wind turbine (HAWT) system designed to harness wind energy and generate electricity for individuals. 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 capability to produce a consistent DC voltage and current, with minimum wind speeds ranging from 35 to 55 km/h or 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. While optimal performance requires outdoor placement to access an adequate wind quantity, it is essential to note the absence of a waterproof protection system, limiting its use during the wet season. Future investigations could lead to the development of an improved portable wind turbine with enhanced electricity generation and a waterproof mechanism, utilizing materials like acrylic or PVC, as showcased by this initial prototype [7].

In the Philippines, support for wind energy systems is increasing because of the recently completed wind resource map of the country. Potential locations for wind energy generation have been pinpointed, with the majority situated on the western side of the archipelago. Some of the notable and promising areas include Cuyo Island (with a wind speed of 5.58 meters per second), Basco, Batanes (5.39 meters per second), Catanduanes (4.15 meters per second), and Tagaytay City (5.0 meters per second) [8]. The study of horizontal-axis-type wind turbines was first carried out by Yoshida illustrating that small wind generators can effectively operate under conditions of low wind velocity and diverse wind directions. The loop wing is designed with three to four fail-safe mechanisms to guarantee safety during typhoons or power outages. This feature is implemented at 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 its flat plains, with elevated areas concentrated in the eastern and northeastern regions along the borders with Tarlac and Nueva Ecija. Notably, in the municipality of Arayat, elevated terrains are contributing to the province's topography. 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 exceptionally high elevations, these eastern areas introduce a noticeable shift in topography, providing a departure from the prevailing flat terrain that defines much of the province.

With the help of a wind power bank, anyone can benefit from the wealth of renewable resources. This is a portable, lightweight gadget that stores electrical energy using wind power. Furthermore, a power bank is a portable gadget with a unique circuit that regulates power flow [10]. Various studies determine the efficiency and effectiveness of small-type wind turbines. Energy from wind is renewable. In general, compared to many other energy sources, wind energy production has fewer environmental effects. Except in rare circumstances, wind turbines don't emit any pollutants into the air or water, and they don't need water to cool down [11]. Previous research concluded a positive response that a wind-powered mechanism can be a mechanical source of a power bank. With an efficiency of 52.30% in terms of power conversion, this wind-powered mechanism is an efficient mechanical input. Subsequently, this wind power bank has the advantage over other power banks because it uses a renewable energy source, it has a low initial cost, it reduces electrical power consumption, and it is as efficient as any other power bank [10].

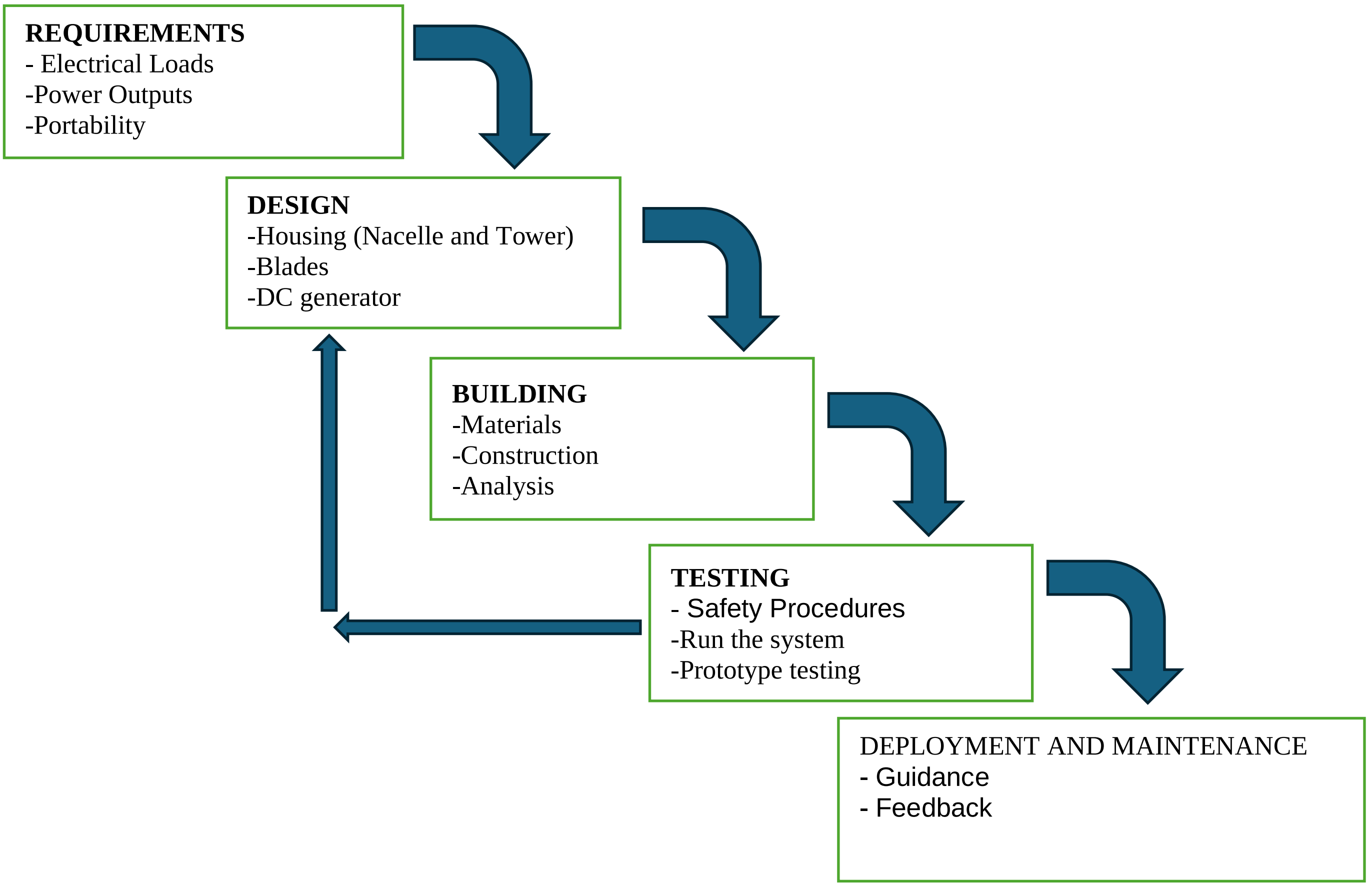
In our modern and mobile-centric society, there is a growing need for self-sufficient power solutions for portable devices. Particularly in isolated regions, especially at higher altitudes where wind resources are viable, access to electricity is often short. In such scenarios, having a reliable source of compact and sustainable power becomes essential for recharging vital devices like mobile phones, walkie-talkies, emergency lights, and other equipment [2].

Thus, this study addresses the following problems, (1) The wind turbine generator has demonstrated lower overall efficiency due to the fluctuating wind power experienced during extended outdoor activities over multiple days; (2) Consequently, there is a need for a power bank generation system to meet the continuous demand for electrical energy; (3) Many individuals participate in outdoor activities such as camping, research, mountaineering, tourism, and expeditions that often extend over several days and necessitate a portable equipment.

Generally, this study aimed to develop a lightweight wind turbine integrated with a power bank for remote areas. Specifically, (1) To identify the wind speed with 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 create a lightweight wind turbine system designed for portability, enabling deployment in various locations, with a specific emphasis on remote areas.

2. Methods

The waterfall method is a sequential method where each project phase starts after the completion of the preceding one. This method is straightforward and effective, especially when the project objectives are well-defined [7]. In the requirements phase, the focus is on determining the desired power output of the generator, supplying smartphones, portable lamps, and portable fans, and portability specifications such as size, weight, and setup ease for folding parts. Moving to the design phase, decisions are made on the blade size and shape, the housing or the Nacelle and Tower, as well as designing the DC generator with portability in mind. The building phase involves gathering materials for blades, the generator of the wind turbine to construct the prototype and the analysis of examining the prototype. Subsequently, the testing phase assesses the system, testing the prototype under various wind speeds to ensure it meets requirements and follows safety procedures. Finally, the deployment and maintenance phase offers guidance on installation and usage in different settings, collecting user feedback as necessary.



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].

Flowchart

The accompanying flowchart for the wind turbine featuring a built-in power bank exemplifies its innovative and efficient design. This intricately crafted diagram delineates the sequential steps of operation, providing a comprehensive visual representation of how the system functions. Each step in the flowchart elucidates the specific processes and interactions within the turbine and power bank integration, revealing the thoughtful engineering behind the device. This visual aid not only enhances our understanding of the product's functionality but also serves as a testament to the meticulous planning and execution involved in creating a seamlessly integrated small wind turbine with a power bank.

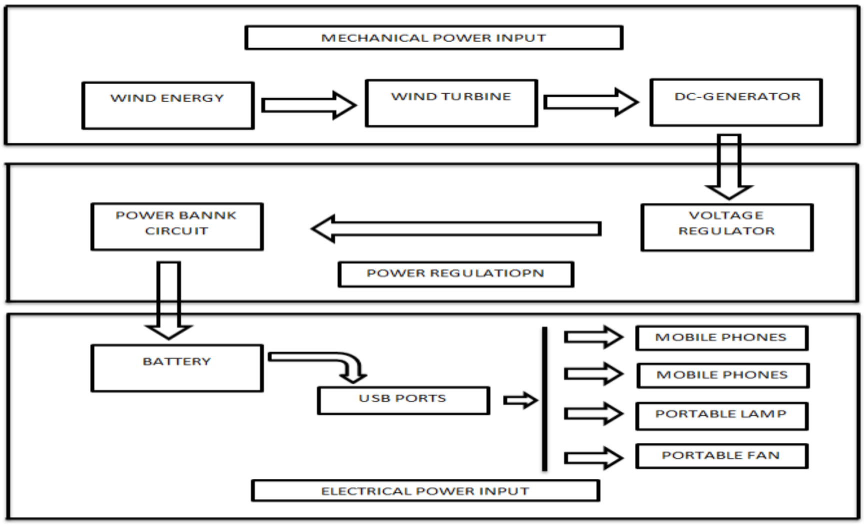


Figure 1: Diagram of the Wind Turbine Generator Integrated with Power Bank

Single Line Diagram

This diagram shows a system that captures wind energy and turns it into electricity. The wind turbine's rotating blades generate mechanical energy, which a DC generator then converts into electrical energy. A volts/amperes indicator measures this electricity. The power then goes to a Voltage regulator, which adjusts it to the right levels for charging a battery. The battery stores the energy, and a USB port allows you to use this stored power to charge devices. This system provides a way to turn wind energy into storable and portable electricity for electronic devices.

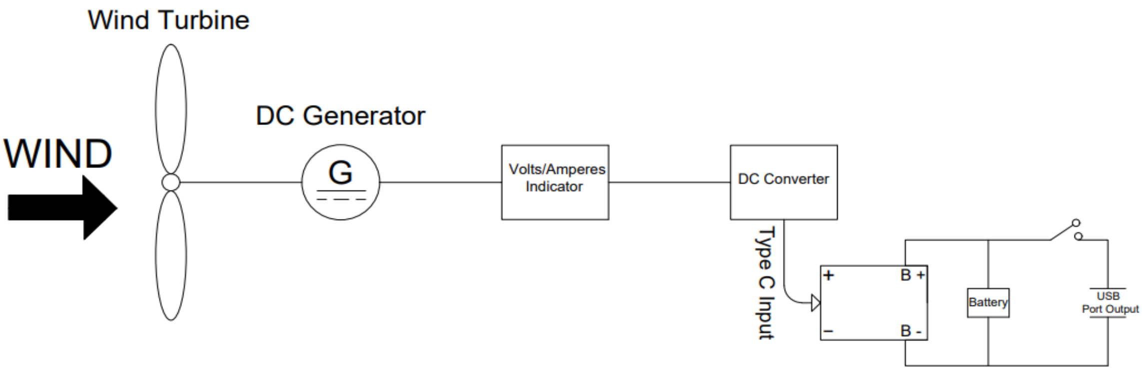


Figure 2: Single Line Diagram (Electrical & Mechanical Parts)

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 an outlet, ideal for travel and camping, available in various sizes and capacities.

To determine the Power Bank Capacity 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 = is the combined power consumption of all devices connected.
Number of hours = is the number of hours that the power bank used.

The voltage regulator will function as the monitoring device for the voltage output of the DC generator, 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 give the user an idea if the wind speed in his/her location is enough to generate power or if the wind speed is too strong for the product's capability and might cause damage to the product.

The digital voltmeter ammeter is a device that displays the voltage and current generated by a DC generator. It is integrated into the product to measure and show the generated volts and amperes. This device will give the user an idea if the volts/amperes being generated is enough to charge the Power bank, and it will also act as a safety feature as it gives the user an idea if the volts/amperes being generated is excessive or too much for the capability of the product.

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

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

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 by the provided formulas. It's essential to note that these formulas offer an approximate estimation, and the actual generation of wind power can be impacted by several factors, including wind direction, turbulence, and the specific design attributes 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 kgm^{-3}),
V is the wind speed (in meters per second),

3. Results and Discussions

Design

As shown in Figure 3, the wind speed can generally be measured through an anemometer. The researchers put tail fins; these fins help the turbine consistently face the wind. The prototype consists of 3 blades with a length of 38cm. These blades will harness wind energy that can go through the wind turbine and deliver it into a 200-watt DC generator, transforming it into direct current electricity. The DC Generator specifications are, 220V, with a maximum rotational speed of 5000rpm and a maximum power output of 40W. This generated electricity flows through cables and delivers it into the Volts/Ampere digital indicator. The Volts/Ampere digital indicator provides real-time readings of the voltage and current generated, helping the researchers ensure the system's performance is within safe limits. As the voltage rises the researchers provide a voltage regulator that adjusts the output from the DC generator to 5 volts, ideal for the power bank. As the voltage reaches the ideal voltage of 5 volts, the power bank will be charged. The power bank has a capacity of 40,000 mAh. To achieve this, 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 will flow in the USB ports and the charging chords can plug in and charge the loads.

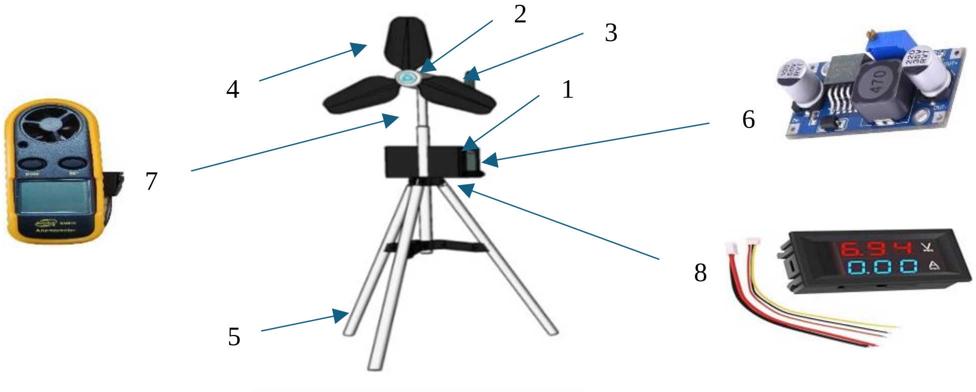


Figure 3: Wind Turbine Generator Integrated with Power Bank

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

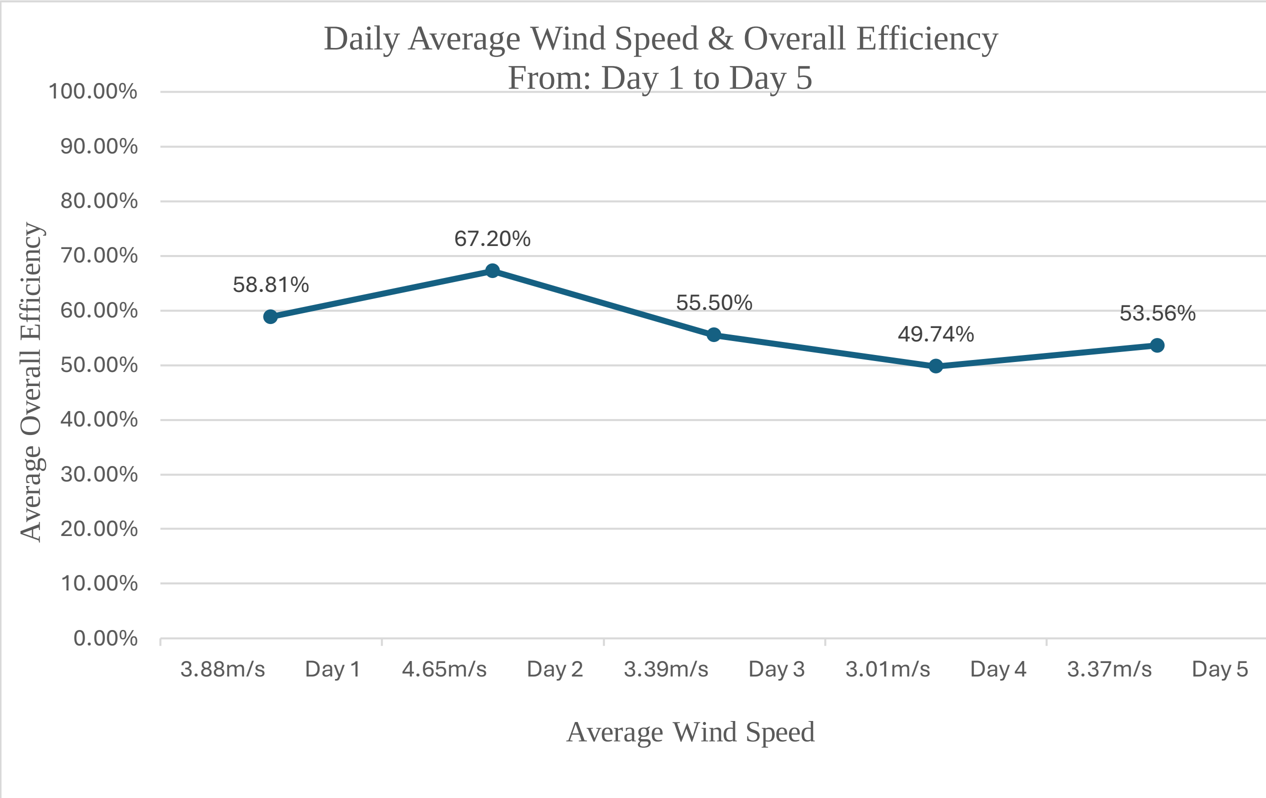


Figure 4: Daily Overall Efficiency

The researcher used the formula for overall efficiency, calculated as Pelectricald/Pwind x 100, to determine the overall efficiency. Illustrated in the figure 7, wind speeds averaged 3.01 m/s - 4.65 m/s, and the overall efficiency of the wind power bank averaged 49.74% - 67.20%. In summary, there's a clear correlation, the higher wind speeds correspond to greater overall efficiency. The wind speed with the greatest overall efficiency is 4.65 m/s.

Table 1: The averages of wind speed (m/s), voltage and current.

	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 2: The averages of Wind power (input), Electrical generator (output) and overall efficiency.

	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 1 the averaged voltage and current for 5 days from 10am - 5pm can meet the needed voltage and current of the wind power bank. The table shows that it can generate an enough electricity to charge the loads with a minimum wind speed of 3.01 m/s and it can generate a minimum of 5V and 0.74A. For the table 2 the table shows the averages of Wind power (input), Electrical generator (output) and overall efficiency. As shown in the table 2 we can observe that the result of wind power (input), Electrical Generator (output), and overall efficiency is not consistent because it depends on the speed of the wind. In summary the higher the wind speeds the higher electricity can generate to charge the mobile phone and operate both a lamp and a small fan.

Survey Tally Form

Title: **Design and Development of a Wind Turbine Generator Integrated with Power Bank for Windy Remote Areas**

RATINGS:

5 – Strongly Agree 4 – Agree 3 – Neutral 2 – Disagree 1 – Strongly Disagree

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 Power Bank for windy Remote Areas. This part is composed of indicators which include the weight of the power bank, the product is easy to transport to different locations, not burdensome to carry the product while walking and lastly a well-balanced weight for its intended use.

1. The weight of the wind power bank is light. (Ang bigat ng wind power bank ay magaan.)		1	4		
2. The product is easy to transport from different locations. (Ang produkto ay madaling dalhin mula sa iba't ibang lokasyon.)		3	2		
3. I had no trouble walking while carrying the product. (Hindi ako nahirapang maglakad habang bitbit ang produkto)		2	3		
4. I find the product`s weight to be well-balanced for its intended use. (Nakikita ko na ang timbang ng produkto ay balanseng mabuti para sa nilalayon nitong paggamit)		2	3		

In the first question, 80% (4 out of 5) of the respondents has a neutral decision that the weight of the wind power bank is light while, 20% (1 out of 5) of the respondents agreed. In the second question, 60% (3 out of 5) of the respondents agreed that the product is easy to transport from different locations on the contrary, 40% (2 out of 5) of the respondents has a neutral decision. Then, in the third question, 60% (3 out of 5) of the respondents have a neutral decision and the rest of the other respondents agreed that they have no trouble walking while carrying the product or prototype. Lastly, in the fourth question, 60% (3 out of 5) of the respondents has a neutral decision that they find the products weight to be well balanced for its intended use while 40% (2 out of 5) of them agreed.

4. 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 showed 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:

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

Primarily, the researchers would like to thank the Almighty God who gives strength, wisdom, and knowledge to the students; And to the beloved parents who support them every time they do the Research; And to the members of the group whom they can depend on in times of need; And especially to the instructor, Engr. Armie Tolentino for guiding and supporting the students throughout the whole process I would like to express my sincere gratitude to our adviser 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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