iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 Issue: XI Month of publication: November 2020

DOI: https://doi.org/10.22214/ijraset.2020.32113

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue XI Nov 2020- Available at www.ijraset.com

A Review of Vortex Bladeless Wind Turbine and Vorticity Effects

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Abstract: Vortex Bladeless is an innovative to harness energy from wind, with different and exciting characteristics which makes it a revolution in alternative energy generation. Vortex technology harvest energy from a fluid when it passes through the surface i.e vortex shedding phenomenon, creating an aeroelastic oscillation movement on the device. It is eco-friendly, it does not include blades like Horizontal axis turbine, therefore effects spacing between each turbine. This Study is to understand about the impacts of vortex bladeless turbine and the vorticity street phenomenon behind the innovation.
Keywords: Bladeless Wind Turbine, Vortex Phenomenon, Vorticity, Vortex Shedding, Vortex induced Vibration

I. INTRODUCTION

Wind Turbine is a device that converts K.E. from wind to electricity. Generally used Wind Turbines are Horizontal Axis Wind Turbine (HAWT) also known as the Conventional Wind Turbine, it is highly used for commercial purpose. Another one is Vertical Axis turbine (VAWT) . But HAWT is used worldwide and is better compared to VAWT as it is prone to less wear and tear thereby the reducing the maintenance than VAWT. Now a new concept of bladeless turbine is emerging in trend. In this study we will focus on Vortex Bladeless Wind Turbine.

Though horizontal axis wind turbine (HAWT) is used worldwide, they have some disadvantages like the structure is heavy, it is transporting the blades and it also cause harm to birdlife. From theoretical point of view large number of turbines placed at a distance reduce the wind speed due to the wake effect, therefore a particular pattern has to adopted to overcome them. A bladeless turbine concept can be considered as a trial to avoid these above effects.

(Goodwin 2018) says that the possible risk posed to vultures and other roaring birds by current and planned developments in the wind farm may remain shortly. While the foremost effective mitigation approaches remain the initial location of future developments at less vulnerable sites and therefore the use of more 'eco-friendly' turbine technology, mitigation at existing sites or late-planning developments could involve some novel thinking.

II. VORTEX BLADELESS WIND TURBINE

(Jesús and Villarreal 2018) In aeroelasticity, the air will cause oscillatory movement in the body if its natural resonance frequency and vortex dispersion are observed (Fig.1). The frequency is close. Vibration caused by vortices in the body is known as the VIV phenomenon. The implementation of an aero-elastic resonance-based wind generation system is feasible. It has been suggested that it is beneficial to capture wind energy from a system that minimises maintenance needs, in particular as regards distributed generation. A Slender and circular cross-section generator, the diameter of which varies according to height, is proposed for this mission (Fig.2).

(Goryachev and Kharchenko 2019) goals to develop generator designs to obtain electrical energy from the wind and to use the system as environmentally friendly. The use of the proposed installation would dramatically reduce the cost of manufacturing, maintenance and repair, as the unit requires a reduced number of components. Maintenance does not take a substantial amount of time.

There is no need for frequent lubrication or replacement of spare parts. Unlike similar wind generators with blades, the bladeless wind generator has no environmental effects. The downside of the system is that the bladeless generator generates an average of 30% less energy than the traditional one. On this basis, bladeless wind devices need to be mounted even more than blade devices. However, this system has smaller dimensions compared to conventional wind turbines, it is possible to install a greater number of installations in a smaller area.

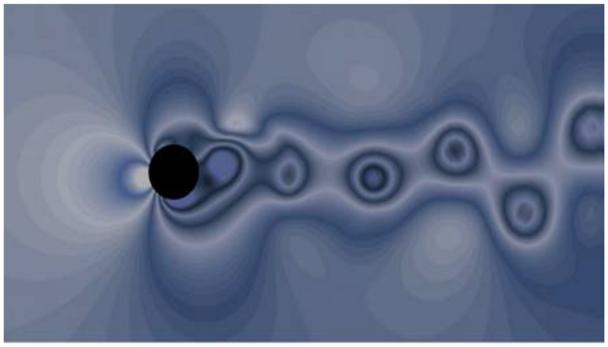

Fig 1. 2D VIV contour of pressures, CFD for a DNS model,

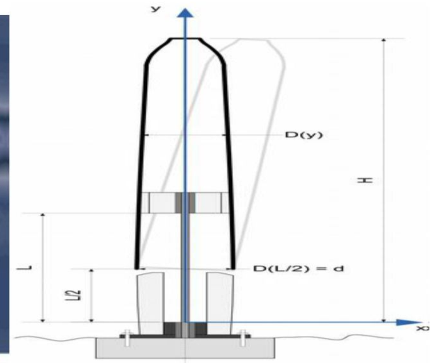

Fig 2. Mast Part of Bladeless turbine

(Bardakjian et al. 2017) research concluded that a single bladeless turbine is 30% less powerful than a HAWT. This is due to the nature of the physical structure as well as its lack of ability to fight the high wind entropy. Because of their small scale, they make better use of the space they occupy, since more can be put in the same area as the HAWTs. This feature bridges the difference between the two turbines and compensates for their lack of performance. While HAWTs are more effective, they need more maintenance due to the increased number of components and moving parts. These involve gears and braking systems. Bladeless turbines do not have moving parts or links that significantly reduce maintenance. From the data obtained, the higher the velocity of the wind acting on the HAWT, the higher the performance. Bladeless turbines, however, operate best when the wind speed is lower, resulting in uniform vortices.

(Davang Shubham S) The feature that sets this wind generator apart from others is that it is completely assisted and rotates without the possibility of animal killing. This is vertically aligned with the middle of the moving mast and generator. The output voltage produced by their prototype is calculated using a multimeter and a value of around 60mV has been found. A country like India, which has a larger rural population and conditions ideal for wind generation through a bladeless wind turbine, is the best option. It will help to raise the percentage of renewable energy for electricity generation which will provide electricity to customers as well as economic efficiency. To conclude the bladeless wind turbine model produces energy at a lower wind speed than the traditional wind turbine hat and also consumes less volume.

(Oswal 2018) Says that Bladeless turbine is a modern concept that has the benefit of an aerodynamic effect called vorticity. In this phenomenon, when the cylinder body is positioned in the flowing fluid, a low alternating pressure is generated on the side of the cylinder, and the body begins to shift in the perpendicular direction of the flowing fluid. When the wind is slow and steady, it impacts against the turbine, rendering the vortex homogeneous and the oscillations generated by it homogeneous. If a massive turbine were to be installed, the wind would operate on it with variable speeds. This will give rise to oscillations of different frequencies in the turbine. Adaptive wind turbine is more effective in terms of operation, power generation and protection. This can be commonly used from household to larger wind farms. (Kumar 2018) The region of high-speed wind is small, and the area needed for the installation of traditional windmills is high due to the wake effect. Bladeless turbine is an alternative to traditional one but is not a turbine since it does not rotate. This latest technique absorbs wind energy based on the aero-elastic resonance phenomenon. In this paper, a distinction was made for various composite materials suitable for the construction of bladeless turbines and the frequency of output for the same turbine. (Balakrishnan et al. 2019) The concept is to transform the vibration generated by taping the wind into electrical energy by means of a piezoelectric crystal. The energy transfer takes place in the mast, where the wind hits the mast of the column and makes it vibrate. This vibration is translated into electrical energy. Once the mast vibrates, the vibration passed to the spring connected to the base seat fixed to the piezoelectric crystals, which transforms this vibration into electrical energy. The oscillation produced by the vortex shedding is transformed into rotary motion and then into power.

(Kshirsagar and Gaikwad 2019) The idea of bladeless windmill is based on the theory of vortex shedding effects. Generally, structures are designed to mitigate vortex-induced vibration (VIV) in order to minimise mechanical failure. In this project function, however, the vortex-induced vibrations (VIV) increased with the full deflection of bladeless windmills to generate electricity. The geometry form most widely used for this application is a tapered or non-tapered cylinder. Static Structural analysis and CFD analysis of vortex bladeless windmill is carried out to evaluate the deflection values of the windmill using glass fibre as a composite material for mast and nylon for tube and deflection have been found to be 10 mm for the 2.7 m model with a cylinder diameter of 200 mm at top and 100 mm at bottom.

III. VORTEX SHEDDING PATTERN

Vortex Shedding effect was first described and mathematically formalized by Theodore von Kármán, the genius of aeronautics, in 1911. This effect is produced by lateral forces of the wind on an object immersed in an exceedingly streamline flow. The wind flow generates a cyclical pattern of vortices, which act as challenges for slender structures, like towers, masts and chimneys. The thought behind Vortex turbine is that it's possible that very same forces are often exploited to supply energy. When the wind vortices match the natural frequency of the device'. The structure begins resonating, hence oscillating, so the bladeless turbine harnesses energy from that movement as an everyday generator.

(Saurabh Bobde 2016) The Bladeless Windmill could also be an idea that works on the phenomenon of vortex shedding to capture the energy generated. Vortex shedding is an oscillating flow which occur when a fluid, like air or water, flows past a bluff (as against a streamlined) body at certain speeds, depending on the dimensions and shape of the body. This technology works by positioning cylindrical bodies in the natural flow of the wind. Flow over this cylinder produces an irregular vortex pattern that induces alternating high lifting forces on the body. Strouhal Number, St is a non-dimensional parameter that defines the output frequency of the vortex to the oscillating flow mechanism. Depending on the length of the mast, Frequency and torque of the system the Power output is obtained.

(Saengsaen et al. 2019) The Model VIV-driven Bladeless Wind Turbine requires fluid flow forces and structural force vibration model obtained by Navier – Stokes equations. The present study considers the 2–D CFD model for flow over the stationary cylinder diameter D of the Bladeless Wind Turbine (Fig.3). The force factor in the flow direction is called drag. The normal force part of the flow is called the lift. A Comparative Computational Analysis between DES-SST and RANS-SST Model was performed, followed by a simulation modelling of two cylinders at a centre-to-center distance greater than 1.4 diameters to determine the Drag and Lift Coefficient. It is found that the RANS – SST model yields fluctuating CD and CL results, while the DES – SST gives convergent simulation results in a flow over a stationary cylinder at Re = 105 (Fig.4).

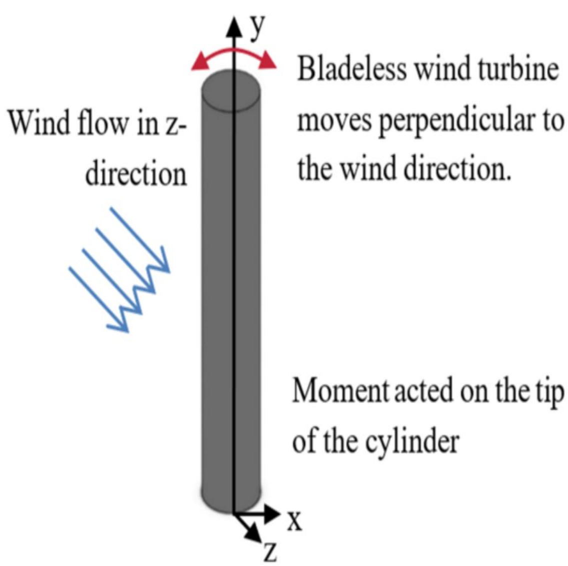

Fig 3. The schematic model of a circular rigid cylinder mounted on a flexible BWT

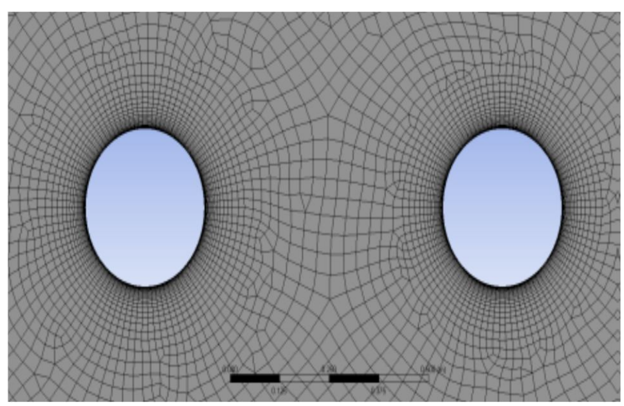

Fig 4. The computational mesh (Re = 105); Detail of Quadrilateral mesh of two cylindrical BWTs simulation

(Chizfahm et al. 2018) The Euler-Bernoulli beam theory and the Galerkin method are used to derive a nonlinear distributed-parameter model for the BWTs under a fluctuating lifting force due to periodic derailment of vortices. The derived dynamic model is validated by comparison with the 3D CFD-FEM numerical simulation. In BWTs, the periodic release of vortices in the air flow along the z-direction causes vibrations in the y-direction. The BWTs consist of a relatively long (right or conical) cylinder, which is either flexible or mounted on a flexible structure exposed to a uniform flow of air. The semi empirical model of the nonlinear wake oscillator was used to obtain an expression for the crosswise flow-induced fluctuating lifting force due to periodically discarding vortices.

IV. VORTEX INDUCED VIBRATIONS

(Giosan and Eng 2000) When the wind blows through the slender structural portion, the vortex is alternately shed from one side to the other, giving rise to a fluctuating force acting at right angles to the wind direction. This structured pattern of vortexes is referred to as the von Karman vortex street. The phenomenon of the vortex shedding forces for circular cylinders is dependent on the Reynolds Number. Tubular, multi-sided or circular, tapered or non-tapered free-standing structures can be subject to significant dynamic stress caused by vortex shedding. In view of these aspects, the possibility of structural fatigue must be considered at the design stage.

(Zheng et al. 2019) The wind-induced reactions of a thousand-metre-scale four-tower-connected mega-tall building was investigated using an aero-elastic model test to take into account the fluid-structure interaction associated with a large aerodynamic damping ratio. In addition, the critical wind speed for vortex-induced resonance and the lock-in area are calculated. At 60 degree wind direction, the rate of precipitation of the vortex increases steadily with the decreased wind velocity Vr and reaches the structural frequency. In both wind and wind directions, a large lock-in area is observed. The VIV-like phenomenon in the wind direction is combined with the vortex-induced resonance in the wind direction. This finding shows that there is aerodynamically coupled vortex shedding of a thousand-metre-scale four-tower-connected mega-tall building in the wind and wind directions.

(Zuo and Letchford 2010) Traffic signal support systems with cantilevered mast arms are known to exhibit high-amplitude vibrations in such wind conditions. On the basis of full-scale measurements, the vibration of the cantilevered tapered traffic signal mast arm was studied. In-interpretation of vibration characteristics and their association with wind speed, it was discovered that, with traffic signals attached. The structure was sensitive to two kinds of vibration. At the low point wind speeds, the structure displayed large-scale vibrations due to the vortex shedding of the cantilevered limb. At high wind speed, the structure vibrated at amplitudes lower than those of the vortex-induced vibrations due to buffeting.

(Transmission 2015) says that Vortex-induced vibration (VIV) is a common phenomenon in a wide variety of transmission line structures. Occasionally high amplitudes are reached due to lock-in which can lead to a risk of failure due to fatigue. Several mitigation steps have proven to be successful, including increasing stiffness. By filling with sand or a weak slurry concrete mixture, applying tuned mass dampers and spoiling the vortices by means of guide valves or helical strakes. Steps suggested at the design level include FEA of the structure for understanding natural frequencies and mode shapes, comparing these to Strouhal No. to warn of the resonant response to vortex spills at large wind speeds, and Scruton No. calculation to warn of extreme amplified response due to lock-in. Fatigue detailing may be necessary. Future design procedures should involve complex effects and resistance to fatigue.

(Zahari and Dol 2014) The application of Vortex induced vibration to produce energy is a feasible alternative energy solution for offshore applications. VIV has the potential to supply energy in a low-speed current area where traditional hydrokinetic applications are unable to work. Although the power output may be relatively poor, this technology is considered to be modern and can therefore be further improved in different segments. It's changed from time to time. With a current speed as low as 0.1 m / s, the VIV application designed is capable of delivering a rated power output as high as 10.4 W with a single array. When such an application farm is built, the power supply can be increased and different industries, ranging from offshore platforms and even land-based operations, can be assisted.

V. DISCUSSION

Thus we have discussed about the innovative of Bladeless Wind Turbine using Vortex Effect, and the impacts of wind induced vibration over slender structures by vortex shedding effect. It is understood that though the slender structures get prone to fatigue due to vortex street , they can be optimised and cylindrical structure like high mast pole can be synthesized to function as a bladeless turbine as the shredding frequency obtained from them will be efficient to produce energy. They also minimize the wake effect produced in conventional turbine. However future study is to be made to understand about the relationship between mass of the structure and vortex induced vibration.

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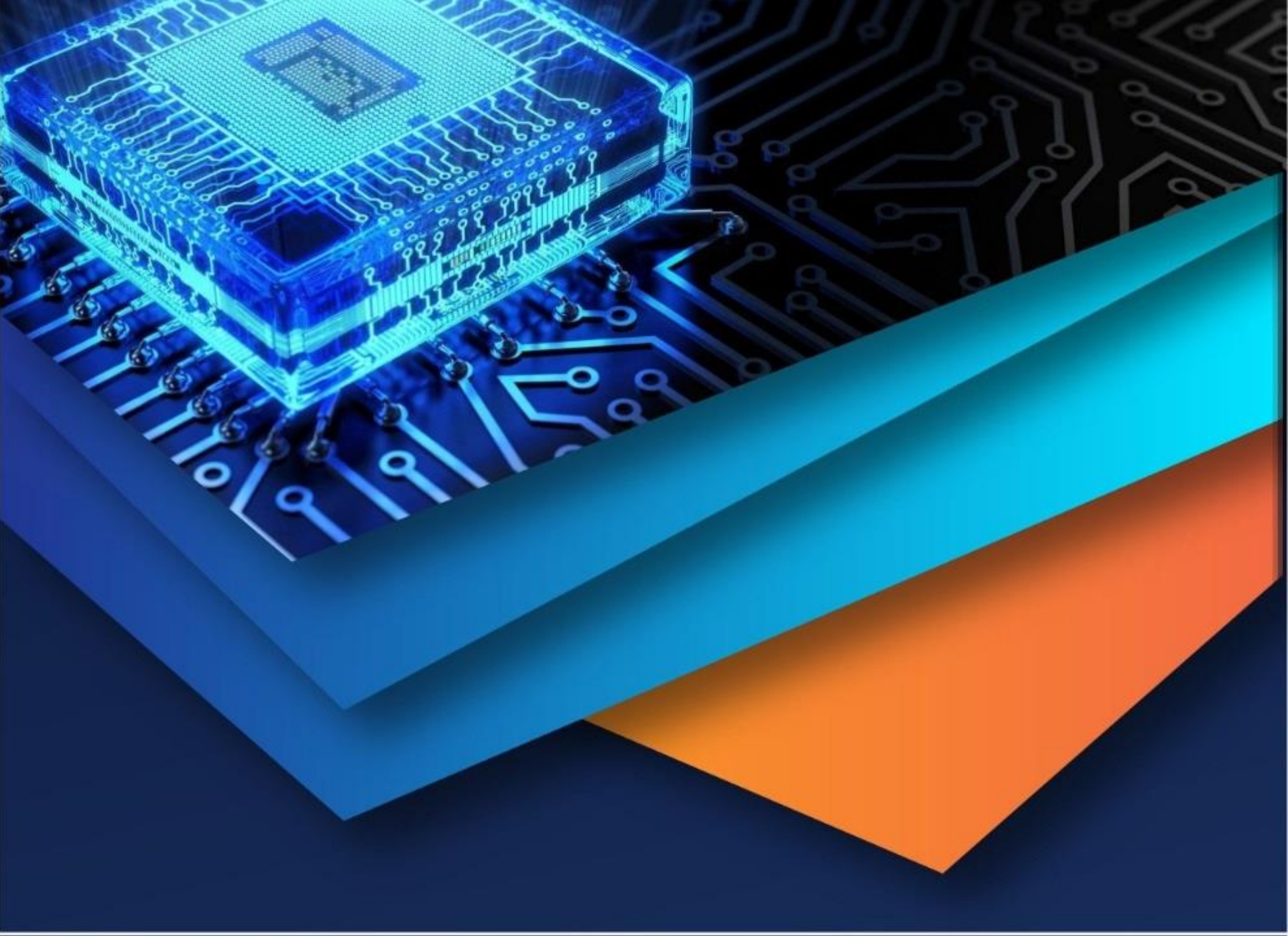

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