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A Review On: Power Generation using Hybrid Force Driven Vertical Axis Wind Turbine

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ABSTRACT

In order to overcome the recognised efficiency range of 20% to 40%, the goal of this research programme is to introduce hybrid force techniques that will considerably improve the efficiency of Vertical Axis Wind Turbines (VAWTs). Because VAWTs convert wind kinetic energy directly into electrical power, they are a key component of the renewable energy landscape. This project's main objective is to increase these turbines' efficiency, by the employment of Magnetic Pistons along with Permanent Magnet DC Generator.The core of this work is a comprehensive investigation of novel approaches to maximise VAWT performance. Through exploration of new ground and incorporation of hybrid force principles, the research aims to transform the conventional design and operation of these turbines. In order to optimise the conversion of wind energy into electrical power, this complex project involves a thorough examination of innovative approaches and state-of-the-art technology. If successful, this might push the efficiency margins of VAWTs beyond their current limitations.By significantly increasing VAWTs' overall efficiency, the project's ultimate goal is to develop a more sustainable energy ecology. The goal of this project is to fulfil the growing need for cleaner, more efficient energy sources worldwide, advance renewable energy technologies, and accelerate the continuous shift to a more ecologically aware future. This research intends to play a key role in guiding mankind towards a more sustainable and environmentally friendly energy paradigm by effectively harnessing wind power.

Keywords: Hybrid Forces, Magnetic Pistons, Permanent Magnet DC Generator, Vertical Axis Wind Turbines.

INTRODUCTION

Vertical axis wind Turbines are widely employed for use in the form of hubs for renewable energy technology innovation because of their omnidirectional wind capture capabilities, low wind efficiency, simplicity of maintenance, and minimal visual and acoustic effect. This study explores the impact of incorporating a slotted airfoil blade into a Darrieus vertical axis wind turbine (VAWT) using computational fluid dynamics (CFD) simulations. The below is a schematic diagram of flow over air foil; a- cleanair foil, b- air foil with slot.

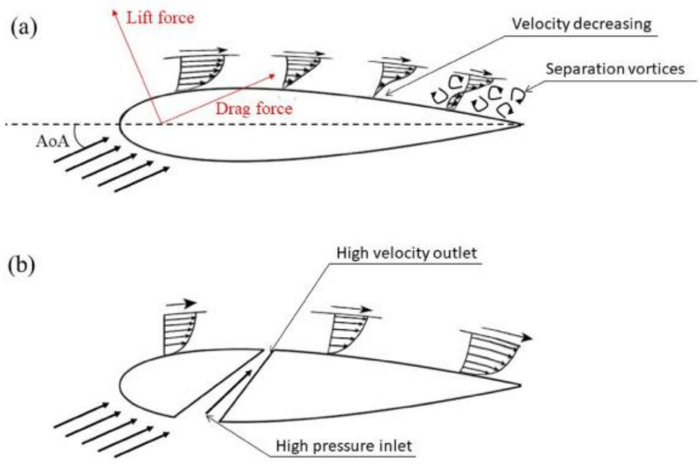

Fig. 1. Schematic representation of flow over air foil; a- cleanair foil, b- air foil with slot

The research begins by evaluating different slot configurations on a NACA0018 airfoil across various angles of attack to refine slot parameters for optimal lift. The resulting optimized slotted airfoil configuration demonstrates a notable improvement in the turbine's torque and power coefficients at low tip speed ratios, surpassing a baseline airfoil. We study the variation of lift coefficient and drag coefficient on the air foil and thus analyze the below characteristic curve.

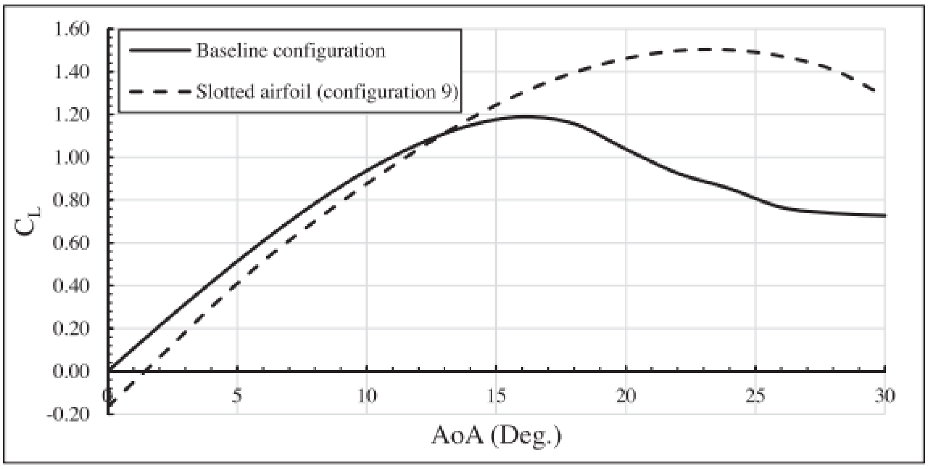

Fig. 2. Predicted characteristic curve of lift coefficient with angle of attack for selected slotted air foil

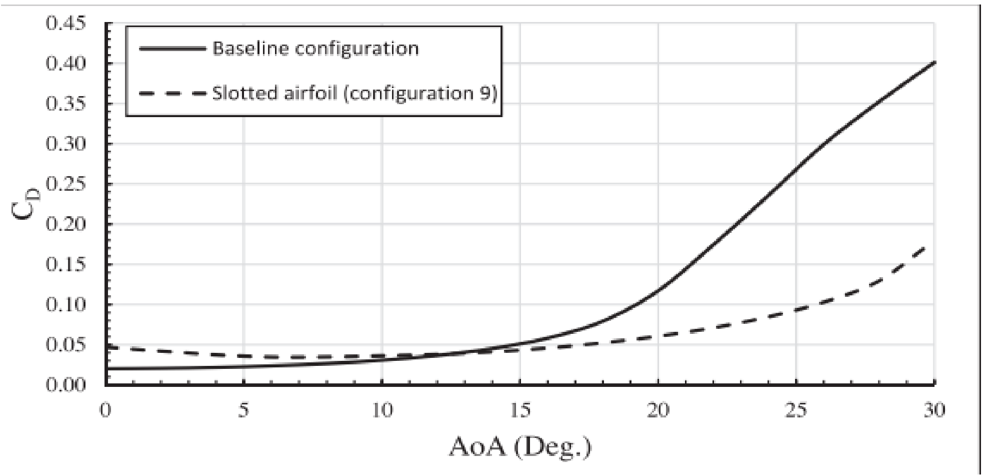

Fig. 3. Predicted characteristic curve of drag coefficient with angle of attack for selected slotted air foil

However, performance diminishes at high tip speed ratios. The integration of the slotted airfoil enhances the turbine's starting capability and static torque [1].Multiple types of wind turbines are available, but the major types of wind turbines are categorized based on the axis of rotation and the aerodynamic force.

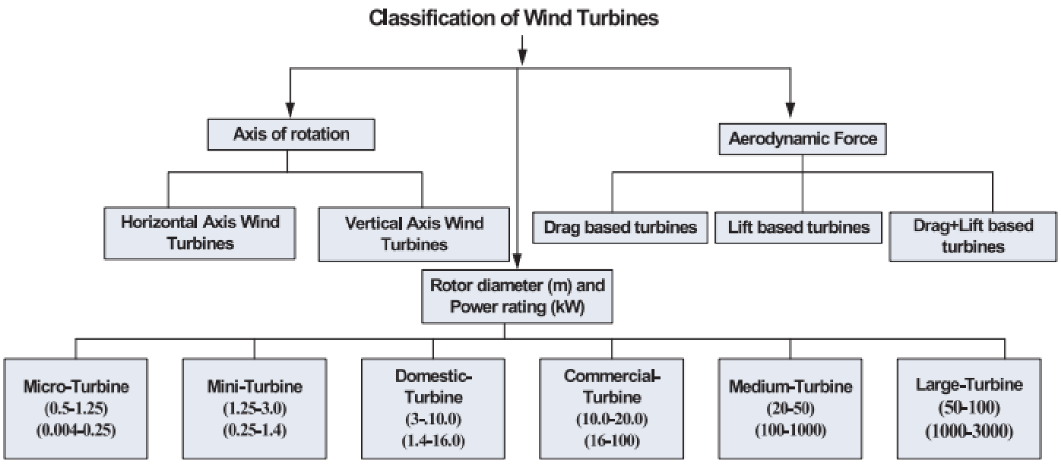

Fig 4.Classification of wind turbines

The applicability of vertical axis wind turbines (VAWTs) in urban settings, categorizing wind turbines based on axis orientation and force mechanisms (drag or lift). Emphasizing the advantages of VAWTs in urban environments, such as resilience to turbulent winds, reduced noise, safety, and aesthetic integration, the document acknowledges challenges, notably lower energy efficiency compared to horizontal axis turbines. The discussion covers extensive research on VAWT aerodynamics, materials, modelling, testing, and performance validation. Despite substantial progress, there remains a need for further refinement in designs, cost reduction, and the development of effective methods for assessing wind resources in urban areas [2].

The performance of a crossflow wind turbine by conducting experiments with varying numbers of blades. The study involved testing a 0.4 x 0.4 m^2 crossflow turbine equipped with 8, 16, and 20 blades across wind speeds ranging from 2 to 5 m/s. Parameters such as the turbine's power coefficient (CP), torque coefficient (CT), and tip speed ratio (TSR) were thoroughly examined. The findings indicated that the 16-blade configuration exhibited the most favorable performance, achieving a peak CP of 0.21 and a maximum output power of 2.01 Watts.

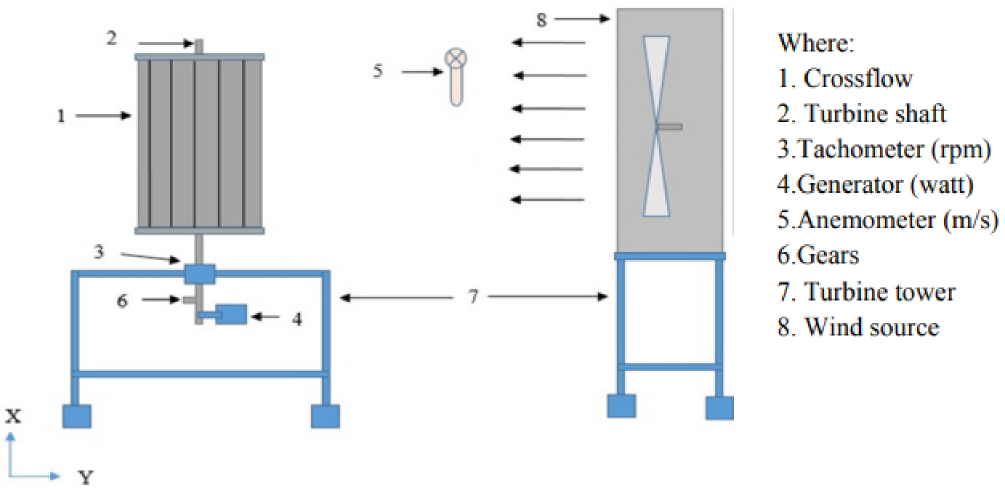

Fig 5. Schematic experimental apparatus of crossflow turbine testing

Generally, augmenting the number of blades up to 16 enhanced the turbine's efficiency, but surpassing 16 blades did not yield additional advantages[3]. A design investigation into propeller hydrokinetic turbines, aiming to assess the optimized blade geometry for various blade counts. The design methodology employs classical blade element momentum theory (BEMT) and Glauert theory to identify optimal blade shapes. The study utilizes BEMT simulations and small-scale wind tunnel experiments on turbine models featuring two, three, and four blades. The findings indicate that, specifically for a low-rotational-speed hydrokinetic machine (HK-10), the four-blade configuration achieves the highest power coefficient near the design operating point when compared to two- and three-blade setups. This implies that, for slower hydrokinetic machines, designs incorporating more blades prove more advantageous in terms of machine performance and starting torque characteristics [4]. An electromagnetic engine's design and operation based on magnetic repulsion between a permanent magnet and an electromagnet. In this system, the permanent magnet is affixed to the piston head, while the electromagnet resides atop the cylinder.

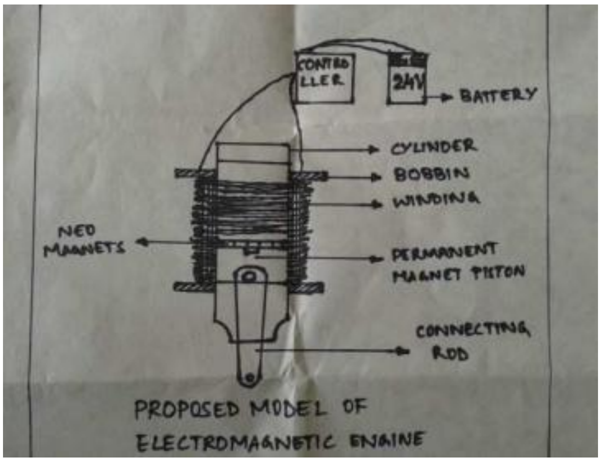

Fig 6. Proposed Model of Electromagnetic Engine

Activation of the electromagnet induces either attraction or repulsion, propelling the piston in an up-and-down motion, thereby rotating the crankshaft and generating power without relying on combustion. The paper delves into the electromagnetic engine's components, such as the permanent magnet, cylinder, and power generation system, offering calculations to ascertain maximum force and torque. Additionally, it conducts a comparative analysis of the engine's performance and advantages against traditional combustion engines [5]. A magnetic piston engine is made and operates. It is made up of several parts, including the electrodes, power source, magnetization unit, cylinder, piston, and bearing. The engine operates based on the attraction and repulsion of electromagnets and permanent magnets. The electromagnets' magnetic force acts onto the piston that is permanently magnetised as current flows through them, resulting in reciprocal motion that eventually transforms into rotary motion. The many parts, their construction, their method of operation, and its benefits—such as not using fossil fuels or causing pollution—are covered in the text. It also discusses future development possibilities and possible uses in vehicles, locomotives, power generation, etc. The study conducted to produce magnetic piston engine prototypes is presented in this academic publication. It highlights the research of several writers who have written in this field and examines them. Along with the main findings and outcomes, each study's aims and methods are discussed. Without utilising any fuel, several writers were able to effectively develop, produce, and test simple engine models based on magnetic repulsion principles. The paper also describes the future scope and possible uses in cars, trains, and as generators [6]. Describes how a DC machine may be used to simulate a wind turbine's production curve. The system comprises of a variable frequency drive that gets the speed setpoint from a computer and uses it to control an asynchronous machine (ASM). A DC generator is mechanically connected to this ASM. To simulate the production curve of the turbine, the produced voltage of the DC generator is adjusted using a DC/DC converter. The ASM's speed replicates the properties of the wind resource. The mimicked curve is used to create a voltage for every speed point. Ultimately, a steady 48V DC bus is reached by regulating the voltage that the DC machine produces. There are descriptions of the DC generator and DC/DC converter models [7].

A dynamic study of a single-rotor wind turbine, which consists of an electric generator that rotates counter-clockwise, a fixed axis speed increaser, and a wind rotor. Using the linear properties of the generator and wind rotor as well as the dynamic equations of rigid bodies, the authors create an analytical model of the mechanical system. They provide a technique for figuring out wind speed-dependent coefficients for wind rotor features. Simulink simulations demonstrate how kinematic parameters, torques, and powers of system shafts change over time, along with mechanical efficiency, in response to varying wind conditions. It is discovered that the efficiency of counter-rotating generators is higher than that of ordinary generators [8]. A novel maximum power point tracking (MPPT) control system that takes wind turbine dynamic performance into account is proposed for variable-speed wind turbines (VSWTs). Blade-pitch angle servo control and torque error feed-forward control are combined in this approach. Newton-Raphson is used to estimate wind speed and tip speed ratio, while an unscented Kalman filter is used to estimate aerodynamic torque. The feed-forward signal is the difference between the estimated and ideal torque, and the feed-forward path's gain parameters are controlled according to the speed of the generator. At non-optimal sites, the blade-pitch angle is optimised using the estimated tip speed ratio. The new approach outperforms traditional MPPT control in terms of dynamic reaction and energy collection, according to simulation findings on a 5 MW turbine[9]. A method that uses observed typhoon data to simulate the dynamic reactions of wind turbines during typhoons. Typhoon "Hagupit" measurement data is used to fit the power spectrum, which produces the varying wind field in the eyewall region. Software is used to develop a 6 MW wind turbine model and calculate its aeroelastic response under simulated typhoon winds at various yaw angles. The combined effects of aerodynamic, inertial, and structural stresses cause the blade to vibrate greatest at a 30 degree yaw angle, according to the data. At both 30 and 120 degree yaw angles, the tower load surpasses the design limitations. Analogous patterns are obtained when a 2MW turbine model is simulated. Typhoons are non-stationary, as evidenced by analysis of instability frequencies [10].

A MATLAB model and simulation of a wind turbine including blades, generator, and other parts is presented. The wind turbine's dynamics are simulated, encompassing the blade modelling that relies on blade element momentum theory. It is investigated how well the turbine performs at different wind speeds. The simulation results show that developed controllers may be used to regulate the rotor output voltage [11]. The effort to create a vertical axis wind turbine system for power generation is described in this publication. A DC generator, charge controller, 12-volt battery, DC to AC inverter, and step-up transformer are all part of the system. Wind energy is transformed into electrical energy by the generator. The charge controller controls charging and keeps the battery from being overcharged. The battery's DC energy is converted to AC via the inverter. The AC voltage is raised by the step-up transformer to the required level to power loads [12]. The design and implementation of an open-loop wind turbine emulator based on a wind turbine simulator modelled in MATLAB/Xilinx System Generation (XSG) environment. The emulator consists of a 300W DC motor powered by a DC/DC buck converter controlled by a pulse-width modulation signal from an FPGA board. The rotational speed of the motor is used to emulate different wind velocities. A hardware test bench was built to validate the simulation results. Linear and sinusoidal wind profiles were modelled and the static and dynamic characteristics of the wind turbine followed the wind profiles in simulations. Experimental results showed the emulator could react similarly to real wind conditions [13].

The generator's size is decreased by using a speed-increasing gearbox, but the wind turbine's overall efficiency is also decreased. In small wind farms, gearless designs—where the wind turbine is installed directly on the generator shaft—were created to lower costs and improve the efficiency of turning wind energy into electricity. Due to the huge diameter of the generator, such direct drive systems mandate the construction of multi-pole generators with moderate rotating speeds.The generator's rotor the generator is shaped like a circle and has a steelsteel rim that is bonded to a neodymium rotor that is also shaped like a circle [19–22]. The ring-shaped magnets are bonded to the 5 mm high by 20 mm broad magnets [19–22]. The magnets have ring-shaped segments, measure 5 mm in height and 20 mm in width, and are magnetised radially [14]. WTGs require a variety of control tasks in order to perform dependably throughout various operational zones, hence the GFM control should be designed specifically for WTGs. The most recent advancements in GFM controls, such as virtual synchronous machine-based GFM, virtual inertia control-based GFM, and multi-loop and single-loop GFM, are reviewed in this paper's study of GFM controls for WTGs. Next, an illustration of a comparative study for these GFM-based WTGs is given. Wind turbines have complicated control systems with several operating zones and control functions like voltage-ride through control, constant torque/speed control, and maximum power point control, etc.Two forms of GFM controls—multi-loop control and single-loop control—are categorised in each category based on the grid-forming controller's inner control loop. By permitting DC-link voltage fluctuation within an acceptable range, the DC-link voltage regulators simulate the synchronous generator's inertia support. This feature has been dubbed virtual inertia control, inertia synchronous control, and power synchronous control[15].

CONCLUSION

In this paper, we have analyzed about the Types of Wind turbines present, The effect of Lag and drag forces on the blades of Vertical Axis Wind Turbine.The construction of Magnetic Pistons and the design of Electromagnetic Engine.A study on the usage of Single-Rotor Wind Turbine along with the generator. The effect of decrease in the size of generator in Wind Turbine. Thus, we aim to Improve the overall efficiency of the vertical axis wind turbine by analyzing the above papers and trying to implement the gap analysis in our project.

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