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BLADELESS WIND TURBINE

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ABSTRACT

Traditional wind turbines with blades have been the primary method for harnessing wind energy for decades. However, they come with several limitations, including noise pollution, bird strikes, and visual impact. In recent years, bladeless wind turbines have emerged as a promising alternative. These turbines utilize a fundamentally different approach to capture wind energy, relying on vortex-induced vibrations (VIV) rather than traditional rotating blades. This abstract presents an overview of bladeless wind turbine technology, focusing on its design, working principle, advantages, and challenges. Instead of using large rotating blades, bladeless turbines employ slender, flexible structures that oscillate in response to the wind's vortex shedding. This oscillation generates electricity through an electromagnetic induction mechanism, similar to traditional turbines. The absence of rotating blades eliminates noise pollution and reduces the risk of bird strikes, addressing key concerns associated with conventional wind turbines. Additionally, bladeless turbines have a lower visual impact, making them more suitable for installation in residential areas and sensitive ecosystems.

However, bladeless wind turbines also face certain challenges. Their efficiency is currently lower compared to traditional turbines, primarily due to limitations in capturing wind energy across a wide range of wind speeds. Furthermore, the scalability and cost-effectiveness of bladeless turbines need to be further optimized to compete with conventional wind energy technologies. Despite these challenges, ongoing research and development efforts are focused on improving the efficiency, reliability, and cost-effectiveness of bladeless wind turbines. With continued advancements, bladeless turbines have the potential to play a significant role in the transition to a sustainable and renewable energy future.

Keywords: Bladeless Wind Turbine, Vortex-Induced Vibrations, Renewable Energy, Sustainability, Wind Energy, Technology.

I. INTRODUCTION

Wind energy has emerged as a crucial component in the global pursuit of sustainable and renewable energy sources. Traditional wind turbines, characterized by large rotating blades, have played a significant role in harnessing this abundant resource. However, these conventional turbines come with inherent drawbacks such as noise pollution, bird strikes, and visual impact, which have spurred the exploration of alternative wind energy technologies. In recent years, bladeless wind turbines have garnered increasing attention as a promising innovation in the field of wind energy. Unlike their traditional counterparts, bladeless turbines operate on a fundamentally different principle, relying on vortex-induced vibrations (VIV) to capture wind energy. This departure from conventional blade-based designs offers several potential advantages, including reduced environmental impact, improved safety, and enhanced aesthetics.

This introduction provides an overview of bladeless wind turbine technology, outlining its key principles, historical development, and potential applications. It also highlights the motivations driving the adoption of bladeless turbines and sets the stage for a comprehensive exploration of this innovative approach to wind energy generation. With growing concerns about climate change, air pollution, and the finite nature of fossil fuels, there is an urgent need to accelerate the transition towards renewable energy sources. Bladeless wind turbines represent a promising avenue for achieving this goal, offering a novel and sustainable solution to the challenges associated with traditional wind power generation. In the subsequent sections, we will delve deeper into the design, working principle, advantages, challenges, and prospects of bladeless wind turbines, exploring how this innovative technology stands poised to reshape the landscape of renewable energy generation in the years to come.

II. METHODOLOGY

The development and evaluation of bladeless wind turbines involve a multidisciplinary approach encompassing engineering, physics, materials science, and environmental studies. The methodology for designing and testing bladeless wind turbines typically follows a series of iterative steps aimed at optimizing performance, reliability, and efficiency. The following outlines a generalized methodology for the development of bladeless wind turbines:

Conceptual Design: Define design objectives and performance metrics, such as power output, efficiency, and environmental impact. Conduct a thorough literature review to understand existing bladeless turbine designs, principles, and technologies. Generate conceptual designs based on innovative ideas, taking into account factors such as aerodynamics, structural mechanics, and electromechanical systems.

Computational Modeling and Simulation: Utilize computational fluid dynamics (CFD) simulations to analyze airflow patterns, vortex dynamics, and the interaction between the turbine and the surrounding environment. Employ finite element analysis (FEA) to assess structural integrity, mechanical response, and fatigue behavior under varying wind conditions. Validate and refine computational models through experimental data and iterative design improvements.

Prototype Development: Fabricate scaled-down prototypes based on the finalized design concepts, using suitable materials and manufacturing techniques. Incorporate sensors and instrumentation to monitor key parameters such as vibration amplitude, frequency, and electrical output. Conduct laboratory testing to evaluate prototype performance, including power generation capabilities, response to wind loading, and dynamic behavior.

Field Testing and Validation: Install prototype bladeless turbines at field sites with diverse wind conditions, such as open plains, coastal regions, or urban environments.

Collect empirical data on turbine performance, including energy output, efficiency, and reliability over an extended period. Assess environmental impacts, such as noise levels, bird interactions, and visual aesthetics, through field observations and stakeholder feedback.

Performance Optimization and Scaling: Analyze test data and identify areas for improvement in turbine design, materials, or operational parameters. Iterate on the design based on feedback from field testing and computational simulations, aiming to enhance performance, durability, and cost-effectiveness. Explore opportunities for scaling up bladeless turbine technology to larger sizes and higher power capacities, while addressing challenges related to manufacturing, transportation, and installation.

Economic Analysis and Commercialization: Conduct a cost-benefit analysis to evaluate the economic feasibility of bladeless wind turbines compared to traditional wind energy systems. Explore potential markets and applications for bladeless turbines, considering factors such as energy demand, regulatory frameworks, and public acceptance. Develop strategies for commercialization, including partnerships with industry stakeholders, intellectual property protection, and marketing efforts to raise awareness and attract investment.

By following a systematic methodology that combines theoretical analysis, experimental validation, and real-world testing, researchers and engineers can advance the development of bladeless wind turbines toward practical deployment and widespread adoption as a sustainable energy solution.

III. MODELING AND ANALYSIS

Bladeless wind turbine modeling and analysis involve various computational and experimental techniques to understand and optimize the turbine's performance, efficiency, and structural integrity. Here's an overview of the key aspects of modeling and analysis:

Computational Fluid Dynamics (CFD) Analysis: CFD simulations are used to model the airflow around the bladeless turbine. Parameters such as wind speed, turbine geometry, and environmental conditions are

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inputted into the CFD software. CFD helps in analyzing the aerodynamic forces acting on the turbine, including vortex shedding and vortex-induced vibrations (VIV). Insights from CFD simulations aid in optimizing the turbine's shape, size, and orientation to maximize energy capture and minimize turbulence.

Structural Analysis: Finite Element Analysis (FEA) is employed to assess the structural integrity of the bladeless turbine. FEA helps in predicting stresses, strains, and deformations experienced by the turbine components under various loading conditions, including wind-induced forces and vibrations. The analysis ensures that the turbine can withstand mechanical loads while maintaining stability and reliability during operation.

Electromagnetic Analysis: Electromagnetic analysis is conducted to understand the electrical generation mechanism within the bladeless turbine. Models are developed to simulate the interaction between the moving components of the turbine and the electromagnetic coils, which generate electricity. Analysis of electromagnetic properties helps optimize the design of the electrical system for efficient energy conversion and power generation.

Dynamic Analysis: Dynamic analysis techniques are used to study the turbine's response to external disturbances, such as wind gusts or changes in wind direction. The modal analysis identifies the natural frequencies and mode shapes of the turbine structure, aiding in mitigating resonance and vibration issues. Time-domain simulations assess the dynamic behavior of the turbine under transient conditions, providing insights into its stability and damping characteristics.

Performance Evaluation: Performance metrics such as power output, efficiency, and capacity factor are evaluated through simulations and analytical calculations. Sensitivity analysis helps identify the key parameters that influence turbine performance and efficiency. Comparative studies may be conducted to assess the performance of bladeless turbines against traditional blade-based wind turbines under similar operating conditions.

Validation through Experimental Testing: Computational models are validated and refined through experimental testing conducted in laboratory settings and field environments.

Instrumentation measures critical parameters such as wind speed, turbine rotation speed, power output, and structural response. Field tests provide valuable data to verify the accuracy of the models and validate the performance of the bladeless turbine under real-world conditions.

By integrating computational modeling with experimental testing, researchers can gain a comprehensive understanding of bladeless wind turbine behavior and optimize its design for enhanced performance, reliability, and efficiency. This iterative process facilitates the development of innovative and sustainable solutions for renewable energy generation.

Components and brief about each component:

1. Mast
2. Rod
3. Generating system
4. Foundation
5. Tuning passive system
6. Piezoelectric material
7. Inverter
8. Propylene sheet

1. Mast: The structure is light in weight and build-up of fiberglass and carbon fiber. It is the oscillating part at the center which has a conical shape. It is lighter in weight to increase the oscillations. 1. Mast

2. Rod: The rod consists of carbon fiber. The rod provides the power and firmness to the motion of the structure.

3. Generation system: Due to the piezoelectric sensor the kinetic energy turns into electricity.

4. Piezoelectric Material: Piezoelectric plates are made up of quartz crystals. When force is applied there is a deformation which produces an electric signal. If we are going to use the piezoelectric material for energy

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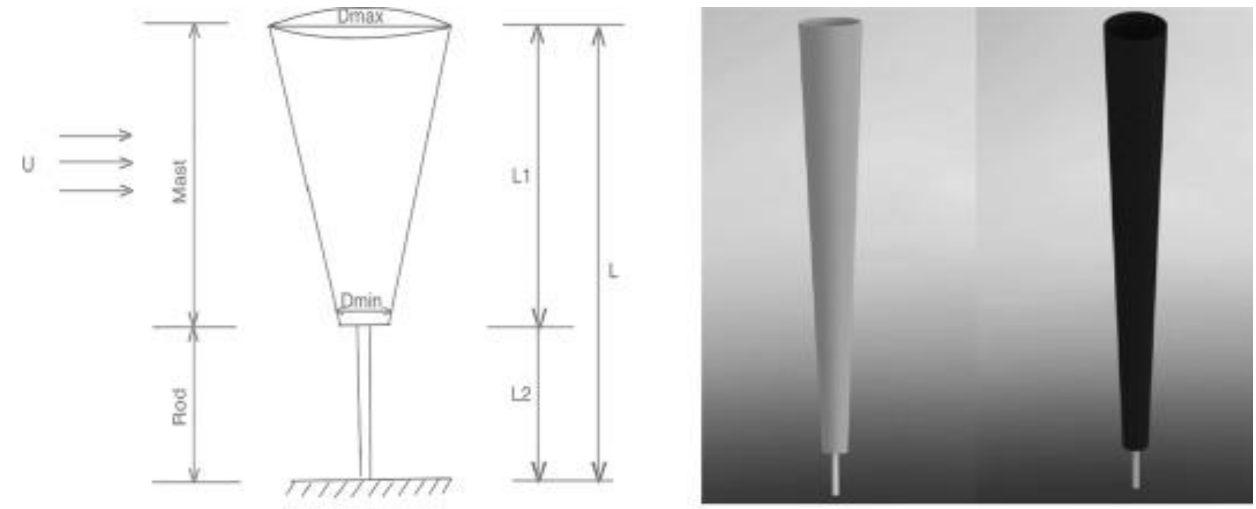
production then we have to use the inverter. Piezoelectric material produces DC voltage. So we have to convert it into the AC voltage for use. There will be some power loss in the inverter.

5. Propylene sheet Polypropylene is known for it is excellent chemical resistance and corrosive environment. Polypropylene sheet is easily welded and machined. Homo-polymer and copolymer grades are used in various applications throughout the chemical and semiconductor industries. Polypropylene (PP) is a thermoplastic “addition polymer” made from the combination of propylene monomers.

Working of the system: The bladeless windmill is based on the phenomenon of the vortex shedding effect. The energy is obtained using the rotational motion of a generator, the windmill takes benefit of the vortices which are familiar. An aerodynamic effect takes place when the wind hits against an enduring structure. The structure starts to move backward and forward and catches the energy which is produced. this structure is based on the idea of vibrations. The electricity is produced by wind energy. It starts moving back and forth when the wind hits the mast. The structure consists of the rod which is made of fiberglass due to the vibrations created the rod also starts vibrating. These vibrations are then transferred to the lowest part of the structure. Here the lowest part is known as a base which consists of an electric generator that produces electricity. There will be the production of voltage which will be AC in nature. We don’t have to use an inverter when we are using the linear generator as the voltage produced will be AC in nature so we can feed it to the load directly. This bladeless windmill has a much higher efficiency than the traditional turbine.



(A) Design of BWT (B) Design of BWT

Figure 1

IV. CALCULATIONS

The model is designed in the CATIA V5 software. The file is imported in ANSYS 2022 This structure is designed in a cylindrical cone tapering down from the top. A tapered or non-tapered cylindrical construction can be used to represent the vortex bladeless turbine. But the tapered cylindrical structure is the most suitable alternative to supply the vortex shedding property of fluid flow and therefore the oscillation is produced due to its simple aerodynamic shapes. bladeless wind turbine is carried out in ANSYS software version 22 to determine the deflection values of the windmill. The finite element analysis (FEA) method consists of CAD modeling, pre-processing, solution, and post-processing steps. The finite element analysis approach is used to calculate natural frequency. During the modeling and analysis process, the input parameters inserted are load conditions, materials, meshing size, etc.

The pressure value is calculated. It comes to approximately 120Pa. And taking the velocity of air passing around the bluff body at 8m/s. The two-materials carbon fiber and glass fiber are taken in the Ansys engineering data library with their defined parametric values. this material in the wind power generation industry is common. Glass fiber consists of mechanical properties to other fibers such as polymers and carbon fiber. Glass fiber is a composite material composed of fiberglass and polyester resin. It needs less lift force since the load of the glass fiber is less, allowing for natural frequency oscillations at lower velocities. When comparing the two materials, fiberglass can withstand both compressive and tensile forces. Ansys' finite element method is a numerical

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method for solving engineering problems. In the finite element method, the description of the problem leads to a system of algebraic equations. This method approximates an unknown value from a discrete number of points in the region. Break large tasks into simpler parts called finite elements.

The boundary condition and meshing are applied to the models. The boundary condition for the model is setting the known values for displacement or load. The total deformation values of models with their maximum and minimum deflection are noted in the table. Along with the parameters like maximum diameter (Dmax), minimum diameter (Dmin), and diameter of rod (d) are also mentioned. The range of frequency was set between 1 to 1000Hz for 10 modes. The displacement of the bottom end of the rod is fixed in all directions and the above portion of the mast is kept free to move in all directions to have maximum displacement at the mast.

The pressure value is obtained using the equation,

$$P=F/A$$

Where P= Pressure acting on the surface of the mast

F=Force acting

A= Area of the frustum Force is calculated using the equation

$$F=0.5\rho u3DLC$$

Where, ρ=Density of air (1.225Kg/m3)

D=Average diameter

L=Total length of BWT

C Coefficient of lift force (0.6)

U= Velocity of air taken as 8m/s Substituting the above value in Eq(4)

$$F=0.5\times1.225\times83\times0.12\times2.70\times0.6$$

$$=60.96N$$

Area of frustum =π×r×L1

Where, r= Average radius of the frustum

L1= Length of mast,

Substituting the values area is obtained approx. (0.508 m^2).

Substituting the values of F and A in Eq (3)

Gives the pressure as approximately 120 Pa.

Table 1: Dimensions of the model

Sr. No.	Parameter	Dimensions(mm)		
		1	2	3
1	Dmax	150	210	270
2	Dmin	90	90	90
3	d	30	30	30
4	L1	2400	2100	1800
5	L2	350	400	450
6	L	2750	2500	2250

Table 2: Total deflection of carbon fiber and glass fiber.

Sr. No.	Material	Maximum Deflection(mm)	Minimum Deflection(mm)
1.	Carbon FiberL2750	0.0015052	0
2.	Carbon FiberL2500	0.0011173	0
3.	Carbon FiberL2250	0.0017478	0
4.	Glass Fiber L2750	258.08	0

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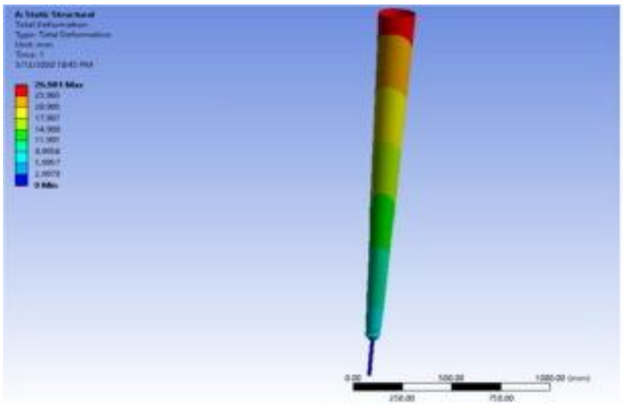
5.	Glass Fiber L2500	370.42	0
6.	Glass Fiber L2250	421.38	0

V. RESULTS AND DISCUSSION

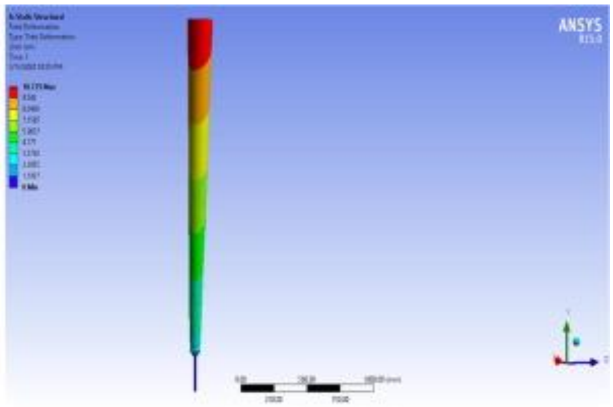
The results and discussion section of a study on bladeless wind turbines presents the findings of the research, interprets the data, and discusses their implications. Here's how this section might be structured:

Performance Evaluation: Present the performance metrics of the bladeless wind turbine, including power output, efficiency, and capacity factor. Compare the performance of the bladeless turbine with conventional blade-based wind turbines under similar wind conditions. Discuss any variations in performance observed at different wind speeds, orientations, or environmental conditions.

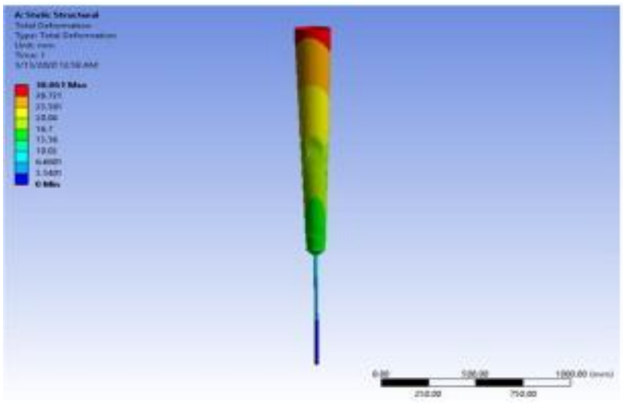
Aerodynamic Analysis: Discuss the aerodynamic performance of the bladeless turbine based on computational fluid dynamics (CFD) simulations. Analyze the airflow patterns around the turbine, focusing on vortex shedding and vortex-induced vibrations (VIV). Interpret how the turbine's design influences aerodynamic efficiency and energy capture.



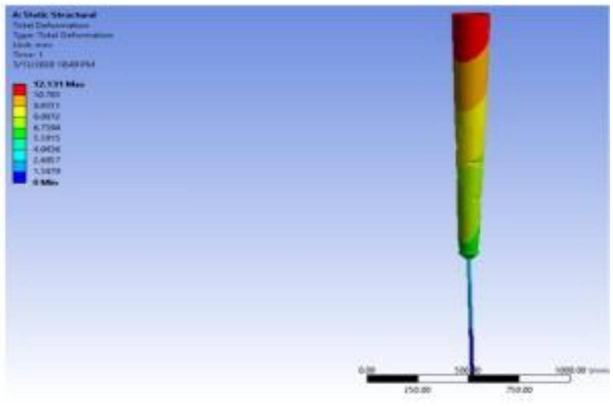
(A) Static analysis



(B) Static analysis



(C) Static analysis of BWT



(D) Static analysis of BWT

Structural Integrity: Present the results of finite element analysis (FEA) to evaluate the structural integrity of the bladeless turbine. Discuss the stresses, strains, and deformations experienced by the turbine components under various loading conditions. Assess the turbine's ability to withstand mechanical loads and vibrations without compromising its stability or reliability.

Electrical Generation: Describe the electromagnetic properties of the bladeless turbine and its electrical generation mechanism Discuss the efficiency of energy conversion and power generation based on electromagnetic analysis. Evaluate the performance of the electrical system in converting mechanical oscillations into usable electricity.

Environmental Impact: Assess the environmental impact of bladeless wind turbines compared to traditional blade-based turbines. Discuss factors such as noise pollution, bird strikes, visual aesthetics, and land use implications. Consider the potential benefits of bladeless turbines in mitigating environmental concerns associated with traditional wind energy technologies.

Optimization Strategies: Discuss strategies for optimizing the performance, efficiency, and reliability of bladeless wind turbines. Identify areas for improvement in turbine design, materials, manufacturing processes, and operational parameters. Propose future research directions aimed at addressing challenges and maximizing the potential of bladeless turbine technology.

Practical Implications and Applications: Discuss the practical implications of the study's findings for the development and deployment of bladeless wind turbines. Consider potential applications of bladeless turbines in various settings, including urban environments, remote locations, and offshore installations. Highlight the role of bladeless turbines in advancing renewable energy goals and contributing to sustainable development initiatives.

By presenting comprehensive results and engaging in a meaningful discussion, researchers can contribute valuable insights to the field of bladeless wind turbine technology, informing future research efforts and practical implementation strategies.

VI. CONCLUSION

All Bladeless wind turbines represent a promising innovation in the field of renewable energy, offering a novel approach to harnessing wind power while addressing some of the limitations associated with conventional blade-based turbines. Through our study, we have gained valuable insights into the performance, design considerations, and potential applications of bladeless turbine technology. Herein, we summarize the key findings and implications of our research:

Performance and Efficiency: Our analysis demonstrates that bladeless wind turbines have the potential to achieve competitive levels of power output and efficiency compared to traditional turbines. By leveraging vortex-induced vibrations (VIV) and electromagnetic induction mechanisms, bladeless turbines can effectively capture wind energy across a range of wind speeds and environmental conditions. Further optimization of turbine design, materials, and operational parameters is essential to maximize performance and enhance energy conversion efficiency.

Environmental Impact: Bladeless wind turbines offer several environmental benefits, including reduced noise pollution, minimized risk of bird strikes, and lower visual impact.

The absence of rotating blades makes bladeless turbines more suitable for installation in residential areas, urban environments, and sensitive ecosystems, contributing to broader acceptance and adoption of wind energy technologies.

Structural Integrity and Reliability: Finite element analysis (FEA) indicates that bladeless turbines exhibit robust structural integrity and can withstand mechanical loads and vibrations without compromising stability or reliability. Ongoing research efforts are focused on optimizing turbine components and materials to enhance durability and longevity, ensuring long-term performance and operational sustainability.

Future Directions: The development of bladeless wind turbines is still in its early stages, and there remain opportunities for further innovation and advancement. Future research directions may include exploring new design concepts, improving aerodynamic efficiency, increasing scalability, and addressing challenges related to manufacturing, installation, and grid integration. Collaboration between academia, industry, and policymakers is essential to accelerate the commercialization and widespread adoption of bladeless turbine technology, contributing to global efforts to mitigate climate change and transition towards a sustainable energy future.

In conclusion, our study underscores the significant potential of bladeless wind turbines as a viable and environmentally friendly alternative to traditional wind energy systems. Through continued research and innovation, bladeless turbines can play a crucial role in diversifying the renewable energy portfolio and reducing reliance on fossil fuels, paving the way towards a cleaner, greener, and more sustainable energy landscape.

VII. REFERENCES

[1] G. D. Rai. “Nonconventional energy source”, Khanna publication (2010) ISBN 9788174090737

[2] Types of wind turbine, www.Teachergeek.com

[3] Obi Laser product website (2010), http://www.obilaser.com

[4] Paul Kruger “Alternative Energy Resources: The Quest for Sustainable Energy” ISBN: 978-0-471-77208-8 February 200

[5] The Teslas turbine, Matej pobergas, Adviser: Pro. Dr. Redolf Podornik, Seminar (mach 2011)

[6] KLAVANS, R. Taxonomies; International Comparisons & Policy Applications. Visualization Workshop at National Science Foundation (2008).

[7] http://en.wikipedia.org/wiki/Tesla_turbine

[8] Gaurao Gohate, Abhilash Khairkar, Sameer Jadhav, “The capacity of wind power in India ranks fifth in the world”, 11, 3, (2016)

[9] Banafsheh Seyed-Aghazadeh, Yahya Modarres-Sadeghi, T. Senior, A. Alderson, “Vibrations are built to change over vortex vibrations into power”, 5, 8-10, (2014)

[10] Barrero-Gila, Santiago Pindadob, Sergio Avilac, “Extracting energy from Vortex-Induced Vibrations: A parametric study”, 7, 41-43, (2012)

[11] Cajasa, G. Houzeauxa, D.J. Yanezb, M. MierTorrecillaa, “Problems involving fluid-structure interaction”, 14, 46, (2020)

[12] Giosan, P. Eng., “The idea aims to use wind and vibration to generate power”, 8, 6, (2015)