

A Novel Approach in Mobile Wind Turbine Generating Electricity from Vehicle Air Movement

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Abstract— This study evaluates the performance of a portable wind generator designed to produce electricity by capturing airflow generated by moving vehicles. With increasing demand for renewable energy, utilizing vehicle-induced wind presents an innovative approach to sustainable power generation. The system was tested through field experiments and theoretical analysis under different environmental and traffic conditions. Key factors such as wind speed, wind direction, and vehicle velocity were considered to assess the generator's efficiency. The results show that the device has potential as a supplementary power source, especially in areas with heavy vehicular traffic. However, challenges such as inconsistent wind patterns and optimal placement of the generator need further investigation. Overall, the study highlights the potential of portable wind energy systems in utilizing unconventional wind resources for sustainable electricity generation.

Keywords: Renewable energy, Wind Energy, Motor, Voltage.

Introduction: As the global demand for clean and sustainable energy increases, researchers and engineers are exploring new ways to use renewable energy resources. One innovative idea is to generate electricity from the airflow created by moving vehicles using portable wind generators. Traditional wind turbines are usually fixed in specific locations where strong winds are available. However, new technology has made it possible to develop portable wind generators that can capture wind energy in different environments, including urban areas with heavy traffic. Using the airflow produced by vehicles provides an opportunity to use an easily available but often unused energy source. With the increasing number of automobiles worldwide, the potential for generating electricity from this source is significant. Portable wind generators are flexible and can be installed in many different places, allowing energy to be produced in various situations. This concept also supports the idea of distributed energy generation and decentralized power systems. In this study, we evaluate the performance of a portable wind generator designed to capture airflow from moving vehicles and convert it into electricity. Field experiments and theoretical analysis are used to examine the performance, efficiency, and practical feasibility of the system under different environmental and traffic conditions. By studying mobile wind energy systems, this research contributes to the development of sustainable energy solutions and supports the transition toward a cleaner and greener future. Wind energy refers to the process of using the natural movement of wind to produce mechanical power or electricity. Wind turbines convert the kinetic energy of wind into mechanical energy, which is then used to generate electrical power. Although wind turbines may cause some environmental effects such as noise, visual impact, and minor climatic changes, these impacts are much smaller compared to the environmental damage caused by burning fossil fuels [3]. Wind energy is one of the most socially accepted renewable energy technologies after solar power and has gained increasing attention since the late twentieth and early twenty-first

centuries. Because of the growing interest in renewable energy sources, especially wind energy, researchers are working on improving design methods for wind energy systems. Energy studies are very important because modern society depends heavily on energy. Wind energy is considered a good option because it is clean, practical, cost-effective, and environmentally friendly [4]. However, one major challenge in wind power generation is the low wind speed that occurs in many locations, with strong winds occurring only occasionally. Therefore, careful planning is required when installing wind turbines. The increasing global investment in wind energy is mainly driven by rising oil prices and concerns about climate change [5]. One study [6] introduced a small-scale and cost-effective method for generating electricity from wind energy using piezoelectric bimorph actuators. The generator had dimensions of $5.08 \times 11.6 \times 7.7$ cm³ and was made from 3.2-mm thick plastic. Under test conditions with a wind speed of 12 mph and a load of 1.7 kilo-ohm, the prototype produced 1.2 mW of electrical power. Another study investigated wind energy harvesting from moving trains, where a large amount of wind energy is wasted due to vehicle drag. In this system, a converging air duct tunnel with a spiral casing placed on the roof drives a vertical axis turbine, which generates electricity to power an alternator [7]. The use of variable-speed wind turbines (VSWT) requires active power control (APC) to manage power system operations effectively [8]. The performance of APC depends on the power reference used. Traditionally, this reference is obtained from available wind power (AWP) based on the maximum power point. However, maintaining stability during operation can be challenging due to the instability of VSWT systems. Therefore, new control techniques are needed to improve APC performance in variable-speed wind turbines. Noman et al. (2020) and Hoque et al. (2024) presented an important project that introduced a strong data retrieval system along with an advanced framework for predicting data accuracy in electricity generation studies [18,19,28,24,29]. Biswas et al. (2024) also discussed industrial sustainability and mechanical characterization in different industries through three separate studies [20,21,22,23,25]. The performance of

wind energy conversion systems (WECs) depends on several subsystems such as the aerodynamic turbine, mechanical gear system, and electrical generator [9]. Conducting a wind survey is important to determine the availability of wind resources in a region, as wind conditions depend on the local climate. Wind power is also used in green building designs, such as in the Solar Energy Institute building. Another study analyzed a 1.5 kW small wind turbine system installed in Turkey with a hub height of 12 m and a rotor diameter of 3 m [10]. Research on wind energy applications also suggests that at an average wind speed of 2 kph, an automobile traveling at 10 kph can generate about 8 kWh of electricity. Since a typical electric car requires about 20 kWh for a full charge, the study indicates that driving at 10 kph while charging could allow the vehicle to travel 200 km in about two hours. If the car travels at 60 km/h, it could reach full charge and cover the same distance in around 20 minutes [11, 12]. Another study analyzing wind data from different locations in Bangladesh found that a minimum wind speed of 4 m/s is required for effective wind energy generation. During periods of low wind speed, a diesel generator can support the system, and additional components such as converters and batteries are used to store extra energy [13]. Research comparing horizontal axis wind turbines (HAWT) with vertical axis wind turbines (VAWT), including the Darrieus turbine and the H-rotor design, found that VAWTs perform better than HAWTs in strong wind conditions such as on rooftops. It was also suggested that the H-rotor should use three blades instead of two [14]. Another study focused on the aerodynamic design of modern wind turbine blades, including blade shape, number of blades, aero foil selection, and optimal angle of attack. Important design parameters such as twist angle and chord length depend on the lift and drag characteristics of the aero foil [15]. Kamal et al. also highlighted the importance of RFID technology in improving electricity testing systems [16]. Another study discussed the technical challenges involved in integrating wind energy into power systems, including issues related to system stability, operating cost, power quality, and energy imbalance. It was found that wind energy has little effect on operating costs when penetration is low (around 5%), but the impact becomes more noticeable when penetration increases to about 20%. Some researchers have also explored generating clean energy from fast-moving vehicles such as trains by designing turbines that capture the wind produced by the vehicle's motion [16]. This research focuses on producing electricity using a small portable wind turbine for people traveling long distances by motorcycle, bus, or speedboat. The portable turbine can generate electricity, store it in a battery, and charge mobile phones or other electronic devices [17]. By focusing on motorcycles as a vehicle platform, this study proposes a practical solution for capturing wind flow and generating electricity efficiently. The lightweight and portable design of the wind generator makes it easy to carry and use, reducing dependence on traditional energy sources such as hydropower or nuclear power while

providing a sustainable energy option during travel.

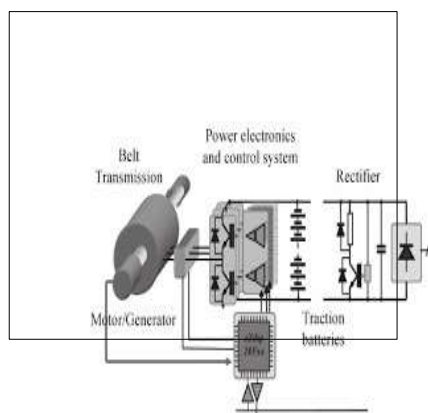
Methodology: Electricity in a generator is produced based on Faraday's electromagnetic induction principle. Both AC generators and DC generators work using this same principle. According to Faraday's law, when a conductor moves through a magnetic field, an electromotive force (EMF) or voltage is produced in the conductor. EMF can be generated in two ways: either by rotating a conductor coil inside a stationary magnetic field or by rotating the magnetic field around a stationary coil. The amount of voltage produced depends on several factors, such as the number of turns in the armature coil, the strength of the magnetic field, and the speed of rotation. These factors determine how much EMF is generated and play an important role in the performance of electrical machines. Understanding and improving these factors helps in designing more efficient generators and motors. Ullah et al. (2023) studied the best production scheduling method using Johnson's algorithm. This method is useful when studying electricity production systems and can help improve productivity in electricity generation from motor vehicles, which is related to our current research. This study uses a systematic method to evaluate how well a wind generator produces alternating current (AC) electricity at different vehicle speeds, based on the methodology from a previous electricity generation study. First, the wind generator is installed and set up properly. This includes placing the generator in a suitable position to capture wind energy effectively and ensuring all parts are correctly connected and working. After the setup, the wind generator is turned on, and it starts producing AC electricity by converting wind energy into electrical energy. During this stage, the output electricity from the generator is carefully monitored. Next, the study examines how the amount of electricity produced changes when the vehicle speed varies. Different speeds are tested to see how they affect the electricity generated. This helps analyze the relationship between vehicle speed and power generation. The goal of this study is to understand how effective wind energy can be for generating electricity in mobile systems like vehicles and to find ways to improve renewable energy solutions for transportation.

Wind Generator Setup

A 50-watt wind generator is assembled by integrating a 50-watt brushless generator motor with a fan mechanism. The setup includes affixing a four-blade fan onto the shaft or rotor of the generator. As wind currents interact with the fan blades, they induce rotation, thereby setting the fan in motion.

This rotational movement of the fan, in turn, drives the rotor of the generator. Consequently, the armature coil within the generator rotates within a magnetic field, facilitating the production of electricity.

In this configuration, the fan serves as the primary driver, harnessing wind energy to initiate the generator's operation.



Consequently, the system qualifies as a wind generator, given its reliance on wind energy to propel the fan and subsequently generate electrical power.

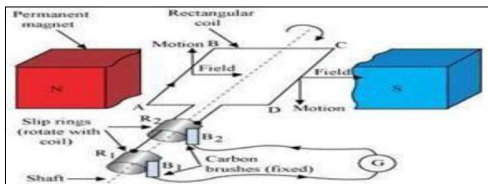
This setup exemplifies a simple yet effective means of converting wind energy into usable electrical energy, offering a sustainable solution for small-scale power generation in various applications, from off-grid power sources to renewable energy experiments.



Figure 2 Parts of the wind generator

LAC power Generation through the wind generator

In a wind generator, multiple components collaborate to facilitate the generation of electricity. The "field" component encompasses a magnetic field where the primary magnetic flux is generated. This field can be established by incorporating permanent magnets or by supplying a direct current (DC) voltage to the field winding conductor coil. Acting as the primary driving force, the "prime mover" component serves as the converter and energy transmitter. Its role involves converting various energy sources such as fuel, steam, hydro,



wind, or atomic energy into mechanical energy. This mechanical energy is then transmitted to the rotor, initiating its rotation. Through the collective operation of these components, the wind generator harnesses the kinetic energy of wind currents to drive the rotor's rotation within the magnetic field, inducing the generation of electricity. This process exemplifies the intricate interplay of mechanical and electromagnetic principles to produce renewable energy from wind resources.

Figure 3 Procedure for electricity generation [18].

The rotor or shaft serves as the rotating element of a generator, facilitating the transmission of mechanical energy from the prime mover to the armature coil, inducing rotation within the magnetic field. The armature, comprising a conductor coil, allows for the induction of electromotive force

(EMF) or voltage as it rotates within the magnetic field, adhering to Faraday's electromagnetic principle. Slip rings, which are hollow rings affixed to the ends of the armature coil, function to transmit the electric power induced in the armature coil to the fixed brushes. These brushes, acting as stationary conductors, are connected to the rotating slip rings and facilitate the passage of generated output power out of the generator. Together, these components orchestrate the conversion of mechanical energy into electrical energy, enabling the generator to produce electricity efficiently.

Energy Transmission and Conversion

To observe the electricity generated against vehicle speed, the apparatus includes a portable wind generator, a multimeter set for measuring electricity, a motorbike for varying speeds, and a smartphone for recording data, as shown in Figure 4. This setup enables real-time monitoring of electricity output under different vehicle velocities.

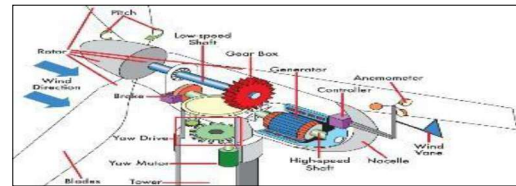


Figure 4 Wind turbine energy conversions

Working Principles

The experiment commenced with the setup of a multimeter, with its two leads connected to the output neutral and conductor phase of the portable wind generator. Positioned against the wind flow generated in the opposite direction of a motorbike, the generator's fan faced the frontal direction of the bike. Subsequently, the multimeter was configured to measure 200V AC. As the motorbike began to move, the output voltages displayed on the multimeter screen were monitored, and approximate stable readings were recorded for speeds ranging from 20 kph to 60 kph. Following this, the multimeter settings were adjusted to measure 20 mA AC, and the average readings for each speed interval were documented. Throughout the observation of electricity generation, data recording was facilitated using a smartphone, capturing audio clips to document the experimental process and results accurately. This systematic approach allowed for the comprehensive analysis of the relationship between vehicle speed and electricity production, providing insight into the performance of the wind generator under varying operational conditions. By meticulously recording and analyzing the generated data, valuable information regarding the efficiency and effectiveness of the wind generator in converting wind energy into electrical power at different speeds was obtained. This experimental methodology, combining precise measurement techniques with modern recording technology, ensured the reliability and accuracy of the findings, thereby contributing to the advancement of research in renewable energy utilization for mobile applications.

Table2 Generated AC Current against Speed

Result and Discussion

While traveling on the bike, the generator was held against the airflow. Initially, there wasn't a significant voltage, as the speed was not high enough. However, as the bike accelerated, a noticeable increase in voltage was observed on the multimeter. For the convenience of the dataset, the voltage readings were categorized into three states: minimum, maximum, and steady state. Although the steady-state value represents consistent output, even the minimum voltage generated during this process was found to be substantial. From 20 kph to 60 kph, the generated AC voltages are presented in Table 1. From Figure 5, it is evident that the voltage increases gradually with speed, maintaining approximately 20 volts at 20 kph and reaching around 105 volts at a speed of 80 kph as the steady value.

Table1 Generated AC Voltage against Speed

Speed[kph]	Minvoltage(Vmin)[Volt]	Maxvoltage(Vmax)[Volt]	Steadyvoltage(v)
15	15	24	20
20	17	31	29
25	20	36	35
30	38	45	44
35	50	60	50
45	53	57	56

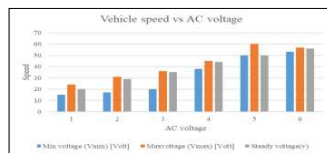
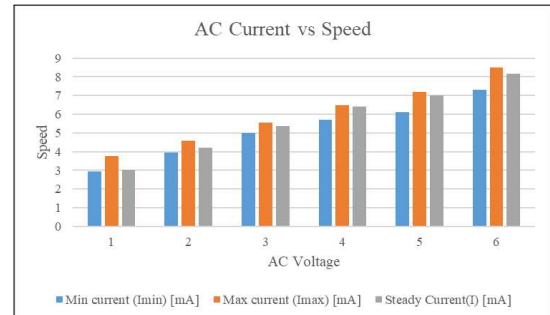


Figure 5: Speed vs. AC Voltage

Following the observation of generated voltage, the multimeter was adjusted to measure current, set at 20 mA AC to determine the generator's current output. Initially, the current generated was modest, but it increased proportionally with rising speed.

Additionally, voltage measurements were conducted under varying conditions—minimum, maximum, and steady state—providing comprehensive insights into the generator's performance. Table 2 presents the recorded currents across the speed range of 20 kph to 60 kph. Figure 6 illustrates a notable increase in electricity production, with a steady current output of 3 mA at 20 kph and 15.5 mA at 80 kph, indicating a significant improvement in power generation at higher speeds.



Speed(kph)	Mincurrent(Imi n)	Maxcurrent(Imax)
	[mA]	[mA]
15	2.95	3.75
20	3.93	4.57
25	5	5.56
30	5.7	6.48
35	6.13	7.2
45	7.3	8.51

Figure6 Generated AC current against Speed

Data Calculation

The generated power (P) is determined by the product of the generated voltage (V) and current (I), expressed as $P = VI$. By applying this formula, the minimum, maximum, and average powers generated are computed for each vehicle speed. These calculations provide insights into the varying levels of power output corresponding to different speeds. The minimum power represents the lowest achievable power output under specific conditions, while the maximum power indicates the peak potential power generation capability. Additionally, the average power offers a comprehensive overview of the generator's performance across the range of vehicle speeds tested. By utilizing the $P = VI$ equation, this analysis enables a quantitative assessment of the wind generator's efficiency and effectiveness in converting wind energy into electrical power under dynamic operating conditions.

Table3 Generated AC Power against Speed

Speed [kph]	V min [Volt]	I min [mA]	V max [Volt]	I max [mA]	V avg [Volt]	I avg [mA]	P min [Watt]	P max [Watt]	P avg [Watt]
15	5	1.01	3.2	2.75	3.8	1.4	0.0552	0.08	0.07
20	8	1.85	3.2	3.57	4.7	2.2	0.0778	0.2198	0.2341
25	1	2.85	4.2	3.56	5.8	3.4	0.12	0.2132	0.2781
30	5	3.99	4.8	3.48	6.9	4.01	0.2166	0.1287	0.9827
35	5	4.32	6.9	5.2	7.9	4.2	0.4065	0.5110	0.46
45	2	5.1	8.1	5.51	8.8	5.32	0.4869	0.4892	0.7643

At speeds of 30 kph, 40 kph, 50 kph, and 60 kph, stable alternating current voltages of 20 V, 35 V, 50 V, 70 V, and 105 V were measured, coupled with steady currents of 3 mA, 5.35 mA, 7 mA, 11 mA, and 15.5 mA (Fig. 7). Hence, the generated steady powers are 0.06 W, 0.19 W, 0.35 W, 0.77 W, and 1.63 W, respectively. The maximum AC values recorded were 113 V and 16.43 mA, resulting in a power output of 1.86 W. This maximum power was observed in the portable generator at a bike speed of 60 kph, indicating that a reasonable amount of power is generated by the portable wind generator under higher-speed conditions. Converting this generated AC power into DC allows it to be stored in a power bank using modules and other electronic components. Mobile phones, torchlight batteries, and other small electronic devices can be charged either simultaneously or at a later time. Additionally, various electronic components used in vehicles can be operated using this generated power.

Conclusion

A portable wind generator offers a readily available solution for generating electricity, providing crucial support to travelers by mitigating the uncertainty of power outages. Its installation on fast-moving vehicles allows for continuous power generation, which can be utilized immediately or stored for later use with power banks.

This innovation presents an unlimited power source for travelers, potentially replacing conventional power banks. During storms or load-shedding scenarios, the generator can swiftly produce electricity, reducing reliance on the national grid and minimizing environmental impact.

However, existing generators and their fans may not be optimally designed for this specific application, suggesting

room for improvement through precise design modifications. Given the need to position the generator against high-speed wind flows, ensuring robust clamping force during installation is imperative.

This study aims to enhance understanding of portable wind generators as renewable energy sources in transportation. By evaluating their effectiveness and addressing design challenges, the research contributes to the advancement of cleaner and more sustainable energy solutions. Moreover, the findings can guide future developments and promote the widespread adoption of wind energy technologies in mobile applications.

Future Recommendation

Investigating alternative designs and materials for wind turbine blades could optimize energy capture efficiency, ensuring maximum utilization of available airflow. Additionally, implementing advanced aerodynamic principles and computational modeling techniques could refine the turbine design to minimize drag and maximize power generation potential.

Furthermore, exploring innovative methods for integrating the wind turbine seamlessly with different types of vehicles, such as trucks, buses, or bicycles, could broaden its applicability and effectiveness. Research could also focus on developing sophisticated control systems to dynamically adjust the turbine's orientation and speed in response to varying airflow conditions, thereby maximizing energy extraction efficiency. Moreover, conducting field experiments and real-world deployments across diverse geographic and climatic regions could provide valuable insights into performance under varied environmental conditions. Lastly, investigating the feasibility of incorporating energy storage solutions, such as batteries or capacitors, could enable efficient utilization of generated electricity, enhancing the overall effectiveness and practicality of the mobile wind turbine system for sustainable energy generation on the move.

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