Utilizing Wind Vibrations from Vehicular Airdrag Using Microwind Harnessing Device

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Abstract. Windbelt has been developed to be an alternative for wind turbines to utilize wind energy, meanwhile, fast-moving vehicles in highways creates wind forces that has potential to be a source of wind energy. This study presents a windbelt prototype and evaluates the output and performance of 1, 5 and 10 connected windbelts when placed on the highway. The results reveal that for every increase in windspeed there is 0.155v and 0.485v increase in output voltage response for 5 and 10 connected windbelt respectively, indicating that the 10 connected windbelt have the highest output voltage response. This indicates that the higher the number of connected windbelts result to larger output voltage.

1. Introduction
Electricity generation in fossil fuel based power plants continuously expands as the demand for power increases. This implies non-stop carbon dioxide emissions which intensified the damage of the ozone layer that led to climate change.

Renewable energy utilization is seen as the solution for this phenomenon. Advantage of this energy source is its availability anytime, anywhere and any season, proper management of this energy source could facilitate the replacement of fossil fuel [1, 2].

Wind turbines are commonly used technology in wind energy production. But it has disadvantages in terms of construction, maintenance and location. Construction of wind turbine will affect land usage and realign the area for energy production rather than crop production [3]. Wind turbines are also sensitive to wind turbulence and gust, other problems usually occur due to the use of gears and bearings [4, 5]. Wind turbines are usually built on coastal or hilly areas and utilizes speed of more than 4m/s for small types, furthermore, the harvesting technologies and equipment for production of renewable energy is costly and location specific, which implies the need for renewable energy generation with simpler, cheaper and less complexity in construction.

With the desire for simple and cheap energy generation another wind energy harnessing device was developed. Windbelt is a device that converts the vibration created by the wind into electrical energy. The main parts of a windbelt device consist of a frame, a membrane and the electromagnetic transducer [6]. The operation starts when a wind causes the flutter/belt to vibrate creating an up and down movement of the magnet between the coils and produces an electrical output (refer to figure 1). It gives many advantages since it does not use gears or bearings like in wind turbines, which are subjected to frictional problems, windbelt can work at either low or high windspeed as it produced 0.6 volts at a minimum windspeed of 2.5 m/s [6].
The concept of energy conversion of windbelt came from Faraday’s law of electromagnetic induction which states that “electromotive force (emf) is produced when there is a change in magnetic field caused by the moving conductor”. Electromagnetic generator is most utilized in low vibration harvesting according to [7, 8]. Wind belt output performance depends on the type and size of electromagnetic generator [9]. Studies revealed that the flutter/belt of the windbelt produces more output when working in parallel with the wind [10, 11]. A comparison between a single windbelt generator and a wind panel with 5 windbelts was conducted at a the same windspeed of less than 8m/s, the said generators were able to produced 3-5mW and 30-100mW respectively [12].

While there is a naturally occurring wind, there is also a type of wind that is caused by daily human activity, the vehicular air drag. Vehicular air drag is the strong wind created from the fast-moving vehicles passing along the highway. This generated wind could be a viable source for wind energy generation. The aerodynamic forces created by the vehicle acts on a fixed object on the road, the strong wind forces usually came from big vehicles, hence; vehicle velocity increases near downstream surfaces resulting to higher airdrag which is also dependent on the environmental turbulent levels [13, 14]. These highways have potential as wind energy source that can address the need for electrical energy sources [15].

This study aimed to construct a windbelt prototype that could be used for harnessing electrical energy along the highway, determine the relationship of the number of windbelt prototype and the production of output voltage and determine the differences in output voltage response of 1, 5, and 10 connected windbelt prototypes on straight and slope highways located in the province of Palawan.

2. Methodology
The study was conducted from January-February 2019, in the province of Palawan, Philippines. Locations were selected based from the results of the initial test done between slopes and straight part of the highways. There were few considerations taken during construction of the device since it was intended to be used outdoors; (1) it should not distract the drivers that will cause them to slow down while passing; (2) it should be on a height/appearance that is noticeable to the drivers to avoid accidents; and lastly, (3) the base of the device should be made heavy to resist strong vehicular airdrag.

The fabricated windbelt device, as shown in figure 2, consist of four major parts: 1) Electromagnetic transducer, produces the output from the vibrations created by the belt; 2) Vibrating belt that captures the wind and gets moved when a vehicle passes and creates an airdrag; 3) Frame that serves as the body of the device, where the flutter/belt as well as the electromagnetic transducer is attached; and 4) Base that supports the device so that it may able to stand and resist strong vehicular airdrag, it was made to be detachable for easy and quick set up on the highway.
Fig. 2. Fabricated windbelt.

The concept of energy production is shown in figure 3. As the vehicle passes along the road it produces strong vehicular airdrag. The turbulent wind that is created due to fast-moving vehicles along the road was captured by the windbelt, inducing the vibration of the flutter which is in turn converted into electrical energy.

2.1. Assembly
Assembly of the device begins with the construction of the frame made from wood. Then the flutter was then attached and tensioned 60 lbs at both ends of the frame with the use of bolts and nuts, the tension of the flutter was measured using Krikit gauge. Two electromagnetic transducers were created and placed at the near ends of the flutter, each transducer has two loop magnetic coils consisting of 500 turns.

Four magnets were used in each transducer to help increase the change in magnetic flux with the magnetic coils. The magnets were attached to both sides of the flutter and was near the center of the looped coils. The electromagnetic generators were connected in series with the use of wires and alligator clips.

2.2. Data gathering
The converted output voltage from the windbelt was measured using potable oscilloscope (JHJDS3012A). The windspeed was measured using cup type anemometer, and all the considered parameters were captured using video camera, manually reviewed and recorded (refer to figure 4).
3. Results

1, 5 and 10 connected windbelts were tested in 6 highway locations, consisting of 3 straight and 3 slope roads. The test was done in 3 different time periods (7:00-8:00 AM, 12:00-1:00 PM and 5:00-6:00 PM) when most of the vehicles are found on the road. There were 6,732 total number of observations in which 6,729 were interpreted using Analysis of Variance (ANOVA) and regression analysis. The results in table 1 show that the number of connected windbelts contribute to the factors that influences the output voltage.

| Variable | Df | Sum Sq  | Mean Sq | F value | Pr(>F) |
|----------|----|---------|---------|---------|--------|
| WB       | 2  | 227.8   | 113.90  | 415.7   | <2e-16 *** |
| Residuals| 6729| 1843.8 | 0.27    |         |        |

The comparisons of 1, 5 and 10 windbelt was done using Least Significant Difference (LSD) method and was shown in table 2. The table indicates that the 5 connected windbelt have 0.1935 difference in output voltage with 1 windbelt, while the 10 connected windbelt have 0.4426 difference in output voltage with 1 windbelt and the 10 connected windbelt have 0.2490 difference in output voltage with 5 connected windbelt.

| Comparison | Difference | lower.ci | upper.ci | P val    |
|------------|------------|----------|----------|----------|
| 5-1        | 0.1935     | 0.1622   | 0.2248   | <2e-16 *** |
| 10-1       | 0.4426     | 0.4123   | 0.4728   | <2e-16 *** |
| 10-5       | 0.2490     | 0.2185   | 0.2795   | <2e-16 *** |

The results of regression analysis revealed that for every increase in windspeed there is 0.485V increase in output voltage response for 10 connected windbelt, which is almost 3 % higher as compared to 0.155V increase of output voltage response for 5 connected windbelt. This indicates that the output voltage increases as the number of connected windbelt increases. The results also indicate that for every unit increase in windspeed the output voltage increases by 0.275V, keeping all the variables constant.
4. Conclusion
The number of windbelt plays an important role in production of electrical energy on highways, connecting more windbelt will affect the production of output voltage. The higher the number of connected windbelts results to an increase of the output voltage. There is an equivalent increase of 0.275V in output voltage every time the windspeed increases. Problems occur with the measurement and recording of other parameters such as output current and power since the measuring device used was not capable of recording/storing data. Good data logger is advisable for more accurate data collection. Boosting the output using a converter and stabilizing it for storage could be further explored.

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Acknowledgment
The authors gratefully acknowledge and thank the DOST-ERDT for the financial support to this study.