

Integration of Vertical Axis Wind Turbines into Urban Environments: Feasibility and Design Considerations

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Abstract

This study aims to comprehensively investigate the performance of Savonius rotor wind turbines through a combination of numerical simulations and experimental testing. Initially, 3-dimensional CAD software SolidWorks and ANSYS will be utilized to design detailed models of the turbines. Numerical meshes will then be generated around these models using FLUENT software, incorporating the k-ε turbulence model to simulate fluid flow fields. Parameters such as drag coefficient, lift coefficient, pressure contours, velocity contours, and torque coefficient will be determined across various wind speeds. Subsequently, numerical power coefficients will be calculated based on the torque coefficients obtained. Additionally, scale models of Savonius rotor wind turbines will be designed and fabricated, optimized for blade numbers and shapes. Experimental measurements of torque in front of the turbines will be conducted using dynamic torque sensors at different wind speeds, allowing for the calculation of torque and power coefficients from empirical data. Finally, a comparative analysis between numerical and experimental results will be carried out to assess the accuracy and reliability of the simulations.

Keywords: Wind Mill, CAD, fossil fuel reservoir, Savonius Types VAWTs, wind energy.

INTRODUCTION

The capacity of natural resources is put under real strain due to the simultaneous increase in population and energy demand; on the other hand, the use of fossil fuel resources for energy is becoming increasingly limited due to the depletion of fossil fuel reservoirs, which poses a threat to global warming, and the rise in oil prices. As a result, using clean and renewable energy sources is increasingly becoming a major global research priority [1].

It has long been known that wind energy may contribute significantly to the production of power from renewable sources. Worldwide recognition of the significance of wind energy resources has led to their classification as one of the most alluring renewable energy alternatives in terms of both environmental impact and cost-effectiveness. Because vertical axis wind turbines (VAWTs) are omnidirectional, they can capture wind energy in any direction. This is a VAWT's main benefit over a horizontal axis wind turbine [2].

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LITERATURE REVIEW AND METHODOLOGY

Vertical Axis Wind Turbines (VAWT)

The rotational axis of the VAWT turbine is oriented vertically. With low cut-in wind speed, VAWTs can generate electricity from wind in any direction. These turbines are lightweight, easily fitted into structures, and much quieter than the conventional HAWTs. With the exception of Darrieus types, these turbines are based on aerodynamic drag forces. The goal of the study on

these turbines is to increase the lift forces and decrease the drag effect in order to increase aerodynamic efficiency. They were expected to be a viable option for populated areas experiencing erratic wind patterns. The VAWT can be designed as a Savonius Turbine [3].

Savonius Types VAWTs

This kind of turbine was created in 1920 by Finnish engineer Savonius, primarily using drag force. This is the most basic WT with a low cut-in wind speed; typically, it is made up of two half cylinders oriented so that they nearly form an S shape while facing different directions (Figure 1). When compared with other turbines, this design's low aerodynamic performance is its primary shortcoming. If power dependability is more important than turbine efficiency or COE, Savonius might be the better option. Savonius is now an efficient WT design for cities because of concentrated work that includes changes to the rotor design, blade shape, blade overlap, and number of blades. The rotor design and torque production of these turbines are distinctive. The rotor design configurations affect the power coefficient.

With a two-bladed Savonius turbine, Roy and Saha carried out a number of wind tunnel tests that were primarily intended for small-scale power applications. To compare these results, the simultaneous experiments were also run with different blade configurations. A noteworthy 34.8% increase was noted for the two-bladed Savonius rotor. Roy and Saha used computational techniques to investigate the Savonius operating parameters in a later investigation. It was observed that the turbine is spun by the differential drag force, which is also the main cause of the poor aerodynamic effect. Additionally, attempts have been made to reduce the drag impact by altering the number, position, and overlap of the blades. The power coefficient is affected by variations in the number of blades, and three blades produced the greatest results [3].

Performance of Savonius Turbines

The Savonius is another conventional VAWT design. The Savonius rotor, as previously shown, is a drag-type device with two or more blades (Figure 1). These turbines' low cut-in wind speed, self-starting capabilities, and acceptability have helped them to some extent, although their rotational performance and overall efficiency are poor. After conducting a thorough investigation on Savonius turbines, I came to the valuable conclusion that this kind of machine's variety of rotor designs is one of its best features. The rotor geometry, the nature of the air flow, and the operating environment all impact the aerodynamic performance. The power coefficient of the various Savonius designs varied and was assessed between 0.05 and 0.30. Roy and Saha examined these turbines' performance evaluation techniques.

They came to the conclusion that using computational approaches can be a low-cost, high-impact approach to advancing Savonius design. Additionally, attempts have been made to improve aerodynamic

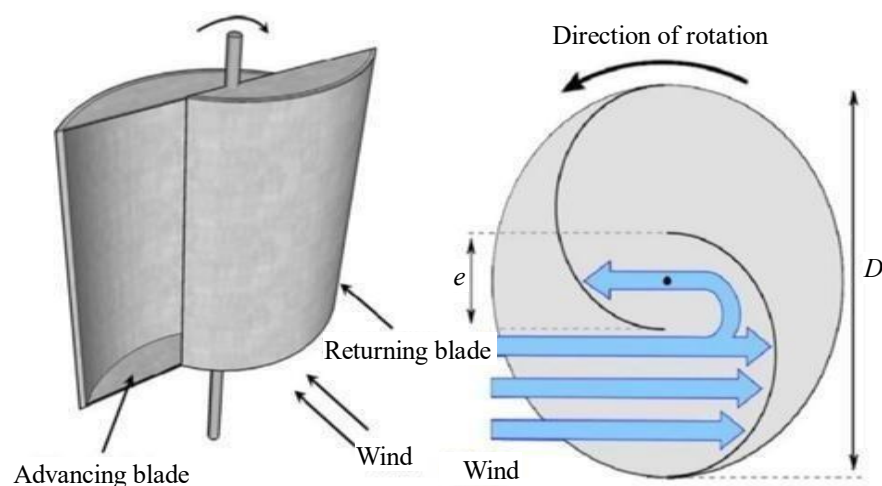


Figure 1. A sectional view of Savonius turbine and operational mechanism [3].

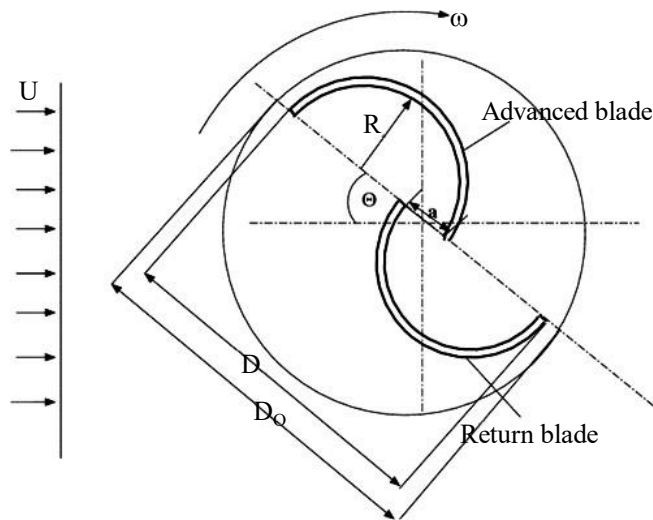


Figure 2. Savonius rotor dimension.

efficiency. Analysis was also done on the changes to the blade's size, shape, and orientation. It was suggested that by using the right computational techniques, the design, aerodynamic efficiency, and power coefficient may all be enhanced [4]. Savonius Rotor Dimension is shown in Figure 2.

System Design

Block diagram of proposed system is shown in Figure 3.

1. Wind energy, derived from the kinetic energy of moving air masses, is captured using blades mounted on wind turbines.
2. These turbines drive a dynamo, converting the mechanical energy into electrical energy through electromagnetic induction. The XL6009 converter boosts the voltage of the generated DC electricity to higher levels for various applications.
3. Batteries store excess electricity for later use during periods of low wind speeds, ensuring continuous power supply.
4. Inverters then convert the DC output into AC electricity, suitable for powering electrical appliances or connecting to the grid.

HOW IT WORKS

Wind energy is converted into rotational energy by a windmill's blades. A windmill's blades are aerodynamically designed to maximize wind energy and convert it into rotational energy, which causes

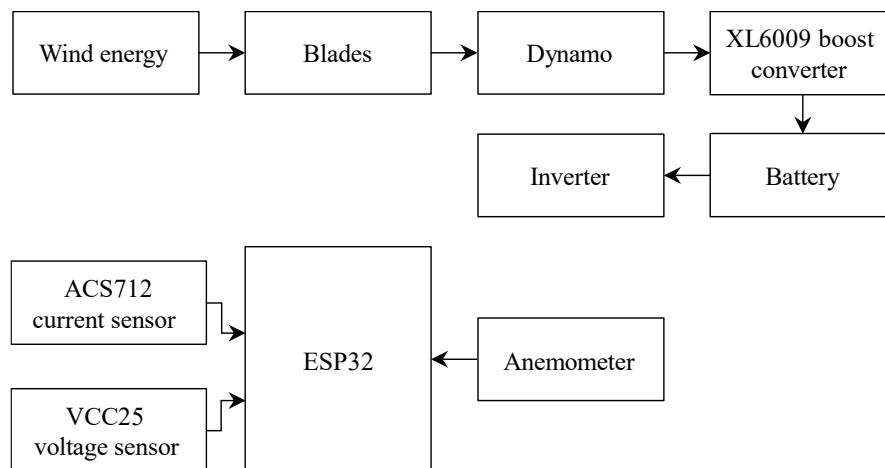


Figure 3. Block diagram of vertical axis wind mill working.

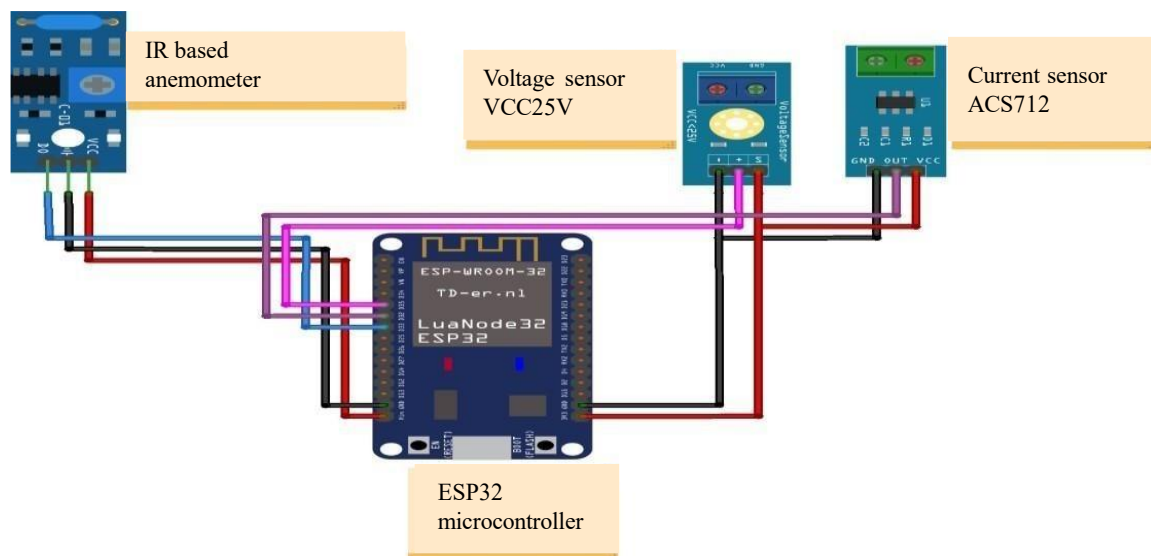


Figure 4. Hardware setup.

the blades to spin. The windmill is constructed with multiple blade variations; the windmill used in this study has three blades. These blades are connected to a generator, which converts the mechanical energy from the spinning blades into electrical energy via a bearing that turns the shafts. Devices may be powered by the electricity once it has been generated and is prepared to be connected to the local grid.

An inverter, which stores the electricity produced by the turbine, is needed for power storage. The circuit is designed to switch electricity from the inverter to the load when there is not enough wind for the windmill. This produces an endless supply of sustainable energy. The blade twists or shreds the wind depending on the conditions. It is well known that the efficiency of the aforementioned mechanical converter to convert the raw wind power into a significant amount of rotational energy ordered by the mill's blades depends, in part, on the proper shaping of the blades and the proper alignment of the mill's physical axis in fences.

The system uses an ESP32 microcontroller to measure variables like voltage via VCC25, current via ACS712 [5, 6], and wind speed via anemometer sensors. Data can also be stored in the cloud using IOT. Hardware setup is shown in Figure 4.

The ACS712 current sensor monitors current flow within the system, facilitating precise control and optimization.

1. The VCC25 voltage sensor measures voltage levels to ensure the system operates within safe limits.
2. The ESP32 microcontroller enables data acquisition, control, and communication tasks for remote monitoring and management.
3. Anemometers measure wind speed and direction, crucial for assessing wind resource availability and optimizing turbine performance.
4. Collectively, these components form an integrated process for efficiently harnessing, converting, storing, and utilizing wind energy in sustainable renewable energy systems.

ADVANTAGES

Benefits of VAWT Since VAWTs are more often erected with the lowest bearing mounted close to the ground, a huge tower structure is employed less frequently. Fixed-pitch rotor designs allow for designs without yaw systems. Compared with HAWTs, VAWTs have slower wind start-up speeds. They usually begin to produce power at a speed of 6 M.P.H. (10 km/h). There might be less noise signature in VAWTs [7–9].

DISADVANTAGES

The drawbacks of VAWT Mostly because of the extra drag they experience as their blades rotate into the wind, VAWTs only generate energy at half the efficiency of HAWTs. Although the parts of VAWTs are on the ground, they are also supported by the weight of the structure above them. If this structure is not designed correctly, this can make replacing parts very impossible without disassembling the entire thing. VAWTs might not generate as much energy at a particular location as a HAWT with the same footprint or height because their rotors are positioned close to the ground, where wind shear causes wind speeds to be lower.

Because VAWTs are not widely used, mostly because of the severe drawbacks listed above, they seem unusual to anyone who is not familiar with the wind sector. Over the past 50 years, this has frequently led to their becoming the target of exaggerated claims and investment scams [10].

CONCLUSION

Remote locations that are not connected to the integrated electrical grid systems can benefit economically from the use of VAWTs. The design of the blades is essential to the turbine's operation and energy extraction. The issues with different designs, such as poor self-starting and low initial torque, low coefficient of power, and poor building integration, need to be resolved in order to increase the use of VAWT. VAWTs can generate high power and serve as an energy generation unit for remote areas if they are installed in a location with moderate wind availability and have optimal blade parameters and design specifications.

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