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VORTEX FLOW WIND TURBINE: AN EXPERIMENTAL STUDY

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Abstract : In this paper capturing of wind energy using bladeless device which is a new approach has been discussed. The energy of vorticity which is an aerodynamic effect has been captured by this device. A cyclical pattern of vortices has been generated when the wind bypasses a fixed structure and the fixed structure starts oscillating when these forces are strong enough. Without avoiding these aerodynamic instabilities this device maximizes the resulting oscillation and captures that energy. Naturally, such device is completely different from traditional turbine. Instead of the usual tower, nacelle and blades, the device has a fixed mast, a power generator and a hollow, light weight and semi-rigid fibreglass cylinder on top. In this device the technology has been used is very cost effective and highly competitive not only against generations of alternative or renewable energy, but even compared to conventional technologies.

Keywords: Vorticity, Aerodynamic effect.

I. INTRODUCTION

The wind energy can be captured by a new approach using vortex flow wind turbine. The device captures the energy of vortex, which is an aerodynamic effect. As the wind bypasses a fixed structure, its flow changes and generates a cyclic pattern of vortices. Once these forces are strong enough, the fixed structure starts oscillating due to the vortices formed around the structure and spring placed at the bottom of the mast. The speciality of our design is that instead of preventing the losses of this aerodynamic effect, it captures that energy and increases the resulting oscillation. Such kinds of devices are completely different from a traditional turbine. Instead of the usual tower, blades, gear box and motor mounted on it, the device has fixed mast, spring to support mast on top of it, magnets, conductor coil(with proper insulation), charging circuit etc. This device can be fabricated at low cost which is highly competitive not only against generations of alternative energy, also compared to conventional technologies.

This proposal has been chosen due to its low initial setup cost, less maintenance, easy installation, easy to fabricate, optimisation of flowing wind. The changes that it will bring about are the quick transportation unlike the conventional wind turbines. Construction and assembly are also simplified which are required for the wind industry.

The impact on the life of birds will also be less since it won't take as much space as the conventional wind turbine. There will also be significant impact on the efficiency of such turbines as it will have lesser components and so the losses will be less.

People had theoretical knowledge of vortex concept i.e. a whirling mass of fluid or air which actually brings about loss to any moving object once it comes in vortex region, it tries to pull it towards the centre, so people whenever designed anything they always took vortex in a negative perspective. But it is known that moving vortex carries some momentum and energy with it, so authors decided to utilise the energy of vortex for the oscillation of mast.

2. LITERATURE SURVEY

The nature of the circulation regions around a bluff body in a cross flow can vary considerably from the normal von Karman vortex-shedding mode when subjected to external excitations. Krishnan et al.[1] correlated the spectral content and characteristics of the force coefficients for a square cylinder externally excited by inline sinusoidal pulsation, to near body vortical events.

The effect of natural frequency of structure vortex induced vibration cylindrical structure in two-dimensional unsteady flow studied by simulation of circular cylinder in cross flow conditions. Effect of natural frequency of structure on its vortex-induced vibration had been studied [2]. Numerical analysis of cylinder shows that maximum response occurs at frequency ratio close to unity and reduced velocity (inverse of the oscillator natural frequency) ranging 4-10. This zone is referred as lock-in zone.

Sareen et al. [3] in their paper discussed that the effect of transverse rotation on the vortex induced vibration response of sphere. The axis of rotation was perpendicular to the flow direction. Unlike cylinder, the VIV response of the sphere reduced gradually and steadily with increase in the rotation ratio.

Khan et al. [4] discussed in their paper that –

– Large amplitude vibration through wake body synchronization.

– Noble wake pattern under fixed rotation.

– Impact of rotation on forced frequency & phasing mechanism. Maximum amplitude captured by RKE model was higher than experimental and 3D DES results, whereas SST k-v model results agreed well with the experimental and 3D DES results. Also the broad range of lock-in region was observed during RKE study. RANS SST k-v model confirmed the formation of different vortex modes in the range of reduced velocity Ur = 3–13.

Bourget et al. [5] observed that free oscillations of the rotating cylinder may also develop in the absence of vortex shedding. The symmetry breaking due to the rotation is shown to directly impact the selection of the higher harmonics appearing in the fluid force spectra. The rotation also influences the mechanism of phasing between the force and the structural response.

3. WORKING METHODOLOGY

Proposed plan of the authors is technically feasible since it will utilize the maximum amount of wind energy from the surrounding to produce electricity. When wind passes one of the cylindrical turbine, it shears off the downward side of the cylinder in a spinning whirlpool or vortex. That vortex then exerts force on the cylinder, causing it to vibrate/oscillate. This kinetic energy of oscillating cylinder can be converted to electricity through a linear generator similar to those used to harness wave energy. This wind generator generates electricity through systems of coil and magnet. During wind flow, if obstruction is created, wind energy is creating a natural vortex in way of the obstruction area. Due to which the obstruction (if kept fixed at the bottom, i.e. it will act as a cantilever) will create a random oscillation in the horizontal plane at top (x-y plane). This oscillation will be arrested through the springs fixed to the ground. Also, the spring fixed at bottom will withstand the weight on its top. Faraday's Law of electromagnetism has been used for generation of induced emf and the circuit is made closed for flow of current. During experiment in the Basic Physics Lab, up to 1 mA current was generated with 1 coil of diameter 37 mm (approx) with 30 turns and permanent magnet of magnetic strength of 37 Gauss. Also, the experiment was conducted with improper insulation to cross verify the Faraday's experiment. Based on the experiment, it was decided to make an array of system of coil and magnets to generate electricity. For easy and quick fabrication of the model six coils and magnet array was decided and each coil was placed 600 with each other. The current generated from the system was brought to single node with copper wire. Then full wave rectifier was used to convert the AC to DC as well as for maximising the current. With the help of charging circuit the current was stored in a battery (2200 mAh). The schematic diagram of model is described with details in Fig. 1.

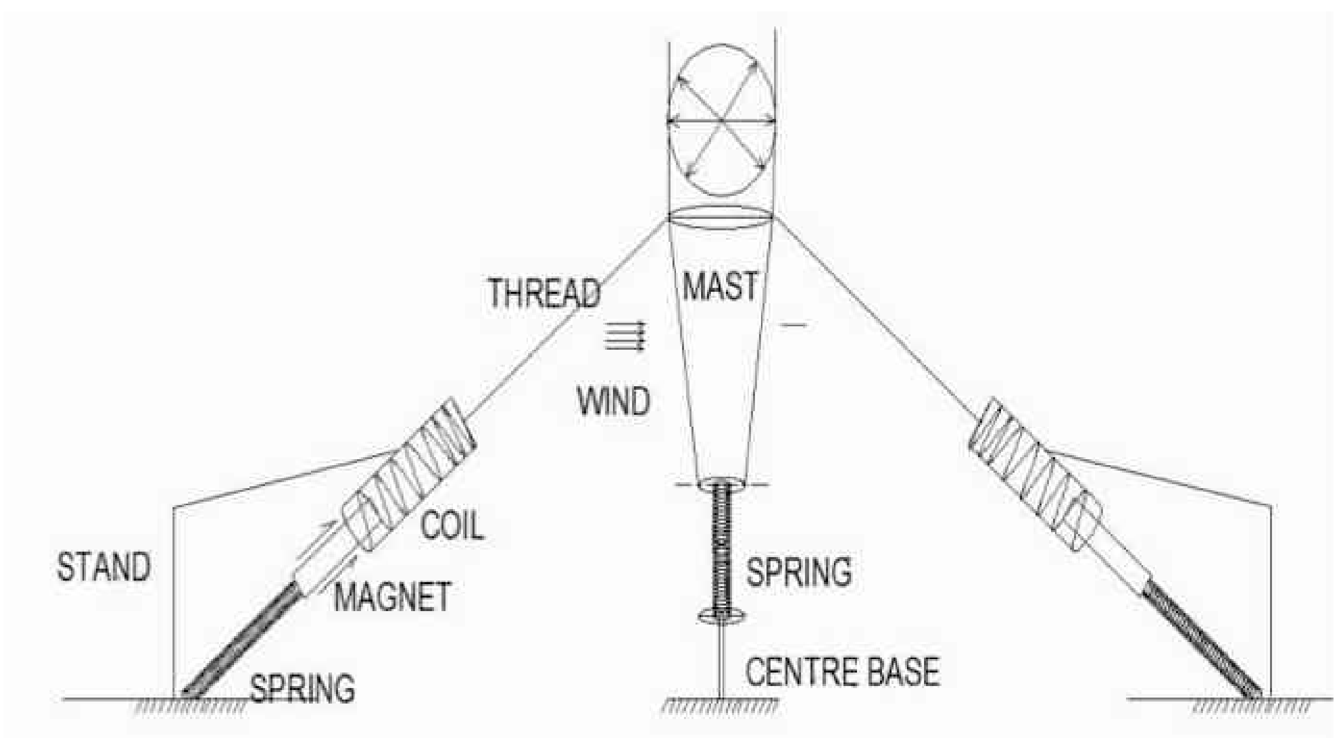

Fig. 1 : Schematic diagram (Source AutoCAD 2016 Version)

4. BILL OF MATERIAL

a) Base: To provide strong foundation to mast and spring.

b) Spring: To support the load acting on it and for oscillation of mast.

c) Mast: Generally, made up of glass fibre or reinforced polymer for its low weight.

d) High power permanent magnets and Copper coil: For generating electricity.

e) Thread: For conversion of oscillation of mast to reciprocating motion of coil and magnet system.

f) Full wave rectifier: To convert the output a.c. current to direct current.

g) Charging circuit: The charging circuit use the micro controller which compare the generated voltage with a predefined value and controls the relays. The relays act as a switch which helps in charging only when power is adequate to charge the battery.

h) Battery(2200 mAh): It stores the charge when power is being generated and gives power to any load connected to it.

I) Load: It can be anything, depends on how much power is stored. In our case, it's 1W LED bulb.

j) Digital Anemometer: It is used for measuring the speed of the wind (Makers-Lutron, model Am4206)

5. OPERATIONAL REQUIREMENT

Proposed working prototype is described as below:

a) Average wind speed should be more than 5 Km/hr.

b) The mast height of 5-7 m from the ground is desirable for better efficiency.

c) High power magnets and copper coil with maximum number of turns can be used for enhanced power generation.

d) The device is placed in an open field for maximum efficiency. However, in urban areas it may be placed on roof-top of any building, malls, etc.

Best output can be achieved from if the working height is maintained at 5-7 m from the datum. Also, it depends on the wind area. The height of mast plays an important role in generating higher output. The operation area should be open/free from any sort of wind obstruction.

6. ADVANTAGES

The model of wind turbine developed is certainly innovative, as the concept of the present model differs significantly from traditional wind turbine. The approach was that, we knew if we could somehow make a mast (of very light weight) oscillate in the wind direction then a relative motion between conductor coil and magnet was possible which would result in generation of induced emf and in turn current if the circuit is closed. As the proposed system will not have so many components such as gear box, motor, blades etc. like traditional wind turbines, it will be of light weight. Hence, the transportation would be easier. It will also involve low labour involvement. The cost and availability of the material will also be affordable and easier to procure. The technology involved is also very user-friendly. Because of the less components used in developing this prototype, this puts the cost very low, hence makes it highly competitive not only against generations of renewable energy, but even compared to conventional technologies.

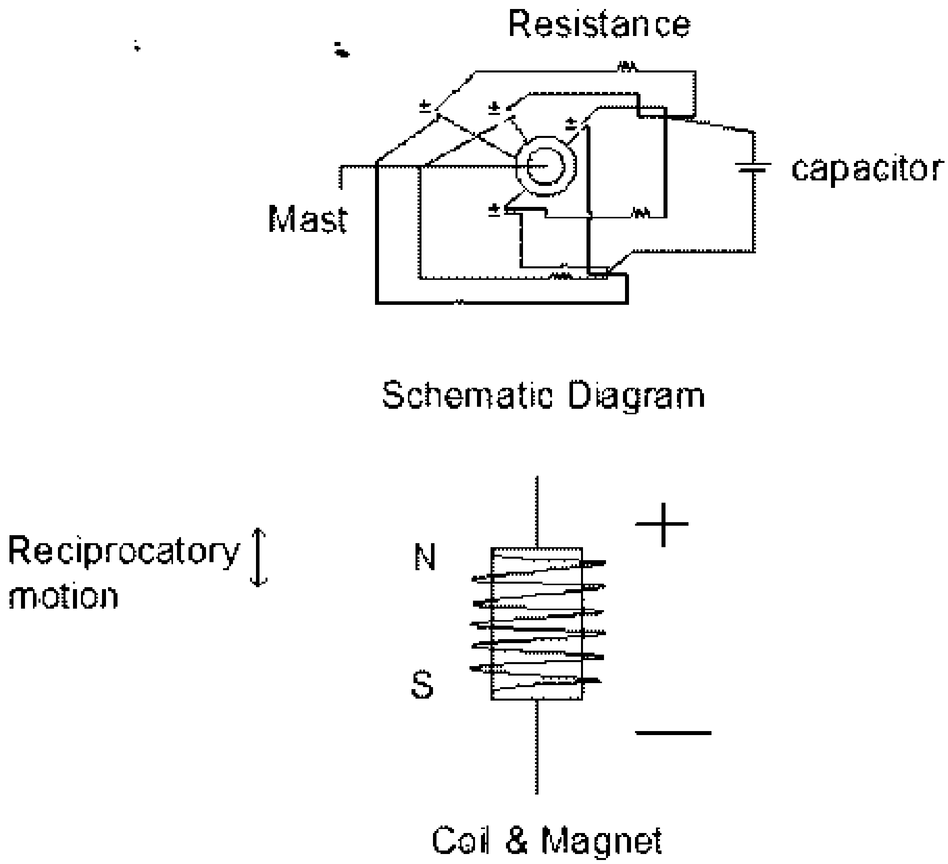

Fig. 2 : Electrical Circuit Diagram (Source AutoCAD 2016 Version)

Also, due to less moving parts in it, lubrication is not needed frequently. Thus maintenance cost is much less than traditional wind turbine.

7. EXPERIMENT PROCEDURE

Experiment carried out for three days. 30th August, 31st August and 1st September 2017, normal sunny day with normal wind condition. Experiment started around morning 06:00 hours and continued till evening 18:30 hours. Hourly readings were taken. Details of readings are noted in Table 1 to 3. Wind velocity noted with a digital anemometer and same were compared with wind velocity data published in internet on hourly basis. The current generated in mille ampere (mA). Height of mast measured from ground is 1 meter. Total numbers of coils are six (06) and number of magnet also six (06). Each coil is maintained at an angular distance of 600 from each other when viewed from top. The graphs are plotted based on the current produced on different wind velocities and specific day time. Fig. 3 to 5 describes the graphs of current generation with wind speed. Also calculation showing the power generated based on equations from first principles. Maximum 30 Watts calculated.

Table 1: Time Period, Wind Velocity and Current (Date: 30-08-2017)

SL.No.	Time Period	Wind Velocity(m/s)	Current (mA)
1	06:00am t0 6:30 am	0.892 S	0.26
2	08:00am to 8:30am	1.786 S	0.46
3	10:00 am to 10:30 am	1.786 S	0.43
4	11:00am to 11:30am	2.68 SW	0.64
5	12:00pm to 12:30pm	2.4 SE	0.49
6	01:30pm to 02:00pm	1.339 SE	0.3
7	02:00pm to 03:00pm	1.339 SE	0.29
8	03:30pm to 04:00pm	1.778 S	0.45
9	04:30pm to 05:00pm	2.233 SE	0.5
10	05:30 pm to 06:00 pm	2.68 SE	0.65

Calculation of power generated:

Average Velocity, V_{avg} = 1.89 m/s SE
Average current, I = 0.447 mA
Resistance of one coil = $25 \times 10^6\ \Omega$

Total no. of coils = 06
Total resistance, R = $150 \times 10^6\ \Omega$
Power generated = $I^2 R$ = 30 Watt (approx.)

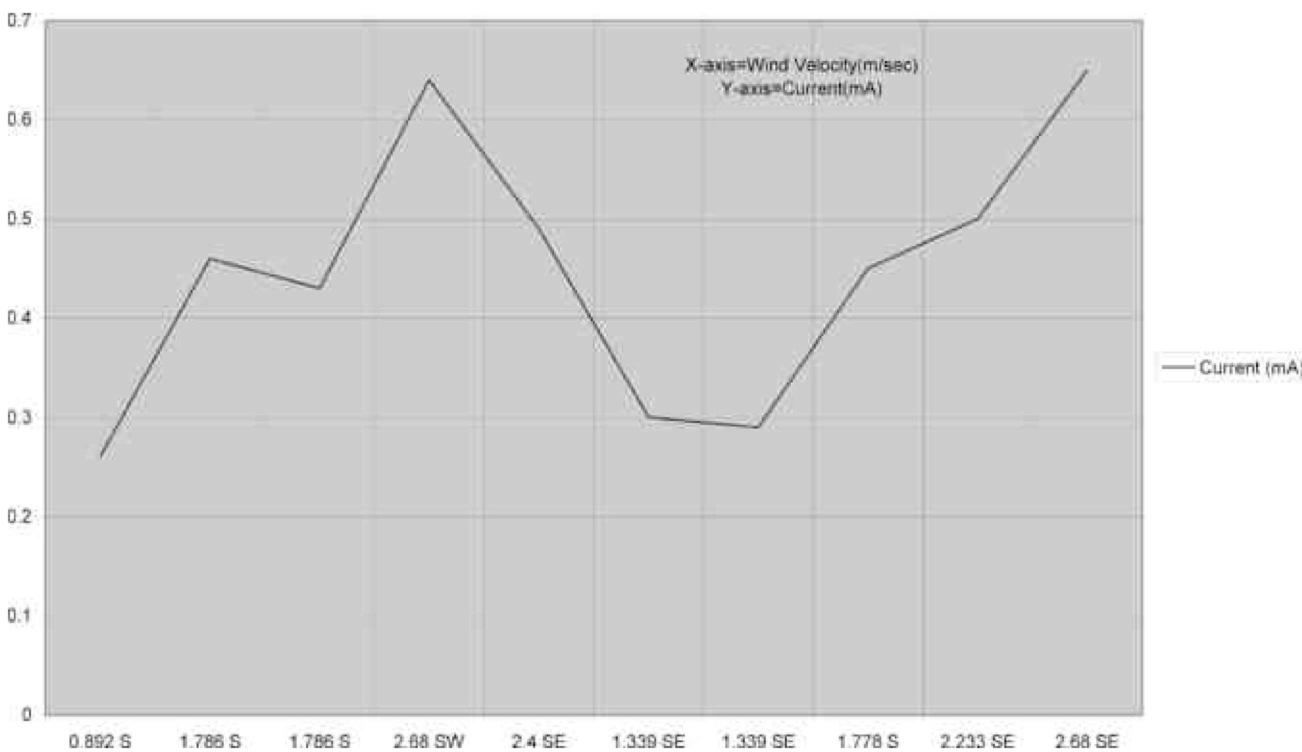

Fig. 3 : Graph plotted between wind velocity vs. current generated, Date: 30-08-2017

Table 2 : Time Period, Wind Velocity and Current (Date: 31-08-2017)

SL. No	Time Period	Wind Velocity(m/sec)	Current(mA)
1	07:00am t0 7:30 am	1.447 S	0.3
2	08:00am to 8:30am	1.786 SW	0.45
3	09:00 am to 09:30 am	2.342 SW	0.46
4	10:00am to 10:30am	2.125 S	0.4
5	11:00pm to 11:30pm	1.569 SE	0.34
6	01:00pm to 01:30pm	1.061 SE	0.26
7	02:30pm to 03:00pm	1.061 SE	0.25
8	04:00pm to 04:30pm	1.508 S	0.31
9	05:00pm to 05:30pm	1.678 SE	0.35
10	06:00pm to 06:30pm	1.847 SE	0.34

Calculation of power generated:

Average Velocity, V_{avg}= 1.645 m/s S
Average current, I = 0.346 mA
Resistance of one coil = 25 x 10^6 Ω

Total no. of coils = 06
Total resistance, R = 150 x 10^6 Ω
Power generated = I^2 R = 18 Watt (approx.)

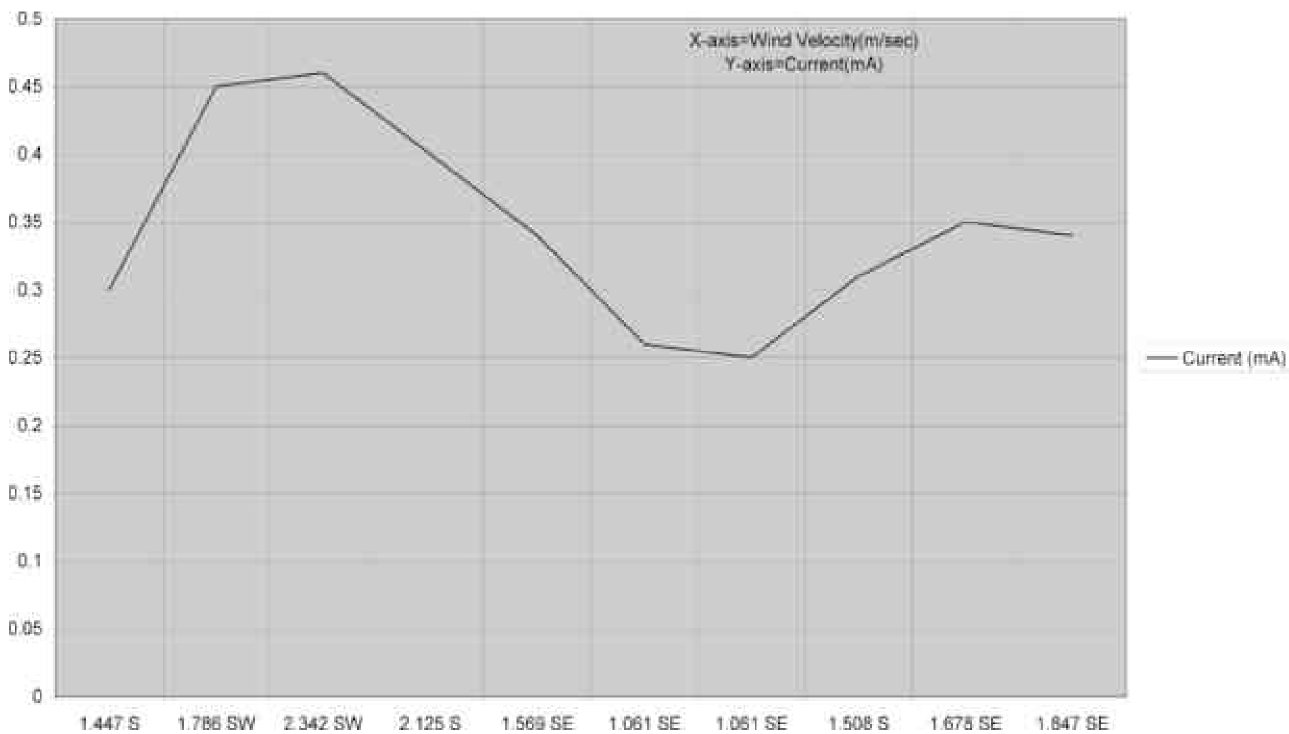

Fig. 4 : Graph plotted between wind velocity vs. current generated, Date: 31-08-2017

Table 3: Time Period, Wind Velocity and Current (Date: 01-09-2017)

SL. No	Time Period	Wind Velocity(m/sec)	Current(mA)
1	06:00am t0 6:10 am	1.725 S	0.4
2	07:20am to 7:30am	1.786 S	0.41
3	08:00 am to 08:10 am	2.342 SW	0.45
4	10:00am to 10:10am	2.125 S	0.4
5	11:25pm to 11:35pm	1.57 SE	0.37
6	12:30pm to 01:00pm	1.06 SE	0.25
7	02:00pm to 02:30pm	0.78 S	0.2
8	03:00pm to 03:30pm	0.953 S	0.21
9	04:30pm to 05:50pm	1.12 SE	0.27
10	06:00pm to 06:10pm	1.85 SE	0.34

Calculation of power generated:

Average Velocity, V_{avg} =1.476 m/s S
Average current, I = 0.33 mA
Resistance of one coil = 25 x 10^6 Ω

Total no. Of coils = 06
Total resistance, R = 150 x 10^6 Ω
Power generated = I^2 R = 16 Watt (approx.)

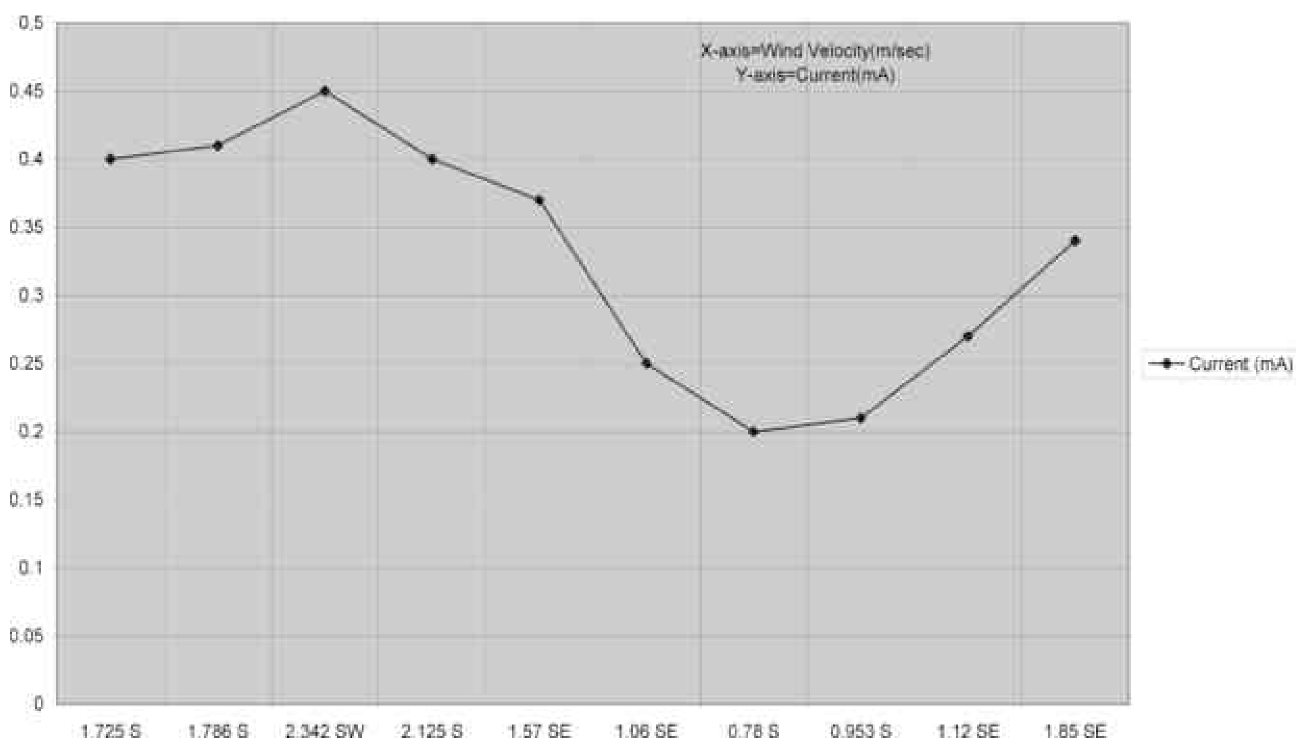

Fig. 5 : Graph plotted between wind velocity vs. current generated, Date: 01-09-2017

Average Power = (30+18+16)/3 =21.33 W
Power developed =21.33/1000=0.02133 KW
(Considering 8 hours of operation in a day)
Unit consumed (in KW) in 1 year = 184.032 KWHr For this model:

Fixed cost (set up cost) = Rs 2000

[Note: this prototype model can easily sustain 3 year minimum. although in actual model it can sustain up to 15 to 20 years.]

So cost for producing 1kw = Rs 11 (approx.)

8. DISCUSSION

The experiment performed in a normal sunny day with a normal wind condition. Though the experiment performed with a lot of constraints on the stability issues of the mast. Since the mast supposed to be unstable in nature and due to wind vortex shielding effect the mast will oscillate. However after fixing the conductor coils, it was observed that the mast becoming very stable. Even a small wind cannot oscillate the mast. Some point of time it was required to oscillate the mast manually to check the current produced in the circuit. To introduce instability in the mast one or two strings need to slacken. However the result that obtained with the single setup is very encouraging.

9. COMMERCIAL FEASIBILITY

This proposed model is of low cost, easy to fabricate, easy maintenance and easy installation. Also an array of the components connected in series if installed on the roof-top of a building or in open ground can produce higher amount of electricity at free of cost. Only the beneficiary needs to pay the installation fee and cost of the components at the time of setting up. This system can be installed as domestic purpose since it light weight. Unlike solar PV system it can be use as off-grid, grid tied or hybrid system.

10. INNOVATION / NOVELTY

In the proposed model, generally the designs of fluid mechanics are made in such a way to reduce the effect of vortex. However in the present the vortex is used to generate electricity from a primitive method by the relative motion of magnet through conductor coil. Where by mechanical losses due to friction are reduced.

This is an oscillating device which has no moving part in contact, therefore no lubrication is required. Since friction between moving parts is absent, the maintenance cost is reduced considerably as compared to the conventional wind turbine with blades. The impact on the bird population is expected to be much smaller, because it does not require the same type or magnitude of movement as a traditional wind turbine. Noise generation is less.

11. APPLICATIONS

The developed equipment can be brought to use at many places such as –

- For auxiliary purpose.
- It can be installed at on-shore and off-shore where there is significant vibration from any source.
- For pumping water at higher altitude for irrigation purpose.
- It can be stored for future use or can be send to power grid.
- It can be installed beside railway tracks.
- It can also be used to some extent in very small scale industries for some work.

- It can also be installed on either side of roads in highways etc. Outdoor lighting – for lighting up streets, parks etc.

12. CONCLUSION

Today, there are lot of research and study going on across the globe in renewable energy sector. This is the sector which is also growing at very fast rate. May be today the purpose of electricity generation is being fulfilled with fossil fuels and natural gases. But it is need of the hour where people have to realize that with the increase in power consumption and introduction of automation across all the sectors the need is to have to leverage the sources of electricity generation. In this regard wind energy can become a significant source of unlimited power generation.

It is known that as long as sun exist, wind will occur and so one needs to give equal importance to both the forms of renewable energy.

The model developed is doing the same thing which the traditional turbines do but authors are presenting it in a new way. The newer aspect is that the model will not have moving blades that the wind turbines have; it will have lesser mechanical components such as nacelles, rotor blades, hub, shaft etc. which are normally present in any wind turbine. Here authors are not trying to compare the model with any of its kind; rather, authors are giving specialties which their model has.

For its optimization the model can be scaled up dimensionally and the strength of components can be varied accordingly. As of now authors are not aiming to increase the power output, rather focus on auxiliary demands and for household purposes. Since, this model is still in developmental stage, it needs time for making it fully operational.

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