Design and Fabrication Of "Vortex Bladeless Wind Turbine"

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Abstract: Bladeless Wind Generation uses a radically approach to capturing wind energy. The device captures the energy of vortices, an aerodynamic effect that has plagued structural engineers and architects for ages as the wind bypasses a fixed structure, it's flow changes and generates a cyclical pattern of vortices. Once these forces are strong then enough, the fixed structure get oscillating. Instead of avoiding these aerodynamic instabilities our design maximizes the resulting oscillation and captures that energy. Naturally, the design of such device is different from a other turbine. Instead of the usual tower, nacelle and blades, the device has a mast, a power generator and a hollow, lightweight and semi rigid fiberglass cylinder top. This puts the technology at the very low range of capital intensity it also makes it highly competitive not only against generations of alternative or renewable energy, but even compared to conventional technologies.

Keywords: Bladeless, Mast, Vortices, Wind Power Generation.

I. INTRODUCTION

Today, India is stepping towards a global super power. This implies that, it is leading the list of developing countries in terms of economic development. Requirement is going to increase manifold in the coming decades. To meet Energy requirement, coal cannot be source of energy. It is estimated that within few year coals will get exhausted. The next choice of energy is solar power, but due to its lower concentration per unit area, it is costly. **India is having fifth largest wind power capacity in the world**. The regions with high wind speed are limited, the installation of conventional limited. The Bladeless is such a concept which works on the phenomenon of vortex shedding to capture the energy. Structures are designed to minimize vortex vibrations in order to minimize mechanical failures. Here, we try to increase the vibrations in order to convert vortex vibrations into electricity. Wind power has become a legitimate source of energy over the past few decades as larger, more efficient designs have produced ever-increasing amounts of power. **The industry saw a record 6,730 billion global investment in 2014**, turbine growth may be reaching its limits. Bladeless will generate electricity for 40 percent lesser in cost compared with conventional turbines. In generation transportation is increasingly challenging because of the size of the components blades and tower sections often require specialized trucks and straight, wide roads. Wind turbines are also heavy. Generators and gearboxes support towers 100 meters off the ground can weigh more than 100 tons. The weight and height of turbines increase, the materials costs, stronger support towers, as well as the cost of maintaining components housed so far from the ground, are cutting into the efficiency benefits of larger turbines.

The alternative energy had repeatedly tried to solve these issues to no avail. But this latest entry promises a radically different type of turbine: a cylinder that oscillates. The Turbine harness vorticity, the spinning motion of air. When wind passes one of turbines, it shears off the downwind side of the cylinder in a spinning vortex. The KE of the oscillating cylinder is converted to electricity through a generator similar to those used to harness energy. It consists of a conical cylinder vertically with an elastic rod. The cylinder oscillates in the wind, then generates electricity through a system of coils and magnets Although, there are three methods of electricity generation using, 1). Rack & Pinion Mechanism, 2). Linear Generator, and 3). Piezoelectric Material.

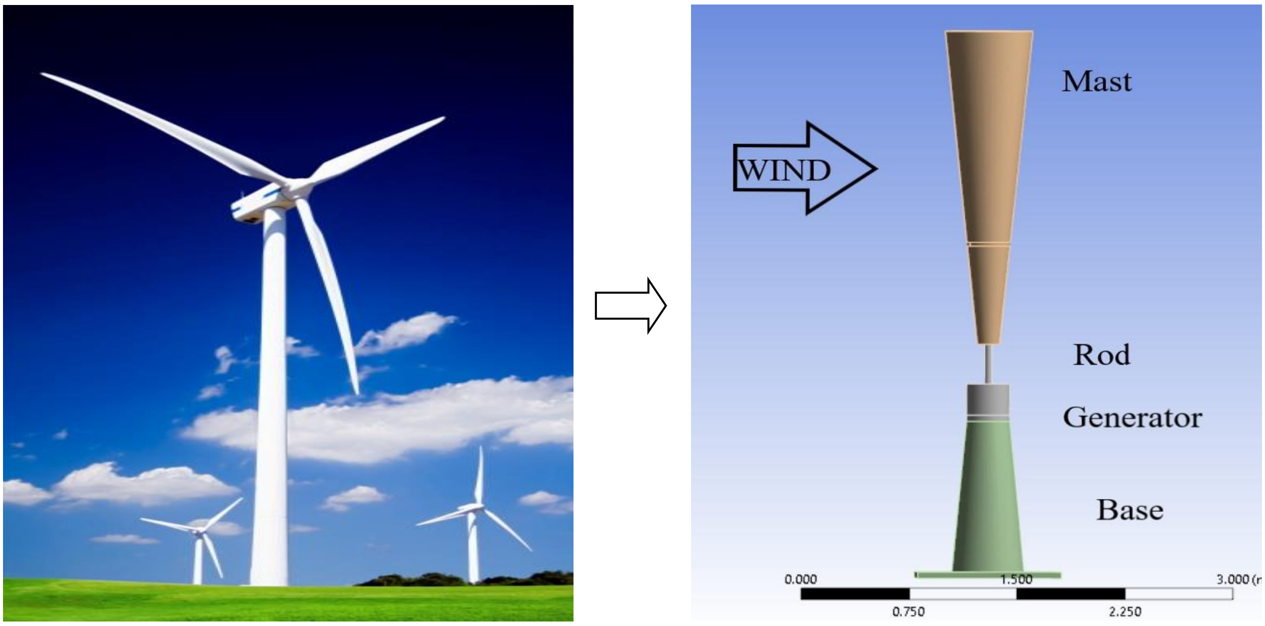

Fig. 1 Different Wind Turbines

II. PROBLEM STATEMENT

Utilization of wind energy with the help of windmills is costly. Huge investment is the big problem for erection of windmills. Conventional windmill requires more places where wind speed is high. Places are limited. Cost of manufacturing different parts of is very high. The transportation of parts is very costly and risky. During transportation components damaged then cost increases. Designing of blades is also a big task. Size of the assembled is also very large. Windmills occupy lots of space. Installation is in 60 acres per megawatt of capacity. Also produce low frequency sound which is not good for human health.

III. OBJECTIVE

Following are the main objectives which have to be covered in this work:

- To increase the efficiency of wind power generation.
- To produce clean energy to meet the increasing demands.
- To make the wind energy economical, efficient and provide electricity in rural areas.
- To reduce pollution & global warming, developing project that can be used in domestic purposes.
- To reduce the manufacturing cost of the turbine. It aims to be a ‘Greener’ Wind alternative leaving less carbon footprint on the environment.

IV. SCOPE

The objective of this work is to develop a New Windmill. This concept allows us to achieve our goal as well as better space management. The new model takes into account all the real time conveying systems and provide solution over their short coming. The New model will get good efficiency compare to old method.

V. LITERATURE REVIEW

Extracting energy from Vortex-Induced Vibrations: A parametric study Antonio Barrero-Gila*, et al.

Here, Vortex-Induced Vibrations (VIVs) of a circular cylinder are analyzed as a potential source for energy harvesting. To this end, VIV is described by a one-degree-of-freedom model where fluid forces are introduced from experimental data from forced vibration tests. The influence of some influencing parameters, like the mass ratio m* or the mechanical damping C in the energy conversion factor is investigated. The analysis reveals that:(i) the maximum efficiency r\M is principally influenced by the mass-damping parameter m*C and there is an optimum value of m*C where r\M presents a maximum; (ii) the range of reduced velocities with significant efficiency is mainly governed by nf, and (iii) it seems that encouraging high efficiency values can be achieved for high Reynolds numbers.

Writing in Treehugger, Derek Markham, commented:

"The Vortex wind generator represents a fairly radical break with conventional wind turbine design, in that it has no spinning blades (or any moving parts to wear out at all), and looks like nothing more than a giant straw that oscillates in the wind. It works not by spinning in the wind, but by taking advantage of a phenomenon called vorticity, or the Kármán vortex street, which is a 'repeating pattern of swirling vortices.'" Raul Martin, Vortex Bladeless co-founder, said, "Compare our invention to a conventional wind turbine with similar energy generation—ours would cost significantly less," around 50 percent or 47 percent less. The company site said that Vortex saves 53 percent in manufacturing costs and 51 percent in operating costs compared to conventional wind turbines.

Vortex-Bladeless is a spanish SME whose objective is to develop a new concept of wind turbine without blades called Vortex or vorticity wind turbine.

This design represents a new paradigm in wind energy and aims to eliminate or reduce many of the existing problems in conventional generators. Due to the significant difference in the project concept, its scope is different from conventional wind turbines. It is particularly suitable for offshore configuration and it could be exploited in wind farms and in environments usually closed to existing ones due to the presence of high intensity winds. The device is composed of a single structural component, and given its morphological simplicity, its manufacturing, transport, storage and installation has advantages. The new wind turbine design has no bearings, gears, etcetera, so the maintenance requirements could be drastically reduced and their lifespan is expected to be higher than traditional turbines. It is clear that the proposed device is of prime interest, and that scientific investigation of the response of this wind energy generator under different operation scenarios is highly desirable. Thus, the objective of this SHAPE project is to develop the needed tools to simulate Fluid-Structure Interaction (FSI) problems and to reproduce the experimental results for scaled models of the Vortex-Bladeless device. In order to do so the Alya code, developed at the Barcelona Supercomputing Center, is adapted to perform the Fluid-Structure Interaction (FSI) problem simulation.

VI. PROJECT DESIGN METHODOLOGY

Calculations:

4.1 Design of Mast-

Considering the notations as,
d0= Dmax,
d1= Dmin,
D= (Dmax+ Dmin)/2
H= L,
U= Air velocity,
ν= Kinematic viscosity,
fs= Oscillation frequency,

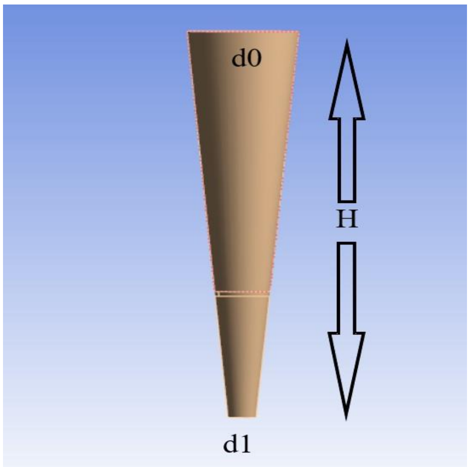

Fig. 3.1 Mast Structure Diagram

Now, we know Reynolds Number (Re)
Re= (UD)/ν

and Strouhal Number (St)
St= (fs*D)/L

Area of tapered cylinder,
Ap= (π/2)*(Dmax+ Dmin)*L

Rt= Taper Ratio =L/(Dmax+ Dmin)

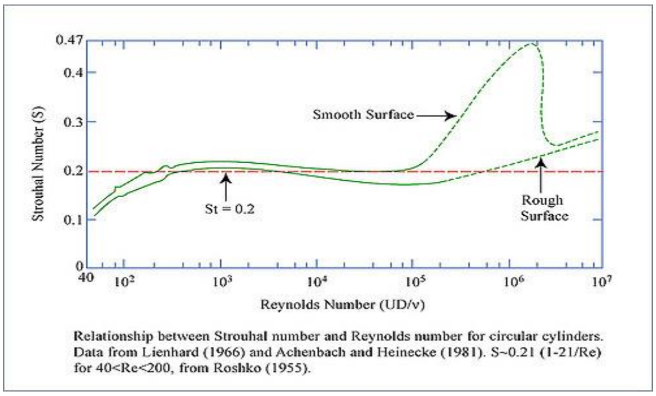

Fig. 3.2 Vortex Shading Periodic pattern

Reynolds Number distinguish the flow of fluid as Laminar or turbulent. So we are targeting Re values 300<Re<3*105 for better frequency of vibration. (From graph)
Now for Reynold number to be 300<Re<3*105, Strouhal Number should be 0.2 or 0.198 (from graph)
St = 0.198

Now all the parameters are known except Mean diameter (D). To find mean diameter, we have to do trial and error. By comparing our value of D with L/D ratio of other such Experiment.
Let us fix length as L= 1 m total length so from precious research paper and past study we take L/D=5 now,
1000/D=5
Dmax=200mm

Now from different Research paper we found the taper ratio lies between 10-16 so selecting 10 as a taper ratio r=10

r=L/Dmax-Dmin
10=1000/200-Dmin
Dmin= 100 mm Approx for smooth taper

Area of taper cylinder,
Ap= (π/2)*(Dmax+ Dmin)*L
$= \frac{\pi}{2} * (200 + 100) * 1000$
Ac =0.4713 Sq. m (1)
And volume of taper cylinder, Vc=Ac*L
=0.4713*1
= 0.4713 Cubic m (2)

A report by Indian Metrological Department PUNE was studied which gives the idea of wind speed and its direction. The wind speed ranges from 0.72 m/s to 3.66 m/s and the average speed is 2.8 m/s.
Density of air is taken as 1 kg/m3
Now,
Mass of taper cylinder,
Density = Mass/Volume,
$\rho = m/V$
$M = \rho * V$
= 1*0.4713
M = 0.4713 Kg (3)
Natural Frequency
We know that from Theory of torsion of shaft
we have

$$k_t = \frac{T}{\theta} = \frac{GJ}{l}$$

So,
Wn=√(T / I)

T-torque of rotating member
I- Moment of inertia

Now from CAD drawing software and selecting material as PP Polypropylene and Determining Thickness Properties considering wall thickness as 2 mm we calculated mass=1.8 Kg
and also found the position of center of gravity. Z= 859.18 mm from top mast

now natural freq fn= 1/2π*√{(KL^2-2mgL)/4I} (4)
putting the values in the formula
I=1/3m*L^2
I=2.4kg-m^2 (5)

Now as we know strouhal frequency should be close to natural frequency
So, we know St=0.2
putting the value in strouhal formula,

St=fs*D/U
fs=St*U/D
=0.2*2.8/0.2
=2.8 Hz ~ 3 Hz

fs=3 Hz (6)
This should be equal to natural frequency
So,
by putting fn=3 Hz in the formula, fn= = 1/2π*√{(KL^2-2mgL)/4I}

We get,
K=892.232 N/m (7)
(value of shaft stiffness) This much force is provided to sustain the Air thrust.

4.2 Design of Bolts-

Bolt is to be fastened tightly. stress for C-25 std. ft=420Kg/cm2 std. nominal diameter of bolt is 10mm, from the table in design data book, diam. corresponding to M12 bolt is 8.160 mm.
Let us check the strength
Also initial tension in the bolt when bolt is fully tightened
P=3.436 kg is the value of force on bolt.
being 4 bolt the load P=3.436 kg is shared as
$P=\frac{p}{4}=\frac{3.436}{4}\times 9.81=8.42N$
Also,
$P=\frac{\pi}{4}\times dc^2\times ft$
$8.42=\frac{\pi}{4}\times (12\times 0.84)^2\times ft$
ft=0.10 N/mm. (8)
The calculated ft is less than maximum ft hence design is safe.

4.3 Design of spring-

Load = 300 N τ = 350 N
Deflection = 25 mm G = 84 × 103 N/mm2
Spring index, c = 8
Stiffness of spring (k) is given by;
K = Load/deflection, k = w/δ
Hence,
K = 300/25
K = 12 N/mm,
Spring index is given by;
C = D/d,
D = C×d (9)
Shear stress factor is given by;
Ks = 1 +1/2C,
Ks = 1 +1/(2×8),
Hence,
Ks = 1.0625
Resultant of shear stress is given by;
Find the value of {D & d},
τ = (8×W×D/ π × d3)×KS,
τ = (8×W×C×d/ π × d3)×KS,
τ = (8×W×C/ π×d2)×Ks,
350 = (8×300×8/π×d2)×1.0625,

d2 = 18.55 mm,
d = 4.307 mm = 5 mm,
D = d×C,
D = 8×5 = 40 mm,
Deflection is given by;
δ = (8×W×D3×n)/(G×d4),
δ = (8×W×C3×d3×n)/(G×d4),
25 = (8×300×83×n)/(84×103×5),
n = 8,
No. of active coil n = 8,
Hence,
Assuming Square & Grounded side spring;
Total No. of Coil = n+2;
Hence,
N= 8 + 2 = 10,
solid length of spring;
Ls = N×d = 10×5 = 50 mm,
Free length of spring;
Lf = Ls + δmax +.15×δmax;
Lf = 50+25+[0.15×25],
Lf = 78.25 mm,
Pitch of coil;
P= Free length /(N-1),
P = 80/(10-1) = 80/9 = 8.88 mm, (10)

VII. WORKING

Our project works on the Principle of Vortex Induced Vibrations (VIV) Theory. In which electricity is generated by Wind energy. The wind strikes the mast, due to which it starts to Oscillate, when this frequency of Oscillation matches with the Natural frequency of mast, Resonance is created. Due to which high vibration is created. This vibration is transferred to the base Rod due to which rod also starts to vibrate. This oscillatory motion is further transmitted to the Generator part. In which generator consist of Piezoelectric material which converts the pressure energy to electrical output (D.C.) Then that generated energy is passed through the diode and capacitor with the help of bridge circuit. Through that the generated energy is provided to battery for charging or storage purpose. After storage of energy it is used further as per requirement. Actual working of the piezoelectric material is as follows,

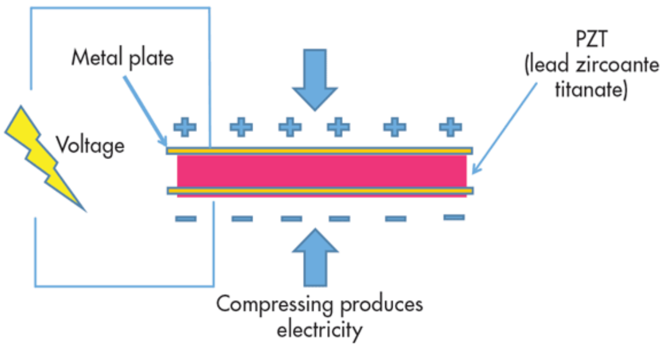

Fig. 4 Working principle of Piezoelectric Crystal

Fig. 5 Actual Generator Part

VIII. CAD AND ANSYS

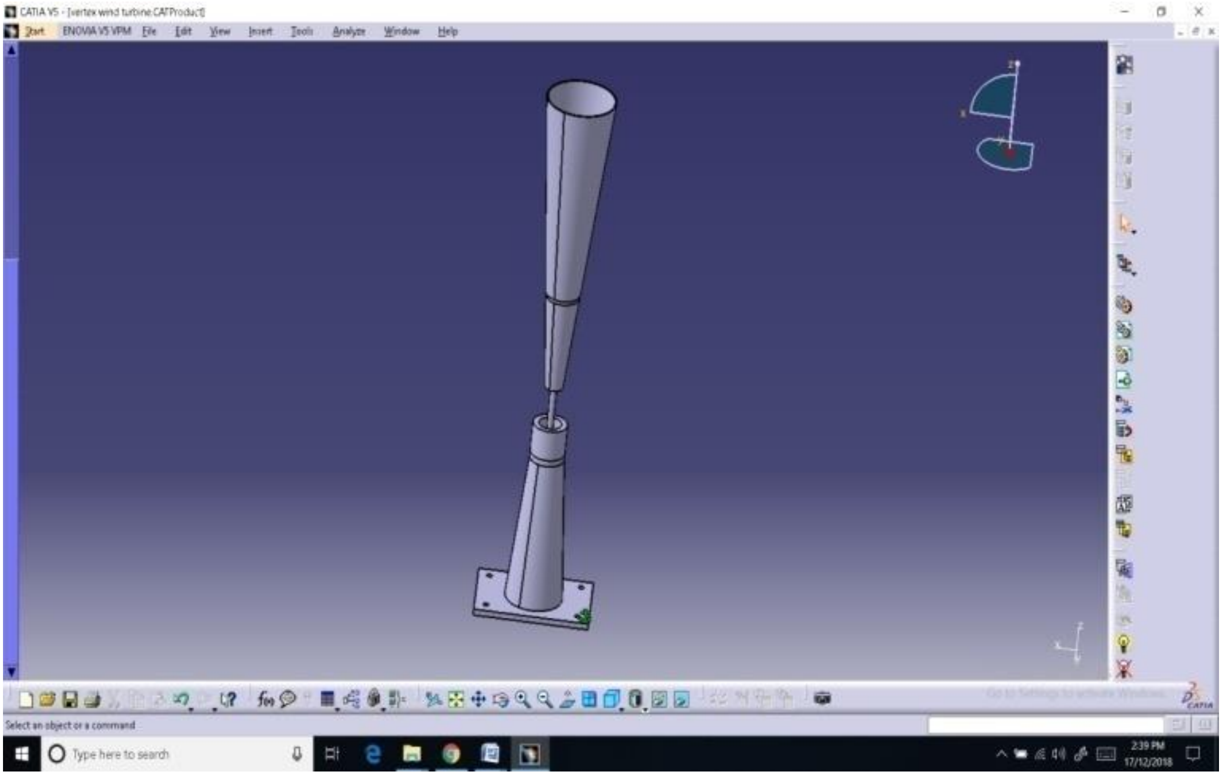

Fig. 6 CAD Modeling

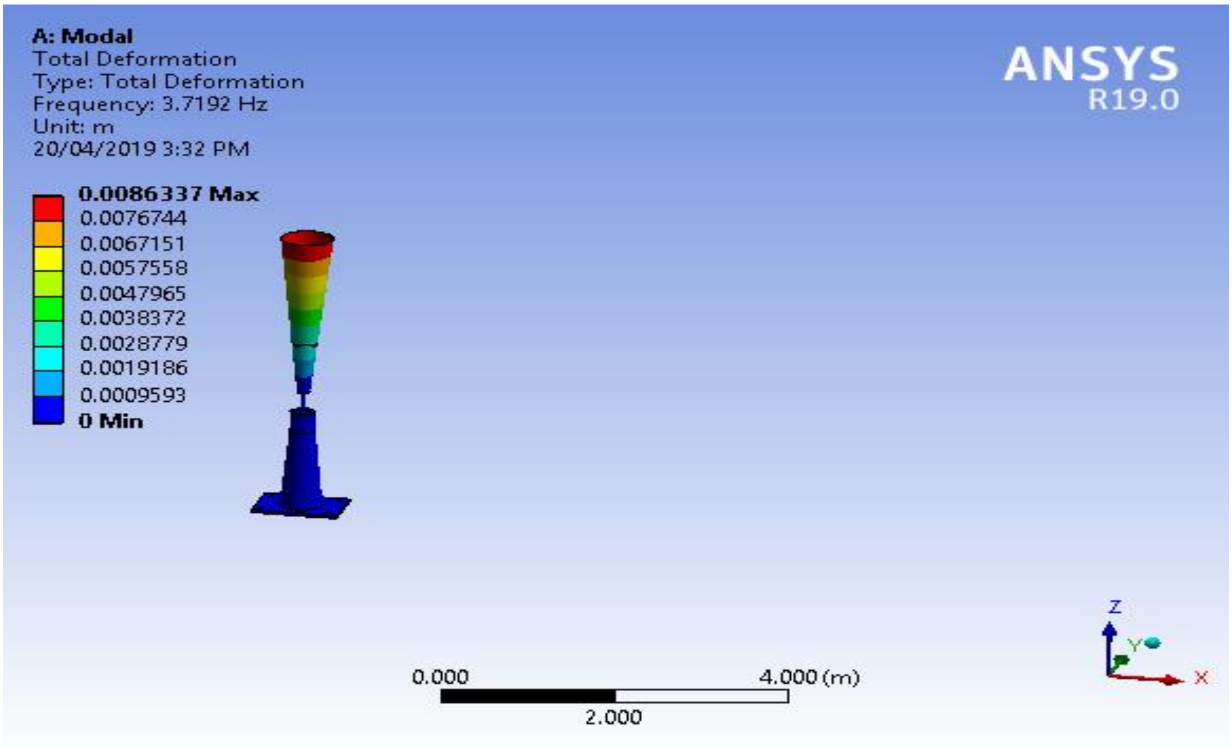

Fig. 7 Analysis of model in ANSYS (Total Deformation)

IX. RESULTS

Actually, results of our project depend on the testing conditions and various environmental factors. Movement of the mast depends upon the velocity of wind at Particular time and place, so as per that generation capacity changes. As we have tasted it near Express highway where air velocity is about 3-4 m/sec. So that its maximum output obtained is up to 5-6 Volts.
Further if wind velocity increases, output will be beyond 8-10 Volts.

Experiment time & place	Wind velocity (Anemometer Reading)	Output DC Voltage (Multimeter Reading)
Morning, Express Highway	3-4 m/s	5-6 volts
Afternoon, Hills & Mountain	5-6 m/s	3-4 volts
Evening, Railway Track	4-5 m/s	6-8 volts

Fig. 8 Actual Testing Results Output

X. CONCLUSION

So as per workplan we had done the literature survey, design and calculations of the Mast, Rod, Spring and Bolts. Then next we had done CAD modeling of the parts & assembly and ANSYS Simulation. On the basis of simulation results we started fabrication, after final fabrication we have started experimentations and testing at different sites, As a result we get DC fluctuating voltage ranges from 3-8 volts and this can be stored in rechargeable battery for further use as per requirements.

Hence, results obtained are very encouraging and we have achieved our objectives of clean, economical and efficient wind power generation. So, we are looking forward Vortex Bladeless as the future of Renewable Energy (wind) harvesting to be seen and used as rural electrification of our Country in upcoming years.

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