Contradistinctive Inquisitions of Windbelt Generator

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Abstract - ***In order to produce electricity from wind, wind turbine was the only option but windbelt generator can be the appropriate substitute of the wind turbine. In windbelt vibrational speed are used and in wind turbine rotational speed are used. Here various types of ribbons, various types diameter of magnet, different coils, different angular position, different length's membrane etc factors are experimented to determine which is the perfect for windbelt generator. The device is easy to install, has low maintenance, and can be used anywhere as long as there are enough wind. The device is designed to provide electricity in remote areas where power transmission line cannot reach easily such as islands, hilly areas etc.***

Keywords: ***windbelt, windbelt array, wind energy, renewable energy source, aero-elastic flutter***

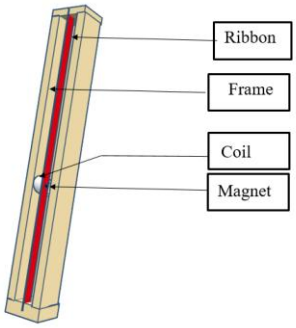
I. INTRODUCTION

Renewable energies are sources of clean, inexhaustible and increasingly competitive energy. They differ from fossil fuels principally in their diversity, abundance and potential for use anywhere on the planet, but above all in that they produce neither greenhouse gases – which cause climate change – nor polluting emissions. Their costs are also falling and at a sustainable rate, whereas the general cost trend for fossil fuels is in the opposite direction in spite of their present volatility. [1]

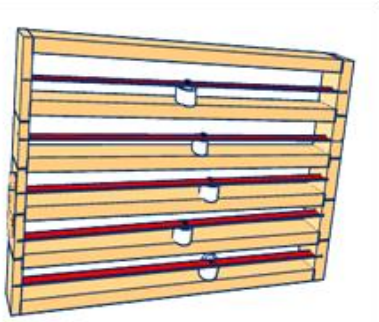
Petite Anse on 2004, Shawn Frayne, a member of a team from MIT came to know about that scenario. After that he was inspired to create and implement a new technology by using the principle of aeroelastic flutter. Then he designed a device named windbelt which is effective at producing electricity at low wind speed. He installed windbelts in that village as he thought that white LEDs powered by an inexpensive micro scale wind based energy generator may be an effective replacement for the poor villagers' kerosene lamps. [2]

In order to produce electricity from wind flow, a new type of device has been introduced which is windbelt generator. The device is easy to install, has low maintenance, and can be used anywhere as long as there are enough wind and light. Wind belt technology is an alternative to the costly and complex wind turbines. Instead of the conventional focus on "rotation", this new wind-based power generator capitalizes on vibration, making use of a physical effect known as Aeroelastic Flutter. In aeroelastic flutter when air pass over a thin strip of material, creates frequencies that translate into vibrations, in the wind belt case, which converts into energy. All the outputs from windbelts go to the charging circuit and charge up a rechargeable battery for convenient use.

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(a) Windbelt generator



(b) Windbelt generator array

Fig. 1. *3D implementation of windbelt generator and windbelt array*

Windbelt array can be made by merging four or five single windbelt generators. The main difference between wind turbine and windbelt is wind turbine works using rotation and windbelt works using vibration. Windbelt is also very cheap device compare to wind turbine but its output is low. The device is designed to provide electricity in remote areas where power transmission line cannot reach easily such as islands, hilly areas etc. It is much cheap and easier than traditional wind turbine, its overall power rating should be higher.

So windbelt generator is an early technology. By observing its basic rules and working principles various data should be noted and different works should be done according to that observed data. In order to improvement and to make windbelt generator updated various factors like environmental impact, mechanical impact and electrical impact should be noted. So in this paper various types of effects of impacts are going to be discussed.

II. LITERATURE REVIEW

The idea of windbelt generator was first introduced by Shawn Frayn in 2004. Then various researches have been done according to the concept.

A. Research by Dr.P.Balaguru, et. al (2013) [3]

The researchers designed a small windbelt to produce electricity using vibration of the ribbon. Two arrays of

windbelts consisting four coils and same number of magnets have been used to design the device. Camera film was used as the ribbon for the system. According to the article, at the lowest wind of 3ms^{-1}, 2A current was produced whereas the maximum 2.9 A of current was produced at wind speed of 5.4 ms^{-1}.

B. Research by R.D.Bhagat, et. al (2014) [4]

Their main research was to produce electricity using vibration of the ribbon. They have also established an equation to measure the output of windbelt. They have used one array of windbelt and used four coils and 4 magnets. VHS tape was used as a ribbon

TABLE I. OUTPUT OBTAINED BY R.D. BHAGAT, ET. al.

Average wind speed (m/s)	Output obtained (V)
3	0.01
4	0.04
5	0.09

C. Research by Vu Dinh Quy, et. al (2016) [5]

In this paper, the researchers have discussed the influences of the design parameters on the performance of a windbelt with the goal of maximizing its output power. An experimental apparatus was developed to study the effects of parameters such as wind speed, position and size of the magnets, pre-applied tension of the membrane, angle of attack of the membrane, and the direction of the generator on the output power and frequency of the windbelt. The experimental tests were carried out with five arrays of windbelts for ten coils and magnets. Ripstop nylon fabric was used as ribbon. The observed outputs are provided in table I.

TABLE II. OUTPUT OBTAINED BY VU DINH QUY, ET. AL.

Wind speed (ms^{-1})	Power (mW)
3	0
4	2
5	10
6	30
7	40
8	150
9	200

III. PRINCIPLES AND CONSTRUCTION OF WINDBELT

A. Working Principle of Windbelt

The working principle of windbelt generator is very simple. The whole device works under two basic laws. They are electromagnetic induction and aeroelastic flutter. Figure 5 demonstrates how a basic windbelt generator works. Here a ribbon was placed over a copper made coil. A set of permanent magnets were placed on the ribbon just over the copper coil. When wind blows the ribbon vibrates along with magnet due to aeroelastic flutter. As the magnet vibrates on the copper coil emf is produced due to farraday's law of induction. Here induced emf is AC voltage. If we compare the whole phenomenon with an alternator here the ribbon is act like prime mover. Besides magnet acts like rotor and coil acts like stator. So, it is the total working principle of windbelt generator.

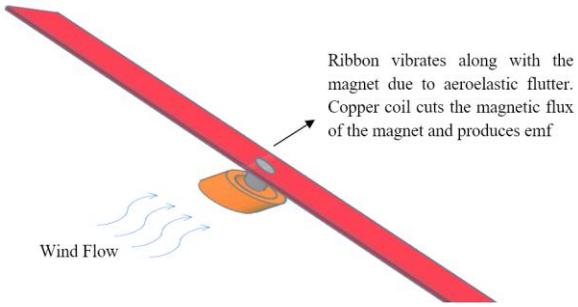


Fig. 2. *Output from windbelt generator*

B. Steps of Power Generation by Windbelt

Block diagram in Fig. 3 is the representation of whole project in different sequential portions. Each block symbolizes the operation of the system. AC voltage was induced from the windbelt. Therefore, at first AC voltage was converted to DC with the help of rectifier. Then it was stored in a battery with the help of a charging circuit.

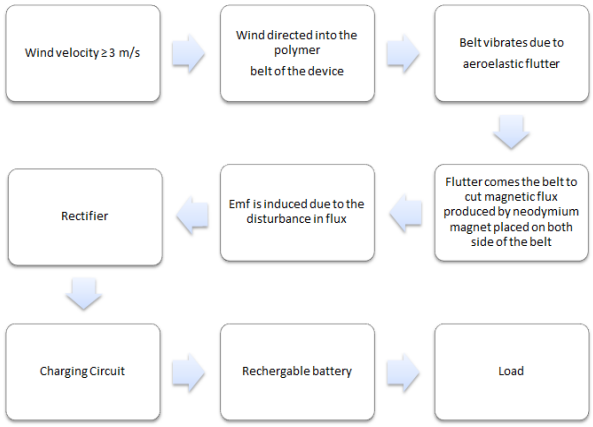


Fig. 3. *Windbelt charging diagram*

C. Construction of Windbelt

In order to find out various data from windbelt generator at first a single basic windbelt generator was made. The length and width of the windbelt was 27.5 and 3 inches. Total five sets of 1.5 cm diameter of Neodymium magnet were also used. The height of the magnet was 1.2 cm. Copper coil consisting of 2600 turns using 0.12 mm diameter copper wire were also taken**.** Binder clips were used to stick the ribbon with the windbelt. A table fan was used to produce wind flow.

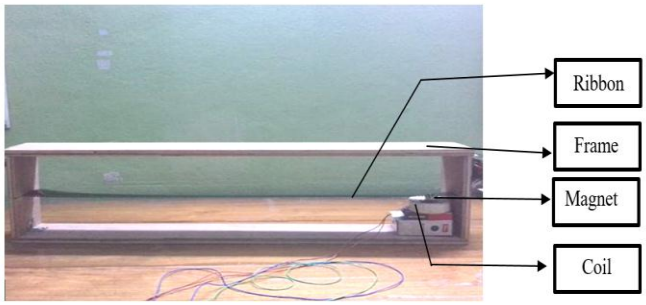


Fig. 4. *Windbelt generator*

TABLE III. STRUCTURE OF WINDBELT GENERATOR

Parameter	Solo Windbelt	Windbelt Array
Length	27.5 inch	27.5 inch
Width	3 inch	18 inch
Height	3 inch	3 inch
Coil	2600 turns	2600 turns (x5)
Ribbon	Camera Film	Camera Film (x5)
Magnet	1.5 cm Diameter	1.5 cm Diameter

D. Windbelt Generator Array

An array of five windbelt generator with five membranes was implemented and corresponding voltage and current were measured. The length and width of the windbelt was 27.5 and 15 inches. Here camera film and 1.5 cm diameter magnet were used. Due to different frequency and phase AC voltage cannot be merged. Therefore, five C808 bridge rectifiers were used to make the rectifier circuit to merge all the outputs from five windbelts. Each rectifier was connected with a copper coil which convert AC signals to the equivalent DC voltage. This conversion allows to merge all the pure DC voltage and pass it to next step. Five 220µF electrolytic capacitors were connected with each rectifier for filtering the noise and to convert to a pure DC signal.



Fig. 5. *Hardware implementation of windbelt generator array*

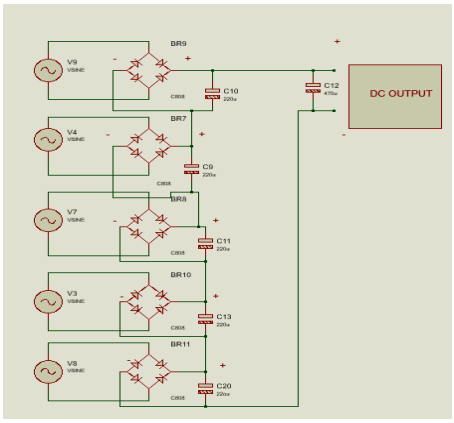


Fig. 6. *Rectifier circuit*

IV. Experimentations Towards Maximizing Output Voltage

In this research emphasis was provided on eight methodized facts that possibly effect the operation of windbelt generator such as effects of the orientation of the generator device, effects of wind flow in different angles. Again, placement and size of the magnet as well as coil were also been tested. In addition, experiments have been done for a range of length and tension on ribbon (membrane) as well as the use of different number of coils in the ribbon.

A. Effects of the Orientation of Generator (Horizontal or Vertical)

Fig. 7 shows the comparison of the changes of the output voltage with respect to the wind speed when the windbelt is placed horizontally and vertically. Two bars are nearly same. The difference of voltage is minor.

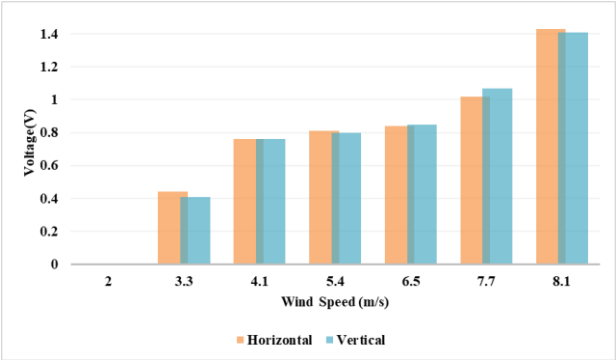


Fig. 7. *Possessions of direction of the generator (horizontal or vertical) along with the output voltage.*

B. Effects of Wind Flow in Different Angles

A stand fan was placed at different positions (angle differences) according to windbelt generator and induces voltages were noted down.

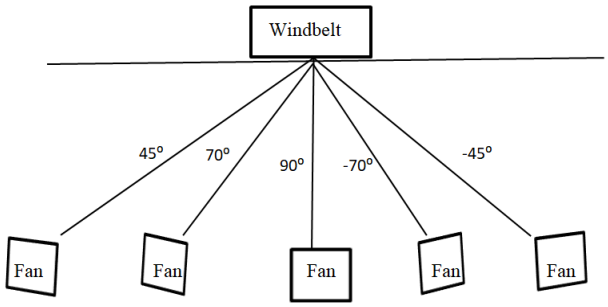


Fig. 8. *Positions of the wind source (fan) in different angle positions.*

Table IV shows the changes of the output voltage with respect to the angle of attack. It is seen that at 90º angle, the lower output voltage is generated when windbelt was placed angle differences greater or less than 90º.

TABLE IV. POSSESIONS OF WINDBELT IN DIFFERENT ANGLE

Angle (Degree)	Voltage (V)
70	0.3
45	0
90	0.4
-45	0
-70	0.2

C. Position of the Magnet and Coil

To operate this experiment three positions of magnet and coil were created. Fig. 9 illustrates these three different positions.

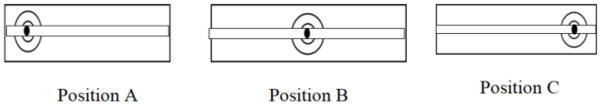


Fig. 9. *Three different positions of magnet and coil.*

The voltage increases strongly when moving the magnets and coil to the centre of the membrane. The voltage decreases when moving the magnets and coil to the right or left edge of the membrane. (Fig. 10)

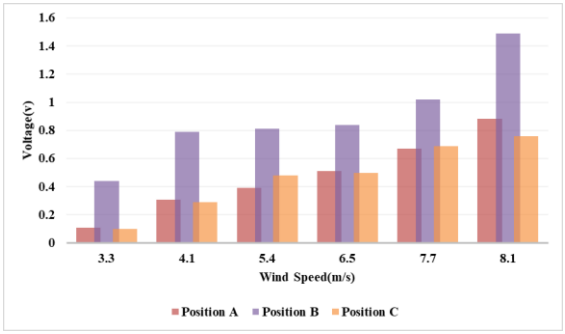


Fig. 10. *Possessions of position of the magnet and coil*

D. Size of the Magnet

Fig. 11 presents the output voltage of the windbelt with respect to the wind speed when using three different magnet sizes: small one is (diameter of 1 cm, thickness of 1.5 cm), medium one is (diameter of 1.5 cm, thickness of 1.5 cm), and big one is (diameter of 2 cm, thickness of 1.5 cm). The bigger the size of the magnets create high amount of induced voltages and smaller size magnets create lower voltages.

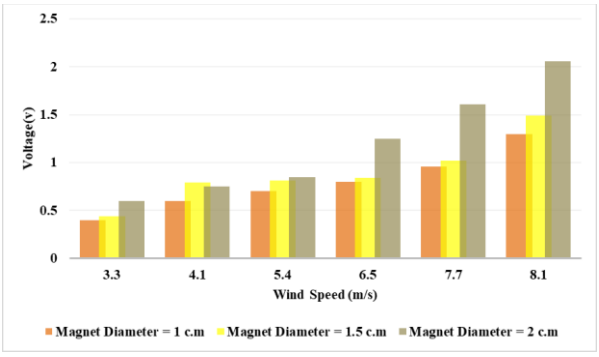


Fig. 11. *Possessions of size of the magnet*

E. Length of the Ribbon

Fig. 12 shows the comparison of the evolutions of the output voltage with respect to the wind speed. When the length of the windbelt is increased the induced voltage are also increased when the length of the windbelt is decreased the induced voltages are also decreased.

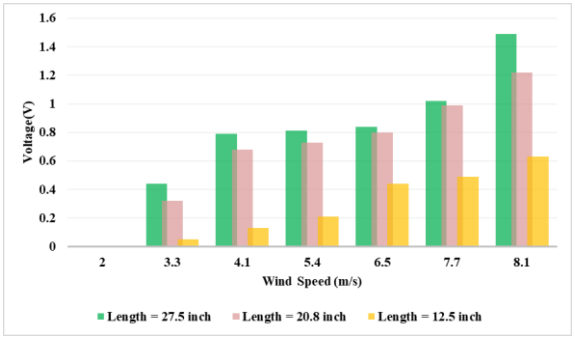


Fig. 12. *Possessions of different length of the ribbon*

F. Applied Tension

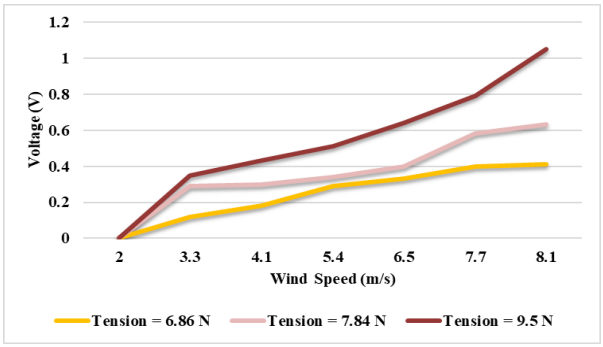
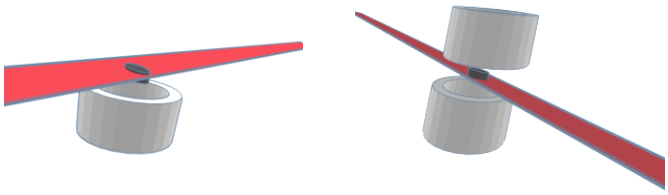


Fig. 13. *Different applied tension of the ribbon*

Fig. 13 shows the characteristics linear chart of the output voltage with respect to the wind speed. When the applied tension of the windbelt's ribbon is increased the induced voltage are also increased and emf is decreased when applied tension is minimized.

G. Use of Single and Double Coils in the Ribbon



(a) Single Coil (b) Double Coils

Fig. 14. *Different figure of coil placement of windbelt*

Fig. 14 shows the evolution of the output voltage with respect to various wind speed. Here (a) Single coil with magnet and (b) Double coils with magnets were used. It can be seen that in double coils, higher output voltage was generated but the operation had started at 4.1 m/s wind speed. So in this case much higher wind speed is needed. On the other hand at the speed of 3.3 m/s voltage were induced in the single coil membrane windbelt generator. Because while using single coil, we can attach the magnet at one side of the ribbon. But when wind speed is lower than 4.1 m/s the double coil voltage is zero because when two coils are placed on two side of the wooden frame we have to stick magnet to both of the side of the ribbon. That's why the overall weight

became bit higher. Thus to start vibration high levels of wind flow is needed.

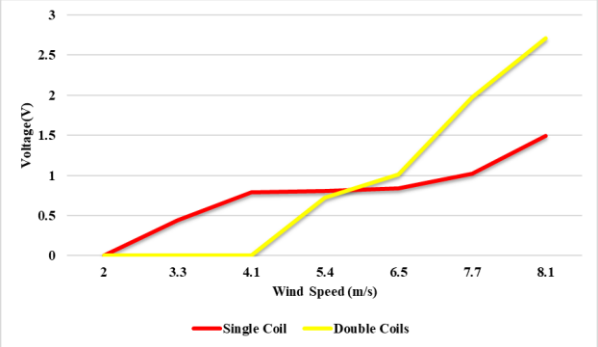


Fig. 15. Possessions of using different number of coils

H. Size of the Coil

From the experiment it is observed that the induce voltages are fully depend on the number of turns of coil. 1600 turns using 0.12 mm diameter copper wire could not able to produce any voltage. However, 0.12 mm diameter copper wire with 2600 turns produced significant amount of voltage.

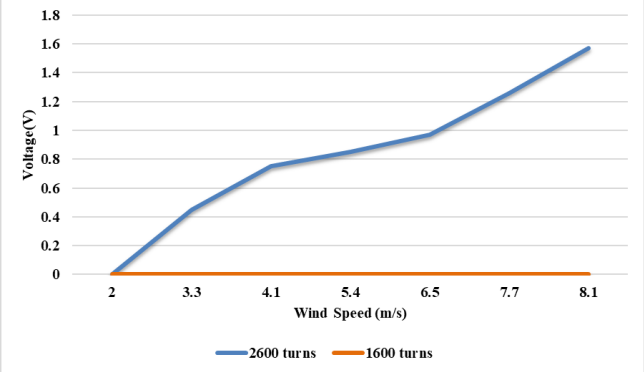


Fig. 16. *Possessions of different size of the coil*

I. Characteristics of Different Ribbons

Various types of ribbon such as taffeta, VHS tape, sticky tape and camera film are used and induced voltages are measured from the windbelt. According to Fig. 17 it is observed that maximum voltages are produced by VHS tape and Taffeta (not myler coated).

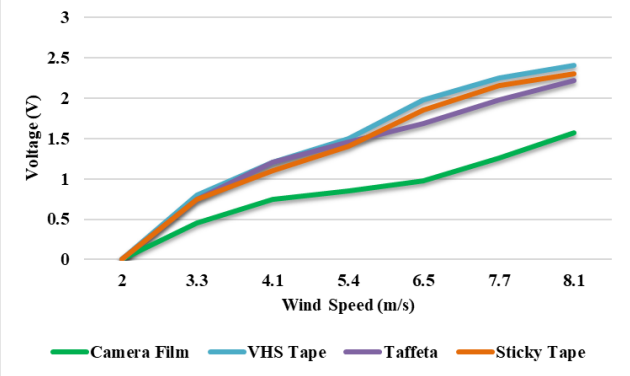


Fig.17. Possessions of using different ribbons

From experimental results, some conclusions can be given about the effects of this phenomenon.

TABLE V. EXPERIMENTAL RESULTS FOR DIFFERENT CONDITIONS

Effect	Result(s)
Orientation of the windbelt generator	Both horizontal and vertical position gives same amount of induced voltages.
Angular position of windbelt	Air flow from 90˚ position from source produces the highest amount of voltage.
Position of the magnet and coil	Maximum voltage was induced when both coil and magnet was kept in middle of the windbelt.
Size of the magnet.	Magnets of bigger diameter provides significantly a better performance than small diameter magnet.
Size of the coil	Higher turns coil provides significantly high induced voltage than lower turns coil.
Length of the ribbon	Longer length ribbon provides significantly a better performance than short length ribbon.
Applied tension	High tension at ribbon provides high output voltage.
Characteristics of different ribbons	VHS tape and Taffeta (not myler coated) are most efficient as windbelt's ribbon.
Use of single and double coils in the ribbon	Double coils system produces much emf but initially higher air flow is needed.

V. Outputs Comparison Between Windbelt Generator and Windbelt Generator Array

Outputs from windbelt generator and windbelt generator array were plotted in Fig. 18. Huge voltage differences were observed between single and multi windbelt generator. To get higher outputs selection of windbelt generator array is recommended.

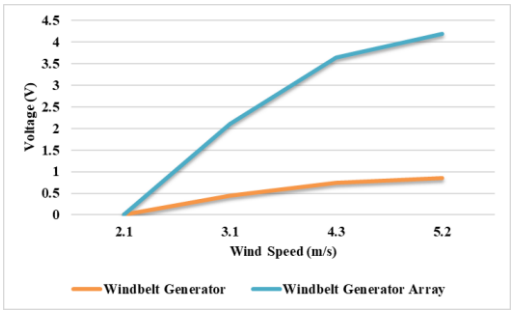


Fig. 18. *Outputs comparison between windbelt generator and windbelt generator array*

VI. Efficiency Calculation

A. Equation Provided by D. Pimentel, et. al [6]

For windbelt, power from wind coming into system is, $P_{wind} = 0.5\rho lTv^3$ where, ρ is density of air, l is the length of the membrane (ribbon), T is the thickness of the ribbon, v is the velocity of wind.

For, $\rho = 1.225$ kg/m^3, length, $l = 0.6985$ m, thickness of membrane, $T = 0.0015$ m for camera film, wind-velocity, $v = 4.5$ ms^{-1}

$P_{wind} = 0.5\rho lTv^3$

$= 0.5 \times 1.225 \times 0.6985 \times 0.0015 \times (4.5)^3$

= 0.0584 W

Power from mechanical system of windbelt = 0.00053W
Efficiency = (Output of Electric Power) / (Power from wind coming into system) × 100% = (0.00053/0.0584) ×100% = 0.908%

B. Equation Provided by Dr. P. Balaguru, et. al [7]

For windbelt, power from wind coming into system is, $P_{wind} = 0.001742A(P/T)v^3$ where, A is area of the ribbon, P is the pressure of the air, T is the atmosphere temperature, v is the velocity of wind.

Here, $A = (l \times w) = 0.6985\ m \times 0.0762\ m = 0.0532\ m^2$, temperature $T = 302.15$ K, pressure $P = 101325$ Pa, and wind- velocity, $v = 4.5\ ms^{-1}$,

$P_{wind} = 0.001742A(P/T)v^3$
$= 0.001742 \times 0.0532 \times (101325/302.15) \times (4.5)^3$
$= 0.0532$ W

Power from mechanical system of windbelt = 0.00053W

Efficiency = (Power from mechanical system) / (Power from wind coming into system)×100% = (0.00053/0.0532) ×100% = 0.996%.

It is clear that the overall efficiency of windbelt generator isn't up to the mark. So in order to increase the efficiency various techniques can be followed. One of them is finding the more flexible ribbon. Taffeta with myler coated should be an ideal option for more efficient windbelt's ribbon. Increasing the turns of the coil and using more powerful magnet will be some of the better methods to increase the efficiency of the generator.

VII. CONCLUSIONS

The device would be made using common tools around us and would be very cheap. Produced electricity would be stored in battery to use afterwards. This device can be used beside coastal areas, riverbanks, on the peak of high hills or skyscrapers where there is moderate breeze and use the wind to vibrate a belt thus cutting electric fields produced by a coil and therefore produce electricity.

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