uOttawa

GNG5140 - Engineering Design

User Manual

Submitted by:

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1 Introduction

This user manual provides essential guidance for assembling, operating, and maintaining the modified Savonius rotor prototype designed to enhance green energy output. The rotor addresses challenges such as unreliable wind energy supply during winter months, a significant issue for off-grid food storage systems like those used by Deep Roots storage in Ottawa. By utilizing cost-effective and lightweight materials, our design ensures ease of construction by volunteers using simple tools. This manual supports the rotor's intended purpose as a reliable and efficient energy source for applications ranging from food storage systems in developed regions to addressing food security in underdeveloped countries.

The document assumes that users have a basic understanding of mechanical systems and access to common tools for assembly and maintenance. The prototype is designed for indoor or controlled environments, as some materials, such as the foam used for wind deflectors, are not fully resistant to moisture or extreme weather conditions. For outdoor applications or long-term use, modifications to improve durability and performance may be required.

This manual is structured to guide the user through the entire lifecycle of the system. It begins with an overview of the Savonius rotor, including its purpose, design goals, and potential applications. Next, the "Getting Started" section details the materials, tools, and initial preparations needed for assembly. "Set-Up Considerations" focuses on site selection, safety measures, and other factors crucial to installation success. The "Using the System" section explains how to operate the rotor effectively and optimize its performance. "Troubleshooting and Support" addresses common issues, their causes, and practical solutions, while also providing information on seeking further assistance if needed.

The manual also includes detailed product documentation, summarizing the rotor's technical specifications, material choices, and design rationale. Testing and validation findings are presented to showcase the rotor's efficiency and stability compared to traditional designs. The final section offers conclusions and recommendations for future improvements, highlighting areas for potential innovation and broader applications.

The purpose of this user manual is to ensure that users can confidently assemble and operate the Savonius rotor while understanding its strengths, limitations, and capabilities. Safety considerations are emphasized, particularly for electrical connections, to prevent accidents. Although this prototype is intended for use in controlled conditions, future iterations with digital monitoring capabilities may introduce weather considerations, weight restriction, which should be addressed appropriately.

2 Overview

The modified Savonius rotor prototype has been developed to address the pressing challenge of unreliable energy sources during harsh winter months, a problem particularly acute for off-grid systems such as food storage hubs. Without consistent energy, essential operations like maintaining proper temperatures for food storage are at risk, leading to spoilage and increased waste. This prototype aims to provide a cost-effective and efficient renewable energy solution that reduces reliance on external power sources like electric vehicles for charging batteries manually.

This product is designed with the needs of diverse users in mind, including volunteers, rural communities, and organizations in underdeveloped regions. These users require a wind energy solution that is not only effective and reliable but also simple to construct using readily available materials. The design of the rotor makes it accessible for individuals with little technical expertise, emphasizing ease of use and assembly.

The Savonius rotor stands out due to its enhanced efficiency and innovative features. Its inclusion of a wind deflector and vane improves stability and performance across a range of wind speeds, with efficiency gains of 15% to 20% compared to traditional rotors. The prototype incorporates lightweight and recyclable materials, including PVC pipes, aluminum sheets, and foam, allowing for rapid assembly by small teams of volunteers. These materials keep costs low while ensuring that the product performs well during testing, even under challenging conditions. The design pictures are shown below.

Figure 1: Prototype

The product is designed to be straightforward and practical in its operation. A simple motor generates electricity, avoiding the need for complex systems or expertise. While the current prototype is optimized for indoor testing, the design lays the groundwork for future adaptations to withstand outdoor environments and extreme weather conditions, such as freezing rain and snow. The structure of the system relies on durable yet lightweight components, making it easy to transport and install.

The overall architecture of the system is simple and effective. It integrates components like the wind deflector and vane to optimize wind flow and increase energy generation. The user interacts with the system through manual setup and adjustments, requiring no specialized training. The design allows it to function efficiently in controlled environments, with future iterations set to address outdoor applications including rain or snow, as shown below is our detailed design.

2.1 Conventions

This manual uses consistent formatting for clarity. Actions the user must take are marked with **Action:** followed by instructions. Key terms are italicized when first introduced. Measurements are in metric units, and diagrams are included to support explanations. Prompts or buttons in the system are shown in brackets, like [Start]. These conventions ensure the manual is easy to follow for all users.

2.2 Cautions & Warnings

When handling the Savonius rotor, be aware that the sheet metal components can be sharp. Always wear protective gloves to avoid cuts or injury. During installation, ensure you are mindful of the wind direction, as strong winds can make the rotor difficult to control. Be cautious of the rotor's turning radius to avoid injury, especially when testing or operating the system.
When using tools, ensure you follow proper safety procedures. Wear safety goggles and other protective gear as needed. Make sure all connections are secure before operating the system to prevent accidents. Additionally, ensure the rotor is mounted in a stable position, as an unstable setup could lead to damage or injury. Always follow safety protocols and exercise caution during assembly and operation.

3 Getting started

To get started with the Savonius Wind Turbine, it's essential to ensure that all required materials are accounted for, and a Bill of Materials (BoM) is prepared. This will help in organizing the components needed for construction and streamline the assembly process. Below is the suggested list of materials, quantities, and brief descriptions to help create the BoM for the system.

- **Base Support**:
  Material: Heavy wood or steel
  Note: Ensure sufficient weight to resist torque generated by turbine rotation.
- **Rotor Blades**:
  Material: Galvanized iron (GI) sheet or barrels to cut to form semi-cylindrical blades.
- **Connection Assembly Parts**:
  Material: PVC pipes (for lightweight systems) or aluminum (for higher stiffness and durability).
- **Rotational Mechanism**:
  Bearings: Ensure proper alignment to minimize friction for the vertical shaft rotation.
- **Deflector**:
  Material: Lightweight and waterproof material to direct wind toward the blades effectively.
- **Power Generation**:
  DC Motor: Sized appropriately for the expected torque and power output.

3.1 Set-up Considerations

Steps to Properly Assemble, Test, and Exit the Savonius Wind Turbine System:

1. Assembling the Shaft with Bearings
Securely attach the vertical shaft to the bearings.
Ensure bearings are well-lubricated and aligned to reduce friction during operation.

2. Installing Semi-Cylindrical Blades
Attach the GI sheets or barrel halves to the shaft to form the rotor blades.
Ensure symmetry and balance to minimize wobbling during rotation.

3. Installing the Base Support
Assemble the heavy base support using wood, steel, or aluminum.
Ensure it is stable and can resist the torque generated by the wind turbine.

4. Installing Assembly Connection Parts
Fix the shaft and blade assembly to the base using PVC or aluminum connection parts.
Verify all connections are secure and can handle operational loads.

5. Installing the Deflector and Vane
Attach a lightweight, waterproof deflector to guide wind toward the blades.
Install the vane to help orient the turbine in the wind's direction.

6. Testing Against Wind
Position the turbine in an open outdoor area or use a fan to simulate wind.
Observe the blades' rotation and ensure smooth operation without excessive vibration.

7. Measuring Voltage
Use a voltmeter to measure the DC motor's output voltage.
Record the voltage value for reference during power calculations.

8. Measuring Current (Amperage)
Connect an ammeter to the circuit to measure the current produced by the DC motor.
Ensure readings are stable for accurate measurement.

9. Calculating Power Output
Use the formula Power (P) = Voltage (V) × Current (I) to determine the turbine's power output in watts. Document the results and evaluate the turbine's efficiency.

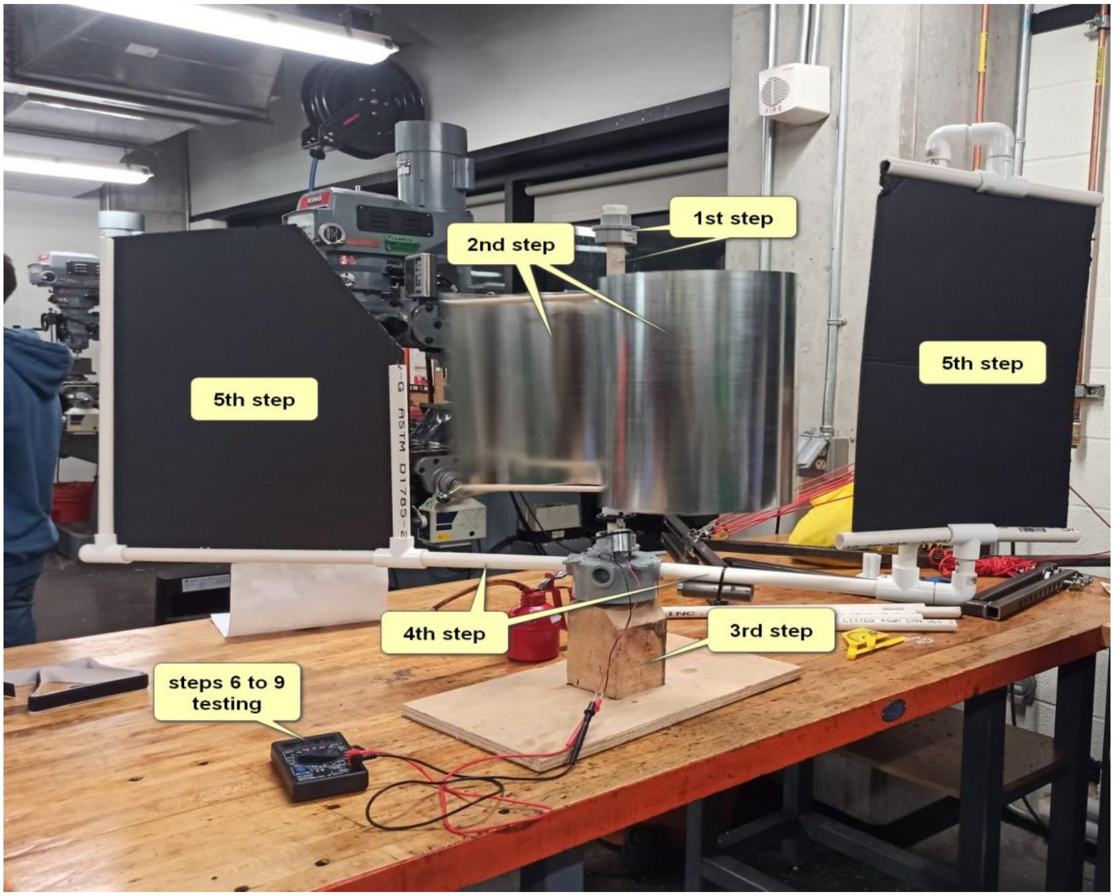

Figure 2: Wind Turbine Construction Sequence

3.2 User Access Considerations

3.2.1 General Users (End Users)

3.2.1.1 Description:

Individuals who use the turbine for personal or small-scale energy generation (e.g., powering small devices or lighting systems).

3.2.1.2 Access Permissions:

- Operate the turbine under normal conditions.
- Measure output voltage and current using provided tools.

3.2.1.3 Restrictions:

- **No modifications**: General users are not permitted to alter system components.
- **Maintenance**: Limited to basic tasks, such as cleaning the deflector and checking for visible damage.
- **Safety Training**: Must be trained to avoid physical contact with moving parts.

3.2.2 Technicians and Maintenance Personnel

3.2.2.1 Description:

Professionals responsible for system installation, maintenance, and troubleshooting.

3.2.2.2 Access Permissions:

- Assemble and disassemble all components.
- Perform inspections, repairs, and component replacements.
- Access internal electrical connections for calibration or upgrades.

3.2.2.3 Restrictions:

- **Testing Limits**: Must follow prescribed wind speed limits during testing to avoid structural damage.
- **Documentation**: All modifications or repairs must be documented for tracking purposes.

3.2.3 Engineers and Designers

3.2.3.1 Description:

Experts involved in improving, testing, or adapting the system for specific applications or environments.

3.2.3.2 Access Permissions:

- Full access to all system components and designs.

- Authority to test, modify, and enhance turbine efficiency.
- Conduct research on system performance under various conditions.

3.2.3.3 Restrictions:

- **Client Approval**: Major design changes must be approved by stakeholders or clients.
- **Safety Compliance**: All modifications must adhere to safety standards and guidelines.

3.2.4 Manufacturers and Suppliers

3.2.4.1 Description:

Entities responsible for fabricating system components and providing raw materials.

3.2.4.2 Access Permissions:

- Access to specifications for production purposes.
- Manufacture or supply parts according to design requirements.

3.2.4.3 Restrictions:

- **Proprietary Information**: Restricted from sharing or altering system designs without authorization.
- **Quality Standards**: Must adhere to specified materials and manufacturing tolerances.

3.3 Accessing the System

Since the Savonius Wind Turbine is a physical system and does not involve digital logins or software-based user IDs, the procedure for "accessing and turning on" the system focuses on operational steps, safety measures, and readiness checks.

3.3.1.1 Physical Access

Ensure that the turbine system is located in a safe, accessible, and open area where the wind can freely flow, or a fan can simulate wind conditions. Follow these steps:

- Verify permission for access if required (e.g., restricted sites or educational setups).
- Inspect the area for hazards such as obstacles, unstable ground, or electrical interference.

3.3.2 Turning On the System

3.3.2.1 Step 1: Perform Pre-Operational Inspections

- **Check Structural Components**: Ensure that the base support, blades, and shaft are securely installed and aligned.
- **Inspect Connections**: Verify that the bearing, deflector, and DC motor connections are tight and free from wear.

- **Safety Clearance**: Ensure no loose objects or personnel are within the turbine's operational range.

3.3.2.2 Step 2: Position the Turbine

- If outdoors, align the turbine to face the prevailing wind direction for maximum efficiency.
- If indoors, position a fan to direct airflow toward the blades at a safe distance.

3.3.2.3 Step 3: Connect the Electrical Components

- Attach the DC motor terminals to the voltmeter and/or ammeter to measure performance metrics.
- If connected to a load or battery system, ensure all wiring is properly insulated and securely attached.

3.3.2.4 Step 4: Initiate Operation

- Allow the wind (or fan-generated airflow) to rotate the blades.
- Monitor the initial rotation for any irregularities, such as wobbling or noise, indicating imbalance or misalignment.

3.3.2.5 Step 5: Measure Output

- Use the voltmeter to record the voltage generated by the DC motor.
- Similarly, measure the current using an ammeter to calculate power output:
  Power (P) = Voltage (V) × Current (I).

3.3.3 Changing and Resetting System Configurations

While the Savonius Wind Turbine is a mechanical system without digital interfaces, the following procedures can adapt to its functionality:

3.3.3.1 Adjusting the Turbine for Better Efficiency

- **Blade Angle**: Modify the position or curvature of the semi-cylindrical blades to optimize wind capture.
- **Deflector Adjustment**: Realign the deflector to improve airflow toward the blades.

3.3.3.2 Resetting the System

- **Shutdown**: Stop the turbine manually by securing the blades. Disconnect the motor from any load.
- **Realignment**: If performance issues arise, realign the components (e.g., blades, shaft, or bearings).
- **Reinstallation**: If major errors persist, disassemble and reassemble the system following the setup guide.

3.4 System Organization & Navigation

The Savonius Wind Turbine system is organized into a series of physical components and operational processes, each designed to ensure efficiency, ease of use, and functionality. Below is a breakdown of the system's structure, navigation paths, and primary features.

3.4.1 Main Component: The Vertical Axis Savonius Wind Turbine

The central structure comprises:

1. **Semi-Cylindrical Blades**: Capture wind energy.
2. **Vertical Shaft**: Transfers rotational energy.
3. **Base Support**: Ensures stability during operation.
4. **Deflector**: Directs wind toward the blades for optimal rotation.
5. **DC Motor**: Converts rotational energy into electrical energy.
6. **Bearings**: Enable smooth rotation of the shaft.

Users interact with these components based on their operational sequence, from assembly to energy output measurement.

3.4.2 System Functions/Features

3.4.2.1 Wind Energy Capture

Description:
The semi-cylindrical blades are the primary elements for capturing wind energy. Their design ensures efficiency by utilizing drag and lift forces.

Navigation Path/Process:

- Align blades to face the wind direction (manual positioning or deflector guidance).
- Adjust blade angles if required to optimize performance.

3.4.2.2 Rotational Energy Transfer

Description:
The vertical shaft transfers the rotational energy generated by the blades to the DC motor.

Navigation Path/Process:

- Inspect the shaft and bearings for smooth, frictionless movement.
- Ensure proper alignment with the DC motor to prevent energy loss.

3.4.2.3 Stability and Support

Description:
The base support anchors the turbine and resists torque and vibrations caused by wind.

Navigation Path/Process:

- Choose materials for the base based on the environment (e.g., steel for durability or wood for portability).
- Secure the base to the ground or mounting surface to prevent tipping.

3.4.2.4 Wind Flow Optimization

Description:
The deflector ensures consistent wind flow toward the blades, enhancing efficiency.
Navigation Path/Process:

- Adjust the deflector to capture maximum wind exposure.
- Inspect for obstructions or damages that may reduce effectiveness.

3.4.2.5 Energy Conversion and Measurement

Description:
The DC motor converts mechanical energy into electrical energy, which is then measured using a voltmeter and ammeter.

Navigation Path/Process:

- Connect the motor terminals to the measurement tools.
- Record voltage (V) and current (I) to calculate power output ($P = V \times I$).
- If connected to a load, ensure proper wiring for energy transfer.

3.4.2.6 Maintenance and Troubleshooting

Description:
Regular inspections and maintenance ensure the turbine operates at peak performance.

Navigation Path/Process:

- Inspect structural components for wear or damage.
- Clean and lubricate moving parts like bearings and the shaft.
- Test electrical connections periodically to avoid power loss.

3.4.3 Connections Between Features

- **Wind Energy → Rotation**: Wind captured by the blades drives the vertical shaft.
- **Rotation → Energy Conversion**: The shaft transfers energy to the DC motor.
- **Energy Conversion → Measurement**: Electrical output is measured for performance analysis.
- **Maintenance → System Longevity**: Regular upkeep supports long-term functionality.

This structured organization allows users to navigate the system easily, ensuring each feature functions optimally for reliable wind energy generation.

3.5 Exiting the System

Properly exiting the system ensures safety, maintains the integrity of the components, and prepares the turbine for its next use. Below are the general steps and considerations for safely shutting down and exiting the system.

3.5.1 Steps to Exit the System

3.5.1.1 Stop the Turbine's Rotation

- **Manual Braking**:
  - Gradually slow down the blades by manually obstructing the wind flow or gently holding a blade (if safe to do so).
  - Do not abruptly stop the turbine to avoid damage to components.
- **Environmental Factors**:
  - If using an external fan for testing, turn off the fan to stop the wind simulation.
  - If outdoors, shield the turbine from strong winds using a protective cover or barrier.

3.5.1.2 Disconnect Electrical Components

- Detach the DC motor's wires from the voltmeter, ammeter, or load.
- If the turbine is connected to a battery or another storage system, disconnect it according to the system’s safety guidelines.

3.5.1.3 Inspect and Secure the System

- **Visual Inspection**:
  - Check all components for wear or damage, including blades, bearings, and the shaft.
  - Verify that all bolts, nuts, and connections are tight.
- **Lubrication**:
  - If the turbine remains idle for a long period, lubricate bearings to prevent rust or wear.
  -
- **Stabilize the Base**:
  - Ensure the base support remains firmly anchored to prevent tipping during inactivity.

3.5.1.4 Store or Cover the Turbine

- For portable models, move the turbine to a safe, sheltered location.
- For fixed installations, cover the blades and motor with a waterproof and wind-resistant material to protect against environmental damage.

3.5.1.5 Record System Performance

- Document any measurements (e.g., voltage, current, or power output) for future analysis.
- Note any issues encountered during operation that may require troubleshooting or improvements.

3.5.2 Safety Considerations

- **Avoid Handling Moving Parts**: Never touch blades or other rotating components while the turbine is in motion.
- **Electrical Safety**: Disconnect electrical connections carefully to prevent short circuits or electric shocks.
- **Environmental Awareness**: If the system is in an outdoor environment, account for weather conditions when shutting it down.

Exiting the Savonius Wind Turbine system safely and effectively ensures the longevity of the components and prepares it for consistent future use.

4 Using the System

This section explains each system's function and feature in detail. The turbine's readiness and performance are determined by monitoring the power output, which eliminates the need for indicator lights. Users are guided step-by-step to ensure optimal operation, with details provided on required inputs, expected outputs, and special instructions.

4.1 Start-Up and Initialization

The start-up process activates the turbine and checks its readiness for energy production. Instead of relying on visual indicators, users monitor the power output to confirm operational status.

4.1.1 Required Input:

1. Turn ON the Power Switch:
   - Locate the power switch on the turbine base or control panel.
   - Switch it to the "ON" position to activate the generator.

2. Check Wind Conditions:
   - Ensure there is sufficient wind to start the turbine. Wind speeds of at least 2-3 m/s are typically required for rotation to begin.

3. Monitor Power Output:

   - Observe the connected power meter or display to track the output in watts (W).

4.1.2 System Output:

- The turbine blades start rotating when wind is present.
- Power output is displayed in real-time. The turbine is ready for use when the output consistently exceeds the minimum operational threshold (e.g., 1W or 800W – for actual design).

4.1.3 Special Instructions:

- If the turbine does not rotate:
  - Check for obstructions around the blades or wind vane.
  - Ensure there is sufficient wind.
- Power output below the threshold may indicate a maintenance issue or inadequate wind conditions. Refer to the troubleshooting section if necessary.\

4.2 Monitoring Power Output

Monitoring the power output is the primary method for assessing the system's functionality and performance. This feature provides real-time data, ensuring the turbine operates efficiently.

4.2.1 Required Input:

Access Power Meter or Display:

- Use the connected power meter or monitoring interface to view the output.
- Navigate to the "Power Monitoring" screen if a digital interface is available.

Interpret Readings:

- Compare the current output to the expected values based on wind speed.

4.2.2 System Output:

- Displays power output in watts (W).
- Reflects changes in wind speed and turbine efficiency.

Table 1: Expected Results

Wind Speed (m/s)	Expected Power Output (W)	Expected Power Output for Actual Design (W)
2-3	1	750 – 800
5	4	900
8	7	1000
10	10	1200

4.2.3 Special Instructions:

- Consistently low power output may indicate issues with the generator, blades, or wind deflector alignment.
- Record readings periodically to track performance trends and identify potential inefficiencies.

4.3 Manual Adjustments for Deflector and Vane

Manual adjustments allow users to optimize the deflector and wind vane to improve wind capture and energy production.

4.3.1 Required Input:

Deflector Adjustment:

- Locate the manual deflector control (knob or slider).
- Adjust the angle to direct wind more effectively toward the turbine blades.

Wind Vane Alignment:

- If the vane is not properly aligning with the wind, use the manual control to rotate it.

Monitor Changes:

- Observe the power output and rotational speed of the turbine to gauge the effectiveness of adjustments.

4.3.2 System Output:

- Increased turbine rotation speed as wind capture improves.
- Higher power output displayed on the monitoring system.

4.3.3 Special Instructions:

- Avoid frequent manual adjustments; the system is designed to handle alignment under normal conditions.
- Adjustments are most effective during low wind speeds or when the system is under maintenance.

4.4 Emergency Stop

The emergency stop function immediately halts the turbine's operation in extreme wind conditions or during emergencies.

4.4.1 Required Input:

Press the Emergency Stop Button:

- Locate the red emergency stop button on the control panel or turbine base.
- Press firmly to deactivate the system.

Verify Shutdown:

- Observe the power meter to confirm the output drops to 0W.
- Ensure the turbine blades have stopped rotating completely.

4.4.2 System Output:

- The turbine ceases operation immediately.
- The power output drops to zero.

4.4.3 Special Instructions:

- Use the emergency stop only in critical situations to avoid unnecessary wear on the system.
- Before restarting, inspect all components to ensure they are free from damage or debris.

4.5 Maintenance Check

Regular maintenance is essential to ensure the efficient and reliable operation of the wind turbine system. Key maintenance tasks include inspecting the blades for wear, damage, or debris that could reduce performance, lubricating the bearings to maintain smooth rotation, and checking the generator and electrical connections for any signs of wear or malfunction. Power output trends should be monitored regularly to identify any decreases in performance that may signal the need for adjustments or repairs. Routine cleaning of the wind vane and deflector ensures they remain free of obstructions for optimal alignment and airflow. Scheduling periodic inspections, especially in harsh weather conditions, will extend the turbine's lifespan and maintain consistent energy generation.

4.5.1 Required Input:

Monitor Power Output:

- Record power output readings at regular intervals (e.g., daily or weekly).

Inspect Key Components:

- Blades: Check for wear, damage, or debris.
- Bearings: Ensure they are lubricated and function smoothly.
- Generator: Verify connections and performance.

4.5.2 System Output:

- Consistent power output indicates the system is functioning well.
- Drops in output may lead to maintenance needs.

4.5.3 Special Instructions:

- If performance issues are detected:
  - Inspect components for damage or misalignment.
  - Refer to the troubleshooting section for guidance on resolving specific problems.
- Schedule routine maintenance based on system usage and environmental conditions.

4.6 Shutting Down the System

Properly shutting down the system prevents damage to components and ensures safe handling during maintenance.

4.6.1 Required Input:

Turn OFF the Power Switch:

- Locate the main power switch and set it to the "OFF" position.

Confirm Shutdown:

- Monitor the power output to ensure it drops to 0W.
- Verify that the turbine blades have stopped rotating.

4.6.2 System Output:

- The turbine stops generating power.
- The system is safely powered down and ready for inspection or maintenance.

4.6.3 Special Instructions:

- Always shut down the system during extreme weather or before performing maintenance.
- Ensure all components are stationary before approaching the turbine.

These detailed instructions are designed to provide users with a comprehensive understanding of the system's functions and features, ensuring safe and efficient operation.

5 Troubleshooting & Support

While constructing and testing the turbine, it is essential to account for both safety and technical considerations. This section examines potential malfunctions that may occur during these stages and suggests appropriate measures to address them effectively.

5.1 Error Messages or Behaviors

Stability:

A key concern for users is the potential instability of the turbine. Since components with varying weights are assembled, it is crucial to balance the weight in all directions. Failure to achieve proper balance can lead to turbine wobbling. Additionally, as the vane and deflector have larger surface areas exposed to the wind, they must be securely attached to the main body to prevent further instability.

Motor:

The motor must be mounted to ensure consistent contact with the gear. Improper placement may cause the motor to rotate inconsistently or stop intermittently, affecting the turbine's performance. Before testing the turbine, it is recommended to manually move the blades to observe the movements of the gears and to ensure the motor is functioning properly.

5.2 Special Considerations

1- Add weight to the pipes connecting the vane and deflector if needed to ensure the turbine remains balanced. Moreover, you can reduce or add to the length of the pipes connecting to the vane and the deflector to help balancing the turbine.

2- Ensure all parts are securely fastened. Loose connections can lead to components disconnecting or breaking during rotation.

3- Select the appropriate sizes for the gear and motor. Using gears or motors that are too large or too small can create challenges during assembly.

4- Use a sturdy foundation to support the turbine. A weak foundation can increase wobbling and compromise stability.

5.3 Maintenance

1- Regularly monitor the motor to ensure it is functioning properly and operating as expected.

2- Periodically inspect the position of the bearings inside the pipes to confirm they remain centered and have not shifted to the sides.

3- Check the wooden sticks connecting the blades for any cracks or damage. Even minor cracks can cause them to break under high-speed wind conditions.

5.4 Support

Ensuring that all parts are firmly and correctly assembled is essential for significantly reducing the likelihood of system breakdown. When working with tools in the laboratory to cut wood or pipes and assemble components, always adhere to safety protocols. Wear protective glasses and gloves at all times, and if you are unsure how to use a tool, do not attempt to use it; instead, seek assistance from someone experienced and knowledgeable. Begin testing with low wind speeds, gradually increasing the speed. If you notice excessive wobbling that appears dangerous, stop the testing immediately. For technical support, the names and email addresses of members of the Sustainable Food Storage System team are provided.

6 Product Documentation

The following 3D models was developed using shapr3D software to better visualise the design concept before building the actual prototype.

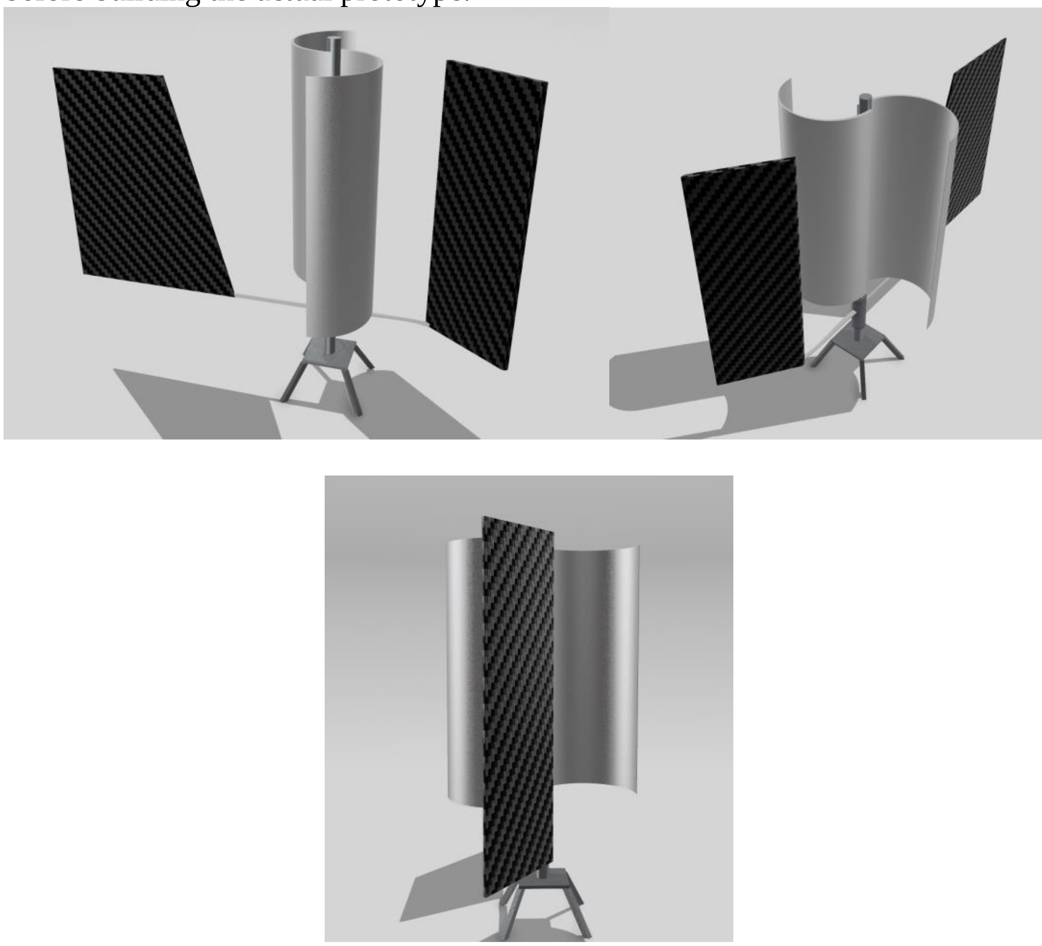

Figure 3: 3D Rendering

The mechanical design of the Savonius wind turbine was focused on creating a balance between simplicity, efficiency, and cost-effectiveness. The rotor blades were constructed from semi-cylindrical aluminum sheets due to their lightweight properties, durability, and resistance to deformation under high wind speeds. Aluminum was chosen over alternative materials such as plastic and steel. Plastic, while lightweight, lacked the strength to endure prolonged use in outdoor conditions, whereas steel, although durable, was significantly heavier, complicating the assembly process and increasing the mechanical load on the central shaft. The final blade dimensions for the prototype were 1 ft in height and 0.8 ft in diameter were determined through calculations and testing to optimize wind capture and torque generation in Ottawa's typically low-wind winter conditions.

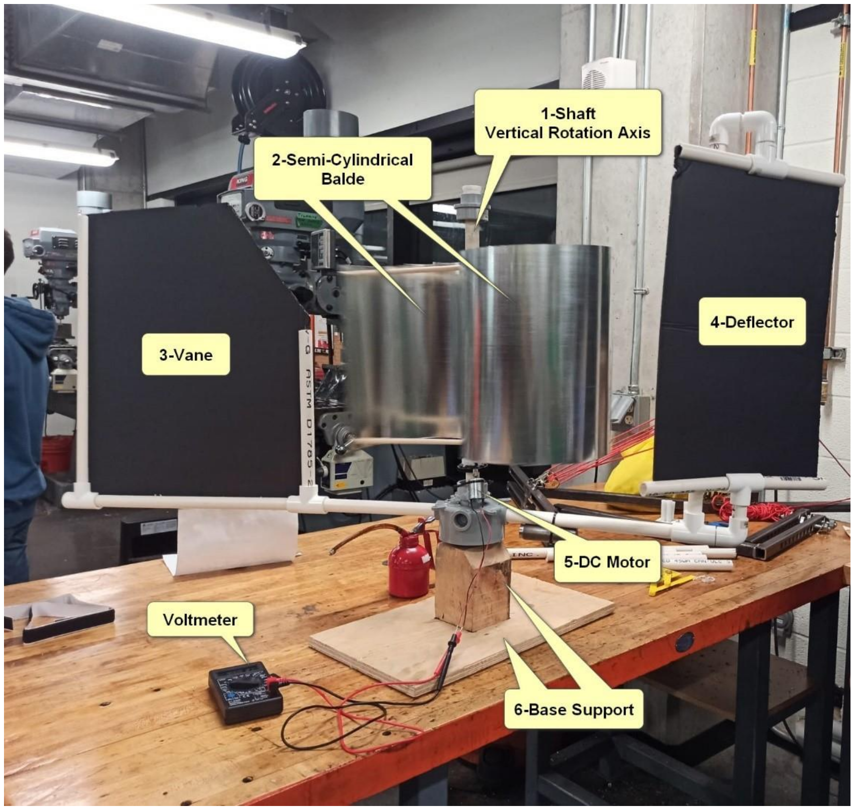

Figure 4: Product Testing

Additional features, such as the wind deflector and vane, were crucial in improving the turbine's performance. The deflector was made from foam for its lightweight properties, which allowed for quick adjustments during testing. Hardboard and plastic sheets were also considered but were ultimately rejected due to higher weight and cost concerns. Testing revealed that a 45° deflector angle maximized energy capture by directing airflow toward the concave side of the blades while reducing drag on the convex side. The wind vane ensured the turbine aligned consistently with changing wind directions, improving its adaptability and making the design suitable for varying environmental conditions.

The frame and base of the turbine were constructed using PVC pipes and scrap wood, respectively. These materials were chosen for their affordability, ease of assembly, and accessibility. Alternatives such as metal frames or plastic bases were considered but rejected due to cost and stability trade-offs. While the PVC and wood provided sufficient support for prototype testing, wobbling under high wind speeds highlighted the need for stronger materials, such as aluminum or treated steel, for future iterations. Reinforced bearings were also added to minimize rotational friction and enhance stability, further improving the turbine's mechanical performance.

The electrical design of the prototype focused on energy generation and performance measurement. A low-cost DC motor was selected as the generator due to its accessibility and simplicity. While stepper motors and specialized generator modules were considered, they were ruled out because of their higher cost and complexity, which would have exceeded the project's budget constraints. The DC motor, though limited in efficiency, successfully produced consistent power output during testing, generating up to 1.5 V under high wind conditions.

To measure the turbine's performance, the DC motor was connected to a multimeter, which recorded voltage output at different wind speeds. Soldered wire connections ensured durability and minimized electrical resistance. The simplicity of this setup allowed for efficient data collection, making it a practical choice for a proof-of-concept prototype. However, for future iterations, the inclusion of more advanced components, such as higher-capacity generators and power monitoring sensors, would improve the turbine's scalability and overall performance.

6.1 Prototype development

6.1.1 BOM (Bill of Materials)

Table 2: Bill of Materials (BoM)

Part Name	Description	Quantity	Cost (CAD $)			Location
			Price	Tax	Total	
5x30 Pipe	Central rod, Rotating platform and Support structure for the turbine	1	15.34	1.99	17.33	Home Deport
Bearing 3/4x40x12	Turbine, Platform and Supporting structure	3	6.99 (x3)	3.05	26.51	Princess Auto
6V motor	As power generator	1	2.49			
½ Pipe	Joints: Connecting turbine, bearing and the platform with the stand	1	12.98	6.70	58.22	Home Deport
PVC EL 90		3	0.62 (x3)			
1.5" x 0.75 FPT		3	10.73 (x3)			
PVC Male ADA		1	1.50			
Bushing 3/4X		2	1.10 (x2)			
PVC TEE ½"		1	0.79			

Wooden dowel set	To keep the turbine scoop, hold together	1	1.50	2.37	20.62	Dollarama
Super glue	For support as needed	1	1.25			
Gun sticks	Glue the materials as needed	1	2.00			
Tools						
Lighter	Heat up the PCV to fit as needed with bearings	1	1.50			
Glue gun	Heat the glue sticks	1	4.00			
Scissors	Cut materials	1	1.50			
Marker	To mark as needed	1	2.50			
Board	To build the vane and the deflector	2	2.00 (x2)			

6.1.2 Equipment list

1) Hacksaw/ sheet cutter/ scissors (for cutting aluminum and wood)
2) Screwdriver and wrench (assembly)
3) Measuring tape and scale (for precise measurements).
4) Electric drill (for mounting components)
5) Prototype testing equipment: fan/ leaf blower, multimeter, Protractor (angle measurement tool)
6) Lighter (Heat up the PCV to fit as needed with bearings)
7) Glue gun / glue sticks
8) Markers.

6.1.3 Instructions

Rotor Construction:

- Cut 2 aluminum sheets into 1ft x 1ft shapes.
- Drill 2 holes from the top and bottom corners of the sheet
- Get the wooden sticks cut to create the semi-circular shape and connect through the pre-drilled holes using a matching screw size.
- Secure the rotors onto the central shaft with screws at three points (top/middle/ bottom) for stability.

Figure 5: View of Turbine Blade

Central shaft & Frame Assembly:

For this prototype ½" PVC pipes were used to create the frame and central shaft

- Cut a PVC pipe of length 1.4 ft (longer that the height of the rotor blade) for central shaft.
- Insert the Gear at the bottom side of the pipe and secure the gear tightly such that there is no free movement between pipe and the gear.
- Slightly scraper off the bottom end and create 4 straight cuts on the bottom edge and squeeze the bottom end carefully to connect the bearing. (Bearing inner diameter is smaller than outer diameter of the central shaft. This creates a perfect and a secure fit with bearing and shaft.)
- Insert the shaft with connected bearing with PVC reducer coupling and connect a 0.5ft length PVC pipe from bottom side of the reducer to extend the central shaft

Figure 6: Connector

- Drill a ½" hole in the 4-way electrical coupling and insert the extended central shaft rod through the hole

Figure 7: Type 4 Connector

- Insert the larger bearing inside the 4-way coupling and fit with the extended central shaft
- Cut 2 PVC pipes 1ft approx and connect on the opposite direction of the 4-way coupling connector points to join the vane and deflector.

Base Construction:

- Cut 2 pieces of wood into the specified dimensions and reinforce it to hold the PVC frame. Base should be considerably heavy and wide enough to withstand the rotation of the rotor at higher wind speeds.
- Drill a hole all the way through the upper wooden block.
- Insert the extended part of the central shaft and secure.

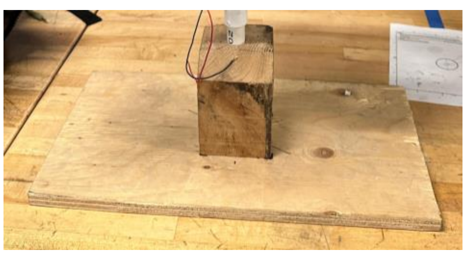

Figure 8: Base Plate

Wind Deflector and Vane:

- Cut the foam into 1.2ft x 0.8ft rectangular shape for the deflector.
- Cut 1.5ft x 1.2ft foam piece for the wind vane (Wind vane should be bigger and heavier than the deflector)

Figure 9: Vane

- Cut PVC pipes to match the height and lengths of vane and deflector.
- Create a small groove on the PVC pipes such that foam can be inserted to the PVC pipe. This behaves as a stabiliser for vane and deflector.
- Attach the deflector and vane with the full structure.

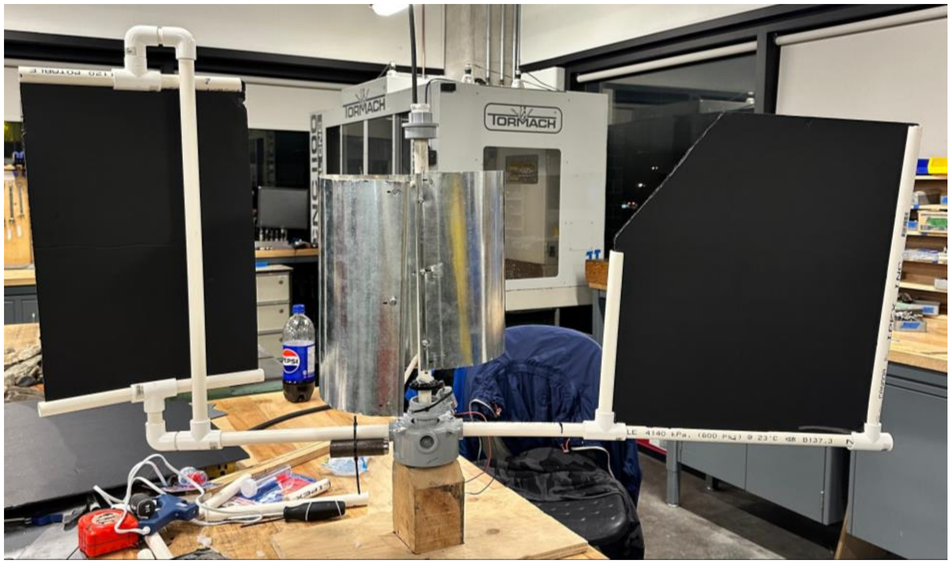

Figure 10: Final Product

Electrical Connections:

- Mount the DC motor at the base of the rotor and get the motor gear teeth connected with central shaft gear. It is critical that both gears are connected perfectly with each other in order to transfer the torque generated by the turbine effectively to the motor.
- Connect the motor to a multimeter to measure power output.
-

6.2 Testing & Validation

The testing phase focused on evaluating the efficiency, stability, and durability of the Savonius wind turbine prototype under various wind conditions. Key performance metrics such as power output, rotational speed, stability, and wind deflector effectiveness were measured and compared to target specifications. The enhanced prototype, which included a wind deflector and vane system, demonstrated significant improvements over the basic design. The results met or exceeded most targets, though some areas required further refinement.

Table 3: Power Output Comparison

Test Condition	Target Output (Volts)	Actual Output (Volts)	Improvement (%)
Low wind speed	0.82	0.97	18.3
Medium wind speed	1.02	1.21	18.6
High wind speed	1.11	1.45	**23.4**

Table 4: Deflector Angle Optimization

Deflector angle	Speed setting	Targeted Power Output (Volts)	Actual Power Output (Volts)
Deflector at 30°	Low	0.7	0.69
	Medium	1.0	1.02
	High	1.2	1.25
Deflector at 45°	Low	0.9	0.97
	Medium	1.2	1.21
	High	1.4	1.45
Deflector at 60°	Low	0.6	0.61
	Medium	1.0	1.08
	High	1.3	1.22

Table 5: Stability and Wobble

Test Condition	Target Stability	Actual Stability	Wobble Observation (Degrees)
No Wind (Manual Test)	Smooth rotation	Minimal wobble rotation	< 2
Low Wind Speed (Fan Test)	Minimal wobble	Little wobble with stable operation	< 5
High Wind Speed (Fan Test)	Stable operation	Wobble with stable operation	< 10

Conclusions and Recommendations for Future Work

6.3 Recommendations

To enhance the performance and stability of the Savonius Wind Turbine, the following improvements are proposed:

6.3.1 Improving Turbine Stability

Challenge: The current design may lack sufficient stability under high wind speeds, potentially leading to vibrations of wind turbine.

Solution: Focus on optimizing the base and joint connections to ensure the turbine remains secure and balanced during operation.

6.3.2 Enhancing Joint Stiffness

Current Material: PVC pipes are used for joints, which are flexible but not stiff enough for long-term stability.

Proposed Improvement: Use aluminum pipes for joint connections, as they are significantly stiffer and more durable than PVC. aluminum offers a lighter alternative without compromising strength.

Expected Benefit: Increased stiffness reduces vibrations, improving the turbine's performance and lifespan.

6.4 Future work

6.4.1 Developing a More Stable Prototype

For future, design and construct a new prototype using aluminum or steel components for critical parts. Incorporate precision-engineered joints to enhance alignment and reduce stress concentrations.

6.4.2 Increasing Power Output

Current Limitation: The existing turbine uses a smaller DC motor, limiting its energy generation capacity.

6.4.3 Proposed Upgrade:

Use a larger DC motor capable of handling higher torque from the rotor.

Expected Benefit: The larger motor will generate higher electrical power output, making the system more efficient for practical applications.

6.4.4 Testing and Validation

field tests to evaluate the stability of the improved prototype. Measure power output to verify the impact of the larger DC motor.

6.4.5 Additional Considerations

Cost Analysis: While steel and aluminum improve stiffness, they may increase costs. Consider aluminum for its lightweight properties if portability is needed.

6.4.6 Environmental Conditions:

Select corrosion-resistant materials or apply protective coatings to ensure durability in outdoor conditions. By implementing these improvements, the turbine's efficiency, durability, and performance will be significantly enhanced, paving the way for more robust prototypes and real-world applications.

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8 APPENDIX I: Design Software Used