DESIGN AND DEVELOPMENT OF A HELICAL ARCHIMEDES WIND TURBINE GENERATOR FOR EFFICIENT MICRO-SCALE POWER GENERATION IN DOMESTIC APPLICATION

Project Reference No.: *48S_BE_5738*

College : Jain College of Engineering and Technology, Hubballi
Branch : Department of Mechanical Engineering
Guide(s) : Prof. Deviprasad N Mirashi
Student(s) : Mr. Malik Rehan Khan Jagirdar
Mr. Sulaiman Ahmed Kankudti
Mr. Faiz Ali K Mulla
Mr. Irshadahemad Nazeerahemaad Navalgund

KEYWORDS:

Archimedes Wind Turbine, Micro Power Generation, Renewable Energy, Wind Energy Conversion, Blade Design Optimization

INTRODUCTION:

The growing global energy demand and the pressing need for sustainable solutions have spurred significant advancements in renewable energy technologies. Among these, wind energy has emerged as a key contender due to its abundance, renewability, and potential to reduce dependency on fossil fuels. However, conventional wind turbines are often limited by their large size, high noise levels, aesthetic concerns, and inefficiency in low wind speed environments, particularly in urban and semi-urban areas. These limitations create a gap in meeting the energy needs of decentralized, small-scale applications.

This project focuses on the design and development of an Archimedes Wind Turbine, a revolutionary concept in wind energy harnessing. Unlike traditional three-blade wind turbines, the Archimedes wind turbine features a **helical, screw-like** design inspired by Archimedean geometry. This design is specifically tailored to maximize wind capture efficiency at **low wind speeds**, ensuring a reliable power output even in environments with fluctuating wind conditions. The turbine's compact, lightweight, and noise-free structure makes it ideal for urban rooftops, residential areas, and small-scale energy needs where traditional turbines are impractical.

This project is significant because it demonstrates a practical and efficient way to harness wind energy for small-scale applications like **household lighting, battery charging, or agricultural sensors**, especially in **semi-urban or rural areas** with moderate wind availability. Through this study, we aim to contribute to the development of cost-effective and scalable renewable energy solutions aligned with global sustainability goals.

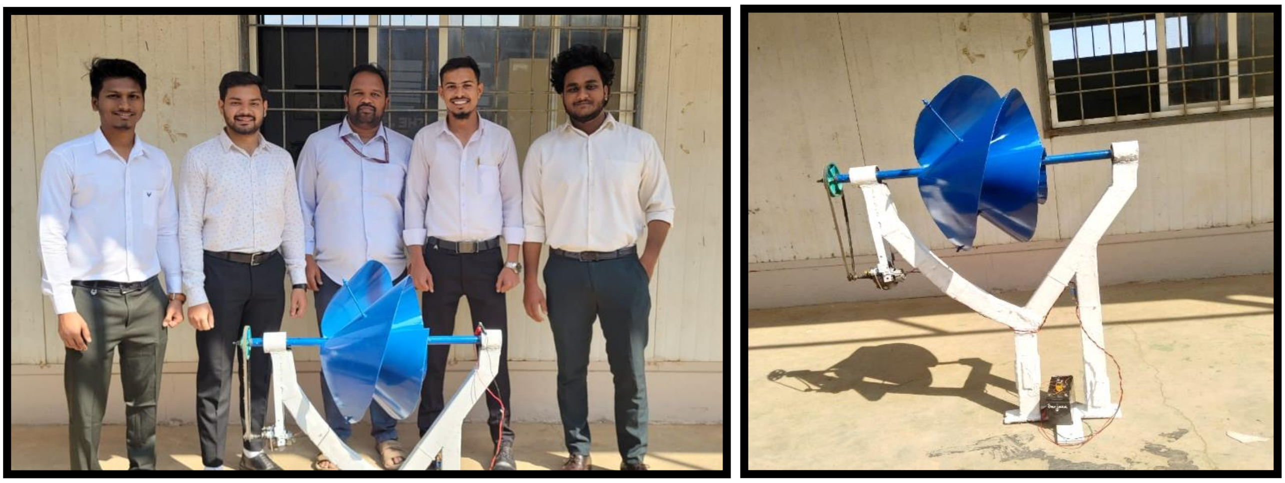


Figure 1: Archimedes Wind Turbine

OBJECTIVES:

1. To design an innovative helical Archimedes wind turbine system
2. To develop a compact and lightweight wind turbine model
3. To fabricate the turbine system using durable and cost-effective materials
4. To achieve efficient power generation at low cut-in wind speeds
5. To promote sustainable energy solutions for households

6. To ensure ease of installation and portability
7. To contribute to achieving energy independence at the micro-scale level

METHODOLOGY:

1. Design approach

The Archimedes wind turbine is designed based on the principles of aerodynamics and efficiency in capturing wind energy. The following aspects were considered:

- **Blade Shape and Design:** The helical shape enhances wind capture and reduces turbulence.
- The Archimedes spiral is a naturally occurring geometric pattern found in various forms in nature. It is characterized by a point moving away from a fixed centre at a constant rate, creating a smooth, expanding curve. This shape appears in:
- **Seashells**: The nautilus and Thatcheria mirabilis exhibit near-perfect Archimedean spirals in their growth patterns.
- **Galaxies**: Many spiral galaxies, such as the Milky Way, follow an approximate Archimedean spiral structure.
- **Weather Systems**: Low-pressure vortex formations, like hurricanes and cyclones, often display spiral patterns resembling the Archimedes spiral.

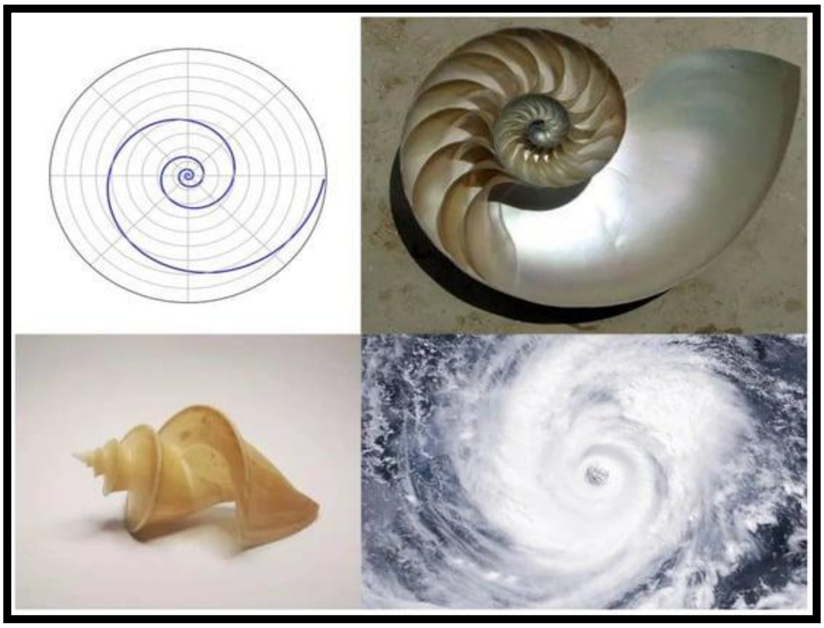


Figure 2: The Archimedes spiral shape in nature.

2. Material selection

Material selection is critical for ensuring durability and efficiency while keeping the structure lightweight. The selected materials include:

- **Blades:** The turbine blades are made up of **0.9 mm thick aluminium sheet**, chosen for its high strength-to-weight ratio and resistance to corrosion.

Figure 3: Selection of aluminium sheet (0.9mm thick).

- **Shaft:** Plane GI shaft to provide high mechanical strength.

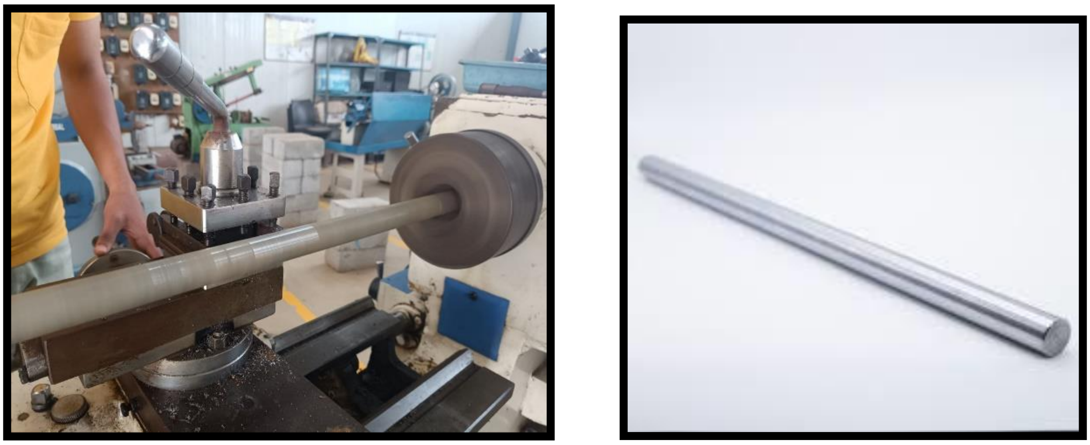


Figure 4: Selection of aluminium shaft (1 inch diameter)

- **Base frame:** MS rectangular hollow tube. Mild steel for robustness and stability.

Height= 30mm, Width = 60 mm and Wall =5mm

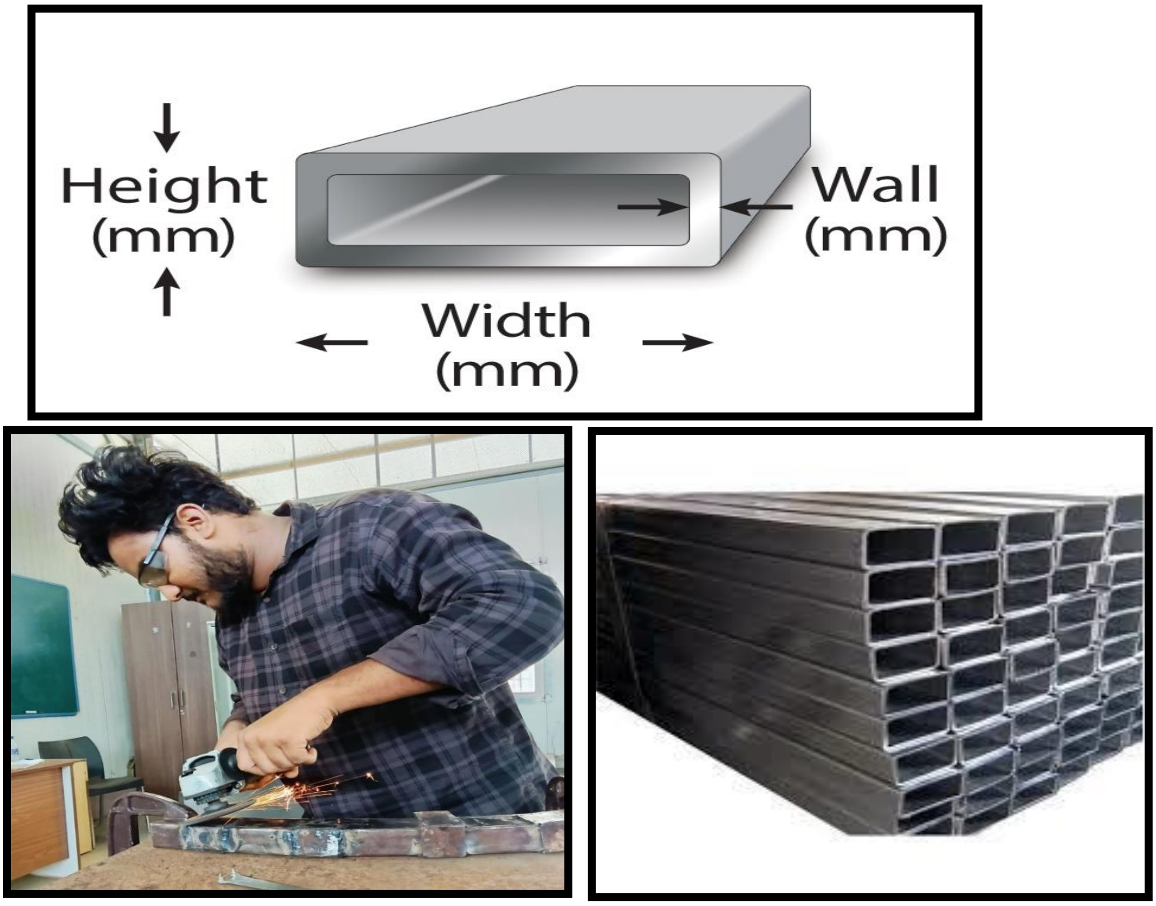


Figure 5: Selection of MS Rectangular hollow tube.

- **Bearings:** High-quality ball bearings to ensure smooth rotation with minimal friction.

(2x) Bearings are used each at end

Inner diameter = **1 inch**

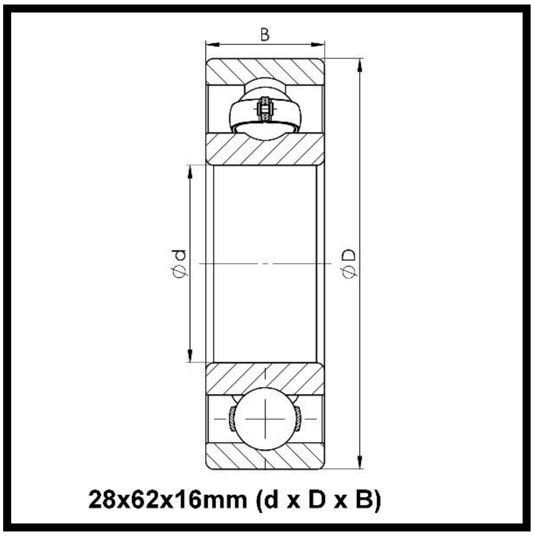


Figure 6: Selection of ball bearing.

- **Pulleys:**

Pulley Selection for Shaft-to-Motor Power Transmission

To efficiently transfer rotational motion from the shaft to the motor, we have chosen a **pulley-belt system** instead of a gear mechanism. This selection is based on key advantages such as smoother operation, minimal noise, reduced maintenance, and the ability to handle misalignment better than gear systems. Below are the details of the selected components:

1. Large Pulley (Connected to Shaft)

- **Outer Diameter:** 104 mm
- **Inner Diameter:** 91 mm
- **Material Consideration:** Typically made from high quality plastic for durability and strength.

- **Function:**
  - This pulley is mounted on the main shaft and acts as the driving element in the system.
  - Due to its larger diameter, it helps reduce the rotational speed when transferring motion to the motor, ensuring efficient torque transmission.
  - The inner diameter of 91 mm ensures a secure fit on the shaft, minimizing slippage.

Figure 7: Grooved Large Pulley (91mm dia)

.

2. Small Pulley (Connected to Motor Shaft)

- **Outer Diameter:** 15 mm
- **Inner Diameter:** 5 mm
- **Material Consideration:** Usually made from steel or aluminium to withstand high-speed rotation.
- **Function:**
  - This pulley is fixed to the motor shaft and acts as the driven component.
  - Its smaller size results in a significant speed increase relative to the shaft's rotation, making it suitable for applications where higher RPM is required at the motor end.
  - The 5 mm inner diameter ensures a proper fit on the motor shaft for efficient power transmission.

Figure 8: Small Pulley (51mm dia)

Pulley belt (connecting both pulleys)

- **Length:** 400 mm
- **Material Consideration:** Commonly made of rubber with reinforced fibres for flexibility and durability.
- **Function:**
  - The belt connects the big pulley on the shaft to the small pulley on the motor, transmitting power smoothly.
  - It absorbs vibrations and reduces shock loads, ensuring longevity of both pulleys and the motor.
  - The belt's flexibility allows slight misalignments without affecting performance, making the system more adaptable.

Figure 9: Pulley belt (400mm)

3. Motors Selection for electricity generation

In our system, we have used two different types of motors to generate electricity

1) 12V DC RS-555 Brushed Motor and

2) (2x) 5V DC Micro Coreless Motors.

These motors are selected based on their efficiency, output voltage, and suitability for small-scale power generation. To increase the overall voltage output, we have connected these motors in **series** in order to get higher voltage.

1. 12V DC RS-555 Multipurpose Brushed Motor

- **Type:** Brushed DC Motor
- **Operating Voltage:** 12V DC
- **Speed:** Typically ranges from 3000 to 15000 RPM, depending on load conditions
- **Torque:** Moderate, making it suitable for small mechanical power applications
- **Size & Build:** Compact cylindrical metal housing, ensuring durability
- **Function:**
    - This motor is used as a **generator**, converting rotational motion from the pulley system into electrical energy.
    - When driven by the shaft via the pulley system, the internal coil and magnets generate DC voltage, which can be used to power small electrical components or stored in a battery.
    - It is widely used in DIY projects, small wind turbines, and low-power applications due to its reliability and ease of use.

Figure10: 12V DC RS-555 Multipurpose Brushed Motor

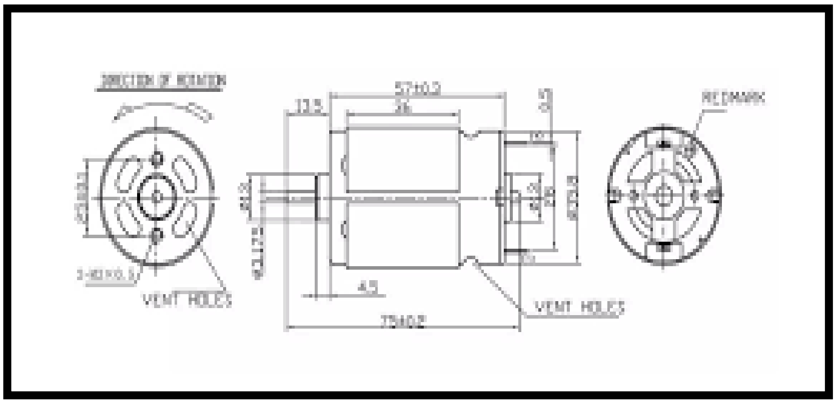


Figure 11: Diagram of RS-555 motor

2. Two 5V DC Micro Coreless Motors

- **Type:** Coreless DC Motor
- **Operating Voltage:** 5V DC
- **Speed:** High-speed rotation, often exceeding 10,000 RPM
- **Size & Build:** Extremely compact and lightweight, making it ideal for low-power applications
- **Function:**
    - These motors are also used as **miniature generators**, converting rotational energy into a small DC voltage output.
    - Their **coreless** design allows for high efficiency and quick response, making them suitable for generating power from high-speed rotation.
    - They are commonly used in precision applications like drones, small wind turbines, and micro energy-harvesting systems.

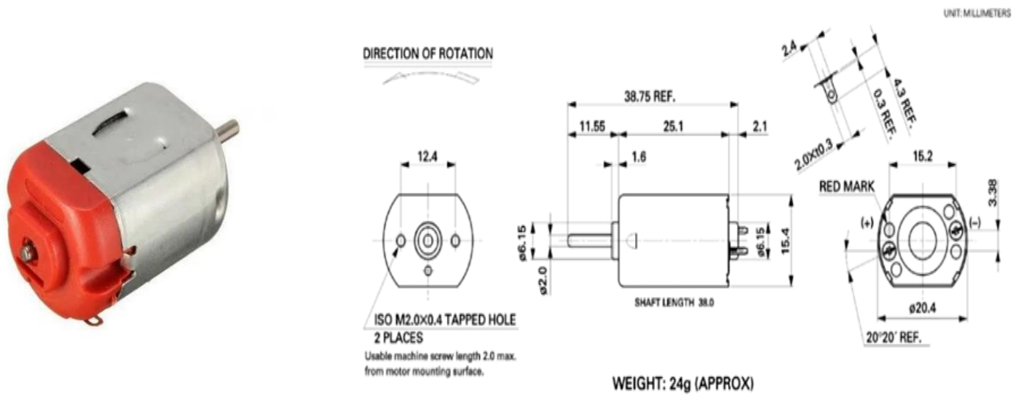


Figure 12: 5V DC Micro Coreless Motor

Series Connection for Higher Voltage Output

To enhance the overall voltage generation, we have connected the **12V RS-555 motor** and the **two 5V coreless motors** in **series**. This configuration allows the individual voltages of each motor to add up, resulting in a higher total output voltage. By doing so, we ensure better energy harvesting, making the system more efficient for practical applications.

This **series-connected motor-generator system** effectively converts rotational energy into a higher DC voltage, which can be utilized for powering electronic devices or charging batteries.

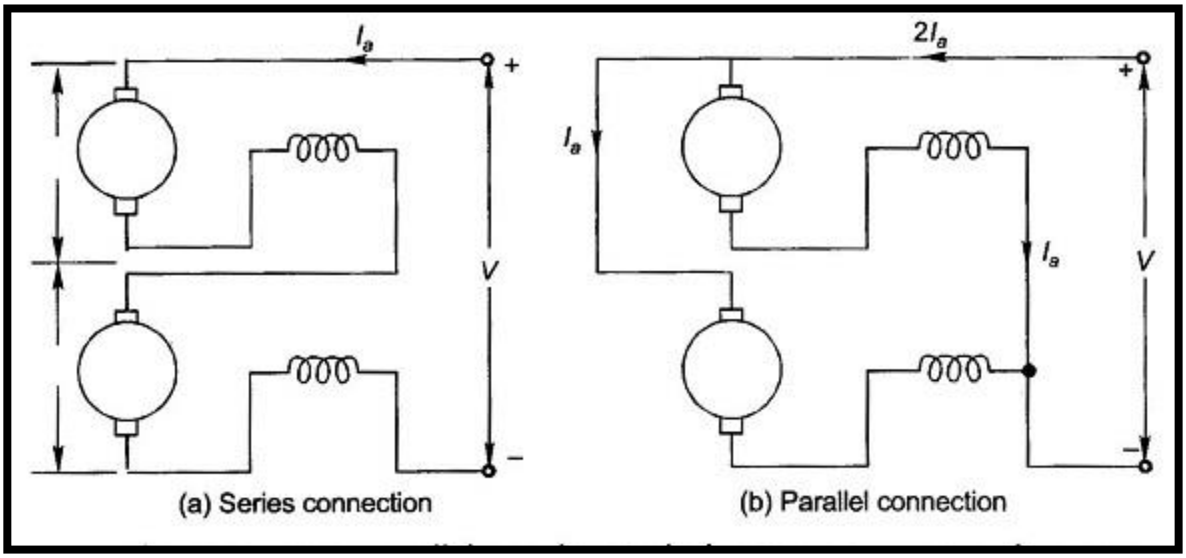


Figure 13: Series and parallel connections

4. Voltage booster module used: XL6009E1

To enhance the electrical output from our generator system, we have integrated an **XL6009E1 DC-DC Boost Converter Module**. This module is essential for increasing the voltage to a desired level, ensuring stable power supply for various applications.

XL6009E1 DC-DC Boost Converter Module

- **Type:** Step-up (Boost) Converter
- **Input Voltage Range:** 3V to 32V DC
- **Output Voltage Range:** 5V to 35V DC (Adjustable)

- **Maximum Output Current:** Up to 4A (with heat dissipation)
- **Efficiency:** ~94% (depending on input/output voltage and load)
- **Key Components:**
    - XL6009E1 switching regulator IC
    - High-frequency inductor for efficient energy conversion
    - Adjustable potentiometer for output voltage control

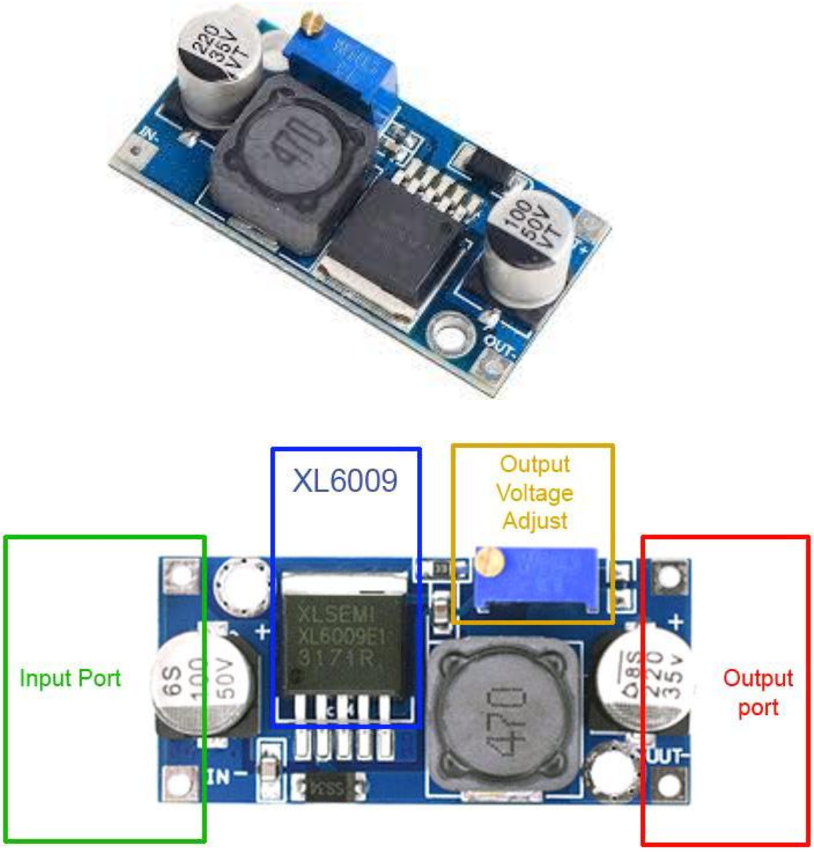


Figure 14: XL6009E1 DC-DC Boost Converter Module

- **Function:**
    - This module **boosts the voltage** generated by the **RS-555 brushed motor and the two 5V coreless motors**.
    - Since our motors are connected in **series** to increase voltage, the booster module further steps up the output to a **higher, stable level** suitable for powering electronics or charging batteries.
    - The module efficiently converts **low DC voltage to a higher level**, ensuring minimal energy loss.

Role in Our System

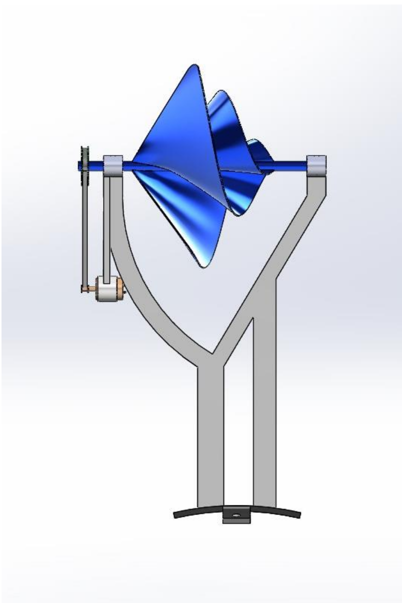
- The **boost converter stabilizes the fluctuating voltage** from the generator motors, making it suitable for practical use.
- Its **adjustable output** allows us to fine-tune the voltage as needed, optimizing performance based on load requirements.
- The **high efficiency** of the XL6009E1 ensures **maximum power transfer with minimal heat generation**, making it ideal for renewable energy applications.

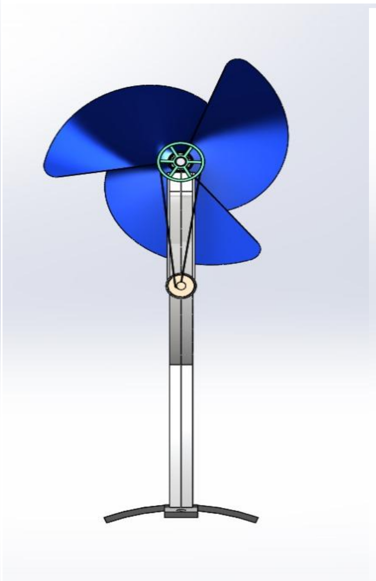
5. Cad modelling and 2D drawing using SolidWorks

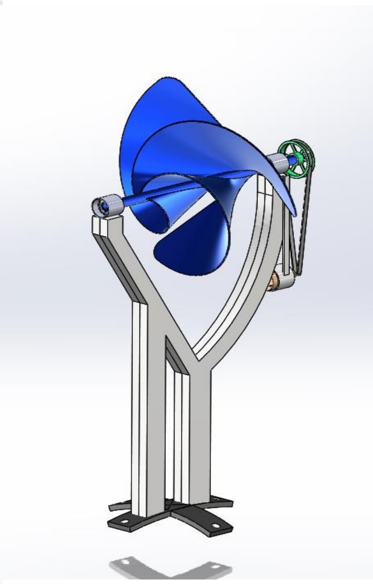
To ensure precise design and accurate fabrication, we have used **SolidWorks** for 3D modelling and visualization of our system. SolidWorks is a powerful CAD (Computer-Aided Design) software that enables detailed part modelling, assembly creation, and motion simulation, helping us optimize the design before actual manufacturing.

CAD Model Specifications

- **Software Used:** SolidWorks
- **Spiral Diameter: 1 foot (≈ 304.8 mm)**
- **Shaft Length: 2 feet (≈ 609.6 mm)**







Front view **Side view** **Isometric View**

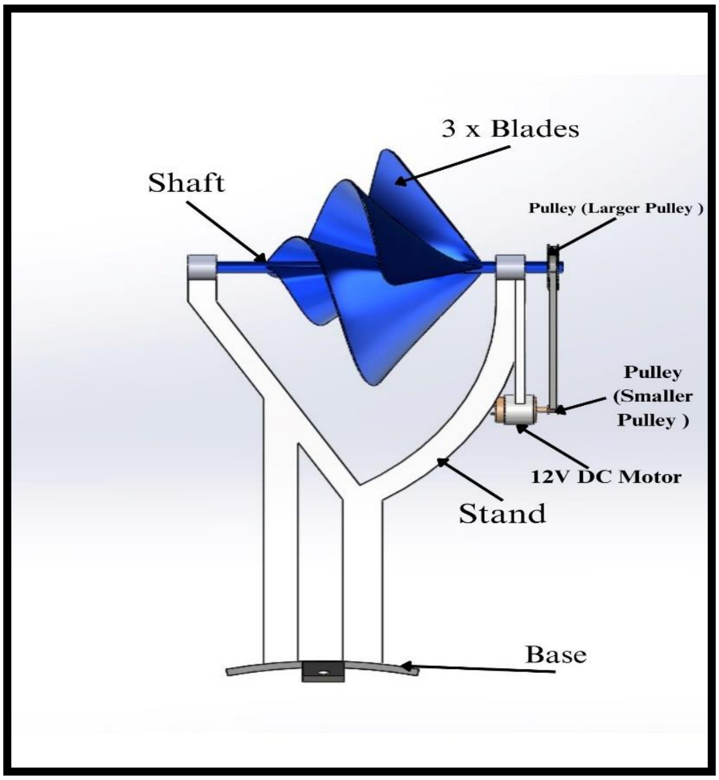


Figure 15: 3D Model of Archimedes wind turbine

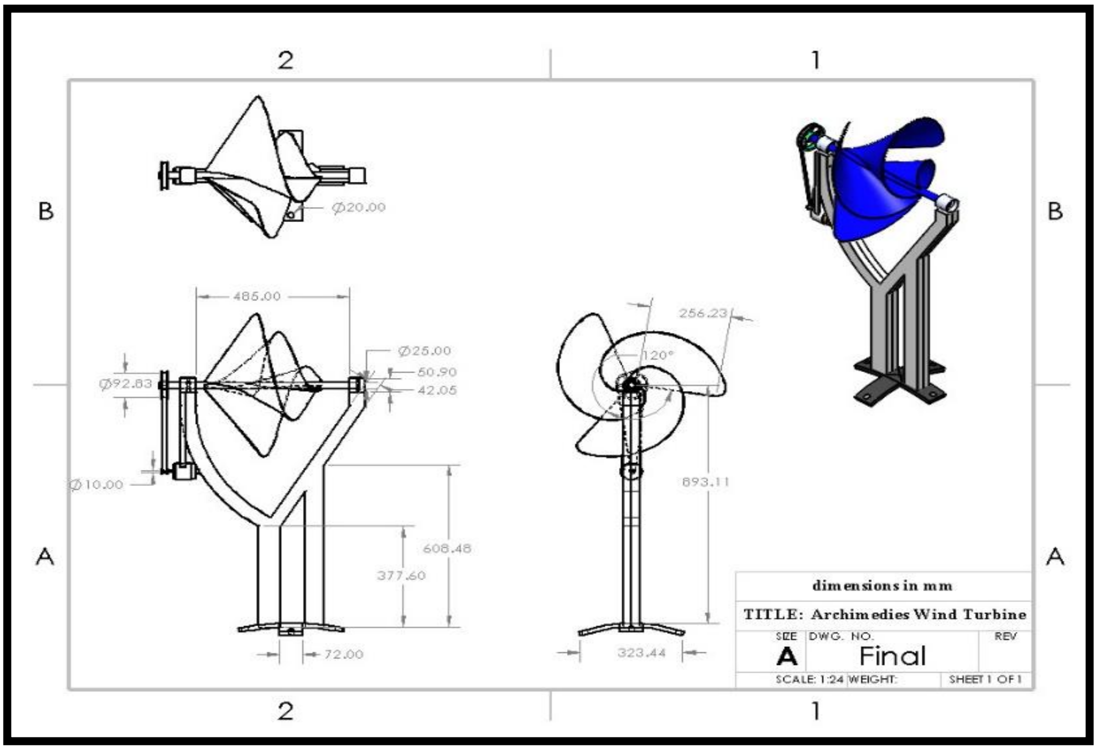


Figure 16: 2D Drawing of Archimedes wind turbine

Role of CAD Modelling in Our Project

1. **Precise Design & Visualization**
   - Using SolidWorks, we created a **3D model** of the system, ensuring accurate dimensions and proper component alignment.
   - The software allows us to **visualize the entire assembly** and make design improvements before fabrication.
2. **Component Integration**
   - The **spiral component (1-foot diameter)** and **shaft (2-foot length)** were modelled with precise dimensions to ensure proper functioning within the system.
   - Additional components like **pulleys, motors, and the voltage booster module** were also considered for proper integration into the design.
3. **Motion & Stress Analysis**
   - The model was used to **simulate motion** and test how the shaft, pulleys, and belt interact under real-world conditions.
   - Basic **stress analysis** was performed to verify the structural integrity of the components.
4. **Fabrication & Assembly Reference**
   - The detailed CAD model serves as a **reference for fabrication**, ensuring accurate manufacturing and assembly of parts.
   - It provides **technical drawings and measurements** required for machining and material selection.

6. Fabrication process

The fabrication of the Archimedes wind turbine followed a structured approach:

1. **Blade Making:**
    - Cutting the aluminium sheet to the required shape.
    - Bending and shaping the blade profile using a hammer (not precise)
    - 3 Blades were Fabricated.

Figure 17: Fabrication of Turbine Blades

2. **Shaft Making:**
   - Performing turning operation to reduce the shaft diameter.
   - Cutting the shaft to 2 feet (from one cap to another).
   - Attaching the shaft and bearings for smooth rotation.



Figure 18: Fabrication of Turbine Shaft

3. Frame Making:

- Cutting the MS Rectangular tube to required size and shapes
- Joining the shape to from the strong and durable frame by Arc welding
- Proving the fine surface finish through grinding operation

Figure 19: Fabrication of Frame

4. Assembly of Frame, Shaft and Blades

- Fixing the 3 blades to the shaft at equal angle (i.e. 360°/3 = 120°)
- Fixing the shaft with blades to the frame manufactured
- Applying metal putty to fill up the cracks and holes

Figure 20: Assembled Picture of Turbine

Figure 21: Applying putty to cover the gaps and holes on the frame

5. Generator (12V DC Motor) and Voltage Booster Integration:

- Mounting the motors (**12V DC Motor**) and ((**2x**) **5V DC motors**) to convert mechanical energy into electrical energy.
- Mounting the Voltage Booster **XL6009E1 DC-DC Boost Converter Module** to boost the Voltage
- Ensuring proper alignment for efficient torque transfer.

Figure 22: Integration of 12V and 5v DC motors

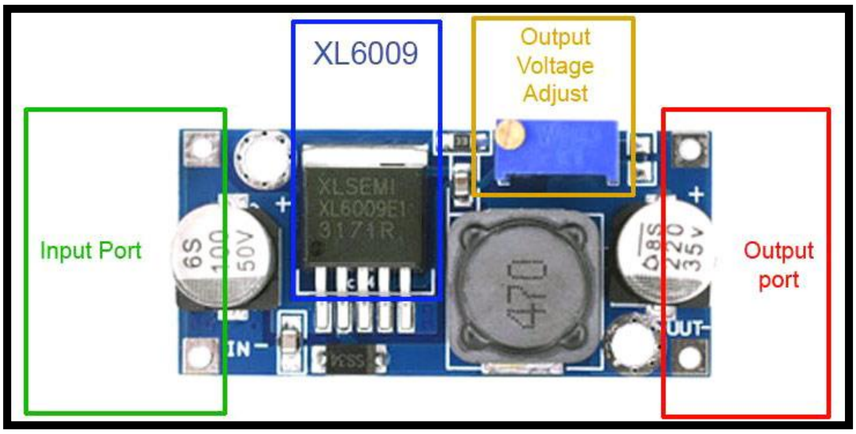


Figure 23: XL6009E1 DC-DC Boost Converter Module to boost the Voltage

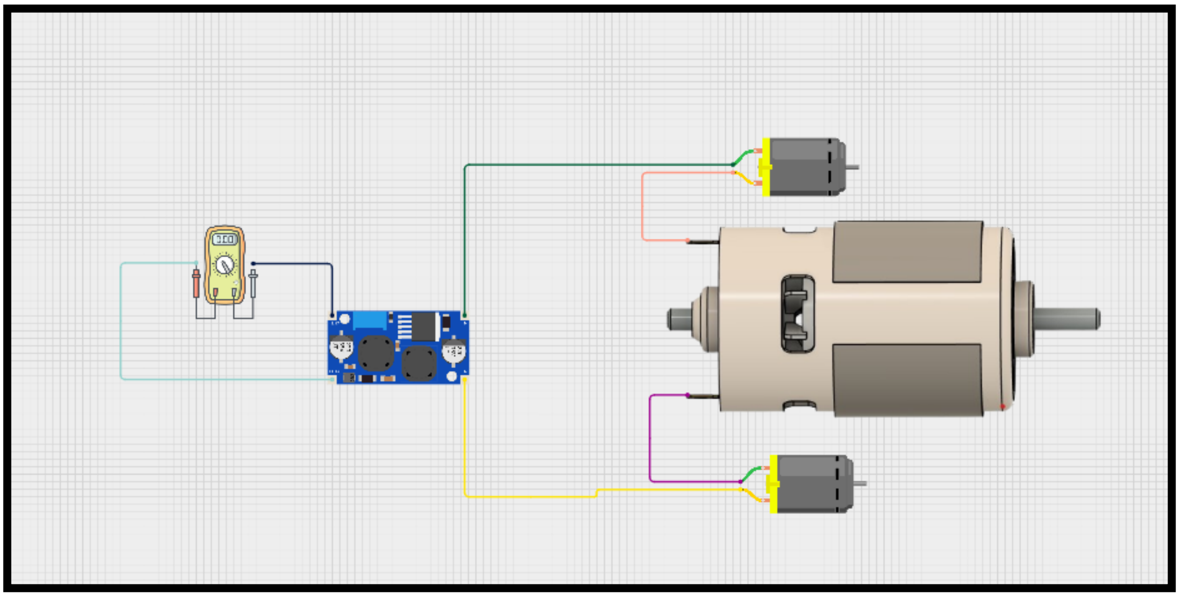


Figure 24: Circuit diagram of series connection

RESULT AND CONCLUSION:

The performance of the Archimedes wind turbine was evaluated by comparing the **theoretical power output** with the **actual measured power output** during experimental testing. The key parameters considered were wind speed, voltage output, and power generation.

1. Theoretical Power Output Calculation

The power available in the wind (P_wind) can be calculated using the following formula:

$P_{\text{wind}} = \frac{1}{2} \times \rho \times A \times V^3$

Where:

- ρ is the air density (approximately 1.225 kg/m³ at sea level).
- A is the swept area of the turbine blades.
- V is the wind speed in meters per second.

For a turbine with a blade diameter of 2 feet (0.6096 meters), the swept area A is:

$A = \pi \times \left(\frac{\text{Diameter}}{2}\right)^2 = \pi \times (0.6096/2)^2 \approx 0.2919\,\text{m}^2$

The actual power extracted by the turbine (P_turbine) is a fraction of the available wind power, determined by the turbine's power coefficient (C_p). For the Archimedes wind turbine, C_p is approximately 0.35. MDPI.COM

Step 1: Calculate the Power in Wind (P_wind)

The formula for wind power available in the turbine is:

$$P_{\text{wind}} = \frac{1}{2}\rho A V^3$$

where:

- $\rho = 1.225$ kg/m³ (air density)
- A = Swept Area of the blades (semi-circle) = $\frac{1}{2}\pi R^2$
- V = Wind speed in m/s

Step 2: Calculate Power Extracted by the Turbine (P_turbine)

$$P_{\text{turbine}} = P_{\text{wind}} \times C_p$$

where $C_p = 0.35$ (efficiency of the turbine).

Here are Theoretical calculations for Archimedes wind turbine.

Wind Speed (m/s)	Wind Power (W)	Turbine Power (W)
3	2.41	0.84
5	11.17	3.91
7	30.66	10.73
9	65.16	22.81
11	118.97	41.64

Table 1: Theoretical Calculations for Turbine

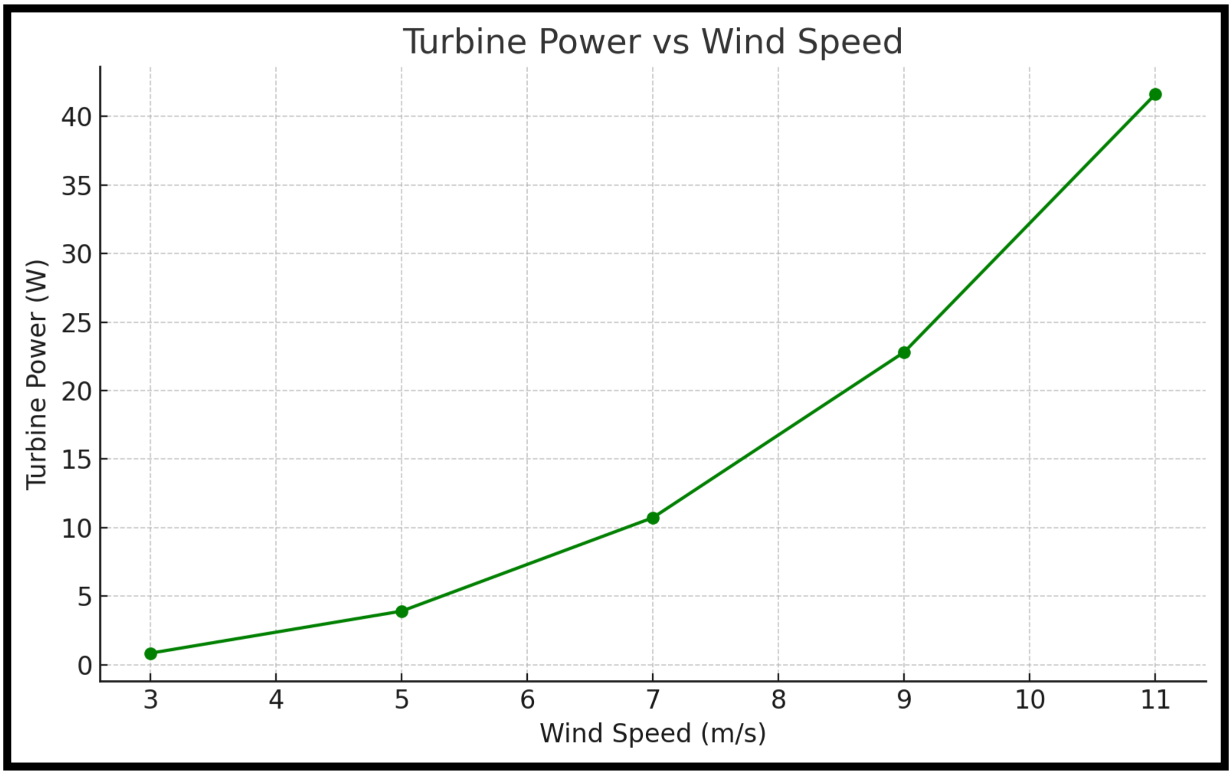


Figure 25: Turbine Power vs Wind Speed graph (Theoretical)

2. Experimental setup

The prototype was installed on the **rooftop of our college (12 meters above the ground)** to ensure unobstructed wind flow. The **multimeter** was used to measure the voltage generated by the turbine at various wind speeds. The testing conditions and setup details are as follows:

- **Location:** Jain College of Engineering and Technology, Hubballi Rooftop (2nd floor, 12 meters above ground)
- **Wind Speed Range:** 3 m/s to 11 m/s
- **Measurement Device:** Digital Multimeter for Voltage and Digital Anemometer for Wind speed
- **Turbine Type:** Archimedes Spiral Wind Turbine
- **Generator Type:** Permanent Magnet DC Generator

Figure 26: Shows the Inner View of the Building to Demonstrate Height

Testing procedure

1. The wind turbine was **securely mounted** on the rooftop at a height of 12 meters.
2. A **multimeter** was connected to the generator terminals to measure the voltage output.
3. The wind speed was recorded at different intervals using weather data.
4. Voltage readings were taken for different wind speeds **(3 m/s, 6 m/s, 8 m/s, 10 m/s and 11 m/s).**
5. The experiment was repeated multiple times to ensure consistent results.

Figure 27: Testing Procedure Carried Out

Experimental results

The performance of the Archimedes wind turbine was evaluated by comparing the **theoretical power output** with the **actual measured power output** during experimental testing. The key parameters considered were wind speed, voltage output, and power generation.

The measured voltage output at different wind speeds is summarized in the table below.

Wind Speed (m/s)	Voltage (V)	Current (A)	Power (W)
3	2.34	0.30	0.71
5	8.75	0.38	3.29
7	15.14	0.60	9.02
9	21.55	0.89	19.17
11	28.21	1.23	34.69

Table 2: Measured voltage output at different wind speeds

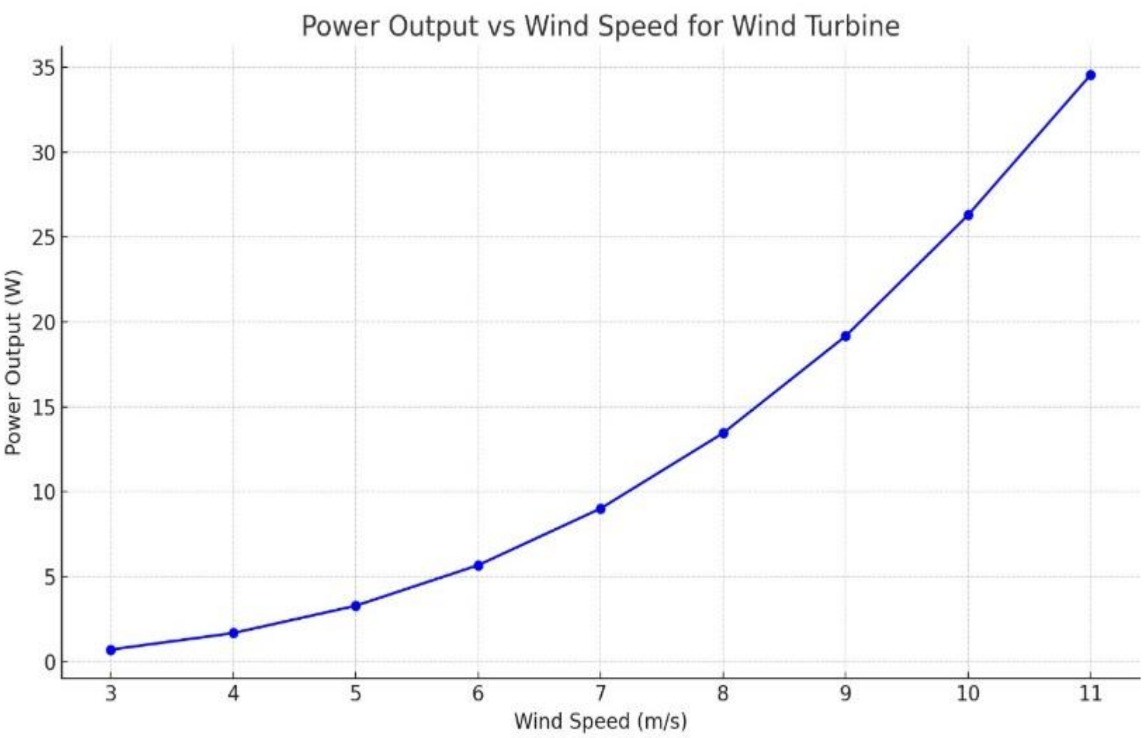


Figure 28: Power Output vs Wind Speed graph (Experimental)

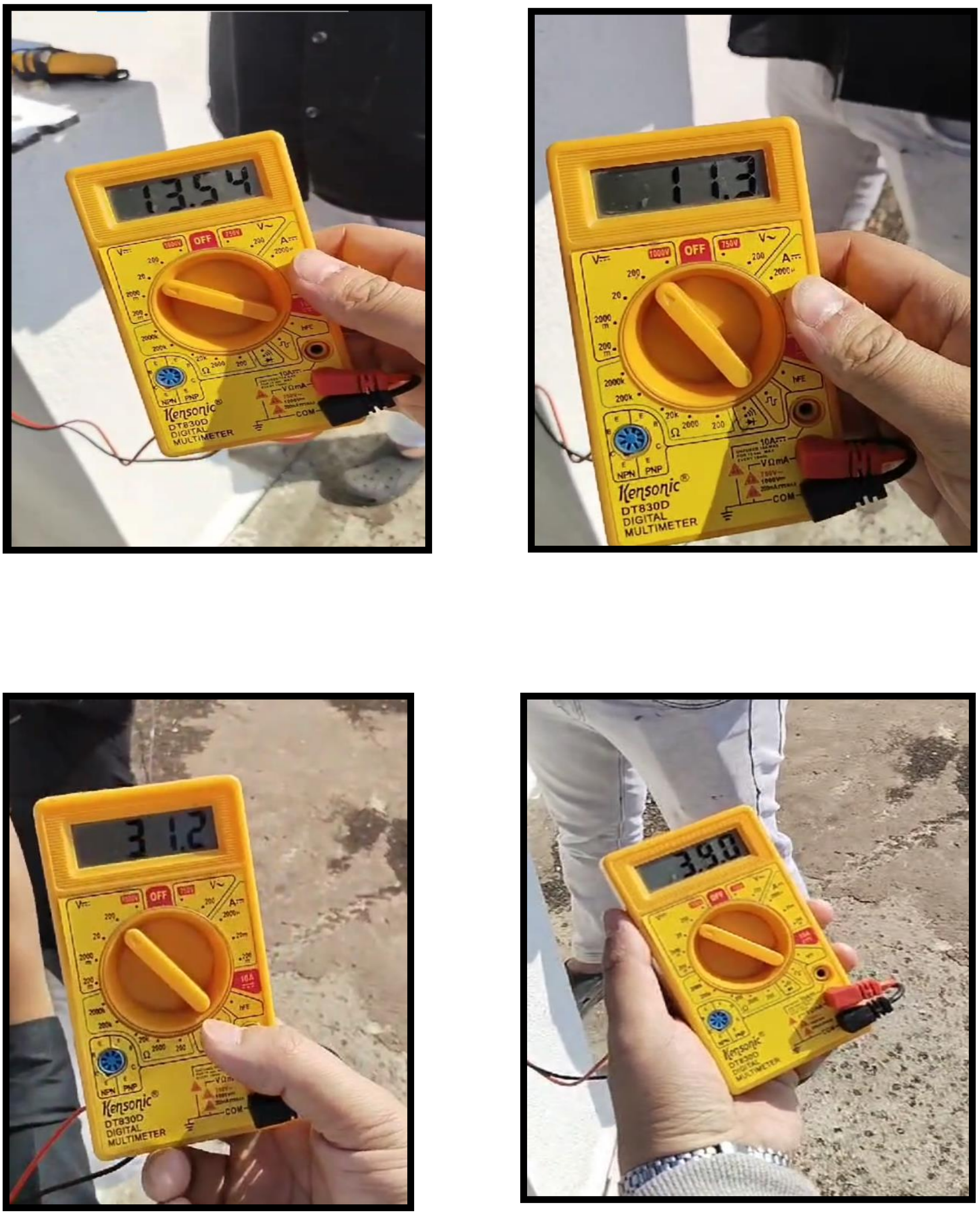


Figure 29: Voltage Generated at Different wind speeds

Comparison of Experimental and Theoretical Power Output

The theoretical power output was calculated based on wind speed and turbine efficiency, while actual power output was measured using a multimeter during rooftop testing.

Wind Speed (m/s)	Theoretical Power Output (W)	Experimental Power Output (W)
3	0.84	0.71
5	3.91	3.29
7	10.73	9.02
9	22.81	19.17
11	41.64	34.69

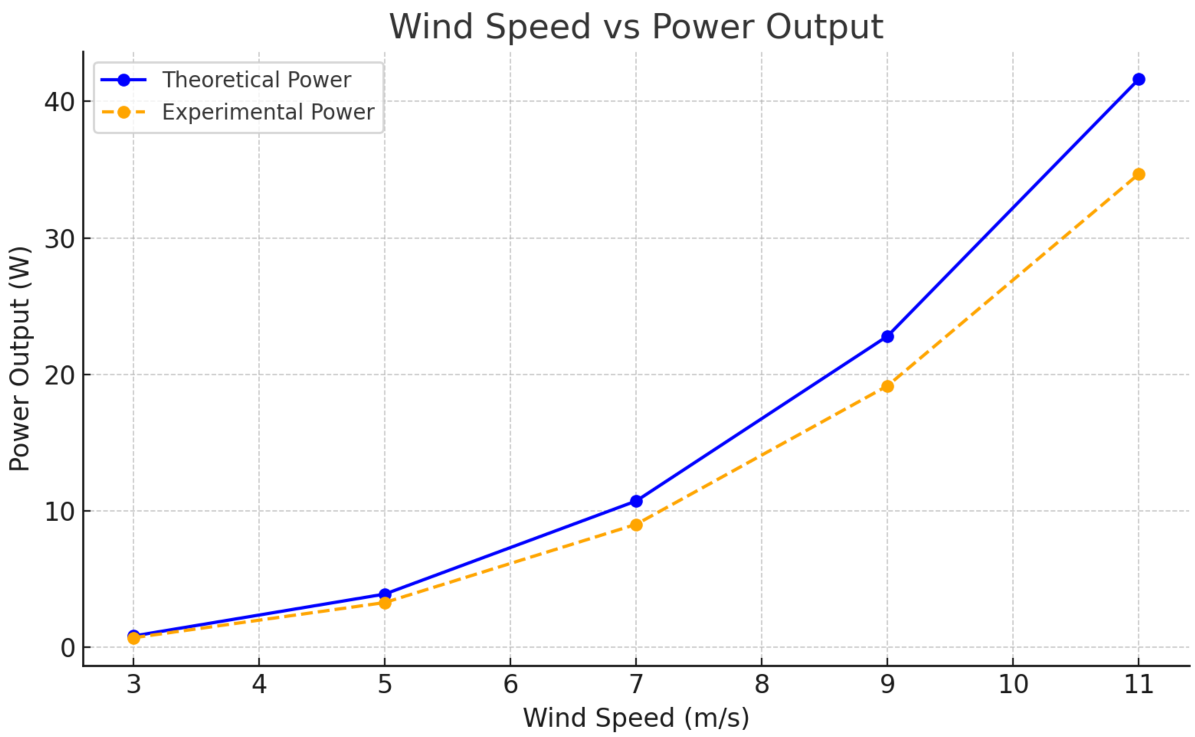


Figure 30: Theoretical V/S Experimental Power Output (W)

PROJECT OUTCOMES AND INDUSTRY RELEVANCE

Project Outcomes:

- Successfully designed and developed a functional **prototype of an Archimedes wind turbine** using CAD software (SolidWorks) with optimal dimensions for micro-power generation.
- Conducted theoretical performance analysis for various wind speeds (3–11 m/s) and validated the results through real-world rooftop testing, achieving a peak Power output of **35W at 11 m/s wind speed.**
- Demonstrated that the Archimedes design outperforms traditional 3-blade turbines in terms **of start-up behaviour, safety, noise reduction, and suitability for low-wind environments.**
- Validated the turbine's potential for decentralized, small-scale energy applications, such as battery **charging or powering small electronic devices in urban/rural settings.**

Industry Relevance:

- The Archimedes wind turbine design offers a compact and efficient solution for industries looking to adopt micro-scale renewable energy systems.
- Its ability to operate at low wind speeds makes it ideal for urban and semi-urban applications, especially where conventional wind turbines are not feasible.
- Can be deployed in the agricultural sector to power devices like soil sensors, irrigation timers, or remote monitoring systems.
- In telecommunication infrastructure, it can support off-grid communication towers and equipment in remote or rural areas.
- Useful in the residential and commercial sectors for powering low-consumption devices or supplementing rooftop solar systems.

- Offers a sustainable energy solution for disaster-prone or power-scarce regions, aiding in energy resilience and grid independence.
- With further refinement, this design has potential for commercial scaling and could contribute to green energy start-ups or local manufacturing initiatives.
- Acts as a learning platform for students, researchers, and clean-tech developers, bridging academic innovation with industry needs.

WORKING MODEL VS. SIMULATION/STUDY

This project involved the design, development, and testing of a **Physical working model** of an Archimedes wind turbine for micro-power generation.

The turbine was fabricated using an aluminium sheet and tested on the rooftop of our college building under real wind conditions.

The core focus remained on building and validating a functional prototype, making it a hands-on, practical project rather than a purely theoretical or simulation-based study.

LEARNINGS:

- Gained hands-on experience in **3D modelling and CAD design** for renewable energy systems.
- Understood the importance of aerodynamics and structural integrity in wind turbine performance and safety.
- Developed practical skills in **data collection, analysis**, and troubleshooting during live experimental testing.
- Improved understanding of how environmental data (like local wind speed patterns) influences renewable energy project planning.
- Enhanced teamwork, project management, and **technical documentation** abilities crucial for real-world engineering projects.

FUTURE SCOPE:

The Archimedes wind turbine prototype developed in this project opens up multiple avenues for future research and development in the field of micro-wind energy. One key area of improvement lies in the **optimization of blade materials and geometry** to increase efficiency and reduce weight. Exploring **composite or lightweight materials** could improve performance in low wind conditions and make the system more portable.

Another potential upgrade is the integration of a **smart control system** that automatically adjusts the load based on wind speed, ensuring maximum power extraction. Coupling the turbine with **energy storage systems like lithium-ion batteries** or **hybrid setups** (wind + solar) can enhance its utility in off-grid and remote locations.

Further research can be directed toward developing a **modular version of the turbine**, allowing users to scale the system based on their energy needs. The use of **Internet of Things (IoT)** technology can also be explored for remote monitoring and diagnostics, making it suitable for industrial and smart city applications.

Additionally, more **aerodynamic and structural simulation studies** can be conducted using advanced CFD tools to refine the blade design for different climate zones. The turbine’s performance can be tested at various altitudes and terrains to ensure broader geographical applicability.

Finally, with sufficient testing and refinement, the design could be **commercialized for urban homes, farms, educational institutes, and micro-industries**, contributing to the global goal of clean and sustainable energy.