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[NCRAES-2019] ISSN 2348 – 8034
Impact Factor- 5.070

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

ADVANCED TECHNIQUES IN BLADELESS WIND MILL POWER GENERATION

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ABSTRACT

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

Key Words: *Bladeless windmill, Vortex, Spring, Polypropylene sheet, Birds*

I. INTRODUCTION

The Bladeless Windmill is such a concept which works on the phenomenon of vortex shedding to capture the energy produced. Generally, structures are designed to minimize vortex induced vibrations in order to minimize mechanical failures. But here, we try to increase the vibrations in order to convert vortex induced vibrations into electricity. The paper studies the scope and feasibility of the bladeless windmill. This study focuses on identifying the effect of governing parameters on the energy extraction efficiency by VIV. The parameters investigated were the mass ratio, the mechanical damping coefficient, and the Reynolds number. Wind power has become a legitimate source of energy over the past few decades as larger, more efficient turbine designs have produced ever-increasing amounts ofpower. But even though the industry saw a record 6,730 billion global investment in 2014, turbine growth may be reaching its limits. Bladeless turbines will generate electricity for 40 percent lesser in cost compared with conventional wind turbines. In conventional wind power generation transportation is increasingly challenging because of the size of the components: individual blades and tower sections often require specialized trucks and straight, wide roads. Today's wind turbines are also incredibly top heavy. Generators and gearboxes sitting on support towers 100 meters off the ground can weigh more than 100 tons. As the weight and height of turbines increase, the materials costs of wider, 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.

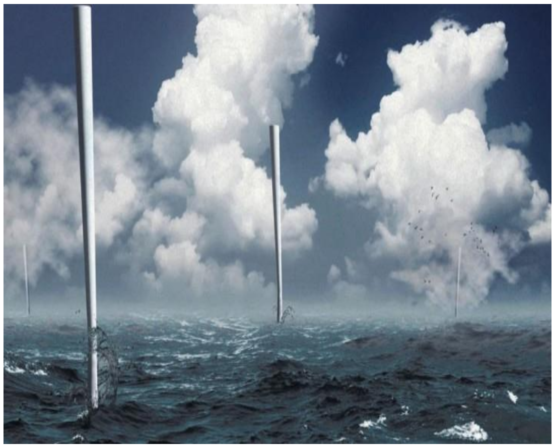

Figure 1 bladeless wind mill

II. HISTORY OF BLADELESS POWER GENERATION

The Vortex Street 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 any fixed object immersed in a laminar flow. The wind flow bypasses the object, generating a cyclical pattern of vortices, which can become an engineering challenge for any vertical cylindrical structures, such as towers, masts and chimneys. The issue is that they may start vibrating, enter into resonance with the lateral forces of the wind, and ultimately, collapse. One of suchexamples is the collapse of three cooling towers of the power station Ferrybridge in 1965. However, it is possible that the same forces can be captured to produce energy - the idea behind Vortex.

In this project we are going to design and develop the working model of a sovenious type of vertical axis bladeless wind turbine for the power generation from wind energy. We are going to design the vortex tube for drag force. The static analysis of turbine blades will be done. The power generation will be demonstrated with the help of stepper motor in place of dynamo.

III. CONSTRUCTION

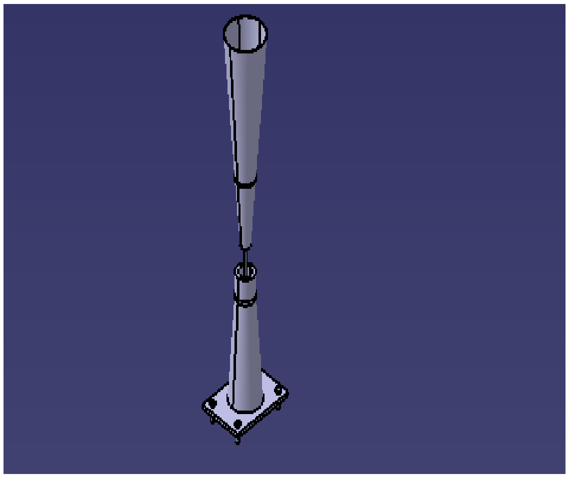

Fig.2 Bladeless Wind Turbine

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Parts - mast

It's a light circular sectic structure made of fiber glass & carbon fiber. Mast act as wind breaker that generates the oscillatory movement.

- **ROD**

Made of carbon fiber. The rod gives strength & flexibility to the movement.

- **Generation system**

Kinetic enegy from the wind is converted into electricity from the piezo sensors.

- **Tunning passive system**

A Magnetic confinement provides movement stability & extend operating hours.

- **Foundation**

Reduce significantly because of the vortex lightness.

Material: fiber glass

Fiberglass is a composite material of glass cloth and polyester resin (Fiberglass). When using this material the fabrication process involves the construction of a foam replica figure, the formation of a basic mold around the replica, and finally the application of the resin and glass cloth to produce the desired shape. Constructing a cylindrical airfoil out of fiberglass is an intriguing option because of its low density and ease with which to fabricate. As the weight of the airfoil directly correlates to the force required to induce movement, fiberglass would require less lift force, allowing for the airfoil to reach natural frequency oscillation at lower flow velocities. Additionally, fiberglass is reasonably affordable, does not require specialized machinery to work with, and can be molded to replicate most geometric shapes, contributing to its feasibility as an airfoil material.

Though fiberglass has generally favorable material characteristics for the fabrication of an airfoil for this device, it fails to satisfy one important criterion; surface finish. After the application of the resin and glass cloth, the fiberglass must be left to set in place. The resin is viscous; however it does settle around the glass cloth strands forming an uneven surface finish (Fiberglass). The material surface finish is an important characteristic to consider for fluid flow applications. In laminar flow conditions, airfoil surface roughness can contribute to a transition to more turbulent flow should the degree of surface inconsistencies be great enough. In turbulent flow conditions, airfoil surface roughness plays a far more important role; Additional surface roughness on the airfoil will compound the inconsistencies found in turbulent flow, causing an increase in Reynolds Number and greater flow turbulence. In the WPI wind tunnel flow conditions are nearly laminar, diminishing any significant effects of surface roughness on aerodynamic performance. Conversely, in outdoor applications wind flow will be turbulent, and a smooth airfoil surface finish will be required to facilitate proper aerodynamic performance. If left with the unfinished surface, the airfoil may not be aerodynamically efficient and achieving lock-in conditions may be considerably more difficult. Commonly fiberglass components are sanded down to a smooth surface and then finished with a glossy resin. This process is rather labor intensive and requires some basic craftsmanship to achieve a truly uniform finish. Should the finishing process not daunting, fiberglass is an appropriate choice for an airfoil assembly material.

Carbon fiber

Carbon fiber is a much more ambitious material to use for the cylindrical airfoil than the aforementioned options. In general, carbon fiber is one of the lightest and strongest fabrication materials currently available. It is formed by weaving miniscule strands of carbon together to form a woven 'sheet'. These strands have a diameter of approximately 5-8 micrometers, and millions are required to form even a small piece of woven carbon fiber (What). As one may conclude, the assembly process for such a material requires specialized machinery and is far more expensive than the other two options listed here. Because of this, the viability of carbon fiber as a fabrication material for the cylindrical airfoil is low. Despite its relative cost, carbon fiber remains a necessary consideration for this purpose because of its significant durability and commercial implications. A carbon fiber airfoil would require minimal lift force to achieve natural frequency oscillation, withstand all but the most extreme weather elements, and remain intact without required maintenance for a longer duration than either of the other two materials. This material longevity and reliability is crucial for the commercial mass production of any product, especially one which is located outside and would undergo immense normal and shear stresses. Though it is not the most feasible, a carbon fiber cylindrical airfoil would undoubtedly be an effective airfoil for this application.

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Working

Our project works on principle of vibration. In which electricity is generated by WIND energy. The wind strike on the mast , it begin to oscillate. When the frequency of air is equal to the natural frequency of mast , the resonance is created. Due to which vibration is created. This vibration is transferred to the rod made of fiber glass due to which rod also start to vibration. This vibratory motion is further transmitted to the base. The base containpiezo sensors, due to vibratory motion of rod electricity is generated in that alternator.

IV. PROBLEM STATEMENT

The utilization of wind energy with the help of conventional windmills is very costly. To find the answer to the above question survey of established literature was done. The problems related to conventional windmills were studied.

- It was found that huge investment is the most significant problem for erection of windmills.
- Conventional windmill requires places where wind speed is more. Such places are limited. Hence windmills working on lesser wind speeds are need of the hour.
- The cost of manufacturing different parts of windmill is very high. A typical windmill will cost $3000-$8000 per kilowatt.
- So also, the transportation of such huge parts is very costly and risky. If during transportation components get damaged then again cost increases.
- Designing of windmill blades is also a big task.
- The size of the assembled windmill is also very large. The conventional windmills occupy lots of space. The commercial turbines can be 160m high.
- Area of installation is 60 acres per megawatt of capacity of wind farms.
- Also they prove fatal to birds.
- They produce low frequency sound which is not good for human health
- To develop unconventional wind turbine which have less moving parts and which is cheap is cost.

Objectives

The main objectives of this project is as follows,

- To increase the efficiency of wind power generation.
- To produce clean energy to meet the increasing demands.
- To make the wind energy economical and efficient.
- Rural electrification.
- To reduce pollution and global warming.
- Development of the project so that it can be used on domestic purposes.
- To reduce the manufacturing cost of the turbine.
- It aims to be a 'Greener' Wind alternative leaving less carbon footprint on theenvironment.

V. ANALYTICAL APPROACH

Vortex Induced Vibration

Let's consider a structure called Tapered Oscillation Cylinder.

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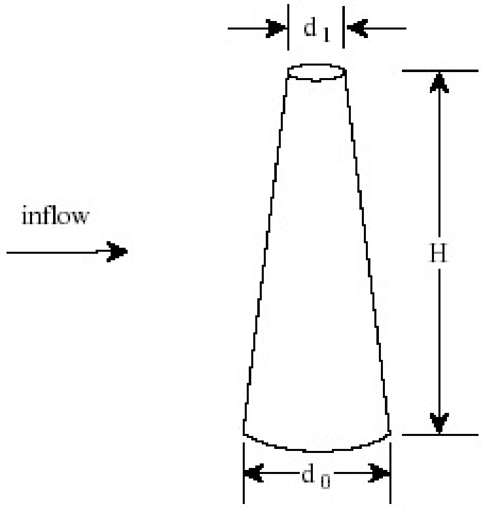

Considering the notations as,
d_0= D_{max},
d_1= D_{min},
D= (D_{max}+ D_{min})/2
H= L,
U= Air velocity,
ν= Kinematic viscosity,
f_s= Oscillation frequency,

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

and Strouhal Number (St)
St= (f_sD)/L

Area of tapered cylinder,
A_p= (π/2)*(D_{max}+ D_{min})*L

R_t= Taper Ratio =L/(D_{max}+ D_{min})

Reynolds Number distinguish the flow of fluid as Laminar or turbulent. So, we are targeting Re values **$300<Re<3*10^5$** for better frequency of vibration. (From graph)
Now for Reynold number to be $300<Re<3*10^5$, 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's fix length as L=2m total length so from precious research paper and past study we take L/D=10
now,
2000/D=10
Dmax=200mm

Now from different Research paper we found the taper ratio lies between 14-19 so selecting 16 as a taper ratio r=16

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r=L/Dmax-Dmin

16=2000/200-Dmin
Dmin=75mm = 80 mm Approx for smooth taper

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 od rotating member
I- Moment of inertia

now from **CAD drawing** software and selecting material as pp polypropylene and Determining Their **mass Properties** considering wall thickness as 2mm we calculated mass=1.8kg
and also found the position of centre of gravity. **Z= 859.18mm from top mast**

now natural freqfn= 1/2∏*√{(KL^2-2mgL)/4/I}

putting the values in the formula
I=1/3m*L^2
I=2.4 kg-m^2
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=3 Hz
This should be equal to natural frequency

so by putting **fn=3**
We get **K=834.2 N/m**
value of spring stifness . **This much force is provided to sustain the Air thrust**

System volt vs current relation:

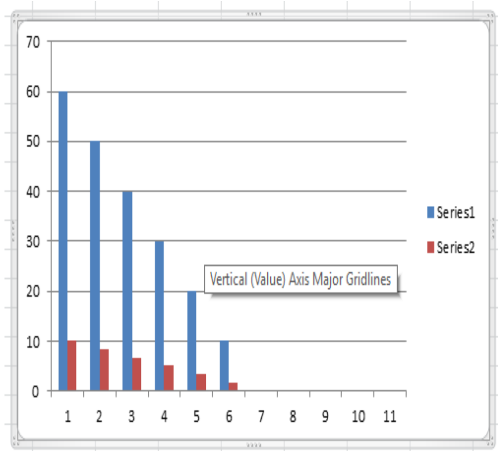


Fig.3 Volt Vs Current Relation

Calculation:

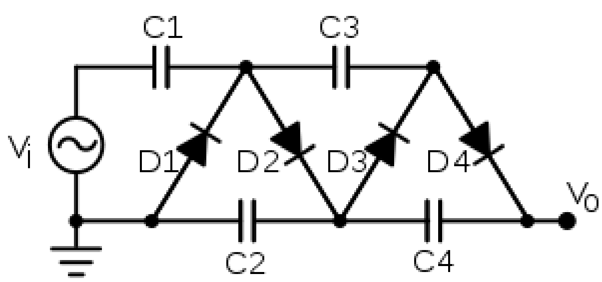
$$I = V/R$$

Where,
I = current generator from sensor.
V= voltage across sensor.
R= resistance of piezo sensor = 6K.

$$I = 50v/6K$$

$$I = 8.8m$$

Voltage multiplier:



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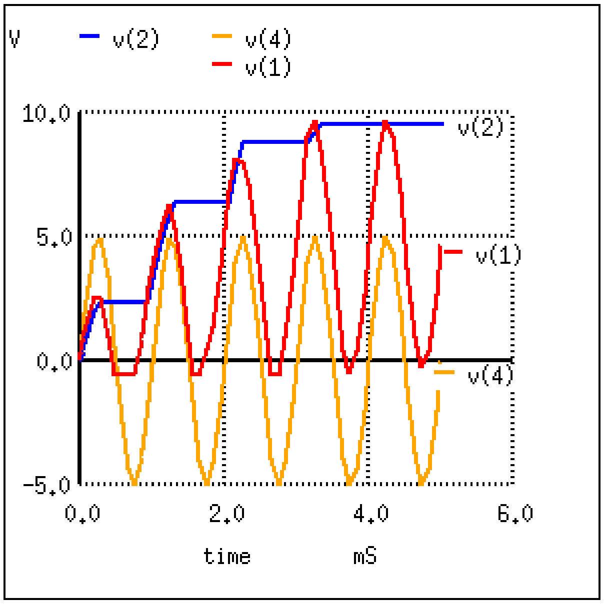

Fig.4 Voltage Multiplier

Half-wave rectification

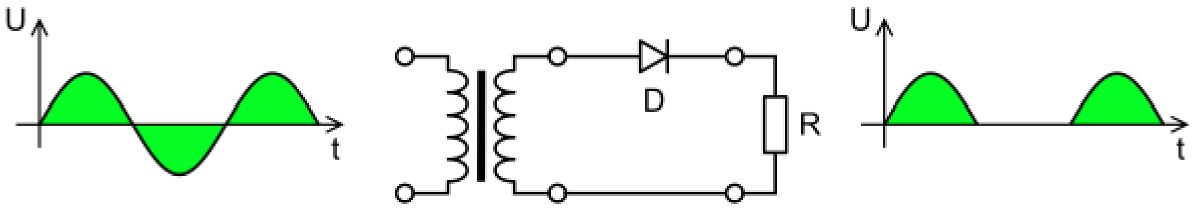

Fig.15 Half Wave Rectification

Full-wave rectification

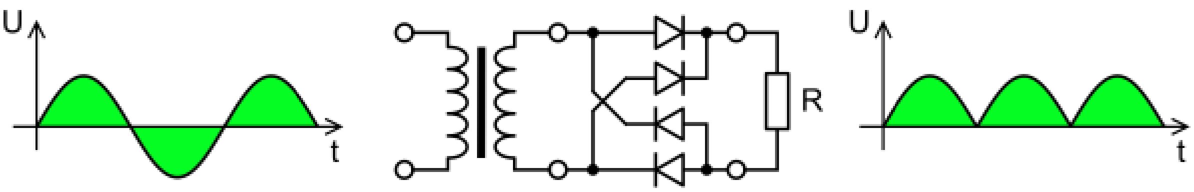

Fig.16 Full Wave Rectification

Rectifiers, we saw that the DC output voltage being controlled by the rectifier is at a value below that of the mains input voltage. The **Voltage Multiplier**, however, is a special type of diode rectifier circuit which can potentially produce an output voltage many times greater than of the applied input voltage.

Although it is usual in electronic circuits to use a voltage transformer to increase a voltage, sometimes a suitable step-up transformer or a specially insulated transformer required for high voltage applications may not always be available. One alternative approach is to use a diode voltage multiplier circuit which increases or "steps-up" the voltage without the use of a transformer.

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Voltage multipliers are similar in many ways to rectifiers in that they convert AC-to-DC voltages for use in many electrical and electronic circuit applications such as in microwave ovens, strong electric field coils for cathode-ray tubes, electrostatic and high voltage test equipment, etc, where it is necessary to have a very high DC voltage generated from a relatively low AC supply.

Generally, the DC output voltage (Vdc) of a rectifier circuit is limited by the peak value of its sinusoidal input voltage. But by using combinations of rectifier diodes and capacitors together we can effectively multiply this input peak voltage to give a DC output equal to some odd or even multiple of the peak voltage value of the AC input voltage. Consider the basic voltage multiplier circuit below

Capacitors:

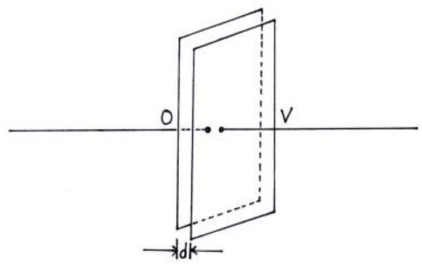

Fig.5 Capacitors

A system of charges, physically separated, has potential energy. The simplest example is that of two metal plates of large area carrying opposite charges so that the potential difference is V. The energy stores are 1 2CV 2 where C is the capacitance of the system. It is defined as the charge (on either plate) per unit potential difference and depends essentially on the geometry of the system. In the above case the capacitance is given by

$$C = \epsilon_o \frac{A}{d}$$

in mks units, where A is the area(in meter^2), d is the separation(in meters), ϵ_0 is a constant (8.85×10^{-12} in MKS units) and the unit of capacitance is a farad.(Refer to any standard text for the derivation of this formula).

A system, such as the above one, is called a condenser or, in modern parlance, simply a capacitor. We shall adopt the modern usage. It must not be assumed that a capacitor is always a set of plane parallel plates. Many other geometrical arrangements may be used and often are more practical(See Appendix I).

Light Emitting Diode Colors:

So how does a light emitting diode get its colour. Unlike normal signal diodes which are made for detection or power rectification, and which are made from either Germanium or Silicon semiconductor materials, Light Emitting Diodes are made from exotic semiconductor compounds such as Gallium Arsenide (GaAs), Gallium Phosphide (GaP), Gallium Arsenide Phosphide (GaAsP), Silicon Carbide (SiC) or Gallium Indium Nitride (GaInN) all mixed together at different ratios to produce a distinct wavelength of colour.

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Different LED compounds emit light in specific regions of the visible light spectrum and therefore produce different intensity levels. The exact choice of the semiconductor material used will determine the overall wavelength of the photon light emissions and therefore the resulting colour of the light emitted.

Light Emitting Diode Colours

Typical LED Characteristics			
Semiconductor Material	Wavelength	Colour	V_F @ 20mA
GaAs	850-940nm	Infra-Red	1.2v
GaAsP	630-660nm	Red	1.8v
GaAsP	605-620nm	Amber	2.0v
GaAsP:N	585-595nm	Yellow	2.2v
AlGaP	550-570nm	Green	3.5v
SiC	430-505nm	Blue	3.6v
GaInN	450nm	White	4.0v

Fig .6 LED Characteristics

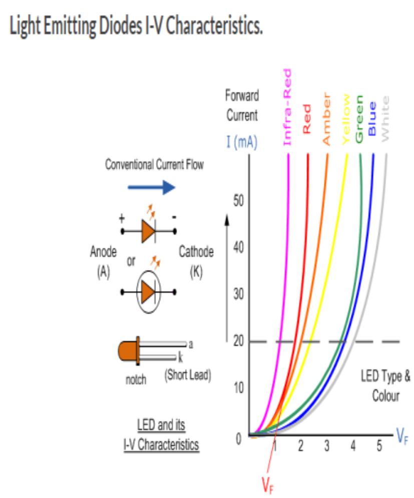

Fig.7 LED IV Characteristics

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LED Series Resistor Circuit

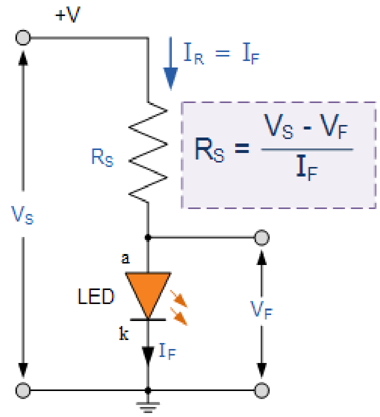

Fig.20 LED Series Resistor Circuit

Light Emitting Diode Example No1

An amber coloured LED with a forward volt drops of 2 volts is to be connected to a 5.0v stabilised DC power supply. Using the circuit above calculate the value of the series resistor required to limit the forward current to less than 10mA. Also calculate the current flowing through the diode if a 100Ω series resistor is used instead of the calculated first.

1). series resistor required at 10mA.

$$R_S = \frac{V_S - V_F}{I_F} = \frac{5v - 2v}{10mA} = \frac{3}{10x10^{-3}} = 300\Omega$$

2). with a 100Ω series resistor.

$$R_S = \frac{V_S - V_F}{I_F}$$

$$\therefore \; I_F = \frac{V_S - V_F}{R_S} = \frac{5 - 2}{100} = 30mA$$

We remember from the Resistors tutorials, that resistors come in standard preferred values. Our first calculation above shows that to limit the current flowing through the LED to 10mA exactly, we would require a 300Ω resistor. In the E12 series of resistors there is no 300Ω resistor so we would need to choose the next highest value, which is 330Ω. A quick re-calculation shows the new forward current value is now 9.1mA, and this is ok.

Connecting LEDs Together in Series

We can connect LED's together in series to increase the number required or to increase the light level when used in displays. As with series resistors, LED's connected in series all have the same forward current, I_F flowing through them as just one. As all the LEDs connected in series pass the same current it is generally best if they are all of the same colour or type.

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Connecting LED's in Series

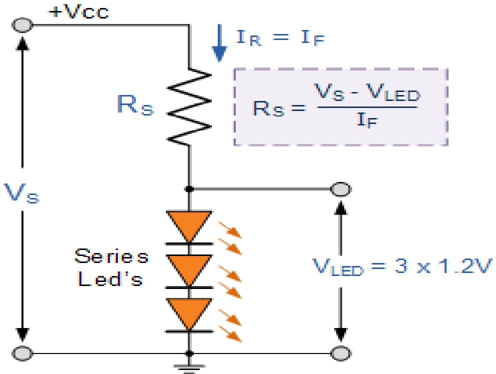

Fig. 21 Connecting LED Series

Although the LED series chain has the same current flowing through it, the series voltage drop across them needs to be considered when calculating the required resistance of the current limiting resistor, R_S. If we assume that each LED has a voltage drop across it when illuminated of 1.2 volts, then the voltage drops across all three will be 3 x 1.2v = 3.6 volts.

If we also assume that the three LEDs are to be illuminated from the same 5-volt logic device or supply with a forward current of about 10mA, the same as above. Then the voltage drops across the resistor, R_S and its resistance value will be calculated as:

$$V_{LED} = 3 \times 1.2\text{volts} = 3 \times 1.2\text{v} = 3.6\text{v}$$

$$R_S = V_S - V_{LED} = 5 - 3.6 = 1.4\text{volts}$$

$$\therefore R_S = \frac{1.4\text{v}}{10\text{mA}} = 140\Omega$$

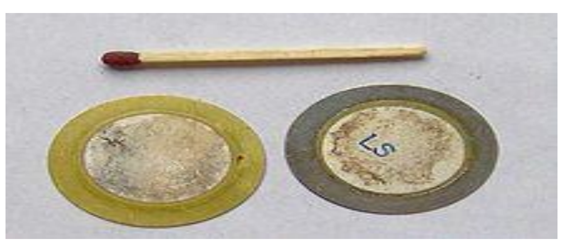

Fig.8 Piezosensors

VI. CONCLUSIONS

In summary, the generation of electricity is made possible by the small structure of bladeless turbine. Efficient power is generated. This project will satisfy the need of continuous generation of electricity. The overall project uses less space area hence highly economical for the rural electrification of India.

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ISSN 2348 – 8034
Impact Factor- 5.070

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