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Design and Implementation of Vertical Axis Wind Turbine System

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Abstract
One of the major issues in this fast-moving world is to meet the demand for energy in the most economical and environment-friendly way. This research focused on designing a Vertical Axis Wind Turbine (VAWT) that gives a solution that is comparatively a cheap alternative to renewable energy. Unlike traditional Horizontal Axis Wind Turbines (HAWTs), VAWTs have their rotor shaft positioned vertically, allowing them to operate independently of wind direction. When there is enough wind to rotate the windmill, magnetic coupling between the rotating and stationary coils causes the windmill to produce energy. The work demonstrates a vertical rotating prototype of the windmill. The wind turbine can charge up to a 12V battery. The advantage of this design is that it works without any consumption of fossil fuel and works efficiently inappropriate weather conditions with- out being closely monitored and the battery charges automatically without any harmful emissions or drawbacks. VAWTs offer advantages such as lower maintenance, compact design, and better performance in turbulent wind conditions. The work presented in this paper is an example of how natural resources like wind energy can be used efficiently to produce electricity.
Keywords: VAWT, Wind Turbine, Vertical axis, Inverter

1. INTRODUCTION

Wind power has emerged as one of the most cost-effective renewable energy sources in recent years. Wind turbines that generate power nowadays use tried-and-true technology and offer a reliable and sustainable energy supply. The first known wind turbine created for electricity production is built by inventor Charles Brush to provide electricity for his mansion in Ohio. A wind turbine is a device that converts wind's kinetic energy into electrical energy. The costs of producing wind energy have reduced by 80 percent since the last century. Today, wind energy is regarded as the least expensive renewable energy source. On the market today, wind turbines are useful. Vertical-Axis wind turbines happen to be the most popular and widely coveted turbines. It is also more practical, reliable and cost effective, it also has the best longevity and durability features. Therefore, we will be able to use efficiently over a long haul.

1.1. Literature Review

Today, wind energy is thought to be the most affordable type of renewable energy. Currently available wind turbines serve a purpose. Their analysis indicates that the vertical axis wind turbine can be able to attain the air from all the direction and produces the power of 1 kilowatt for a movement of 25 m/s. D.A.nikam et al. analysed that the generation of electricity is affected by the geometry and orientation of the blade in the wind turbine .He analysed the blade plays critical role

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in the performance and energy production of the turbine. Altab hossain et al. analysed that the power production will increases when the velocity is high. Parth Rathod et al. study of a combined vertical axis wind turbine review. The experiment is conducted to increase the power production and efficiency of a wind turbine. The outcome suggests that a turbine's efficiency is always dependent on the wind speed and weather. Piyush Gulve et al. analysed the design and construction of vertical axis wind turbine. He conclude that the vertical axis wind turbine is more efficient than horizontal axis wind turbine because it requires compact room for making the same amount of electricity while making less noise.

1.2. Problem Statement

The electricity we get today in our homes is generated from nuclear energy or any other atmosphere destroying ways. For both large-scale and small-scale and distributed power generation applications, wind power is a desirable and alternative energy source. One of the most important advantages of wind energy is that it is modular and scalable. A wind turbine is a machine that transforms wind's kinetic energy into electrical power. The main rotor shaft of a vertical axis wind turbine (VAWT), which can take wind from any direction, is one form of wind turbine. The primary objective of this research is to design and model a small-scale VAWT, which can be used to meet the power for low demand applications.

2. Simulation and Analysis

A vertical axis wind turbine (VAWT) system with an inverter consists of several key components modeled in MATLAB Simulink. The system begins with a wind turbine that harnesses wind energy and converts it into mechanical power. This mechanical power drives a permanent magnet synchronous generator (PMSG), which generates AC electricity. Since the output voltage of the PMSG varies with wind speed, a boost converter is used to regulate and step up the voltage to a desired level. The regulated DC voltage is then fed to an inverter, which converts the DC power into AC power suitable for driving an AC load. The inverter ensures that the output voltage and frequency match the requirements of the connected load. The entire system is controlled through appropriate algorithms to optimize power extraction and maintain stable operation.

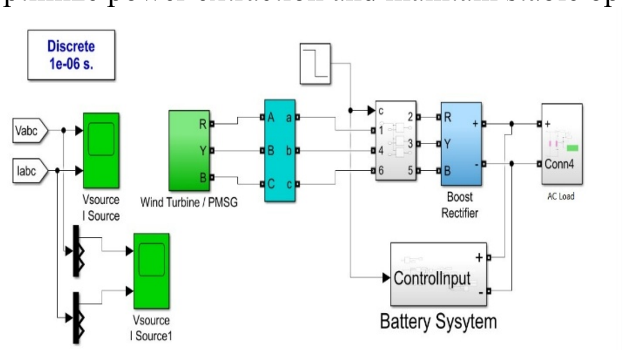

FIGURE 1. Simulation of VAWT System

2.1. Simulation Results and Waveforms

The simulation waveforms illustrate the voltage and current characteristics of the vertical axis wind turbine (VAWT) system with an inverter. The output voltage waveform shows a stable AC voltage of 212V, ensuring that the system operates at the standard voltage level for AC loads. The corresponding current waveform indicates a steady current of 30A, demonstrating the system's capability to deliver sufficient power to the connected load. These waveforms validate the effectiveness of the boost converter in maintaining voltage regulation and the inverter in producing a pure sinusoidal AC output. The results confirm the stable operation of the system, highlighting its efficiency in converting wind energy into usable electrical power.

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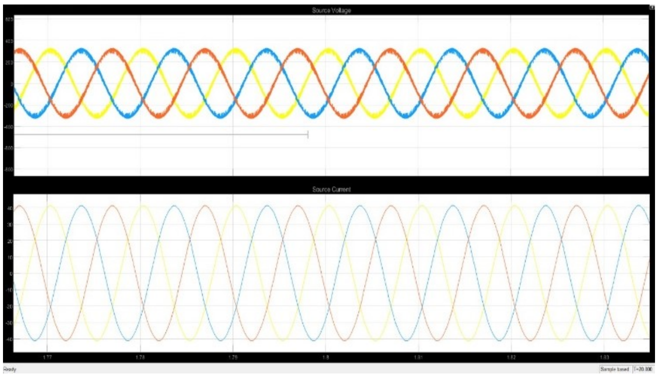

FIGURE 2. Simulation Analysis of VAWT System

3. Design of Wind Turbine

A vertical axis wind turbine (VAWT) with an H-rotor design can be efficiently constructed using PVC pipes for both the blades and the stand. The H-rotor configuration consists of vertical blades attached to a central rotating shaft, allowing it to harness wind energy from any direction. PVC pipes are an excellent choice for blades due to their lightweight, durability, and ease of modification. The blades can be cut and shaped from larger PVC pipes, split into sections, and curved to improve aerodynamic performance. The stand, also made of PVC pipes, provides a stable support structure while keeping the turbine elevated for optimal wind exposure. The central shaft, mounted on bearings, ensures smooth rotation, while a simple generator or dynamo can be connected to convert mechanical energy into electricity. This PVC-based design offers a cost-effective and easily assembled solution for small-scale wind energy applications.

FIGURE 3. Design of Wind Turbine Blades With PVC Pipes

3.1. Block Diagram

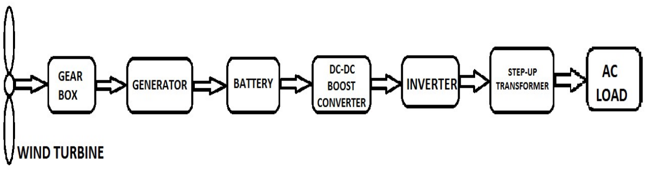

FIGURE 4. Block Diagram of VAWT System

3.2. Hardware Components

Our system comprises a several hardware components including a Generator, DC-DC Boost converter, Battery, Inverter, Step-Up Transformer and AC Load.

Generator

A 1000 RPM 12V DC motor can be used as a generator, it converts mechanical energy into electrical energy produced by the wind power. As wind strikes on the blades the rotor rotates and simultaneously the generator also rotates and generate DC Voltage.

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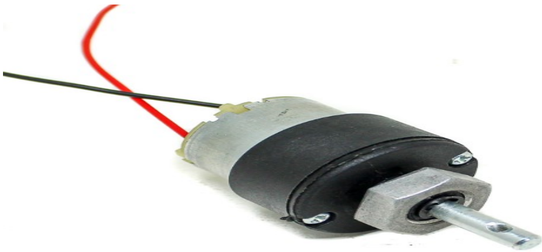

FIGURE 5. Generator

DC-DC Boost Converter

This module features the XL6009E1 4 Amp step up (boost) converter, which can take input voltages as low as 5V and step up the output to as high as 35V. This module has a multi-turn trimpot (potentiometer) that you can use to adjust the output voltage. Since the trimpot has 25 turns of adjustment you can easily adjust the output of the module to exactly the voltage you need. Boost converters are a great way to easily increase a given voltage, but that boost comes at the cost of less output current compared to input current. Since this is a boost converter the output voltage has to be higher than the supplied input voltage.

FIGURE 6. Boost Converter

Battery

A 12V 1.3Ah (1300mAh) Sealed Lead Acid (SLA) Rechargeable Battery is a compact and reliable power source commonly used in backup power systems and it is used to store the energy supplied from charge controller circuit.

FIGURE 7. Rechargeable Battery

Inverter

The inverter starts with a 12V DC power source, usually a battery, which is fed into an oscillator circuit. This oscillator generates a high-frequency AC signal, which is then fed into a step-up transformer to increase the voltage to around 220V AC. A MOSFET or transistor-based switching circuit is used to drive the transformer, ensuring efficient conversion. This 200W inverter can power small appliances such as LED bulbs, chargers, fans, and other low-power AC devices, making it ideal for portable and backup power applications.

FIGURE 8. Inverter Circuit

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Step-Up Transformer

In this we will be using a step up transformer to step up the voltage to the required value to run the load transformer will step up the AC voltage converted by using the DC Inverter Circuit. The rating of the transformer used is 12-0-12 Volt. The step up transformer will step up the output given by inverter which is 12V AC into 212V AC.

FIGURE 9. Transformer

Working Methodology

A windmill uses blades to transform wind energy into rotational energy. The blades of a windmill are aerodynamically optimized to make the most of the energy in the wind and turn it into rotational energy making the blades spin around. The windmill is designed with a number of variations in the blade and the windmill designed for this research work has 4 blades. Through a gearbox that in turn turns the shafts, these blades are linked to a generator, which transforms mechanical energy from the blades' spinning into electrical energy. Once the electricity is produced and is ready to enter the local grid, it may then be used to power devices. For storage of power, we will require an inverter which stores the electricity converted by the turbine. When there is insufficient wind required for the windmill, the circuit will be made to switch power from the inverter to the load, this creates an unlimited amount of sustainable energy. According to the wind circumstances the blade twists or shreds the wind. It is well known that proper shaping of the blades of a windmill and the proper alignment of the physical axis of that mill in fences to a large extent, the efficiency of the said mechanical converter to convert the 'raw' wind power to a considerable value of rotational energy ordered by the blades of the mill. In this we have used a 12V DC generator with a maximum speed of 1000 RPM. The generator converts mechanical energy into electrical energy produced by the wind power. As wind strikes on the blades the rotor rotates and simultaneously the generator also rotates. Then the output of generator is given to charge controller A charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from electric batteries to protect against electrical overload, overcharging, and may protect against overvoltage. This prevents conditions that reduce battery performance or lifespan and may pose a safety risk. It may also prevent completely draining ("deep discharging") a battery, or perform controlled discharges, depending on the battery technology, to protect battery life. The terms "charge controller" or "charge regulator" may refer to either a stand-alone device, or to control circuitry integrated within a battery pack, battery-powered device, or battery charger. With the help of Charge controller battery gets charged. We are using a rechargeable battery to store the energy passed through the charge controller circuit. The concept of our project is something like this, whenever wind will blow from any of the direction it will strikes to the turbine blades, which will rotate the turbine blades and in turn rotates the shaft of the turbine. Now this whole arrangement is connected to the DC generator, because of which we get DC voltage as output. Now this DC voltage is then passed through the charge controller to charge the battery appropriately and to protect the reverse flow of current. After that we use the DC inverter circuit to convert DC voltage into AC voltage, since our load needs AC voltage to glow. After that we have to step up the voltage to 230 Volt, so that our load gets appropriate voltage, because our load operates at 212 Volt, then we have used MOSFET switch to generate the frequency of 50Hz which is needed for it and thus we glow the load and charging the batteries.

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FIGURE 10. Hardware Circuit

Results

This setup allows the phone to be charged directly from wind-generated power, making the system more energy-efficient and cost-effective. A mobile phone charger was connected as the AC load. The system effectively provided a stable voltage output, allowing the phone battery to charge. This validates the system's capability to generate and convert renewable energy for practical use. The results indicate that the VAWT system, combined with an inverter, can be a sustainable solution for low-power applications, offering an eco-friendly alternative to conventional power sources. According to the proposed plan the final outcome of this paper leads to the development of a Vertical axis wind turbine with inverter. Through this project, power generation system has been created so that we wind pressure created in Highway or tunnels can be used and power can be easily generated. One of the objectives of this project is to design low cost Power generation.

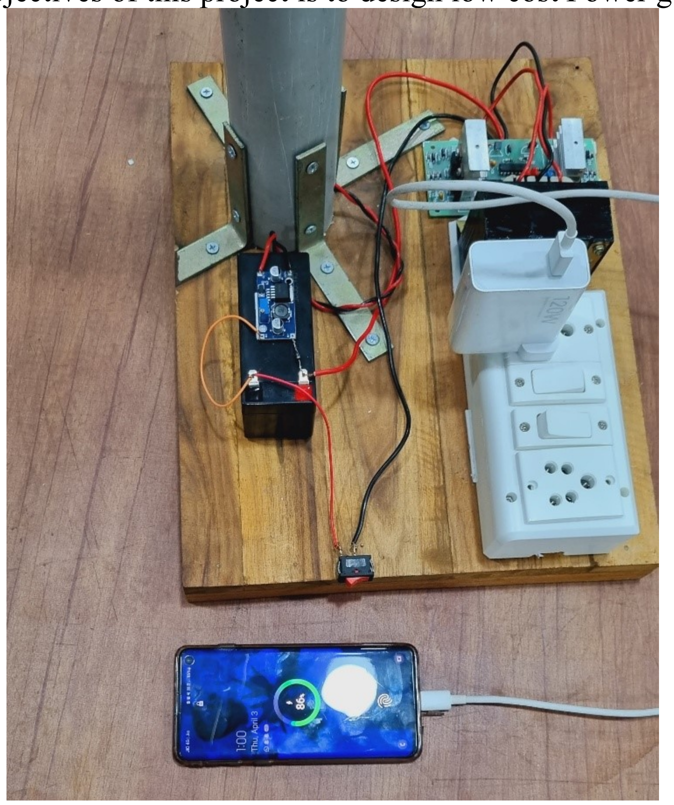

FIGURE 11. Hardware Output

Applications and Future Scope

The development and testing of the small-scale VAWT energy system have demonstrated the feasibility and potential of utilizing vertical axis wind turbines for localized renewable energy generation. The system, comprising a VAWT generator, battery storage, DC-AC inverter, and control system, successfully converted wind energy into usable electrical power. In Urban Areas VAWTs can be installed on rooftops and urban infrastructure. The Remote Locations provides power in off-grid areas where traditional electricity supply is unavailable in Hybrid Renewable Systems it can be integrated with solar panels and other renewable sources for efficient energy management. For Industrial Power Backup it acts as a supplementary power source in industries needing uninterrupted power supply. Future research on vertical axis wind turbines (VAWTs) could focus on enhancing aerodynamic efficiency, structural stability, and noise reduction through advanced materials and design optimization. Additionally, exploring innovative applications such as urban integration, floating platforms, and hybrid renewable energy systems could broaden the scope of VAWT deployment. Furthermore, addressing socio-economic factors, environmental impacts, and regulatory challenges is crucial for promoting widespread adoption. Overall, continued research and development efforts hold potential for expanding the role of VAWTs in the renewable energy landscape. In Future research on vertical axis wind turbines (VAWTs) with inverter produces power which can be used in DC Load. By pursuing these future enhancements, the VAWT energy system can be further optimized, leading to more efficient, reliable, and cost-effective renewable energy solutions. These advancements will contribute to the broader transition towards a sustainable energy future, reducing reliance on fossil fuels and mitigating the impacts of climate change.

Conclusion

In this paper we have compared both the types of wind turbines, vertical axis wind turbines (VAWTs) offer unique advantages such as omnidirectional wind capture and simplified design, making them suitable for urban and decentralized energy applications. Despite challenges in efficiency optimization and public acceptance, ongoing research and technological advancements hold promise for enhancing VAWT performance and integration into diverse energy landscapes. With continued innovation and strategic deployment, VAWTs can contribute significantly to the transition towards a sustainable and resilient energy future. Vertical axis wind turbine has economically feasible energy solution for isolated areas missing from combined grid systems. Design of wind turbine rotor blades plays an important role in performance evaluation and extraction of energy from turbine. Vertical axis wind turbine placed in a location where moderate wind is available and by optimizing blade parameters, design specifications higher power generation can be achieved. For remote areas, the designed vertical axis wind turbine will be serving as good feasible energy generation unit.

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