IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 6, May 2024

Develop an Energy Storage Strategy for Emerging Wind Farms in India Over IoT

Sakshi Dashmukhe[1], Kamini Gavande[2], Ashutosh Budharam[3], Ashwini Dhule[4], Prof. Dnyaneshwar Nemane[5], Prof V. M. Venkateswara Rao[6]
Students, Shree Ramchandra College of Engineering, Lonikand, Pune, India[1,2,3,4]
Assistant Professor, Shree Ramchandra College of Engineering, Lonikand, Pune, India[5]
HoD, Shree Ramchandra College of Engineering, Lonikand, Pune, India[6]

Abstract*: Energy is a fundamental component of daily life, essential for performing various tasks. Currently, non-renewable energy sources such as oil, coal, and gas dominate energy consumption. However, these resources are unsustainable and significantly contribute to global warming, posing serious environmental hazards. In contrast, renewable energy sources, including solar, wind, tidal, and biogas, offer sustainable and abundant alternatives to meet energy needs. Among these, wind energy stands out as the purest form of renewable energy, extensively utilized for electricity production due to its minimal environmental impact.Wind energy harnesses the kinetic energy of atmospheric air, converting it into mechanical energy through wind turbines. Both Vertical Axis Wind Turbines (VAWT) and Horizontal Axis Wind Turbines (HAWT) are employed for this conversion. Countries worldwide, including India, recognize the importance of wind energy and adopt it as a primary renewable energy source, primarily due to its cost-effectiveness compared to other renewable options.This research focuses on the design and development of a multi-axis windmill integrated with the Internet of Things (IoT) to enhance efficiency and monitoring capabilities. The proposed system incorporates components such as the Atmega 328 microcontroller, LCD, voltage sensor, IoT module, load, battery, inverter, DC motor, gear ball bearing, and control board. The successful implementation of this system demonstrates the feasibility of an advanced wind energy solution, contributing to a more sustainable and environmentally friendly energy landscape.*

Keywords: Renewable Energy, Wind Energy, Non-Renewable Energy, Vertical Axis Wind Turbine (VAWT)

I. INTRODUCTION

Energy is an indispensable element of modern life, essential for powering homes, industries, and transportation. The current global energy landscape is heavily reliant on non-renewable energy sources such as oil, coal, and natural gas. These resources, while effective at meeting immediate energy demands, present significant drawbacks, including their finite availability and substantial environmental impacts. The burning of fossil fuels is a major contributor to global warming and climate change, prompting an urgent need to shift towards more sustainable energy solutions.

Renewable energy sources offer a promising alternative to non-renewable resources. Among these, wind energy stands out due to its abundance, sustainability, and minimal environmental footprint. Wind energy harnesses the kinetic energy of atmospheric air, converting it into mechanical energy and subsequently into electricity through wind turbines. This process does not emit greenhouse gases, making wind energy a clean and environmentally friendly option. Wind turbines are broadly classified into two types based on the orientation of their rotational axis: Vertical Axis Wind Turbines (VAWTs) and Horizontal Axis Wind Turbines (HAWTs). VAWTs, which rotate around a vertical axis, offer unique advantages such as the ability to capture wind from any direction, ease of maintenance due to ground-level placement of heavy components, and reduced noise. On the other hand, HAWTs, which rotate around a horizontal axis, are more commonly used for large-scale electricity production due to their higher efficiency and capacity. This research focuses on the design and development of a multi-axis windmill incorporating the Internet of Things (IoT) to optimize energy production and monitoring. The integration of IoT technology enables real-time data collection and remote management, enhancing the overall efficiency and reliability of the wind energy system. The proposed system includes components such as the Atmega 328 microcontroller, LCD, voltage sensor, IoT module, battery, inverter, DC motor, gear ball bearing, and control board. The primary objective of this study is to explore the potential of VAWTs in combination with IoT technology for improved energy generation and management. By leveraging the advantages of VAWTs and the capabilities of IoT

1.1 Problem Statement

The primary challenge addressed in this research is the design and development of a prototype model of a multi-axis windmill. This involves not only the theoretical design but also the practical fabrication of the model to demonstrate the desired operational characteristics of a multi-axis windmill. Traditional windmills, predominantly single-axis designs, have limitations in efficiency, noise production, and maintenance. By exploring multi-axis configurations, this research seeks to overcome these limitations and present a more effective solution for wind energy conversion.

1.2 Objective

The objectives of this research are multifaceted and focus on improving the efficiency and practicality of wind energy conversion systems:

- **Cost-effective Energy Conversion**: Develop a windmill that can convert wind energy into electrical energy at a remarkably low cost, both in terms of initial investment and ongoing operational expenses. The goal is to make wind energy more accessible and economically viable.
- **Time Efficiency**: Streamline the design and development process to save time, ensuring that the prototype can be quickly and efficiently moved from the conceptual stage to a working model.
- **Noise Reduction**: Utilize a multi-axis design to minimize friction and reduce noise production. Conventional windmills can generate significant noise, which is a barrier to their widespread adoption, especially in residential areas. The multi-axis design aims to address this issue by providing a quieter alternative.

II. LITERATURE REVIEW

2.1 Power Generation by Vertical Axis Wind Turbine

Niranjana S.J: In the study conducted by Niranjana S.J, a vertical axis wind turbine (VAWT) was designed and fabricated with specific attention to the aerofoil shape of the blades, aiming for less weight and more stiffness. This VAWT was mounted on highway dividers to harness the air velocity generated by moving vehicles. The innovative design allows vehicles moving on both sides of the highway to cut the blades, which are connected to a shaft and generator, producing power stored in a battery. The model was tested in a laboratory setting, achieving up to 1W power at 25 m/s wind velocity and operational capability in wind speeds ranging from 4 m/s to 35 m/s.

VAWTs offer several advantages: they can harness wind from any direction, heavy components can be ground-mounted for easy maintenance, and they operate with low acoustic noise. Moreover, the asynchronous generator connected directly to the power grid simplifies the wind generation system. Despite these benefits, Horizontal Axis Wind Turbines (HAWTs) remain more favored for large-scale electricity generation due to higher efficiency and larger capacity.

2.2 Review on Vertical and Horizontal Axis Wind Turbine

C.M. Vivek, P. Gopikrishnan, R. Murugesh, R. Raja Mohamed: This review highlights the distinctions and applications of vertical axis wind turbines (VAWTs) and horizontal axis wind turbines (HAWTs). VAWTs are preferred for domestic applications due to their moderate efficiency and ease of maintenance, while HAWTs are used for large-scale electricity production. The paper proposes a hybrid system combining VAWT and HAWT on the same tower, aiming to enhance efficiency and reduce space and costs for large-scale power generation.

2.3 Development and Analysis of Vertical-Axis Wind Turbines

Paul Cooper: Paul Cooper's research summarizes the development of various VAWT designs, including Savonius, Darrieus, and Giromill. The study explores the aerodynamics and performance of VAWTs using multiple-stream tube analysis, providing insights into blade loads and rotor power output. VAWTs can achieve performance coefficients comparable to HAWTs and offer significant advantages such as the ability to capture wind from any direction and simplified mechanical load connections.

2.4 Wind Turbine Blade Design

Peter J.: Peter J. reviews the principles and advancements in wind turbine blade design, emphasizing HAWTs. The review covers theoretical and practical efficiencies, aerodynamic design principles, and the impact of design loads on turbine blades. Modern HAWT designs have evolved significantly from early windmills, leveraging advanced materials and aerodynamic knowledge to optimize power extraction.

2.5 A Review of Research on Large Scale Modern Vertical Axis Wind Turbines at Uppsala University

Senad Apelfröjd, Sandra Eriksson, and Hans Bernhoff: This paper reviews over a decade of VAWT research at Uppsala University, focusing on the development of large-scale VAWTs. The 200 kW VAWT in Falkenberg and the 12 kW prototype in Marsta demonstrate the effectiveness of an electrical control system with a direct-driven energy converter. The H-rotor design allows omnidirectional energy extraction without a yaw system, reducing investment costs and maintenance needs.

2.6 Horizontal Axis Wind Turbine Blade Design Methodologies for Efficiency Enhancement—A Review

Shafiqur Rehman: ShafiqurRehman's review examines methodologies to enhance HAWT efficiency through blade design optimization. The review discusses various models, techniques, and experimental approaches to improve wind turbine performance, focusing on reducing cut-in speeds and optimizing power coefficients. The research highlights the importance of blade redesign and material advancements in achieving higher energy yields.

2.8 Early Development of Modern Vertical and Horizontal Axis Wind Turbines: A Review

Shikha, T.S. Bhatti, D.P. Kothari: This paper traces the early development of VAWTs and HAWTs, noting significant milestones and design improvements following the 1973 oil crisis. The review includes historical projects like the EoleDarrieus turbine and modern developments in HAWTs. The comparison underscores VAWTs' potential in specific applications, despite the dominance of HAWTs in large-scale wind energy production.

III. METHODOLOGY

3.1 Working Principle

The proposed system utilizes Light Dependent Resistors (LDRs) as sensors to track the sun's exact position, thereby enhancing the efficiency of the windmill. The working principle is outlined as follows:

- **LDRs as Sensors**: LDRs are employed to sense the sun's position along the vertical axis. These sensors detect the intensity of light, and their resistance decreases as the incident light intensity increases. This change in resistance is used to determine the sun's position.
- **Light Comparison Unit**: The signals from the LDRs are sent to a light comparison unit. This unit processes the information to determine the relative position of the sun.
- **Night Mode Detection**: Another LDR senses the absence of light to detect night mode. The signal is then sent to the light comparison unit, ensuring that the system can adjust accordingly during nighttime.
- **Microcontroller Control**: An 8051 microcontroller acts as the main control unit. It receives inputs from the light comparison unit and controls the direction of motor movement along the vertical axis. The microcontroller ensures that the photovoltaic (PV) panel is always perpendicular to the sunlight, maximizing efficiency.
- **Shadow-Based Design**: The system is designed to use the shadow of a cylinder to help align the PV panel. If the PV panel is not perpendicular to the sunlight, the shadow will fall on one side of the sensor, creating a difference in light intensity received by the sensing device.

3.2 Block Diagram

Below is a simplified block diagram representing the system architecture:

POWER I/P
|
[Battery]
|
[Voltage Sensor]
|
[IOT Module]
|
[LCD Display]
|
[Motor Control]
|
[Windmill]

3.3 Block Diagram Description

The block diagram illustrates the integration of an IoT module for windmill power generation. The process is as follows:

- **Power Storage**: The power generated by the windmill is stored in a battery.
- **Voltage Sensing**: The stored power is then measured by a voltage sensor to predict the voltage generated.
- **Data Display and Storage**: The voltage data is displayed on an LCD screen and simultaneously stored on the ThingSpeak cloud platform via the IoT module.

3.4 Components Details

The components used in this project are critical to the system's functionality. Below are the details:

- **Atmega 328**: A microcontroller used for processing the inputs and controlling outputs.
- **LCD**: A display unit to show the voltage and other system data.
- **Voltage Sensor**: Measures the voltage generated by the windmill.
- **IoT Module**: Facilitates data transmission to the cloud for storage and monitoring.
- **Load**: The electrical devices or systems powered by the windmill-generated electricity.
- **Battery**: Stores the electrical energy generated by the windmill.
- **Inverter**: Converts DC power stored in the battery to AC power for use by the load.
- **DC Motor**: Converts electrical energy into mechanical energy for various system operations.
- **Gear Ball Bearing**: Ensures smooth rotation of the windmill components.
- **Control Board**: Houses the microcontroller and other control circuitry.
- **Chassis**: The wooden base on which all components are assembled, providing structural support.

Chassis

The chassis is constructed from wood and serves as the foundation for assembling all system components. Wheels are attached using L angles to allow movement in forward and backward directions.

DC Motors

DC motors convert direct current electrical power into mechanical power. They operate based on the forces produced by magnetic fields and include mechanisms to periodically change the direction of current flow. These motors are essential for producing the rotary motion needed in the windmill.

Shaft

The shaft transmits torque and rotation, connecting various drive train components. It is designed to withstand torsion and shear stress while minimizing additional weight.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 6, May 2024

Bearings

Bearings reduce friction between moving parts and ensure the desired motion is achieved. They come in various types, including plain, ball, and roller bearings, each suited to different applications.

This methodology outlines the principles and components involved in developing an efficient, cost-effective, and low-noise multi-axis windmill system, leveraging modern technology and innovative design to enhance renewable energy generation.

IV. RESULTS AND DISCUSSION

The multi-axis windmill prototype was successfully designed, developed, and fabricated, achieving the following key results:

- **Energy Conversion Efficiency**: The prototype demonstrated efficient conversion of wind energy into electrical energy. Initial tests indicated that the multi-axis design significantly reduced energy loss due to friction, leading to higher overall efficiency compared to conventional single-axis windmills.
- **Cost-Effectiveness**: The use of readily available materials and components, such as the Atmega 328 microcontroller and DC motors, resulted in a prototype that is remarkably cheap to build and maintain. The low operating costs further enhance the economic viability of the design.
- **Noise Reduction**: One of the primary objectives of the project was to reduce noise production. The multi-axis design successfully achieved this, producing considerably less noise compared to traditional windmills. This is largely due to the minimized friction and optimized aerodynamic structure.
- **IoT Integration**: The implementation of the IoT module for real-time monitoring and data logging was effective. The voltage sensor and LCD display provided accurate readings of the power generated, which were also successfully uploaded to the ThingSpeak cloud platform. This real-time data availability is crucial for predictive maintenance and optimization of energy generation.
- **System Mobility**: The prototype's chassis, equipped with wheels, allowed for easy movement and reorientation, enhancing the flexibility of the windmill's deployment. This feature is particularly beneficial for applications requiring temporary or adjustable positioning.

V. DISCUSSION

The results of the prototype testing indicate that the multi-axis windmill design offers several advantages over conventional windmills, particularly in terms of efficiency, cost, and noise reduction. Here are the key points of discussion:

- **Efficiency Gains**: The multi-axis design reduces energy losses associated with friction in single-axis windmills. By allowing the windmill blades to adjust their orientation dynamically, the system can capture wind energy more effectively from varying directions. This adaptability translates into higher energy conversion efficiency.
- **Economic Benefits**: The choice of materials and components was guided by the need to keep costs low without compromising functionality. The successful use of a microcontroller-based control system and affordable sensors demonstrates that high-efficiency renewable energy solutions can be economically feasible.
- **Noise Reduction**: Traditional windmills often suffer from noise pollution due to mechanical friction and aerodynamic drag. The prototype's design minimizes these issues, making it suitable for use in noise-sensitive environments, such as residential areas or wildlife reserves.
- **IoT and Data Analytics**: The integration of IoT technology not only enhances monitoring capabilities but also opens up opportunities for advanced data analytics. By continuously collecting and analyzing data on windmill performance, it is possible to predict maintenance needs, optimize energy output, and even integrate the system into larger smart grid applications.
- **Scalability and Future Work**: While the prototype has shown promising results, further research and development are needed to scale the design for commercial applications. Future work could focus on optimizing blade design for different environmental conditions, enhancing the durability of materials, and incorporating more sophisticated control algorithms for even greater efficiency.

In conclusion, the prototype model of the multi-axis windmill demonstrates significant potential as a viable alternative to conventional windmills. Its enhanced efficiency, cost-effectiveness, and reduced noise production, coupled with the benefits of IoT integration, make it a promising solution for sustainable energy generation. Further development and scaling could pave the way for its widespread adoption in various energy sectors.

VI. CONCLUSION

The project aimed to design and develop a prototype model of a multi-axis windmill and fabricate it to demonstrate its working principles. The successful completion and testing of this prototype have yielded several significant findings and advancements in wind energy technology.

- **Enhanced Energy Efficiency**: The multi-axis design of the windmill prototype effectively reduces frictional losses and optimizes energy capture from varying wind directions. This results in higher energy conversion efficiency compared to conventional single-axis windmills.
- **Cost-Effectiveness**: By using commonly available materials and cost-effective components, the prototype demonstrates that it is possible to produce an economically viable wind energy solution. The low initial costs and minimal operating expenses make this design an attractive option for sustainable energy generation.
- **Noise Reduction**: One of the major advantages of the multi-axis windmill design is its significant reduction in noise production. This feature addresses a common issue associated with traditional windmills, making the multi-axis design more suitable for deployment in noise-sensitive areas.
- **IoT Integration for Smart Monitoring**: The incorporation of IoT technology for real-time monitoring and data logging has proven effective. This capability allows for better predictive maintenance, optimization of energy output, and integration into smart grid systems, enhancing the overall functionality and reliability of the windmill.
- **System Mobility**: The prototype's chassis with wheels provides flexibility in positioning and deployment, making it adaptable to various environmental conditions and specific site requirements.

The results of this project indicate that the multi-axis windmill design holds significant promise for improving the efficiency and feasibility of wind energy systems. The prototype's successful performance demonstrates the potential for further development and scaling to commercial applications. Future work could focus on refining the design, enhancing material durability, and integrating advanced control systems to further optimize performance.

REFERENCES

[1]. Hau, E. Wind Turbines, Fundamentals, Technologies, Application, Economics, 2nd ed.; Springer: Berlin, Germany, 2019.

[2]. Dominy, R.; Lunt, P.; Bickerdyke, A.; Dominy, J. Self-starting capability of a Darrieus turbine. Proc. Inst. Mech. Eng. Part A J. Power Energy 2020, 221, 111–120.

[3]. Holdsworth, B. Green Light for Unique NOVA Offshore Wind Turbine, 2020. Available online: Reinforced Plastics (accessed on 8 May 2020).

[4]. Gasch, R.; Twele, J. Wind Power Plants; Solarpraxis: Berlin, Germany, 2019.

[5]. Gorban, A.N.; Gorlov, A.M.; Silantyev, V.M. Limits of the turbine efficiency for free fluid flow. J. Energy Resour. Technol. Trans. ASME 2001, 123, 311–317.

[6]. Rathod, P.; Khatik, K.; Shah, K.; Desai, H.; Shah, J. A Review on Combined Vertical Axis Wind Turbine. Int. J. Innov. Res. Sci. Eng. Technol. 2019, 5, 5748–5754.

[7]. Omijeh, B.O.; Nmom, C.S.; Nlewem, E. Modeling of a Vertical Axis Wind Turbine with Permanent Magnet Synchronous Generator for Nigeria. Int. J. Eng. Technol. 2019, 3, 212–220.

[8]. Reddy, K.A.; Dagamoori, K.; Sruthi, A.P.; Apurva, N.S.; Naidu, N.N.M.L.; Reddy, A.V.K.; Rajesh, B.; Kumar, K.K.; Shivasri, C.; Ali, S.Y. A Brief Research, Study, Design and Analysis on Wind Turbine. Int. J. Mod. Eng. Res. 2018, 5, 5–30.

[9]. Gulve, P.; Barve, S.B. Design and Construction of Vertical Axis Wind Turbine. Int. J. Mech. Eng. Technol. 2017, 5, 148–155.