VORTEX RESONANT WIND GENERATORS

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ABSTRACT:

New wind generations with different characteristics compared with conventional wind turbines can improve the exploitation of this clean energy source. Aero elastic resonance phenomena are usually considered a problem, but they can also constitute the basis of a technology for wind energy transformation. This paper is a condensed synopsis of the most general aspects of an alternative technology based on VIV fluid-structure interaction that avoids the use of gears or shafts. The application of magnetic forces to the resonant structure allows to passively modifying the structure rigidity, which leads to an increase of the lock-in range and consequently a higher number of working hours per year. Electromagnetic induction is also one of the available strategies to transform the energy of the oscillatory movement into electricity.

Keywords— resonant wind turbines component, power generation, wind generators.

INTRODUCTION

The efficiency of renewable energies has grown significantly in recent years and wind energy has been one of the most important responsible. The increasing size of wind turbines is making wind power to be one of the most relevant energy sources. However, in the distributed energy sector, where energy is generated close to the point of use, the most remarkable technology may be photovoltaic solar energy. The lacking of mobile mechanical parts allows to collect energy from the sun with minimal maintenance and no environmental noise impact. In addition, it is well known that the combined use of different renewable energy sources is synergistic due to mutual compensation in periods of absence of wind, sunlight, etc. The development of a new wind generator can be very useful if it is able to emulate the features that have made photovoltaics the main energy source in the distributed energy sector.

In relation to large-scale wind power, the offshore technology (turbines installed in the ocean) is very promising. One of the faced problems is the aggressiveness of marine environments, especially the corrosion of mobile mechanical parts of the mills. Therefore the absence of gears, bearings, etc. in a device capable of collecting wind energy can also be an important advantage.

Resonance

One of the most well-known events produced by aerodynamic resonance is the collapse of the Tacoma Narrows bridge [1] Resonance phenomenon arises when an oscillation is reinforced by a periodic movement. In aeroelasticity, the air can induce an oscillatory movement in a body if its natural resonance frequency and the vortex shedding's wake frequency are similar. The vibrations induced in a body by vortices are known as VIV phenomena [2] The vortex shedding (figure 1) happens with periodicity, with forces perpendicular to the incident wind flow direction. There is a constant of proportionality St between the average velocity of the incident wind flow v, the inverse of its characteristic length and the frequency of vortex shedding f.

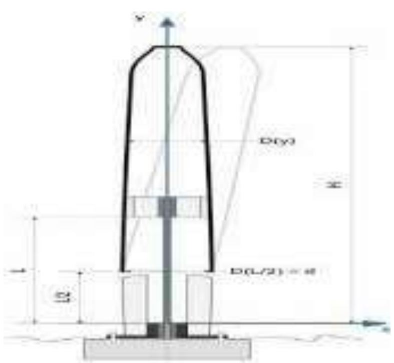
$$F=St.v/\ t$$

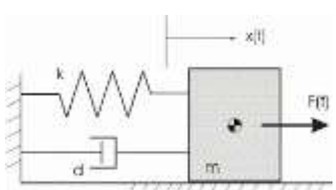
The resonance phenomenon often appears associated with the normal mode of oscillation. Reaching higher performance than if they did not However, in the distributed energy sector, where energy is generated close to the point of use, the most remarkable technology may be photovoltaic solar energy. The lacking of mobile mechanical parts allows to collect energy from the sun with minimal maintenance and no environmental noise impact. In addition, it is well known that the combined use of different renewable energy sources is synergistic due to mutual compensation in periods of absence of wind, sunlight, etc. The development of a new wind generator can be very useful if it is able to emulate the features that have made photovoltaics the main energy source in the distributed energy sector.

Figure 2D XIV contour of pressures, CFD for a DNS model, Reertisementsolve v14, HyperWorks 8, Altair®).

Generally, the wind direction is variable. The cross section of a device without mechanical shafts and always well oriented to the wind direction has to be circular. Vortex shedding formation, unlike other dynamic phenomena such as fluttering or galloping are easily formed in circular section bodies. On the other hand, normally the higher you are from the ground, the more increases the grahent of wind velocition. The Hellmann's exponential law [3] is a well studied approximation to this fact. Due to the aforementioned rcasems, a vertical, slender and circular cross section structure seems to be adequate to collect wind energy without requiring mechanical shafts

The performance in the conversion of wind's kinetic energy into mechanical energy should be as close as possible to the Betz limit [4] Regarding this, the mast is the rigid part of the structure directly interacting with the wind. As showed below, we can reach a synchronised vortes shedding along the whole mast by modifying the diameter according to height. In this way, the perpendicular forces to the wind flow direction do work in phate all together.

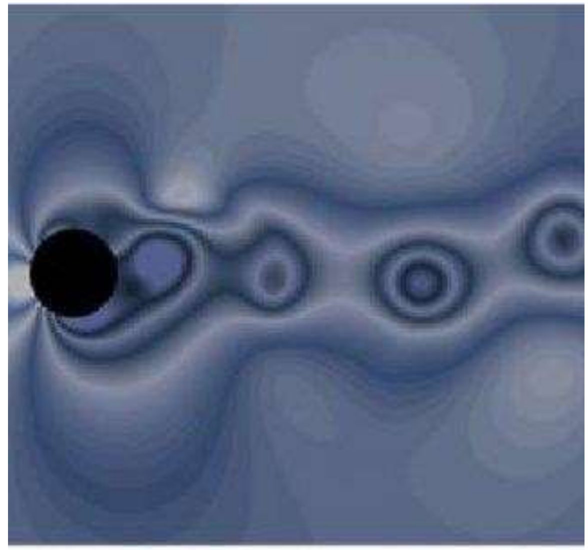




The characteristic length of cylindrical structures mentioned in equation (1) takes the value from the structure's diameter. This approach fits well for static structures, but with structures whose cecillation is not negligible, it can be proven that a better fit is Is obtained with:

$$\emptyset = D + a - X \qquad (2)$$

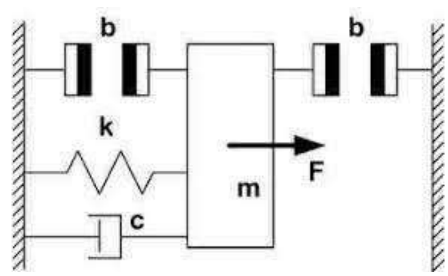
Where the characteristic length is the sum of the diameter of the mast and the amplitude of its oscillation X multiplied by an adjustment factor which



in Reynolds Number dependent. A correct adjustment of this factor allows an orderly vortex shedding

Suppose a flexible and free length I rod (figure 2) embedded in the mast (upper part) and in the ground flower part) Considering the must as a rigid solid able to oscillate small angles, it is acceptable to same that the amplitude of oscillation is null [5] at the height of y 1/2. In this postion the characteristic length according to (2) matches the diameter of the mast-DL2-d and the vortex shedding frequency with wind velocity 1/2) is:

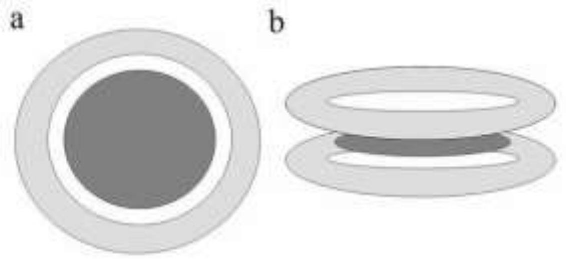
$$F = St.V\infty(L/2)/d \quad (3)$$



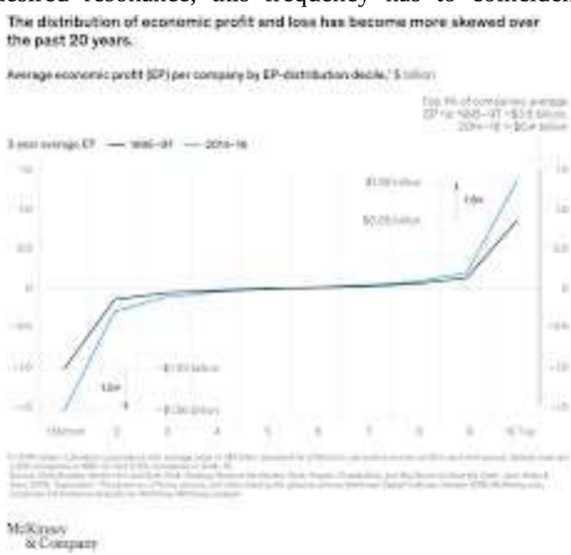
In any other section of the mast, where the oscillation value is not negligible, the frequency of vortes shedding result:

$$f(y) = S.V\infty[y]/D(y) + a.X[y]$$

In any other section of the mast, where the oscillation value is not negligible, the frequency of vortes shedding result. the velocity of the fluid and the oscillation amplitude of the mast at each height y respectively. Therefore, I is the distance between the ground anchor of the flexible rod and the highest part of the device. If the displacement in the upper part of the device is y times the mast diameter at its lowest part, As the ones shedding frequency is the same throughout the length of the mast, we finally obtain. A proper estimation of the velocity gradient. including the discontinuity effect in the highest part of the mast,



should serve to find the same vones shedding frequency along the whole mast. In under to reach the desired resonance, this frequency has to coincident



with the one of the whole structures normal oscillation mode 3 Tuning system. As seen above, the frequency of vonex shedding is proportional to the wind speed which is not constant On the other hand, the range of wind velocities within the structure resonates (look in range) [6] is arrow due to the fact that the normal oscillation frequency of a structure is a single one. To increase the number of equivalent working hours per year, we have to increase this range of useful wind velocitics A strategy that allows us to avoid mechanical shifts is shown below.

Figure 3 shows the ampoid harmoni oscillate diagram where a mass m oscillates under the action of a force F and it is connected to a spring of clasticity constant and damper of contant C.

The behavior of a VIV resonant aerogenerator without built-in tuning system can be understood. regarding to this model. The mass of a mast is supported by a rod with a certain rigidity and the system is damped by the alternator and other power lenses. This whole system will resonate if the oscillatory force induced by the wind has the as the following frequency:

F=1/2□√k/m(c/2m)

An available strategy to increase the range of working wind velocities tresonance) can be illustrated as follows:

Two pairs of permanent magnets have been added to the dumped harmonic oscillator. The same poles are facing each other. These pair of magnets has onefixed to the oscillating mass and the other fixed to the ground. The magnetic force that appean between two permanent magnets is inversely proportional to the square of the average distance between their poles, in away that they behave like a compression spring with non-constant clasticity dependent on the displacement. As they get closer, the growth of the repulsive force between them grows higher than a fineur order. So, now the frequency of oscillation increasing with the oscillation amplitude:

f(x)=1/2□√(k+k'(x)/m) -(c/2m)Where represents the amount of corresponding to the magnetic repulsion clasticity.

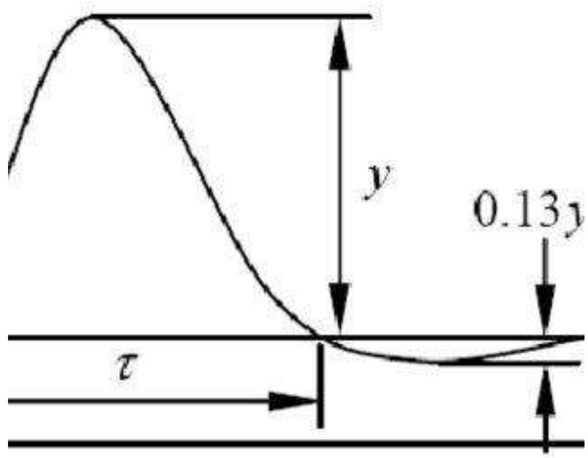
As already mentioned in the design of the device a complete axial symmetry is sought with the aim of having an independent behavior of the wind flow direction. The desired effect can be implemented with one or more pairs of permanent magnets rings, where the une with smaller diameter is the fixed one and it i magactically confined inside of the one with bigger deter. As an example, ita polarization can be axial

As an example, figure 6 shows the temporal evolution of forces in a complete oscillation of a lab model mast.

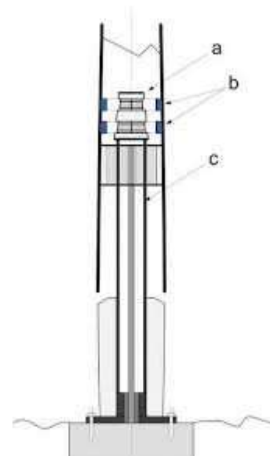
The force a is magnetically originated. The evolution of the force b is due to the elasticity of the rod. The resultant force c (sum of a and b forces) is the one that the must perceives A wind speed increase causes an augmentation of oscillation amplitude. As the oscillation amplitude grows, the potential energy accumulated in a flexion grows faster than if it were a linear spring, so the oscillation frequency of the whole system increases. Hence, without the use of any actuator, the lock-in range (figure 7b) reaches higher values on the horizontal axis than those achieved with a classic lock-in

It has been observed in wind tunnel tests that when the a model with built-in tuning system exceeds the lock-in range it stops working suddenly (figure 8). As a result, braking systems are not necessary to deal with strong winds Testing device in the wind tunnel Acute in the CIDA DRUPM). In height model, max must drum 95mm and suited by a solid sinular section. He pulled carbon fiber rod (February, 2018). The conversion of structural energy into electricity can be made by different methods. As the oscillation. Currently, the most developed option to obtain electrical energy is electromagnetic induction, especially by using a permanent-magnets alternator. The imposition of excluding mobile shafts and the spherical/variable character of the mast movement condition the design of a suitable alternator for this technology. In a first approximation, and due to the fact that the maximum mast velocity take place where it passes over the oscillation neutral position, it seems to be attractive from an electromagnetic point of view that the interaction between magnets and coils occurs with the mast in a vertical position. It has been proven that this strategy leads us to circular and weakened trajectories of the mast or even the disappearance of resonance. This happens because the system logically searches a minimum energy trajectory. On the other hand, the interaction between magnets and coils in position of maximum bending and even the induced forces between magnets and electric iron cores are allowed by the system dynamics.

Another important aspect to be taken into account in the design of the alternator is the need to maintain a complete axial symmetry. The device must behave identically independent of the wind direction. Thus, the use of permanent magnets arranged in a ring and fixed to the mast are the most indicated strategy again. Finally, the aerodynamic benefits related to a light mast should be highlighted (mast amplitude and lock-in range) 17]. The simultaneous use of the mobile ring for power generation and tuning of the structure saves weight and costs Figure 9 shows the different components of the alternator. The permanent magnet rings bare fixed to the mast. As the mast flexes, the interaction with the coils and tuning magnets fixed to the stator a increases. The stator part of the alternator is supported by the structure e fixed to the ground. Conventional rectifying, filtering and electrical



regulation methods are equally applicable as expected.



As on other alternators electric power output is AC with variable amplitude and frequency. After rectification and filtering it is transformed into DC. Other more exotic strategies of conversion of mechanical energy into electrical energy have not been evaluated for the time being.

5 Fatigue

The VIV resonant wind generators are characterized by the lack of mechanical components that can be deteriorated by friction. However, the device has a carbon fiber rod subjected to a dynamic cyclic bending load. This type of demand usually causes the material failure due to fatigue. A brief preliminary analysis will help us to approach its magnitude. In line with the principle of prudence it is considered a device whose bending was always on the same plane, with a maximum angle and 5Hz uninterrupted working frequency. The classic formulation:

S_1 =a-N - (9)

with S-500 Mpa, S',-252 MPa and factors K.- 0,96, K 0,94, K, -0,98, K. 1. K, 0.98, K. 0.97 y K

= 0,897, it lead us to an expected operational lifespan of 19.83 years.

TYPES OF TURBINES:

Many types of turbines exist today and their designs are usually inclined towards one of the two categories: horizontal-axis wind turbines (HAWTs) and vertical-axis wind turbines VAWTS). As the name pertains, each turbine is distinguished by the orientation of their rotor shafts. The former is the more conventional and common type everyone has come to know, while the latter due to its seldom usage and exploitation, is quiet unpopular. The HAWTS usually consist of two or three propeller-like blades attached to a horizontal shaft and mounted on bearings at top of a support tower.

DRAW BACKS OF TURBINE:

The main drawback is that the wind turbine is costlier. Starting wind speed of conventional windmill is high and similarly conventional windmill not able to rotate with high speed and as well as conventional windmill can't harness energy at low wind 36m/s to speed less than 1.5m/s other type of problem associated with conventional windmill is that the bearing

BLADELESS CONCEPT :

The characteristic that set this wind generator apart from others is that it is fully supported and rotates with no risk of animal killing. This is vertically oriented with at the center moving mast and generator.

It seems that basic generator would be most effective placing inside mast. This fig. Shows a basic structure regarding how the bladeless turbine integrated into design. The magnet used inside coil is cylindrical shape magnet, which moves and cause electricity generation output.

COMPONENT DETAILS MAGNETS

Out of the four options of magnets and as seen from the B-H graph the permanent magnets that that were chosen for this application were the N52 magnets. These Nd-Fe-B permanent magnets are nickel plated to strengthen and protect the magnet itself. For maximum output the coil must be such that a complete circular magnet move in or move out of the winding in this case only the maximum energy generation is possible. If the magnet moves only in half part of coil instead of moving in or out completely then there is less energy generation than first case, so proper care must taken while designing the coils and selecting magnet length In this project we only implemented the circular type magnet diameter.

MAST:

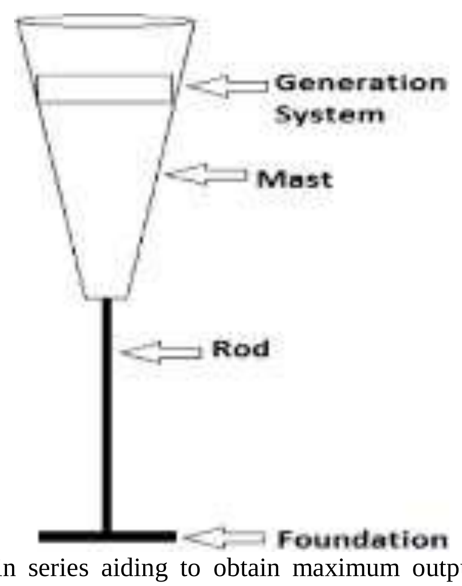
After a thorough research into both sub types of vertical axis wind turbine blades configuration, we decided to base the foundation of our design on the CATIA model. We tool a bit of different approach in our design by modifying it with curvature design from the bottom to top. This design was attained with only single sheet of triangular shape cut out from aluminium metal sheet and due to flexibility of sheet metal, we are able to make it in conical shape which uses vortex shedding effect for electricity generation which explained previously in effect of wind structure on wind turbine.

WINDING:

The number of winding per coil produces a design challenge. The more windings will increases the voltage produced by each coil but in turn it will also increase the size of each coil. In order to reduce the size of each coil a wire with greater size gauge can be utilized. Again another challenge is presented, the smaller the wire becomes the less current will flow before the wire begins to heat up due to the increased resistance of small.

COIL DESIGN:

These coils are arranged inside the blade, the coils are raised to a certain height for maximum energy generation and for maximum output the coil must be such that a complete circular magnet move in or move out of the winding in this case only the maximum energy generation is possible. If the magnet moves only in half part of coil instead of moving in or out completely then there is less energy generation than first case, so proper care must take while designing the coils and selecting magnet length. The coils are



arranged in series aiding to obtain maximum output voltage. The series connections of the coils are preferred over the parallel connection for optimizing a level between the output current and voltage.

POWER GENERATION

The relationship between area and field density is known as flux (q). The way in which this flux varies in time depends on generator design. The axial flux generator uses the changing magnetic flux to produce a voltage. The voltage produced by each coil can be calculated using Faraday's law of induction: v=-

N "d q dt. The term magnetic flux is formulated from the dot product of the area and the magnetic field density in uniform field. In most cases a uniform magnetic field cannot be produced so the flux is calculated by integral B=BdA magnetic field with respect to the area.

FINAL MODEL

The overall structure of the prototype designed is shown in fig 6.6. The output voltage obtained from this prototype is measured using a multimeter and it is found be some value around 60mV.

FUTURE SCOPE:

From above information it is clear that the Bladeless turbine wind generator is the best option for electricity generation using wind power due to its various advantages. The country like India which having more rural population and condition suitable for wind generation through bladeless wind turbine is the best solution. It will help to increase percentage of renewable energy for electrical power generation and provides electrically as well as economically efficient power to the consumers. Here it can be mounted to a roof and be very efficient and practical. A home owner would be able to extract free clean energy thus experiencing a reduction in their utility cost and also contribute to the "Green Energy" awareness that is increasingly gaining popularity. Problem with bladeless wind turbine is that it's initial cost is high but once it get implemented then it's operational cost is very less since it compensates initial cost. Another problem is, awareness about this concept. This concept having very less awareness among the world hence research and development of this concept is very slow. Hence have to spread this concept because only renewable energy can survive the world in coming future and in that wind energy is efficient option.

One of the main advantages of Vortex is its dramatically low cost. In fact, the normalized cost of energy generation (LCOE) for a typical onshore facility is $0.035/kWh (about 35 euros/MWh), including capital costs, operation and maintenance, performance, land leases, insurance, and other administrative expenses.

Discussion:

The calculation of the cost of any electric generation system (LCoE) relates the total investment that is faced in its manufacture, installation, maintenance and scrapping/recycling and the energy generated during its lifespan. Many aspects influence the final value of this ratio. The influence of the wake on the behavior of neighboring devices determines the minimum distance that there should be between two installed devices. A shorter required distance is favorable to a reduction in the energy cost. Preliminary experiments in this area allow us to anticipate the appearance of synchrony phenomena between neighboring devices and other typical emergent properties of chaotic systems. A distance between devices of half their height will not cause a dramatic performance reduction but more rigorous studies must be carried out in this regard.

The ability of the device to withstand high winds is important in many areas of the planet. To safeguard their integrity, conventional windmills are designed to face high wind speeds by using a braking and a pitch systems. In the case of VIV resonant wind generators, strong winds produce a decoupling between the structural oscillation frequency and the appearance of vortices. Thus, the resonance and oscillation disappear and lift forces become less important than drag forces. Preliminary tests in this respect point to a remarkable tolerance to strong winds and a low resistance to the collision with objects projected by them. More rigorous studies must be carried out in this regard.

The visual and environmental impacts will influence the cost and acceptance of the device as a new energy generation device, especially in urban emplacements. Preliminary experiments in this area allow us to anticipate the appearance of synchrony phenomena between neighboring devices and other typical emergent properties ofchaotic systems. A shorter required distance is favorable to a reduction in the energy cost.

CONCLUSION:

From above information it is clear that the Bladeless turbine wind generator is the best option for electricity generation using wind power due to its various advantages. The country like India which having more rural population and condition suitable for wind generation through bladeless wind turbine is the best solution. It will help to increase percentage of renewable energy for electrical power generation and provides electrically as well as economically efficient power to the consumers. Hence we have to spread this concept because only renewable energy can survive the world in coming future and in that wind energy is efficient.

The implementation of a wind generation device based on aeroelastic resonance is feasible. It has been suggested that it is desirable to collect wind energy with a device that minimizes maintenance needs, especially as far as distributed generation is concerned. A slender and circular cross section wind generator whose diameter is variable according to height is proposed for achieve this mission. To maintain the resonance in a wider range of wind speeds. a strategy based on magnetic repulsion by using permanent magnets has been shown. Finally, regarding to the conversion of mechanical energy into electricity, the use of permanent magnets alternators whose stator is fixed to the ground and its mobile part is fixed to the oscillating structure part has been illustrated. No mechanical components susceptible to wear due to friction are required. The implementation of a wind generation device based on aeroelastic resonance is feasible.

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