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IMPACT OF FLOW ALTERATIONS WITH WIND REDUCERS

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ABSTRACT

The use of flow over wind reducers is a novel method for improving wind turbine efficiency and lowering risk. Enhancing energy collection, decreasing turbulence-induced stress, and addressing noise problems are all possible because to these devices' ability to intentionally modify the flow patterns of incoming wind. Using wind reducers helps make wind energy more accessible to more people in more places, including large-scale wind farms, metropolitan regions, and rural locations. The power generated by the wind is proportional to the wind's speed. Wind speeds were measured at a variety of altitudes for a 300-degree slope wind reducer. The speeds were measured simultaneously at uniform heights on a flat surface. Wind speed and force were measured using a micro-mini vane anemometer. According to the data, the top of the reducer has a wind speed that is 1.35 times lower than the bottom. Around 300 degrees, you'll see the biggest jump. Since the power is multiplied by 3.38, a typical wind mill has dimensions of 10 feet in height, 300 feet in slope, and 10 feet in length.

Keywords: Wind reducers, Slope, Speed, Velocity, Energy

I. INTRODUCTION

Flow over wind reducers is a topic of paramount importance in the realm of wind energy and fluid dynamics. As the world grapples with the escalating concerns of climate change and the need for sustainable energy sources, harnessing the power of the wind has emerged as a critical solution. Wind turbines have become synonymous with renewable energy generation, but they are not without their challenges. One such challenge is the aerodynamic interaction between the rotating blades and the oncoming wind, leading to inefficiencies, noise, and structural stress. To mitigate these issues, wind reducers have garnered significant attention in recent years. These innovative devices, often positioned in front of wind turbines, alter the flow characteristics of the incoming wind, optimizing energy conversion and reducing the environmental impact. In this comprehensive exploration, we delve into the intricate world of flow over wind reducers, unveiling their fundamental principles, design considerations, real-world applications, and their indispensable role in advancing the clean energy revolution.

Flow over wind reducers, a relatively nascent but rapidly evolving field, represents a confluence of engineering, physics, and environmental science. As the demand for renewable energy surges, wind turbines have proliferated across landscapes, from remote wind farms to urban rooftops, as iconic symbols of clean power generation. However, these colossal structures face several challenges that hinder their performance and integration into various environments. The interaction between the rotating turbine blades and the wind can induce a range of adverse effects. These include aerodynamic losses due to the generation of turbulence, excessive noise emissions, and structural fatigue caused by fluctuating loads. To address these issues, wind reducers have emerged as innovative solutions designed to modify the flow pattern of the incoming wind, optimizing the energy capture process and mitigating negative impacts.

At the heart of flow over wind reducers lies the profound understanding of fluid dynamics, particularly the behavior of air when it encounters obstacles and changes in velocity. By strategically manipulating these flow patterns, wind reducers hold the potential to unlock substantial gains in wind energy efficiency. Moreover, their implementation can pave the way for the expansion of wind energy generation into previously untapped regions, reducing our reliance on fossil fuels and curbing greenhouse gas emissions. The significance of flow over wind reducers extends beyond mere theoretical concepts. It encompasses a diverse range of practical applications, from large-scale wind farms to small-scale distributed energy systems. As the technology matures and becomes more accessible, it promises to democratize the benefits of wind energy, making it a viable option for communities and industries worldwide. However, this journey into the intricacies of flow over wind reducers must begin with a foundational understanding of the underlying principles governing their operation.

In essence, wind reducers act as precursors to wind turbines, modifying the incoming wind to create conditions that are more favorable for energy conversion. They are designed to redirect, reshape, and condition the wind flow before it encounters the turbine blades, thereby optimizing their performance. These devices come in various forms and sizes, tailored to specific environmental conditions and project requirements. While some are attached directly to the turbine hub, others are positioned at a distance in front of the turbine, altering the flow patterns over a larger area. The fundamental principles guiding the design of wind reducers revolve around aerodynamics, fluid mechanics, and materials science. Engineers and researchers in this field must navigate a complex web of variables, including wind speed, wind direction, turbulence intensity, and the specific geometry of the wind reducer itself. Achieving the delicate balance between maximizing energy capture and minimizing undesirable effects such as noise and structural stress is at the core of wind reducer design.

One crucial aspect of wind reducer design is the determination of their optimal shape and size. This decision is guided by a careful consideration of the trade-offs involved. Larger wind reducers can capture more wind energy and create greater flow modifications, but they also increase installation and maintenance costs. Smaller wind reducers, on the other hand, are cost-effective but may have limited impact on flow patterns. Striking the right balance between these factors is crucial for ensuring the economic viability and performance of wind reducer installations. Another critical consideration in wind reducer design is the choice of materials. These devices must withstand harsh environmental conditions, including high winds, temperature variations, and exposure to the elements. Additionally, they should be lightweight to minimize structural loads on the supporting infrastructure. Material selection involves a careful evaluation of strength, durability, and cost-effectiveness to ensure the long-term reliability of wind reducer installations.

The intricate interplay of these design parameters is a testament to the multidisciplinary nature of flow over wind reducers. Engineers and scientists must collaborate across fields to develop innovative solutions that not only maximize energy production but also adhere to sustainability principles. Moreover, the dynamic nature of wind flow and the variability of environmental conditions demand continuous research and development efforts to refine wind reducer technologies and adapt them to different contexts. As we delve deeper into the world of flow over wind reducers, we must also explore the diverse range of challenges and opportunities they present in various applications. These devices hold the potential to revolutionize wind energy production in numerous ways, each with its unique set of advantages and considerations.

One of the primary applications of wind reducers is in large-scale wind farms. These sprawling installations, often comprising dozens or even hundreds of wind turbines, benefit immensely from the deployment of wind reducers. By strategically placing these devices throughout the wind farm, operators can significantly improve the overall efficiency of energy capture. Wind reducers can mitigate the wake effect, where downstream turbines receive less wind energy due to the turbulence generated by upstream turbines. This optimization leads to higher energy yields, increased revenue, and a reduced environmental footprint.

Moreover, wind reducers can enhance the stability and reliability of wind farms. By reducing turbulence and structural stress on the turbines, they extend the lifespan of critical components, reducing maintenance costs and downtime. This is particularly crucial in offshore wind farms, where maintenance and repair operations are logistically challenging and expensive. Thus, wind reducers have the potential to unlock the vast offshore wind energy resources that remain largely untapped.

Beyond large-scale wind farms, flow over wind reducers also has applications in distributed energy systems. These smaller-scale installations, often integrated into urban and rural environments, face unique challenges related to space constraints, noise emissions, and aesthetic considerations. Wind reducers can play a pivotal role in addressing these challenges by enhancing the performance of turbines while minimizing their impact on the surrounding community.

II. REVIEW OF LITERATURE

Rabiul, Md et al., (2020) The need for energy in daily living is growing quickly. That's why it's crucial to speed up manufacturing right now. However, most of the energy comes from traditional sources, which are finite and deplete with time. As a result, we need to come up with creative solutions to bridge the power divide. To alleviate this situation, renewable energy sources should be prioritized. When it comes to renewable energy, wind is both the most accessible and clean option. Due to the steady flow of vehicles, the highway provides a major and reliable source of wind energy. But The wind power created by the highway's speeding cars is going to waste. A wind turbine can use this kinetic energy to generate electricity. Toll booths, public lighting, and other public facilities might all benefit from the power reserve. This project's key benefit is its ability to provide reliable electrical power. Using a vertical axis wind turbine (VAWT) atop highway dividers in Bangladesh, this article seeks to collect wind energy from fast-moving automobiles. This study used the Monte Carlo Simulation (MCS) method to forecast the power output from 10,000 random wind samples in the Matlab environment. Second, a theoretical framework was developed for the proposed power generation system. At long last, theoretical wind-produced electricity is reflected in actual generated power.

Teli HG and Kokare Y (2018) Renewable energy, such as that from the sun, wind, and rivers, is one of the finest ways to put the notion of sustainability into practice. Wind power has the advantage of being used around the clock, 365 days a year. This study explores the engineering and production of a wind turbine that harnesses the power of the wind using Vertical Axis Wind Turbines (VAWT). In this article, we'll talk about the logistics of installing Vertical Axis Wind Turbines along highways to generate power. (VAWT). The total cost per unit of energy produced using this technology is lower than the cost of producing and installing additional coal or natural gas. This makes it simpler to put into action than competing strategies. The dynamo is attached to the top or lower section of the wind turbine, depending on which section is more exposed to the wind.

Kumara, E.A.Dinesh et al., (2017) This article introduces the fundamentals of a wind turbine with a vertical axis. We looked at how VAWTs function, where the technology is at the moment, what we've learned from our modeling efforts, and where we think VAWTs are headed in the future. VAWT was shown to be crucial in solving the current energy issue. Due to the current energy issue with non-renewable energy, one might see humans living in a planet with wind turbines and solar panels. The use of wind power has been singled out as a potentially useful renewable resource. Full life cycle accounting demonstrates VAWTs are more cost-effective or material-efficient than HAWTs, however this study discusses the obstacles that prevent VAWTs from producing enough power at the present time. Adding a deflector system that directs the wind into the turbine blades improves the efficiency of drag driven VAWTs (Savonius type), lift driven VAWTs (Darrieus type), and hybrids of both (D+S). At this stage, several studies are now under way. According to a recent analysis of international trends in VAWT research, China has been the world's foremost authority on the topic for the last several years, while European nations have played an important supporting role.

Samir Deshmukh & Sagar Charthal (2017) Energy from the wind is the kinetic energy of moving enormous volumes of air. These movements are due to the sun's uneven heating of the atmosphere, which leads to variations in temperature, density, and pressure. It's a roundabout way of harnessing the sun's power. A wind turbine is a machine that uses the kinetic energy of wind to generate electricity. There is great hope for the future of wind power production in the form of vertical axis wind turbines. The Maglev turbine in this research is a vertical axis wind turbine (VAWT) that uses magnetic levitation to generate electricity at wind speeds of less than 4 meters per second. More power can be generated by a single massive Maglev turbine than by several smaller HAWTs. Using the Maglev effect to its advantage, the rotor can capture enough air to revolve the shaft at low and high wind speeds while still keeping the center of mass low. By using magnets in repulsion instead of traditional bearings, turbine efficiency may be boosted and the shaft can spin at a much higher speed thanks to magnetic levitation. The safety of the turbine is ensured by the placement of its main components on the ground.

Chavan, Prakash et al., (2016) New technologies that use alternative energy sources are classified as renewable energy and are utilized to lessen the financial burden of generating electricity from nonrenewable sources. Wind energy plays a significant part in lowering global warming gas emissions. Today, horizontal axis wind turbines (HAWT) are more popular than their vertical axis counterparts (VAWT), in which the axis of rotation is perpendicular to the ground. The emphasis here is on variable-axis wind turbines (VAWT), which can harness energy from the wind blowing in any direction and take up considerably less room than conventional horizontal-axis turbines (HAWT). When compared to HAWTs, VAWTs excel in areas such as 1) Easy building. They can take in water from any direction, lowering building costs, and they are more cost-effective. VAWT are effective when the wind is weak and stable. Drag-type and lift-type VAWTs are also available. In this project, we will try to build a wind turbine with a vertical axis.

Raj, Mithun (2015) The pressure differential caused by passing automobiles generates a significant quantity of wind energy. Vertical axis wind turbines are able to harness this wind energy and convert it into usable electricity. The goal of this endeavor is to harness the power in the most effective way possible. A wind turbine with a vertical axis may be placed in the road's median to increase the effective wind speed acting on the turbine from the wind coming from both sides of the median. The speed of the vehicle, the size of the vehicle, and the volume of traffic will all affect the direction and strength of the wind. Therefore, a comprehensive survey is required for investigating these dispersions. It is necessary to construct the best possible wind turbine based on the data gathered. The wind energy collected in this way may power things like street lamps, traffic signals, toll booths, and more.

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Ashish Saxena et al., (2015) In this piece, we take a look back at the history of vertical axis wind turbine research and development. Vertical axis wind turbine (VAWT) research and development have been advanced thanks to this state-of-the-art effort. Given the current state of affairs, it is generally agreed that Horizontal axis wind turbines (HAWTs) account for the vast majority of the market. However, problems with cost, manufacturing, and installation have prompted researchers to look for an alternative in the form of VAWTs, in the hopes of improving their power to cost ratio and thus making them suitable for use in urban areas. As such, this review paper provides a summary of relevant case studies and draws the conclusion that future research is likely to focus on hybrid drag-and-lift VAWTs. In addition, the current review research recommends the usage of other materials.

Gulve, Piyush & Barve, Dr. Shivprakash (2014) The primary goal of this project is to provide electricity to rural areas using a hybrid system that makes use of both wind and solar power. Our goal is to create a wind turbine that is small enough to be mounted on rooftops. Therefore, we choose to create a VAWT instead of a HAWT (horizontal axis wind turbine). When compared to HAWT, the benefits of VAWT include a smaller footprint at the same level of energy production, lower operating and maintenance costs, and the ability to capture wind from any direction. The wind turbine can provide enough power for a typical home. The battery will store the power until it is needed by the load. In order to fulfill the demand of metropolitan regions, this project prioritizes the cost-effective electrification of far-flung locations by performing load shading.

III. VALUE OF WIND SPEED

When assessing the potential wind power that may be harnessed, the figure of wind speed indicated in meteorological data is typically at a height of around 12.2 meters. Gain in field may be calculated by determining wind speed in relation to the aforementioned parameter. The results are shown graphically, along with a wind profile over a simple turbine. It is clear from the graph that the largest benefit is about 1.5, making the power of the expression (1.5)3 = 3.38.

Further tests were conducted using a curved (concave shaped) 300 model and a symmetrical triangular 300 model in an effort to discover a solution for the frequent reversals in wind direction. Wind velocities were measured at the ends and the center of the curved model, and it was determined that the increase was about normal (around 1.5 times) at roughly half the height. At half the height, the triangle model predicted a 1.4-fold increase in wind speed. These findings demonstrate that a symmetrical 300 wind reducer may be used in coastal locations where the wind direction varies throughout the day and night. Curved wind reducers are beneficial in places where the wind direction often changes. Adding a partial slant section to a 300 slope model increased wind speed by nearly 1.3 times in subsequent testing. The second set of experimental findings may be effective for boosting wind velocity at current windmill locations.

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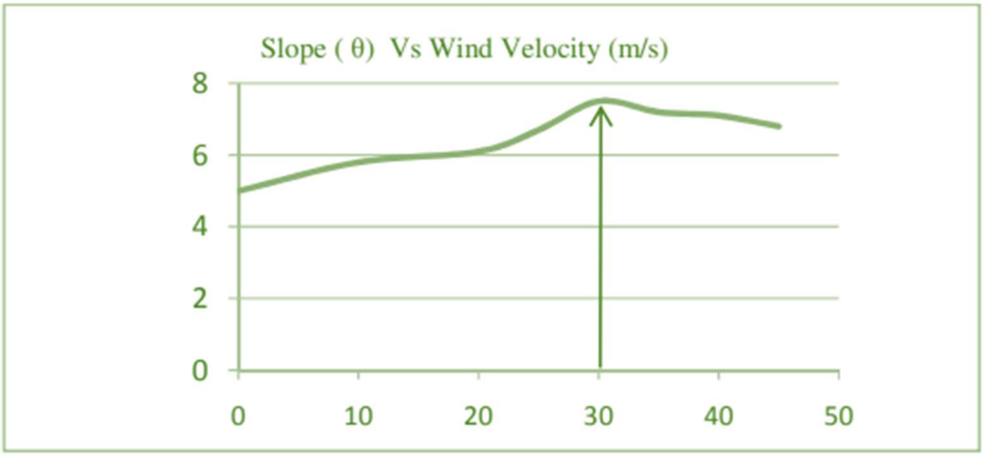

Figure 1: Slope Vs Velocity

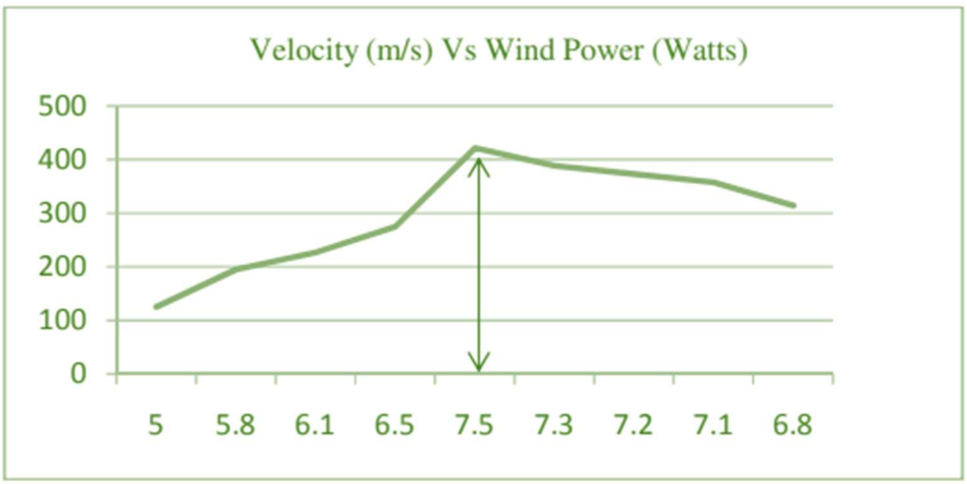

Figure 2: Velocity Vs Wind power

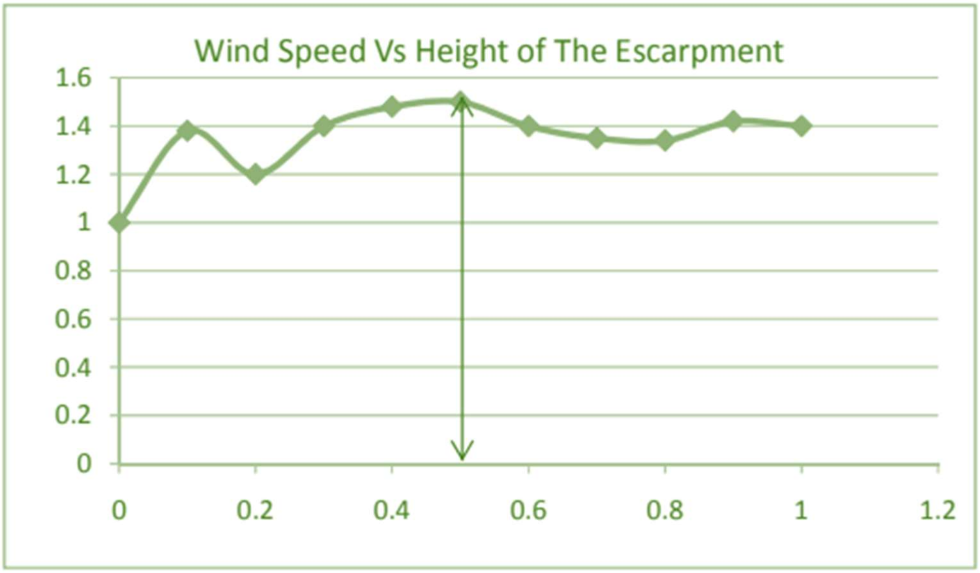

Figure 3: Wind Speed at Different Heights over the Reducer

IV. PRACTICAL AND ECONOMIC FEASIBILITY

Experiments were conducted by positioning 300 slopes of varying roughness in front of a model windmill and the results showed a significant increase in wind speed. Bowen and Lindley's findings demonstrate excellent agreement between full-scale field measurements and wind tunnel results, even though full-scale field testing have not yet been completed. Field testing were performed by Bowen and Lindley on a 13 m high and 260 sloping cliff. Therefore, it is thought that the increase in wind speed seen on a sloping model in a wind tunnel is due to this change.

V. CONCLUSION

Flow over wind reducers represents a testament to human ingenuity and determination to harness the forces of nature for a cleaner, more sustainable future. With continued dedication and innovation, these devices have the potential to transform the energy landscape, mitigate the impacts of climate change, and usher in an era where wind energy plays a central role in meeting our global energy needs. As we continue our journey towards a greener tomorrow, flow over wind reducers will undoubtedly be a key component of the solution, propelling us closer to a more sustainable and resilient world.

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