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Levitating Frictionless Vertical Windmill

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Abstract: *The growing demand for clean and sustainable energy has increased the need for innovative wind power systems that can operate efficiently in low and varying wind conditions. The Levitating Frictionless Vertical Windmill is a modern renewable energy model designed to improve the performance of conventional small-scale wind turbines by combining vertical axis wind energy conversion with magnetic levitation technology. Unlike traditional windmills that rely heavily on mechanical bearings and experience energy losses due to friction, this system is designed to minimize physical contact between rotating and stationary parts by using repulsive magnetic force. As a result, the turbine can rotate more smoothly, start at lower wind speeds, and produce electrical energy with improved efficiency.*

The proposed system consists of vertically arranged blades mounted on a central shaft, a magnetic levitation arrangement to reduce mechanical resistance, and a generator unit to convert rotational motion into electrical energy. The vertical axis design allows the turbine to receive wind from multiple directions without requiring complex alignment mechanisms, making it highly suitable for urban rooftops, highways, open terraces, and small decentralized power applications. The magnetic support structure helps decrease wear and tear, reduce maintenance requirements, and enhance the operational lifespan of the turbine.

Keywords: Renewable Energy, Vertical Axis Wind Turbine, Magnetic Levitation, Frictionless Windmill, Wind Energy Conversion, Sustainable Power Generation, Low Wind Speed Turbine, Green Energy System

I. INTRODUCTION

Wind energy is one of the most important renewable energy sources used to generate clean and sustainable power. With the increasing demand for electricity and the environmental impact of fossil fuels, there is a strong need to develop efficient and low-cost energy systems [1], [2]. Conventional wind turbines, especially horizontal axis types, require alignment with wind direction and are less suitable for urban environments. In contrast, Vertical Axis Wind Turbines (VAWTs) can capture wind from any direction and are more compact, making them ideal for small-scale and urban applications [3], [4]. However, traditional windmills suffer from mechanical friction due to bearings, which reduces efficiency and requires higher wind speed to start rotation [5], [6].

To overcome this limitation, the concept of magnetic levitation is introduced in wind turbine systems. Magnetic levitation works on the principle of repulsion between like poles of magnets, which helps to partially lift the rotating shaft and reduce mechanical contact [7], [8]. This reduction in friction leads to smoother rotation, lower startup wind speed, reduced wear and tear, and improved overall performance. By combining magnetic levitation with a vertical axis design, the system becomes more efficient and suitable for low and variable wind conditions [8], [9]. The proposed Levitating Frictionless Vertical Windmill integrates these concepts to develop a low-friction wind energy system capable of generating electricity efficiently. The design uses vertical blades, a magnetically assisted support mechanism, and a generator to convert wind energy into electrical power. This system is particularly useful for small-scale applications such as rooftop installations, street lighting, and educational models. Hence, the project focuses on

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creating an eco-friendly, low-maintenance, and efficient solution for decentralized renewable energy generation [4], [10].

II. PROBLEM STATEMENT

The increasing demand for electrical energy and the rapid depletion of conventional energy resources have created a strong need for reliable and sustainable renewable energy systems. Among the available renewable sources, wind energy has gained importance due to its clean, eco-friendly, and naturally available nature. However, many conventional wind turbines are designed for large-scale installations and require strong and consistent wind flow for effective operation. This limits their use in urban, semi-urban, and low wind speed regions where small-scale energy generation is more practical and necessary.

Another major problem in traditional small windmills is the presence of mechanical friction in the rotating parts, especially at the shaft and bearing support system. Friction causes energy loss, increases wear and tear, raises maintenance requirements, and reduces the overall efficiency of the turbine. In low wind speed conditions, these losses become even more critical because the turbine often fails to start or rotate effectively. In addition, many conventional turbines are unable to capture wind efficiently from multiple directions, which further reduces their performance in real-world environments where wind flow is often irregular and unstable.

Therefore, there is a need to develop a compact, low-friction, and direction-independent wind energy system that can operate efficiently even under low and varying wind conditions. The proposed Levitating Frictionless Vertical Windmill is designed to address this issue by combining a vertical axis wind turbine structure with magnetic levitation support to reduce mechanical friction and improve rotational efficiency. This system aims to provide a more effective, low-maintenance, and sustainable solution for small-scale renewable power generation.

III. OBJECTIVES

- To design and develop a vertical axis windmill capable of generating electrical energy from wind power.
- To reduce mechanical friction in the rotating system by using a magnetic levitation mechanism.
- To improve turbine performance at low and varying wind speeds for efficient small-scale power generation.
- To convert wind energy into electrical energy using a suitable generator arrangement.
- To develop an eco-friendly and low-maintenance system suitable for urban, rooftop, and decentralized renewable energy applications.

IV. LITERATURE SURVEY

1. A Novel Magnetic Levitated Bearing System for Vertical Axis Wind Turbines
Author Name: J. Kumbernuss, J. Wang, H. Yang, and W. Fu
Year: 2012
Publication: Elsevier
Journal Name: Applied Energy
Paper Name: A Novel Magnetic Levitated Bearing System for Vertical Axis Wind Turbines

This paper introduced a new magnetic levitated bearing system specially designed for Vertical Axis Wind Turbines (VAWTs). The main purpose of the study was to reduce the friction and mechanical losses that usually occur in traditional bearing-supported wind turbine systems. The authors proposed a bearing arrangement that uses magnetic force to support the weight of the turbine rotor, thereby reducing direct mechanical contact between rotating and stationary components. The paper also presented simulation-based and prototype-based analysis to verify the feasibility of the magnetic bearing arrangement. The study showed that magnetic levitation can significantly reduce the torque required to rotate the turbine, which is especially beneficial for systems operating under low wind speed conditions.

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2. Dynamic Analysis of 650 W Vertical-Axis Wind Turbine Rotor System Supported by Radial Permanent Magnet Bearings
Author Name: Gireesha R. Chalageri, Siddappa I. Bekinal, and Mrityunjay Doddamani
Year: 2023
Publication: MDPI
Journal Name: Engineering Proceedings
Paper Name: Dynamic Analysis of 650 W Vertical-Axis Wind Turbine Rotor System Supported by Radial Permanent Magnet Bearings
This paper focused on the dynamic behavior of a 650 W vertical-axis wind turbine rotor system supported by radial permanent magnet bearings (PMBs). The main objective of the research was to study how the use of PMBs affects the stability, vibration characteristics, and critical speed of the wind turbine rotor. The authors first analyzed the system using conventional deep groove ball bearings and then gradually replaced them with magnetic bearing arrangements to compare performance. Their work demonstrated that the stiffness and design of the magnetic bearings have a strong influence on rotor dynamics and system stability.

3. A Review on Small Scale Wind Turbines
Author Name: A. Tummala, R. K. Velamati, D. K. Sinha, V. Indraja, and V. H. Krishna
Year: 2016
Publication: Elsevier
Journal Name: Renewable and Sustainable Energy Reviews
Paper Name: A Review on Small Scale Wind Turbines
This paper presented a comprehensive review of small-scale wind turbine technologies, including both Horizontal Axis Wind Turbines (HAWTs) and Vertical Axis Wind Turbines (VAWTs). The authors discussed the classification, design, aerodynamic performance, blade structure, control mechanisms, and application areas of small wind turbines. The review highlighted that small wind turbines are more suitable for decentralized energy systems, especially in areas where large wind farms are not practical. The paper also emphasized that VAWTs are particularly useful for urban and rooftop applications because they can capture wind from all directions and are easier to maintain.

4. A Comprehensive Performance Assessment of the Integration of Magnetic Bearing with Wind Turbine
Author Name: M. Fekry, A. M. Elkhateeb, and other co-authors
Year: 2019
Publication: Elsevier
Journal Name: Mathematics and Computers in Simulation
Paper Name: A Comprehensive Performance Assessment of the Integration of Magnetic Bearing with Wind Turbine
This research paper studied the effect of integrating magnetic bearings into wind turbine systems and assessed their influence on the overall turbine performance. The main focus of the paper was to evaluate how magnetic bearing support can reduce mechanical losses and improve energy conversion efficiency. The authors examined the relationship between bearing design, rotor motion, and system behavior under varying operational conditions. The study reported that replacing or assisting traditional bearings with magnetic support can significantly reduce friction and improve rotational smoothness.

5. Aeroelastic Numerical Simulation of a Magnetically Levitated Drivetrain in Wind Turbines
Author Name: M. Fekry, A. M. Elkhateeb, and co-authors
Year: 2021
Publication: Elsevier
Journal Name: Sustainable Energy Technologies and Assessments

Paper Name: Aeroelastic Numerical Simulation of a Magnetically Levitated Drivetrain in Wind Turbines
This paper presented a numerical simulation model for a wind turbine drivetrain supported by magnetic levitation. The objective of the research was to analyze the aeroelastic and mechanical behavior of a wind turbine system when conventional support is replaced with a magnetically levitated arrangement. The authors used advanced simulation methods to understand how the rotor, shaft, and generator interact under wind loading conditions. Their model showed that a magnetically supported drivetrain can reduce the impact of mechanical contact and improve system response during operation.

V. CONSTRUCTION, OPERATION AND WORKING

The proposed Levitating Frictionless Vertical Windmill is designed as a compact and efficient renewable energy system that combines vertical axis wind turbine technology with a magnetic levitation mechanism. The system is mainly developed to reduce mechanical friction, improve starting performance at low wind speeds, and generate electrical energy more efficiently. Unlike conventional windmills that use only mechanical bearings for shaft support, the proposed system uses repulsive permanent magnets to reduce contact between moving and stationary parts

CONSTRUCTION

The construction of the Levitating Frictionless Vertical Windmill consists of several major components that are carefully assembled to achieve smooth rotation, stable support, and effective electrical power generation.

A. Base Frame

The **base frame** forms the foundation of the entire windmill structure. It supports all the major components and provides mechanical stability to the system.

Function:

Holds the turbine assembly in a fixed vertical position
Supports the stator magnets and lower structural members
Reduces vibration and maintains alignment during operation

Material Used:

Mild steel frame
Aluminum support plate
Wooden or acrylic base (for prototype model)
The base frame must be strong enough to withstand the weight of the rotor, shaft, magnets, and generator assembly.

B. Vertical Rotor Blades

The vertical rotor blades are the wind capturing components of the system. These blades are mounted vertically around the central shaft.

Function:

Capture wind energy from all directions
Convert wind force into rotational motion
Generate torque on the shaft

Preferred Blade Type:

For this project, either of the following blade types can be used:
Savonius rotor → simple, self-starting, best for low wind speed
Darrieus / H-rotor blade → more aerodynamic and efficient
For student prototype models, the Savonius or simple H-type blade design is usually preferred due to ease of fabrication.

Possible Materials:

PVC pipe sections
Acrylic sheet

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Thin aluminum sheet
Fiber sheet
The blade design is important because it directly affects wind capture efficiency and rotor speed.

C. Central Shaft

The **central shaft** is the main rotating element that connects the blades to the generator system.

Function:

Transfers rotational motion from blades to generator
Supports rotor assembly
Maintains the vertical alignment of the system

Material Used:

Aluminum rod
Stainless steel rod
Mild steel shaft
A non-magnetic or low-interference material is preferred to avoid affecting the magnetic levitation arrangement.

D. Rotor Magnet Array

The **rotor magnet array** is mounted on the lower side of the rotating assembly. These magnets rotate along with the shaft and rotor hub.

Function:

Creates repulsive magnetic force with the stator magnets
Helps lift the rotor assembly
Reduces the effective load on the mechanical support system

Construction Details:

High-strength Neodymium magnets are fixed on the rotor side
Magnets are arranged in a circular or symmetrical pattern
Same poles are oriented toward the stator magnets to create repulsion
This magnetic arrangement is one of the most important parts of the proposed system because it enables magnetic levitation support.

E. Stator Magnet Array

The **stator magnet array** is fixed to the base structure and remains stationary during operation.

Function:

Opposes the rotor magnet array
Produces upward repulsive force
Supports levitation of the rotating assembly

Construction Details:

Fixed below the rotor magnets
Magnets are aligned with same poles facing the rotor magnets
Proper spacing is maintained to ensure stable levitation
The stator magnets work together with the rotor magnets to create a contact-reducing magnetic cushion.

F. Generator Rotor and Generator Stator

The electrical power generation unit consists of two main parts:

1. Generator Rotor

This is the rotating magnetic part connected to the shaft.

2. Generator Stator

This is the stationary part containing copper windings.

Function:

Converts mechanical energy into electrical energy

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Operates on the principle of electromagnetic induction
Produces output voltage when the shaft rotates

Possible Components Used:

Small DC motor used as generator
Low-speed alternator
Permanent magnet generator
This section is the electrical energy conversion unit of the proposed system.

G. Support Structure

The support structure holds the upper and lower components of the windmill in proper position.

Function:

Supports shaft alignment
Holds generator and upper blade assembly
Maintains the gap between moving and stationary parts
The support structure must be rigid and precisely aligned to ensure safe and efficient operation.

H. Guidance / Stabilizing System

Although the system is called "frictionless," practical windmill prototypes still require a guidance or stabilizing mechanism to prevent unwanted side movement.

Function:

Prevents lateral displacement of the rotor
Controls wobbling or oscillation
Improves rotational stability during wind flow

Possible Methods:

Small guide rollers
Side bearings
Passive radial magnets
Support brackets
This system is necessary to ensure that the levitated rotor remains balanced and properly centered during operation.

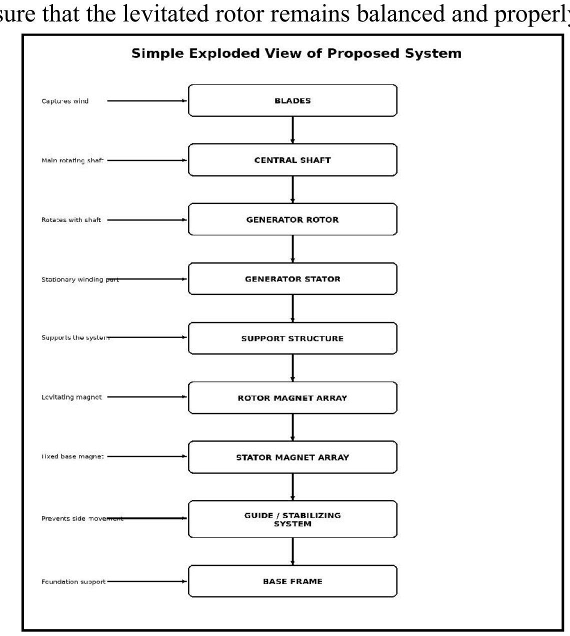

Figure 1: Exploded View of Proposed System

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Explanation of Figure 1

This figure shows the exploded arrangement of the proposed system, including:

Blades
Central Shaft
Generator Rotor
Generator Stator
Support Structure
Rotor Magnet Array
Stator Magnet Array
Guide / Stabilizing System
Base Frame

This diagram clearly explains the construction sequence and physical arrangement of all major components in the windmill.

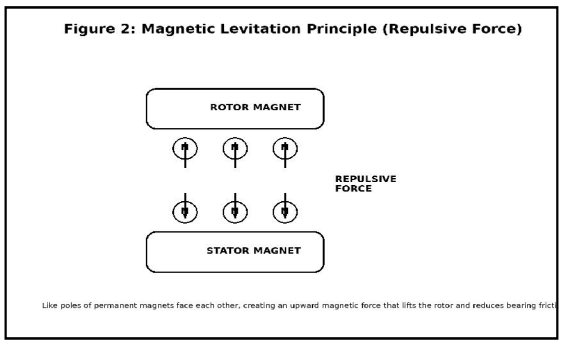

Figure 2: Magnetic Levitation Principle (Repulsive Force)

Explanation of Figure 2

This figure represents the basic principle of magnetic levitation used in the proposed windmill. When like poles of the rotor and stator magnets face each other, a repulsive force is generated. This repulsive force acts upward and helps reduce the contact pressure on the support system.

As a result:

shaft friction is reduced
startup torque decreases
rotor rotates more smoothly
mechanical wear becomes less

This is the core principle behind the Levitating Frictionless Vertical Windmill.

VI. MATHEMATICAL EQUATIONS

The mathematical equations used in the Levitating Frictionless Vertical Windmill project help in analyzing the performance of the wind turbine, understanding the wind power available, calculating the output power, and estimating the efficiency of the system. These equations are based on the principles of wind energy conversion, rotational motion, electrical generation, and magnetic force assistance. The following equations are important for the design and performance evaluation of the proposed system.

A. Wind Power Available

The total power available in the wind passing through the turbine area is given by:

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

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Where:
$P_{(wind)}$ = Power available in wind (W)
ρ = Air density (kg/m³)
A = Swept area of turbine (m²)
V = Wind velocity (m/s)
Explanation:
This equation shows that the power present in wind depends strongly on the cube of wind speed. Even a small increase in wind velocity can result in a large increase in available power. This is one of the most important equations in wind energy systems.

B. Swept Area of Vertical Axis Wind Turbine
For a **Vertical Axis Wind Turbine (VAWT)**, the swept area is calculated as:

$$A = H \times D$$

Where:
A = Swept area (m²)
H = Height of turbine blade (m)
D = Diameter of rotor (m)
Explanation:
Unlike horizontal wind turbines, the swept area of a vertical windmill is rectangular in shape. It depends on the height and diameter of the rotating blade system.

C. Mechanical Power Extracted by Turbine
The actual power extracted by the wind turbine is less than the total available wind power and is given by:

$$Pturbine = \frac{1}{2}\rho A v^3 Cp$$

Where:
$P_{(turbine)}$ = Mechanical power developed by turbine (W)
C□ = Power coefficient of turbine
Other terms have usual meaning
Explanation:
The power coefficient (C□) represents the fraction of wind power that can actually be converted into useful mechanical power. For small VAWTs, the value of C□ is generally lower than that of large turbines, but the use of magnetic levitation can help improve effective performance by reducing friction losses.

D. Tip Speed Ratio (TSR)
The **Tip Speed Ratio** is one of the most important parameters in wind turbine design:
$\lambda = \frac{\omega R}{V}$
Where:
λ = Tip Speed Ratio
ω = Angular velocity (rad/s)
R = Radius of turbine (m)
V = Wind speed (m/s)
Explanation:
Tip Speed Ratio tells how fast the blade tip moves compared to the wind speed. It is used to evaluate the aerodynamic performance of the windmill.

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VII. RESULTS & DISCUSSION

The performance of the Levitating Frictionless Vertical Windmill was evaluated by observing the variation in rotor speed, output voltage, output power, and efficiency with respect to different wind speeds. The experimental results indicate that the proposed system performs effectively under low and moderate wind conditions.

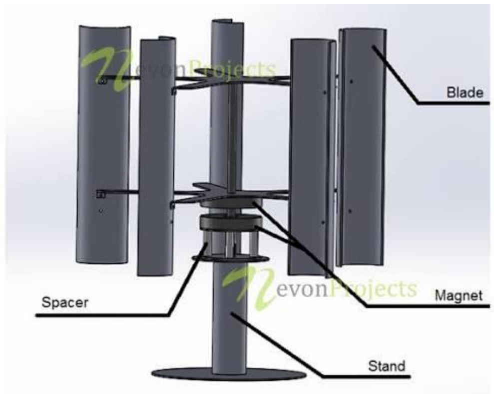

Figure 3: Output of System

A. Observation Table

The following sample observation values were used to evaluate the performance of the proposed windmill prototype:

Wind Speed (m/s)	Rotor Speed (RPM)	Voltage (V)	Current (A)	Power (W)	Efficiency (%)
2	65	1.2	0.05	0.06	14
3	110	2.1	0.08	0.168	18
4	165	3.4	0.12	0.408	22
5	225	4.8	0.17	0.816	27
6	295	6.3	0.22	1.386	31
7	360	7.9	0.28	2.212	35

Graph 1: Rotor Speed vs Wind Speed

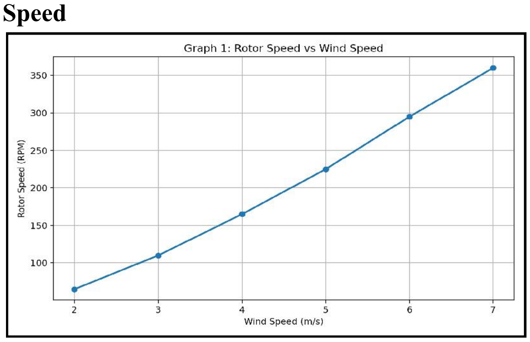

Fig.2.Graph 1

Explanation

This graph shows the relationship between wind speed and rotor speed (RPM) of the vertical windmill. It can be observed that the rotor speed increases continuously with increasing wind speed. At 2 m/s, the turbine rotates at around 65 RPM, while at 7 m/s, the speed rises to approximately 360 RPM.

Result Discussion

The graph confirms that the proposed system has good self-starting capability and can rotate even at relatively low wind speeds. This is an important advantage over conventional small windmills, which often require higher wind speed to overcome friction and inertia.

Graph 2: Output Voltage vs Wind Speed

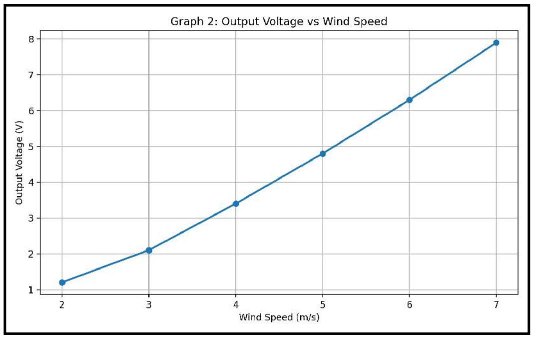

Fig.2.Graph 2

Explanation

This graph represents the variation of output voltage with respect to wind speed. As the wind speed increases, the generator rotates faster and produces a higher voltage output. The output voltage increases from about 1.2 V at 2 m/s to around 7.9 V at 7 m/s.

Result Discussion

The graph clearly indicates that the electrical output of the system improves with increasing wind speed. This proves that the proposed system is suitable for low-power applications such as LED lighting, battery charging, and small electronic loads.

Graph 3: Output Power vs Wind Speed

Download Graph

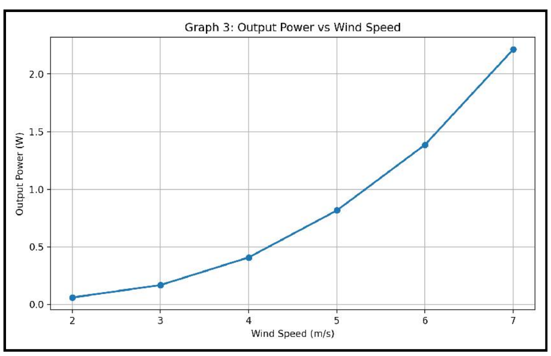

Fig.3.Graph 3

Explanation

This graph shows the variation of electrical power output with respect to wind speed. The output power is calculated using the formula:

P=V×IP = V \times IP=V×I

As wind speed increases, both voltage and current increase, resulting in a significant rise in output power. The generated power increases from about 0.06 W at 2 m/s to around 2.21 W at 7 m/s.

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Result Discussion

The graph indicates that the system can produce measurable electrical power suitable for demonstration and small-scale usage. The gradual rise in power confirms that the generator coupling, blade motion, and low-friction shaft support are functioning effectively.

Graph 4: Efficiency vs Wind Speed

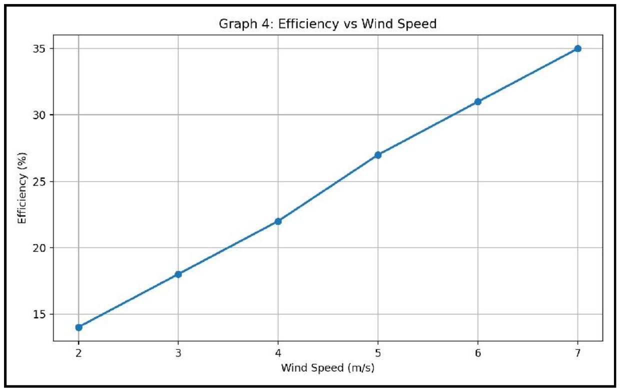

Fig.4.Graph 4

Explanation

This graph represents the variation of overall efficiency of the proposed windmill system with changing wind speed. The efficiency increases from approximately 14% at 2 m/s to nearly 35% at 7 m/s.

Result Discussion

The graph proves that the proposed system performs better as the wind speed increases. It also validates the concept of using magnetic levitation to reduce frictional losses, which improves the effective utilization of wind energy.

VIII. CONCLUSION

The project "Levitating Frictionless Vertical Windmill" successfully demonstrates the concept of generating electrical energy by combining a Vertical Axis Wind Turbine (VAWT) with a magnetic levitation based low-friction support mechanism. The developed prototype shows that wind energy can be effectively converted into useful electrical output even at low and moderate wind speeds when friction in the rotating system is minimized. The use of a vertical axis blade structure allows the turbine to receive wind from multiple directions, while the magnetic support helps reduce mechanical resistance, thereby improving smoothness of rotation and startup performance.

The results obtained from the prototype confirm that the performance of the turbine improves as the wind speed increases. Parameters such as rotor speed, output voltage, output power, and efficiency showed a positive growth trend with increasing wind flow. The use of magnetic levitation proved beneficial in lowering the effective load on the bearing system, which reduced energy loss due to friction and contributed to improved efficiency. This validates the practical usefulness of integrating magnetic repulsion principles into small-scale wind energy systems for better mechanical performance and low-maintenance operation.

The proposed system is found to be compact, economical, eco-friendly, and technically feasible for educational and small-scale renewable energy applications. It can be used in locations such as rooftops, roadside installations, institutions, and smart micro-energy setups where wind direction is irregular and the power demand is low. Although the prototype output is limited for large-scale applications, the project successfully proves the concept of friction-reduced wind energy generation and provides a strong foundation for further improvement. Therefore, the Levitating Frictionless Vertical Windmill can be considered a promising and innovative approach toward future decentralized clean energy solutions.

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